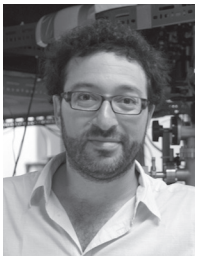
CLEO: QELS-Fundamental Science

08:00–10:00
FM1A • Quantum Metrology and Measurement
Presider: Nicholas Peters; Oak Ridge National Lab, USA

FM1A.1 • 08:00 Tutorial

Quantum Measurement Techniques: Modern Approaches and Trends, Aephraim M. Steinberg[1,2]; [1]*Dept. of Physics & CQIQC, Univ. of Toronto, Canada;* [2]*Canadian Inst. for Advanced Research, Canada.* While quantum measurement has long been seen as a deep philosophical conundrum, technological progress and new potential applications such as quantum information processing have turned it into a respectable experimental discipline as well. I will introduce a modern perspective on real-world quantum measurement, including the new paradigm of "weak measurement" and its (controversial) potential for addressing fundamental issues as well as for improving the precision of practical measurement.



Aephraim Steinberg is a Professor of Experimental Quantum Optics at the Univ. of Toronto. Working with entangled photons and ultracold atoms, his lab has made numerous contributions to the science of quantum measurement, ranging from the observation of superluminal tunneling times to advances in quantum tomography to entanglement-assisted superresolution to "violating" the Heisenberg relation. He is a Fellow of the APS and The Optical Society, and his work has been twice selected as among the top 10 physics "Breakthroughs of the Year" by Physics World.

08:00–10:00
FM1B • Exciton Dynamics in 1D/2D Nanostructures
Presider: Kin Mak; Columbia Univ., USA

FM1B.1 • 08:00

Ultrafast Terahertz Probes of Interacting Dark Excitons in Chirality-specific Single-walled Carbon Nanotubes, Liang Luo[1,2], Ioannis Chatzakis[1,2], Aaron Patz[1,2], Jigang Wang[1,2]; [1]*Physics and Astronomy, Iowa State Univ., USA;* [2]*Ames Lab-US DOE, USA.* Ultrafast terahertz intra-excitonic transition ~6 meV reveals stable quasi-1D many-exciton states that evolve uniquely from a predominant dark exciton population to complex phase-space filling of both dark and bright pair states in (6,5) SWNTs

FM1B.2 • 08:15

Control of Coherent Intersubband Excitations by a Nonresonant THz Pulse, Michael Woerner[1], Carmine Somma[1], Drew Morrill[1], Giulia Folpini[1], Klaus Reimann[1], Thomas Elsaesser[1], Klaus Biermann[2]; [1]*Max Born Inst., Germany;* [2]*Paul Drude Inst., Germany.* Using fully phase-resolved two-dimensional terahertz spectroscopy we study coherent intersubband Rabi oscillations in GaAs quantum wells. A strong terahertz field modifies particularly the phase of the nonlinearly emitted field during the Rabi oscillation.

FM1B.3 • 08:30

Measurement of Transversal Polarization Forces on Excitons in GaAs Quantum Wells, Eric Martin[1,3], Markus Borsch[2], Mackillo Kira[2], Steven Cundiff[1,3]; [1]*JILA, Univ. of Colorado & NIST, USA;* [2]*Philipps-Univ. Marburg, Germany;* [3]*Univ. of Colorado, USA.* We observe resonant optical tweezing of quantum-well excitons created by an excitation pulse. The ultrafast dynamics of a small excitation spot show that the tweezing is due to the first-order polarization induced by the pump.

08:00–10:00
FM1C • Nonlinear Metamaterials
Presider: Vinod Menon; City College of New York, USA

FM1C.1 • 08:00 Tutorial

Recent Progress in Optical Metamaterials, Xiang Zhang[1]; [1]*Univ. of California Berkeley, USA.* I will discuss progress in metamaterials including symmetry breaking related phenomena. I will also discuss non-Hermitian optics and parity-time symmetry and PT lasers of single mode.

Xiang Zhang is the Ernest S. Kuh Chaired Professor at the Univ. of California Berkeley and Director of Materials Science Division at Lawrence Berkeley National Laboratory. He is also the Director of the NSF Nano-scale Science and Engineering Center. He is a member of the US National Academy of Engineering, Academia Sinica and fellow of APS, OSA, AAAS and SPIE. His group's research in optical metamaterials was selected by Times Magazine as Top 10 Scientific Discoveries in 2008. In 2014, he was awarded Fitzroy Medal for pioneering contributions in metamaterials and superlens. He received his BS/MS in physics in Nanjing Univ., China, and Ph.D from UC Berkeley.

08:00–10:00
FM1D • Accelerating Beams & Beamshaping Application
Presider: Demetrios Christodoulides; Univ. of Central Florida, USA

FM1D.1 • 08:00

Laser Guided Curved Electric Discharges, Matteo Clerici[1,2], Yi Hu[2], Carles Milián[3], Arnaud Couairon[3], Demetrios N. Christodoulides[4], Zhigang Chen[5], Luca Razzari[2], François Vidal[2], François Légaré[2], Daniele Faccio[1], Roberto Morandotti[2]; [1]*Heriot-Watt Univ., UK;* [2]*INRS-EMT, Canada;* [3]*Centre de Physique Theorique, Ecole Polytechnique, France;* [4]*College of Optics, Univ. of Central Florida, USA;* [5]*Dept. of Physics and Astronomy, San Francisco State Univ., USA.* We report laser-guided electric discharges along curved trajectories, and hence around obstacles in line of sight between electrodes. Furthermore, beam self-healing enables direct discharge on target even when the laser beam directly hits the obstacle.

FM1D.2 • 08:15

Improving Electron Microscopy by Shaping the Electron Beam Wavefunction, Maor Mutzafi[1], Ido Kaminer[2,1], Gal Harari[1], Mordechai Segev[1]; [1]*Physics, Technion Israel Inst. of Technology, Israel;* [2]*Physics, MIT, USA.* We show a novel technique to enhance resolution and SNR in electron microscopes - by shaping the quantum wavefunction of electrons. Our technique overcomes fundamental limits that currently set the resolution and SNR in electron microscopy.

FM1D.3 • 08:30

Prolonging the Lifetime of Relativistic Particles by Self-Accelerating Dirac Wavepackets, Ido Kaminer[1,2], Mikael Rechtsman[1], Rivka Bekenstein[1], Jonathan Nemirovsky[1], Mordechai Segev[1]; [1]*Technion Israel Inst. of Technology, Israel;* [2]*Dept. of Physics, MIT, USA.* We show that shaping the wavepackets of Dirac particles can alter fundamental relativistic effects such as length contraction and time dilation. For example, shaping decaying particles as self-accelerating Dirac wavepackets extends their lifetime.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

08:00–10:00
FM1E • Symposium on Single-photon Nonlinear Optics I
Presider: Jacob Taylor; NIST, USA

FM1E.1 • 08:00 Invited
Demonstration of Deterministic Photon-Photon Interactions with a Single Atom, Serge Rosenblum[1], Itay Shomroni[1], Yulia Lovsky[1], Orel Bechler[1], Gabriel Guendelman[1], Barak Dayan[1]; [1]*Weizmann Inst. of Science, Israel*. We demonstrate all-optical deterministic photon-atom and photon-photon interactions with a single Rb atom coupled to high-Q fiber-coupled microresonator. This scheme enables all-optical photon routing, passive quantum memory and quantum gates activated solely by single photons.

FM1E.2 • 08:30
Observation of the Nonlinear Phase Shift Due to Single Post-Selected Photons, Amir Feizpour[1], Matin Hallaji[1], Greg Dmochowski[1], Aephraim M. Steinberg[1]; [1]*Physics, Univ. of Toronto, Canada*. We implement a strong optical nonlinearity using electromagnetically-induced transparency in cold atoms, and measure the resulting nonlinear phase shift for postselected photons. We believe that this represents the first direct measurement of the cross-phase shift due to individual photons.

08:00–10:00
SM1F • Semiconductor Laser Physics
Presider: Sven Hofling; Univ. of St. Andrews., UK

SM1F.1 • 08:00 Invited
Quantum Coherent Interactions in Room Temperature InAs/InP Quantum Dot Amplifiers, Gadi Eisenstein[1]; [1]*Technion Israel Inst. of Technology, Israel*. We survey the latest advances in initiation and observation of quantum coherent interactions in room temperature quantum dot amplifiers operating at 1550 nm. Single and double pulse FROG measurements accompanied by detailed modeling are described.

SM1F.2 • 08:30
Crossed Exciton States in Complex Semiconductor Nanostructures, Nina Owschimikow[1], Mirco Kolarczik[1], Yuecel Kaptan[1], Nicolai B. Grosse[1], Ulrike K. Woggon[1]; [1]*Technische Universität Berlin, Germany.* Based on gain excitation spectra derived from two-color pump-probe experiments, we identify crossed exciton states formed in semiconductor nanostructures of mixed dimensionality and investigate their influence on the carrier dynamics.

08:00–10:00
SM1G • Nanostructures
Presider: Ofer Levi; Univ. of Toronto, Canada

SM1G.1 • 08:00
Germanium Nanowires as Spectrally-selective Photodetectors in the Visible-to-Infrared, Amit Solanki[1], Kenneth B. Crozier[2,3]; [1]*Harvard Univ., USA;* [2]*School of Physics, Univ. of Melbourne, Australia;* [3]*Dept. of Electrical and Electronic Engineering, Univ. of Melbourne, Australia.* We experimentally demonstrate arrays of vertical Ge nanowires as spectrally-selective photodetectors at visible to infrared wavelengths. Measurements reveal that the external quantum efficiency spectra of fabricated devices vary with the radius of the constituent nanowires.

SM1G.2 • 08:15
Ultrafine ferroelectric nanostructure in layered Mg:$LiNbO_3$ thin film, Taichi Okada[1,2], Masaki Shimizu[1,2], Satoshi Horikawa[1,2], Takuya Utsugida[1,2], Kazufumi Fujii[1], Sunao Kurimura[1,2], Hirochika Nakajima[2]; [1]*National Inst. for Materials Science, Japan;* [2]*Waseda Univ., Japan*. We reported a fabrication of ultrafine ferroelectric domain structure with 540 nm period into layered Mg-doped/insulator/non-doped $LiNbO_3$.

SM1G.3 • 08:30 Invited
Tunable Coloration with Flexible High-Contrast Metastructures, Li Zhu[1], Jonas Kapraun[1], James Ferrara[1], Connie J. Chang-Hasnain[1]; [1]*Univ. of California Berkeley, USA.* Actively controlling the perceived color of objects is highly desirable for a variety of applications. We report a new flexible high contrast metastructure (HCM) with color being varied by stretching the elastomeric membrane.

08:00–10:00
SM1H • THz Quantum Cascade Lasers
Presider: David Burghoff; MIT, USA

SM1H.1 • 08:00
Selection of Longitudinal Modes in a Terahertz Quantum Cascade Laser via Narrow-band Injection Seeding, Hanond Nong[1], Shovon Pal[1], Sergej Markmann[1], Negar Hekmat[1], Paul Dean[2], Reshma A. Mohandas[2], Li Lianhe[2], Edmund Linfield[2], Giles Davies[2], Andreas D. Wieck[1], Nathan Jukam[1]; [1]*Ruhr-Universität Bochum, Germany;* [2]*Univ. of Leeds, UK*. A terahertz quantum cascade laser is injection seeded with narrowband seed pulses generated from a periodically poled lithium niobate crystal. The spectral emission of the quantum cascade laser is controlled by the seed spectra.

SM1H.2 • 08:15
kW-Peak-Power Terahertz-Wave Parametric Generation and 70 dB-Dynamic-Range Detection Based on Efficient Surface-Coupling Configuration, Yuma Takida[1], Takashi Notake[1], Kouji Nawata[1], Yu Tokizane[1], Shin'ichiro Hayashi[1], Hiroaki Minamide[1]; [1]*RIKEN, Japan*. We have demonstrated kW-peak-power terahertz (THz)-wave parametric generation and 70 dB-dynamic-range detection by using efficient surface-coupling configuration. The system is capable of producing and detecting monochromatic THz-wave pulses in the wide frequency range from 0.8 to 2.8 THz.

SM1H.3 • 08:30
Broadly-Tunable Room-Temperature Monolithic Terahertz Quantum Cascade Laser Sources, Aiting Jiang[1], Seungyong Jung[1], Yifan Jiang[1], Karun Vijayraghavan[1], Jaehyun Kim[1], Mikhail A. Belkin[1]; [1]*Univ. of Texas at Austin, USA*. We report a monolithic terahertz source made of an array of 10 electrically-tunable mid-infrared quantum cascade lasers with intra-cavity terahertz difference-frequency generation. Continuous tunability between 2 and 4 THz is demonstrated at room temperature.

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CLEO: Science & Innovations

08:00–10:00
SM1I • Silicon Photonics
Presider: Bahram Jalali; Univ. of California Los Angeles, USA

SM1I.1 • 08:00
Plasmonic-organic hybrid (POH) modulators for OOK and BPSK signaling at 40 Gbit/s, Argishti Melikyan[1], Kira Köhnle[1], Matthias Lauermann[1], Robert Palmer[1], Sebastian R. Koeber[1], Sascha Muehlbrandt[1], Philipp Schindler[1], Delwin Elder[2], Stefan Wolf[1], Wolfgang Heni[3], Christian Haffner[3], Yuriy Fedoryshyn[3], David Hillerkuss[3], Martin Sommer[1], Larry Dalton[2], Dries VanThourhout[4], Wolfgang Freude[1], Manfred Kohl[1], Juerg Leuthold[3], Christian Koos[1]; *[1]Karlsruher Institut für Technologie, Germany; [2]Dept. of Chemistry, Univ. of Washington, USA; [3]ETH Zürich, Switzerland; [4]Ghent Univ. - IMEC, Belgium*. We report on plasmonic-organic hybrid(POH) phase modulator generating error free (BER<10^{-10}) BPSK signals at 40Gbit/s. In addition, generation and direct detection of 40Gbit/s OOK signals are discussed using POH Mach-Zehnder modulators on the transmitter side.

SM1I.2 • 08:15
Ultra-Compact Hybrid Silicon-VO_2 Electroabsorption Optical Switch, Arash Joushaghani[1], Junho Jeong[1], Suzanne Paradis[2], David Alain[2], J. Stewart Aitchison[1], Joyce K. Poon[1]; *[1]Electrical and Computer Engineering, Univ. of Toronto, Canada; [2]Defence Research and Development Canada - Valcartier, Canada.* A 1 μm-long hybrid Si-VO_2 electroabsorption switch with integrated electrical contacts is demonstrated. A record extinction ratio of ~12 dB/μm is achieved over a bandwidth of ~100 nm with a power dissipation of 2.55 mW.

SM1I.3 • 08:30
Hybrid Silicon Ring Laser with Unidirectional Emission, Wesley D. Sacher[1], Michael Davenport[2], Martijn J. Heck[2], Jared Mikkelsen[1], Joyce K. Poon[1], John Bowers[2]; *[1]Dept. of Electrical and Computer Engineering, Univ. of Toronto, Canada; [2]Dept. of Electrical and Computer Engineering, Univ. of California at Santa Barbara, USA.* A hybrid silicon ring laser in which the counter-clockwise circulating power is coupled into the clockwise mode is demonstrated. Unidirectional clockwise laser output is achieved with a suppression ratio of 19 dB over the counter-clockwise mode.

CLEO: Applications & Technology

08:00–10:00
AM1J • Light Sources and Devices for Biomedical Imaging I
Presider: Ilya Bezel; KLA-Tencor Corp., USA

AM1J.1 • 08:00 Invited
The Cell Laser, Seok-Hyun A. Yun[1,2]; *[1]Harvard Medical School, USA; [2]Massachusetts General Hospital, USA.* The first demonstration of a cell laser in 2011 opened new avenues for generating coherent light from living matters. Here we show progress in this new class of light sources and demonstrate their applications for sensing.

AM1J.2 • 08:30
Analysis of Optical Properties of Cell Lasers and Their Use as Biological Sensors, Matjaz Humar[2,1], Seok-Hyun A. Yun[2]; *[1]Condensed Matter Dept., J. Stefan Inst., Slovenia; [2]Wellman Center for Photomedicine, Dept. of Dermatology, Harvard Medical School and Massachusetts General Hospital, USA.* We analyzed single-cell lasers made from different cell types and fluorescent dyes. Two mirrors enclose the cells forming a laser cavity. The different transversal cell laser modes are dependent on cell shape, refractive index and gain distribution enabling single cell characterization and sensing.

08:00–10:00
AM1K • Microprocessing Ultra-Fast Processing of Dielectries
Presider: Yves Bellouard; Ecole Polytechnique Federale de Lausanne, Switzerland

AM1K.1 • 08:00 Invited
Ultrashort Pulse Lasers for Precise Processing: Results of a Recent German Research Initiative, Stefan Nolte[1]; *[1]Friedrich-Schiller-UniversitÃ¤t Jena, Germany.* We review results of 10 joint research projects on ultrashort pulse technology. Topics include novel laser sources, reliable components and specialized applications from eye surgery to processing of semiconductors, carbon fiber reinforced plastics and metals.

AM1K.2 • 08:30
High Density Data Storage in Transparent Plastics Using Femtosecond Laser Microstructuring, Deepak L. Kallepalli[1]; *[1]Physics Dept., Univ. of Ottawa, Canada.* We report high data storage ~ 66 GB/cm^3 in Poly (methylmethacrylate) by utilizing locally confined fluorescent data bits fabricated by a femtosecond (fs) laser.

CLEO: Science & Innovations

08:00–10:00
SM1L • Fiber Sensing and Measurement
Presider: Axel Schulzgen; Univ. of Central Florida, USA

SM1L.1 • 08:00 Invited
Novel Technologies for High Precision Characterization of Fibers, Andrew D. Yablon[1]; *[1]Interfiber Analysis, LLC, USA.* Optical fiber gain profiling, spectrogram modal analysis, and interferometric refractive index and residual stress measurement are reviewed. These novel characterization technologies are important for designing, assembling and optimizing fiber-based lasers and amplifiers.

SM1L.2 • 08:30
Design and Fabrication of Side-channel Photonic Crystal Fiber for Surface Enhanced Raman Scattering Applications, Nan Zhang[1,2], Georges Humbert[3], Tianxun Gong[1,4], Ping Shum[1,2], Jean-Louis Auguste[3], Zhifang Wu[1,2], Malini Olivo[4,5], Quyen X. Dinh[2,6], Lei Wei[1]; *[1]School of Electrical and Electronic Engineering, Nanyang Techonogical Univ., Singapore; [2]CINTRA CNRS/NTU/THALES, Singapore; [3]Univ. of Limoges/CNRS, France; [4]Bio-Optical Imaging Group, Singapore Bioimaging Consortium (SBIC), A*STAR, Singapore; [5]School of Physics, National Univ. of Ireland, Ireland; [6]R&T Dept., Thales Solutions Asia Pte Ltd, Singapore.* We demonstrate a side-channel photonic crystal fiber for surface enhanced Raman scattering applications. A low detection concentration of 5 pM 4-aminothiophenol solution and an accumulative effect of Raman signal along the fiber length are achieved.

CLEO: Science & Innovations

08:00–09:45
SM1M • Parametric Processing
Presider: Francesca Parmigiani; Univ. of Southampton, UK

SM1M.1 • 08:00 Tutorial
Optical and Hybrid Signal Processing, Stojan Radic[1]; [1]*Univ. of California, San Diego, USA.* Physics and implementation of optical signal processing in communication and sensing links is introduced. Hybrid processing schemes capable of interfacing with high-rate network traffic and electronic backplane are described and illustrated using application examples.

Stojan Radic graduated from the Inst. of Optics, Univ. of Rochester, in 1995 and has subsequently served at Corning and Bell Laboratories. After leaving Bell Laboratories, he was a Nortel Chair at Duke Univ.. Currently he is a professor and a Director of the Photonics System Laboratory at Qualcomm Inst. at the Univ. of California San Diego. Radic's laboratory currently pursues national projects in coherent communications, advanced signal processing and unconventional medical imaging.

08:00–09:45
SM1N • Symposium on Remote Atmospheric Lasing I
Presider: Pavel Polynkin; Univ. of Arizona, USA

SM1N.1 • 08:00 Invited
Remote Backward-Propagating Lasing of Nitrogen and Oxygen in Air, Arthur Dogariu[1], Richard Miles[1]; [1]*Princeton Univ., USA.* We present the latest developments in remote atmospheric air lasing. Stimulated emission induced by two-photon atomic excitation following molecular dissociation creates robust coherent emission in the backwards direction.

SM1N.2 • 08:30 Invited
Experiments on Deep-UV Two-photon Pumping of Fluorescence and Stimulated Emission in Oxygen and Nitrogen Atoms in Flames, Joakim Bood[1], Marcus Aldén[1]; [1]*Lund Univ., Sweden.* Flame experiments using stimulated emission in oxygen and nitrogen atoms induced by 2-photon excitation are reviewed and discussed in terms of today's development of remote sensing concepts based on backward lasing in air.

08:00–10:00
SM1O • Advanced Spectroscopic Techniques
Presider: Scott Howard; Univ. of Notre Dame, USA

SM1O.1 • 08:00
Analysis of Trace Gas Mixtures Using an External Cavity Quantum Cascade Laser Sensor, Mark C. Phillips[1], Matthew S. Taubman[1], Brian Brumfield[1], Jason Kriesel[2]; [1]*Pacific Northwest National Lab, USA;* [2]*Opto-Knowledge Systems Inc., USA.* We measure and analyze mixtures of trace gases at ppb-ppm levels using an external cavity quantum cascade laser sensor with a 1-second response time. Accurate spectral fits are obtained in the presence of overlapping spectra.

SM1O.2 • 08:15
Fundamental Limits in Chirped Laser Dispersion Spectroscopy, Genevieve Plant[1], Andreas Hangauer[1], Gerard Wysocki[1]; [1]*Princeton Univ., USA.* We present performance analysis of chirped laser dispersion spectroscopy (CLaDS) under shot noise limited conditions. A comparison to direct laser absorption spectroscopy (DLAS) is also provided.

SM1O.3 • 08:30 Invited
Mid-IR Quantum Cascade Lasers as an Enabling Technology for Analytical Chemistry, Christian Kristament[1], Markus Brandstetter[1], Andreas Schwaighofer[1], Mirta Alcaraz[1], Bernhard Lendl[1]; [1]*Chemical Technologies and Analytics, Vienna Univ. of Technology, Austria.* An overview on the state of the art on the analysis of liquids by QCLs is given with special focus on the determination of secondary structure elements in aqueous protein solutions using an EC-QCL system.

08:00–10:00
SM1P • Few-cycle Infrared Sources
Presider: Nobuhisa Ishii; Institute for Solid State Physics, Japan

SM1P.1 • 08:00
A Compact Single Cycle Driver for Strong Field Applications based on a Self-compression in a Kagome Fiber, Guangyu Fan[1], Tadas Balciunas[1], Stefan Hässler[1], Coralie Fourcade Dutin[2], Tobias Witting[3], Aleksandr Voronin[4], Aleksei Zheltikov[4,5], Frédéric Gérôme[2], Gerhard Paulus[6], Andrius Baltuska[1], Fetah Benabid[2]; [1]*Vienna Univ. of Technology, Photonics Inst., Austria;* [2]*Univ. de Limoges, GPPMM group, Xlim Research Inst., France;* [3]*Imperial College London, Blackett Lab, UK;* [4]*M.V. Lomonosov Moscow State Univ., Physics Dept., International Laser Center, Russia;* [5]*Texas A & M Univ., College Station Texas, Dept. of Physics and Astronomy, USA;* [6]*Universität Jena, Institut fuer Optik und Quantenelektronik, Germany.* We report on Kagome fiber based self-compression of 100 µJ IR pulses to single cycle duration and demonstrate HHG in an integrated scheme which allows a compact isolated attosecond XUV source implementation above 50 eV.

SM1P.2 • 08:15
Mid-IR 0.4TW Pulses Achieved Through Hollow-Core Fiber Compression, Vincent Cardin[1], Nicolas Thiré[1], Vincent Wanie[1], Samuel Beaulieu[1], François Légaré[1], Bruno E. Schmidt[1]; [1]*INRS-EMT, Canada.* By employing hollow-core fiber compression using a stretched flexible fiber, we achieved 2-cycles pulses centered on 1.8µm with more than 5mJ energy per pulse.

SM1P.3 • 08:30
Broadband ZGP OPA Pumped by Femtosecond Ho:YAG Chirped Pulse Amplifier, Pavel Malevich[2], Tsuneto Kanai[2], Gregory Gitzinger[1], Raman Maksimenka[1], Nicolas Forget[1], Andrius Baltuska[2,3], Audrius Pugzlys[2,3]; [1]*Fastlite, France;* [2]*Vienna Univ. of Technology, Austria;* [3]*Center for Physical Sciences & Technology, Lithuania.* We demonstrate a broadband parametric amplifier at 6 µm driven by a femtosecond 2.1µm Ho:YAG chirped-pulse amplifier. The scheme offers an all-in-one solution for seeding, pumping and phase stabilization of few-cycle pulses in $ZnGeP_2$ and similar mid-IR crystals.

CLEO: QELS-Fundamental Science

FM1A • Quantum Metrology and Measurement—Continued

FM1A.2 • 09:00
Experimentally Quantifying the Advantages of Weak-Values-Based Metrology, Gerardo Viza[1,2], Julian Martinez[1,2], Gabriel Alves[3], Andrew N. Jordan[1,2], John Howell[1,2]; *[1]Dept. of Physics and Astronomy, Univ. of Rochester, USA; [2]The Center for Coherence and Quantum Optics, Univ. of Rochester, USA; [3]Instituto de Fisica, Universidade Federal do Rio de Janeiro, Brazil.* We measure optical beam deflections both using a weak-values technique and by focusing. By introducing controlled modulations, the WVT outperforms focusing. Post-selecting on 1\% of the photons, we obtain 99\% of the available Fisher information.

FM1A.3 • 09:15
Particle vs. Mode Entanglement in Optical Quantum Metrology, Nicolas Quesada[1], Jaspreet Sahota[1]; *[1]Univ. of Toronto, Canada.* We present a constructive proof of the fact that mode entanglement is not necessary for optical quantum enhanced metrology (QEM) but particle entanglement is. We provide a particle entanglement witness that detects all path symmetric states useful for QEM in a Mach-Zender interferometer.

FM1B • Exciton Dynamics in 1D/2D Nanostructures—Continued

FM1B.4 • 08:45
Ultrafast Modulation of Strong Light-Matter Coupling, Christoph Lange[1], Emiliano Cancellieri[2], Lee A. Rozema[3], Rockson Chang[3], Shreyas Potnis[3], Aephraim M. Steinberg[3], Mark Steger[4], David W. Snoke[4], Loren N. Pfeiffer[5], Kenneth W. West[5], Alex Hayat[6]; *[1]Universität Regensburg, Germany; [2]Univ. of Sheffield, UK; [3]Dept. of Physics, Centre for Quantum Information and Quantum Control, and Inst. for Optical Sciences, Univ. of Toronto, Canada; [4]Dept. of Physics and Astronomy, Univ. of Pittsburgh, USA; [5]Dept. of Electrical Engineering, Princeton Univ., USA; [6]Dept. of Electrical Engineering, Technion, Israel.* We modulate strong coupling in a GaAs/AlGaAs microcavity by transiently decoupling exciton and cavity through the optical Stark effect induced by intense, red-detuned laser pulses. Pulses longer (1500 fs) and shorter (225 fs) than the Rabi cycle time of 500 fs yield distinctly different line shapes.

FM1B.5 • 09:00
Coherent Control of Correlation Transport between Semiconductor Quantum Wells, Osmo Vänskä[1,2], Ilkka Tittonen[2], Stephan W. Koch[1], Mackillo Kira[1]; *[1]Philipps-Universität Marburg, Germany; [2]Aalto Univ., Finland.* Terahertz control of semiconductor excitations is analyzed theoretically in a double-quantum-well by theoretical modeling. The results demonstrate that selective transport of electrons, excitons and even pure correlations is realizable in present-day experiments.

FM1B.6 • 09:15
Quantum Optics with Dropletons, Martin Mootz[1], Mackillo Kira[1], Stephan W. Koch[1], Andrew E. Almand-Hunter[2,3], Kai Wang[2], Steven Cundiff[2,3]; *[1]Dept. of Physics, Philipps-Univ. Marburg, Germany; [2]JILA, Univ. of Colorado and National Inst. of Standards and Technology, USA; [3]Dept. of Physics, Univ. of Colorado, USA.* Dropletons are highly correlated quasiparticles, recently found in GaAs quantum wells. We demonstrate that they can be controlled by adjusting light source's quantum fluctuations and that their size grows with increasing temperature.

FM1C • Nonlinear Metamaterials—Continued

FM1C.2 • 09:00
Third-Harmonic Generation from Silicon Oligomers and Metasurfaces, Maxim R. Shcherbakov[3], Dragomir N. Neshev[1], Ben Hopkins[1], Alexander S. Shorokhov[3], Isabelle Staude[1], Elizaveta V. Melik-Gaykazyan[3], Andrey Miroshnichenko[1], Igal Brener[2], Andrey A. Fedyanin[3], Yuri S. Kivshar[1]; *[1]Nonlinear Physics Centre, Research School of Physics and Engineering, The Australian National Univ., Australia; [2]Center for Integrated Nanotechnologies, Sandia National Lab, USA; [3]Faculty of Physics, Lomonosov Moscow State Univ., Russia.* Third-harmonic generation spectroscopy of silicon oligomers and metasurfaces reveals the nonlinear spectra reshaping with electric and magnetic dipolar Mie-type resonances and up-conversion increase by two orders of magnitude as compared to the bulk silicon.

FM1C.3 • 09:15
Multipolar analysis of linear and nonlinear unidirectional response from plasmonic dimers, Ekaterina Poutrina[2,1], Augustine Urbas[2]; *[1]UES, Inc., USA; [2]Air Force Research Lab, USA.* We develop the retrieval procedure for linear and nonlinear polarizabilities of plasmonic nanodimers and present examples of unidirectional scattering and nonlinear unidirectional generation from such geometries. Related effective parameters of periodic dimer arrangements are discussed.

FM1D • Accelerating Beams & Beamshaping Application—Continued

FM1D.4 • 08:45
Accelerating Self-Imaging: the Airy-Talbot Effect, Yaakov Lumer[1], Lee Drori[1], Yaov Hazan[1], Mordechai Segev[1]; *[1]Physics Dept., Technion Israel Inst. of Technology, Israel.* We present self-imaging of optical waves along curved trajectories, theoretically and experimentally. Unlike the Talbot effect, the field wave need not be periodic. Paraxially, self-imaging persists indefinitely, while non-paraxially is limited by overall bending angle.

FM1D.5 • 09:00
Optical Wavepackets Overcoming Gravitational Effects, Rivka Bekenstein[1], Ran Schley[1], Maor Mutzafi[1], Carmel Rotschild[1], Mordechai Segev[1]; *[1]Technion Israel Inst. of Technology, Israel.* We find specific wavepackets that overcome analogue gravitational phenomena due to the complex interplay between interference effects and various optical gravitational effects, and demonstrate them in experiments with nonlocal nonlinear interactions.

FM1D.6 • 09:15
Three-Dimensional Abruptly Autofocusing Optical Wave Packet, Qian Cao[2,3], Chenchen Wan[2,1], Xin Huang[2], Andy Chong[2,4]; *[1]DESY, Germany; [2]Electro-Optics Program, Univ. of Dayton, USA; [3]FS-CFEL-2, Center of Free-Electron Laser Science, Germany; [4]Physics, Univ. of Dayton, USA.* We generate a three-dimensional (3D) autofocusing wave packet by combining counter-propagating Airy pulses and an Airy ring beam. A 3D profile measurement reveals unique 3D autofocusing of such wave packet in a linear medium.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FM1E • Symposium on Single-photon Nonlinear Optics I—Continued

FM1E.3 • 08:45
How a Single Photon Can Act Like Many Photons, Matin Hallaji[1], Amir Feizpour[1], Greg Dmochowski[1], Josiah Sinclair[1], Aephraim M. Steinberg[1]; [1]*Physics, Univ. of Toronto, Canada*. The weak nonlinear effect of a single photon on a probe beam is amplified by postselecting on a rare final state ("WVA" effect). The resulting cross-phase shift is up to five times greater than the usual single-photon phase shift.

FM1E.4 • 09:00 Invited
Few-photon Nonlinear Optics Using Interacting Rydberg Atoms, Sebastian Hofferberth[1]; [1]*Harvard Univ., USA*. Mapping the interaction between Rydberg excitations onto photons enables the realization of optical nonlinearities on the single-photon level. We present a single-photon transistor, where one gate photon controls the transmission of many source photons.

SM1F • Semiconductor Laser Physics—Continued

SM1F.3 • 08:45
High-Speed Electrical Modulation of Polariton Lasers, Md Zunaid Baten[1], Thomas Frost[1], Saniya Deshpande[1], Pallab K. Bhattacharya[1]; [1]*Univ. of Michigan, USA*. Room temperature electrical modulation response of a bulk GaN-based electrically injected polariton laser is reported. The frequency response is derived from the measured time-resolved electroluminescence and a maximum -3dB bandwidth of 0.65 GHz is obtained.

SM1F.4 • 09:00
Lasers With Distributed Loss Have Sublinear Power Output, Tobias Mansuripur[3], Guy-Mael de Naurois[1], Alexey Belyanin[2], Federico Capasso[1]; [1]*School of Engineering and Applied Sciences, Harvard Univ., USA;* [2]*Dept. of Physics, Texas A&M Univ., USA;* [3]*Dept. of Physics, Harvard Univ., USA*. We provide a simple explanation for why laser media with distributed loss should have a sublinear output power characteristic. This understanding clarifies the role of long-range spatial hole burning in reducing the efficiency of semiconductor lasers, and is essential for optimizing power output.

SM1F.5 • 09:15
Measuring a Radiative Recombination Current in an Optically Pumped Gain Medium, Robert Thomas[1], Peter M. Smowton[1], Peter Blood[1]; [1]*Cardiff Univ., UK*. An analytical technique for determining the radiative current in optically pumped gain media is presented. A means of seperately identifying the effects of gain compression and pump non-uniformities in amplified spontaneous emission spectra is introduced.

SM1G • Nanostructures—Continued

SM1G.4 • 09:00
Hybrid Diamond-Silicon Carbide Structures Incorporating Silicon-Vacancies in Diamond as Quantum Emitters, Jingyuan Linda Zhang[1], Hitoshi Ishiwata[1], Marina Radulaski[1], Thomas M. Babinec[1], Kai Muller[1], Konstantinos G. Lagoudakis[1], Robert Edgington[1], Kassem Alassaad[2], Gabriel Ferro[2], Nicholas Melosh[1], Zhi-Xun Shen[1], Jelena Vuckovic[1]; [1]*Stanford Univ., USA;* [2]*Universite de Lyon, France*. We demonstrate a novel technique for generating several hybrid solid state nano- and micro-photonic devices. Our approach combines the growth of nanodiamonds on silicon carbide substrate from molecular diamond with the use of these particles as hard mask for pattern transfer into the substrate.

SM1G.5 • 09:15
Experimental Demonstration of CMOS-Compatible Long-Range Dielectric-Loaded Surface Plasmon-Polariton Waveguides (LR-DLSPPWs), Roy T. Zektzer[1], Boris Desiatov[1], Noa Mazurski[1], Sergey bozhevolnyi[2], Uriel Levy[1]; [1]*The hebrew Univ. of Jerusalem, Israel;* [2]*Technology and Innovation, Univ. of Southern Denmark, Denmark*. We demonstrate the design, fabrication and experimental characterization of longrange dielectric-loaded SPP waveguides (LR-DLSPPWs) that are compatible with CMOS technology. The demonstrated waveguides feature good mode confinement together with long propagation at telecom wavelengths.

SM1H • THz Quantum Cascade Lasers—Continued

SM1H.4 • 08:45
QCL-based Metrological-grade THz Spectroscopy Tools, Luigi Consolino[1], Mario Siciliani de Cumis[1], Davide Mazzotti[1], Annamaria Campa[1], Marco Ravaro[1], Miriam S. Vitiello[2], Saverio Bartalini[1], Pablo Cancio Pastor[1], Paolo De Natale[1]; [1]*CNR - INO, Italy;* [2]*CNR-NEST, Italy*. We present the latest results on high-resolution QCL-based THz spectroscopy: the possibility to perform saturated absorption or cavity-enhanced spectroscopy on THz molecular transitions, strengthened by the realization of a new generation THz FCS.

SM1H.5 • 09:00 Invited
Coherent absorption control in polaritonic systems, Alessandro Tredicucci[2,1]; [1]*NEST, Istituto Nanoscienze-CNR, Italy;* [2]*Dipartimento di Fisica "E. Fermi", Università di Pisa, Italy*. Coherent Perfect Absorption is discussed in the context of strongly-coupled polariton systems. It occurs when the cavity loss rate matches the material one, as demonstrated for intersubband transitions in a photonic crystal resonator.

CLEO: Science & Innovations

SM1I • Silicon Photonics—Continued

SM1I.4 • 08:45
Integrated on-chip C-band optical spectrum analyzer using dual-ring resonators , Ying Li[1], Qi Li[1], Yang Liu[2], Tom Baehr-Jones[2], Michael Hochberg[2], Keren Bergman[1]; *[1]Columbia Univ., USA; [2]Coriant Advanced Technology Group, USA.* We demonstrate an on-chip optical spectrum analyzer (OSA) using two cascade optical ring resonators. The OSA's span is wider than 50nm and resolution is ~0.1nm. A germanium photodetector and a p-i-n modulator are integrated on the chip and used for detection.

SM1I.5 • 09:00
Effective Carrier Sweepout In A Silicon Waveguide by a Metal-Semiconductor-Metal Structure, Yunhong Ding[1], Hao Hu[1], Haiyan Ou[1], Leif K. Oxenløwe[1], Kresten Yvind[1]; *[1]DTU Fotonik, Dept. of Photonics Engineering, Technical Univ. of Denmark, Denmark.* We demonstrate effective carrier depletion by metal-semiconductor-metal junctions for a silicon waveguide. Photogenerated carriers are efficiently swept out by applying bias voltages, and a shortest carrier lifetime of only 55 ps is demonstrated.

SM1I.6 • 09:15
Apodized Focusing Fully Etched Sub-wavelength Grating Couplers With Ultra-low Reflections, Yun Wang[1], Han Yun[1], Zeqin Lu[1], Richard Bojko[2], Fan Zhang[1], Michael Caverley[1], Nicolas A. Jaeger[1], Lukas Chrostowski[1]; *[1]Univ. of British Columbia, Canada; [2]Univ. of Washington, USA.* We experimentally demonstrated apodized focusing fully etched sub-wavelength grating couplers for the transverse electric (TE) mode. An insertion loss of 4.2 dB, 1-dB bandwidth of 36 nm, and back reflection of -24 dB have been obtained.

CLEO: Applications & Technology

AM1J • Light Sources and Devices for Biomedical Imaging I—Continued

AM1J.3 • 08:45
Sensitive and Selective Detection of Prostate Specific Antigen beyond ELISA Using Photonic Crystal Nanolaser, Shoji Hachuda[1], Takumi Watanabe[1], Daichi Takahashi[1], Toshihiko Baba[1]; *[1]Electrical and computer engineering, Yokohama National Univ., Japan.* We sensitively detected prostate specific antigen (PSA) using photonic crystal nanolaser sensors. In pure water and impure sample including 1 μM BSA, we detected <100 fM PSA, which is lower than the limit of ELISA.

AM1J.4 • 09:00
4.4 nJ, 114 fs Nd-doped Fiber Laser Pulses at 920nm for *in Vivo* Two-photon Microscopic Imaging, Bingying Chen[1], Tongxiao Jiang[1], Weijian Zong[1,2], Fuzeng Niu[1], Liangyi Chen[1], Zhigang Zhang[1], Yanrong Song[3], Aimin wang[1]; *[1]Peking Univ., USA; [2]China Dept. of Cognitive Sciences, Inst. of Basic Medical Sciences, China; [3]Beijing Univ. of Technology, School of Applied Science, China.* We optimized pre-chirp in an Nd-doped fiber amplifier to achieve high-quality femtosecond 920 nm pulses. The *in vivo* zebrafish imaging proves the laser amplifier an ideal source in two-photon microscopic imaging.

AM1J.5 • 09:15
Highly Compact, Low-Noise All-Solid-State Laser System for Stimulated Raman Scattering Microscopy, Tobias Steinle[1], Vikas Kumar[2], Andy Steinmann[1], Marco Marangoni[2], Giulio Cerullo[2], Harald W. Giessen[1]; *[1]4th Physics Inst., Univ. of Stuttgart, Germany; [2]IFN-CNR, Dipartimento di Fisica, Politecnico di Milano, Italy.* We present a simple, compact and very robust laser source for low-noise stimulated Raman scattering microscopy using a single-stage optical parametric amplifier seeded with tunable cw radiation from an external-cavity diode laser.

AM1K • Microprocessing Ultra-Fast Processing of Dielectries—Continued

AM1K.3 • 08:45
Femtosecond laser cutting of glass by controlled fracture propagation, Clemens Hoenninger[1], Konstantin Mishchik[2], Clémentine Javaux[3], Ophélie Dematteo-Caulier[2], Stefan Skupin[2], Benoit Chimier[2], Guillaume Duchateau[2], Antoine Bourgeade[4], Rainer Kling[3], Amélie Letan[1], Eric Mottay[1], John Lopez[2]; *[1]Amplitude Systemes, France; [2]Université Bordeaux, CNRS, CEA, CELIA UMR5107, France; [3]Alphanov, France; [4]CEA, France.* We present the use of a compact femtosecond laser with 300-fs pulse duration and pulse energy on the order of 10s of μJ for the cutting of glass by controlled fracture propagation.

AM1K.4 • 09:00 Invited
Microfabrication of Ion Trap Platforms with Integrated Optics and Three-dimensional Electrodes, Mark Dugan[1], Chris Schenck[1], Ali Said[1], Philippe Bado; *[1]Translume Inc., USA.* We discuss a laser-based process to fabricate three-dimensional electromagnetic microtraps on silica platforms. Design flexibility for extended electrode geometries with a high degree of optical access and component intergration is supported by this fabrication process.

CLEO: Science & Innovations

SM1L • Fiber Sensing and Measurement—Continued

SM1L.3 • 08:45
Distributed Temperature and Strain Discrimination Using a Few-Mode Fiber, An Li[1], Yifei Wang[1,2], Jian Fang[1], William Shieh[1]; *[1]Univ. of Melbourne, Australia; [2]National ICT Australia, Australia.* We propose a novel method for distributed measurement of temperature and strain using a few-mode fiber (FMF). High discrimination accuracies of 0.115 °C and 0.283 με are achieved, under a spatial resolution of 2.5 m.

SM1L.4 • 09:00
Simultaneous Measurement of Strain and Temperature using High Sensitivity Multicore Fiber Sensors, Amy Van Newkirk[1], Enrique Antonio-Lopez[1], Guillermo Salceda-Delgado[1,2], Mohammad Umar Piracha[3], Rodrigo Amezcua-Correa[1], Axel Schulzgen[1]; *[1]Univ. of Central Florida, USA; [2]CIO, Centro de Investigaciones en Optica, Mexico; [3]FAZ Technology Inc., USA.* We demonstrate strain sensors consisting of multicore fiber spliced between two single mode fibers, with increased sensitivity to a factor of 12x a standard FBG. Simultaneous decoupling of strain and temperature measurements are also demonstrated.

SM1L.5 • 09:15
Fiber Optic Sensors Based on Orbital Angular Momentum, Robert Niederriter[1], Mark E. Siemens[2], Juliet Gopinath[3]; *[1]Dept. of Physics, Univ. of Colorado, USA; [2]Dept. of Physics and Astronomy, Univ. of Denver, USA; [3]Dept. of Electrical, Computer, and Energy Engineering, Univ. of Colorado, USA.* Fiber optic sensors based on orbital angular momentum (OAM) have unexplored potential. We propose a design for an OAM-based fiber sensor and analyze its ability to measure changes in strain and temperature.

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SM1M • Parametric Processing—Continued

SM1M.2 • 09:00
Optical phase lock loop circuit for Non-degenerate optical parametric phase sensitive amplifiers with wide signal-idler optical frequency spacing, Yasuhiro Okamura[1], Koryo Higashiyama[1], Masafumi Koga[2], Atsushi Takada[1]; [1]*The Univ. of Tokushima, Japan;* [2]*Oita Univ., Japan.* Optical phase lock loop circuit for non-degenerate parametric phase sensitive amplifiers with wide signal- idler light frequency spacing is proposed. The proof-of-principle experiment is successfully demonstrated for 40-GHz spaced signal-idler lights using 5-GHz beat signals.

SM1M.3 • 09:15
Multichannel Wavelength Multicasting for QAM Signals Free of Pump-Phase-Noise using Flexible Coherent Multi-Carrier Pump, Guo-Wei Lu[2,1], Takahide Sakamoto[1], Tetsuya Kawanishi[1]; [1]*Natl. Inst. of Info. & and Comm. Tech., Japan;* [2]*Tokai Univ., Japan.* We propose and demonstrate pump-phase-noise-free 2-to-7 multichannel wavelength multicasting for QAM signals using flexible coherent multi-carrier pump. <0.4dB penalty is obtained after multicasting with the proposed scheme even using 3-MHz-linewidth DFB laser as pump source.

SM1N • Symposium on Remote Atmospheric Lasing I—Continued

SM1N.3 • 09:00 Invited
How Do Basic Nonlinear Optical Processes Lead to Atmospheric Lasing?, Robert W. Boyd[1,2]; [1]*Dept. of Physics, Univ. of Ottawa, Canada;* [2]*Inst. of Optics, Univ. of Rochester, USA.* We review some of the experimental observations of atmospheric lasing and describe how basic nonlinear optical processes such as self-focusing, beam filamentation, amplified spontaneous emission and superradiance could lead to some of this behavior.

SM1O • Advanced Spectroscopic Techniques—Continued

SM1O.4 • 09:00
Background-Free Heterodyne Photoexpansion Infrared Nanospectroscopy, Feng Lu[1], Mingzhou Jin[1], Mikhail A. Belkin[1]; [1]*Univ. of Texas at Austin, USA.* The unwanted photoacoustic pressure force in photoexpansion spectroscopy, which comes from light absorption of the sample not below the AFM tip, was suppressed at the heterodyne frequency of laser pulses and piezo-driven cantilever oscillation.

SM1O.5 • 09:15
Large Amplitude Wavelength Modulation Spectroscopy for Sensitive Measurements of Broad Absorbers, Torrey Hayden[1], Paul Schroeder[1], Gregory B. Rieker[1]; [1]*Univ. of Colorado at Boulder, USA.* We demonstrate wavelength modulation spectroscopy of CO_2 at >30 atm using a fast-scanning MEMS laser. The technique shows promise for sensitive measurements of species with broadband absorption features, such as high-pressure gases and large molecules.

SM1P • Few-cycle Infrared Sources—Continued

SM1P.4 • 08:45
Millijoule 1-ps Pulses from a kHz Ho:YAG Regenerative Amplifier Seeded with a Tm,Ho-Fiber Laser, Pavel Malevich[1], Tsuneto Kanai[1], Heinar Hoogland[3,4], Ronald Holzwarth[3,5], Andrius Baltuska[1,2], Audrius Pugzlys[1,2]; [1]*Vienna Univ. of Technology, Austria;* [2]*Center for Physical Sciences & Technology, Lithuania;* [3]*Menlo Systems GmbH, Germany;* [4]*Dept. of Physics, Univ. of Erlangen-Nuremberg, Germany;* [5]*Max-Planck-Inst. of Quantum Optics, Germany.* We demonstrate a 2090-nm 1-ps MOPA based on a Tm,Ho-fiber laser seeder and a Ho:YAG regenerative amplifier delivering 1.25-mJ pulses at a repetition rate of 1-kHz as a prospective driver laser for mid-IR frequency conversion.

SM1P.5 • 09:00
Ultrastable and High-Power Yb:Fiber Amplifier for Nonlinear Frequency Conversion at High Repetition Rate, Patrick Storz[1], Marcel Wunram[1], Daniele Brida[1], Alfred Leitenstorfer[1]; [1]*Dept. of Physics, Univ. of Konstanz, Germany.* We demonstrate an ultrastable Yb:fiber amplifier delivering 145 fs pulses with 6 µJ energy at 10 MHz repetition rate. The Er:fiber seed laser provides inherently synchronized broadband continua whose power is boosted via optical parametric amplification.

SM1P.6 • 09:15
Coherent Mid-IR Supercontinuum Generation in a Hydrogenated Amorphous Silicon Waveguide, Hongcheng Sun[1], Ke-Yao Wang[1], Reza Salem[2], Peter Fendel[2], Amy C. Foster[1]; [1]*Johns Hopkins Univ., USA;* [2]*Thorlabs Inc., USA.* A 790-nm wide Mid-IR supercontinuum generation, spanning from 1.63 µm to 2.42 µm, is demonstrated in a hydrogenated amorphous silicon waveguide. The pump source is a 160-fs Thulium doped fiber laser centered at 1910 nm.

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FM1A • Quantum Metrology and Measurement—Continued

FM1A.4 • 09:30
Quantum Refractometer, Anna Paterova[1], Dmitry Kalashnikov[1], Sergei Kulik[2], Leonid A. Krivitsky[1]; [1]*Data Storage Inst., Singapore;* [2]*Dept. of Physics, Lomonosov Moscow State Univ., Russia*. We exploit interference of two Parametric Down Conversion (PDC) sources to observe infrared resonances of CO_2. Frequency correlations of PDC enable determination of the refractive index at IR wavelengths with visible range optics and photodetectors.

FM1A.5 • 09:45
Experimental Demonstration of Quantum Sensing in the Presence of Quantum Decoherence, Zheshen Zhang[1], Sara Mouradian[1], Franco N. Wong[1], Jeffrey Shapiro[1]; [1]*MIT, USA*. We report the first experimental demonstration of an entanglement-enhanced sensing system that is resilient to environmental loss and noise.

FM1B • Exciton Dynamics in 1D/2D Nanostructures—Continued

FM1B.7 • 09:30
Terahertz Magneto-spectroscopy of Quantum Wells: Stability of High-Density Excitons in High Magnetic Fields, Qi Zhang[1], Weilu Gao[1], John Watson[2], Michael Manfra[2], Junichiro Kono[1]; [1]*Rice Univ., USA;* [2]*Purdue Univ., USA*. We study the dynamics of excitons in GaAs quantum wells via optical-pump/terahertz-probe spectroscopy in magnetic fields. We found that the 1*s*-2*p*$_+$ intra-excitonic transition is robust at high magnetic fields even under high excitation fluences, indicating magnetically enhanced stability of excitons.

FM1B.8 • 09:45
Terahertz magneto-optical spectroscopy of two-dimensional hole and electron systems, Kamaraju Natarajan[1], Wei Pan[3], Ulf Ekenberg[2], Dejan M Gvozdić[4], stephane Boubanga-Tombet[6,5], Prashanth C Upadhya[1,6], John Reno[3], Antoinette J. Taylor[1], Rohit P. Prasankumar[1]; [1]*Center for Integrated nanotechnologies, Los Alamos National Laboratary, USA;* [2]*Semiconsultants, Sweden;* [3]*Sandia National Lab, USA;* [4]*School of Electrical Engineering, Univ. of Belgrade, Serbia;* [5]*Research Inst. of Electrical Communication, Tohoku Univ., Japan;* [6]*Lab for Electro-Optics Systems Indian Space Research Organization,, India*. Terahertz magneto-optical spectroscopy on a two-dimensional hole gas reveal a nonlinear dependence on the applied magnetic field. This is due to its complex non-parabolic valence band structure, as verified by multiband Landau level theoretical calculations.

FM1C • Nonlinear Metamaterials—Continued

FM1C.4 • 09:30
Enhanced Magnetic Second-Harmonic Generation from Resonant Metasurfaces, Sergey S. Kruk[1], Martin Weismann[2,3], Anton Bykov[4], Evgeniy Mamonov[4], Irina Kolmychek[4], Tatiana Murzina[4], Nicolae Panoiu[2], Dragomir N. Neshev[1], Yuri S. Kivshar[1]; [1]*Australian National Univ., Australia;* [2]*Univ. College London, UK;* [3]*Photon Design Ltd, UK;* [4]*Moscow State Univ., Russia*. We demonstrate enhancement of second-harmonic generation efficiency in resonant nanostructures supporting optically induced magnetic response. This is achieved through simultaneous excitation of electric and magnetic multipoles at the second-harmonic wavelength and their constructive interference.

FM1C.5 • 09:45
A new type of optical activity in a toroidal metamaterial, Tim Raybould[1], Vassili Fedotov[1], Nikitas Papsimakis[1], Ian Youngs[2], Wei Ting Chen[3], Din Ping Tsai[3], Nikolay Zheludev[1]; [1]*Univ. of Southampton, UK;* [2]*DSTL, UK;* [3]*National Taiwan Univ., Taiwan*. We demonstrate experimentally and numerically the first ever observation of optical activity in a chiral metamaterial that is underpinned by the exotic resonant combination of an electric quadrupole and the elusive toroidal dipole.

FM1D • Accelerating Beams & Beamshaping Application—Continued

FM1D.7 • 09:30
Beam Shaping and Production of Vortex Beams in Coherent Raman Generation, Miaochan Zhi[2], Kai Wang[3], Hua Xia[1], Alexandra Zhdanova[1], Maria Shutova[1], Alexei Sokolov[1]; [1]*Texas A&M Univ., USA;* [2]*Biosystems and Biomaterials Division, National Inst. of Standards and Technology, USA;* [3]*Dept. of Physics and JILA, Univ. of Colorado, USA*. We explore the role of spatial shaping in nonlinear interactions of ultrafast laser beams. We investigate the coherent transfer of orbital angular momentum in $PbWO_4$ crystal by using two time-delayed linearly chirped infrared pulses.

FM1D.8 • 09:45
Visualizing Fast Molecular Dynamics by Coherent Feedback in an Optical Oscillator, Avi Pe'er[1], Igal Aharonobich[1]; [1]*Bar-Ilan Univ., Israel*. We exploit the inherent mode competition in a laser resonator to solve in real time the major coherent control problem - how to shape a pulse that will dump a general wavepacket into a single target state.

10:00–10:30 Coffee Break, *Concourse Level*

NOTES

CLEO: QELS-Fundamental Science

FM1E • Symposium on Single-photon Nonlinear Optics I—Continued

FM1E.5 • 09:30 Invited

The Birth, Care, and Feeding of Cat States in Circuit QED: Quantum Jumps of Photon Parity, Robert Schoelkopf[1]; *[1]Yale Univ., USA.* I will describe recent experiments where we store quantum information in Schrodinger cat states of a microwave cavity, and perform the first continuous observation of a quantum error syndrome, based on the photon number parity.

CLEO: Science & Innovations

SM1F • Semiconductor Laser Physics—Continued

SM1F.6 • 09:30

Suppressed Relaxation-Oscillation Dynamics in a DFB laser Monolithically Integrated with Weak Optical Feedback, Daan Lenstra[1], Domenico D'Agostino[1], Huib Ambrosius[1], Meint Smit[1]; *[1]Electrical Engineering, Eindhoven Univ. of Technology, Netherlands.* We experimentally demonstrate a laser which operates under weak optical feedback, showing two broad regions of operation without relaxation-oscillation induced instabilities and where high side-mode suppression above 40 dB is maintained, irrespective of the feedback phase.

SM1F.7 • 09:45

Electrically pumped random lasing based on Au-ZnO nanowire Schottky junction, Fan Gao[2], Muhammad Morshed[3], Sunayna Bashar[3], Youdou Zheng[2], Shi Yi[2], Jianlin Liu[1]; *[1]Electrical and Computer Engineering, Univ. of California, USA; [2]Nanjing Univ., China; [3]Univ. of California, USA.* Electrically pumped random lasing based on Au-ZnO nanowire Schottky junction diode is demonstrated. Good lasing behavior is achieved and excitonic recombination is responsible for lasing generation. It provides an alternative approach towards semiconductor random lasers.

SM1G • Nanostructures—Continued

SM1G.6 • 09:30

Flat metallic surface with sub-10-nm gaps using modified atomic-layer lithography, Dengxin Ji[1], Borui Chen[1], Xie Zeng[1], Tania Moein[1], Haomin Song[1], Qiaoqiang Gan[1], Alexander Cartwright[1]; *[1]State Univ. of New York at Buffalo, USA.* We developed a novel atomic layer lithography procedure to fabricate large area flat metallic surfaces with sub-10-nm features, which is particularly useful for fabrication of nanostructures with strongly localized field enhancement.

SM1G.7 • 09:45

Investigation of the reflection and transmission of nano-scale gold films, Haoliang Qian[1], Yuzhe Xiao[1], Dominic Lepage[1], Zhaowei Liu[1,2]; *[1]Dept. of Electrical and Computer Engineering, UC San Diego, USA; [2]Materials Science and Engineering, UC San Diego, USA.* The reflection and transmission of thin gold films with thickness varying from 2.5 nm to 30 nm are experimentally investigated. A theory is proposed and explains all experimental data.

SM1H • THz Quantum Cascade Lasers—Continued

SM1H.6 • 09:30

Amplification of broadband terahertz pulses in a quantum cascade heterostructure, Juraj Darmo[1], Dominic Bachmann[1], Markus Roesch[2], Norbert Leder[1], Giacomo Scalari[2], Mattias Beck[2], Holger Arthaber[1], Jerome Faist[2], Karl Unterrainer[1]; *[1]Technische Universität Wien, Austria; [2]ETH Zürich, Switzerland.* We demonstrate an amplification of broadband terahertz pulses in the bandwidth of 500 GHz centered at 2.5 THz. The amplification is based on gain switched quantum cascade structure width the heterogeneous active region.

SM1H.7 • 09:45

A Hybrid Plasmonic Waveguide Terahertz Quantum Cascade Laser, Riccardo Degl'Innocenti[1], Yash Shah[1], Robert Wallis[1], Adam Klimont[1], Yuan Ren[1], David Jessop[1], Harvey Beere[1], David Ritchie[1]; *[1]Univ. of Cambridge, UK.* We present a quantum cascade laser emitting around 2.9 THz, based on a new hybrid plasmonic waveguide design. The resultant optical mode provides a performance commensurate with a metal-metal waveguide, while improving the far-field pattern.

10:00–10:30 Coffee Break, *Concourse Level*

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SM1I • Silicon Photonics—Continued

SM1I.7 • 09:30
Sinusoidal Anti-coupling SOI Strip Waveguides, Fan Zhang[1], Han Yun[1], Valentina Donzella[1], Zeqin Lu[1], Yun Wang[1], Zhitian Chen[1], Lukas Chrostowski[1], Nicolas A. Jaeger[1]; [1]*Univ. of British Columbia, Canada.* We experimentally demonstrate sinusoidal anti-coupling silicon-on-insulator strip waveguides, separated by 200 nm, that have a minimum inter-waveguide crosstalk suppression of 26.8 dB within the C-band for the fundamental transverse electric mode.

SM1I.8 • 09:45
Asymmetric-waveguide-assisted 3-dB Broadband Directional Coupler, Zeqin Lu[1], Han Yun[1], Yun Wang[1], Zhitian Chen[1], Fan Zhang[1], Nicolas A. Jaeger[1], Lukas Chrostowski[1]; [1]*Univ. of British Columbia, Canada.* We demonstrate 3-dB broadband directional couplers that use asymmetric-waveguide-based phase compensation. Average coupling ratios of 46.57% and 48.28% were obtained from 1500 nm to 1600 nm for transverse electric and transverse magnetic modes, respectively.

CLEO: Applications & Technology

AM1J • Light Sources and Devices for Biomedical Imaging I—Continued

AM1J.6 • 09:30
High Power 780 nm Femtosecond Fiber Laser, Zuosheng Liu[1], Weijian Zong[2,3], Yizhou Liu[1], Lijun Zuo[1], Cai Wen[1], Tongxiao Jiang[1], Jian Zhang[1], Yuxuan Ma[1], Zhigang Zhang[1], Liangyi Chen[1], Aimin wang[1]; [1]*Peking Univ., China;* [2]*The State Key Lab of Biomembrane and Membrane Biotechnology, Inst. of Molecular Medicine, China;* [3]*China Dept. of Cognitive Sciences, Inst. of Basic Medical Sciences, China.* We demonstrate an 880 mW 780 nm femtosecond laser based on a high-order dispersion compensated Er-doped fiber laser and frequency doubling. It has been used on a two-photon three-axis digital scanned light-sheet microscopy.

AM1J.7 • 09:45
A Six-Color Four Laser Mobile Platform for Multi-Spectral Fluorescence Imaging Endoscopy, John F. Black[1], Tyler Tate[2], Molly Keenan[3], Elizabeth Swan[2], Urs Utzinger[3], Jennifer Barton[3]; [1]*Glannaventa, Inc., USA;* [2]*College of Optical Sciences, Univ. of Arizona, USA;* [3]*Biomedical Engineering, Univ. of Arizona, USA.* A Q-switched alexandrite laser is frequency doubled and tripled to the ultraviolet, combined with 3 visible wavelengths, and fiber coupled to form the illumination source for a micro-endoscope designed for minimally invasive ovarian cancer screening.

AM1K • Microprocessing Ultra-Fast Processing of Dielectries—Continued

AM1K.5 • 09:30 Invited
Laser Processing of Optofluidic Devices for Lab-on-a-chip and Lab-in-fiber, Peter R. Herman[1]; [1]*Univ. of Toronto, Canada.* Ultrafast laser 3D structuring enables fiber cladding circuits and optofluidic microsystems to form and integrate seamlessly inside optical fiber. Efficient coupling with the fiber core waveguide opens prospects for ubiquitous sensing networks and smart catheters.

CLEO: Science & Innovations

SM1L • Fiber Sensing and Measurement—Continued

SM1L.6 • 09:30
Optical manipulation of microparticles using graded-index fiber taper and its microfluidic sensing application, Yuan Gong[1], Chenlin Zhang[1], Yunjiang Rao[1]; [1]*Univ of Electronic Science & Tech China, China.* Contactless optical manipulation of microparticles is demonstrated based on graded-index multimode fiber taper, which is further applied for microfluidic flow rate sensing. The manipulation length can be as long as 177.0 μm.

SM1L.7 • 09:45
Elongated abruptly tapered micro fiber interferometer for nanoparticles attraction and analyses, Nan-Kuang Chen[1], Zhao-Ying Chen[1], Kuan-Yu Lou[1], Wood-Hi Cheng[2], Chin-Lon Lin[3]; [1]*National United Univ., Taiwan;* [2]*National Chung Hsing Univ., Taiwan;* [3]*Bell Labs and Bellcore, USA.* The nanoparticle analyses based on elongated-abruptly-tapered microfiber interferometer. The charged nanoparticles generating from incomplete combustion of carboncontaining compounds are stringently attached onto micro interferometer at equal distance separation to analyze nanoparticle sizes.

10:00–10:30 Coffee Break, *Concourse Level*

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CLEO: Science & Innovations

SM1M • Parametric Processing—Continued

SM1M.4 • 09:30
Broadband Counter-Phase Dithering of Multi-Terabit/s DP-QPSK Signals for Low Noise FWM with a Single CW Pump, Mark D. Pelusi[1], Karen Solis-Trapala[2], Hung Nguyen Tan[2], Takashi Inoue[2], Shu Namiki[2]; [1]*School of Physics, Univ. of Sydney, Australia;* [2]*National Inst. of Advanced Industrial Science and Technology (AIST), Japan.* Counter-phase modulation of WDM 24×100Gb/s DP-QPSK channels in a polarization-insensitive fiber-loop is demonstrated for low noise degenerate four-wave mixing with a CW pump. The OSNR is boosted by »9dB enabling an average »4dB Q^2-factor improvement.

SM1N • Symposium on Remote Atmospheric Lasing I—Continued

SM1N.4 • 09:30
Low-threshold bidirectional air lasing, Alexandre Laurain[1], Maik Scheller[1], Pavel G. Polynkin[1]; [1]*Univ. Of Arizona, USA.* We demonstrate directional forward and backward emission from atmospheric oxygen and nitrogen pumped by a tunable deep-UV laser source. Significant emission enhancement is achieved, in both cases, through predissociation by an additional IR laser pulse.

SM1O • Advanced Spectroscopic Techniques—Continued

SM1O.6 • 09:30
Fourier-Transform-Based Noise-Immune Cavity-Enhanced Optical Frequency Comb Spectroscopy, Amir Khodabakhsh[1], Alexandra C. Johansson[1], Lucile Rutkowski[1], Aleksandra Foltynowicz-Matyba[1]; [1]*Dept. of Physics, Umeå Univ., Sweden.* We achieve absorption sensitivity of 6.4 × 10^{-11} cm^{-1} $Hz^{-1/2}$ per spectral element with near-infrared Fourier-transform-based noise-immune cavity-enhanced optical frequency comb spectroscopy (NICE-OFCS), which allows detection of CO_2 at ppb concentration levels.

SM1O.7 • 09:45
Photo-thermal Effects in Gases as a Method For Concentration Measurements, Karol Krzempek[1], Michal P. Nikodem[2], Krzysztof M. Abramski[1]; [1]*Laser&Fiber Electronics Group Wroclaw Univ. of Technology, Poland;* [2]*Wroclaw Research Center EIT+, Poland.* We present preliminary results on using photo-thermal effects for gas composition analysis. Proof-of-concept experiments will be discussed and several unique detection schemes will be presented.

SM1P • Few-cycle Infrared Sources—Continued

SM1P.7 • 09:30
220-fs 110-mJ Yb:CaF_2 Cryogenic Multi-pass Amplifier, Giedrius Andriukaitis[1], Edgar Kaksis[1], Gyula Polonyi[3], József Fülöp[4], Andrius Baltuska[1,2], Audrius Pugzlys[1,2]; [1]*Vienna Univ. of Technology, Austria;* [2]*Center for Physical Sciences & Technology, Lithuania;* [3]*MTA-PTE High-Field Terahertz Research Group, Hungary;* [4]*Univ. of Pécs, Hungary.* We report on the design and performance of a Yb:CaF_2 booster with a pass-by-pass compensated spatial gain narrowing. A 5-concave-mirror design affords a flexible number of passes as well as 4f-image relay and progressive beam magnification onto the laser crystal.

SM1P.8 • 09:45
An Approach for Intense Subcycle Pulse Generation in Air, Yuichiro Kida[1], Totaro Imasaka[1]; [1]*Kyushu Univ., Japan.* Four-wave mixing in air is employed for the generation of energetic multicolor femtosecond pulses. After the subsequent propagation in air, the multicolor emissions are phase locked to each other to form intense subcycle laser pulses.

10:00–10:30 Coffee Break, *Concourse Level*

NOTES

CLEO: QELS-Fundamental Science

10:30–12:30
FM2A • Single Photon Sources
Presider: Aephraim Steinberg; Univ. of Toronto, Canada

FM2A.1 • 10:30
Ultra-pure single-mode photon generation in high-Q silicon microdisks, Xiyuan Lu[1], Wei Jiang[1], Jidong Zhang[1], Qiang Lin[1]; [1]*Univ. of Rochester, USA.* We report ultra-pure single-mode photon generation through four-wave mixing in high-Q silicon microdisks. The cross correlation of photon pairs peaks over 25,000 and the self-correlations of both photon modes peak around 1.8.

FM2A.2 • 10:45
Efficient Single Photon Generation using a Fiber-integrated Diamond Micro-Waveguide, Rishi Patel[2,1], Tim Schroder[2], Noel Wan[2], Luozhou Li[2], Sara Mouradian[2], Edward Chen[2], Dirk R. Englund[2]; [1]*Stanford, USA;* [2]*MIT, USA.* We demonstrate the efficient coupling of a diamond micro-waveguide containing a single nitrogen-vacancy center to a single mode optical fiber. Strong photon anti-bunching is observed with a raw single-photon count rate exceeding 712,000 Hz.

FM2A.3 • 11:00
Enhancing the heralded single photon rate from a silicon photonic chip by pump pulse interleaving, Jiakun He[1], Xiang Zhang[1], Iman Jizan[1], Alex Clark[1], Duk-Yong Choi[2], Chang Joon Chae[3], Benjamin J. Eggleton[1], Chunle Xiong[1]; [1]*School of Physics, Univ. of Sydney, Australia;* [2]*Laser Physics Centre, Australian National Univ., Australia;* [3]*Advanced Photonics Research Inst., Gwangju Inst. of Science and Technology, Korea.* We demonstrate heralded single photon source on a silicon photonic chip by a pump interleaving technique. We have achieved 90±5% enhancement to single photon rate with only 14±2% reduction in quantum signal to noise ratio.

FM2A.4 • 11:15
Pure Heralded Single photons, Annamaria Dosseva[2], Lukasz Cincio[1], Agata Branczyk[1]; [1]*Perimeter Inst. for Theoretical Physics, Canada;* [2]*Univ. of Waterloo, Canada.* We show an order-of-magnitude increase in the spectral purity of heralded single photons by engineering the joint spectrum of downconverted photon-pairs. We do this by customizing the crystal poling configuration using simulated annealing.

10:30–12:30
FM2B • Ultrafast Dynamics in Quantum Dots and Organic Materials
Presider: Kamaraju Natarajan; Los Alamos National Lab, USA

FM2B.1 • 10:30
Femtosecond coherent nano-spectroscopy of coupled molecular dynamics, Joanna M. Atkin[1], Paul Sass[1], Honghua Yang[1], Paul Teichen[2], Joel Eaves[2], Markus B. Raschke[1,2]; [1]*Physics, Univ. of Colorado, USA;* [2]*Chemistry, Univ. of Colorado, USA.* We isolate the vibrational free-induction decay of a homogeneous molecular sub-ensemble using ultrafast infrared scattering-scanning near-field microscopy. The observed long lifetimes, intramolecular coherence transfer, and spatial variations in vibrational modes indicate non-ergodic behavior.

FM2B.2 • 10:45
Nanoscale Transport of Excitons at the Interface Between ZnO and a Molecular Monolayer, sebastian friede[1], Sergei Kuehn[1], Sergey Sadofev[2], Sylke Blumstengel[2], Fritz Henneberger[2], Thomas Elsaesser[1]; [1]*Max-Born-Inst., Germany;* [2]*Institut für Physik, Humboldt-Universität zu Berlin, Germany.* Time-resolved near-field optical microsopy maps exciton transport in a hybrid system. Within the 100 ps photoluminescence lifetime, an equilibrium distribution of surface and bound excitons displays lateral diffusion on a 50 nm length scale.

FM2B.3 • 11:00
Single Molecular Vibrational Relaxation Dynamics and Adsorbate Fluctionality, Kyoung-Duck Park[1], Vasily Kravtsov[1], Paul Sass[1], Joanna M. Atkin[1], Eric A. Muller[1], Markus B. Raschke[1]; [1]*Univ. of Colorado Boulder, USA.* Tip-enhanced Raman spectroscopy at cryogenic temperatures probes the intrinsic linewidths of vibrational modes. Temperature dependence in small ensembles reveals ultrafast vibrational relaxation dynamics, conformational heterogeneity, and single molecule fluctionality on the seconds time scale.

FM2B.4 • 11:15
Probing Coherent Ultrafast Exciton Dissociation in a Polymer:Fullerene Photovoltaic Absorber, Antonietta De Sio[1], Ephraim Sommer[1], Margherita Maiuri[2], Julien Rehault[2], Carlo Andrea Rozzi[3], Elisa Molinari[3], Giulio Cerullo[2], Christoph Lienau[1]; [1]*Institut für Physik, Universität Oldenburg, Germany;* [2]*Politecnico di Milano, Italy;* [3]*CNR Centro S3, Italy.* Combining high-time resolution optical spectroscopy and time-dependent density functional theory calculations, we provide strong evidence for the role of vibronic coupling in driving the initial steps of the current photogeneration in an organic photovoltaic system.

10:30–12:30
FM2C • Hyperbolic Metamaterials
Presider: Viktor Podolskiy; Univ. of Massachusetts Lowell, USA

FM2C.1 • 10:30
Mid-infrared Hyperbolic Metamaterial Based on Graphene-dielectric Multilayers, You-Chia Chang[1], Chang-Hua Liu[1], Che-Hung Liu[1], Zhaohui Zhong[1], Theodore B. Norris[1]; [1]*Univ. of Michigan, USA.* We have designed and fabricated a mid-infrared hyperbolic metamaterial composed of alternating Al_2O_3 and chemical-vapor-deposited graphene. Infrared ellipsometry shows a topological transition from elliptical to hyperbolic dispersion at the wavelength of 7.4 μm.

FM2C.2 • 10:45
Thermal Radiation of Hyperbolic Metamaterials and Metallic Surfaces, Mikhail A. Noginov[1], Ahmad Mozafari[1], Thejaswi Tumkur[1], John Kitur[1], Evgenii Narimanov[2]; [1]*Norfolk State Univ., USA;* [2]*Purdue Univ., USA.* We have studied angular distribution and spectra of thermal radiation of lamellar metal/dielectric metamaterials with hyperbolic dispersion and have found them to be reasonably close to the corresponding properties of simple metallic films.

FM2C.3 • 11:00
Optical Imaging with Photonic Hypercrystals, Zun Huang[1,2], Evgenii Narimanov[1,2]; [1]*School of Electrical and Computer Engineering, Purdue Univ., USA;* [2]*Birck Nanotechnology Center, Purdue Univ., USA.* We present an optical imaging system based on photonic hypercrystal, an artificial optical medium combining the properties of hyperbolic materials and photonic crystals. This system functions as a negative refraction lens with substantially reduced image aberrations.

FM2C.4 • 11:15
Light Emission in Nonlocal Plasmonic Nanowire Metamaterials, Brian Wells[1], Pavel Ginzburg[2], Anatoly V. Zayats[2], Viktor A. Podolskiy[1]; [1]*Univ Massachusets Lowell, USA;* [2]*Physics, King's College, UK.* We analyze, analytically and computationally, light emission in nonlocal plasmonic nanowire metamaterials and analyze the contribution of longitudinal wave to the density of optical states in the system.

10:30–12:30
FM2D • Novel Optical Phenomena
Presider: Roberto Morandotti; INRS-Energie Mat & Tele Site Varennes, Canada

FM2D.1 • 10:30
Nonlinear Transmission of Light Through Biological Suspensions, Anna Bezryadina[1], Graham Siggins[1], Andrew Kalmbach[2], Edward Carpenter[2], Zhigang Chen[1,3]; [1]*Physics and Astronomy, San Francisco State Univ., USA;* [2]*Romberg Tiburon Center for Environmental Studies, San Francisco State Univ., USA;* [3]*TEDA Applied Physics Inst. and School of Physics, Nankai Univ., China.* We study nonlinear light propagation through suspensions of *Synechococcus* cells. Such cyanobacteria in aqueous solution enable self-focusing or -defocusing of a light beam, leading to controlled transmission despite extremely low absorption and weak polarizability.

FM2D.2 • 10:45
Rapid Manipulation of the Spatial Coherence, Ronen Chriki[1], Micha Nixon[1], Vishwa Pal[1], Chene Tradonsky[1], Gilad Barach[1], Asher A. Friesem[1], Nir Davidson[1]; [1]*Physics of Complex Systems, Weizmann Inst. of Science, Israel.* Efficient method for manipulating the spatial coherence of a laser is presented. Different mutual intensity coherence functions, such as cosine or Bessel functions, are obtained, and number of modes is controlled in 1D and 2D.

FM2D.3 • 11:00
Total Internal Reflection in Gain Media, Hanan Herzig Sheinfux[1], Bo Zhen[1,2], Ido Kaminer[1,2], Mordechai Segev[1]; [1]*Technion Israel Inst. of Technology, Israel;* [2]*MIT, USA.* We resolve the controversy around total internal reflection from gain media, propose new effects of (extremely) amplified reflection from a single interface, and show sensitivity to subwavelength features.

FM2D.4 • 11:15
CW Laser Light Condensation, Michael Zhurahov[1], Alexander Bekker[1], Boris Levit[1], Rafi Weill[1], Baruch Fischer[1]; [1]*Technion Israel Inst. of Technology, Israel.* We present a first experimental demonstration of classical CW laser condensation in the frequency (mode) domain. It also sheds light on the general question of photon-BEC (Bose-Einstein condensation) in laser cavities.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

10:30–12:30
FM2E • Symposium on Single-photon Nonlinear Optics II
Presider: Sergey Polyakov; NIST, USA

FM2E.1 • 10:30 Invited

Nonlinear Optics via Hybrid Quantum Systems, Xunnong Xu[2], Haitan Xu[2], Michael Gullans[1,2], Corey Stambaugh[1], Utku Kemiktarak[2], John Lawall[1], Jacob Taylor[1,2]; [1]*NIST, USA;* [2]*Joint Quantum Inst., USA.* Realization of a quantum optical nonlinearity at the single-photon level remains an outstanding challenge. Here we consider optomechanical and microwave-domain approaches for such nonlinearities, and develop applications in quantum sensing and simulation.

FM2E.2 • 11:00

Fluorescent Nanodiamonds from Molecular Diamond Seed, Hitoshi Ishiwata[1], Jingyuan Linda Zhang[1], Robert Edgington[1], Thomas M. Babinec[1], Kai Muller[1], Konstantinos G. Lagoudakis[1], Nicholas Melosh[1], Zhi-Xun Shen[1], Jelena Vuckovic[1]; [1]*Stanford Univ., USA.* We present a new materials growth technique using diamondoid molecular diamonds as a seed for chemical vapor deposition growth. We show that both nanoscopic high quality diamond crystals with silicon vacancy color centers can be grown from self-assembled monolayers of pentamantane ($C_{26}H_{32}$).

FM2E.3 • 11:15

On-Chip generation of photon-triplet states in integrated waveguide structures, Stephan Krapick[1], Benjamin Brecht[1], Viktor Quiring[1], Raimund Ricken[1], Harald Herrmann[1], Christine Silberhorn[1]; [1]*Physics Dept., Univ. of Paderborn, Germany.* We present a miniaturized integrated waveguide source providing 11.3±0.7 photon-triplet states per hour, measured with off-the-shelf components. By double-stage heralding and integration times of 83 hours, we achieve statistical significance of more than 27 σ.

10:30–12:30
SM2F • Novel Materials for Semiconductors Lasers
Presider: Peter Smowton; Cardiff Univ., UK

SM2F.1 • 10:30 Invited

Room-temperature lasing in GaAs nanowires embedding multi-stacked InGaAs/GaAs quantum dots, Jun Tatebayashi[2], Satoshi Kako[2], Jinfa Ho[2], Yasutomo Ota[2], Satoshi Iwamoto[2,1], Yasuhiko Arakawa[2,1]; [1]*IIS, the Univ. of Tokyo, Japan;* [2]*NanoQUINE, the Univ. of Tokyo, Japan.* We report the demonstration of room-temperature lasing in a single GaAs nanowire embedding 50-stacked $In_{0.22}Ga_{0.78}As$/GaAs quantum dots at a lasing emission energy of 1.37 eV with a threshold pump pulse fluence of 138 μJ/cm².

SM2F.2 • 11:00

Nonpolar InGaN/GaN multi-quantum-well core-shell nanowire lasers, Changyi Li[1], Jeremy B. Wright[2], Sheng Liu[2,3], ping lu[2], Jeffrey Figiel[2], Benjamin Leung[2], Ting S. Luk[2,3], Igal Brener[2,3], Daniel Feezell[1], Steven Brueck[1], George Wang[2]; [1]*Center for High Technology Materials, Univ. of New Mexico, USA;* [2]*Sandia National Labs, USA;* [3]*Center for Integrated Nanotechnology, Sandia National Labs, USA.* Lasing is demonstrated from nonpolar III-nitride core-shell multi-quantum-well nanowires. The nanowire lasers were fabricated by coupling a top-down and bottom-up methodology and achieved lasing at wavelengths below the GaN bandedge.

SM2F.3 • 11:15

A novel, highly-strained structure with an integrated optical cavity for a low threshold germanium laser, Shashank Gupta[1], Donguk Nam[1], Jan Petykiewicz[1], David Sukhdeo[1], Jelena Vuckovic[1], Krishna Saraswat[1]; [1]*Stanford Univ., USA.* We propose a novel low threshold, CMOS-compatible laser structure with a strained germanium gain medium and a photonic crystal cavity. We demonstrate 1.70% uniaxial tensile strain through experiments and design a high quality factor (>11,000) optical cavity around the gain medium.

10:30–12:30
SM2G • Characterization Techniques
Presider: Avi Zadok; Bar-Ilan Univ., Israel

SM2G.1 • 10:30

Improvement for characterizing micro-ring resonator by low coherence interferometry measurement, Wei Kang Liu[1], Chun Yen Chen[1], Chia Chien Wei[1], Yung-Jui Chen[1]; [1]*National Sun-Yat-sen Univ., Taiwan.* We demonstrate an effective technique which allows one to characterize a small radius micro-ring resonator via low coherence interferometric measurement beyond light source bandwidth limitation. The experimental results show significant improvements in the extracted parameters.

SM2G.2 • 10:45

Efficient Coefficient Extraction from Doublet Resonances in Microphotonic Resonator Transmission Functions, Adam Jones[1,2], Anthony L. Lentine[1], Christopher T. DeRose[1], Starbuck L. Andrew[1], Pomerene Andrew[1], Robert Norwood[2]; [1]*Sandia National Labs, USA;* [2]*Optical Sciences, Univ. of Arizona, USA.* We develop a computationally efficient and robust algorithm to automatically extract the coefficients of doublet resonances and apply this technique to 418 resonances in ring resonator transmission data with a mean RMS deviation of 7.28×10−4.

SM2G.3 • 11:00

Verdet Constant and Magnetic Permeability in Microstructured FePt Nanoparticles in PS-P2VP Copolymer Composite Films, Alex Miles[1], Palash Gangopadhyay[1], Yue Gai[2], Xinyu wang[2], James Watkins[2], Robert Norwood[1]; [1]*Univ. of Arizona, USA;* [2]*Dept. of Polymer Science and Engineering, Univ. of Massachusetts Amherst, USA.* Complex Faraday effect and magnetic permeability measurements on iron-platinum (FePt) nanoparticles embedded in a polystyrene-poly(2-vinyl)pyridine (PS-P2VP) copolymer matrix are reported. Possible applications include high performance biomagnetic field sensors and optical isolators.

SM2G.4 • 11:15

Diffusion Characterization Using Electron Beam Induced Current and Time-Resolved Photoluminescence of InAs/InAsSb Type-II Superlattices, Daniel Zuo[1], Runyu Liu[1], Dan Wasserman[1], James Mabon[2], Zhaoyu He[3], Shi Liu[3], Yong-Hang Zhang[3], Emil A. Kadlec[4], Benjamin V. Olson[4], Eric A. Shaner[4]; [1]*Dept. of Electrical and Computer Engineering, Univ. of Illinois at Urbana-Champaign, USA;* [2]*Frederick Seitz Materials Research Lab, Univ. of Illinois at Urbana-Champaign, USA;* [3]*Center for Photonics Innovation and School of Electrical, Computer, and Energy Engineering, Arizona State Univ., USA;* [4]*Sandia National Labs, USA.* We present the characterization of minority carrier diffusion length and surface recombination velocity, as well as vertical diffusivity and mobility by performing an electron beam induced current measurement in addition to an optical lifetime measurement.

10:30–12:30
SM2H • Strong-Field THz Science and Technology
Presider: Koichiro Tanaka; Kyoto Univ., Japan

SM2H.1 • 10:30 Tutorial

Nonlinear THz Optics and Control in Complex Solids, Andrea Cavalleri[1,2], Matthias Hoffmann[3]; [1]*Max Planck Inst. for the Structure and Dynamics of Matter, Germany;* [2]*Dept. of Physics, Univ. of Oxford, UK;* [3]*Stanford Linear Accelerator Laboratory, USA.* I will discuss nonlinear interaction between THz light and matter. Especially, I will discuss the nonlinear response of infrared active phonons and superconducting plasmons in High T_c cuprates.

Matthias Hoffmann received his Diplom (2001) and PhD (2006) in physics at the University of Freiburg, Germany. As a postdoc at the Massachusetts Institute of Technology he developed intense THz sources for nonlinear spectroscopy. He then moved to the newly founded Max Planck Institute for Structure and Dynamics of Matter in Hamburg, Germany where his research was focused on interactions of strong THz fields with correlated electron systems such as high temperature superconductors. Since 2011 he is a staff scientist at the Stanford Linear Accelerator Laboratory where he explores non-equilibrium states of matter with femtosecond x-ray pulses.

CLEO: Science & Innovations

10:30–12:30
SM2I • Silicon Photonic Systems
Presider: Chin-Hui (Janet) Chen; Hewlett Packard Company, USA

SM2I.1 • 10:30 Invited
Integrated Hardware-Software Implementation of Silicon Photonic Interconnected Computing System, Keren Bergman[1]; [1]*Columbia Univ., USA*. Silicon photonics interconnect technology can potentially deliver computing systems energy efficient data movement with extreme bandwidth densities. We discuss the first complete experimental silicon photonic interconnected hardware-software implementation that demonstrates the system-level performance benefits.

SM2I.2 • 11:00
Active Resonance Wavelength Stabilization for Silicon Microring Resonators Using Slope-Detection with an In-resonator Defect-state-absorption-based Photodetector, Yu Li[1], Andrew W. Poon[1]; [1]*Photonic Device Lab, Dept. of Electronic and Computer Engineering, The Hong Kong Univ. of Science and Technology, China*. We demonstrate active resonance wavelength stabilization for silicon microrings with an in-resonator BF_2-implanted photodetector using a slope-detection method. Our experiment reveals active resonance wavelength stabilization with ~1dB transmission intensity variations upon a 7°C 10mHz modulation.

SM2I.3 • 11:15
Photoresistive Microring Heater with Resonance Control Loop, Christopher V. Poulton[1], Po Dong[1], Young-Kai Chen[1]; [1]*Bell Labs, Alcatel-Lucent, USA*. We demonstrate a germanium photoresistive microring heater that acts as a single device to sense and tune the resonant wavelength of the ring. A control loop to lock the resonance to a laser is shown.

CLEO: Applications & Technology

10:30–12:30
AM2J • Light Sources and Devices for Biomedical Imaging II
Presider: Seok-Hyun Yun; Harvard Medical School, USA

AM2J.1 • 10:30
A Full-Field Tomographic Imaging Camera Based on a Linearly Swept Frequency DFB at 1064 nm, Mark Harfouche[1], Naresh Satyan[2], George Rakuljic[2], Amnon Yariv[3]; [1]*Electrical Engineering, California Inst. of Technology, USA;* [2]*Telaris Inc., USA;* [3]*Applied Physics and Materials Science, California Inst. of Technology, USA*. High resolution, full-field tomograms are acquired in four exposures of a CCD camera using a swept laser. The imaged depth is selected by modulating the swept laser output power enabling volumetric imaging with no moving parts.

AM2J.2 • 10:45
A Joint Richardson-Lucy Deconvolution Algorithm for the Reconstruction of Multifocal Structured Illumination Microscopy Data, Florian Stroehl[1], Clemens F. Kaminski[1]; [1]*Univ. of Cambridge, UK*. We demonstrate the reconstruction of multifocal structured illumination microscopy images using a joint Richardson-Lucy deconvolution algorithm, which is based on an underlying widefield image-formation model and particularly well suited for noise corrupted data.

AM2J.3 • 11:00
Electron-injection Detectors for Swept Source Optical Coherence Tomography, Vala Fathipour[1], Hooman Mohseni[1]; [1]*Northwestern Univ., USA*. Electron-injection detectors are used in an OCT system for the first time. Compared to a commercial p-i-n detector, electron-injection detectors show ~20 dB higher SNR. This could lead to OCT systems without the need for balanced-detection.

AM2J.4 • 11:15
Concentric Si Annular Photodiode Arrays for Spatially Resolved Diffuse Reflectance Spectroscopy, Ozlem Senlik[1], Nan M. Jokerst[1]; [1]*Electrical and Computer Engineering, Duke Univ., USA*. This paper describes the design, fabrication, and test of a custom concentric PD array for spatially resolved diffuse reflectance (SRDR) measurements. To the best of our knowledge, this is the first reported compact, densely packed semiconductor SRDR probe.

10:30–12:30
AM2K • Microprocessing Laser Processing of Silicon and Other Materials
Presider: Peter Herman; Univ. of Toronto, Canada

AM2K.1 • 10:30 Invited
Industrial Processing of Various Materials using Ultrashort Pulsed Laser Sources, Dimitrij Walter[1]; [1]*MANZ, Germany*. Micro machining using ultra short laser pulses renders high ablation quality along with superb precision. Due to a very short interaction time in combination with high power densities various applications such as cutting, patterning, marking etc. may be carried out on a wide range of materials from brittle to ductile. Implementing suitable laser sources along and its periphery in high-throughput industrial machinery is a key for efficient production facilities.

AM2K.2 • 11:00
Nonlinear Laser Lithography for Enhanced Tribological Properties, Iaroslav Gnilitskyi[1]; [1]*UNIMORE, Italy*. This paper investigates a new field for application of femtosecond laser-induced periodic surface structures (LIPSS). We designed an innovative solution to reduce coefficient of friction of mechanical parts by using the nonlinear laser lithography technique (NLL).

AM2K.3 • 11:15
Radially Polarized Optical Vortex Micro-Converters Imprinted by Femtosecond Laser Nanostructuring in Amorphous Silicon, Rokas Drevinskas[1], Martynas Beresna[1], Mindaugas Gecevičius[1], andrey G. kazanskii[2], oleg I. konkov[3], Yuri P. Svirko[4], Peter Kazansky[1]; [1]*Univ. of Southampton, UK;* [2]*M.V. Lomonosov Moscow State Univ., Russia;* [3]*A.F. Ioffe Physicotechnical Inst., Russia;* [4]*Univ. of Eastern Finland, Finland*. We demonstrate space variant polarization and phase converters imprinted by femtosecond laser nanostructuring in hydrogenated amorphous silicon thin film. Giant birefringence of imprinted structures allows fabrication of microoptic element arrays.

CLEO: Science & Innovations

10:30–12:30
SM2L • Modes in Fiber
Presider: Ayman Abouraddy; Univ. of Central Florida, CREOL, USA

SM2L.1 • 10:30
Multiple-Cladding-Resonance All-Solid Photonic Bandgap Fibers with Large Mode Area, Guancheng Gu[1], Fanting Kong[1], Thomas W. Hawkins[1], Maxwell Jones[1], Liang Dong[1]; [1]*Clemson Univ., USA*. We demonstrated both theoretically and experimentally robust single-mode operation in all-solid photonic bandgap fibers with record effective mode areas of ~2650μm² by introducing multiple strongly coupled smaller cores in the cladding.

SM2L.2 • 10:45
Scaling the mode area of Rare-Earth doped step index fiber under current state of the art MCVD technology, Deepak Jain[1], Yongmin Jung[1], Pranabesh Barua[1], Shaiful Alam[1], Jayanta Sahu[1]; [1]*Univ. of Southampton, UK*. We demonstrate an ultra-low-NA (~0.038) Yb-doped step-index-fiber fabricated using conventional MCVD and solution-doping process. The fiber ensures ~700μm² A_{eff} for effective-single-mode operation and 81% laser efficiency with M^2 ~1.1 at a bend diameter of 32cm.

SM2L.3 • 11:00
Experimental Observation of Non-Linear Mode Conversion in Few-Mode Fiber, Jing Xu[1], George S. Gordon[2], Timothy Wilkinson[2], Christophe Peucheret[3]; [1]*Huazhong Univ. of Sci. and Tech., China;* [2]*Engineering Dept., Electrical Engineering Division, UK;* [3]*CNRS UMR 6082, Foton Lab, France*. We show for the first time directly experimentally observed nonlinear spatial mode coupling in a 10 km long graded-index few-mode fiber.

SM2L.4 • 11:15
Reconstructing Core-to-Core Variations of Propagation Constant in Coupled Multicore Fiber for Quantum Walks, Peter J. Mosley[1], Itandehui Gris-Sanchez[1], James Stone[1], Robert Francis-Jones[1], Rowan A. Hoggarth[1], Douglas J. Ashton[2], Tim A. Birks[1]; [1]*Centre for Photonics and Photonic Materials, Univ. of Bath, UK;* [2]*Dept. of Physics, Univ. of Bath, UK*. We present a novel method of determining differences in propagation constant between coupled cores in multicore fiber by a Markov chain Monte Carlo reconstruction and discuss its implications for quantum walks of photons.

CLEO: Science & Innovations

10:30–12:00
SM2M • Nonlinear Signal Processing
Presider: Michael Vasilyev; Univ. of Texas at Arlington, USA

SM2M.1 • 10:30
Investigation into the Role of Pump to Signal Power Ratio in FWM-based Phase Preserving Amplitude Regeneration , Kyle Bottrill[1], Graham Hesketh[1], Francesca Parmigiani[1], david Richardson[1], P Petropoulos[1]; *[1]Univ. of Southampton, UK.* We carry out a detailed experimental characterization of a four-wave mixing based amplitude limiter in highly nonlinear fiber based on the Bessel-like power transfer characteristics and highlight trade-offs for phase preserving capabilities.

SM2M.2 • 10:45
Investigation of 3-Channel All-Optical Regeneration in a Group-Delay-Managed Nonlinear Medium, Lu Li[1], Michael Vasilyev[1], Taras I. Lakoba[2]; *[1]Electrical Engineering, Univ. of Texas at Arlington, USA; [2]Dept. of Mathematics and Statistics, Univ. of Vermont, USA.* We investigate three-channel performance of a stand-alone Mamyshev 2R regenerator based on Raman-assisted group-delay-managed medium. Our results indicate, for the first time to our knowledge, the feasibility of simultaneous regeneration of 100-GHz-spaced WDM channels.

SM2M.3 • 11:00
Spectrally Efficient Comb Source with Coupled Microresonators, Yoshitomo Okawachi[1], Steven Miller[2], Sven Ramelow[1], Kevin Luke[2], Alessandro Farsi[1], Michal Lipson[2,3], Alexander L. Gaeta[1,3]; *[1]School of Applied and Engineering Physics, Cornell Univ., USA; [2]School of Electrical and Computer Engineering, Cornell Univ., USA; [3]Kavli Inst. at Cornell for Nanoscale Science, USA.* We demonstrate a spectrally efficient parametric comb source for WDM applications using a Si_3N_4 dual-coupled microring resonator. This geometry allows for operating wavelength flexibility and avoidance of mode crossings for stable comb generation.

SM2M.4 • 11:15
Broadband Uniform Wavelength Conversion and Time Compression of WDM Channels, Mohammad Amin Shoaie[1], Armand Vedadi[1], Camille-Sophie Brès[1]; *[1]École polytechnique fédérale de Lausanne, Switzerland.* A scheme based on 2-pump OPA is proposed for uniform wavelength conversion and optimized compression. We show 4.7-fold compression over 32 nm range resulting in Gaussian pulses from sinusoidal modulation and enabling simultaneous compression of WDM channels for granularity adaptation.

10:30–12:30
SM2N • Symposium on Remote Atmospheric Lasing II
Presider: Ya Cheng; Shanghai Inst of Optics and Fine Mech, China

SM2N.1 • 10:30 Invited
From Single Photon Superradiance to Coherence-Brightened Lasers in the Sky, Marlan O. Scully[1,2]; *[1]TEXAS A&M UNIV., USA; [2]BAYLOR UNIV., USA.* A single photon stored in a large cloud of atoms provides new insights into the radiation physics of single-photon superradiance. In further work, we have developed a detailed theoretical study of a recent experiment [PNAS, 109, 15185 (2012)] in which a laser-like source is created in air by pumping with a nanosecond pulse. Our analysis indicates that the emission is largely governed by quantum coherence via cooperation between atoms of an ensemble.

SM2N.2 • 11:00 Invited
Lasing from Plasma Filaments in Air, Yi Liu[1], Sergey Mitryukovskiy[1], Pengji Ding[1], Aurelien Houard[1], Andre Mysyrowicz[1]; *[1]Laboratoire d'Optique AppliquÃ©e, France.* The stimulated emission obtained from the filamentation of a femtosecond laser pulse is discussed. The crucial role of pump laser polarization is emphasized.

10:30–12:30
SM2O • Fiber-based Sensing
Presider: Dirk Richter; Univ. of Colorado, USA

SM2O.1 • 10:30
Gas Sensing Fiber Network with Simultaneous Multi-node Detection using Range-resolved Chirped Laser Dispersion Spectroscopy, Genevieve Plant[1], Andreas Hangauer[1], Ming-Fang Huang[2], Ting Wang[2], Gerard Wysocki[1]; *[1]Princeton Univ., USA; [2]NEC Labs America, USA.* We present a laser-spectroscopic method for continuous and simultaneous interrogation of multiple passive gas sensor nodes in a fiber based sensor network. Enabled by chirped laser dispersion spectroscopy, methane leak detection is demonstrated as an example application.

SM2O.2 • 10:45
Fiberoptic Evanescent Wave Spectroscopy in Water at ppm Sensitivity with a tunable Quantum Cascade Laser, Guy-Maël De Naurois[1], Ilan Gaby[1], Federico Capasso[1], Abraham Katzir[2]; *[1]Harvard Univ., USA; [2]School of Physics and Astronomy, Sackler Faculty of Exact Sciences, Tel Aviv Univ., Israel.* We present in water chemical spectroscopy by the use of a AgClBr fiber and a tunable mid-IR Quantum Cascade Laser source (QCL. We show detection of ppm concentration of ethanol in water.

SM2O.3 • 11:00
Characterization of Temperature and Strain Sensitivity of Low Cost Few-mode Fiber Based Interferometer Sensor, Yifei Wang[2,1], An Li[1], Xi Chen[1], William Shieh[1]; *[1]The Univ. of Melbourne, Australia; [2]Victoria research Lab, NICTA Ltd., Australia.* We experimentally characterize a two-mode fiber (TMF) based intermodal interferometer sensor for temperature and strain. A wavelength-temperature coefficient of - 43 pm/°C and wavelength-strain coefficient of - 2.3 pm/με have been characterized.

SM2O.4 • 11:15
Near-Infrared Absorption Gas Sensors using Metal-Organic Framework-Coated Optical Fibers, Alan X. Wang[1]; *[1]Oregon State Univ., USA.* We report a near-infrared fiber-optic CO_2 sensor with only 8-centimeter sensing length coated with nanoporous metal-organic framework materials. We achieved 500ppm detection limit with an overall response time of 40 seconds in a gas cell.

10:30–12:30
SM2P • Novel Ultrafast Techniques
Presider: Robert Levis, Temple Univ., USA

SM2P.1 • 10:30
Coherent Pulse Stacking Amplification using Cascaded and Multiplexed Gires-Tournois Interferometers, Tong Zhou[1], John Ruppe[1], Cheng Zhu[1], I-Ning Hu[1], John Nees[1], Russell Wilcox[2], Wim Leemans[2], Almantas Galvanauskas[1]; *[1]Univ. of Michigan, USA; [2]Lawrence Berkeley National Lab, USA.* We show stacking of multiple equal-amplitude pulses into a single pulse using properly configured sequences of Gires-Tournois interferometers, which in conjunction of chirped pulse amplification in fibers can enable large increase in extractable pulse energies.

SM2P.2 • 10:45
Stabilizing the relative carrier-envelop phase of hybridly synchronized ultrafast Yb and Er fiber laser systems by the feed-forward scheme, Wei-Wei Hsiang[1], Bo-Jyun Fong[1], Wei-Ting Lin[1], Shang-Ying Wu[2], Jin-Long Peng[3], Yinchieh Lai[2,4]; *[1]Dep. of Physics, Fu Jen Catholic Univ., Taiwan; [2]Dept. of Photonics & Inst. of Electro-Optical Engineering, National Chiao-Tung Univ., Taiwan; [3]Center for Measurement Standards, Industrial Technology Research Inst., Taiwan; [4]Research Center for Applied Sciences, Academia Sinica, Taiwan.* Stabilization of the relative carrier-envelope (CE) phase for hybridly synchronized two-color fs Yb and Er fiber laser systems is demonstrated for the first time by utilizing the feed-forward scheme based on an acousto-optic frequency shifter.

SM2P.3 • 11:00
Passive coherent combining of CEP-stable few-cycles pulses from a temporally divided hollow fiber compressor, Hermance Jacqmin[4,1], Aurelie Jullien[4], Brigitte Mercier[4], Marc Hanna[2], Frederic Druon[2], Dimitrios Papadopoulos[3], Rodrigo Lopez-Martens[4]; *[1]Thales Optronique SA, France; [2]Institut d'Optique, France; [3]LULI, France; [4]Laboratoire d'Optique Appliquee, France.* We demonstrate a robust passive coherent combining technique for post-compression of mJ energy CEP-stable laser pulses down to few-cycle duration in a gas-filled hollow fiber. High combining efficiency is achieved using carefully oriented calcite plates.

SM2P.4 • 11:15
Arbitrary-Detuning Asynchronous Optical Sampling with Amplified Laser Systems, Laura Antonucci[1], Adeline Bonvalet[1], Xavier Solinas[1], Louis Daniault[1], Manuel Joffre[1]; *[1]Ecole Polytechnique, France.* We demonstrate a new method for pump-probe spectroscopy by applying arbitrary detuning asynchronous optical sampling (AD-ASOPS) to two independent amplified laser systems. The resulting time dynamics ranges from 400 fs up to 1 ms.

CLEO: QELS-Fundamental Science

FM2A • Single Photon Sources—Continued

FM2A.5 • 11:30
Temporal Multiplexing toward Periodic and Deterministic Single-Photon Sources, Fumihiro Kaneda[1], Bradley Christensen[1], Jia Jun Wong[1], Heesu Park[2], Kevin McCusker[1,3], Paul kwiat[1]; *[1]Univ. of Illinois at Urbana-Champaign, USA; [2]Korea Research Inst. of Standards and Science, Korea; [3]Northwestern Univ., USA.* Utilizing time multiplexing of a heralded single-photon source based on spontaneous parametric downconversion pumped by periodic laser pulses, we observed large enhancements in the single-photon probability.

FM2A.6 • 11:45
Thermal light cannot be represented as a statistical mixture of pulses, Aurelia Chenu[2], Agata Branczyk[1], John E. Sipe[2]; *[1]Perimeter Inst. for Theoretical Physics, Canada; [2]Univ. of Toronto, Canada.* Can thermal light be represented by a mixture of single pulses? It cannot; only a modified mixture can yield the correct first-order correlation function at equal space-points. Still, this fails to reproduce higher orders.

FM2A.7 • 12:00
Monolithic Source of Tunable Narrowband Photons for Future Quantum Networks, Sven Ramelow[1,2], Alessandro Farsi[1], Stephane Clemmen[1], Kevin Luke[3], Michal Lipson[3,4], Alexander L. Gaeta[1,4]; *[1]School of Applied and Engineering Physics, Cornell Univ., USA; [2]Faculty of Physics, Univ. of Vienna, Austria; [3]School of Electrical and Computer Engineering, Cornell Univ., USA; [4]Kavli Inst. at Cornell for Nanoscale Science, Cornell Univ., USA.* Using high-Q Si_3N_4 microresonators, we generate the narrowest bandwidth (40 MHz) photon pairs, yet achieved for a chip-based source. Its high intrinsic stability and broad tunability are highly promising for interfacing to quantum memory networks.

FM2B • Ultrafast Dynamics in Quantum Dots and Organic Materials—Continued

FM2B.5 • 11:30
Decoupling Bulk and Surface Contributions in Water-Splitting Photocatalysts by *In Situ* Ultrafast Spectroscopy, Kannatassen Appavoo[1]; *[1]Center for Functional Nanomaterials, Brookhaven National Lab, USA.* By performing ultrafast emissionspectroscopy in an operating, bias-controlled photoelectrochemical cell, we distinguish between bulk and surface recombination processes in a nanostructured photocatalyst and correlate its electronic properties directly with its incident-photon-to-current efficiency.

FM2B.6 • 11:45
Fast High-Fidelity Hole Spin Initialisation in a Single Quantum Dot at Zero Magnetic Field, Alistair Brash[1], Luis M. Martins[1], Feng Liu[1], John H. Quilter[1,2], Maurice S. Skolnick[1], A. Mark Fox[1]; *[1]Dept. of Physics and Astronomy, Univ. of Sheffield, UK; [2]Dept. of Physics, Royal Holloway, UK.* Fast (~50 ps) initialisation of a long-lived hole spin qubit in a single InGaAs quantum dot is achieved by exciton ionisation. A QD exhibiting no fine structure yields fidelities exceeding 98% at zero external field thus forming a key building block for high fidelty quantum information processing.

FM2B.7 • 12:00
Femtosecond Hole Relaxation and Biexcitonic Transient Absorption in Single CdSe/ZnSe Quantum Dots, Christopher Hinz[1], Christian Traum[1], Johannes Haase[1], Benjamin Bauer[1], Alfred Leitenstorfer[1], Denis Seletskiy[1]; *[1]Physics, Univ. of Konstanz, Germany.* Femtosecond few-fermion dynamics in single CdSe/ZnSe quantum dots is studied by two-color pump-probe measurements. We observe sub-picosecond hole relaxation and induced absorption into biexciton states when pumping p-p and d-s transitions.

FM2C • Hyperbolic Metamaterials—Continued

FM2C.5 • 11:30
Simultaneous enhancement of decay rate and light extraction from active hyperbolic metamaterial, Tal Galfsky[1,2], Harish Krishnamoorthy[1,2], Ward Newman[3], Evgenii Narimanov[4], Zubin Jacob[3], Vinod M. Menon[1,2]; *[1]Physics, Graduate Center of the City Univ. of New York, USA; [2]Physics, City College of the City Univ. of New York, USA; [3]Dept. of Electrical and Computer Engineering, Univ. of Alberta, Canada; [4]Birck Nanotechnology Center, School of Computer and Electrical Engineering, Purdue Univ., USA.* We demonstrate simultaneous enhancement in spontaneous emission rate and light extraction from hyperbolic metamaterials embedded with quantum dots using a high contrast grating. Enhancements of twenty-fold in extraction and thirteen-fold in emission rate are observed.

FM2C.6 • 11:45
Non-Resonant Hyperlens in the Visible Range, Jingbo Sun[1], Mikhail Shalaev[1], Natalia M. Litchinitser[1]; *[1]State Univ. of New York at Buffalo, USA.* A non-resonant hyperlens operating in the visible wavelength range is demonstrated experimentally. Non-resonant indefinite properties, enabling low-loss, broadband sub-wavelength imaging, were realized using a fan-like structure made using a combination of top-down and bottom-up techniques.

FM2C.7 • 12:00
Multilayer Cladding with Hyperbolic Dispersion for Plasmonic Waveguides, Viktoriia Babicheva[1,2], Mikhail Y. Shalaginov[2], Satoshi Ishii[2,3], Alexandra Boltasseva[2,4], Alexander V. Kildishev[2]; *[1]ITMO Univ., Russia; [2]Purdue Univ., USA; [3]International Center for Materials Nanoarchitectonics (MANA), National Inst. for Materials Science (NIMS), Japan; [4]DTU Fotonik, Technical Univ. of Denmark, Denmark.* We study the properties of plasmonic waveguides with a dielectric core and multilayer metal-dielectric claddings that possess hyperbolic dispersion. The waveguides hyperbolic multilayer claddings show better performance in comparison to conventional plasmonic waveguides.

FM2D • Novel Optical Phenomena—Continued

FM2D.5 • 11:30
Resonant Phase Matching of Josephson Junction Traveling Wave Parametric Amplifiers, Kevin O'Brien[1], Chris Macklin[2], Irfan Siddiqi[2], Xiang Zhang[1]; *[1]Univ. of California at Berkeley, USA; [2]QNL, Univ. of California at Berkeley, USA.* We propose a technique to phase-match Josephson-junction traveling wave parametric amplifiers to achieve high gain over a broad bandwidth for applications such as the multiplexed readout of quantum coherent circuits.

FM2D.6 • 11:45
Photoluminescence Upconversion Study of GaN Nanowires: Potential for Optical Refrigeration, Ruolin Chen[1], Guan Sun[1], Yujie J. Ding[1], Hieu Nguyen[2], Zetian Mi[2]; *[1]Electrical and Computer Engineering, Lehigh Univ., USA; [2]Electrical and Computer Engineering, McGill Univ., Canada.* Up-converted photoluminescence of GaN nanowires is observed at the temperature above 375 K. At 475 K, the mechanism of the photoluminescence was identified as phonon-assisted bandtail emission. Such a phenomenon contributes to optical refrigeration.

FM2D.7 • 12:00
Guide-wave Photonic Pulling Force Using One-way Photonic Chiral Edge States, Danlu Wang[1], Chengwei Qiu[3], Peter T. Rakich[2], Zheng Wang[4]; *[1]Dept. of Physics, The Univ. Of Texas at Austin, USA; [2]Dept. of Applied Physics, Yale Univ., USA; [3]Dept. of Electrical and Computer Engineering, National Univ. of Singapore, Singapore; [4]Dept. of Electrical and Computer Engineering, The Univ. Of Texas at Austin, USA.* We provide a new scheme of photonic pulling force in one-way waveguides. Objects of arbitrary shape and dielectric properties can be pulled all the way to the light source, regardless of waveguide geometry.

CLEO: QELS-Fundamental Science

FM2E • Symposium on Single-photon Nonlinear Optics II—Continued

FM2E.4 • 11:30 Invited

Nonlinear Interactions in Optical Lattice Systems, Demetrios N. Christodoulides[1]; [1]*Univ. of Central Florida, USA.* Photonic lattices provide a versatile classical platform for observing a host of nonlinear processes. In this talk we provide an overview of recent activities in such arrangements with a special emphasis on quantum-inspired systems.

FM2E.5 • 12:00

Complete Conversion of One to Two Photons in Dispersion-Engineered Nonlinear Waveguides, Alexander S. Solntsev[1], Andrey A. Sukhorukov[1]; [1]*Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National Univ., Australia.* We predict that complete deterministic conversion of one to two photons can be achieved at a finite propagation distance in specially engineered nonlinear waveguides, by designing quantum frequency mixing across a broad range of frequencies.

CLEO: Science & Innovations

SM2F • Novel Materials for Semiconductors Lasers—Continued

SM2F.4 • 11:30

Long Wave, Room Temperature, II-VI - Based Quantum Cascade Emitters, Arvind Pawan Ravikumar[1], Thor A. Garcia[2], Joel De Jesus[2], Maria C. Tamargo[2], Claire F. Gmachl[1]; [1]*Princeton Univ., USA;* [2]*The Graduate Center and The City College of New York of CUNY, USA.* We demonstrate the first long-wave, room temperature II-VI materials based Quantum Cascade emitter around 7.2 μm. At 80 K, a device differential resistance of 2.6 Ω and a narrow electroluminescent width of 16% was obtained.

SM2F.5 • 11:45

Fe:ZnSe Channel Waveguide Laser Operating at 4122 nm, Adam Lancaster[1], Gary Cook[2], Sean McDaniel[3], Jonathan Evans[2], Patrick Berry[2], Jonathan Shephard[1], Ajoy Kar[1]; [1]*Heriot-Watt Univ., UK;* [2]*Sensors Directorate, Air Force Research Lab, USA;* [3]*Leidos Inc, USA.* The first demonstration of a waveguide laser in Fe:ZnSe is presented. The waveguide laser produces 49 mW of output power at 4122 nm with a spectral bandwidth of 6 nm FWHM.

SM2F.6 • 12:00

Optically Pumped Distributed Feedback Laser from Organo-Lead Iodide Perovskite Thin Films, Songtao Chen[1], Wee Kiang Chong[2,3], Joonhee Lee[1], Kwangdong Roh[1], Emre Sari[1], Nripan Mathews[4], Tze Chien Sum[2], Arto Nurmikko[1]; [1]*School of Engineering and Dept. of Physics, Brown Univ., USA;* [2]*School of Physics & Mathematical Sciences, Nanyang Technological Univ., Singapore;* [3]*Energy Research Inst. Nanyang Technological Univ., Singapore;* [4]*School of Materials Science and Engineering, Nanyang Technological Univ., Singapore.* Perovskite ($CH_3NH_3PbI_3$) films possessing optical quality were prepared by solution-based spin-casting at room temperature. We report near infrared lasing with well-defined spatially coherent output from second-order surface-emitting distributed feedback grating structure with perovskite active media.

SM2G • Characterization Techniques—Continued

SM2G.5 • 11:30

Broadband (3.9 - 9.6 μm) Photocurrent in Quantum Cascade Detector with Diagonal Transitions, Germano Maioli Penello[1], Benjamin Merkel[1,2], Claire F. Gmachl[1], Deborah L. Sivco[1]; [1]*Princeton Univ., USA;* [2]*Dept. of Physics, Univ. of Duisburg-Essen, Germany.* By carefully designing diagonal transitions in the active region, we present a broadband mid-infrared quantum cascade detector with photocurrent ranging from 3.9 to 9.6 mm, more than 2 times broader than stacked designs.

SM2G.6 • 11:45

Spectral Dependence of Third-Order Nonlinear Optical Properties in InN, Hyeyoung Ahn[1], Min-Tse Lee[1]; [1]*National Chiao Tung Univ., Taiwan.* Spectral dependence of nonlinear optical absorption cross-section (s) near and below the bandgap (E_g) is measured for InN by using Z-scan technique. A drastic increase of s near E_g can be understood by the band-filling model.

SM2G.7 • 12:00

Characterization of Graphene Photothermoelectric Detector via Two-wave Mixing Technique, Mohammad Mehdi Jadidi[1], Ryan J. Suess[1], Xinghan Cai[2], Andrei B. Sushkov[2], Martin Mittendorff[1], Michael S. Fuhrer[2], H. Dennis Drew[2], Thomas E. Murphy[1]; [1]*Inst. for Research in Electronics and Applied Physics, Univ. of Maryland, USA;* [2]*Center for Nanophysics and Advanced Materials, Univ. of Maryland, USA.* We study the response of a graphene photothermoelectric-based detector illuminated by two continuous-wave optical beams. The power and frequency dependence of the photoresponse are used to probe the graphene hot-electron cooling rates and mechanisms.

SM2H • Strong-Field THz Science and Technology—Continued

SM2H.2 • 11:30

Generation of mJ THz pulses in organic crystal pumped by a Cr:Mg_2SiO_4 laser, Carlo Vicario[1], Andrey Ovchinnikov[2], Sergey Ashitkov[2], S. I. Agranat[2], Vladimir E. Fortov[2], Christoph P. Hauri[1,3]; [1]*Paul Scherrer Inst., Switzerland;* [2]*Joint Inst. for High Temperatures of RAS, Russia;* [3]*Ecole Polytechnique Federale de Lausanne, Switzerland.* We demonstrated 0.9 mJ terahertz pulses by optical rectification of a high-energy Cr:Mg_2SiO_4 laser in large organic crystal. The emitted spectrum covers 0.1- 5 THz and the peak fields exceed 42 MV/cm and 14 Tesla.

SM2H.3 • 11:45

On Extracting the Maximum Terahertz Conversion Efficiency from Optical Rectification in Lithium Niobate, Sergio Carbajo[2,3], Paula Alcorta[2], Anne-Laure Calendron[2,3], Huseyin Cankaya[2], Xiaojun Wu[2], Koustuban Ravi[1], Frederike Ahr[2,3], Wenqian Ronny Huang[1], Franz X. Kaertner[1,2]; [1]*MIT, USA;* [2]*Center for Free Electron Laser Science, Germany;* [3]*Physics Dept., Univ. of Hamburg, Germany.* We report on a record 2% extracted optical-to-terahertz conversion efficiency in the mm-wavelength range through optical rectification in cryogenically-cooled lithium niobate by exploiting spatial and temporal shaping of the optical pump beam.

SM2H.4 • 12:00

Generation of Elliptically Polarized Half-Cycle Terahertz Pulses Generated by 6H-SiC Large Aperture Photocondictive Antenna, xavier ropagnol[1], marcel bouvier[2], Christian-Yves Côté[2], Matt Reid[3], Marc-André Gauthier[1], Tsuneyuki Ozaki[1]; [1]*INRS-EMT, Canada;* [2]*Axis photonique INC, Canada;* [3]*UNBC, Canada.* We demonstrated the generation of elliptically half-cycle terahertz pulses with 167 nJ energy generated by a 6H-SiC large aperture photoconductive antenna covered by a phase mask. By optimizing the design of the antenna and the mask, we could generate circularly polarized half-cycle THz pulses.

CLEO: Science & Innovations

SM2I • Silicon Photonic Systems—Continued

SM2I.4 • 11:30
Demonstration of Reconfigurable Electro-Optical Directed-Logic Circuit by Carrier Depletion Micro-ring Resonators, Ciyuan Qiu[2,1], Weilu Gao[2], Richard Soref[3], Jacob Robinson[2], Qianfan Xu[2]; [1]*Shanghai Jiao Tong Univ., China;* [2]*Rice Univ., USA;* [3]*Univ. of Massachusetts, USA.* Here we demonstrate a reconfigurable electro-optical directed-logic circuit based on a 4-fold array of switches. We showed that this circuit can be reconfigured to perform arbitrary two-input logic functions with speed up to 3 Gb/s.

SM2I.5 • 11:45
Integrated Mode-Locked Lasers in a CMOS-Compatible Silicon Photonic Platform, Cheryl M. Sorace-Agaskar[1], Patrick T. Callahan[1], Katia Shtyrkova[1], Anna Baldycheva[1,2], Michele Moresco[1], Jonathan Bradley[1], Michael Y. Peng[1], Nanxi Li[1], E. Salih Magden[1], Purnawirman Purnawirman[1], Michelle Y. Sander[1,3], Gerald Leake[5], Douglas D. Coolbaugh[5], Michael R. Watts[1], Franz X. Kaertner[1,4]; [1]*MIT, USA;* [2]*Univ. of Exeter, UK;* [3]*Boston Univ., USA;* [4]*Univ. of Hamburg, Germany;* [5]*College of Nanoscale Science and Engineering - Univ. of Albany, USA.* Integrated components necessary for a mode-locked laser are demonstrated on a platform that allows for monolithic integration with active silicon photonics and CMOS circuitry. CW lasing and Q-switched mode-locking are observed in the full structures.

SM2I.6 • 12:00
Noise and fluctuations in silicon photonics caused by free carrier and two-photon absorption, Dimitris Dimitropoulos[1], Bahram Jalali[2]; [1]*-, Greece;* [2]*Electrical Engineering, UCLA, USA.* Non-linear optical losses result from convergence of wafer scale economics and information theory in silicon nanophotonics. We discuss new sources of noise and fluctuations that arise from two-photon and free carrier plasma effects.

CLEO: Applications & Technology

AM2J • Light Sources and Devices for Biomedical Imaging II—Continued

AM2J.5 • 11:30
Two-photon excited ReaChR by a three-stage femtosecond optical parametric amplifier, Chia-lun Tsai[1], Po-Yen Hsiao[1], Ming-Chang Chen[1], Shang-Da Yang[1], Yen-Yin Lin[1], Ann-Shyn Chiang[1,2]; [1]*Natl Tsing Hua Univ, Taiwan;* [2]*Academia Sinica, Taiwan.* A three-stage optical parametric amplifier is built to produce 1 kHz, 31 fs, ~200 μJ signal pulses with tunable wavelengths. Red-activatable channelrhodopsin in fruit fly is optimally two-photon excited to copulation behavior at 1250 nm.

AM2J.6 • 11:45
End-Fire Silicon Waveguide Array as a Platform for High Power Beam Shaping and Steering, Michael Kossey[1], Charbel Rizk[1,2], Amy C. Foster[1]; [1]*Johns Hopkins Univ., USA;* [2]*Johns Hopkins Applied Physics Lab, USA.* We demonstrate a scalable array of end-firing silicon waveguides as a platform for high-speed, high-power operation beam-steering applications. We fabricate devices, culminating in 16×1 arrays with a measured central lobe FWHM of 7°±0.6°.

AM2J.7 • 12:00
Tunable Dual Color Source For Multiphoton Imaging, Kriti Charan[1], Dylan Heberle[1], Chris Xu[1]; [1]*Cornell Univ., USA.* We present a tunable-wavelength, multi-color source for imaging several fluorophores simultaneously. The source is based on amplitude modulation of the seed in a chirped-pulse amplification system, followed by soliton self-frequency shift in a large-mode-area fiber.

AM2K • Microprocessing Laser Processing of Silicon and Other Materials—Continued

AM2K.4 • 11:30 Invited
Excimer Laser Annealing for LTPS on Large Substrates, Rainer Paetzel[1]; [1]*Coherent GmbH, Germany.* Low-Temperature Polycrystalline Silicon (LTPS) is the enabling backplane technology for AMOLED displays and small to medium sized high-resolution AMLCDs. Progress on Excimer Laser Annealing towards large-scale production of LTPS is described.

AM2K.5 • 12:00
Random Surface Texturing of mc-Silicon for Solar Cells with Picosecond Lasers; a Comparison between 1064 nm, 532 nm and 355 nm Laser Emission Wavelengths, sergio pellegrino[4], luca longoni[4], davide scorticati[4], simona binetti[1], Alessia Le Donne[1], Andrea Rolfi[1], Emanuele Grilli[1], Chiara Busto[2], Beat Neuenschwander[3], Beat Jaeggi[3]; [1]*Università Milano Bicocca, Italy;* [2]*ENI, Italy;* [3]*Bern Univ. of Applied Sciences, Switzerland;* [4]*Laserpoint, Italy.* Multicrystalline Silicon was textured with picosecond laser. Different laser wavelengths (λ = 1064, 532, 355 nm) where compared regarding laser-induced damage. We found that λ = 355 nm picosecond radiation resulted in shallower defect-reach region.

CLEO: Science & Innovations

SM2L • Modes in Fiber—Continued

SM2L.5 • 11:30
Comparing Inter-Core Skew Fluctuations in Multi-Core and Single-Core Fibers, Ruben S. Luis[1], Benjamin Puttnam[1], Jose M. Mendinueta[1], Werner Klaus[1], Yoshinari Awaji[1], Naoya Wada[1]; [1]*National Inst Information & Comm Tech, Japan.* We measure the dynamic skew fluctuations between cores in a multicore fiber and show that they are more than one order of magnitude smaller than those of parallel single-core fibers over a 24 hour period.

SM2L.6 • 11:45
Spatiotemporal Nonlinear Optics in Multimode Fibers, Logan Wright[1], Demetrios N. Christodoulides[2], Frank W. Wise[1]; [1]*Cornell Univ., USA;* [2]*College of Optics and Photonics, CREOL, Univ. of Central Florida, USA.* We study nonlinear pulse propagation of high-energy ultrashort pulses in graded-index multimode fibers. By adjusting initial conditions, we observe and control a wide range of nonlinear effects including spatiotemporal effects resembling self-focusing and multiple filamentation.

SM2L.7 • 12:00
Complete Spatiotemporal Measurement of Ultrashort Pulses Emerging from Multimode Optical Fiber, Zhe Guang[1], Rick Trebino[1]; [1]*Georgia Inst. of Technology, USA.* Using a newly developed technique, we measure the complete spatiotemporal field of ultrashort pulses emerging from dual-mode optical fibers, finding spatiotemporal complexity, introduced by the different spatial modes, having different group velocities and modal dispersions.

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CLEO: Science & Innovations

SM2M • Nonlinear Signal Processing—Continued

SM2M.5 • 11:30
Nonlinear Compensation with Modified Adaptive Digital Backpropagation in Flexigrid Networks, Edson Porto da Silva[1], Rameez Asif[1], Knud J. Larsen[1], Darko Zibar[1]; [1]*DTU Fotonik, Technical Univ. of Denmark, Denmark*. We present a modified version of adaptive digital backpropagation based on EVM metric, and numerically access its performance in a flexigrid WDM scenario.

SM2M.6 • 11:45
Low Complexity and Adaptive Nonlinearity Compensation, Zhiyu Chen[1], Lianshan Yan[1], Anlin Yi[1], Lin Jiang[1], Yan Pan[1], Wei Pan[1], Bin Luo[1]; [1]*Ctr Info Photonics & Communications, China*. A low complexity adaptive nonlinearity compensation algorithm is experimentally demonstrated based on variance of intensity noise and low-pass filter. Digital-back propagation efficiency is improved about four times in 40-Gb/s DP-QPSK transmission over 720-km SMF.

SM2N • Symposium on Remote Atmospheric Lasing II—Continued

SM2N.3 • 11:30 Invited
Standoff Sources of Coherent Radiation Initiated by Femtosecond Filaments, Daniil Kartashov[1], Skirmantas Alisauskas[2], Giedrius Andriukaitis[2], Audrius Pugzlys[2], Stefan Haessler[2], Andrius Baltuska[2], Mikhail Shneider[3], Bjorn Landgraf[1], Andreas Hoffmann[1], Christian Spielmann[1], Pavel G. Polynkin[4], Alexander Mitrofanov[5,6], Dmitri Sidorov-Biryukov[5,6], Aleksei Zheltikov[5,7], Jens Möhring[8], Dmitri Starukhin[8], Marcus Motzkus[8], Misha Ivanov[9], Maria Richter[9], Felipe Morales[9]; [1]*Inst. for Optics and Quantum Electronics, Friedrich-Schiller-Univ. Jena, Germany;* [2]*Photonics Inst., Vienna Univ. of Technology, Austria;* [3]*Dept. of Mechanical and Aerospace Engineering, Princeton Univ., USA;* [4]*Univ. of Arizona, USA;* [5]*International Laser Center, Lomonosov Moscow State Univ., Russia;* [6]*Russian Quantum Center, Russia;* [7]*Dept. of Physics and Astronomy, Texas A&M Univ., USA;* [8]*Physikalisch-Chemisches Institut, Heidelberg Univ., Germany;* [9]*Max-Born Inst., Germany*. We present the results of experimental and theoretical investigations for remote initiation of lasing in nitrogen and air by femtosecond filaments generated by laser pulses with different wavelengths, polarization and applying adaptive control methods.

SM2N.4 • 12:00
Lasing Actions in a Flame Filament, Huailiang Xu[1], Ya Cheng[2]; [1]*Jilin Univ., China;* [2]*SIOM, China*. We demonstrate lasing in a femtosecond filament with the combustion intermediate of CN as the gain target by femtosecond laser excitation. The lasing action is ascribed to amplified spontaneous emission.

SM2O • Fiber-based Sensing—Continued

SM2O.5 • 11:30
Distributed Temperature and Strain Sensing using Spontaneous Brillouin Scattering in Optical Few-Mode Fibers, Yi Weng[1,2], Ezra Ip[1], Zhongqi Pan[2], Ting Wang[1]; [1]*NEC Labs America, Inc., USA;* [2]*Dept. of Electrical & Computer Engineering, Univ. of Louisiana at Lafayette, USA*. A novel approach to achieve simultaneous distributed temperature and strain sensing based on spontaneous Brillouin scattering in few-mode optical fibers is proposed and experimentally investigated, with high sensitivity using heterodyne detection and optical time-domain reflectometry.

SM2O.6 • 11:45
Simultaneous Measurement of Temperature and Refractive Index Using a Photonic Crystal Cavity on a Fiber Tip, Martijn Boerkamp[2], Yingying Lu[2], Jan Mink[2], Zarko Zobenica[1], Rob W. van der Heijden[1]; [1]*Applied Physics, Eindhoven Univ. of Technology, Netherlands;* [2]*VTEC Lasers & Sensors, Netherlands*. The operation of a luminescent semiconductor photonic crystal cavity on an optical fiber tip is demonstrated for simultaneous measurement of temperature and refractive index by measuring the wavelength-shifts of two different cavity modes.

SM2O.7 • 12:00
Distance Measurement Using Second Harmonic Signal Component of Two-Photon Absorption Photocurrent from Si-APD, Yosuke Tanaka[1], Yoshiki Yamada[1], Takashi Kurokawa[1]; [1]*Tokyo Univ. of Agriculture and Technology, Japan*. We propose a laser distance measurement using second harmonic signal component of two-photon absorption photocurrent from a Si-APD. The proof-of-concept experiment demonstrates the accurate measurement with short data acquisition time of several tens of seconds.

SM2P • Novel Ultrafast Techniques—Continued

SM2P.5 • 11:30
Optimized Ancillae Generation for Ultra-Broadband Two-Dimensional Spectral Shearing Interferometry, Cristian Manzoni[1], Rocio Borrego Varillas[1], Giulio Cerullo[1], Aurelio Oriana[1], Federico Branchi[1]; [1]*Politecnico di Milano, IFN-CNR, Italy*. We introduce a scheme to overcome the challenges of ancillae preparation in traditional spectrally-sheared interferometry techniques for pulse characterization. The approach, applied to two-dimensional spectral shearing interferometry, reliably characterizes few-optical-cycle pulses from UV to IR.

SM2P.6 • 11:45
Generation of Parabolic Pulses with Optimized Duration & Energy by Use of Dispersive Frequency-to-time Mapping, Jeonghyun Huh[1], David Duchesne[1], José Azaña[1]; [1]*Institut National de la Recherche Scientifique— Énergie, Matériaux et Télécommunications, Canada*. Parabolic pulses with durations ranging from the picosecond to the sub-nanosecond range (100-ps reported here) were generated through frequency-to-time mapping. A virtual time-lens was applied in the spectral shaping stage in order to relax the constraints imposed by the far-field condition.

SM2P.7 • 12:00
Multiwavelength Ultrafast $LiNbO_3$ Raman Laser With Cascaded Terahertz-wave Generation, Aravindan M. Warrier[1], Jipeng Lin[1], Helen M. Pask[1], Andrew J. Lee[1], David J. Spence[1]; [1]*Macquarie Univ., Australia*. We demonstrate an ultrafast Raman laser to extend the wavelength versatility of mode-locked lasers. Polariton scattering in $LiNbO_3$ is used to make a tunable ultrafast laser with potential for terahertz generation.

CLEO: QELS-Fundamental Science

FM2A • Single Photon Sources—Continued

FM2A.8 • 12:15
Ultra-fast heralded single photon source based on telecom technology and non-linear optics, Lufti Arif Ngah[1], Olivier Alibart[1], Laurent Labonté[1], Virginia D'Auria[1], Sebastien Tanzilli[1]; [1]*Lab.de Physique de la Matière Condensée, France.* We realize an ultra-fast source of telecom single photons heralded at MHz-rates by combining a 10-GHz repetition-rate laser with off-the-shelf fiber components and waveguide non-linear stages. Measured 2nd-order autocorrelation functions are the lowest reported to date.

FM2B • Ultrafast Dynamics in Quantum Dots and Organic Materials—Continued

FM2B.8 • 12:15
Charged Exciton Linewidth Narrowing via Nuclear Spin Screening in an InAs QD Ensemble, Galan Moody[1], Mingming Feng[1], Corey McDonald[1], Richard P. Mirin[1], Kevin Silverman[1]; [1]*National Inst. of Standards and Technology, USA.* Differential transmission spectroscopy of InAs QDs reveals that the positively charged exciton homogeneous linewidth is broadened by the electron hyperfine interaction. Application of a Faraday magnetic field screens the interaction, narrowing the linewidth by 25%.

FM2C • Hyperbolic Metamaterials—Continued

FM2C.8 • 12:15
Effect of a Hyperbolic Metamaterial on Radiation Patterns of a Single-Photon Source, Mikhail Y. Shalaginov[1], Alexei Lagutchev[1], Vladimir M. Shalaev[1], Alexander V. Kildishev[1]; [1]*Purdue Univ., USA.* We explore the effect of a planar hyperbolic metamaterial (a superlattice of TiN and $Al_{0.7}Sc_{0.3}N$ on MgO substrate) on the far-field radiation patterns of a single-photon source (a nitrogen-vacancy center in a nanodiamond).

FM2D • Novel Optical Phenomena—Continued

FM2D.8 • 12:15
Experimental Detection of Forces in an Optical Analog of Aharonov-Bohm Effect, Sergey Sukhov[1], Veerachart Kajorndejnukul[1], John Broky[1], Aristide Dogariu[1]; [1]*Univ. of Central Florida, CREOL, USA.* Wavefront dislocations in scattering create an Aharonov-Bohm setting where nonconservative reaction forces can be detected experimentally. Observing the dynamics of microscopic particles clarifies the role the finite wave-packets on the transfer of wave's canonical momentum.

12:00–16:00 SC270 • High Power Fiber Lasers and Amplifiers
SC301 • Quantum Cascade Lasers: Science, Technology, Applications and Markets

12:30–13:30 Lunch Break *(on your own)*

13:00–16:00 SC271 • Quantum Information—Technologies and Applications
SC376 • Plasmonics

NOTES

CLEO: QELS-Fundamental Science

FM2E • Symposium on Single-photon Nonlinear Optics II—Continued

FM2E.6 • 12:15
Phase-Noise Limitations on Nonlinear-Optical Quantum Computing, Justin Dove[1], Christopher Chudzicki[1], Jeffrey H. Shapiro[1]; *[1] Research Laboratory of Electronics, MIT, USA.* We establish a framework for evaluating CPHASE gates that use single-photon Kerr nonlinearities in which one pulse overtakes another. We show that causality-induced phase noise precludes the possibility of high-fidelity π-radian conditional phase shifts.

CLEO: Science & Innovations

SM2F • Novel Materials for Semiconductors Lasers—Continued

SM2F.7 • 12:15
Monolayer Tungsten Disulfide Laser, Yu Ye[1], Zi Jing Wong[1], Xiufang Lu[2], Hanyu Zhu[1], Yuan Wang[1], Xianhui Chen[2], Xiang Zhang[1,3]; *[1]UC Berkeley, USA; [2]Hefei National Lab for Physics Science at Microscale and Dept. of Physics, Univ. of Science and Technology of China, China; [3]Lawrence Berkeley National Lab, Materials Sciences Division, USA.* We demonstrate the first realization of monolayer tungsten disulfide laser embedded in a microdisk resonator.

SM2G • Characterization Techniques—Continued

SM2G.8 • 12:15
Tricycloquinazoline-Based Organometallic Compounds for Optical Switching, William Shensky[1], Jianmin Shi[1], Michael J. Ferry[1], Timothy Pritchett[1]; *[1]US Army Research Lab, USA.* The nonlinear absorption was studied for compounds linking tricycloquinazoline to a number of iridium groups. It was determined that the excited-state cross section was highest for the compound with a single iridium group.

SM2H • Strong-Field THz Science and Technology—Continued

SM2H.5 • 12:15
Extreme Terahertz brightness by focusing to a lambda-cubic volume, Christoph P. Hauri[1,2], Mostafa Shalaby[1]; *[1]Paul Scherrer Institut, Switzerland; [2]Ecole Polytechnique Federale de Lausanne, Switzerland.* We demonstrate bright low-frequency terahertz (<5 THz) radiation confined to a diffraction-limited spot size by wavefront manipulation. Focusing to a lambda-cubic volume provides bright THz radiation at the PW/m^2 level.

12:00–16:00 SC270 • High Power Fiber Lasers and Amplifiers
SC301 • Quantum Cascade Lasers: Science, Technology, Applications and Markets

12:30–13:30 Lunch Break *(on your own)*

13:00–16:00 SC271 • Quantum Information—Technologies and Applications
SC376 • Plasmonics

NOTES

CLEO: Science & Innovations

SM2I • Silicon Photonic Systems—Continued

SM2I.7 • 12:15
High contrast and power-efficient thermally-controlled optical switch on Silicon-on-Insulator, Zheng Han[2], Gregory Moille[1], Xavier Checoury[2], Jérôme Bourderionnet[1], Gaëlle Lehoucq[1], Philippe Boucaud[2], Alfredo De Rossi[1], Sylvain Combrié[1]; [1]*Thales Research & Technology, France;* [2]*Univ. Paris-Sud, CNRS UMR 8622, Institut d'Electronique Fondamentale, France.* A low-loss and fast optical switch is demonstrated on Silicon-on-Insulator. Low insertion losses (6dB), a large dynamic contrast (30dB) and a wide tuning range (6nm) are achieved with an operating electric power consumption in the milliwatt range.

CLEO: Applications & Technology

AM2J • Light Sources and Devices for Biomedical Imaging II—Continued

AM2J.8 • 12:15
Tether-less Implantable Upconverting Microscale Light Bulbs for Deep Brain Neural Stimulation and Imaging, Maysamreza Chamanzar[1], David Garfield[2], jillian iafrati[3], Vikaas Sohal[3], Bruce Cohen[2], P. James Schuck[2], Michel Maharbiz[1]; [1]*Univ. of California Berkeley, USA;* [2]*Lawrence Berkeley National Lab, USA;* [3]*UCSF, USA.* We demonstrate the design and fabrication of implantable micro-scale light "bulbs" comprising of parylene-encapsulated upconverting lanthanide-doped nanocrystals (absorbing near-infrared and emitting blue light) for non-invasive targeted optogenetic stimulation of local neuronal ensembles.

AM2K • Microprocessing Laser Processing of Silicon and Other Materials—Continued

AM2K.6 • 12:15
Elucidating the Mechanism of Nanocone and Nanohole Formation on Si by Optical Trap Assisted Nanopatterning, Ting Hsuan Chen[1], Yu-Cheng Tsai[1], Romain Fardel[1], Craig B. Arnold[1]; [1]*Princeton Univ., USA.* Using optical trap-assisted nanopatterning (OTAN), we are able to control the formation of nanocones and nanoholes in Silicon. The effects are described by integrating FDTD and heat transfer modeling to account for the nanoscale features.

CLEO: Science & Innovations

SM2L • Modes in Fiber—Continued

SM2L.8 • 12:15
Transmission of Focused Picosecond Light Pulse through a Multimode Fiber, Yin Cen[2,1], Ying-Chih Chen[2,1]; [1]*Dept. of Physics, City Univ. of New York Graduate Center, USA;* [2]*Dept. of Physics and Astronomy, Hunter College, USA.* We report the experimental demonstration and numerical simulation for delivery of spatially focused temporally compressed picosecond laser pulse through a 10-meter-long step-index multimode fiber by shaping the wavefront of incident light using a deformable mirror.

12:00–16:00 SC270 • High Power Fiber Lasers and Amplifiers
SC301 • Quantum Cascade Lasers: Science, Technology, Applications and Markets

12:30–13:30 Lunch Break *(on your own)*

13:00–16:00 SC271 • Quantum Information—Technologies and Applications
SC376 • Plasmonics

NOTES

CLEO: Science & Innovations

SM2N • Symposium on Remote Atmospheric Lasing II—Continued

SM2N.5 • 12:15
Characterization of Forward ASE Pulses Generated in Nitrogen with a Circularly Polarized Femtosecond Laser, Ya Cheng[1], Bin Zeng[1], Ziting Li[1], Jinping Yao[1], Hongqiang Xie[1], Guihua Li[1], Wei Chu[1], Chenrui Jing[1], Jielei Ni[1]; [1]*Shanghai Inst of Optics and Fine Mech, China*. We report on generation of forward amplified spontaneous emission (ASE) pulses in nitrogen with a circularly polarized femtosecond pump laser as well as characterization of polarization and temporal properties of the ASE pulses.

SM2O • Fiber-based Sensing—Continued

SM2O.8 • 12:15
Multipoint Hollow Core Photonic Crystal Fiber Sensor Network Based on Intracavity Absorption Spectroscopy, Haiwei Zhang[1,2], Ying Lu[1,2], Wei Shi[1,2], Liangcheng Duan[1,2], Zhiqiang Zhao[1,2], jianquan yao[1,2]; [1]*School of Precision Instrument and Opto-electronics Engineering, Inst. of Laser and Opto-electronics, Tianjin Univ., China;* [2]*Key Lab of Opto-electronics Information Technology (Tianjin Univ.), Ministry of Education, China*. We firstly demonstrate an automatic intracavity absorption multipoint acetylene sensor network via dense wavelength division multiplexing filters by applying voltage gradient to the F-P tunable filter. The sensitivity is up to 100ppmV at 1536.71nm.

SM2P • Novel Ultrafast Techniques—Continued

SM2P.8 • 12:15
Injection-Locked VCSEL Arrays for Line-by-Line Pulse-Shaping with Update Times of Less Than 1 ns, Sharad Bhooplapur[1], Anthony Klee[1], Peter J. Delfyett[1]; [1]*Univ. of Central Florida, USA*. Dynamic and static optical pulse shaping with line-by-line control is shown, using a 12-channel injection-locked VCSEL linear array. With channel modulation frequencies up to 3.125 GHz, pulse shape changes within 1 ns are conclusively demonstrated.

12:00–16:00 SC270 • High Power Fiber Lasers and Amplifiers
SC301 • Quantum Cascade Lasers: Science, Technology, Applications and Markets

12:30–13:30 Lunch Break *(on your own)*

13:00–16:00 SC271 • Quantum Information—Technologies and Applications
SC376 • Plasmonics

NOTES

CLEO: QELS-Fundamental Science

13:30–15:30
FM3A • Frequency Conversion
Presider: Xiao Li; Joint Quantum Inst., USA

FM3A.1 • 13:30
Demonstration of background-free, phase-preserving parametric up-conversion at the single-photon level, Yu-Hsiang Cheng[2,1], Tim O. Thomay[2,1], Glenn S. Solomon[2,1], Alan L. Migdall[2,1], Sergey V. Polyakov[1]; [1]*National Inst. of Standards and Technology, USA;* [2]*Joint Quantum Inst., National Inst. of Standards and Technology, Univ. of Maryland, USA.* We demonstrate single-photon-level phase preservation in an up-converting interferometer. The up-conversion process is background-free to within experimental uncertainty, allowing high fringe contrast even at low photon levels. This enables faithful up-conversion of entangled photon pairs.

FM3A.2 • 13:45
Ultrafast Time-to-Frequency Demultiplexing of Polarization-Entangled Photons, John M. Donohue[1], Jonathan Lavoie[1,2], Kevin J. Resch[1]; [1]*Inst. for Quantum Computing and Dept. of Physics & Astronomy, Univ. of Waterloo, Canada;* [2]*Group of Applied Physics, Univ. of Geneva, Switzerland.* Using shaped pulses and nonlinear optics, we have experimentally demonstrated the demultiplexing of a train of polarization-encoded single photons through time-to-frequency conversion. We have shown this technique to preserve polarization entanglement with a partner photon.

FM3A.3 • 14:00
Low noise single photon frequency upconversion using Ti-indiffused periodically-poled lithium niobate waveguides with efficient narrowband filtering, Zhenda Xie[2,1], Kai-hong Luo[3], Harald Herrmann[3], Christine Silberhorn[3], Chee Wei Wong[2,1]; [1]*Columbia Univ., USA;* [2]*Univ. of California, Los Angeles, USA;* [3]*Paderborn Univ., Germany.* We demonstrate single-photon frequency-upconversion using a titanium-infused periodically-poled lithium niobate waveguide by L-band erbium-doped fiber amplifier pump. Internal efficiencies up to 84.4% and dark-count rate of 44kHz are achieved with narrowband filtering down to 3.5GHz.

13:30–15:15
FM3B • Light-matter Interactions in 2D Nanostructures
Presider: Rohit Prasankumar; Los Alamos National Lab, USA

FM3B.1 • 13:30
Ultrafast Coulomb Intervalley Interaction in Monolayer WS_2, Robert Schmidt[1], Gunnar Berghäuser[2], Ermin Malic[2], Andreas Knorr[2], Robert Schneider[1], Philipp Tonndorf[1], Steffen Michaelis de Vasconcellos[1], Rudolf Bratschitsch[1]; [1]*Inst. of Physics and Center for Nanotechnology, Univ. of Münster, Germany;* [2]*Dept. for Theoretical Physics, Technical Univ. Berlin, Germany.* We reveal the ultrafast intervalley dynamics in monolayer WS_2 with a spectrally-resolved ultrafast pump-probe experiment and a microscopic theory. We find strong intervalley Coulomb coupling in the atomically thin semiconductor.

FM3B.2 • 13:45
Ultrafast mid-infrared intraexcitonic spectroscopy of monolayer MoS_2, Soonyoung Cha[1], Ji Ho Sung[2], Jooyoun Kim[1], Sangwan Sim[1], Moon-Ho Jo[2], Hyunyong Choi[1]; [1]*School of Electrical and Electronic Engineering, Yonsei Univ., Korea;* [2]*Center for Artificial Low Dimensional Electronic Systems, Inst. for Basic Science, Division of Advanced Materials Science, Pohang Univ. of Science and Technology (POSTECH), Korea.* We report the first ultrafast mid-infrared (IR) spectroscopy in monolayer MoS_2. The observed mid-IR dynamics show multiple, yet broadened absorption, indicating the predominant intraexcitonic transition from the ground to the higher-lying excitonic states.

FM3B.3 • 14:00 Invited
Manipulating the Valley Pseudospin in MoS2 Transistors, Kin F. Mak[2,1]; [1]*Columbia Univ., USA;* [2]*Penn State Univ., USA.* Monolayer MoS2 possess a new valley-pseudospin degree of freedom besides electronic charge and spin. In this talk I will talk about our recent results on optical generation of valley polarization, based on which a novel Hall effect associated with the new degree of freedom is demonstrated. The mechanisms responsible for driving the new valley Hall effect will be discussed.

13:30–15:30
FM3C • Hyperbolic Metamaterial Waveguides
Presider: Ekaterina Poutrina; AFRL, USA

FM3C.1 • 13:30
Super-Coulombic Energy Transfer: Engineering Dipole-Dipole Interactions with Metamaterials, Ward D. Newman[1], Cristian L. Cortes[1], David Purschke[3], Amir Afshar[2], Zhijiang Chen[1], Glenda De los Reyes[3], Frank Hegmann[3], Kenneth Cadien[2], Robert Fedosejevs[1], Zubin Jacob[1]; [1]*Electrical and Computer Engineering, Univ. of Alberta, Canada;* [2]*Dept. of Chemical and Materials Engineering, Univ. of Alberta, Canada;* [3]*Dept. of Physics, Univ. of Alberta, Canada.* We demonstrate experimentally that hyperbolic metamaterials fundamentally alter dipole-dipole interactions conventionally limited to the near-field. The effect is captured in long-range energy transfer and lifetime reduction of donor emitters due to acceptors placed 100 nm away.

FM3C.2 • 13:45
On-chip Super-robust All-dielectric Zero-Index Material, Shota Kita[1], Yang Li[1], Philip Muñoz[1], Orad Reshef[1], Daryl Vulis[1], Bobby Day[1], Eric Mazur[1], Charles Lieber[1], Marko Loncar[1]; [1]*Harvard Univ., USA.* The robustness of the modal degeneracy for photonic Dirac-cone can be engineered by designing all-dielectric pillar arrays giving on-chip platform of zero index material for any wavelength regime. We demonstrate this concept for telecom regime.

FM3C.3 • 14:00
Transparent subdiffraction optics: nanoscale light confinement without metal, Saman Jahani[1], Zubin Jacob[1]; [1]*Univ. of Alberta, Canada.* We introduce a paradigm shift in light confinement strategy and show that light can be confined below the diffraction limit using completely transparent artificial media (metamaterials with $\varepsilon_{ij}>1$ and $\mu_{ij}=1$).

13:30–15:30
FM3D • Frequency Conversion and its Application
Presider: Ryan Behunin; Yale Univ., USA

FM3D.1 • 13:30
Nonlinear Frequency Mixing in a Surface Nanoscale Axial Photonics Resonator, Michael Kues[2], Christian Reimer[2], Tabassom Hamidfar[1], Roberto Morandotti[2], Pablo Bianucci[1]; [1]*Dept. of Physics, Concordia Univ., Canada;* [2]*INRS-EMT, Canada.* We report on four-wave mixing in a simple-to-fabricate surface nanoscale axial photonics resonator (SNAPR) obtained by pumping with two spectral modes while exploiting a self-locked pump scheme.

FM3D.2 • 13:45
Second-harmonic Generation in a Phase-Matched Nonlinear 2D Crystal, Mervin Zhao[1], Ziliang Ye[1], Yu Ye[1], Hanyu Zhu[1], Yuan Wang[1], Yoshihiro Iwasa[2], Xiang Zhang[1]; [1]*Univ. of California, USA;* [2]*Applied Physics, Univ. of Tokyo, Japan.* We studied the phase-matched SHG from thin crystals of 3R-MoS_2. Due to the noncentrosymmetric nature of the crystal, the typically observed intensity oscillation in 2H-MoS_2 is replaced with constructive interference of the second harmonic light.

FM3D.3 • 14:00
Efficient Generation of Twin Photons at Telecom Wavelengths with 10 GHz Repetition-Rate-Tunable Comb Laser, Rui-Bo Jin[1], Ryosuke Shimizu[2], Isao Morohashi[1], Kentaro Wakui[1], Masahiro Takeoka[1], Shuro Izumi[1,3], Takahide Sakamoto[1], Mikio Fujiwara[1], Taro Yamashita[1], Shigehito Miki[1], Hirotaka Terai[1], Zhen Wang[1], Masahide Sasaki[1]; [1]*NICT, Japan;* [2]*Univ. of Electro-Communications, Japan;* [3]*Sophia Univ., Japan.* We demonstrate a down-conversion-based twin photon source pumped by a 10 GHz repetition-rate-tunable comb laser at 1553 nm wavelength. We show high Hong-Ou-Mandel interference visibilities, which are free from the pump-power induced degradation.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

13:30–15:30
FM3E • Nonlinear Plasmonics
Presider: Roderick Davidson; Vanderbilt Univ., USA

FM3E.1 • 13:30
Giant nonlinear response of polaritonic metasurfaces coupled to intersubband transition, JONGWON LEE[1], Nishant Nookala[1], Mykhailo Tymchenko[1], Juan Sebastian Gomez-Diaz[1], Frederic Demmerle[2], Gerhard Boehm[2], Markus-Christian Amann[2], Andrea Alu[1], Mikhail A. Belkin[1]; [1]*Electrical and Computer Engineering, Univ. of Texas at Austin, USA;* [2]*Walter Schottky Institut, Technische Universität München, Germany.* We report highly-nonlinear metasurfaces based on combining electromagnetically-engineered plasmonic nanoresonators with quantum-engineered intersubband nonlinearities. Experimentally, effective nonlinear susceptibility over 480 nm/V was measured for second-harmonic generation at normal incidence.

FM3E.2 • 13:45
Highly efficient SHG in NLO polymer-coated Au nanoparticles by doubly resonant excitations, Atsushi Sugita[1], Takuma Hirabayashi[1], Shunsuke Nihashi[1], Atsushi Ono[1], Yoshimasa Kawata[1]; [1]*Shizuoka Univ., Japan.* We present localized SP-assisted SHG in NLO polymer-coated Au nanoparticles. More than threefold enhancement in the SHG conversion efficiencies was recorded by tuning the transition frequency of the NLO polymers to the excitation light frequency.

FM3E.3 • 14:00
Tip-enhanced Upconversion of Er^{3+}/Yb^{3+}:$NaYF_4$ Nanoparticles, Gengxu Chen[1], E Wu[1], Chengjie Ding[1], Botao Wu[1], Xueting Ci[1], Yan Liu[1], Youying Rong[1], Yingxian Xue[1], Heping Zeng[1]; [1]*State Key Lab of Precision Spectroscopy, East China Normal Univ., China.* We demonstrated tip-enhanced upconversion luminescence from a single Er^{3+}/Yb^{3+}:$NaYF_4$ nanoparticle due to plasmonic effect. The gold-coated tip enabled improved reception and transmission of incident electromagnetic fields, which increased both absorption and emission processes.

13:30–15:30
SM3F • Ultrafast, High Speed and High Power Semiconductor Lasers
Presider: Leif Johansson; Freedom Photonics, LLC, USA

SM3F.1 • 13:30
Intracavity Loss and Dispersion Managed Mode-Locked Diode Laser, Jan C. Balzer[1], Benjmain Döpke[1], Rouven H. Pilny[1], Carsten Brenner[1], Andreas Klehr[2], Götz Erbert[2], Günther Tränkle[2], Martin R. Hofmann[1]; [1]*Ruhr Universitat Bochum, Germany;* [2]*Ferdinand-Braun-Institut, Leibniz Institut für Höchstfrequenztechnik im Forschungsverbund Berlin e.V., Germany.* We present a self-optimizing diode laser, which generates 216 fs Fourier-limited pulses after external pulse compression. This is achieved by a closed-loop learning concept that optimizes the intracavity spectral phase and amplitude.

SM3F.2 • 13:45
Sub-300-femtosecond Semiconductor Disk Lasers, Dominik Waldburger[1], Mario Mangold[1], Sandro M. Link[1], Matthias Golling[1], Emilio Gini[2], Bauke W. Tilma[1], Ursula Keller[1]; [1]*ETH Zurich, Switzerland;* [2]*FIRST Center for Micro- and Nanosicence, Switzerland.* We present the first sub-150-fs SESAM-modelocked vertical external-cavity surface-emitting laser (VECSEL) in the 100-mW average output power regime and the first sub-300-fs modelocked integrated external-cavity surface-emitting laser (MIXSEL) with 180 mW of average output power.

SM3F.3 • 14:00
Synthesis of coherent optical pulses using a field-programmable gate array (FPGA)-based gradient descent phase-locking algorithm with three semiconductor lasers, Kenneth J. Underwood[1], Andrew M. Jones[1], Juliet Gopinath[1]; [1]*Univ. of Colorado at Boulder, USA.* We demonstrate optical pulse synthesis through coherent combination of AOM-separated light by phase-locking feedback from an FPGA. An order of magnitude improvement in phase stability is shown, limited by the noise of the AOM driver.

13:30–15:30
SM3G • Group IV Photonics
Presider: Michael Menard; McGill Univ., Canada

SM3G.1 • 13:30 Invited
Optical Interconnects based on Ge/SiGe Multiple Quantum Well Structures, Delphine Marris-Morini[1], Papichaya Chaisakul[1,2], Jacopo Frigerio[3], Daniel Chrastina[3], Vladyslav Vakarin[1], Stefano Cecchi[3], Giovanni Isella[3], Laurent Vivien[4]; [1]*Institut d'Electronique Fondamentale, Université Paris Sud, France;* [2]*Dept. of Materials Engineering, The Univ. of Tokyo, Japan;* [3]*Politechnico Di Milano, L-NESS, Italy;* [4]*CNRS, Institut d'Electronique Fondamentale, France.* Silicon photonics devices based on Ge/SiGe structures are promising. However their integration with silicon on insulator waveguides is a challenging point. We present an innovative approach to monolithically integrate low-voltage, broadband photonic interconnection on silicon.

SM3G.2 • 14:00
Relaxation Dynamics of Optically Generated Carriers in Graphene-on-Silicon Nitride Waveguide Devices, Jiaqi Wang[1], Zhenzhou Cheng[1], Qijie Xie[1], Chester Shu[1], Hon Ki Tsang[1]; [1]*The Chinese Univ. of Hong Kong, Hong Kong.* We studied the carrier relaxation dynamics in graphene-on-silicon nitride waveguides. Optically generated carriers from a quasi-continuous wave pump laser show a microsecond response time while those generated from mode-locked laser pulses exhibit accelerated relaxation dynamics.

13:30–15:15
SM3H • THz Materials Science
Presider: David Cooke; McGill Univ., Canada

SM3H.1 • 13:30
Extended-Drude Response of Photocarriers in InSb Revealed with Ultrabroadband Infrared Time-Domain Spectroscopy, Eiichi Matsubara[1,2], Tomohide Morimoto[2], Masaya Nagai[2], Masaaki Ashida[2]; [1]*Dept. of Physics, Osaka Dental Univ., Japan;* [2]*Graduate School of Engineering Science, Osaka Univ., Japan.* We visualized the extension of Drude response of photoexcited carriers by energy-dependent scattering time and effective mass of electrons in InSb, making full use of the advantage of air plasma based ultrabroadband infrared time-resolved spectroscopy.

SM3H.2 • 13:45
Photovoltaic Polymer-Fullerene Blends: Terahertz Carrier Dynamics and Device Performance, Zuanming Jin[1], Dominik Gehrig[1], Clare Dyer-Smith[1], Edwin J. Heilweil[2], Frédéric Laquai[1], Mischa Bonn[1], Dmitry Turchinovich[1]; [1]*MPI for Polymer Research, Germany;* [2]*National Inst. of Standards and Technology, USA.* Ultrafast THz spectroscopy of photovoltaic polymer-fullerene blends PTB7:PC_{70}BM and P3HT:PC_{70}BM reveals differences in conductivity lifetimes and quantum yields, well correlated with different power conversion efficiencies of photovoltaic devices utilizing these compounds.

SM3H.3 • 14:00 Invited
Probing Superconducting Gap Dynamics with THz Pulses, Matthias Beck[2], Maximilian Klammer[2], Ian Rousseau[2], Gregory Gol'tsman[3], Itay Diamant[4], Yoram Dagan[4], Jure Demsar[1,2]; [1]*Johannes Gutenberg Universitat Mainz, Germany;* [2]*Physics Dept., Univ. of Konstanz, Germany;* [3]*Moscow State Pedagogical Univ., Russia;* [4]*Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv Univ., Israel.* We studied superconducting gap dynamics in a BCS superconductor NbN and electron doped cuprate superconductor PCCO following excitation with near-infrared (NIR) and narrow band THz pulses. Systematic studies on PCCO imply very selective electron-phonon coupling.

CLEO: Science & Innovations

13:30–15:30
SM3I • WDMs and Filters
Presider: Jessie Rosenberg; International Business Machines Corp, USA

SM3I.1 • 13:30
Design of a Polarization-Insensitive WDM Demultiplexing Lattice Filter in SOI, Antoine Bois[1], Alexandre D. Simard[1], Wei Shi[1], Sophie LaRochelle[1]; [1]*Université Laval, Canada.* We propose a novel design method for polarization-insensitive optical lattice filters. The technique takes advantage of the spectral periodicity of the Mach-Zehnder building blocks and optimizes the coupler and interferometer lengths to minimize cost functions.

SM3I.2 • 13:45
Inverse Design and Implementation of a Wavelength Demultiplexing Grating Coupler, Alexander Y. Piggott[1], Jesse Lu[1], Thomas M. Babinec[1], Konstantinos Lagoudakis[1], Jan Petykiewicz[1], Jelena Vuckovic[1]; [1]*Stanford Univ., USA.* We have developed a general inverse design algorithm for designing micro- and nano-photonic devices, where the user only specifies the desired device performance. We experimentally demonstrate a vertical-incidence wavelength demultiplexing grating designed by this algorithm.

SM3I.3 • 14:00
All-Optically Controlled Fabry-Perot Cavity-Assisted Add-Drop Microring Resonator on a Silicon Chip, Weifeng Zhang[1], Jianping Yao[1]; [1]*Univ. of Ottawa, Canada.* An all-optically controlled Fabry-Perot cavity-assisted add-drop microring resonator (MRR) on a silicon chip, in which one bus waveguide is replaced by a sidewall Bragg grating Fabry-Perot cavity, is proposed and experimentally demonstrated.

CLEO: Applications & Technology

14:00–15:30
AM3J • Neurophotonics and Optogenetics
Presider: Robert Campbell; Univ. of Alberta, Canada

AM3J.1 • 13:30 Invited
Withdrawn

AM3J.2 • 14:00 Invited
Visualizing Mammalian Brain Area Interactions by Dual-axis Two-photon Calcium Imaging, Mark Schnitzer[1]; [1]*Dept.s of Biology and Applied Physics, Stanford Univ., USA.* Fluorescence Ca2+ imaging enables large-scale recordings of neural activity, but collective dynamics across mammalian brain regions are generally inaccessible within single fields of view. Here we introduce a two-photon microscope possessing two articulated arms that can simultaneously image two brain areas (~0.38 mm2 each), either nearby or distal, using microendoscopes, in awake behaving rodents.

13:30–15:30
AM3K • Components and Enabling Technologies
Presider: Wilhelm Kaenders; Toptica Photonics AG, Germany

AM3K.1 • 13:30
High Speed Surface Micromachined MEMS Tunable VCSEL for Telecom Wavelengths, Sujoy Paul[1], Christian Gierl[1], Julijan Cesar[1], Quang Trung Le[1], Mohammadreza Malekizandi[1], Franko Kueppers[1], Benjamin koegel[2], Juergen Rosskopf[2], Christoph Gréus[2], Markus Görblich[2], Yan Xu[2], Christian Neumeyr[2], Markus Ortsiefer[2]; [1]*TU Darmstadt, Germany;* [2]*Vertilas GmbH, Germany.* We report direct modulation of a widely tunable surface micromachined MEMS VCSEL. The MEMS is electro-thermally actuated for tuning the emission wavelength over 60 nm with a center wavelength of 1554 nm. Error-free transmission is achieved at 10 Gbit/s for 47 nm tuning range.

AM3K.2 • 13:45
New Generation of VBGs for Efficient Spectral Beam Combination of Semiconductor Lasers, Vadim I. Smirnov[1]; [1]*OptiGrate Corp, USA.* Novel types of volume Bragg gratings with enhanced parameters were recorded in PTR glass. They were used for efficient spectral beam combination of high power multimode semiconductor lasers with high spectral density of 1 nm/channel.

AM3K.3 • 14:00
Efficient Chirped Bragg Gratings for Stretching and Compression of High Energy Ultrashort Laser Pulses at 800 nm Spectral Region, Vadim I. Smirnov[1]; [1]*OptiGrate Corp, USA.* This paper reports on new generation of recorded in PTR glass chirped gratings with enhanced beam quality and efficiency for stretching and compression of ultrashort laser pulses in 800 nm spectral region.

CLEO: Science & Innovations

13:30–15:30
SM3L • Novel Fiber Materials
Presider: Shinji Yamashita; Univ. of Tokyo, Japan

SM3L.1 • 13:30
Glass-clad Ti:sapphire crystal fiber laser, Shih-Chang Wang[1], Chun-Yang Hsu[1], Dong-Yo Jheng[1], Tuan-Shu Ho[1], Teng-I Yang[1], Yaqin Xu[1], Sheng-Lung Huang[1]; [1]*National Taiwan Univ., Taiwan.* Glass-clad Ti:sapphire crystal fibers were grown using the co-drawing laser-heated pedestal growth method. A laser threshold of less than 100 mW was achieved at room temperature with an a-cut-core diameter as small as 18 μm.

SM3L.2 • 13:45
Grating Effect in Lanthanum Aluminum Silicate Glass Fiber, Zhifang Wu[1,2], Xuguang Shao[1], Ping Shum[1,2], Hailiang Zhang[1,2], Tianye Huang[1,2], Nan Zhang[1,2], Georges Humbert[3], Jean-Louis Auguste[3], Stéphanie Leparmentier[3], Kay Schuster[4], Doris Litzkendorf[4]; [1]*School of Electrical and Electronics Engineering, Nanyang Technological Univ., Singapore;* [2]*CNRS-International-NTU-Thales Research Alliance (CINTRA), Singapore;* [3]*XLIM Research Inst., UMR 7252 CNRS/Univ. of Limoges, France;* [4]*Leibnitz Inst. of Photonic Technology (IPHT), Germany.* We experimentally demonstrate a Type I grating effect in a lanthanum-aluminum silicate fiber for the first time, to the best of our knowledge. This grating shows a temperature sensitivity ~8.71 pm/°C, which is lower than that of FBG in standard single-mode fiber.

SM3L.3 • 14:00
Mid-infrared Raman sources with highly GeO2 doped silica optical fibers, Xinyong Dong[3,2], Lulu Wang[1,4], Xiaohui Li[4], Ping Shum[4,2], Haibin Su[3,2], Qijie Wang[4]; [1]*China Jiliang Univ., China;* [2]*CINTRA, Research Techno Plaza, 50 Nanyang Drive, Singapore;* [3]*Nanyang Technological Univ., School of Materials Science and Engineering, Singapore;* [4]*Nanyang Technological Univ., School of Electrical & Electronic Engineering, Singapore.* Mid-infrared Raman sources based on highly GeO-doped silica-fibers pumped at ~2.0 μm pulsed/cw lasers are studied. Supercontinuum generation up to 3.0 μm and cascaded Raman scattering up to 2.53 μm are achieved, respectively.

CLEO: Science & Innovations

13:30–15:30
SM3M • High Energy, High Power Systems & Enabling Technology
Presider: Jay Doster; Northrop Grumman Cutting Edge Optronics, USA

SM3M.1 • 13:30 Tutorial

High Power Diode Lasers for Pumping High Energy Solid State Lasers, Paul Crump[1], Carlo Frevert[1], Götz Erbert[1], Günther Tränkle[1]; [1]*Ferdinand-Braun Institut, Germany.* The optical energy used in high-energy-class solid state laser facilities is generated by high power diode lasers. This tutorial reviews and summarizes progress in ongoing efforts world-wide to improve the performance of these critical components.

Paul Crump completed his Ph.D. in physics from Nottingham Univ. (UK) in 1996. After 6 years with Agilent Technologies and 6 years with nLight Photonics (USA), he joined the FBH (Berlin, Germany). Crump is currently group leader responsible for high-power broad area diode lasers and bars.

13:30–15:15
SM3N • Ultrafast High-field Phenomena and Laser Filamentation
Presider: Pavel Polynkin; Univ. of Arizona, USA

SM3N.1 • 13:30 Invited

Filament-Based Impulsive Raman Excitation of Vibrational and Rotational Modes of Polyatomic Molecules, Robert J. Levis[1]; [1]*Temple Univ., USA*. Femtosecond laser filamentation serves as a source well-suited for detection using impulsive excitation of vibrational and rotational modes of molecules. The resulting coherent motion serves a route to remote detection through single shot Raman scattering.

SM3N.2 • 14:00

Picosecond Ionization Dynamics in Femtosecond Filaments at High Pressures, Xiaohui Gao[1], Gauri Patwardhan[1], Samuel Schrauth[1], Daiwei Zhu[1], Alexander L. Gaeta[1]; [1]*School of Applied and Engineering Physics, Cornell Univ., USA*. We observe a 3-fold increase in the electron density within 30 picoseconds after the filamentary propagation of femtosecond pulses in 60-bar argon gases. This suggests that electron-impact ionization dominates on this time scale.

13:30–15:30
SM3O • Nano and Micro-Optical Sensors
Presider: Gerard Wysocki; Princeton Univ., USA

SM3O.1 • 13:30 Invited

Single Nucleic Acid Interactions Monitored with Optical Microcavity Biosensors, Frank Vollmer[1]; [1]*Max-Planck-Inst Physik des Lichts, Germany.* We have developed a label-free biosensing platform that is capable of monitoring single DNA molecules and their interaction kinetics, hence achieving an unprecedented sensitivity in the optical domain.

SM3O.2 • 14:00

Differentiating surface and bulk interactions in nanoplasmonic interferometric sensor arrays, Beibei Zeng[1], Filbert Bartoli[1]; [1]*Lehigh Univ., USA*. We present a nanoplasmonic interferometric sensor platform that can differentiate the adsorption of a thin protein layer on the sensor surface from bulk refractive index changes, exploiting the different penetration depths of multiple SPPs.

13:30–15:30
SM3P • Mode Locked Lasers
Presider: Omer Ilday; Bilkent Univ., Turkey

SM3P.1 • 13:30

50.5 nJ, 750 fs all-fiber all polarization-maintaining fiber laser, Jiaqi Zhou[1], Xijia Gu[1]; [1]*ECE, Ryerson Univ., Canada.* We report on our recent experiments of a 50.5 nJ, 750 fs ultra-stable dissipative soliton fiber laser in the presence of Raman scattering in a long ring cavity. We demonstrated that a transition from noise-like soliton to stable dissipate soliton took place at sufficiently high pulse energy.

SM3P.2 • 13:45

A Harmonically Mode-locked Femtosecond Fiber Laser using Bulk-structured Bi_2Te_3 Topological Insulator, Junsu Lee[1], Joonhoi Koo[1], Cheolhwan Chi[1], Ju Han Lee[1]; [1]*Univ. of Seoul, Korea*. We experimentally demonstate femtosecond harmonic mode-locking of a fiber laser using a bulk-structured Bi_2Te_3 topological insulator (TI)-deposited side-polished fiber.

SM3P.3 • 14:00

Tm/Ho Co-doped Mode-locked Fiber Laser based on Graphene Transferred on Side-polished Fiber, Xiaohui Li[1], Xuechao Yu[1], Zhiyu Yan[1], Qijie Wang[2], Xia Yu[3], Ying Zhang[3]; [1]*Nanyang Technological Univ., Singapore;* [2]*Centre for Disruptive Photonic Technologies, Nanyang Technological Univ., Singapore;* [3]*Singapore Inst. of Manufacturing Technology, Singapore*. All-fiber Tm/Ho co-doped mode-locked fiber laser based on a side polished fiber with atom-layered graphene manufactured by chemical-vapor-deposition (CVD) method as platform has been investigated, which can operate from fundamental to thirteenth harmonic mode locking.

CLEO: QELS-Fundamental Science

FM3A • Frequency Conversion—Continued

FM3A.4 • 14:15
Low-Noise Quantum Frequency Translation of Single Photons, Alessandro Farsi[1], Stephane Clemmen[1], Sven Ramelow[1], Alexander L. Gaeta[1]; [1]*Cornell Univ., USA.* We demonstrate quantum frequency translation of single photons via four-wave-mixing Bragg scattering using a liquid nitrogen cooled dispersion-shifted fiber. We achieve 80% photon conversion efficiency with less than 0.001 noise photons per 5ns gate.

FM3A.5 • 14:30
Background-free Quantum Frequency Downconversion for Two-photon Interference of Heterogeneous Photon Sources, Leo Yu[1], Chandra M. Natarajan[2,1], Tomoyuki Horikiri[3,1], carsten langrock[1], Jason Pelc[4], Mike G. Tanner[5], Eisuke Abe[3], Sebastian Maier[6], Sven Höfling[7,6], Christian Schneider[6], Martin Kamp[6], Robert H. Hadfield[2], Martin M. Fejer[1], Yoshihisa Yamamoto[1,3]; [1]*Stanford Univ., USA;* [2]*Univ. of Glasgow, UK;* [3]*National Inst. of Informatics, Japan;* [4]*Hewlett-Packard Labs, USA;* [5]*Heriot-Watt Univ., UK;* [6]*Univ. of Wurzburg, Germany;* [7]*Univ. of St Andrews, UK.* We report background-free, near-infrared-to-telecom quantum frequency downconversion, mediating two-photon interference with a mean wavepacket overlap larger than 0.89, regardless of the original separation between photon sources in wavelength (900- and 911-nm), wavepacket, and distance (2 km).

FM3A.6 • 14:45
Ramsey Interferometry for Manipulation of Single Photons, Alessandro Farsi[1], Stephane Clemmen[1], Sven Ramelow[1], Alexander L. Gaeta[1]; [1]*Cornell Univ., USA.* We demonstrate a Ramsey interferometer for single photons via consecutive quantum frequency conversions where the phase depends on the propagation between the two interaction regions. Such an interferometer offers control over frequency encoded quantum states.

FM3B • Light-matter Interactions in 2D Nanostructures—Continued

FM3B.4 • 14:30
Single Photon Emission from Localized Excitons in Monolayer WSe_2, Philipp Tonndorf[1], Robert Schmidt[1], Johannes Kern[1], Michele Buscema[2], Gary Steele[2], Andres Castellanos-Gomez[2], Herre van der Zant[2], Steffen Michaelis de Vasconcellos[1], Rudolf Bratschitsch[1]; [1]*Inst. of Physics and Center for Nanotechnology, Univ. of Münster, Germany;* [2]*Kavli Inst. of Nanoscience, Delft Univ. of Technology, Netherlands.* We observe stable and narrowband single photon emission from localized quantum emitters in a WSe_2 monolayer. Photoluminescence excitation spectroscopy reveals that the emission originates from single excitons trapped in a local potential well.

FM3B.5 • 14:45
Emergent photophenomena in three dimensional van der Waals heterostructures, Bala Murali Krishna Mariserla[1], Michael K L Man[1], Soumya Vinod[2], Catherine Chin[1], Takaaki Harada[1], Jaime Taha-Tijerina[2], Chandra Sekhar Tiwary[3], Patrick Nguyen[2], Patricia Chang[4], Tharangattu N Narayanan[5], Angel Rubio[6,7], Pulickel M Ajayan[2], Saikat Talapatra[1,8], Keshav M. Dani[1]; [1]*Femtosecond Spectroscopy Unit, Okinawa Int. of Sci. & Tech. Grad. Univ., Japan;* [2]*Dept. of Materials Science and Nanoengineering, Rice Univ., USA;* [3]*Materials Engineering, Indian Inst. of Science, India;* [4]*Dept. of Chemistry, Rice Univ., USA;* [5]*TIFR Center for Interdisciplinary Sciences (TCIS), Tata Inst. of Fundamental Research, India;* [6]*: Max Planck Inst. for the Structure and Dynamics of Matter, Germany;* [7]*Nano-Bio Spectroscopy Group and European Theoretical Spectroscopy Facility (ETSF), Universidad del País Vasco CFM CSIC-UPV/EHU-MPC & DIPC, Spain;* [8]*Dept. of Physics, Southern Illinois Univ., USA.* We report on the fabrication and observation of emergent opto-electronic phenomena in three dimensional, micron-sized van der Waals heterostructures self-assembled from atomic layers of graphene and hexagonal boron nitride in varying ratios.

FM3C • Hyperbolic Metamaterial Waveguides—Continued

FM3C.4 • 14:15
Light Guiding by Gauge Field for Photons, Qian Lin[1], Shanhui Fan[1]; [1]*Stanford Univ., USA.* We propose a waveguiding mechanism based on the effective gauge field for photons, where the core and cladding are subject to different gauge potentials. This can be realized in a modulated resonator lattice, and provides a dynamically reconfigurable mechanism for generating a one-way waveguide.

FM3C.5 • 14:30
General Conditions for Lossless Propagation in Near-Infrared Hyperbolic Metamaterial Waveguides, Joseph S. Smalley[1], Felipe Vallini[1], Boubacar Kante[1], Yeshaiahu Fainman[1]; [1]*Univ. of California at San Diego, USA.* We present general conditions for lossless propagation in near-infrared hyperbolic metamaterial (HMM) waveguides with lateral confinement. We conclude that HMMs based on noble metals, rather than transparent conducting oxides, offer greatest promise for low-loss propagation.

FM3C.6 • 14:45
Dispersion Control of High-k Waves in Tapered Hyperbolic Waveguides, Nathaniel Kinsey[2], Paul West[2], Marcello Ferrera[2,1], Alexander V. Kildishev[2], Vladimir M. Shalaev[2], Alexandra Boltasseva[2]; [1]*Engineering and Physical Sciences, Heriot-Watt, UK;* [2]*Electrical and Computer Engineering, Purdue Univ., USA.* The fundamental problem of efficiently outcoupling high-k waves from hyperbolic metamaterials is approached with an in-plane configuration, and enhanced with adiabatic tapering. This strategy may allow for better efficiency of Purcell enhanced quantum sources.

FM3D • Frequency Conversion and its Application—Continued

FM3D.4 • 14:15
Significant Enhancement of Third- and Fifth-Harmonic Generation in Air via Two-Color, Time-Resolved Methods, Darshana Weerawarne[1], Ross Grynko[1], Henry J. Meyer[1], Bonggu Shim[1]; [1]*SUNY Binghamton, USA.* We report two orders of magnitude enhancement of third- and fifth-harmonic generation in air via time-resolved methods using two-color, femtosecond beams. We attribute the significant enhancement to cross-phase modulation and/or plasma assisted phase matching effects.

FM3D.5 • 14:30 Invited
Single-Pulse Two-dimensional Raman Spectroscopy, Hadas Frostig[1], Tim Bayer[1], Nirit Dudovich[1], Yonina C. Eldar[2], Yaron Silberberg[1]; [1]*Weizmann Inst., Israel;* [2]*Technion, Israel.* We present a single-pulse two-dimensional Raman spectroscopy scheme. Our scheme offers not only a major simplification of the conventional setup but also an inherent favoring of the direct fifth-order signal over the cascaded signal, the latter being a signal that carries no coupling information.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FM3E • Nonlinear Plasmonics—Continued

FM3E.4 • 14:15
Large and Ultrafast Nonlinear Absorption of an Air/Gold Plasmonic Waveguide, Alexandre Baron[1], Thang B. Hoang[1], Chao Fang[1], Maiken H. Mikkelsen[1], David R. Smith[1]; *[1]Duke Univ., USA.* We investigate theoretically and experimentally the nonlinear propagation of surface plasmons on an air/gold interface which reveals large and ultrafast (≈100 fs) self-induced absorption. The experiment enables a direct measurement of the third-order nonlinear susceptibility.

FM3E.5 • 14:30
Tailoring the Shape of Metallic Nanocavities for Enhanced Four-Wave Mixing, Euclides C. Almeida[1], Yehiam Prior[1]; *[1]Weizmann Inst. of Science, Israel.* Efficient four-wave mixing, with nonlinear response equivalent to BBO of the same thickness, is demonstrated for arrays of nanocavities milled in a free-standing gold film when their shape is properly designed.

FM3E.6 • 14:45
All-Optical Electric-Field-Induced Second-Harmonic Generation, Roderick Davidson[1,2], Anna Yanchenko[3], Jed Ziegler[1], Sergey Avanesyan[1], Richard F. Haglund[1]; *[1]Physics, Vanderbilt Univ., USA; [2]Quantum Information Sciences, Oak Ridge National Lab, USA; [3]Physics, Univ. of Virginia, USA.* Interferometric pump-probe spectroscopy is used to demonstrate all-optical second-harmonic generation from a polymer dielectric in a serrated nanogap structure. Strong optical frequency electric-fields from surface plasmons create ultrafast controllable nonlinear light pulses.

SM3F • Ultrafast, High Speed and High Power Semiconductor Lasers—Continued

SM3F.4 • 14:15
A High Power and Ultrahigh Frequency Mode-Locked Laser Monolithically Integrated with an SOA, Lianping Hou[1], John H. Marsh[1]; *[1]School of Engineering, Univ. of Glasgow, UK.* We report 628 GHz and 1.20 THz pulse repetition frequencies with 142 mW peak powers from a passively mode-locked side-wall SGDBR laser integrated with an SOA, demonstrating high reproducibility, controllability and a wide operation range.

SM3F.5 • 14:30
Tracking the Ultrafast Light-Matter Interaction in Population-Inverted Quantum Dots via Quantum State Tomography, Nicolai B. Grosse[1], Nina Owschimikow[1], Alexej Koltchanov[1], Mirco Kolarczik[1], Ulrike K. Woggon[1], Roland Aust[2], Benjamin Lingnau[2], Kathy Lüdge[2]; *[1]IOAP, Technische Universität Berlin, Germany; [2]ITP, Technische Universität Berlin, Germany.* Based on the full characterization of a pulse transmitted through a semiconductor optical amplifier by quantum state tomography, we determine the degree of population inversion and the momentary signal-to-noise ratio at sub-picosecond times and RT.

SM3F.6 • 14:45
Application of Strong Slow-Light Feedback to Boost the Modulation Bandwidth of VCSELs Beyond 70 GHz, Moustafa Ahmed[1,2], Ahmed Bakry[1], Hamed Dalir[3], Fumio Koyama[3,1]; *[1]King Abdulaziz Univ., Saudi Arabia; [2]Physics, Minia Univ., Egypt; [3]Tokyo Inst. of Technology, Japan.* We present modeling of strong slow-light feedback in VCSEL coupled with a transverse cavity. We show boosting of the modulation bandwidth to frequencies reaching 70 GHz as well as resonance modulation around 90 GHz.

SM3G • Group IV Photonics—Continued

SM3G.3 • 14:15
A Black Phosphorus FET Integrated on a Silicon Waveguide for High Speed, Low Dark Current Photodetection, Nathan Youngblood[1], Che Chen[1], Steven J. Koester[1], Mo Li[1]; *[1]UMN, USA.* A waveguide-integrated black phosphorus photodetector with high responsivity and low dark current is demonstrated for telecom wavelengths with an RC-limited bandwidth of 3 GHz. Electrostatic doping and frequency dependent photoresponse are used to identify photocurrent generation mechanisms.

SM3G.4 • 14:30
Germanium Photonic Crystal Nanobeam Cavity with Q > 1,300, Michihiro Kuroki[1], Satoshi Kako[1], Satomi Ishida[1], Katsuya Oda[2], Tatemi Ido[2], Satoshi Iwamoto[1], Yasuhiko Arakawa[1]; *[1]Inst. of Industrial Science and Inst. for Nano Quantum Information Electronics, Univ. of Tokyo, Japan; [2]Hitachi Ltd., Japan.* We fabricate germanium-based photonic crystal nanobeam cavities and observe a large enhancement (≈170 times) of room-temperature photoluminescence signal at a cavity resonance of ≈1,700 nm. A cavity quality factor as high as 1,350 is achieved.

SM3G.5 • 14:45
A Direct Band Gap GeSn Laser on Si, Richard Geiger[1,2], Stephan Wirths[3], Nils von den Driesch[3], Zoran Ikonic[4], Jean-Michel Hartmann[5], Jerome Faist[2], Siegfried Mantl[3], Detlev Grützmacher[3], Dan Buca[3], Hans Sigg[1]; *[1]Lab for Micro- and Nanotechnology, Paul Scherrer Inst., Switzerland; [2]Inst. for Quantum Electronics, ETH Zürich, Switzerland; [3]Peter Grünberg Inst. 9, Forschungszentrum Jülich, Germany; [4]Inst. of Microwaves and Photonics, Univ. of Leeds, UK; [5]CEA, LETI, France.* Temperature-dependent photoluminescence spectroscopy reveals that partially strain-relaxed $Ge_{0.87}Sn_{0.13}$ exhibits a fundamental direct band gap. For such an alloy, we show lasing at ≈ 2.3 µm emission wavelength under optical pumping up to 90 K.

SM3H • THz Materials Science—Continued

SM3H.4 • 14:30
ENhancement of THz emission from GaN surface by Ga vacancy-related defects, Yuji Sakai[1], Iwao Kawayama[1], Hidetoshi nakanishi[2], Masayoshi Tonouchi[1]; *[1]Osaka Univ., Japan; [2]SCREEN Holdings Co., Ltd., Japan.* The enhancement of terahertz emission from a GaN wafer induced by Ga vacancy-related defects was observed. This phenomena can be explained by the change of the band bending at these defects.

SM3H.5 • 14:45
Ultrabroadband, Lightweight, Flexible, and Polarization Sensitive Photodetector Based on Carbon Nanotube Fibers, Ahmed Zubair[1], Dmitri Tsentalovich[2], Colin C. Young[2], Naoki Fujimura[3], Xuan Wang[1], Xiaowei He[1], Weilu Gao[1], Yukio Kawano[3], Matteo Pasquali[2,4], Junichiro Kono[1,5]; *[1]Electrical and Computer Engineering, Rice Univ., USA; [2]Chemical and Biomolecular Engineering, Rice Univ., USA; [3]Physical Electronics, Tokyo Inst. of Technology, USA; [4]Chemistry, Rice Univ., USA; [5]Physics and Astronomy, Rice Univ., USA.* We present a flexible ultrabroadband (visible to terahertz), polarization-sensitive carbon nanotube fiber photodetector. This photothermoelectric-effect-based room-temperature photodetector fabricated using a unique technique has high responsivities, up to 2.2 mA/W in the terahertz regime.

CLEO: Science & Innovations

SM3I • WDMs and Filters—Continued

SM3I.4 • 14:15
Multichannel Optical Filters in Nanoscale Silicon Waveguides, Matthew W. Puckett[1], Felipe Vallini[1], Andrew Grieco[1], Shaya Fainman[1]; [1]*Univ. of California, San Diego, USA.* We design and characterize asymmetric Bragg gratings in waveguides which possess multiple reflected wavelengths. We experimentally demonstrate devices with two independent stopbands, then use finite-difference time domain software to characterize more complex grating designs.

SM3I.5 • 14:30
Narrowband Waveguide Bragg Gratings with Fully-etched Side Corrugations and Large Fabrication Tolerance, Keng-Hsien Lin[1], Yung-Jr Hung[1], Chong-Jia Wu[1], Cheng-Yu Wang[1], Yung-Jui Chen[1]; [1]*National Sun Yat-sen Univ., Taiwan.* Fully-etched cladding-modulated grating allows not only flexible control of the reflection response but also large fabrication tolerance. A reflection bandwidth of < 0.6 nm and a Bragg wavelength variation of within 1 nm is experimentally demonstrated.

SM3I.6 • 14:45
High-Quality Bragg Gratings Operating in Reflection without Circulators in SOI, Alexandre D. Simard[1], Sophie LaRochelle[1]; [1]*Universite Laval, Canada.* We demonstrate that apodized Bragg gratings placed in the two arms of a Mach-Zehnder structure in SOI can provide high-quality filtering functions overcoming phase noise distortions. As examples, we present narrowband, phase-shifted and dispersion-less filters.

CLEO: Applications & Technology

AM3J • Neurophotonics and Optogenetics—Continued

AM3J.3 • 14:30 Invited
Engineering the Next Generation of Optogenetic Reporters to Illuminate Neuronal Activity, Robert E. Campbell[1]; [1]*Univ. of Alberta, Canada.* The Campbell group uses protein engineering to develop fluorescent protein-based reporters for cell imaging. I will describe our most recent efforts to engineer an improved generation of reporters for calcium ion, membrane potential, and neurotransmitters.

AM3K • Components and Enabling Technologies—Continued

AM3K.4 • 14:15
Beam Shaping Concepts with Aspheric Surfaces, Ulrike Fuchs[1], Sabrina Matthias[2]; [1]*Asphericon GmbH, Germany;* [2]*asphericon Inc, USA.* The potpourri of aspheric surfaces offers many possibilities in optical design, even the chance for flexible beam shaping setups. Since these are refractive optical elements the beam shaping is robust with respect to wavelength changes.

AM3K.5 • 14:30
Generation of continuous-wave and pulsed vortex beams in an a-cut Nd:YVO_4 laser with annular end-pumping, Ajian Hu[1], Peifeng Chen[1], Ying Wang[1], Shumo Li[1]; [1]*Huazhong Univ of Science & Technology, China*. We directly produced continuous-wave (CW) and pulsed first order Laguerre-Gaussian vortex beams from an annular end-pumped Nd:YVO_4 laser with a general fiber coupled LD source (core diameter, 800 μm).

AM3K.6 • 14:45
Development of YCOB Crystals for Large Aperture SHG, THG and OPA Applications, Yanqing Zheng[1]; [1]*Shanghai Inst. of Ceramics, CAS, USA.* Large clear aperture elements bigger than 30 mm x 30 mm are difficult to growth and are of high cost for BBO, LBO crystals. YCOB grown by Czochralski method was shown a good choice of large aperture applications.

CLEO: Science & Innovations

SM3L • Novel Fiber Materials—Continued

SM3L.4 • 14:15
Low-Loss Tellurite Fibers With Embedded Nanodiamonds, Heike Ebendorff-Heidepriem[1], Yinlan Ruan[1], Hong Ji[1], Brett Johnson[2], Takeshi Ohshima[4], Andrew Greentree[3], Brant C. Gibson[3], Tanya Monro[1]; [1]*Univ. of Adelaide, Australia;* [2]*Univ. of Melbourne, Australia;* [3]*RMIT, Australia;* [4]*Japan Atomic Energy Agency, Japan.* We report the development of nanodiamond-doped tellurite fibers with both preserved single photon emission properties of the nanodiamonds embedded in the glass and fiber loss reduced to levels suitable for practical applications.

SM3L.5 • 14:30
Graphene-deposited Microfiber for Ultrafast Optical Modulation, Shaoliang Yu[1], Limin Tong[1]; [1]*State Key Lab of Modern Optical Instrumentation, Dept. of Optical Engineering, Zhejiang Univ., China.* With a convenient and controllable evanescent-field-induced transfer method, graphene flakes were deposited on the surface of a 1-μm-diameter microfiber, which can be used for ultrafast optical modulation based on it's distinct saturable absorption.

SM3L.6 • 14:45
Multiwavelength Thulium-doped Fiber Laser Based on Four-wave Mixing in Highly Germania-doped Fiber , Tianye Huang[1], Xiaohui Li[1], Ping Shum[1], Qijie Wang[1], Xuguang Shao[1], Lulu Wang[1], Huizi Li[1], Zhifang Wu[1], Xinyong Dong[1]; [1]*Nanyang Technological Univ., Singapore.* An all-fiber multiwavelength Tm-doped laser based on four-wave mixing in highly-germania-doped-highly-nonlinear-fiber (HG-HNLF) has been demonstrated. By using 50-m HG-HNLF to provide intensity-depended gain, 36 lasing lines with wavelength spacing of 0.86 nm within 30-dB bandwidth is obtained.

SM3M • High Energy, High Power Systems & Enabling Technology—Continued

SM3M.2 • 14:30
A Solid State 100 mJ Diode Pumped Temporally and Spatially Shaped Front End System for Seeding a 10 Hz 100 J Laser System, Waseem Shaikh[1], Thomas Butcher[1], Saumyabrata Banerjee[1], Paul Mason[1], Klaus Ertel[1], Johnathan Phillips[1], Jodie Smith[1], Martin Divoky[2], Mariastefania De Vido[1], Oleg Cheklov[1], Justin Greenhalgh[1], Stephanie Tomlinson[1], Ian Musgrave[1], Cristina Hernandez-Gomez[1], John L. Collier[1]; *[1]CLF, STFC, UK; [2]Laser, HiLase Project, Czech Republic.* We describe a 100 mJ three component ytterbium based laser system operating at 1030 nm. Capabilities of both temporal pulse shaping and efficient active/passive spatial shaping for amplification in a 100 J system are incorporated.

SM3M.3 • 14:45
High energy pump laser for Multi-Petawatt laser, Olivier Casagrande[1], Christophe Derycke[1], Alexandre Soujaeff[1], Philippe Ramos[1], Laurent Boudjemaa[1], Christophe Simon-Boisson[1], Sebastien Laux[1], Francois Lureau[1]; *[1]Laser Solutions Unit, Thales Optronique, France.* ATLAS 100, a compact high energy laser delivering more than 100 joules at the repetition rate of 1 shot per minute has been developed for the two 10 PetaWatt beamlines of ELI NP infrastructure.

SM3N • Ultrafast High-field Phenomena and Laser Filamentation—Continued

SM3N.3 • 14:15
On the Role of Freeman Resonances in Pump-Probe Measurements of the Nonlinear Refractive Index, Michael Hofmann[1], Carsten Bree[1]; *[1]Weierstrass-Inst., Germany.* We demonstrate the dramatic impact of Freeman resonances on the cross-induced transient refractive index. Its nonperturbative character must be carefully considered in pump-probe based measurements of the all-optical Kerr effect.

SM3N.4 • 14:30
Group-velocity mismatch effect in high-order harmonic generation, Carlos Hernandez-Garcia[1,2], Tenio Popmintchev[1], Margaret M. Murnane[1], Henry C. Kapteyn[1], Luis Plaja[2], Agnieszka Jaron-Becker[1], Andreas Becker[1]; *[1]JILA, Univ. of Colorado, USA; [2]Universidad de Salamanca, Spain.* We theoretically investigate the role of group velocity matching in high-order harmonic generation. We introduce the associated walk-off length, and present its scaling with wavelength and pulse duration.

SM3N.5 • 14:45 Invited
Laser Acceleration of Non-relativistic Electrons at Dielectric Structures: Status and Outlook, Joshua McNeur[1], Ang Li[1], Norbert Schönenberger[1], Alexander Tafel[1], Peter Hommelhoff[1,2]; *[1]Dept. of Physics, Univ. of Erlangen-Nuremberg, Germany; [2]Max Planck Inst. for Quantum Optics, Germany.* Dielectric laser acceleration of electrons is the optical counterpart of phase-synchronous RF-acceleration of electrons in classical accelerators, demonstrated by us and at Stanford/SLAC recently. We discuss concept, experiments and detail highlights of this high-gradient scheme.

SM3O • Nano and Micro-Optical Sensors—Continued

SM3O.3 • 14:15
Universal Enhancement of Raman Scattering Sensing by Plasmonic Nanotubes Coupled with Photonic Crystal Slab, Zheng Wang[1,2], Chao Liu[1,3], Swapnajit Chakravarty[4], D.L. Fan[1,3], Alan X. Wang[5], Ray T. Chen[1,2]; *[1]Materials Science and Engineering Program,Texas Materials Inst., The Univ. of Texas at Austin, USA; [2]Dept. of Electrical and Computer Engineering, The Univ. of Texas at Austin, USA; [3]Dept. of Mechanical Engineering, The Univ. of Texas at Austin, USA; [4]Omega Optics, Inc., USA; [5]School of Electrical Engineering and Computer Science, Oregon State Univ., USA.* We experimentally demonstrate 2-D photonic crystal slab-coupled plasmonic nanocapsules for surface enhanced Raman spectroscopy (SERS). A strong Raman signal enhancement can be unambiguously detected even with a low concentration 10 nM dye molecules.

SM3O.4 • 14:30
Low-Loss Titanium Dioxide Waveguides for Integrated Evanescent Raman Spectroscopy, Christopher C. Evans[1], Chengyu Liu[1], Jin Suntivich[1]; *[1]Cornell Univ., USA.* We propose an integrated-optical device consisting of a channel waveguide, capable of exciting and collecting Raman-scattered light of surrounding chemicals via the evanescent field, as a new chemical sensing platform.

SM3O.5 • 14:45
Monolithical Absorption Sensor Based on Bi-functional Quantum Cascade Structures, Daniela Ristanic[1], Benedikt Schwarz[1], Peter Reininger[1], Hermann Detz[1], Aaron M. Andrews[1], Werner Schrenk[1], Donald C. MacFarland[1], Tobias Zederbauer[1], Gottfried Strasser[1]; *[1]Technische Universität Wien, Austria.* An integrated mid-infrared sensor consisting of an array of DFB lasers and detectors built from a bi-functional quantum cascade structure is demonstrated. The different frequencies enable the identification of the chemicals in a liquid mixture.

SM3P • Mode Locked Lasers—Continued

SM3P.4 • 14:15
Mid-infrared Two-color Optical Parametric Oscillator across a 30 THz Spectral Range, Yuwei Jin[1], Simona M. Cristescu[1], Frans J. Harren[1], Julien Mandon[1]; *[1]Dept. of Molecular and Laser Physics, Radboud Universiteit Nijmegen, Netherlands.* We present a broadband tunable two-color optical parametric oscillator. The single cavtiy is capable of generating two idlers that are separated up to 30 THz. Fourier transform spectroscopy with this source has been demonstrated for multi-gas detection.

SM3P.5 • 14:30
Few-Femtosecond Synchronization Between a Few-MHz Ti:Sapphire Laser and a Multi-GHz Microwave Signal, Jungwon Kim[1], Matthew Walbran[2,3], Alexander Gliserin[2,3], Kwangyun Jung[1], Peter Baum[2,3]; *[1]Korea Advanced Inst of Science & Tech, Korea; [2]Ludwig-Maximilians Univ., Germany; [3]Max-Planck Inst. for Quantum Optics, Germany.* We show 3.7-fs (rms) synchronization between a 5-MHz, 0.5-μJ Ti:sapphire laser and a 6.2-GHz microwave signal [integration bandwidth: 1 Hz - 2.5 MHz]. This result may help advancing pump-probe imaging in free-electron lasers or ultrafast electron diffraction.

SM3P.6 • 14:45
Low Phase Noise Hybrid Silicon Mode Locked Laser Using On-Chip Coherent Photon Seeding, sudharsanan srinivasan[1], Erik Norberg[2], Tin Komljenovic[1], Michael Davenport[1], Greg Fish[2], John Bowers[1]; *[1]UCSB, USA; [2]Aurrion Inc., USA.* We demonstrate 6dB improvement in phase noise of a mode-locked semiconductor laser using coherent photon seeding, achieving a record linewidth of 29kHz. The complete photonic-circuit including the feedback cavity is integrated on a single chip.

CLEO: QELS-Fundamental Science

FM3A • Frequency Conversion—Continued

FM3A.7 • 15:00
Upconversion of Microwave to Optical Photons using Erbium Impurities in a Solid, Xavier Fernandez-Gonzalvo[1], Lewis A. Williamson[1], Yu-Hui Chen[1], Chunming Yin[2], Sven Rogge[2], Jevon J. Longdell[1]; [1]*Univ. of Otago, New Zealand;* [2]*Physics, Univ. of New South Wales, Australia.* We present a proposal for the efficient, quiet conversion of quantum states encoded as microwave photons into telecomunications photons using erbium dopants in solids. We also present initial results showing low efficiency conversion.

FM3A.8 • 15:15
Progress towards quantum state transfer between microwave and optical light using an electro-optomechanical resonator, Robert Peterson[1], Peter S. Burns[1], Reed Andrews[1], Thomas P. Purdy[1], Katarina Cicak[2], Raymond W. Simmonds[2], Cindy A. Regal[1], Konrad W. Lehnert[1,2]; [1]*JILA, USA;* [2]*NIST, USA.* We have constructed a bidirectional and efficient converter between microwave and optical light using a mechanically compliant membrane coupled via the optomechanical interaction. Ongoing work towards quantum state transfer is discussed.

FM3B • Light-matter Interactions in 2D Nanostructures—Continued

FM3B.6 • 15:00
Topologically tunable Fano resonance in $(Bi_{1-x}In_x)_2Se_3$, Sim Sangwan[1], Nikesh Koirala[2], Matthew Brahlek[2], Jun Park[1], Soonyoung Cha[1], Seongshik Oh[2], Hyunyong Choi[1]; [1]*Yonsei Univ., Korea;* [2]*Rutgers Univ., USA.* We report new tunable Fano interference phenomena depending on topological phase in $(Bi_{1-x}In_x)_2Se_3$. The controlled spatial overlap of topological surface wavefunction with bulk phonon is responsible for the ultrafast tunability of the Fano resonance.

FM3B.7 • 15:15
Quantum Interference Control of Photocurrents in Topological Insulator Films, Derek A. Bas[1], Kevin Vargas-Valez[1], Sercan Babakiray[1], Trent A. Johnson[1], David Lederman[1], Tudor Stanescu[1], Alan D. Bristow[1]; [1]*West Virginia Univ., USA.* Charge currents in thin films of Bi_2Se_3 are controlled using a two-color scheme that exploits quantum interference of single- and two-photon absorption pathways. Injection and shift currents are observed and linked to surface state excitations.

FM3C • Hyperbolic Metamaterial Waveguides—Continued

FM3C.7 • 15:00
Singular Evanescent Wave Resonances, Yu Guo[1], Zubin Jacob[1]; [1]*Univ. of Alberta, Canada.* We report on the discovery of a unique resonance in moving media, impossible in a stationary system. It leads to giant non-contact fluctuational drag force between moving bodies (giant quantum friction).

FM3C.8 • 15:15
Mode selection filter using THz metamaterials surfaced on $LiNbO_3$ sub-wavelength slab waveguide, Bin Zhang[1], Chongpei Pan[1], Yusong Pan[1], Shibiao Wang[1], Qiang Wu[1], Jingjun Xu[1]; [1]*Nankai Univ., China.* We implemented periodic bar arrays metamaterials to separate waveguide modes of terahertz waves propagating in a $LiNbO_3$ sub-wavelength waveguide. The spatial and temporal electric field profiles were recorded using a time-resolved phase contrast imaging system.

FM3D • Frequency Conversion and its Application—Continued

FM3D.6 • 15:00
Raman oscillation, frequency upconversion, and Raman amplification at phonon-polariton resonance, Yujie J. Ding[1]; [1]*Lehigh Univ., USA.* We have shown that Raman oscillation, frequency upconversion, and Raman amplification can be achieved in a second-order nonlinear medium at the phonon-polariton resonance.

FM3D.7 • 15:15
Enhanced stimulated Brillouin scattering via saturable phonon losses, Ryan Behunin[1], William H. Renninger[1], Heedeuk Shin[1], Prashanta Kharel[1], Eric Kittlaus[1], Faustin Carter[1], Peter T. Rakich[1]; [1]*Yale Univ., USA.* Using stimulated Brillouin spectroscopy we demonstrate that nonlinear phonon dynamics emerging at cryogenic temperatures can be effectively harnessed to enhance Brillouin gain and extend phonon lifetimes in fiber.

15:30–16:00 Coffee Break, *Concourse Level*

16:00–18:00 JM4A • Plenary Session I, *Grand Ballroom*

18:30-19:30 OSA Technical Group Poster Sessions, *Technical Session Corridor near 210 A-D*
* Nanophotonics Technical Group
* Optoelectronics Technical Group
* Optical Fabrication and Testing Technical Group

18:30-19:30 Optical Material Studies Technical Group Networking Event, *Meeting Room 211 B/D*

18:30–20:30 OSA Student Member Happy Hour (RSVP Required)

CLEO: QELS-Fundamental Science

FM3E • Nonlinear Plasmonics—Continued

FM3E.7 • 15:00
Scaling of the Nonlinear Response of Metal/Dielectric Plasmonic Waveguides, Alexandre Baron[1], Stéphane Larouche[1], Daniel J. Gauthier[1], David R. Smith[1]; [1]*Duke Univ., USA.* The scaling of the nonlinear response of a single-interface plasmonic waveguide is studied, where both the metal and dielectric display nonlinearity. We introduce a figure-of-merit that guides metal/dielectric nanophotonic device design for specific applications.

FM3E.8 • 15:15
Suppression and Subsistence of Fano EIT Transmission Wndows in Plasmonic-Vapor System, Liron Stern[1], Meir Y. Grajower[1], Uriel Levy[1]; [1]*Applied Physics, Hebrew Univ. of Jerusalem, Israel.* We report on the sub Doppler transmission characteristics of a pump-probe V-type surface plasmon and atomic system. Suppression and subsistence of EIT windows is demonstrated due to the unique character of the plasmonic-atomic hybrid system.

CLEO: Science & Innovations

SM3F • Ultrafast, High Speed and High Power Semiconductor Lasers—Continued

SM3F.7 • 15:00
DBR-free Semiconductor Disk Lasers, Zhou Yang[1], Alexander R. Albrecht[1], Jeffrey G. Cederberg[2], Mansoor Sheik-Bahae[1]; [1]*Univ. of New Mexico, USA;* [2]*Sandia National Labs, USA.* We demonstrate a novel DBR-free semiconductor disk laser, where multiple quantum well active region is fusion bonded directly onto a diamond heat spreader. CW output powers of 2.5 W have been demonstrated at 1150 nm.

SM3F.8 • 15:15
Low-temperature Optimized 940 nm Diode Laser Bars with 1.98 kW Peak Power at 203 K, Carlo Frevert[1], Paul Crump[1], Frank Bugge[1], Steffen Knigge[1], Arnim Ginolas[1], Götz Erbert[1]; [1]*Ferdinand-Braun-Institut, Leibniz-Institut fuer Hoechstfrequenztechnik, Germany.* Passively cooled 1-cm wide QCW diode laser bars with low-temperature optimized vertical designs reach output powers of 1.98 kW at 203 K, with conversion efficiency of 64% at 1 kW and 57% at 1.9 kW.

SM3G • Group IV Photonics—Continued

SM3G.6 • 15:00 Invited
Monolithically Grown Superluminescent Diodes on Germanium and Silicon substrates, Qi Jiang[1], Siming Chen[1], Mingchu Tang[1], Jiang Wu[1], Alywn Seeds[1], Huiyun Liu[1]; [1]*UCL, UK.* We demonstrate the first InAs/GaAs quantum-dot (QD) superluminescent diode (SLD) monolithically grown on both Ge and Si substrates by molecular beam epitaxy.

SM3H • THz Materials Science—Continued

SM3H.6 • 15:00
Ultrafast Carrier Transport in Silicon Nanocrystal Superlattices, Hynek Nemec[1], Petr Kuzel[1], Petr Maly[2], Sebastian Gutsch[3], Daniel Hiller[3], Margit Zacharias[3]; [1]*Inst. of Physics AS CR, v.v.i, Czech Republic;* [2]*Chares Univ., Czech Republic;* [3]*Albert-Ludwigs-Univ. of Freiburg, Germany.* Time-resolved terahertz spectroscopy is employed to study silicon nanocrystals prepared by thermal decomposition of silicon-rich SiO_x layers. We observe that higher silicon content favors formation of larger silicon clusters with short-range percolation.

15:30–16:00 Coffee Break, *Concourse Level*

16:00–18:00 JM4A • Plenary Session I, *Grand Ballroom*

18:30-19:30 OSA Technical Group Poster Sessions, *Technical Session Corridor near 210 A-D*
* Nanophotonics Technical Group
* Optoelectronics Technical Group
* Optical Fabrication and Testing Technical Group

18:30-19:30 Optical Material Studies Technical Group Networking Event, *Meeting Room 211 B/D*

18:30–20:30 OSA Student Member Happy Hour (RSVP Required)

CLEO: Science & Innovations

SM3I • WDMs and Filters—Continued

SM3I.7 • 15:00
Bragg Grating Spiral Strip Waveguide Filters for TM Modes, Zhitian Chen[1], Jonas Flueckiger[1], Xu Wang[1], Han Yun[1], Yun Wang[1], Zeqin Lu[1], Fan Zhang[1], Nicolas A. Jaeger[1], Lukas Chrostowski[1]; [1]*Univ. of British Columbia, USA*. We demonstrate a 1 cm long Bragg grating filter, on a compact spiral SOI waveguide, for the fundamental transverse magnetic mode, that has a 0.5 nm bandwidth, 40 dB extinction ratio, and 1 dB/cm loss.

SM3I.8 • 15:15
Plasmonic Fano Nanoantenna for On-chip Wavelength Demultiplexing, Rui Guo[1], Manuel Decker[1], Frank Setzpfandt[1], Isabelle Staude[1], Dragomir N. Neshev[1], Yuri S. Kivshar[1]; [1]*Australian National Univ., Australia*. We demonstrate a single-element Fano nanoantenna allowing for strong directional coupling of light to a silicon waveguide depending on the operational wavelength. This antenna can spatially separate wavelength-encoded optical signals, realizing an ultra-compact plasmonic demultiplexer.

CLEO: Applications & Technology

AM3J • Neurophotonics and Optogenetics—Continued

AM3J.4 • 15:00
Label-Free Imaging of Single Neuron Activities by Stimulated Raman Scattering, Delong Zhang[1], Hyeon Jeong Lee[1], Pei-Yu Shih[1], Ryan Drenan[1], Ji-Xin Cheng[1]; [1]*Purdue Univ., USA*. We report the observation of single neuron activities by spectral focusing stimulated Raman scattering (SRS) microscopy. Changes in SRS signal intensity in live neurons correlate to action potentials indicated by fluorescent calcium indicator.

AM3J.5 • 15:15
Multifunctional Transparent Optoelectrode Array for *in-vivo* Optogenetic Studies, Joonhee Lee[1], Ilker Ozden[1], Yoon-Kyu Song[2,3], Arto Nurmikko[1]; [1]*Brown Univ., USA;* [2]*Seoul National Univ., Korea;* [3]*Advanced Inst.s of Convergence Technology, Korea*. We developed fully transparent 2-dimensional intracortical neural probe microarrays based on ZnO single crystal. The unique material and device design enabled efficient multifunctional, multi-site patterned optical stimulation and simultaneous electrical recording in rodents.

AM3K • Components and Enabling Technologies—Continued

AM3K.7 • 15:00
Development, Fabrication, and Real-World Applications of Polymeric Nanolayer Gradient Index Optical Components, Howard Fein[1], Michael Ponting[1]; [1]*PolymerPlus LLC, USA*. Specially formulated Gradient-Index polymeric optical materials offer capabilities not possible in present GRIN optics. A novel technology that enables large scale processing of nanolayered polymer films into real, performance-enhancing lenses for military Night-Vision-Goggle eyepieces is discussed.

AM3K.8 • 15:15
Fabrication of dielectric Bragg reflectors composed of CaF_2 and ZnS for delicate lasing materials, Alex Palatnik[1], Merav Mualem[1], Gilbert D. Nessim[1], Yaakov Tischler[1]; [1]*Chemistry, Bar Ilan Univ., Israel*. We describe the fabrication and characterization of highly reflecting distributed Bragg reflectors (DBR) composed of thermally evaporated thin films of CaF_2 and ZnS without substrate heating. Proposed technique enables DBR deposition on delicate lasing materials.

CLEO: Science & Innovations

SM3L • Novel Fiber Materials—Continued

SM3L.7 • 15:00
Thermo-optic Degradation of Single-Modedness in Active LMA fibers and Simple Compensation Mechanisms, V R Supradeepa[1], John M. Fini[2]; [1]*Indian Inst. of Science, India;* [2]*OFS Labs, USA*. We demonstrate significant thermo-optic degradation of single-modedness in active large mode area fibers due to heat generation in the fiber. We propose and demonstrate through simulations, simple compensation mechanisms using custom length dependent fiber coiling.

SM3L.8 • 15:15
Influence of Al/Ge ratio on radiation-induced attenuation in nanostructured erbium-doped fibers preforms, Monica Leon-Pichel[1], Matthieu Lancry[1], Nadège Ollier[2], Laurent Bigot[3], Hicham El Hamzaoui[3], Inna Savelii[3], Alain Pastouret[4], Ekaterina Burov[4], Bertrand Poumellec[1], Mohamed Bouazaoui[3]; [1]*Universite de Paris Sud, France;* [2]*IRAMIS/DSM/CNRS/Ecole Polytechnique, France;* [3]*PhLAM/IRCICA, France;* [4]*Draka Comteq France, France*. We studied the radiation resistance of Er^{3+}-doped fiber preforms manufactured with different technologies: Si and Al nanoparticles and sol-gel fibers. They have been irradiated with gamma rays and then studied using absorption and EPR spectroscopies.

Monday, 11 May

15:30–16:00 Coffee Break, *Concourse Level*

16:00–18:00 JM4A • Plenary Session I, *Grand Ballroom*

18:30-19:30 OSA Technical Group Poster Sessions, *Technical Session Corridor near 210 A-D*
* Nanophotonics Technical Group
* Optoelectronics Technical Group
* Optical Fabrication and Testing Technical Group

18:30-19:30 Optical Material Studies Technical Group Networking Event, *Meeting Room 211 B/D*

18:30–20:30 OSA Student Member Happy Hour (RSVP Required)

CLEO: Science & Innovations

SM3M • High Energy, High Power Systems & Enabling Technology—Continued

SM3M.4 • 15:00
Recent Advances on the J-KAREN laser upgrad, Hiromitsu Kiriyama[1], Michiaki Mori[1], Alexander Pirozhkov[1], Koichi Ogura[1], Mamiko Nishiuchi[1], Masaki Kando[1], Hironao Sakaki[1], Akira Kon[1], Masato Kanasaki[1], Hirotaka Tanaka[3], Yuji Fukuda[1], James Koga[1], Akito Sagisaka[1], Timur Esirkepov[1], Yukio Hayashi[1], Hideyuki Kotaki[1], Sergei Bulanov[1], Kiminori Kondo[1], Paul Bolton[1], Yuji Mashiba[2], Makoto Asakawa[2], Ondrej Slezak[4], Magda Sawicka-Chyla[4], Venkatesan Jambunathan[4], Antonio Lucianetti[4], Tomas Mocek[4]; [1]*Japan Atomic Energy Agency, Japan;* [2]*Faculty of Science and Engineering, Kansai Univ., Japan;* [3]*Interdisciplinary Graduate School of Engineering Sciences, Kyushu Univ., Japan;* [4]*HiLASE, Czech Republic.* We report recent progress on the J-KAREN laser upgrade to realize 10^{22} W/cm^2 intensity at 0.1 Hz. Our current high-spatiotemporal-quality broadband pulses of over 20 J will be further amplified in the final amplifier.

SM3M.5 • 15:15
Apparatus and Techniques for Measuring Laser Damage Resistance of Large-Area, Multilayer Dielectric Mirrors for Use with High Energy, Picosecond Lasers, Raluca A. Negres[1], Isaac Bass[1], Ken A. Stanion[1], Gabe Guss[1], David A. Cross[1], David A. Alessi[1], Chris Stolz[1], Christopher W. Carr[1]; [1]*Lawrence Livermore National Lab, USA.* We present techniques for measuring the damage performance of a variety of optical components with ps laser pulses, introduce a novel beam diagnostic technique, and explore the sensitivity of damage resistance to laser spot size for the case of high-reflectivity, multilayer dielectric (MLD) mirrors.

SM3N • Ultrafast High-field Phenomena and Laser Filamentation—Continued

SM3O • Nano and Micro-Optical Sensors—Continued

SM3O.6 • 15:00
Frequency locked cascaded micro ring resonators enabling real time and highly precise long and short time sensing, Liron Stern[1], Gal Keinan[1], Alex Naiman[1], Noa Mazurski[1], Uriel Levy[1]; [1]*Applied Physics, Hebrew Univ. of Jerusalem, Israel.* We demonstrate an ultrasensitive differential sensing apparatus, based on a frequency locked cascaded microresonator scheme. By measuring the lasers beat frequency a highly sensitive sensor both in short (seconds) and long (hours) times is demonstrated.

SM3O.7 • 15:15
Whispering gallery mode-based magnetometer, Trung D. Vo[1], Eric Magi[2], Benjamin J. Eggleton[2], Brian Ferguson[1]; [1]*Dept. of Defence, Defence Science & Technology Organisation, Australia;* [2]*CUDOS, the Univ. of Sydney, Australia.* We demonstrate a compact all-optical magnetic sensor based on whispering gallery modes in a photonic crystal fiber infiltrated with ferrofluid. We achieve a sensitivity of ~0.18 pm/μT and a resolution of ~222 nT.

SM3P • Mode Locked Lasers—Continued

SM3P.7 • 15:00
Broadband, Low Noise Modelocked Semiconductor Laser with Intracavity Programmable Dispersion Control, Anthony Klee[1], Kristina Bagnell[1], Peter J. Delfyett[1]; [1]*Univ. of Central Florida, CREOL, USA.* An intracavity pulseshaper is used to broaden the spectrum of a 10 GHz semiconductor frequency comb to greater than 28 nm. Timing jitter is measured to be 15.4 fs integrated from 1 kHz to 100 MHz offset.

SM3P.8 • 15:15
All-optical Q-switching limiter for a 5-GHz SESAM-modelocked laser with record-high peak power, Alexander Klenner[1], Ursula Keller[1]; [1]*Eidgenossische Tech Hochschule Zurich, Switzerland.* We use a Kerr-lens induced all-optical limiter to reduce Q-switching instabilities in a high-power diode-pumped 5GHz SESAM-modelocked Yb:CALGO laser. This supports cw modelocking with 4.1W average output power and 96fs pulses, leading 7.5kW peak power.

15:30–16:00 Coffee Break, *Concourse Level*

16:00–18:00 JM4A • Plenary Session I, *Grand Ballroom*

18:30-19:30 OSA Technical Group Poster Sessions, *Technical Session Corridor near 210 A-D*
* Nanophotonics Technical Group
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18:30-19:30 Optical Material Studies Technical Group Networking Event, *Meeting Room 211 B/D*

18:30–20:30 OSA Student Member Happy Hour (RSVP Required)

CLEO: QELS-Fundamental Science

JOINT

08:00–10:00
FTu1A • Quantum Entanglement I
Presider: James Dailey; Applied Communication Sciences, USA

FTu1A.1 • 08:00
Generation of Hybrid Entanglement of Light Between Wave-like and Particle-like Qubits, Hanna LE JEANNIC[1], Olivier Morin[1], Kun Huang[1,2], Jianli Liu[1], Claude Fabre[1], Josselin Ruaudel[1], Youn-Chang Jeong[1], Julien Laurat[1]; *[1]Laboratoire Kastler Brossel, UPMC-Sorbonne Universites, CNRS, ENS-PSL Research Univ., College de France, France; [2]State Key Lab of Precision Spectroscopy, East China Normal Univ., China.* The wave-particle duality of light has led to two different encodings for optical quantum information processing. We report here the remote generation of entanglement between particle-like discrete-variable qubits and wave-like continuous-variable qubits.

FTu1A.2 • 08:15
Witness of Macroscopic Entanglement in Classical Statistical Optical Fields, Xiao-Feng Qian[1], bethany little[1], John Howell[1], Joseph H. Eberly[1]; *[1]Univ. of Rochester, USA.* We examine correlations between polarization and amplitude degrees of freedom for classical statistical optical fields with Bell-analysis experiments. Strong violations of the Clauser-Horne-Shimony-Holt inequality are observed. These constitute a new witness of classical macroscopic entanglement.

FTu1A.3 • 08:30
Generation of multipartite spin entanglement from multimode squeezed states, Niranjan Sridhar[1], Olivier Pfister[1]; *[1]Univ. of Virginia, USA.* We investigate the use of the Schwinger representation for casting multimode squeezed states into multipartite spin entangled states. While the generalization is not straightforward, we can still find highly entangled multipartite states.

08:00–09:45
FTu1B • Ultrafast Dynamics in Strongly Correlated Materials
Presider: Robert Kaindl; Lawrence Berkeley National Lab, USA

FTu1B.1 • 08:00
Mott behavior in $K_xFe_{2-y}Se_2$ superconductors revealed by pump-probe spectroscopy, Chunfeng Zhang[1], Wei Li[1], Min Xiao[2]; *[1]Nanjing Univ., China; [2]Dept. of Physics, Univ. of Arkansas, USA.* Pump-probe spectroscopic data on $K_xFe_{2-y}Se_2$ superconductors exhibit signatures of orbital-selective Mott transition with a significant enhancement of a slow decay component alongside a decrease in oscillatory coherent-phonon signals upon raising temperature to 160 K.

FTu1B.2 • 08:15
Critical Speeding-Up of Non-Equilibrium Electronic Relaxation Near Ising-Nematic Transition in Unstrained $Ba(Fe_{1-x}Co_x)_2As_2$, Aaron Patz[1,2], Tianqi Li[1,2], Sheng Ran[1,2], Sergey Bud'ko[1,2], Paul Canfield[1,2], Jigang Wang[1,2]; *[1]Physics, Iowa State Univ., USA; [2]Ames Lab -USDOE, USA.* We observe a critical speeding up in the electronic relaxation time that implies that nematic fluctuations govern the electronic thermalization/cooling dynamics and that magnetic fluctuations dominate the nonlinear signals that arise from the Ising-nematicity.

FTu1B.3 • 08:30
Ultrafast dissection of excitonic and structural orders in a persisting charge density wave, Michael Porer[1], Ursula Leierseder[1], Jean-Michel Ménard[1], Hatem Dachraoui[2], Leonidas Mouchliadis[3], Ilias E. Perakis[3], Ulrich Heinzmann[2], Jure Demsar[4], Kai Rossnagel[5], Rupert Huber[1]; *[1]Dept. of Physics, Univ. of Regensburg, Germany; [2]Molecular and Surface Physics, Univ. of Bielefeld, Germany; [3]Dept. of Physics, Univ. of Crete & FORTH/IESL, Greece; [4]Inst. of Physics, Ilmenau Univ. of Technology, Germany; [5]Inst. of Experimental and Applied Physics, Univ. of Kiel, Germany.* We monitor the terahertz fingerprints of electronic and structural orders of the charge density wave in 1*T*-$TiSe_2$ on the femtosecond scale. NIR photoexcitation selectively melts electronic ordering while the structural distortion persists in a coherently excited state.

08:00–10:00
FTu1C • Optics of Metasurfaces
Presider: Viktor Podolskiy; Univ. of Massachusetts Lowell, USA

FTu1C.1 • 08:00
Ohmic Loss Produces Chiral Dichroism in Plasmonic Metasurfaces: First Experimental Demonstration, Gennady Shvets[1], Nihal Arju[1], Mikhail A. Belkin[1], Rainer Hillenbrand[2], Feng Lu[1], Martin Schnell[2], Jongwon Lee[1], Alexander B. Khanikaev[3]; *[1]Univ. of Texas at Austin, USA; [2]CIC nanoGUNE Consolider, Spain; [3]Physics, Queens College, USA.* A combination of experimental techniques is used to demonstrate that optical field concentration and Ohmic losses in planar chiral plasmonic metasurfaces depends on the handedness of circularly polarized light. Chiral dischroism in transmission is demonstrated.

FTu1C.2 • 08:15
Liquid Crystal Tuning of All-dielectric Metasurfaces, Juergen Sautter[1], Isabelle Staude[1], Manuel Decker[1], Evgenia Rusak[1], Igal Brener[2], Dragomir N. Neshev[1], Yuri S. Kivshar[1]; *[1]Australian National Univ., Australia; [2]Sandia Natial Labs, USA.* We experimentally realize active tuning of electric and magnetic resonances of all-dielectric optical metasurfaces based on the temperature-dependent refractive-index change of liquid crystals. We achieve 40nm spectral tuning and modulation contrast of 500%.

FTu1C.3 • 08:30
Dynamic Beam Steering in Micro-fluidic-meta-surface, Libin Yan[1], Pin Chieh Wu[1], Qinghua Song[1], Weimiing Zhu[1], Zhang Wu[1], Din Ping Tsai[2], Federico Capasso[3], Ai-Qun LIU[1]; *[1]School of Electrical and Electronic Engineering, Nanyang Technological Univ., Singapore; [2]Dept. of Physics, National Taiwan Univ., Taiwan; [3]Harvard Univ., USA.* We present a widely tunable metasurface composed of microfluidic antennas with subwavelength thickness for dynamic beam steering. By controlling actively the length of supercell, the reflection can be tuned to arbitrary direction under normal illumination.

08:00–10:00
JTu1D • Symposium on Advanced Optical Microscopy for Brain Imaging I
Presider: Na Ji; Howard Hughes Medical Inst., USA

JTu1D.1 • 08:00 Invited
Multi-photon Microscopy to Image Neuronal and Vascular Function in the Mammalian Brain, David Kleinfeld[1]; *[1]Univ. of California, San Diego, USA.* I will review the application of two-photon laser scanning microscopy to problems in neuroscience as well as discuss current needs and challenges for the analysis of neuronal circuits and signaling in neocortical and other forebrain structures in mouse.

JTu1D.2 • 08:30 Invited
Reconstructing Nervous System Development and Function with Light-Sheet Microscopy, Philipp Keller[1]; *[1]Howard Hughes Medical Inst., USA.* I will present our integrated, imaging-based technology framework for reconstructing development and function of the early nervous system *in vivo*, which combines high-speed multi-view light-sheet microscopy with automated approaches to large-scale image analysis.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

08:00–10:00
FTu1E • 2D Materials for Nanoplasmonics and Nanophotonics
Presider: To be Determined

FTu1E.1 • 08:00 Invited
Nano-photonic Phenomena in van der Waals heterostructures, Dmitri N. Basov[1]; [1]*Univ. of California, San Diego, USA.* In van der Waals heterostructures assembled from atomically thin layers of graphene, hexagonal boron nitride and other related materials electronic, plasmonic and phonon polaritonic phenomena are all intertwined. We explored these effects via infrared nano-imaging.

FTu1E.2 • 08:30
Generation of Graphene Surface Plasmons and Their Applications in Beam Steering, Mohamed Farhat[1], Pai-Yen Chen[2], Sebastien Guenneau[3], Hakan Bagci[1]; [1]*King Abdullah Univ of Science & Tech, Saudi Arabia;* [2]*Wayne State Univ., USA;* [3]*Aix-Marseille Univ., France.* We propose a novel concept that uses mechanical and electronic properties of graphene to efficiently couple light to surface plasmon polaritons. A graphene-based infrared beam-former based on the concept of surface leaky-wave is also discussed.

08:00–10:00
STu1F • Optical Integration on Chip
Presider: Weidong Zhou; Univ. of Texas at Arlington, USA

STu1F.1 • 08:00
Multicast 4x20 Silicon Photonic MEMS Switches, Sangyoon Han[1], Tae Joon Seok[1], Chang Kyu Kim[1], Richard S. Muller[1], Ming C. Wu[1]; [1]*Univ. of California Berkeley, USA.* We report on monolithic 4x20 silicon photonic MEMS switches capable of multicast functions. The switch has small footprint (1.2x4.5mm^2), low optical insertion loss (<4.0dB), fast switching (9.6μs). 1x2 and 1x4 multicasts were successfully demonstrated.

STu1F.2 • 08:15
All-optical programmable integrated signal processor, Hongchen Yu[1], Minghua Chen[1], Hongwei Chen[1], Sigang Yang[1], Shizhong Xie[1]; [1]*Tsinghua Univ., China.* An all-optical programmable signal processor has been proposed and experimentally demonstrated. The record resolution is measured to be 145 MHz and the processing range can be enlarged by a channelized filter to > 100 GHz.

STu1F.3 • 08:30 Invited
Nonlinear Integrated Optoelectronics, Shayan Mookherjea[1]; [1]*Univ. of California, San Diego, USA.* Compared to traditional crystal-based nonlinear optical devices, photonic integrated circuits on a silicon platform may enable advanced and parallelized functionality in chip-scale energy-efficient nonlinear optics, such as combinations of mixers, filters and photodetectors.

08:00–10:00
STu1G • Cascade Lasers I
Presider: Sanjay Krishna; Univ. of New Mexico, USA

STu1G.1 • 08:00
Evaluating the temporal profile of quantum cascade laser frequency combs, David P. Burghoff[1], Yang Yang[1], Darren Hayton[2], J.R. Gao[2,3], John Reno[4], Qing Hu[1]; [1]*MIT, USA;* [2]*SRON, Netherlands;* [3]*TU Delft, Netherlands;* [4]*Sandia, USA.* The temporal profile of frequency combs based on quantum cascade lasers has been unclear for some time. We show how the SWIFTS technique directly measures such properties, obtaining combs' intensities and frequencies versus time.

STu1G.2 • 08:15
Injection Seeding and Modelocking of Metal-metal Terahertz Quantum Cascade Lasers, Feihu WANG[1], anthony Brewer[2,1], Joshua Freeman[1,3], Jean Maysonnave[1], Souad Moumdji[4], Raffaele Colombelli[4], Iman Kundu[3], Li Lianhe[3], Edmund Linfield[3], Giles Davies[3], Harvey Beere[2], David Ritchie[2], Sukhdeep Dhillon[1], Jérôme Tignon[1]; [1]*Laboratoire Pierre Aigrain, Ecole Normale Supérieure-PSL Research Univ., CNRS, Université Pierre et Marie Curie-Sorbonne Universités, Université Paris Diderot-Sorbonne Paris Cité, France;* [2]*Semiconductor Physics Group, Univ. of Cambridge, UK;* [3]*School of Electronic and Electrical Engineering Univ. of Leeds, UK;* [4]*Institut d'Electronique Fondamentale, Université Paris Sud, France.* Injection seeding of terahertz quantum-cascade-lasers with metal-metal waveguides is demonstrated at liquid nitrogen temperatures through injection of phase-locked terahertz pulses. Coherent detection and modelocking of the QCL are demonstrated with the generation of 11ps pulse.

STu1G.3 • 08:30
Investigation of Time-resolved Gain Dynamics in an Injection Seeded Terahertz Quantum Cascade Laser, Sergej Markmann[1], Hanond Nong[1], Shovon Pal[1], Negar Hekmat[1], Paul Dean[2], Reshma A. Mohandas[2], Li H. Lianhe[2], Edmund Linfield[2], Giles Davies[2], Andreas D. Wieck[1], Nathan Jukam[1]; [1]*Ruhr-Universitat Bochum, Germany;* [2]*Univ. of Leeds, UK.* The evolution of the gain of terahertz quantum cascade laser during injection seeding is probed as a function of time. Oscillations of the gain are commensurate with the variations of the field envelope.

08:00–10:00
STu1H • Terahertz Photonics
Presider: Marco Rahm; Technische Universität Kaiserslautern, Germany

STu1H.1 • 08:00
Investigation of Extraordinary Optical Transmission Inside a Terahertz Parallel-Plate Waveguide, Kimberly S. Reichel[1], Peter Y. Lu[2], Rajind Mendis[1], Daniel Mittleman[1]; [1]*Dept. of Electrical and Computer Engineering, Rice Univ., USA;* [2]*Dept. of Physics, Harvard Univ., USA.* We study extraordinary optical transmission by placing a metal screen with a 1-D array of holes inside a parallel-plate waveguide at terahertz frequencies. We find excitation with TE_1 or TEM mode strongly affects output transmission characteristics.

STu1H.2 • 08:15
Dynamic light-induced THz resonators in a waveguide, Lauren Gingras[1], Marcel Georgin[1], David G. Cooke[1]; [1]*McGill Univ., Canada.* We demonstrate all-optical photoinjection of a one-dimensional resonator inside a terahertz parallel-plate waveguide. The pulsed pump enables us to study dynamic effects where the structure is written on timescales faster than the terahertz transit time.

STu1H.3 • 08:30
THz Artificial Dielectric Lens, Rajind Mendis[1], Masaya Nagai[2], Yiqiu Wang[1], Nicholas Karl[1], Daniel Mittleman[1]; [1]*Rice Univ., USA;* [2]*Osaka Univ., Japan.* We demonstrate a THz lens designed using an artificial-dielectric medium fabricated from a stack of stainless-steel plates. The lens is capable of focusing a 20 mm diameter beam to a spot size of 4 mm.

CLEO: Science & Innovations

08:00–10:00
STu1I • Nonlinear Optics
Presider: Qiang Lin; Univ. of Rochester, USA

STu1I.1 • 08:00
Miniaturized Optical Frequency References in the Telecom Regime, Liron Stern[1], Eliran Talker[1], Noa Mazurski[1], Boris Desiatov[1], Marissa Shefer[2], Aharon Segal[2], Uriel Levy[1]; *[1]Applied Physics, Hebrew Univ. of Jerusalem, Israel; [2]Micro System and Smart Technologies, Rafael, Israel.* We present two platforms for miniaturized telecom optical frequency references, based on TPA in rubidium vapor. Record efficiency of light vapor interaction in a serpentine atomic cladding wave guide, and micro-machined mm-scale cells are demonstrated.

STu1I.2 • 08:15
Non-reciprocal light storage in a silica microsphere, Chunhua Dong[1], Zhen Shen[1], Changling Zou[1], Yanlei Zhang[1], Wei Fu[1], Guang-Can Guo[1]; *[1]Univ of Science and Technology of China, China.* We report an experimental study of Brillouin-scattering-induced transparency (BSIT) in a silica microsphere. Because of the phase-matching requirement, the non-reciprocal light storage based on the BSIT is observed in our experiment.

STu1I.3 • 08:30
Highly Efficient Four-Wave Mixing in an AlGaAs-On-Insulator (AlGaAsOI) Nanowaveguide, Minhao Pu[1], Luisa Ottaviano[1], Elizaveta Semenova[1], Kresten Yvind[1]; *[1]Danmarks Tekniske Universitet, Denmark.* We propose an AlGaAs-on-insulator platform for nonlinear integrated photonics. We demonstrate highly efficient four-wave mixing in a 3-mm long AlGaAs-on-insulator nanowaveguide. A conversion efficiency of -21.1 dB is obtained with only a 45-mW pump.

CLEO: Applications & Technology

08:00–10:00
ATu1J • Applications for Energy and Environment
Presider: David Bomse; Mesa Photonics, USA

ATu1J.1 • 08:00
A Bistatic, Open-Path, Quantum Cascade Laser Array-Based Sensor for Methane and Nitrous Oxide Measurements, Anna P. Michel[3], Jason Kapit[3], Mark F. Witinski[1,2], Romain Blanchard[2], Aysun Gokoglu[2]; *[1]School of Engineering and Applied Sciences, Harvard Univ., USA; [2]Eos Photonics, USA; [3]Applied Ocean Physics and Engineering, Woods Hole Oceanographic Institution, USA.* A next-generation bistatic, open-path sensor is currently in development that utilizes a Quantum Cascade cascade Laser laser array for the source in order to achieve methane and nitrous oxide detection over path lengths exceeding 100 m.

ATu1J.2 • 08:15
UAV-based laser spectrometer to quantify methane from agricultural and petrochemical activities, Lei Tao[1], Da Pan[1], Levi Golston[1], Kang Sun[1], Suman Saripalli[2], Mark A. Zondlo[1]; *[1]Dept. of Civil and Environmental Engineering, Princeton Univ., USA; [2]KalScott Engineering, USA.* A lightweight (1.8 kg) UAV-based methane sensor using a 3.27 mm GaSb DFB laser has been developed. Small UAVs can quantify very localized methane emissions but severely constrain sensor mass/volume while still requiring high-sensitivity detection.

ATu1J.3 • 08:30
Modeling the dependence of fork geometry on the performance of quartz enhanced photoacoustic spectroscopic sensors, Samara Firebaugh[1], Angelo Sampaolo[2], Pietro Patimisco[2], Vincenzo Spagnolo[2], Frank K. Tittel[3]; *[1]Electrical and Computer Engineering, USA Naval Academy, USA; [2]Dipartimento Interateneo di Fisica, Universita e Politecnico di Bari, Italy; [3]Dept. of Electrical and Computer Engineering, Rice Univ., USA.* A finite element model for Quartz Enhanced Photoacoustic Spectroscopy (QEPAS) was developed and applied to study the dependence of performance on sensor dimensions. This model can be a design tool for optimizing tuning fork dimensions.

CLEO: Science & Innovations

08:00–10:00
STu1K • Integrated Optofluidics: Sensing, Guiding and Tailored Fabrication
Presider: Timo Mappes; Carl Zeiss AG, Germany

STu1K.1 • 08:00
Field-portable optofluidic plasmonic biosensor for wide-field and label-free monitoring of molecular interactions, Ahmet F. Coskun[1,5], Arif Cetin[2,3], Betty Galarreta[2,4], Daniel A. Alvarez[2], Hatice Altug[3,2], Aydogan Ozcan[5,6]; *[1]Division of Chemistry and Chemical Engineering, California Inst. of Technology, USA; [2]Dept. of Electrical and Computer Engineering, Boston Univ., USA; [3]Bioengineering Dept., EPFL, Switzerland; [4]Departamento de Ciencias-Quimica, Pontificia Universidad Catolica del Peru, Peru; [5]Dept.s of Electrical Engineering and Bioengineering, UCLA, USA; [6]California NanoSystems Inst., UCLA, USA.* We demonstrate a field-portable optofluidic plasmonic sensing device, weighing 40 g and 7.5 cm in height, which merges plasmonic microarrays with dual-wavelength lensfree on-chip imaging for real-time monitoring of protein binding kinetics.

STu1K.2 • 08:15
Spectrally Reconfigurable Multi-Spot Trap on Optofluidic ARROW Chip, Kaelyn D. Leake[2], Michael Olson[1], Damla Ozcelik[2], Aaron Hawkins[1], Holger Schmidt[2]; *[1]Electrical and Computer Engineering, Brigham Young Univ., USA; [2]School of Engineering, Univ. of California, Santa Cruz, USA.* We demonstrate an on-chip spectrally reconfigurable multi-spot trap using an integrated multimode interference waveguide. This device is able to trap multiple particles simultaneously as well as transport particles along a channel in controlled manner.

STu1K.3 • 08:30
Physical insight into optical coupling between photoreceptor cell nuclei, Hoang T. Xuan[1]; *[1]Singapore-MIT Alliance, Singapore.* We study optical coupling and light transport among photoreceptor cell nuclei of mammals' retina. This study also sheds light on light focusing and transport phenomena along microsphere-chain waveguides. The resonance's role is discussed in details.

08:00–10:00
STu1L • Symposium on Breaking Limits with Unconventional Optical Fields I
Presider: Qiwen Zhan; Univ. of Dayton, USA

STu1L.1 • 08:00 Invited
Tailoring Light at the Source: Structured Light from Laser Resonators, Andrew Forbes[1,2]; *[1]CSIR National Laser Centre, South Africa; [2]Physics, Univ. of the Witwatersrand, South Africa.* We outline various approaches to creating structured light directly from a laser cavity. By exploiting intra-cavity dynamic and geometric phase control, as well as complex amplitude modulation, custom modes may be generated on-demand.

STu1L.2 • 08:30
High-Topological Charge Vortex Tweezers with Continuous Control of Orbital Angular Momentum by Ultrafast Laser Machining, Rokas Drevinskas[1], Mindaugas Gecevičius[1], Martynas Beresna[1], Peter Kazansky[1]; *[1]Univ. of Southampton, UK.* We demonstrate a single beam generated optical vortices of topological charge up to 100 with tunable orbital angular momentum. The continuous control of torque without altering the intensity distribution was implemented in optical trapping.

CLEO: Applications & Technology

CLEO: Science & Innovations

08:00–10:00
ATu1M • Process Control and Metrology Applications
Presider: Jana Jágerská; UiT Norges Arktiske Universitet, Norway

ATu1M.1 • 08:00 Invited
Advanced optical distance measurements using femtosecond laser pulses, Seung-Woo Kim[1], Young-Jin Kim[1], Byung Jae Chun[1], Keun-woo Lee[1], Seongheum Han[1], Yoon-Soo Jang[1], HuynJay Kang[1]; [1]*Korea Advanced Inst of Science & Tech, Korea.* Femtosecond lasers began to draw attention as a new light source for high-precision absolute distance measurements (ADMs) allowing for advanced principles such as synthetic wavelength generation, Fourier-transform-based dispersive analysis and multi-wavelength interferometry. In this talk, we present the state-of-the-art measurement principles and performance demonstrated by exploiting the unique temporal and spectral characteristics of femtosecond laser pulses for ADM applications.

ATu1M.2 • 08:30
High speed two-dimensional temporal compressive sampling microscopic camera, Qiang Guo[1], Hongwei Chen[1], Minghua Chen[1], Zhiliang Weng[1], Yunhua Liang[1], Fangjian Xing[1], Shizhong Xie[1]; [1]*Tsinghua Univ., China.* A two-dimensional temporal compressive sampling microscopic camera with a frame rate of 500 kHz is demonstrated in this paper, achieving higher frame rate and lower sampling bandwidth than the conventional compressive sampling cameras.

08:00–10:00
STu1N • Fiber Components & Devices
Presider: Juliet Gopinath; Univ. of Colorado at Boulder, USA

STu1N.1 • 08:00
Splicing Tapered Inhibited-coupling Hypocycloid-core Kagome Fiber to SMF Fibers, Zheng Ximeng[1], Benoît Debord[1], Meshaal Alharbi[1], Luca Vincetti[2], Frédéric Gérôme[1], Fetah Benabid[1]; [1]*Xlim Research Inst., UMR CNRS 7252, Univ. of Limoges, France, France;* [2]*Dept. of Engineering, Univ. of Modena and Reggio Emilia, Italy.* We report on tapered inhibited coupling Kagome-fiber with a down-ratio as large as 2.4 while maintaining the hypocycloid-core shape. The insertion-loss of SMF spliced to tapered Kagomefiber was measured with minimum of 0.48dB at 1550nm.

STu1N.2 • 08:15
High Power Effects in Long Period Optical Fiber Gratings, Tristan Kremp[1], Jeffrey W. Nicholson[1], John M. Fini[2], Paul S. Westbrook[1]; [1]*OFS Fitel LLC, USA;* [2]*JDS Uniphase, USA.* We investigate nonlinear effects in long period gratings in a large mode area fiber. Simulations indicate that self-focusing effects can be significant at the power levels where self and cross phase modulation impair the mode conversion.

STu1N.3 • 08:30
High Power WDM with Narrow Wavelength Separations, Bhabana Pati[1], wenyen Tian[1], Amy Van Newkirk[2], Axel Schulzgen[2]; [1]*Q-Peak, Inc., USA;* [2]*College of optics and photonics, CREOL, USA.* We designed and manufactured a high power WDM to enable a high power Raman lasers. We used a custom designed glass processing machine to fuse the WDM. We tested the WDM at 100 W of power with 0.05 dB loss.

08:00–10:00
STu1O • Advanced Ultrafast Sources
Presider: Hiromitsu Kiriyama; Japan Atomic Energy Agency, Japan

STu1O.1 • 08:00 Invited
Laser Technologies and Challenges for XFEL Beamlines, Alan Fry[1,2]; [1]*SLAC National Accelerator Lab, USA;* [2]*PULSE Inst., Stanford Univ., USA.* X-ray FEL facilities place challenging demands on the stability and configuration of ultrafast optical lasers for user experiments; future facilities will push the frontiers for high peak and average power ultrafast lasers.

STu1O.2 • 08:30
Sub-300 fs, 0.5 mJ Pulse at 1kHz from Ho:YLF Amplifier and Kagome Pulse Compression, krishna murari[1,2], Huseyin Cankaya[1,2], Benoît Debord[3], Peng Li[1], Giovanni Cirmi[1], Shaobo Fang[1], Giulio M. Rossi[1], Oliver D. Muecke[1], Peter Kroetz[2], Gregory J. Stein[4], Axel Ruehl[1], Ingmar Hartl[1], Frédéric Gérôme[3], Fetah Benabid[3], Franz Kaertner[1,4]; [1]*Deutsche Electron Synchrotron, Germany;* [2]*Centre For Free Electron Laser Science, Germany;* [3]*GPPMM Group, Xlim Research Inst., France;* [4]*MIT, USA.* We demonstrate a compact 290 fs, 0.5 mJ laser source at 2-mm wavelength generated from mJ-level 3.4-ps pulses from a fiber laser seeded Ho:YLF regenerative amplifier system via pulse compression in a gas-filled Kagome type HC-PCF.

CLEO: QELS-Fundamental Science

JOINT

FTu1A • Quantum Entanglement I—Continued

FTu1A.4 • 08:45
Measurement of Quantum Two-Mode Squeezing Inspired by Classical Radio-Frequency Analogy, Yaakov Shaked[1], Tzahi Geller[1], Avi Pe'er[1]; [1]*Bar-Ilan Univ., Israel.* From analogy to RF theory and applications, we devise general measurement schemes for two-mode squeezing using nonlinear optical mixing as the physical detector. We provide complete quantum and classical theory, with RF and optical demonstrations.

FTu1A.5 • 09:00
Varying the Entanglement of 1.55 μm Photon Pairs Generated by a Silicon Nanophotonic Chip, Ranjeet Kumar[1], Marc Savanier[1], Jun Rong Ong[1], Shayan Mookherjea[1]; [1]*Univ. of California San Diego, USA.* We characterize the strength of entanglement corresponding to different Joint Spectral Intensities of telecommunications-wavelength photon pairs generated using spontaneous four-wave mixing in a diode-pumped compact CMOS-compatible silicon chip.

FTu1A.6 • 09:15
Twin Photon Pairs in a High-Q Silicon Microresonator, Steven Rogers[1], Xiyuan Lu[1], Wei Jiang[2], Qiang Lin[3,2]; [1]*Dept. of Physics and Astronomy, Univ. of Rochester, USA;* [2]*Inst. of Optics, Univ. of Rochester, USA;* [3]*Dept. of Electrical and Computer Engineering, Univ. of Rochester, USA.* We report the generation of twin photon pairs in a high-Q silicon microdisk resonator. The device is able to produce pairs at a flux of 5.31 x 10^5 pairs/s within a bandwidth of 0.73 GHz, and a coincidence-to-accidental ratio as large as 155, the highest value reported to date for twin photon pairs.

FTu1B • Ultrafast Dynamics in Strongly Correlated Materials—Continued

FTu1B.4 • 08:45
Probing Short- and Long-range Stripe Correlations in a Nickelate via Multi-THz Spectroscopy, Giacomo Coslovich[1], Wei-Sheng Lee[3], Hans Bechtel[2], Michael M. Martin[2], Takao Sasagawa[4], Zhi-Xun Shen[3], Robert A. Kaindl[1]; [1]*Materials Sciences Division, Lawrence Berkeley National Lab, USA;* [2]*Advanced Light Source, Lawrence Berkeley National Lab, USA;* [3]*SIMES, SLAC National Accelerator Lab and Stanford Univ., USA;* [4]*Materials and Structures Lab, Tokyo Inst. of Technology, Japan.* We report opticalpump THzprobe reflectivity studies around the resonance frequency (≈11 THz) of the in-plane bending mode of a stripe-ordered nickelate. The experiments reveal signatures of both short and long-range nanoscale charge order dynamics.

FTu1B.5 • 09:00
Ultrafast Dynamics of Multiferroic *h*-$LuFeO_3$, John Bowlan[1], Xiaoshan Xu[2], Kishan Sinha[2], Stuart Trugman[1], Antoinette J. Taylor[1], Rohit P. Prasankumar[1], Dmitry Yarotski[1]; [1]*Los Alamos National Lab, USA;* [2]*Physics and Astronomy, Univ. of Nebraska, Lincoln, USA.* Hexagonal $LuFeO_3$ is a multiferroic showing ferroelectricity and antiferromagnetism at room temperature. Below T_R=130 K, it becomes ferrimagnetic. Ultrafast optical pump-probe measurements reveal that the dynamics are correlated with the structural changes responsible for ferrimagnetism.

FTu1B.6 • 09:15
Transient Exchange Interaction in a Helical Antiferromagnet, Matt Langner[1], Sujoy Roy[1], A. F. Kemper[1], Y.-D. Chuang[1], S. Mishra[1], R. B. Versteeg[1], Yi Zhu[1], M. P. Hertlein[1], T. E. Glover[1], K. Dumesnil[2], R. W. Schoenlein[1]; [1]*Lawrence Berkeley National Lab, USA;* [2]*Institut Jean Lamour, France.* We measure dynamics of the helical ordering in the Lanthanide metal Dy resulting from transient changes in the conduction electron Fermi surface and subsequent scattering events that transfer the excitation to the core spin.

FTu1C • Optics of Metasurfaces—Continued

FTu1C.4 • 08:45
Diffraction Interface Theory: A nonlocal approach to metasurfaces, Christopher Roberts[1], Sandeep Inampudi[1], Viktor A. Podolskiy[1]; [1]*Univ. of Massachusetts Lowell, USA.* We present a novel formalism to describe diffractive optics of metasurfaces, diffractive interface theory (DIT).

FTu1C.5 • 09:00
Surface plasmon polariton control with Metasurfaces , Patrice Genevet[1], Daniel Wintz[2], Antonio Ambrosio[2], Alan She[2], Federico Capasso[1]; [1]*A*star, SIMTech, Singapore;* [2]*Harvard, USA.* Acting as subwavelength converters with controllable responses, metasurfaces can now engineer surface plasmon for applications in integrated optics and flat photonics. Plasmon focusing, wavelength demultiplexing, and generation and control of plasmons wakes will be discussed.

JTu1D • Symposium on Advanced Optical Microscopy for Brain Imaging I—Continued

JTu1D.3 • 09:00 Invited
Integrated Neurophotonics: Toward Massively-Parallel Mapping of Brain Activity, Michael L. Roukes[1]; [1]*California Inst. of Technology, USA.* I describe a new paradigm for functional imaging that surmounts limitations of free-space optics - based on integrated nanophotonics, to distribute an ultraminiaturized imager within the brain; and optogenetics, to transduce neural signals into the optical domain.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FTu1E • 2D Materials for Nanoplasmonics and Nanophotonics—Continued

FTu1E.3 • 08:45
Plasmon Resonance in Single- and Double-layer CVD Graphene Nanoribbons, Di Wang[1,2], Naresh K. Emani[1,2], Ting-Fung Chung[3], Ludmila Prokopeva[1,2], Alexander V. Kildishev[1,2], Vladimir M. Shalaev[1,2], Yong P. Chen[3,1], Alexandra Boltasseva[1,2]; *[1]Electrical & Computer Engineering, Purdue Univ., USA; [2]Birck Nanotechnology Center, USA; [3]Physics, Purdue Univ., USA.* Dynamic tunability of the plasmonic resonance in graphene nanoribbons is desirable in the near-infrared. We demonstrated a constant blue shift of plasmonic resonances in double-layer graphene nanoribbons with respect to single-layer graphene nanoribbons.

FTu1E.4 • 09:00
Nanoantenna-enhanced light-matter interaction in atomically thin WS2, Johannes Kern[1], Andreas Trügler[2], Iris Niehaus[1], Johannes Ewering[1], Robert Schmidt[1], Robert Schneider[1], Sina Najmaei[3], Antony George[3], Jing Zhang[3], Jun Lou[3], Ulrich Hohenester[2], Steffen Michaelis de Vasconcellos[1], Rudolf Bratschitsch[1]; *[1]Inst. of Physics and Center for Nanotechnology, Univ. of Münster, Germany; [2]Inst. of Physics, Univ. of Graz, Austria; [3]Dept. of Mechanical Engineering and Material Science, Rice Univ., USA.* We present a hybrid system consisting of an atomically-thin semiconductor and a plasmonic nanoantenna. The intense optical near-fields provided by the antenna increase the photoluminescence intensity of WS_2 by more than one order of magnitude.

FTu1E.5 • 09:15
Enhanced Spontaneous Emission from an Optical Antenna Coupled WSe_2 Monolayer, Michael Eggleston[1], Sujay Desai[1], Kevin Messer[1], Surabhi Madhvapathy[1], Jun Xiao[1], Xiang Zhang[1], Eli Yablonovitch[1], Ali Javey[1], Ming C. Wu[1]; *[1]Univ. of California Berkeley, USA.* A self-aligned process is developed to couple monolayer WSe_2 (30nm x 300nm) to a silver cavity-backed slot-antenna. Optical emission measurements show 340x enhancement in spontaneous emission. Carrier lifetimes of <1ps are measured by streak camera.

STu1F • Optical Integration on Chip—Continued

STu1F.4 • 09:00
Unidirectional Coupling with Two Matched Dielectric and Metal Long-Period Gratings along a Polymer Waveguide, Kin S. Chiang[1], Bing Zou[1]; *[1]City Univ. of Hong Kong, Hong Kong.* We propose a grating structure for the achievement of unidirectional coupling, which consists of two matched dielectric and metal long-period gratings. We verify our idea theoretically and experimentally with gratings formed along a polymer waveguide.

STu1F.5 • 09:15
An Opto-Electro-Mechanical Phase Shifter, Marcel W. Pruessner[1], Doewon Park[1], Todd H. Stievater[1], Dmitry A. Kozak[2,1], William S. Rabinovich[1]; *[1]US Naval Research Lab, USA; [2]NRC Postdoc, USA.* We demonstrate an opto-electro-mechanical phase shifter. A suspended microbridge is electrostatically actuated to strongly-interact with a weakly-confined waveguide mode. The resulting effective index tuning substantially exceeds that achievable with thermo-optic and electro-optic approaches.

STu1G • Cascade Lasers I—Continued

STu1G.4 • 08:45
Scanning Voltage Microscopy Study of Lasing and Non-lasing Terahertz Quantum Cascade Lasers, Rudra Dhar[1], Ghasem Razavipour[1], Emmanuel Dupont[2], Zbig Wasilewski[1], Dayan Ban[1]; *[1]Univ. of Waterloo, Canada; [2]National Research Council, Canada.* Scanning voltage microscopy results clearly show that the formation of electric field domains is responsible for the missing of lasing operation in a resonant-phonon based terahertz quantum cascade laser with a highly diagonal transition.

STu1G.5 • 09:00
Two-Dimensional Pump Frequency Study of THz Generation in Mid-Infrared Quantum Cascade Lasers, Yifan Jiang[1], Karun Vijayraghavan[1], Frederic Demmerle[2], Gerhard Boehm[2], Markus-Christian Amann[2], Mikhail A. Belkin[1]; *[1]The Univ. of Texas at Austin, USA; [2]Technische Universität München, Germany.* The dependence of THz difference-frequency generation in mid-infrared quantum cascade lasers on the position of mid-infrared pump frequencies is investigated. Experiments are performed at room-temperature using dual-diffraction-grating modified Littrow-type external cavity setup.

STu1G.6 • 09:15
Laterally-Coupled Dual-Grating Distributed Feedback Lasers for Generating Mode-Beat Terahertz Signals, Lianping Hou[1], Mohsin Haji[2], Iain Eddie[3], Hongliang Zhu[4], John H. Marsh[1]; *[1]School of Engineering, Univ. of Glasgow, UK; [2]National Physical Lab, UK; [3]3CST Global Ltd, UK; [4]Inst. of Semiconductors, China.* We present a laterally-coupled AlGaInAs/InP DFB laser emitting two longitudinal modes simultaneously within the same cavity and integrated with EAM. A stable 0.82 THz beating signal was observed over a wide range of bias parameters.

STu1H • Terahertz Photonics—Continued

STu1H.4 • 08:45
Efficient Terahertz Phase Modulation Using Vanadium Dioxide Meta-Surfaces, Mohammed Reza Hashemi[1], Shang-Hua Yang[1,2], Tongyu Wang[3], Nelson Sepúlveda[3], Mona Jarrahi[1,2]; *[1]Univ. of California, Los Angeles, USA; [2]Univ. of Michigan, USA; [3]Michigan State Univ., USA.* Voltage-controlled THz phase modulation using vanadium dioxide reconfigurable meta-surfaces is presented and a proof-of-concept phase modulator for sub-THz frequencies is fabricated. We demonstrate the highest reported phase modulation of 600 at 85 GHz through a fully-integrated device platform.

STu1H.5 • 09:00
Ultrathin Flexible and Optically Tunable Terahertz Bandpass Filter with Embedded Silicon, Michael A. Hoeh[1], Jens Neu[1], Klemens M. Schmitt[1], Marco Rahm[1]; *[1]Technische Universität Kaiserslautern, Germany.* A new fabrication technique for ultra-thin, flexible and optically tunable metamaterials with embedded silicon is presented. We demonstrated a 25-µm-thick optically tunable terahertz bandpass filter with a maximal amplitude transmission of 80 % and an amplitude modulation depth of 94 % at 0.65 THz.

STu1H.6 • 09:15
Terahertz Surface Wave Modulation in a Dielectric Slab Metasurface, Nicholas Karl[1], Hou-Tong Chen[2], Antoinette J. Taylor[2], Igal Brener[3], Alexander Benz[3], John Reno[3], Rajind Mendis[1], Daniel Mittleman[1]; *[1]Dept. of Electrical and Computer Engineering, Rice Univ., USA; [2]Center for Integrated Nanotechnologies, Los Alamos National Lab, USA; [3]Center for Integrated Nanotechnologies, Sandia National Labs, USA.* We experimentally and numerically investigate a switchable dielectric-slab-waveguide metasurface device. We use an active metasurface to manipulate the interaction with a propagating THz surface wave, giving us dynamic control of the wave at 0.3 THz.

CLEO: Science & Innovations

STu1I • Nonlinear Optics—Continued

STu1I.4 • 08:45
Low-power on-chip all-optical Kerr switch with silica microcavity, Wataru Yoshiki[1], Takasumi Tanabe[1]; [1]*Keio Univ., Japan.* We achieved on-chip optical Kerr switching with an input power of 2 mW using a silica toroid microcavity. This is the lowest power for any demonstrated on-chip optical Kerr switch.

STu1I.5 • 09:00
Broadband low-phase-noise 18 GHz Kerr frequency microcomb, Shu-Wei Huang[1], Jinghui Yang[1], Heng Zhou[2], Mingbin Yu[3], Dim-Lee Kwong[3], Chee Wei Wong[1]; [1]*UCLA, USA;* [2]*Univ. of Electronic Science and Technology of China, China;* [3]*Inst. of Microelectronics, Singapore.* We report a half-octave-spanning Kerr frequency comb which has the record-low phase noise floor with -130 dBc/Hz at 1 MHz offset for 18 GHz carrier frequency, and long-term Allan deviation of $7'10^{-11}/\tau^{0.84}$ with active stabilization.

STu1I.6 • 09:15
High-Q Silicon Nitride Microresonator for Low Power Frequency Comb Initiation at Normal Dispersion Regime, Yi Xuan[1], Yang Liu[1], Xiaoxiao Xue[1], Pei-Hsun Wang[1], Jian Wang[1], Ben Niu[1], Kyunghun Han[1], Min TENG[1], Daniel E. Leaird[1], Andrew M. Weiner[1], Minghao Qi[1]; [1]*Purdue Univ., USA.* SiN microresonators with a cross section of 3×0.6 μm² and an FSR of 25 GHz were demonstrated with intrinsic Qs up to 17 million, showing frequency comb onset power as low as 5.6 mW.

ATu1J • Applications for Energy and Environment—Continued

ATu1J.4 • 08:45
Ultralow-Noise Infrared Spectroscopy at Single-Photon Level Based on Frequency Upconversion System, Wenjie Wu[1], Ruikai Tang[1], Xiongjie Li[1], Haifeng Pan[1], E Wu[1], Heping Zeng[1]; [1]*East China Normal Univ., China.* We realized an efficient infrared spectrometer with high detection sensitivity at single photon level by using the wavelength tunable frequency upconversion detection technique with synchronized laser source. This kind of spectrometers also can be used in remote spectrum analysis.

ATu1J.5 • 09:00
Thermal Emission of GaAs Nanowire Solar Cells, Shao-Hua Wu[1], Michelle Povinelli[1]; [1]*Electrical Engineering, Univ. of Southern California, USA.* Despite concentrated light absorption and low thermal conductivities, GaAs nanowire solar cells can still have larger thermal emission cooling power than planar ones, resulting in a nearly 10 K lowering in operating temperature.

ATu1J.6 • 09:15
Temperature-dependent Characterization of $G_{0.94}Sn_{0.06}$ Light-Emitting Diode Grown on Si via CVD, Seyed Amir Ghetmiri[2], Wei Du[1], Yiyin Zhou[1], Joe Margetis[3], Thach Pham[2], Aboozar Mosleh[1], Benjamin Conley[1], Amjad Nazzal[4], Gregory Sun[5], Richard Soref[5], John Tolle[3], Hameed Naseem[2], Baohua Li[6], Shui-Qing Yu[2]; [1]*Univ. of Arkansas, USA;* [2]*Electrical engineering, Univ. of Arkansas, USA;* [3]*ASM, USA;* [4]*Electrical Engineering and Physics, Wilkes Univ., USA;* [5]*Dept. of Engineering, Univ. of Massachusetts Boston, USA;* [6]*Arktonic LLC, USA.* Temperature-dependent electroluminescence from a double heterostructure n-Ge/i-$Ge_{0.94}Sn_{0.06}$/p-Ge LED was studied. The peak position of EL spectra showed a blue-shift as the temperature decreased. A maximum emission power of 7 mW was obtained under the current density of 800 A/cm².

CLEO: Science & Innovations

STu1K • Integrated Optofluidics: Sensing, Guiding and Tailored Fabrication—Continued

STu1K.4 • 08:45
Optofluidic Polarization Beam Splitter, Yang Liu[1], Lei Shi[1], Xudong Fan[2], Xinliang Zhang[1]; [1]*Huazhong Univ of Science and Technology, China;* [2]*Biomedical Engineering, Univ. of Michigan, USA.* An efficient polarization beam splitter (PBS) based on a silica microcapillary is proposed and experimentally demonstrated. This PBS relies on the inherent-geometry-induced birefringence. A maximum extinction ratio of up to 25 dB is achieved.

STu1K.5 • 09:00
Optical Waveguides from a Lithographically-Defined Wetting of a High-Index Liquid, Christopher C. Evans[1], Emily Hsu[1], Michelle Ji[1], Chengyu Liu[1], Jin Suntivich[1]; [1]*Cornell Univ., USA.* We present a new approach to realize liquid-core optical waveguides via selective wetting on lithographically patterned oleophobic and oleophilic patches for sensing and adaptable optics applications.

STu1K.6 • 09:15
Density Assisted Optofluidic Fabrication of 3D Shaped Particles, Kevin Paulsen[1], Aram Chung[1]; [1]*RPI, USA.* We present a novel method of creating complex 3D particles by flow deformation and UV light polymerization. An infinite number of particle shapes can be obtained by manipulating flow and light conditions.

STu1L • Symposium on Breaking Limits with Unconventional Optical Fields I—Continued

STu1L.3 • 08:45
Optical Coherency Matrix Tomography of Unconventional Beams, Kumel Kagalwala[1], H. Esat Kondacki[1], Ayman F. Abouraddy[1], Bahaa E. Saleh[1]; [1]*Univ. of Central Florida, CREOL, USA.* We present the first experimental measurement of the coherency matrix **G** associated with an electromagnetic beam with two binary degrees of freedom. We consider beams with polarization and a spatially varying amplitude or phase: spatial parity modes and orbital angular momentum modes, respectively.

STu1L.4 • 09:00
Study of Turbulence Induced Orbital Angular Momentum Channel Crosstalk in a 1.6 km Free-Space Optical Link, Martin P. Lavery[1], Bettina Heim[2], Christian Peuntinger[2], Ebrahim Karimi[4], Omar S. Magaña-Loaiza[3], Thomas Bauer[2], Christoph Marquardt[2], alan willner[5], Robert W. Boyd[3,4], Miles Padgett[1], Gerd Leuchs[2]; [1]*Univ. of Glasgow, UK;* [2]*Max Planck Inst. for the Science of Light and Inst. of Optics, Information and Photonics,, Friedrich-Alexander-Universitat Erlangen-Nurnberg, Germany;* [3]*Inst. of Optics, Univ. of Rochester, USA;* [4]*Dept. of Physics, Univ. of Ottawa, Canada;* [5]*Electrical Engineering, Univ. of Southern California, USA.* We experimentally study the turbulence induced crosstalk between orbital angular momentum channels transmitted over a 1.6 km optical link. Our presented results indicate that turbulence mitigation techniques will be required for links of this length.

STu1L.5 • 09:15
Single-aperture STED illumination using a *q*-plate and fiber, Lu Yan[1], Ebrahim Karimi[2], Patrick Gregg[1], Robert W. Boyd[2,3], Siddharth Ramachandran[1]; [1]*Dept. of Electrical and Computer Engineering, Boston Univ., USA;* [2]*Dept. of Physics, Univ. of Ottawa, Canada;* [3]*Inst. of Optics, Univ. of Rochester, USA.* We demonstrate single-aperture STED nanoscopy illumination with vortex-fiber modes excited by a dispersive *q*=1/2 plate at visible wavelengths. The vortex-fiber-compatible bias-voltage-tunable mode conversion of *q*-plates enables easy switching between multiple STED-wavelength pairs.

CLEO: Applications & Technology

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ATu1M • Process Control and Metrology Applications—Continued

ATu1M.3 • 08:45
Design Challenges of a High Speed Tunable Laser Interrogator for Future Spacecraft Health Monitoring, Selwan K. Ibrahim[1], John O'Dowd[1], Raymond McCue[1], Arthur Honniball[1], Martin Farnan[1]; *[1]FAZ Technology Ltd., Ireland.* We report the performance results achieved for a high speed, high resolution optical FBG interrogator with a repeatability <5fm@80Hz BW and precision <200fm (p-p), designed for space applications on a launcher or atmospheric re-entry vehicle.

ATu1M.4 • 09:00
Safety Monitoring of Long Distance Power Transmission Cables and Oil Pipelines with OTDR Technology, Huijuan Wu[1], Ya Qian[1], Hanyu Li[1], Shunkun Xiao[1], Zhizhong Fu[1], Yunjiang Rao[1]; *[1]Univ of Electronic Sci & Tech of China, China.* This paper presents two typical applications of polarization- and phase-sensitive OTDRs, which are representative Distributed Optical Fiber Sensors (DOFSs), for on-line safety monitoring of long-distance power transmission cables and oil pipelines in the energy industry.

ATu1M.5 • 09:15
Curvature Sensor Based on Long-Period Grating in Dual Concentric Core Fiber, Zhifang Wu[1,2], Nan Zhang[1,2], Ping Shum[1,2], Xuguang Shao[1], Hailiang Zhang[1,2], Tianye Huang[1,2], Georges Humbert[3], Jean-Louis Auguste[3], Frédéric Gérôme[3], Jean-Marc Blondy[3], Quyen X. Dinh[2]; *[1]School of Electrical and Electronics Engineering, Nanyang Technological Univ., Singapore; [2]CNRS-International-NTU-Thales Research Alliance (CINTRA), Singapore; [3]XLIM Research Inst., UMR 7252 CNRS/Univ. of Limoges, France.* We report on a curvature sensor based on a long-period grating in a dual-concentric-core fiber. By measuring the relative shifting of two adjacent resonant dips, the curvature sensitivity reaches 7.635 nm/m^{-1}.

STu1N • Fiber Components & Devices—Continued

STu1N.4 • 08:45
Towards a Plasma-Core PCF for Tunable UV-DUV Radiation, Benoît Debord[1], Frédéric Gérôme[1], Damien Passerieux[1], Philippe Coche[2], Luis Lemos Alves[2], Fetah Benabid[1]; *[1]Xlim Research Inst., UMR CNRS 7252, Univ. of Limoges, France; [2]Instituto de Plasmas e Fusão Nuclear, Instituto Superior Técnico, Universidade de Lisboa, Portugal.* We report on recent results toward development of tunable and miniaturized UV-DUV radiation using microwave-driven plasma-core photonic crystal fiber. Gas-mixture optimized UV-DUV emission and highly efficient microwave ring resonators couplers are demonstrated.

STu1N.5 • 09:00
Hollow Core Silicon-Silica Bragg Fiber, Subhasis Chaudhuri[1], Justin Sparks[1], Rongrui He[1], John Badding[1]; *[1]Pennsylvania State Univ., USA.* A hollow core four layered Bragg fiber has been fabricated using silicon and silica as alternating layers via high-pressure chemical vapor deposition, which can be used for the guidance of near infrared light.

STu1N.6 • 09:15
Inspection of Defect-Induced Mode Coupling in Hollow-Core Photonic Bandgap Fibers Using Time-of-Flight, Nicholas H. Wong[1], Syed Reza Sandoghchi[1], Yongmin Jung[1], Tom Bradley[1], Natalie V. Wheeler[1], Naveen Baddela[1], John R. Hayes[1], Francesco Poletti[1], Marco Petrovich[1], Shaiful Alam[1], P Petropoulos[1], david Richardson[1]; *[1]Univ. of Southampton, UK.* We analyze defect-induced mode coupling in a hollow-core photonic bandgap fiber using time-of-flight, and show its utility in complementing optical time-domain reflectometry.

STu1O • Advanced Ultrafast Sources—Continued

STu1O.3 • 08:45
Ultrafast Diode-Pumped Ti:Sapphire Laser Generating 200-mW Average Power in 68-fs Pulses, Kutan Gurel[1], Martin Hoffmann[1], Clara J. Saraceno[1,2], Valentin J. Wittwer[1], Sargis Hakobyan[1], Bojan Resan[3], Andreas Rohrbacher[3], Kurt Weingarten[3], Stephane Schilt[1], Thomas Sudmeyer[1]; *[1]Laboratoire Temps-Fréquence, Université de Neuchâtel, Switzerland; [2]Inst. for Quantum Electronics, ETH Zurich, Switzerland; [3]JDSU Ultrafast Lasers AG, Switzerland.* We present the highest average power from a diode-pumped Ti:Sapphire laser. Using self-starting SESAM-modelocking we obtain 200 mW in 68-fs pulses at 378 MHz. The laser is pumped by two air-cooled 520 nm AlInGaN laser diodes.

STu1O.4 • 09:00
CPA-free ultrafast fiber laser source based on pre-chirp managed nonlinear amplification, Damian N. Schimpf[1,2], Wei Liu[1], Tino Eidam[3,4], Jens Limpert[3,4], Andreas Tünnermann[3,4], Franz Kaertner[1,2], Guoqing Chang[1,2]; *[1]Center for Free-Electron Laser Science, DESY, Germany; [2]The Hamburg Centre for Ultrafast Imaging, Germany; [3]Inst. of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Germany; [4]Helmholtz Institut Jena, Germany.* Pre-chirp managed nonlinear amplification delivering high quality 60 fs pulses is compared to conventionally employed CPA. We present a compact rod-type system that outputs >100 W at 75 MHz.

STu1O.5 • 09:15
Optimized SESAMs for Kilowatt Ultrafast Lasers, Andreas Diebold[1], Thomas Zengerle[1], Mario Mangold[1], Cinia Schriber[1], Florian Emaury[1], Martin Hoffmann[2], Clara J. Saraceno[1,2], Matthias Golling[1], David Follman[3], Garrett Cole[3,4], Markus Aspelmeyer[5], Thomas Sudmeyer[2], Ursula Keller[1]; *[1]Dept. of Physics, ETH Zurich, Switzerland; [2]Laboratoire Temps-Frequence, Universite de Neuchatel, Switzerland; [3]Crystaline Mirror Solutions LLC, USA; [4]Crystalline Mirror Solutions GmbH, Austria; [5]Vienna Center for Quantum Science and Technology, Austria.* We present SESAMs with different substrate-removal techniques, optimized for kWpower operation. These SESAMs show significant improvements in terms of surface quality without affecting their nonlinear parameters.

CLEO: QELS-Fundamental Science

JOINT

FTu1A • Quantum Entanglement I—Continued

FTu1A.7 • 09:30
Falsifying Local Realism, Lynden Shalm[1], Yanbao Zhang[1], Kevin Coakley[1], Scott Glancy[1], Sae Woo Nam[1], Emanuel Knill[1]; [1]*NIST, USA.* Standard methods of analyzing Bell's inequalities are fundamentally flawed when it comes to ruling out local realism. Here we present a powerful analysis technique that can falsify local realism in a certifiable manner.

FTu1A.8 • 09:45
Quantum Entanglement Distillation Using an Optical Metamaterial, Muriel Béchu[1], Motoki Asano[2], Mark Tame[3,4], Sahin K. Ozdemir[5], Rikizou Ikuta[2], Takashi Yamamoto[2], Durdu Guney[6], Lan Yang[5], Martin Wegener[1,7], Nobuyuki Imoto[2]; [1]*Inst. of Applied Physics, Karlsruhe Inst. of Technology, Germany;* [2]*Dept. of Material Engineering Science, Osaka Univ., Japan;* [3]*School of Chemistry and Physics, Univ. of KwaZulu Natal, South Africa;* [4]*National Inst. for Theoretical Physics, Univ. of KwaZulu Natal, South Africa;* [5]*Dept. of Electrical and Systems Engineering, Washington Univ., USA;* [6]*Dept. of Electrical and Computer Engineering, Michigan Technological Univ., USA;* [7]*Inst. of Nanotechnology, Karlsruhe Inst. of Technology, Germany.* We perform an entanglement distillation protocol on pure and mixed states using optical metamaterials composed of gold nano-antennas and measure the density matrices by quantum-state tomography. The fidelity is improved from 0.85 to 0.97.

FTu1B • Ultrafast Dynamics in Strongly Correlated Materials—Continued

FTu1B.7 • 09:30
Direct Observation of Magnon Dynamics in Multiferroic $HoMnO_3$, Pamela R. Bowlan[1], Dmitry Yarotski[1], Namjung Hur[2], Antoinette J. Taylor[1], Rohit P. Prasankumar[1]; [1]*Center for Integrated Nanotechnologies, Los Alamos National Lab, USA;* [2]*Dept. of Physics, Inha Univ., Korea (the Democratic People's Republic of).* We directly resolve energy transfer pathways from electrons to magnons in multiferroic $HoMnO_3$ using ultrafast optical/terahertz spectroscopy. This reveals that energy is initially transferred from electrons to phonons and subsequently to magnons through spin-lattice relaxation.

FTu1C • Optics of Metasurfaces—Continued

FTu1C.7 • 09:30
Plasmonic Metasurface for Color Hologram, Yao-Wei Huang[1], Wei Ting Chen[1], Wei-Yi Tsai[1], Pin Chieh Wu[1], Chih-Ming Wang[3], Gregory Sun[2], Din Ping Tsai[1,4]; [1]*Dept. of Physics, National Taiwan Univ., Taiwan;* [2]*Dept. of Engineering, Univ. of Massachusetts Boston, USA;* [3]*Inst. of Opto-electronic Engineering, National Dong Hwa Univ., Taiwan;* [4]*Research Center for Applied Sciences, Academia Sinica, Taiwan.* We report a full-color meta-hologram based on a reflective metasurface. The reconstructed image of the meta-hologram is polarization-dependent with three primary colors, arranged in a plasmonic array in visible light region.

FTu1C.8 • 09:45
Achromatic metasurfaces enable multi-wavelength flat optical components: demonstration of a dispersion-less beam deflector, Francesco Aieta[1], mikhail kats[1], patrice genevet[1], reza Khorasaninejad[1], Federico Capasso[1]; [1]*SEAS, Harvard Univ., USA.* Achromatic metasurfaces are introduced for multiwavelength light control. A wavelength-dependent phase response preserves the functionality within a certain bandwidth. Scattering properties of dielectric resonators are explored to demonstrate a dispersion-free beam deflector and an achromatic lens.

JTu1D • Symposium - Advanced Optical Microscopy for Brain Imaging I—Continued

JTu1D.4 • 09:30 Invited
Photoacoustic Tomography: Ultrasonically Beating Optical Diffusion and Diffraction, Lihong V. Wang[1]; [1]*Washington Univ. in St Louis, USA.* Photoacoustic tomography provides *in vivo* multiscale functional, metabolic, molecular, and histologic imaging across the scales of organelles, cells, tissues, and organs with consistent contrast. Penetration and resolution have reached 7 cm and 90 nm, respectively.

09:00–12:00 SC352 • Introduction to Ultrafast Pulse Shaping–Principles and Applications
SC362 • Cavity Optomechanics: Fundamentals and Applications of Controlling and Measuring Nano- and Micro-mechanical Oscillators with Laser Light
SC410 • Finite Element Modelling Methods for Photonics and Optics

10:00–10:30 Coffee Break, *Concourse Level*

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FTu1E • 2D Materials for Nanoplasmonics and Nanophotonics—Continued

FTu1E.6 • 09:30
Ultrafast Nonlinear Absorption and Nonlinear Refraction of 2D Layered Molybdenum Dichalcogenide Semiconductors, Kangpeng Wang[1], Jung Wang[2], Long Zhang[2], Werner Blau[1]; *[1]Trinity College Dublin, Ireland; [2]Shanghai Inst. of Optics and Fine Mechanics, China.* The nonlinear optical properties of a series of layered transition metal dichalcogenides prepared by liquid-phase exfoliation technique, i.e., MoX2 (X=S, Se and Te), were investigated by open- and closed- aperture z-scan from visible to near-infrared.

FTu1E.7 • 09:45
Pseudospin Selective Microcavity Polariton Emission From Two-dimensional Atomic Crystal, Zheng Sun[1], Xiaoze Liu[1], Hsuan-Hao Huang[2], Yu-Wen Tseng[2], Yi-Hsien Lee[2], Stéphane Kéna Cohen[3], Vinod M. Menon[1]; *[1]Physics, City Univ. of New York, USA; [2]National Tsing Hua Univ., Taiwan; [3]École Polytechnique de Montréal, Canada.* We demonstrate helicity-dependent microcavity polariton emission from 2D atomic crystal at room temperature via non-resonance pump. The observed effect is in contrast to conventional spin polariton emission above the condensation threshold.

STu1F • Optical Integration on Chip—Continued

STu1F.6 • 09:30
Optofluidic Double-layer Fano Resonance Photonic Crystal Slab Liquid Sensors, Shuling Wang[1], Yonghao Liu[1], Deyin Zhao[1], Yichen Shuai[1], Hongjun Yang[1], Weidong Zhou[1], Yuze A. Sun[1]; *[1]Univ. of Texas at Arlington, USA.* We report refractive index sensing with ultra-compact surface-normal double-layer stacked Fano resonance photonic crystal slabs. A quality factor of 6,757 and a limit of detection of $5.6x10^{-5}$ RIU were experimentally demonstrated, respectively.

STu1F.7 • 09:45
All-Fiber Polarization-Maintaining Electrooptic Pulse-Picker, Mikael Malmström[2,1], Simon Boivinet[3,4], Oleksandr Tarasenko[5], Jean-Bernard Lecourt[3], Yves Hernandez[3], Walter Margulis[5,1], Fredrik Laurell[1]; *[1]Dept. of Applied Physics, Laser Physics, Kungliga Tekniska Hogskolan, Sweden; [2]Dept. of Engineering Sciences, Applied Materials Science, Uppsala Univ., Sweden; [3]Applied Photonics Dept., Multitel, Belgium; [4]Electromagnetism and Telecommunication Dept., Univ. of Mons, Belgium; [5]Dept. of Fiber Optics, Acreo AB, Sweden.* An alignment free all-fiber pulse-picker running at variable repetition rate for selecting pulses from an 86 MHz mode-locked Yb-fiber laser at 0-0.6 MHz with better than 35 dB extinction ratio is presented.

STu1G • Cascade Lasers I—Continued

STu1G.7 • 09:30
Optical Sideband Generation up to Room Temperature with Mid-Infrared Quantum Cascade Lasers, Sarah Houver[1], Armand Lebreton[1], Pierrick Cavalié[1], Margaux Renaudat Saint-Jean[2], Maria Amanti[2], Carlo Sirtori[2], Li Lianhe[3], Edmund Linfield[3], Giles Davies[3], Teldo Pereira[4], Jérôme Tignon[1], Sukhdeep Dhillon[1]; *[1]Laboratoire Pierre Aigrain, USA; [2]Laboratoire Matériaux et Phénomènes Quantiques, France; [3]Univ. of Leeds, UK; [4]Universidade Federal de Mato Grosso, Brazil.* Room temperature sideband generation on an optical carrier is demonstrated using mid-infrared quantum cascade lasers. This is achieved via an enhancement of the nonlinear susceptibility via resonant interband and intersubband excitations, compensating the large phase-mismatch.

STu1G.8 • 09:45
Long-infrared InAs-based quantum cascade lasers, Daniel Chastanet[1], Adel Bousseksou[1], Raffaele Colombelli[1], Guillaume Lollia[2], Michael Bahriz[2], Alexei Baranov[2], roland Teissier[2]; *[1]IEF, CNRS-Universite Paris Sud, France; [2]IES, Université Montpellier 2 and CNRS, France.* We report recent developments on InAs/AlSb based quantum cascade laser operating at of 17-19 μm, with improved design and metal-metal ridge resonators. The maximum operating temperature is 333 K at λ=17.9 μm. We also report distribued feedback lasers featuring spectrally single mode operation.

STu1H • Terahertz Photonics—Continued

STu1H.7 • 09:30
Terahertz Radiation Enhancement in Large-Area Photoconductive Sources by Using Plasmonic Nanoantennas, Nezih Yardimci[1], Shang-Hua Yang[2,1], Christopher Berry[2], Mona Jarrahi[1,2]; *[1]Univ. of California - Los Angeles, USA; [2]Univ. of Michigan, USA.* We demonstrate that incorporating plasmonic nanoantennas in large-area photoconductive sources enables record-high terahertz radiation powers as high as 3.8 mW over 0.1-5 THz and an order-of-magnitude higher optical-to-terahertz conversion efficiencies compared to conventional designs.

STu1H.8 • 09:45
Mechanically tunable bi-layer terahertz metamaterials, Liming Liu[2,3], Wen-chen Chen[1], David A. Powell[3], Willie J. Padilla[1], Fouad Karouta[4], Haroldo T. Hattori[2], Dragomir N. Neshev[3], Ilya Shadrivov[3]; *[1]Dept. of Physics, Boston College, USA; [2]School of Engineering and Information Technology, UNSW, Australia; [3]Nonlinear Physics Centre, Australian National Univ., Australia; [4]Dept. of Electronic Materials Engineering, Australian National Univ., Australia.* We propose a post-processing approach for tuning terahertz metamaterials by modifying the coupling between two metamaterial layers. We demonstrate that this method allows the metamaterial resonance to be shifted by 31% of the central frequency.

09:00–12:00 SC352 • Introduction to Ultrafast Pulse Shaping–Principles and Applications
SC362 • Cavity Optomechanics: Fundamentals and Applications of Controlling and Measuring Nano- and Micro-mechanical Oscillators with Laser Light
SC410 • Finite Element Modelling Methods for Photonics and Optics

10:00–10:30 Coffee Break, *Concourse Level*

CLEO: Science & Innovations

STu1I • Nonlinear Optics—Continued

STu1I.7 • 09:30
Octave-Spanning Supercontinuum Generation in a Silicon Nitride Waveguide Pumped by a Femtosecond Fiber Laser at 1.9 μm, Reza Salem[2,1], Yoshitomo Okawachi[3], Mengjie Yu[3], Michael Lamont[3], Kevin Luke[4], Peter Fendel[2], Michal Lipson[4], Alexander L. Gaeta[3]; *[1]PicoLuz, LLC, USA; [2]Thorlabs, Inc., USA; [3]Applied and Engineering Physics, Cornell Univ., USA; [4]Electrical and Computer Engineering, Cornell Univ., USA.* We report supercontinuum generation from 1250 - 2600 nm using a 2-cm-long silicon nitride waveguide pumped with an all-fiber femtosecond laser source at 1920 nm.

STu1I.8 • 09:45
Low-Noise Stimulated Brillouin Lasing in a Microrod Resonator, William Loh[1], Joe Becker[1], Frederick N. Baynes[1], Adam Green[1], Daniel C. Cole[1], Franklyn Quinlan[1], Hansuek Lee[2], Kerry Vahala[2], Scott B. Papp[1], Scott Diddams[1]; *[1]NIST, USA; [2]California Inst. of Technology, USA.* We demonstrate a Brillouin microcavity laser based on a microrod resonator exhibiting a frequency noise of 140 Hz/√Hz at 10 Hz offset. The corresponding laser linewidth is measured to be below 400 Hz.

CLEO: Applications & Technology

ATu1J • Applications for Energy and Environment—Continued

ATu1J.7 • 09:30
Advanced Laser Lift Off in the Manufacturing of LEDs, Marco Mendes[1], Cristian Porneala[1], Xiangyang Song[1], Mathew Hannon[1], Rouzbeh Sarrafi[1], Joshua Schoenly[1], Dana Sercel[1], Sean Dennigan[1], Roy VanGemert[1], Heath Chaplin[1], John Bickley[1], Jeff Sercel[1]; *[1]IPG Photonics - Microsystems Division, USA.* Advanced laser lift off (LLO) techniques leading to high quality and high throughput fabrication of vertical and flip chip GaN and AlN based LEDs are discussed.

ATu1J.8 • 09:45
Enhancement of Quantum Dot Luminescence by using Plasmonic Resonance Scheme of Stacking Asymmetric Split-Ring Metamaterials, Tien Lin Shen[1], Tsung-Sheng Kao[1], Hao-Chung Kuo[1]; *[1]National Chiao Tung Univ., Taiwan. Coupling of nanostructured metal with quantum dots have been widely used in various technologies. We have designed a stacking split-ring metamaterial with tunanble resonance and enhanced the quantum dots fluorescence by a factor over 4.5.*

CLEO: Science & Innovations

STu1K • Integrated Optofluidics: Sensing, Guiding and Tailored Fabrication—Continued

STu1K.7 • 09:30
Tailoring Light Flow in Microfluidics, Haitao Zhao[1], Lip Ket Chin[1], Weiming Zhu[1], Eric Peng Huat Yap[2], Wee Ser[1], Ai-Qun LIU[1]; *[1]School of Electrical and Electronic Enginnering, Nanyang Technological Univ., Singapore; [2]Lee Kong Chian School of Medicine, Nanyang Technological Univ., Singapore.* This paper proposes an approach to tailor the light flow by using the liquid diffusion-generated gradient. A microfluidic network is designed to generate the required linear and parabolic profiles. Maxwell's fisheye lens and optical bend are realized on a single microfluidic chip.

STu1K.8 • 09:45
Ultra-broadband SERS substrates for "all" excitation wavelengths, Nan Zhang[1], Kai Liu[1], Haomin Song[1], Xie Zeng[1], Dengxin Ji[1], Qiaoqiang Gan[1]; *[1]State Univ. of New York at Buffalo, USA.* We developed an ultra-broadband super-absorbing metasurface substrate for SERS sensing. In contrast to conventional substrates working for limited excitation wavelengths, this structure can work for almost "all" available laser lines from 450-nm to 1000-nm.

STu1L • Symposium on Breaking Limits with Unconventional Optical Fields I—Continued

STu1L.6 • 09:30 Invited
Increasing the Quantum Number, Dimensionality and Complexity of Entanglement, Robert Fickler[1,2], Mario Krenn[1,2], Radek Lapkiewicz[1,2], Marcus Huber[3,4], William N. Plick[1,5], Sven Ramelow[1,6], Anton Zeilinger[1,2]; *[1]Vienna Center for Quantum Science and Technology, Faculty of Physics, Univ. of Vienna, Austria; [2]Austrian Academy of Sciences, Inst. for Quantum Optics and Quantum Information, Austria; [3]Fisica Teorica: Informacio i Fenomens Quantics, Departament de Fisica, Universitat Autonoma de Barcelona, Spain; [4]ICFO-Institut de Ciencies Fotoniques, Spain; [5]CNRS - Telecom ParisTech, France; [6]Cornell Univ., USA.* We use transverse spatial modes of photons to demonstrate quantum entanglement of angular momentum up to 300 quanta and verify (100x100)-dimensional entanglement. Additionally, we investigate entanglement of complex polarization patterns and find interesting entanglement structures.

09:00–12:00 SC352 • Introduction to Ultrafast Pulse Shaping–Principles and Applications
SC362 • Cavity Optomechanics: Fundamentals and Applications of Controlling and Measuring Nano- and Micro-mechanical Oscillators with Laser Light
SC410 • Finite Element Modelling Methods for Photonics and Optics

10:00–10:30 Coffee Break, *Concourse Level*

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CLEO: Applications & Technology

ATu1M • Process Control and Metrology Applications—Continued

ATu1M.6 • 09:30
Highly Sensitive Liquid Level Sensor using a Polymer Optical Bragg Grating for Industrial Applications, Carlos Marques[1], Gang-Ding Peng[2], David J. Webb[1]; [1]*Aston Inst. of Photonic Technologies, Aston Univ. B4 7ET Birmingham, UK, UK;* [2]*Univ. of New South Wales, School of Electrical Engineering and Telecommunications, Australia.* A novel and highly sensitive liquid level sensor based on a polymer optical fiber Bragg grating (POFBG) is reported for the first time. The sensitivity of the sensor is found to be 57 pm/cm of liquid, enhanced by more than a factor of 5 when compared to an equivalent sensor based on silica fiber.

ATu1M.7 • 09:45
Integrated Fabry-Perot/Fiber Bragg Grating Sensor for Simultaneous Measurement, Peixiang Lu[1], Fahad M. Abdulhussein[2]; [1]*Huazhong Univ of Science and Technology, China;* [2]*Inst. of laser for postgraduate studies, Baghdad Univ., Iraq.* An all-fiber sensor for simultaneous measurements is demonstrated. Fiber Bragg grating (FBG) inside the core of all solid photonic band gap fiber (ASPBGF) was connected to FPI micro cavity for simultaneously measure load and temperature with sensitivities 4.07nm/N and 13.7pm/°C respectively.

CLEO: Science & Innovations

STu1N • Fiber Components & Devices—Continued

STu1N.7 • 09:30
Kagome-type HC-PCF pulse compression: high average power (>100 W), high efficiency and very low noise performance, Florian Emaury[1], Andreas Diebold[1], Benoît Debord[2], Frédéric Gérôme[2], Clara J. Saraceno[1,3], Thomas Sudmeyer[3], Fetah Benabid[2], Ursula Keller[1]; [1]*ETH Zurich, Switzerland;* [2]*XLIM, France;* [3]*Univ. of Neuchatel, Switzerland.* We present sub-100-fs external pulse compression and noise characterization from ultrafast multi-100-W thin disk lasers using gas-filled-Kagome-type HC-PCFs. We demonstrate high compression efficiency and excellent phase and amplitude low-noise properties.

STu1N.8 • 09:45
Scaling Laws in Tube Lattice Fibers, Masruri Masruri[2], Annamaria Cucinotta[2], Luca Vincetti[1]; [1]*Dept. of Engineering "Enzo Ferrari", Univ. of Modena and Reggio Emilia, Italy;* [2]*Dept. of Information Engineering, Univ. of Parma, Italy.* Scaling laws of confinement loss and dielectric overlap in circularly arranged tube lattice fibers are numerically analyzed. Confinement loss scales as the 4.5 power of wavelength-core size ratio whereas dielectric overlap dependence is weaker.

STu1O • Advanced Ultrafast Sources—Continued

STu1O.6 • 09:30
Multi-Terawatt CO_2 Laser with Chirped-Pulse Amplification, Mikhail N. Polyanskiy[1], Marcus Babzien[1], Igor Pogorelsky[1]; [1]*Brookhaven National Lab, USA.* A chirped-pulse amplification technique is implemented for the first time in a picosecond CO_2 laser. A considerable increase in peak power is achieved, mainly as a result of eliminating nonlinear effects in the optical elements.

STu1O.7 • 09:45
Generation of 33-fs laser pulses from a Kerr-lens mode-locked Yb:$CaYAlO_4$ laser, Ziye Gao[1], Jiangfeng Zhu[1], Junli Wang[1], Zhiyi Wei[2], Lihe Zheng[3], Liangbi Su[3], Jun Xu[3]; [1]*Xidian Univ., China;* [2]*Beijing National Lab for Condensed Matter Physics, Inst. of Physics, Chinese Academy of Sciences, China;* [3]*Key Lab of Transparent and Opto-functional Inorganic Materials, Shanghai Inst. of Ceramics Chinese Academy of Sciences, China.* We experimentally demonstrated a diode-pumped Kerr-lens mode-locked femtosecond laser based on a Yb:$CaYAlO_4$ crystal. Pulses with a duration as short as 33 fs at the center wavelength of 1059 nm were obtained.

09:00–12:00 SC352 • Introduction to Ultrafast Pulse Shaping–Principles and Applications
SC362 • Cavity Optomechanics: Fundamentals and Applications of Controlling and Measuring Nano- and Micro-mechanical Oscillators with Laser Light
SC410 • Finite Element Modelling Methods for Photonics and Optics

10:00–10:30 Coffee Break, *Concourse Level*

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CLEO: QELS-Fundamental Science

JOINT

10:30–12:30
FTu2A • Quantum Entanglement II
Presider: Todd Pittman; Univ. of Maryland Baltimore County, USA

FTu2A.1 • 10:30
Chip-to-chip quantum entanglement distribution, Jianwei Wang[1], Matteo Villa[1], Damien Bonneau[1], Raffaele Santagati[1], Joshua W. Silverstone[1], Chris Erven[1], Shigehito Miki[2], Taro Yamashita[2], Mikio Fujiwara[2], Masahide Sasaki[2], Hirotaka Terai[2], Michael G. Tanner[3], Robert H. Hadfield[3], Jeremy O Brien[1], Mark G. Thompson[1]; [1]*Centre for Quantum Photonics, H. H. Wills Physics Lab & Dept. of Electrical and Electronic Engineering, Univ. of Bristol, UK;* [2]*National Inst. of Information and Communications Technology (NICT), Japan;* [3]*School of Engineering, Univ. of Glasgow, UK.* We present the first experimental demonstration of quantum entanglement distribution between silicon integrated photonic chips, linked by a single mode optical fiber. Entanglement states generation, transmission, manipulation and measurement are implemented intra/inter chips.

FTu2A.2 • 10:45
Realization of Sub-picosecond Clock Synchronization based on Second-Order Quantum Coherence, Runai Quan[1], Ruifang Dong[1], Yiwei Zhai[1], Mengmeng Wang[1], Shaofeng Wang[1], Feiyan Hou[1], Tao Liu[1], Shougang Zhang[1]; [1]*Key Lab of Time and Frequency Primary Standards, National Time Service Center, CAS, China.* Based on the second-order quantum interference between entangled photons generated by parametric down conversion, we have demonstrated a proof-of-principle experiment of synchronizing two clocks separated by 4-km fiber link. A sub-picosecond accuracy is achieved.

FTu2A.3 • 11:00
Controlling frequency distinguishability of photons using cross phase modulation, Nobuyuki Matsuda[1]; [1]*NTT Basic Research Labs, Japan.* The frequency distinguishability of photon pairs was controlled using spectral reshaping via cross phase modulation. A non-classical dip in a Hong-Ou-Mandel quantum interference experiment was observed for the photons with diminished spectral distinguishability.

10:30–12:15
FTu2B • Quantum Optics in Semiconductor Microcavities
Presider: Keshav Dani; Okinawa Inst of Science & Technology, Japan

FTu2B.1 • 10:30 Tutorial
Manipulating Quantum Fluids of Light in Microstructured Semiconductor Cavities, Jacqueline Bloch[1]; [1]*LPN, CNRS, France.* Semiconductor microcavities provide a new platform for quantum fluids of light manipulation, quantum simulation, and non-linear optical device development. Recent experimental achievements will be discussed with particular emphasis on polaritonic circuits and polaritons in lattices.

Jacqueline Bloch is Director of Research at CNRS. The group she leads has pioneered several avenues in the exploration of polariton condensate physics. Bloch has authored 140 publications and given more than 85 invited talks and seminars. She is a member of the National Committee for Scientific Research (CoNRS).

10:30–12:15
FTu2C • Topological Photonics I
Presider: Marta Autore; Dip. di Fisica, Italy

FTu2C.1 • 10:30
Optical Access to Topological-Insulator Surface States with Plasmonic Rotating Fields, Grisha Spektor[1], Asaf David[1], Guy Bartal[1], Meir Orenstein[1], Alex Hayat[1]; [1]*Technion, Israel Inst. of Technology, Israel.* We implemented a square plasmonic cavity supporting an array of counter rotating field elements. The controlled, highly confined angular momenta array is a means for coupling to the spin helical surface states of topological insulators.

FTu2C.2 • 10:45
Reflections-Free Wave Propagation at the Interface of Photonic Topological Insulators: Theory and Experiment, Tzuhsuan Ma[1], Kueifu Lai[1], Gennady Shvets[1]; [1]*Physics, Univ. of Texas at Austin, USA.* A comprehensive library of photonic topological insulators (gyromagnetic, bianisotropic, and 2D-asymmetric) is established. An interface between any two of them supports reflectionless surface waves, as is experimental demonstrated for wave propagation along a zigzag interface.

FTu2C.3 • 11:00
Large Chern number one-way waveguides, Scott Skirlo[1], Yuichi Igarashi[1], Ling Lu[1], Marin Soljacic[1]; [1]*MIT, USA.* We predict quantum anomalous Hall phases in photonic crystals with large Chern numbers of 2, 3 and 4, and demonstrate their applications. Finally, we present experimental evidence for multimode unidirectional waveguides at microwave frequencies.

10:30–12:30
JTu2D • Symposium on Advanced Optical Microscopy for Brain Imaging II
Presider: Chris Xu; Cornell Univ., USA

JTu2D.1 • 10:30 Invited
Adaptive Optics to Study the Structure and Function of the Human Visual System, Austin J. Roorda[1]; [1]*Univ. of California Berkeley, USA.* Adaptive optics (AO) corrects the blur caused by the eye's optical imperfections, enabling optical access to single human retinal cells. An AO scanning laser ophthalmoscope is described for cellular level retinal imaging and vision testing.

JTu2D.2 • 11:00 Invited
Wave Front Shaping and Optogenetics, Valentina Emiliani[1]; [1]*Neurophotonic Laoratory, CNRS and Univ. Paris Descartes, France.* A series of optical methods (temporal focusing, computer generated holography and generalized phase contrast) for patterned ontogenetic with cellular resolution will be presented with exemplary experiments in vitro and in vivo.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

10:30–12:30
FTu2E • Plasmonic Nanoantennas and Nanocavities
Presider: Rashid Zia; Brown Univ., USA

FTu2E.1 • 10:30
Filter Design Method for Construction of 3D Plasmonic Directional Light Sensors, Matthew Davis[1,2], Jay K. Lee[1], Amit Agrawal[2], Henri J. Lezec[2]; *[1]Electrical Engineering and Computer Science, Syracuse Univ., USA; [2]Center for Nanoscale Science and Technology, National Inst. of Standards and Technology, USA.* We propose an analytic method for plasmonic filter design, freeing the design process from time-consuming FDTD simulations. We demonstrate the utility of the design model by constructing a prototype 3D plasmonic directional light sensor.

FTu2E.2 • 10:45
Hybrid Metal-Dielectric Nanoantennas for Directional Emission Enhancement, Evgenia Rusak[1], Rui Guo[1], Isabelle Staude[1], Manuel Decker[1], Juergen Sautter[1], Andrey Miroshnichenko[1], David A. Powell[1], Dragomir N. Neshev[1], Yuri S. Kivshar[1]; *[1]Australian National Univ., Australia.* We suggest a novel hybrid nanoantenna, consisting of a gold nanorod and a silicon nanodisk, which provides giant enhancement of directional emission together with high radiation efficiency. We demonstrate its fabrication by two-step electron-beam lithography.

FTu2E.3 • 11:00
Slanted 3D Plasmonic Antenna Arrays, Pierfrancesco Zilio[1], Mario Malerba[1], Andrea Toma[1], Francesco De Angelis[1]; *[1]Istituto Italiano di Tecnologia, Italy.* We report experimental and Finite Elements simulation results of slanted silver nanoantenna dimers arrays on silver baseplate. Strong field enhancements and diffractive couplings are correlated to the peculiar near-field properties of these structures.

10:30–12:30
STu2F • Optical Interconnect on Chip
Presider: Weidong Zhou; Univ. of Texas at Arlington, USA

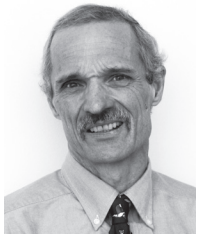
STu2F.1 • 10:30
Hybrid 3D Photonic Integrated Circuit for Optical Phased Array Beam Steering, Binbin Guan[1], Chuan Qin[1], Ryan P. Scott[1], Burcu Ercan[1], Nicolas K. Fontaine[2], Tiehui Su[1], S.J.B. Yoo[1]; *[1]Dept. of Electrical and Computer Engineering, Univ. of California, Davis, USA; [2]Bell Labs, Alcatel-Lucent, USA.* We demonstrate a hybrid integrated optical phased array (OPA) based on a 2D photonic integrated circuit and 3D waveguides. The 4×4 OPA supports 4.93° horizontal and vertical beam steering near 1550 nm with 7.1-dB loss.

STu2F.2 • 10:45
Multi-Chip Integration of Lasers and Silicon Photonics by Photonic Wire Bonding, Muhammad Rodlin Billah[1], Tobias Hoose[1], Temitiope Onanuga[1], Nicole Lindenmann[1], Philipp Dietrich[1], Tobias Wingert[1], Maria Laura Goedecke[1], Andreas Hofmann[1], Ute Troppenz[2], Ariane Sigmund[2], Martin Möhrle[2], Wolfgang Freude[3], Christian Koos[1]; *[1]Karlsruhe Inst. of Technology, Germany; [2]Heinrich Hertz Inst., Fraunhofer Institut for Telecommunications, Germany; [3]Inst. of Photonics and Quantum Electronics, Karlsruhe Inst. of Technology, Germany.* We demonstrate coupling of a horizontal-cavity surface-emitting laser (HCSEL) to a silicon photonic chip using photonic wire bonding. The technique does not require high-precision alignment of the chips. Measured coupling losses amount to approximately 4.1 dB.

STu2F.3 • 11:00 Invited
High-Speed and Stable Operation of Highly Unidirectional III-V/Silicon Microring Lasers for On-chip Optical Interconnects, Kazuya Ohira[1], Hirotaka Uemira[1], Norio Iizuka[1], Haruhiko Yoshida[1], Hiroshi Uemura[1], Yoichiro Kurita[1], Hideto Furuyama[1], Mizunori Ezaki[1]; *[1]Photonics Electronics Technology Research Association, Japan.* We demonstrated high-speed, stable and unidirectional microring III-V laser diodes with in-cavity feedback silicon waveguide, and the integration with III-V photodetector on a silicon-on-insulator platform to achieve on-chip data transmission with a data rate of 12.5 Gb/s.

10:30–12:30
STu2G • Cascade Lasers II
Presider: Raffaele Colombelli; Universite Paris Sud and CNRS, France

STu2G.1 • 10:30 Tutorial
High-Brightness Interband Cascade Lasers, Jerry R. Meyer[1], Chadwick L. Canedy[1], Chul S. Kim[1], Mijin Kim[2], William W. Bewley[1], Charles Merritt[1], Igor Vurgaftman[1]; *[1]US Naval Research Lab, USA; [2]Sotera Defense Solutions, Inc., USA.* Mid-IR interband cascade lasers will be reviewed. Advantages include 3-6 mm spectral coverage, wallplug efficiency up to 18% when operated in cw mode at ambient temperature, and ultra-low threshold drive power.



Jerry R. Meyer completed his Ph.D. in Physics at Brown Univ. in 1977. Since then he has carried out basic and applied research at the Naval Research Laboratory in Washington DC, where he is the Navy Senior Scientist for Quantum Electronics (ST) and Acting Head of the Quantum Optoelectronics Section. He is a Fellow of OSA, APS, IEEE, IOP, SPIE. In 2012, he was recipient of NRL's 2012 E. O. Hulbert Annual Science Award, and co-recipient of the IEEE Photonics Society Engineering Achievement Award. He has co-authored over 360 refereed journal articles, 30 patents (7 licensed), and over 150 invited conference presentations.

10:30–12:15
STu2H • THz Spectroscopy of Graphene and Magnetic Materials
Presider: Dmitry Turchinovich; Max Planck Inst. for Polymer Research, Germany

STu2H.1 • 10:30 Invited
Terahertz Nonlinear Magnetic Response in in Antiferromagnets, Koichiro Tanaka[1,2], Y Mukai[1,3], H Hirori[2,3], T Yamamoto[4], H Kageyama[2,4]; *[1]Dept. of Physics, Kyoto Univ., Japan; [2]Inst. for Integrated Cell-Material Sciences (WPI-iCeMS), Kyoto Univ., Japan; [3]CREST, Japan Science and Technology Agency, Japan; [4]Dept. of Energy and Hydrocarbon Chemistry, Kyoto Univ., Japan.* We report on the nonlinear magnetization dynamics of a HoFeO3 crystal induced by a strong terahertz magnetic field resonantly enhanced with a split ring resonator. The terahertz magnetic field induces a large magnetization change of 40% of the spontaneous magnetization. The frequency of the antiferromagnetic resonance decreases in proportion to the square of the magnetization change.

STu2H.2 • 11:00
Nonlinear THz Transmission of Gated Graphene, Sayyed Hadi Razavipour[1], Wayne Yang[1], Francois Blanchard[1], Abdeladim Guermoune[1], Michael Hilke[1], David G. Cooke[1]; *[1]McGill, Canada.* THz field-induced transparency has been measured and characterized for gel-gated multilayer graphene. It is shown that upon changing the Fermi level by ionic electrostatic gating, the transmission bleaching decreases as the Fermi level approaches the Dirac point.

CLEO: Science & Innovations

10:30–12:30
STu2I • Nonlinear Optics in Microresonators and Nanostructures
Presider: Paulina Kuo; NIST, USA

STu2I.1 • 10:30 Invited
Nonlinear and Quantum Optics with Whispering Gallery Resonators, Dmitry V. Strekalov[1]; [1]*Jet Propulsion Lab, USA.* Whispering Gallery Mode resonators made from optically nonlinear crystals have small mode volume and extremely high quality factor which makes them ideal for various nonlinear conversion process at low power, ultimately at single photon level.

STu2I.2 • 11:00
Surface-normal Coupled Four-wave Mixing in a High Contrast Grating Resonator, Tianbo Sun[1], Connie J. Chang-Hansnain[1]; [1]*EECS, Univ. of California, Berkeley, USA.* We demonstrate four-wave mixing using a Si-based high contrast gratings (HCG) resonator directly coupled in surface-normal direction. Quality-factor of the resonator is ~7000 and peak conversion efficiency is -19.5dB at low pump power levels.

CLEO: Applications & Technology

10:30–12:30
ATu2J • Solar Optics and Cells
Presider: Homan Yuen; Solar Junction, USA

ATu2J.1 • 10:30 Invited
Self-Tracking Concentrator for Photovoltaics, Peter Kozodoy[1], Christopher Gladden[1], Michael Pavilonis[1], Christopher Rhodes[1], Tobias Wheeler[1], Chadwick Casper[1]; [1]*Glint Photonics, Inc., USA.* We present a novel solar concentrator architecture in which integrated microscale liquid optics provide passive solar tracking, eliminating the need for high-precision mechanical tracking. Optical efficiency as high as 72% and effective acceptance angle of 50° are demonstrated. The design can reduce the cost of concentrator photovoltaics and broaden its applicability.

ATu2J.2 • 11:00
Microphotonic spectrum-splitting & concentration for high-efficiency photovoltaic, Nabil Mohammed[1], Peng Wang[1], Daniel Friedman[2], Kannan Ramanathan[2], Lorelle Mansfield[2], Rajesh Menon[1]; [1]*Univ. of Utah, USA;* [2]*NREL, USA.* We present a diffractive microphotonic element that can split solar spectrum into 2 or more spectral bands, and concentrate these bands onto optimal absorbers. We experimentally demonstrated an increase in output power of 35% with a 3-band configuration.

CLEO: Science & Innovations

10:30–12:30
STu2K • Computational Bioimaging
Presider: Kevin Tsia; Univ. of Hong Kong, Hong Kong

STu2K.1 • 10:30
Low-Light Reflective Correlation Imaging, Milad Akhlaghi Bouzan[1], Thomas Kohlgraf-Owens[1], Aristide Dogariu[1]; [1]*CREOL, College of Optics and Photonics, Univ. of Central Florida, USA.* Numerical and experimental evaluation of a reflective microscopy technique based on sequential random pattern illumination and integrated detection is conducted to demonstrate imaging at the low-light levels of interest for live-cell imaging.

STu2K.2 • 10:45
Differential Interference Imaging via Radio-frequency Sideband Encoding, Ali M. Fard[1,2], Ata Mahjoubfar[2], Bahram Jalali[2]; [1]*Harvard Medical School, USA;* [2]*Univ. of California Los Angeles, USA.* We introduce and demonstrate an imaging modality that performs differential interference imaging via frequency-to-space mapping and radio-frequency (RF) heterodyne detection.

STu2K.3 • 11:00
High-resolution On-chip Imaging using Synthetic Aperture, Wei Luo[1], Alon Greenbaum[1], Yibo Zhang[1], Aydogan Ozcan[1]; [1]*Univ. of California Los Angeles, USA.* We report a synthetic-aperture-based on-chip lensfree microscope. Having a wide field-of-view of ~20.5 mm2, this technique sets the largest numerical aperture (1.4) for on-chip microscopy.

10:30–12:30
STu2L • Symposium on Breaking Limits with Unconventional Optical Fields II
Presider: Uriel Levy; The Hebrew Univ. of Jerusalem, Israel

STu2L.1 • 10:30 Invited
Relativistic Few-cycle Cylindrical Vector Beams for Novel Table-top Particle Accelerators, Sergio Carbajo[1,2], Emilio A. Nanni[1], Liang Jie Wong[1], R.J. Dwayne Miller[2,3], Franz X. Kaertner[1,2]; [1]*MIT, USA;* [2]*Center for Free Electron Laser Science, Germany;* [3]*Univ. of Toronto, Canada.* Few-cycle highly-intense radially polarized lasers unfold a novel compact accelerator uniquely capable of direct laser-to-particle energy transfer. We present the technology that proofs this concept yielding highly-directional multi-GeV/m non-relativistic electron accelerating gradients.

STu2L.2 • 11:00
Topological Nature of Optical Bound States in the Continuum and its Application in Generating High-order Vector beams, Bo Zhen[1], Chia Wei Hsu[1], Ling Lu[1], A. Doug Stone[2], Marin Soljacic[1]; [1]*MIT, USA;* [2]*Yale Univ., USA.* We demonstrate all robust bound states in the continuum in photonic crystal slabs are vortex centers in the polarization directions of far-field radiation. They are robust because they carry conserved and quantized topological charges under PT symmetry. They also generate high-order vector beams.

Marriott Salon III

CLEO: Applications & Technology

10:30–12:30
ATu2M • Process Controls, Monitoring & Novel Sources
Presider: Oliver Heckl; Univ. of Colorado at Boulder JILA, USA

ATu2M.1 • 10:30 Invited
MIR Spectroscopy beyond Trace Levels - Environmental and Industrial Applications, Lukas Emmenegger[1]; [1]*EMPA, Switzerland.* MIR spectroscopy using QCL allows sensitive, selective and fast gas detection. This is illustrated by many environmental and industrial applications. Recent developments show significant advances towards portable, high-sensitivity sensors for multiple components.

ATu2M.2 • 11:00
Application of a widely tunable Sampled Grating Distributed Bragg Quantum Cascade laser for multi-species spectroscopy, Abdou Diba[1], Feng Xie[2], Barry Gross[1], Chung-en Zah[2], Fred Moshary[1]; [1]*Electrical Engineering, City College of New York, USA;* [2]*Science and Technology, Corning Incorporate, USA.* We demonstrate the feasibility of multicomponent trace gas sensing using a tunable sampled-grating distributed Bragg reflector QCL. We have achieved continuous fine tuning over 10 cm^{-1} to retrieve N_2O, H_20 and CO.

Marriott Salon V & VI

CLEO: Science & Innovations

10:30–12:30
STu2N • Control & Diagnostics
Presider: Heng Li; Stanford Univ., USA

STu2N.1 • 10:30
Optical differentiation wavefront sensor based on binary pixelated transmission filters, Jie Qiao[1,2], Anton Travinsky[1], Christophe Dorrer[2]; [1]*Rochester Inst. of Technology, USA;* [2]*Aktiwave LLC, USA.* An optical differentiation wavefront sensor based on measurements of wavefront slopes in two orthogonal directions obtained by far-field spatial modulation with a binary pixelated filter inducing a linear amplitude transmission is demonstrated.

STu2N.2 • 10:45
Design and performance of an integrated phase and amplitude diversity sensor, Nicolas Védrenne[1], Frédéric Cassaing[1], Laurent M. Mugnier[1], Vincent Michau[1], Gregory Iaquaniello[3], Leonardo Blanco[3], Gilles Chériaux[3,2]; [1]*Theoretical and Applied Optics Dept., Onera, The French Aerospace Lab, France;* [2]*Laboratoire pour l'Utilisation des Lasers Intenses, Ecole Polytechnique, France;* [3]*Laboratoire d'Optique Appliquée, LOA-UMR7639, France.* The practical implementation of a phase diversity sensor for high resolution measurement of disturbed laser beams is detailed here. Numerical simulations show that, with simple material, a 60x60 map of complex amplitude with lambda/100 accuracy can be obtained.

STu2N.3 • 11:00
High-Contrast, Closed-Loop Control of Laser Beam Profiles, Leva E. McIntire[1,3], Martin Divoky[2], Wayne H. Knox[1], Seung-Whan Bahk[3], Jonathan D. Zuegel[3]; [1]*The Inst. of Optics, Univ. of Rochester, USA;* [2]*HiLASE, Inst. of Physics ASCR, Czech Republic;* [3]*Lab for Laser Energetics, Univ. of Rochester, USA.* A 1053-nm laser beam profile was controlled using the diffractive mode of a spatial light modulator in closed loop for the first time, producing high-contrast spatial intensity shaping, as well as independent wavefront control.

CLEO: QELS-Fundamental Science

JOINT

FTu2A • Quantum Entanglement II—Continued

FTu2A.4 • 11:15
Bell State Free Dense Coding with Linear Optics, Pavel Lougovski[1], Dmitry B. Uskov[2]; [1]*Oak Ridge National Lab, USA;* [2]*Dept. of Mathematics and Natural Sciences, Brescia Univ., USA.* We explore the possibility of implementing dense coding with linear optics and coincidence photodetection without Bell state discrimination. We discover that such implementations exist for two-photon in N-mode (N=4,6,8) scenarios and provide examples.

FTu2A.5 • 11:30
Experimental Reconstruction of Time-Bin-Entangled Qutrit States using Polarization Projective Measurements, Samantha Nowierski[1,2], Neal N. Oza[2], Prem Kumar[2], Gregory S. Kanter[2]; [1]*Applied Physics, Northwestern Univ., USA;* [2]*Electrical Engineering and Computer Science, Northwestern Univ., USA.* We generate and reconstruct two-photon, 100-ps-separated time-bin-entangled qutrit states. By pairwise mapping time bins onto orthogonal polarizations, we perform a tomography and demonstrate high fidelity to maximally entangled qutrit states

FTu2A.6 • 11:45
Distributing Energy-Time Entangled Photon Pairs in Demultiplexed Channels over 110 km, Djeylan Aktas[1], Bruno Fedrici[1], Florian Kaiser[1], Laurent Labonté[1], Sebastien Tanzilli[1]; [1]*Université de Nice Sophia Antipolis, Laboratoire de Physique de la Matière Condensée, CNRS UMR7336, France.* We propose a novel approach to quantum cryptography using the latest demultiplexing technology to distribute photonic entanglement over a fully fibred network.We achieve unprecedented bit-rates, beyond the state of the art for similar approaches.

FTu2B • Quantum Optics in Semiconductor Microcavities—Continued

FTu2B.2 • 11:30
Quantum Optics for Studying Ultrafast Processes in Condensed Matter, Martina Esposito[1], Francesco Randi[1], Francesca Giusti[1], Davide Boschetto[2], Fulvio Parmigiani[1,3], Daniele Fausti[1,3]; [1]*Univ. of Trieste, Italy;* [2]*ENSTA ParisTech, France;* [3]*Elettra Sincrotrone Trieste S.C.p.A., Italy.* Quantum state reconstruction techniques are used to address non equilibrium matter states. Proof of principle experiments reveal that few photons coherent pulses can be squeezed by the interaction with impulsively excited coherent phonons in quartz.

FTu2B.3 • 11:45
A Spin-controlled Microcavity Laser, Fengkuo Hsu[1], Wei Xie[1], Yi-Shan Lee[2], Sheng-Di Lin[2], Chih-Wei Lai[1]; [1]*Michigan State Univ., USA;* [2]*National Chiao Tung Univ., Taiwan.* We demonstrate highly circularly polarized lasing under non-resonant elliptically polarized optical pumping in a semiconductor microcavity at room temperature.

FTu2C • Topological Photonics I—Continued

FTu2C.4 • 11:15
Topological Control of Bloch Oscillations of Edge Modes in Photonic Lattices, Yonatan Plotnik[1], Miguel A. Bandres[1], Yaakov Lumer[1], Mikael Rechtsman[1], Mordechai Segev[1]; [1]*Technion Israel Inst. of Technology, Israel.* We demonstrate a novel method for controlling the modal trajectories of Bloch oscillations initiated on the edge of a honeycomb lattice, via the topology of its band structure.

FTu2C.5 • 11:30
Single-Sided Diffraction by PT-Symmetric Metasurfaces, Nicholas S. Nye[1], Mohammad-Ali Miri[1], Demetrios N. Christodoulides[1]; [1]*Univ. of Central Florida, CREOL, USA.* We explore light diffraction by parity-time-symmetric metasurfaces. Such structures can lead to one-sided diffraction when operating close to their exceptional points. In this regime, the negative diffraction orders are eliminated while the positive are enhanced.

FTu2C.6 • 11:45
***PT*-symmetric cavities with simultaneous unidirectional lasing and reflectionless modes,** Hamidreza Ramezani[1], Hao-kun Li[1], Yuan Wang[1], Xiang Zhang[1]; [1]*Univ. of California Berkeley, USA.* Using parity-time *(PT)* symmetric cavities, we introduce a new family of spectral singularities with highly directional response. At these singularities the *PT*-symmetric cavity support a simultaneous lasing mode from one side and zero reflection mode from the opposite side.

JTu2D • Symposium on Advanced Optical Microscopy for Brain Imaging II—Continued

JTu2D.3 • 11:30 Invited
Rapid Adaptive Optical Recovery of Diffraction-Limited Resolution Over Large Multicellular Volumes, Eric Betzig[1]; [1]*Howard Hughes Medical Inst., USA.* The heterogeneity of biological tissue essential to life induces aberrations that wreaks havoc on image quality. I will describe our work with adaptive optical microscopy to recover optimal performance under such challenging conditions.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FTu2E • Plasmonic Nanoantennas and Nanocavities—Continued

FTu2E.4 • 11:15
Parity-time symmetry breaking and amplifier-absorber transitions in plasmonic nanoparticles, Nasim Mohammadi Estakhri[1], Andrea Alu[1]; [1]*Electrical and Computer Engineering, The Univ. of Texas at Austin, USA.* Abrupt transitions in the scattering response of parity-time (PT)-symmetric nanoparticles is discussed. Based on the closed-form analytical solution of a complex scattering problem, we show that material imbalance can generate strong absorbing or amplifying scattering states above PT threshold.

FTu2E.5 • 11:30
Coil-type Fano Resonances: a Plasmonic Approach to Magnetic Sub-diffraction Confinement, Simone Panaro[1], Adnan Nazir[1], Remo Proietti Zaccaria[1], Carlo Liberale[1], Francesco De Angelis[1], Andrea Toma[1]; [1]*Italian Inst. of Technology, Italy.* Matrices of nanodisk trimers are introduced as plasmonic platforms for the generation of localized magnetic hot-spots. In Fano resonance condition, the optical magnetic fields can be squeezed in sub-wavelength regions, opening promising scenarios for spintronics.

FTu2E.6 • 11:45
Coupling Nano-Antennas to Microcavities: Radiative Interactions Cause Strong and Tunable Frequency Shifts, Freek Ruesink[1], Hugo M. Doeleman[1], Ruud Hendrikx[1], Femius Koenderink[1], Ewold Verhagen[1]; [1]*FOM Inst. AMOLF, Netherlands.* We develop coupled cavity-antenna systems in which the frequency and linewidth of the eigenmodes can be strongly tuned. Interference of cavity and antenna radiation provides the dominating contribution to changes of dispersion and dissipation.

STu2F • Optical Interconnect on Chip—Continued

STu2F.4 • 11:30
Heterogeneous Microring and Mach-Zehnder Lithium Niobate Electro-Optical Modulators on Silicon, Ashutosh Rao[1], Aniket Patil[2], Jeff Chiles[1], Marcin Malinowski[1], Spencer Novak[1,3], Kathleen Richardson[1,3], Payam Rabiei[2], Sasan Fathpour[1,4]; [1]*CREOL, The College of Optics and Photonics, Univ. of Central Florida, USA;* [2]*Partow Technologies LLC, USA;* [3]*School of Materials Science and Engineering, COMSET, Clemson Univ., USA;* [4]*Dept. of Electrical and Computer Engineering, Univ. of Central Florida, USA.* Heterogeneous integration of submicron films of lithium niobate on silicon substrates, rib-loaded with chalcogenide glass, is used to demonstrate lithium niobate microring modulators with Q of 1.2×10^5 and Mach-Zehnder modulators with $V_\pi.L$ of 3.8 V.cm.

STu2F.5 • 11:45
Hybrid Silicon and Lithium Niobate Racetrack Modulator with Large Spurious Free Dynamic Range, Li Chen[1], Jiahong Chen[1], Jonathan T. Nagy[1], Ronald M. Reano[1]; [1]*Ohio State Univ., USA.* We present a hybrid silicon and $LiNbO_3$ racetrack modulator with spurious free dynamic range of 98.1 dB $Hz^{2/3}$ at 1 GHz, which is comparable to a packaged $LiNbO_3$ Mach-Zehnder modulator biased at quadrature.

STu2G • Cascade Lasers II—Continued

STu2G.2 • 11:30
Double-Ridge Interband Cascade Lasers for High-Power Spectroscopy in the Mid-Infrared, Carl Borgentun[1], Siamak Forouhar[1], Clifford Frez[1], Ryan Briggs[1], Mahmood Bagheri[1], Mathieu Fradet[1]; [1]*Jet propulsion Lab, USA.* Lasers employing a new double-ridge waveguide design emit 18 mW at 3.57 µm and 20 mW at 3.37 µm. The top ridge confines the optical mode while the bottom ridge limits lateral current spreading.

STu2G.3 • 11:45
Type-I Interband Cascade Lasers Near 3.2µm, James Gupta[1], Geof Aers[1], Emmanuel Dupont[1], Jean-Marc Baribeau[1], Xiaohua Wu[1], Yuchao Jiang[2], Lu Li[2], Rui Yang[2], Matthew Johnson[3]; [1]*National Research Council of Canada, Canada;* [2]*School of Electrical and Computer Engineering, Univ. of Oklahoma, USA;* [3]*Homer L. Dodge Dept. of Physics and Astronomy, Univ. of Oklahoma, USA.* Interband cascade lasers with type-I InGaAsSb/AlAsSb quantum well active regions were demonstrated. Ridge-waveguide devices exhibit room-temperature continuous-wave emission at 3.2µm, providing a potential alternative to quantum cascade and diode lasers in this wavelength range.

STu2H • THz Spectroscopy of Graphene and Magnetic Materials—Continued

STu2H.3 • 11:15
Terahertz Emission in Double-Graphene-Layer Structure, Deepika Yadav[1], Boubanga T. Stephane[1], Takayuki Watanabe[1], Victor Ryzhii[1,2], Taiichi Otsuji[1]; [1]*Research Inst. of Electrical Communication, Tohoku Univ., Japan;* [2]*Inst. of Ultra-High-Frequency Semiconductor Electronics, Russia.* Terahertz emission by the photon-assisted resonant radiative transitions between graphene layers (GLs) in double-GL structures is theoretically and experimental demonstrated. Devices such as terahertz/infrared lasers base on this technology are very promising for terahertz optoelectronics.

STu2H.4 • 11:30
Intense Terahertz Field-induced Carrier Dynamics in Gated Monolayer Graphene, Hassan Hafez Eid[1], P Lévesque[2], Ibraheem Al-Naib[3], Marc M. Dignam[3], Xin Chai[1], D Ferachou[1], R Martel[2], Tsuneyuki Ozaki[1]; [1]*INRS-EMT, Canada;* [2]*Université de Montréal,, Canada;* [3]*Queen's Univ., Canada.* Using optical-pump/THz-probe spectroscopy on gated, undoped graphene, we find that as the amplitude of the THz probe is increased, we observe a cross-over from optically-induced transmission decrease to increase.

STu2H.5 • 11:45
Graphene on Nanoscale Gratings for Terahertz Smith-Purcell Radiation, Khwanchai Tantiwanichapan[1], Xuanye Wang[1], Anna Swan[1], Roberto Paiella[1]; [1]*Electrical and Computer Engineering, Boston Univ., USA.* Generation of THz radiation based on the Smith-Purcell effect in graphene deposited on a periodic hole array is investigated numerically. Technologically significant output power levels at geometrically tunable THz frequencies are computed.

CLEO: Science & Innovations

STu2I • Nonlinear Optics in Microresonators and Nanostructures—Continued

STu2I.3 • 11:15
Cascaded Four-Wave Mixing in Silicon-on-Sapphire Microresonators at λ=4.5 μm, Stefan Kalchmair[1], Raji Shankar[2], Shota Kita[1], Christopher Mittag[1], Irfan Bulu[2], Marko Loncar[1]; *[1]Harvard Univ., USA; [2]Schlumberger-Doll Research Lab, USA.* We report cascaded four-wave mixing in a silicon micro-ring resonator operating at 4.5 μm wavelength. Our results present an important milestone for extending optical frequency combs further into the mid-infrared range.

STu2I.4 • 11:30
Second Harmonic Generation In a GaN Photonic Crystal Cavity on Silicon, Philippe Boucaud[1], Yijia Zeng[1], Iannis Roland[1], Xavier Checoury[1], Zheng Han[1], Moustafa El Kurdi[1], Sébastien Sauvage[1], Bruno Gayral[2], Christelle Brimont[3], Thierry Guillet[3], Meletios Mexis[4], Fabrice Semond[4]; *[1]IEF-CNRS-Univ Paris Sud, France; [2]Univ. Grenoble Alpes, INAC-SP2M, CEA-CNRS, France; [3]L2C-Université Montpellier 2, France; [4]CRHEA-CNRS, France.* We report on near-infrared second harmonic generation in a free-standing gallium nitride photonic crystal cavity fabricated on a silicon substrate. High-resolution spatial imaging allows us to correlate harmonic emission pattern and second-order polarization P_z.

STu2I.5 • 11:45
Resonant Wavelength Conversion in Gallium Phosphide Nanostructures, David Lake[1,2], Matthew Mitchell[1,2], Aaron Hryciw[2], Harishankar Jayakumar[1], Paul E. Barclay[1,2]; *[1]Physics, Univ. of Calgary, Canada; [2]NRC-National Inst. for Nanotechnology, Canada.* Second Harmonic Generation in gallium phosphide microdisks is demonstrated.

CLEO: Applications & Technology

ATu2J • Solar Optics and Cells—Continued

ATu2J.3 • 11:15 Invited
High Concentration Solar Photovoltaic Systems using Glass Dish Collectors, Roger P. Angel[2,1]; *[1]Univ. of Arizona, USA; [2]REhnu, Inc, USA.* Glass solar reflectors, similar to those widely used to concentrate sunlight in solar thermal plants, form the basis for REhnu's HCPV generators. Multijunction cells are housed in small, upgradeable units at each mirror focus.

ATu2J.4 • 11:45
Microcavity-Integrated Colored Perovskite Solar Cells, Kyu-Tae Lee[1], Masanori Fukuda[1], Chengang Ji[1], L. Jay Guo[1]; *[1]EECS, Univ. of Michigan, USA.* We demonstrate optical cavity-embedded perovskite solar cells capable of creating transmissive colors that can be easily tuned by altering the spacer layer thickness in the cavity and simultaneously generating ~4% of power conversion efficiency.

CLEO: Science & Innovations

STu2K • Computational Bioimaging—Continued

STu2K.4 • 11:15
Compressive 39.6-gigapixel/s continuous imaging using spectrally-structured ultrafast laser pulses, Bryan T. Bosworth[1], Jasper Stroud[1], Dung Tran[1], Trac Tran[1], Sang Chin[1], Mark A. Foster[1]; *[1]Johns Hopkins Univ., USA.* We demonstrate ultrahigh-speed spectral shaping of broadband laser pulses to create structured illumination of a high-speed flow for compressive microscopy. We achieve up to 39.6 gigapixel/s continuous imaging rates using a 720-MHz ADC sampling rate.

STu2K.5 • 11:30
Compressive Optical Imaging Using Wavelength Dependent Scattering, Jaewook Shin[1], Mark A. Foster[1]; *[1]Johns Hopkins Univ., USA.* We demonstrate 2D compressive image reconstruction from wavelength-defined illumination patterns generated by wavelength-dependent scattering from a single-mode fiber with a TiO_2-tip.

STu2K.6 • 11:45
Field-Portable Nanoparticle and Virus Sizing Enabled by On-Chip Microscopy and Vapor-Condensed Nanolenses, Euan McLeod[1], T. U. Dincer[1], Muhammed Veli[1], Yavuz N. Ertas[1], Chau Nguyen[1], Wei Luo[1], Alon Greenbaum[1,2], Alborz Feizi[1], Aydogan Ozcan[1]; *[1]Univ. of California Los Angeles, USA; [2]California Inst. of Technology, USA.* Vapor-condensed nanolenses make label-free lensfree holographic microscopy sensitive to individual particles 40 nm and larger. Detected signals correlate with particle size with accuracy ±11 nm. Automated image processing measures >10^5 particles within a single field-of-view.

STu2L • Symposium on Breaking Limits with Unconventional Optical Fields II—Continued

STu2L.3 • 11:15
Multiple Wavefront Shaping by a Single Gradient Metasurface, Nir Shitrit[1], Dekel Veksler[1], Elhanan Maguid[1], Dror Ozeri[1], Vladimir Kleiner[1], Erez Hasman[1]; *[1]Technion-Israel Inst. of Technology, Israel.* We report on a generic concept to control multiple wavefronts by disordered gradient metasurfaces (DGMs) with a custom-tailored geometric phase. DGMs offer all-optical manipulation by multitask wavefront shaping via a single ultrathin photonic nanodevice.

STu2L.4 • 11:30 Invited
Cylindrical Vector Beams for Spectroscopic Imaging of Single Molecules and Nanoparticles and Localization with Nanometer Precision in Tunable Microresonators, Alfred J. Meixner[1]; *[1]Eberhard-Karls-Univ, Germany.* Due to their unique polarization properties cylindrical vector beams are ideal for imaging and spectroscopy single nanoparticles or quantum systems in confocal optical microscopy with a high numerical aperture objective lens or a parabolic mirror.

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Marriott Salon III

CLEO: Applications & Technology

ATu2M • Process Controls, Monitoring & Novel Sources—Continued

ATu2M.3 • 11:15
Direct Calorimetric Measurement of Powder Absorptivity, Alexander M. Rubenchik[1], Sheldon S. Wu[1], Mary M. LeBlanc[1], Scott C. Mitchell[1], Noel L. Peterson[1], Ilya V. Golosker[1]; [1]*Lawrence Livermore National Lab, USA.* We present a method for direct calorimetric measurement of powder absorptivity using a thin laser illuminated disc. Powder porosity is measured independently and a scheme eliminating the effect of convective and radiative losses is implemented.

ATu2M.4 • 11:30
Withdrawn

ATu2M.5 • 11:45
Robust Non-Reciprocal Optical DC Phase Shift Measurement with Differential Modulation Phase Detection, Xun Gu[1], Sergio V. Marchese[1], Klaus Bohnert[1]; [1]*Corporate Research, ABB Switzerland Ltd, Switzerland.* We propose and experimentally demonstrate a novel differential modulation phase detection scheme, which unleashes the powerful modulation phase detection technique for use in sensors with a bulk-optic sensing element, such as an electro-optic voltage sensor.

Marriott Salon V & VI

CLEO: Science & Innovations

STu2N • Control & Diagnostics—Continued

STu2N.4 • 11:15
Adaptive Laser Beam Shaping with a Linearized Transport-of-Intensity Equation, Leonardo Blanco[1], Nicolas Védrenne[2], Vincent Michau[2], Laurent M. Mugnier[2], Gilles Cheriaux[1,3]; [1]*Laboratoire d'Optique Appliquée - ENSTA, France;* [2]*DOTA, ONERA - The French Aerospace Lab, France;* [3]*LULI, Ecole Polytechnique, France.* We present a novel method to control the phase and amplitude of a femtosecond laser beam using a linearized version of the transport-of-intensity equation. Simulations show a peak power improvement better than 30\%.

STu2N.5 • 11:30
High-throughput Lensfree Ion-Track Analysis for Laser-Driven Accelerators, Wei Luo[1], Faizan Shabbir[1], Chao Gong[1], Cagatay Gulec[1], Jeremy Pigeon[1], Jessica Shaw[1], Alon Greenbaum[1], Ting-wei Su[1], Ahmet F. Coskun[1], Sergei Tochitsky[1], Chandrashekhar Joshi[1], Aydogan Ozcan[1]; [1]*Univ. of California Los Angeles, USA.* We report a lensfree imaging based high-throughput ion-track analysis platform for laser driven accelerators. This computational on-chip imaging platform, owing to its large field-of-view of 18cm^2, provides >20-fold improved imaging speed than lens-based analysis systems

STu2N.6 • 11:45
A Time-Multiplexed Pulse-Shaping System for Generating Multiple High-Bandwidth, Low-Jitter Optical Waveforms, Christophe Dorrer[1], Wade Bittle[1], Robert Cuffney[1], Elizabeth Hill[1], John Kelly[1], Tanya Kosc[1], Jonathan D. Zuegel[1]; [1]*Univ. of Rochester, USA.* A time-multiplexed fiber-based system that can deliver eight low-jitter optical waveforms to eight distinct laser systems using a single Mach-Zehnder pulse-shaper driven by an arbitrary waveform generator and a low-loss, high-extinction demultiplexer is described.

CLEO: QELS-Fundamental Science

FTu2A • Quantum Entanglement II—Continued

FTu2A.7 • 12:00
Multi-photon Generation and Interference in an Interferometric Optical Fiber Gyroscope, Tianzhu Niu[1], Shuai Dong[1], Wei Zhang[1], Junjie Wu[2], Weijun Zhang[2], Lixing You[2], Yidong Huang[1], Zhen Wang[2]; *[1]Tsinghua Univ., China; [2]Shanghai Inst. of Microsystem and Information Technology, China.* Two-photon and four-photon interference are realized in an interferometric fiber optical gyroscope, respectively. The visibility of four-photon interference fringe is 29.4% with a high coincidence count rate of 1000 per minute.

FTu2A.8 • 12:15
Experimental Tests of Nonlocality with Entangled Photons, Bradley Christensen[1], Nicolas Gisin[2], Nicolas Brunner[3,4], Yeong-Cherng Liang[5], Paul kwiat[1]; *[1]Univ. of Illinois, USA; [2]Group of Applied Physics, Université de Genéve, Switzerland; [3]Département de Physique Théorique, Université de Genéve, Switzerland; [4]H. H. Wills Physics Lab, Univ. of Bristol, UK; [5]Inst. for Theoretical Physics, ETH Zurich, Switzerland.* We report on a variety of Bell tests performed with a high-quality photonic entanglement source. These tests begin to quantify nonlocal resources available in quantum mechanics, as well as place bounds on beyond-quantum theories.

FTu2B • Quantum Optics in Semiconductor Microcavities—Continued

FTu2B.4 • 12:00
Polariton Condensates in Complex Potential Landscapes, Christian Schneider[1], Karol Winkler[1], Anne Schade[1], Robert Dall[2], Matthias Amthor[1], Elena Ostrovskaya[2], Martin Kamp[1], Sven Hoefling[1,3]; *[1]Univeristy of Würzburg, Germany; [2]Australian National Univ., Australia; [3]Univ. of St. Andrews, UK.* We establish a technology which allows for deep and tunable polariton trapping. Pronounced band structures with full gaps and condensation at high symmetry points is observed in square lattice arrangements of evanescently coupled potential traps.

FTu2B.5 • 12:15
Withdrawn

FTu2C • Topological Photonics I—Continued

FTu2C.7 • 12:00
Parity-time (PT) symmetric topological interface states, Steffen Weimann[2], Mikael Rechtsman[3,4], Yonatan Plotnik[3], Yaakov Lumer[3], Konstantinos Makris[5,1], Mordechai Segev[3], Alexander Szameit[2]; *[1]Princeton Univ., USA; [2]Inst. of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Germany; [3]Physics Dept. and Solid State Inst., Technion-Israel Inst. of Technology, Israel; [4]Physics Dept., The Pennsylvania State Univ., USA; [5]Inst. for Theoretical Physics, Vienna Univ. of Technology, Austria.* We demonstrate theoretically and experimentally topological interface states in a passive effective PT-symmetric dimerized waveguide array. The PT-symmetric system has unbroken PT symmetry: all eigenvalues in the spectrum are real, despite the system's non-Hermiticity.

JOINT

JTu2D • Symposium on Advanced Optical Microscopy for Brain Imaging II—Continued

JTu2D.4 • 12:00 Invited
Ultrafast Fluorescent Probes for Brain Activity Imaging, Michael Lin[1]; *[1]Depts. of Pediatrics and Bioengineering, Stanford Univ., USA.* Methods for visualizing electrical activity in neurons would be useful for understanding circuit function. We describe the ASAP family of voltage indicators featuring cofactor independence, bright fluorescence, large responses, efficient membrane localization, and fast kinetics.

12:30–13:30 Lunch *(on your own)*

13:30–14:30 JTu3A • Plenary Session II, *Grand Ballroom*

14:30–20:00 Exhibition Open, *Exhibit Halls 1 & 2*

14:30–16:00 Coffee Break (14:30–15:00) and Unopposed Exhibit Only Time, *Exhibit Hall*

15:00–17:00 Market Focus: Spectroscopy and Gas Sensing, *Exhibit Hall Theater*

CLEO: QELS-Fundamental Science

FTu2E • Plasmonic Nanoantennas and Nanocavities—Continued

FTu2E.7 • 12:00
Localized Surface Phonon Polariton Resonators in GaN, Kaijun Feng[1], William Streyer[2], S.M. Islam[1], Jai Verma[1], Debdeep Jena[1], Dan Wasserman[2], Anthony Hoffman[1]; *[1]Univ. of Notre Dame, USA; [2]Univ. of Illinois Urbana Champaign, USA.* GaN micro-disk resonator arrays were fabricated and measured within the Restrahalen band of GaN. Far-IR spectroscopy shows evidence for localized surface phonon polariton resonances, results which are confirmed by finite-element models of the fabricated structures.

FTu2E.8 • 12:15
Plasmonic whispering-gallery modes in a semiconductor-insulator-metal hybrid structure, Chien-Ju Lee[1], Han Yeh[1], Yen-Chun Chen[2], Chun-Yuan Wang[2], Shangir Gwo[2], Jer-Shing Huang[3], Wen-Hao Chang[1]; *[1]Dept. of Electrophysics, National Chiao Tung Univ., Taiwan; [2]Dept. of Physics, National Tsing Hua Univ., Taiwan; [3]Dept. of Chemistry, National Tsing Hua Univ., Taiwan.* We demonstrate a plasmonic cavity based on a hybrid semiconductor-insulator-metal structure, which can support plasmonic whispering-gallery modes (WGMs). By optimizing the insulator gap thickness, coupled modes consisting of photonic and plasmonic WGM with efficient cavity feedback can be formed.

CLEO: Science & Innovations

STu2F • Optical Interconnect on Chip—Continued

STu2F.6 • 12:00
Si_3N_4 Multilayer Platform for Photonic Integrated Circuits, Kuanping Shang[1], Shibnath Pathak[1], Binbin Guan[1], Guangyao Liu[1], Chuan Qin[1], Ryan P. Scott[1], S.J.B. Yoo[1]; *[1]Univ. of California, Davis, USA.* We design, fabricate, and demonstrate an optimized silicon nitride multilayer platform including ultra-low interlayer vertical coupling loss of 0.05 dB, multilayer crossing loss of 0.265 dB at 90o crossing angle, and 50 μm bending radius.

STu2F.7 • 12:15
Crystalline Silicon on Silicon Nitride Hybrid Platform for Integrated Photonic Applications, Amir Hossein Hosseinnia[1], Amir H. Atabaki[1], Qing Li[1], Hesam Moradinejad[1], Majid Sodagar[1], Farshid Ghasemi[1], Ali Eftekhar[1], Ali Adibi[1]; *[1]Georgia Inst. of Technology, USA.* We demonstrate a hybrid material platform, in which a layer of crystalline silicon is placed on top of a silicon nitride on a silicon dioxide die. We also report an efficient interlayer coupling structure with 0.02 dB insertion loss. Using this hybrid platform, high-Q resonators are demonstrated.

STu2G • Cascade Lasers II—Continued

STu2G.4 • 12:00
Ultra-Broadband (3.3-12.5 μm) Single Stack Quantum Cascade Gain Medium, Loan Le[1], Xiaojun Wang[2], Jen-Yu Fan[2], Mariano Troccoli[2], Deborah L. Sivco[1], Claire F. Gmachl[1]; *[1]Princeton Univ., USA; [2]AdTech Optics Inc., USA.* Electroluminescence spanning 3.3μm to 12.5μm and with a full width half maximum of 4μm is achieved using a single stack quantum cascade gain medium. The free-running laser emits from 7.4μm to 12.1μm.

STu2G.5 • 12:15
High Power Spiral Cavity Quantum Cascade Superluminescent Emitter , Mei Chai Zheng[1], Nyan L. Aung[1], Abanti Basak[1], Peter Q. Liu[2], Xiaojun Wang[3], Jen-Yu Fan[3], Mariano Troccoli[3], Claire F. Gmachl[1]; *[1]Princeton Univ., USA; [2]Inst. of Quantum Electronics, ETH Zürich, Switzerland; [3]AdTech Optics Inc., USA.* Quantum cascade devices have been shaped into compact, yet long spiral cavities to increase mid-infrared superluminescence power. A peak power of ~57 mW at 250 K is obtained with a coherence length of ~107 μm.

STu2H • THz Spectroscopy of Graphene and Magnetic Materials—Continued

STu2H.6 • 12:00
Polarization-Dependent Terahertz Spectroscopy of Macroscopically Aligned Carbon Nanotubes, Weilu Gao[1], Ahmed Zubair[1], John Robinson[1], Xiaowei He[1], Colin C. Young[2], Dmitri Tsentalovich[2], Noe Alvarez[3], Robert Hauge[4], Matteo Pasquali[2,4], Junichiro Kono[1,5]; *[1]Dept. of Electrical and Computer Engineering, Rice Univ., USA; [2]Dept. of Chemical and Biomolecular Engineering, Rice Univ., USA; [3]Dept. of Mechanical, Industrial and Nuclear Engineering, Univ. of Cincinnati, USA; [4]Dept. of Chemistry, Rice Univ., USA; [5]Dept. of Physics and Astronomy, Rice Univ., USA.* We have examined the anisotropic terahertz response of highly aligned single-wall, double-wall, and multiwall carbon nanotubes and quantitatively characterized their performance as low-cost terahertz polarizers.

12:30–13:30 Lunch *(on your own)*

13:30–14:30 JTu3A • Plenary Session II, *Grand Ballroom*

14:30–20:00 Exhibition Open, *Exhibit Halls 1 & 2*

14:30–16:00 Coffee Break (14:30–15:00) and Unopposed Exhibit Only Time, *Exhibit Hall*

15:00–17:00 Market Focus: Spectroscopy and Gas Sensing, *Exhibit Hall Theater*

CLEO: Science & Innovations

STu2I • Nonlinear Optics in Microresonators and Nanostructures—Continued

STu2I.6 • 12:00
Coherent Second Harmonic Generation in a Quantum Well-Metasurface Coupled System, omri wolf[1], Salvatore Campione[1], Alexander Benz[1], Arvind P. Ravikumar[2], Sheng Liu[1], Emil A. Kadlec[1], Eric Shaner[1], John F. Klem[1], Michael B. Sinclair[1], Igal Brener[1]; [1]*Sandia National Lab, USA;* [2]*Princeton Univ., USA*. Strongly coupling metallic nanoresonators with specially designed intersubband-transitions in quantum-wells results in efficient, saturation-limited second-harmonic (SH) generation. This method also grants full control over the polarization and phase-front of the emitted SH radiation.

STu2I.7 • 12:15
Low-Power Parametric Wavelength Conversion in 45nm Microelectronics CMOS Silicon-On-Insulator Technology, Cale M. Gentry[1], Mark T. Wade[1], Xiaoge Zeng[1], Fabio Pavanello[1], Milos Popovic[1]; [1]*Univ. of Colorado at Boulder, USA*. We demonstrate seeded four-wave mixing in a photonic circuit fabricated within an unmodified commercial microelectronics CMOS SOI platform, using a minimally dispersive microcavity design.

CLEO: Applications & Technology

ATu2J • Solar Optics and Cells—Continued

ATu2J.5 • 12:00 Invited
Wide-angle Nonimaging Optics for Concentration and Illumination; Principles and Applications, Roland Winston[1]; [1]*Univ. of California Merced, USA*. Nonimaging designs allow non-tracking wide angle solar concentrators to attain high temperature operation. Of special interest to the optics community is the deep connection between the "Hottel strings" and the flow-line algorithm of nonimaging optics design.

CLEO: Science & Innovations

STu2K • Computational Bioimaging—Continued

STu2K.7 • 12:00
A cannula-based computational fluorescence microscope for neuronal imaging, Ganghun Kim[1], Naveen Nagarajan[1], Amihai Meiri[1], Sean Merrill[1], Mario Capecchi[1], Erik Jorgensen[1], Rajesh Menon[1]; [1]*Univ. of Utah, USA*. We applied nonlinear optimization to convert a cannula into a high-resolution computational-fluorescence microscope. The microscope was used to image fluorescent microspheres, genetically-encoded mouse-brain slices, genetically-encoded and fluorescent-stained C. *elegans* nematodes.

STu2K.8 • 12:15
Adaptive Optics in Three-Photon Fluorescence Microscopy, David Sinefeld[1], Hari P. Paudel[2], Dimitre G. Ouzounov[1], Thomas G. Bifano[2], Chris Xu[1]; [1]*Applied and engineering physics, Cornell Univ., USA;* [2]*Photonics Center, Boston Univ., USA*. We demonstrate three-photon fluorescence adaptive-optics system based on 1660-nm femtosecond pulses and MEMS spatial light modulator. We use the higher nonlinearity of the signal resulting in ×700 improvement in fluorescence beads signal after aberrations correction.

STu2L • Symposium on Breaking Limits with Unconventional Optical Fields II—Continued

STu2L.5 • 12:00 Invited
Smaller Spot Formation by Vector Beam for Higher Resolution Microscopy, Shunichi Sato[1], Yuichi Kozawa[1]; [1]*Tohoku Univ., Japan*. Smaller focal spot formation by using vector beams is demonstrated for achieving higher lateral resolution, which is beyond conventional diffraction limit, in confocal microscopy, two-photon microscopy and subtraction microscopy.

12:30–13:30 Lunch *(on your own)*

13:30–14:30 JTu3A • Plenary Session II, *Grand Ballroom*

14:30–20:00 Exhibition Open, *Exhibit Halls 1 & 2*

14:30–16:00 Coffee Break (14:30–15:00) and Unopposed Exhibit Only Time, *Exhibit Hall*

15:00–17:00 Market Focus: Spectroscopy and Gas Sensing, *Exhibit Hall Theater*

Marriott Salon III

CLEO: Applications & Technology

ATu2M • Process Controls, Monitoring & Novel Sources—Continued

ATu2M.6 • 12:00
Demonstration of Soliton Self Shifting Employing Er^{3+} Doped VLMA- and HOM-Fiber Amplifiers, Armin Zach[1], Wilhelm Kaenders[1], Jeffrey W. Nicholson[2], John M. Fini[2], Anthony DeSantolo[2]; *[1]TOPTICA Photonics AG, Germany; [2]OFS Labs, USA.* We demonstrate soliton self-frequency shifted Very-Large-Mode-Area and Higher-Order-Mode fiber amplifiers. The output wavelength is shifted more than 50 nm with a soliton pulse energy of up to 186 nJ. Subsequent, high-efficiency, frequency doubling is demonstrated.

ATu2M.7 • 12:15
Difference-frequency Generation of Spectrally Bright, ~1 W Average-power Mid-IR Radiation Using a ns-pulse Fiber Laser, Paul Belden[1], DaWun Chen[1], Fabio Di Teodoro[1]; *[1]The Aerospace Corporation, USA.* We obtained average power/pulse energy of ~1W/5mJ at ~3520nm wavelength via difference-frequency generation in periodically poled lithium niobate using an all-fiber, few-ns pulsed laser source operating at 1064nm and a 10mW continuous-wave 1525 nm single-frequency diode laser.

Marriott Salon V & VI

CLEO: Science & Innovations

STu2N • Control & Diagnostics—Continued

STu2N.7 • 12:00
Sub-Femtosecond Free-Electron Laser Pulses, Wolfram Helml[1], Andreas R. Maier[2], Wolfgang Schweinberger[3], Ivanka Grguras[2], Paul Radcliffe[4], Gilles Doumy[5], Chris Roedig[6], Justin Gagnon[3], Marc Messerschmidt[7], Sebastian Schorb[7], Christoph Bostedt[7], Florian Grüner[2], Louis F. DiMauro[6], Denis Cubaynes[8], John D. Bozek[7], Thomas Tschentscher[4], John T. Costello[9], Michael Meyer[4], Ryan Coffee[7], Stefan Düsterer[10], Adrian L. Cavalieri[2], Reinhard Kienberger[1]; *[1]Physik-Dept., Technische Universität München, Germany; [2]CFEL, Germany; [3]Max-Planck-Institut für Quantenoptik, Germany; [4]European XFEL, Germany; [5]Argonne National Lab, USA; [6]Ohio State Univ., USA; [7]LCLS, USA; [8]Institut des Sciences Moléculaires d'Orsay, France; [9]School of Physical Sciences and National Center for Plasma Science and Technology, Ireland; [10]DESY, Germany.* Deploying the so-called 'Streaking Spectroscopy' technique at LCLS, we demonstrate a non-invasive scheme for temporal characterization of X-ray pulses with sub-femtosecond resolution. Analyzing the substructure indicates pulse durations on the order of hundreds of attoseconds.

STu2N.8 • 12:15
Remote two-color optical-to-optical synchronization between two passively mode-locked lasers, Heng Li[1,2], Li-Jin Chen[3], Haynes Pak Hay Cheng[3], Justin E. May[2], Steve Smith[2], Kerstin Muehlig[2], Akshaya Uttamadoss[2,4], Josef C. Frisch[2], Alan Fry[2], Franz Kaernter[5,6], Philip H. Bucksbaum[1,2]; *[1]Stanford Univ., USA; [2]SLAC National Accelerator Lab, USA; [3]Idesta Quantum Electronics, LLC., USA; [4]Dept. of Electrical Engineering, Princeton Univ., USA; [5]Dept. of Electrical Engineering and Computer Science, and Research Lab of Electronics, MIT, USA; [6]Center for Free-Electron Laser Science, and Physics Dept., DESY, and Univ. of Hamburg, Germany.* We present remote two-color optical-to-optical synchronization between a Ti:sapphire and Er-doped fiber laser through 360 m single-mode fiber with 3.3 fs rms jitter over 24 hours.

12:30–13:30 Lunch *(on your own)*

13:30–14:30 JTu3A • Plenary Session II, *Grand Ballroom*

14:30–20:00 Exhibition Open, *Exhibit Halls 1 & 2*

14:30–16:00 Coffee Break (14:30–15:00) and Unopposed Exhibit Only Time, *Exhibit Hall*

15:00–17:00 Market Focus: Spectroscopy and Gas Sensing, *Exhibit Hall Theater*

CLEO: QELS-Fundamental Science

16:00–18:00
FTu4A • Fundamental Quantum Optics
Presider: William Munro; NTT Basic Research Labs, Japan

FTu4A.1 • 16:00
Direct measurement of the Wigner function by photon-number-resolving detection, Niranjan Sridhar[1], Reihaneh Shahrokhshahi[1], Aaron Miller[2], Thomas Gerrits[3], Adriana Lita[3], Sae Woo Nam[3], Olivier Pfister[1]; *[1]Univ. of Virginia, USA; [2]Albion College, USA; [3]National Inst. of Standards and Technology, USA.* We extended the seminal experiment of Banaszek et al. of quantum tomography by photon counting without Radon transform postprocessing to the more general case of photon fluxes with more than one photon per detection time.

FTu4A.2 • 16:15
Direct measurement of the quantum density matrix in the basis of azimuthal angle, Mohammad Mirhosseini[1], Omar S. Magaña-Loaiza[1], Seyed Mohammad Hashemi Rafsanjani[1], Changchen Chen[1], Ebrahim Karimi[2], Robert W. Boyd[2,1]; *[1]Inst. of Optics, Univ. of Rochester, USA; [2]Dept. of Physics, Univ. of Ottawa, Canada.* We theoretically propose and experimentally demonstrate a method for directly measuring the density matrix of an unknown quantum system in the basis of azimuthal angle. We apply our method for characterizing 7-dimensional pure and mixed superpositions of orbital-angular-momentum modes.

FTu4A.3 • 16:30
Quantum Process Estimation with Unknown Measurements, Brian J. Smith[1], Merlin Cooper[1], Michal Karpinski[1]; *[1]Univ. of Oxford, UK.* Quantum process estimation without assumptions about measurements used is presented. The detector response is characterized with a finite set of probe states. Numerical simulations for quantum optical processes demonstrate the technique for complex systems.

16:00–18:00
FTu4B • Light-matter Interaction in Graphene/Other Carbon-based Materials
Presider: Keshav Dani; OIST, Japan

FTu4B.1 • 16:00
Ultrafast electron diffraction can visualize strong-field phenomena in graphene, Vladislav S. Yakovlev[1,3], Ferenc Krausz[2,3], Mark Stockman[1], Peter Baum[2,3]; *[1]Center for Nano-Optics (CeNO), Dept. of Physics and Astronomy, Georgia State Univ., USA; [2]Fakultät für Physik, Ludwig-Maximilians-Universität München, Germany; [3]Attosekundenphysik, Max-Planck-Institut für Quantenoptik, Germany.* We show with simulations that ultrafast electron diffraction can provide snapshots of charge-density evolution in condensed matter with few-femtosecond and sub-atomic resolutions. Using graphene as an example, we discuss real-space aspects of light-matter interaction.

FTu4B.2 • 16:15
Ultrafast Pseudospin Dynamics in Graphene, Alexander Grupp[1], Maxim Trushin[1], Giancarlo Soavi[1,2], Arne Budweg[1], Domenico De Fazio[3], Antonio Lombardo[3], Andrea C. Ferrari[3], Wolfgang Belzig[1], Alfred Leitenstorfer[1], Daniele Brida[1]; *[1]Univeristy of Konstanz, Germany; [2]Dipartimento di Fisica, Politecnico di Milano, Italy; [3]Cambridge Graphene Centre, Cambridge Univ., UK.* We investigate pseudospin-selective ultrafast optical excitation in monolayer graphene. We track the evolution of anisotropy in momentum space as a function of excited carrier density. Results are well described by an analytical model.

FTu4B.3 • 16:30
Lateral Photo-Dember Effect in Graphene, Chang-Hua Liu[1], You-Chia Chang[1], Seunghyun Lee[1], Yaozhong Zhang[2], Yafei Zhang[2], Theodore B. Norris[1], Zhaohui Zhong[1]; *[1]Univ. of Michigan, USA; [2]Shanghai Jiao Tong Univ., China.* The photocurrent at graphene/metal junctions under femtosecond laser excitation is found to have its polarity fully determined by asymmetry in the electron-hole mobility; this suggests the existence of unexpected lateral photo-Dember effect in graphene.

16:00–18:00
FTu4C • Topological Photonics II
Presider: Natalia Litchinitser; State Univ. of New York at Buffalo, USA

FTu4C.1 • 16:00
Optical Topological Transitions in Photonic Hypercrystals, Evgenii E. Narimanov[1]; *[1]Purdue Univ., USA.* We demonstrate that Dirac dispersion cones in photonic hypercrystals originate from an optical topological transition. The resulting singularity in the photonic density of states has a strong effect on the emissivity of the hypercrystal.

FTu4C.2 • 16:15
Observing Light Dynamics in Micro-sized Schwarzschild Metric, Rivka Bekenstein[1], Yossef kabessa[2], Or Tal[1], Miguel A. Bandres[1], Aharon J. Agranat[2], Mordechai Segev[1]; *[1]Physics Dept. and Solid State Inst., Technion Israel Inst. of Technology, Israel; [2]Dept. of Applied Physics and the Brojde Center for Innovative Engineering and Computer Science, Hebrew Univ. of Jerusalem, Israel.* We study the dynamics of light in the Schwarzschild metric using a specifically fabricated micro-sized curved waveguide analogous to the black hole and the whormhole metrics, demonstrating complex dynamics and tunneling through the horizon.

FTu4C.3 • 16:30 Invited
Dirac Plasmons in Topological Insulators, Stefano Lupi[1]; *[1]INFN and Dip. di Fisica, Italy.* Topological Insulators, characterized by 2D Dirac fermions on their surface, sustain Dirac plasmons. In this talk, I will discuss the terahertz response of these plasmons vs. a strong magnetic field, and their sub-ps dynamics.

16:00–18:00
FTu4D • Optical Filamentation and Compression
Presider: Steven Cundiff; Univ. of Colorado at Boulder JILA, USA

FTu4D.1 • 16:00
250-GW Sub-Three-Cycle Multi-Millijoule Mid-IR Pulses Self-Compressed in a YAG plate, Valentina Shumakova[1], Pavel Malevich[1], Skirmantas Alisauskas[1], Aleksander Voronin[3], Aleksei Zheltikov[3,4], Daniele Faccio[5], Daniil Kartashov[6], Raman Maksimenka[7], Gregory Gitzinger[7], Nicolas Forget[7], Andrius Baltuska[1,2], Audrius Pugzlys[1,2]; *[1]Vienna Univ. of Technology, Austria; [2]Center for Physical Sciences & Technology, Lithuania; [3]Physics Dept., International Laser Center, M.V. Lomonosov Moscow State Univ., Russia; [4]Dept. of Physics and Astronomy, Texas A&M Univ., USA; [5]Inst. of Photonics and Quantum Sciences, Heriot-Watt Univ., UK; [6]Friedrich-Schiller Univ. Jena, Germany; [7]FASTLITE, France.* Virtually lossless self-compression of 10-mJ 3.9-um sub-100 fs pulses in bulk YAG resulting in 9-mJ 33-fs pulses is reported. Generated peak power exceeds 250 GW which is suitable for filamentation in ambient air.

FTu4D.2 • 16:15
Mid-IR Filamentation in Dielectrics: 3-octave-spanning Supercontinuum Generation and Sub-2-cycle Self-compression, Hou Kun Liang[1], Peter R. Krogen[1], Ross Grynko[2], Ondrej Novak[1], Chun-Lin L. Chang[1], Gregory J. Stein[1], Darshana Weerawarne[2], Bonggu Shim[2], Franz Kaernter[1,3], Kyung-Han Hong[1]; *[1]MIT, USA; [2]Binghamton Univ., State Univ. of New York, USA; [3]Univ. of Hamburg, Germany.* We report on 3-octave supercontinuum generation from ZnS in the normal dispersion regime and self-compression of mid-IR pulses to sub-2-cycle in CaF_2 in the anomalous dispersion regime. Temporal characterization shows good agreement with 3D simulations.

FTu4D.3 • 16:30
White-light Generation Pumped by Sub-ps Pulse, Anne-Laure Calendron[1,2], Huseyin Cankaya[1,2], Giovanni Cirmi[1,2], Giulio M. Rossi[1,2], Franz Kaertner[1,3]; *[1]Deutsches Elektronen Synchrotron, Germany; [2]Universität Hamburg, The Hamburg Centre for Ultrafast Imaging, Germany; [3]Dept. of Electrical Engineering and Computer Science, MIT-RLE, USA.* The phase and stability characterization of white-light supercontinuum generated by sub-picosecond pulses at 1 μm in YAG and sapphire for different pump focusing and duration shows compressible pulses, suitable for applications like waveform synthesis.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

16:00–18:00
FTu4E • Plasmonic Nanoatennas for Sensing and Focusing
Presider: Arian Kriesch; University of Erlangen, Germany

FTu4E.1 • 16:00
Infrared Vibrational Molecular Hybridization with a Single Optical Antenna, Eric A. Muller[1], Benjamin Pollard[1], Hans Bechtel[2], Ronen Adato[3], Hatice Altug[4], Honghua Yang[1], Michael M. Martin[2], Markus B. Raschke[1]; *[1]Univ. of Colorado Boulder, USA; [2]Advanced Light Source Division, Lawrence Berkeley National Lab, USA; [3]Boston Univ., USA; [4]Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland*. We observe impedance matched coupling between molecular vibrations and infrared optical antennas. Broadband synchrotron near-field spectroscopy reveals antenna-vibration hybridization, mode splitting, and tip excitation of coupled dark plasmon modes.

FTu4E.2 • 16:15
High-Brilliance Mid-Infrared Femtosecond Light Source for Surface-Enhanced Infrared Spectroscop, Frank Neubrech[1], Tobias Steinle[1], Andy Steinmann[1], Xinghui Yin[1], Harald W. Giessen[1]; *[1]Univ. of Stuttgart, Germany.* We combine surface-enhanced infrared absorption and a high brilliance optical parametric light source to enable ultra-sensitive and fast Fourier-transform infrared spectroscopy of only 10 000 molecules; inaccessible with conventional thermal light sources or synchrotron radiation.

FTu4E.3 • 16:30
Plasmonic Nanoantennas on Nanopedestals for Ultra-Sensitive Vibrational IR-Spectroscopy, Dordaneh Etezadi[1], Arif Cetin[1], Hatice Altug[1]; *[1]EPFL, Switzerland.* We experimentally demonstrate that elevating polarization-insensitive nanoring antennas on nanopedestals enables high surface enhanced infrared absorption (SEIRA) signals. This is due to larger and accessible nearfields offering better overlap with biomolecules.

16:00–18:00
STu4F • Components and Optical Interconnects
Presider: Leif Johansson; Freedom Photonics, LLC, USA

STu4F.1 • 16:00
A Comb Laser-Driven DWDM Silicon Photonic Transmitter with Microring Modulator for Optical Interconnect, Chin-Hui (Janet) Chen[1], Tsung-Ching Huang[1], Daniil Livshit[2], Alexey Gubenko[2], Sergey Mikhrin[2], Vladimir Mikhrin[2], Marco Fiorentino[1], Raymond Beausoleil[1]; *[1]Hewlett Packard Company, USA; [2]Innolume GmbH, Germany.* A five-channel microring modulator-based DWDM silicon photonic transmitter driven by a quantum dot comb laser is demonstrated for the first time. 10Gbps eye diagrams are shown at both 25°C and 40°C.

STu4F.2 • 16:15
5 x 20 Gb/s III-V on Silicon Electroabsorption Modulator Array Heterogeneously Integrated with a 1.6nm Channel-Spacing Silicon AWG, Xin Fu[1,2], Qiangsheng Huang[1,2], Yingtao Hu[2], Martijn Tassaert[2], Jochem Verbist[3], Jianxin Cheng[4], Keqi Ma[1], Jianhao Zhang[1], Kaixuan Chen[4], Chenzhao Zhang[4], Yaocheng Shi[1], Johan Bauwelinck[3], Gunther Roelkens[2], Sailing He[1,4]; *[1]Zhejiang Univ., China; [2]Photonics Research Group, Belgium; [3]INTEC_design, Belgium; [4]South China Normal Univ., China.* We demonstrate a five-channel wavelength division multiplexed modulator module that heterogeneously integrates a 1.6nm channel-spacing arrayed-waveguide grating and a 20Gbps electroabsorption modulator array, showing the potential for 100 Gbps capacity on a 1.5x0.5 mm^2 footprint.

STu4F.3 • 16:30 Invited
Demonstration of Error Free Operation Up To 32 Gb/s From a CMOS Integrated Monolithic Nano-Photonic Transmitter, Douglas M. Gill[1], Chi Xiong[1], Jonathan Proesel[1], Jessie Rosenberg[1], John Ellis-Monaghan[2], Jason Orcutt[1], Marwan Khater[1], Doris Viens[3], Yurii A. Vlasov[1], Wilfried Haensch[1], William Green[1]; *[1]IBM T.J. Watson Research Center, USA; [2]Systems & Technology Group, Microelectronics Division, IBM, USA; [3]Systems & Technology Group, Microelectronics Division, IBM, Canada.* We present a monolithic CMOS Integrated Nano Photonic transmitter with a link sensitivity comparable to a 25 Gb/s commercial reference transmitter, exhibiting a 5.2 dB extinction ratio, 4.9 dB insertion loss, and error free operation up to 32 Gb/s.

16:00–18:00
STu4G • Cascade Lasers III
Presider: Jerry Meyer; US Naval Research Lab, USA

STu4G.1 • 16:00
Sampled Grating Quantum Cascade Lasers with High Tuning Stability, Stefan Kalchmair[1], Romain Blanchard[2], Tobias Mansuripur[1], Guy-Mael de Naurois[1], Laurent Diehl[2], Christian Pflügl[2], Mark F. Witinski[2], Federico Capasso[1], Marko Loncar[1]; *[1]Harvard Univ., USA; [2]Eos Photonics, Inc., USA.* We report a sampled grating quantum cascade laser with excellent tuning stability over the full tuning range (106 cm^{-1}). Spatial hole burning and facet reflections can cause unpredictable mode jumping. We present a stabilization method.

STu4G.2 • 16:15
Surface emitting, single-mode quantum cascade laser array, Christopher Bonzon[1], Pierre Jouy[1], Johanna Wolf[1], Martin Suess[1], Mattias Beck[1], Jerome Faist[1]; *[1]ETHZ, Switzerland.* We present the first realization of a single-mode surface-emitting quantum cascade laser array. The ten lasers operate over a bandwidth of 175 cm-1 from 8-10 um and show similar pumping characteristics. The device is suitable for spectroscopic applications due to its continuous wave operation.

STu4G.3 • 16:30
Coherent Beam-Combining of Quantum Cascade Amplifier Arrays, Brian G. Saar[1], Kevin Creedon[1], Leo Missaggia[1], Christine A. Wang[1], Michael K. Connors[1], Joseph Donnelly[1], George W. Turner[1], Antonio Sanchez-Rubio[1], William Herzog[1]; *[1]MIT Lincoln Lab, USA.* We present design, packaging and coherent beam combining of quantum cascade amplifier (QCA) arrays, measurements of QCA phase noise, the drive-current-to-optical-phase transfer function, and the small signal gain for QCAs

16:00–18:00
STu4H • THZ Spectroscopic Techniques
Presider: Philip Taday; TeraView Ltd, UK

STu4H.1 • 16:00
Self-referenced Transient THz Spectroscopy with ABCD Detection, Francesco D'Angelo[1], Sapun Parekh[1], Mischa Bonn[1], Dmitry Turchinovich[1]; *[1]Max Planck Inst. f. Polymer Research, Germany.* A new scheme for simultaneous acquisition of reference and sample THz signals in transient THz spectroscopy with ABCD detection is demonstrated, with demodulation at pump beam chopping and ABCD voltage switching frequencies.

STu4H.2 • 16:15
Electron Dynamics in a Gold Thin Film Accelerated via an Intense Terahertz Field, Yasuo Minami[1], Thang D. Dao[2], Tadaaki Nagao[2], Jun Takeda[1], Masahiro Kitajima[3], Ikufumi Katayama[1]; *[1]Yokohama National Univ., Japan; [2]National Inst. for Materials Science, Japan; [3]LxRay Co. Ltd, Japan*. Nonlinear electron dynamics in gold thin films was observed via intense terahertz spectroscopy. Under the intense terahertz wave illumination, the damping constant of electrons becomes smaller due to the suppression of the grain-boundary effect on electrons induced by the intense terahertz field.

STu4H.3 • 16:30
Time-resolved THz Laser spectra using a Fibre-interfaced Optical Heterodyne system, Thomas Folland[1], Antonio ramospulido[1], owen marshall[1], Harvey Beere[2], David Ritchie[2], Subhasish Chakraborty[1]; *[1]Univ. of Manchester, UK; [2]Univ. of Cambridge, UK.* We report the first fully fibre-interfaced heterodyne system for time-resolved spectral characterization of THz quantum cascade lasers. By exploiting the bias probe rise time we study the current dependant mode tuning with 50ns temporal resolution.

CLEO: Science & Innovations

16:00–18:00
STu4I • Mid-IR Photonics
Presider: Bernhard Lendl; Technische Universität Wien, USA

STu4I.1 • 16:00
Nano-Silicon-Photonic Fourier Transform Infrared (FTIR) Spectrometer-on-a-Chip, Bin Dong[1,2], Hong Cai[2], Yuandong Gu[2], Zhenchuan Yang[3], Yufeng Jin[3], Yilong Hao[3], Dimlee Kwong[2], Ai-Qun LIU[1]; *[1]Nanyang Technological Univ., Singapore; [2]Inst. of Microelectronics, Singapore; [3]Peking Univ., China.* This paper reports a nano-silicon-photonic Fourier transform infrared (FTIR) spectrometer-on-a-chip, which is integrated with fiber-waveguide coupler and photo detector on a waveguide based silicon photonic chip.

STu4I.2 • 16:15
Monolithically Integrated Quantum Cascade Lasers, Detectors and Dielectric Waveguides at 9.5μm for Far-Infrared Lab-on-Chip Chemical Sensing, Yi Zou[1], Karun Vijayraghavan[1], Parker Wray[1], Swapnajit Chakravarty[2], Mikhail A. Belkin[1], Ray T. Chen[1,2]; *[1]Univ. of Texas at Austin, USA; [2]Omega Optics Inc., USA.* We provide the first experimental demonstration of room temperature far-infrared lab-on-chip chemical sensing via monolithic integration of quantum cascade laser, quantum cascade detector and dielectric waveguides at the long infrared wavelength of 9.5μm.

STu4I.3 • 16:30
Experimental Demonstration of Mid-Infrared Holey and Slotted Photonic Crystal Waveguides in Silicon on Sapphire, Yi Zou[1], Parker Wray[1], Swapnajit Chakravarty[2], Ray T. Chen[1,2]; *[1]Univ. of Texas at Austin, USA; [2]Omega Optics Inc., USA.* We provide the first experimental demonstration of propagation characteristics of holey and slotted two dimensional photonic crystal waveguides in silicon-on-sapphire at mid-infrared wavelength of 3.43μm.

CLEO: Applications & Technology

16:00–18:00
ATu4J • Environmental Sensing
Presider: Mark Phillips; Pacific Northwest National Lab, USA

ATu4J.1 • 16:00 Invited
Nitrogen oxide radicals and organic nitrate photochemistry in Earth's atmosphere, Ronald Cohen[1]; *[1]Univ. of California Berkeley, USA.* Textbook descriptions of atmospheric nitrogen oxide photochemistry focus on the role of NOx as a control over OH and on limiting behavior at high and low NOx. In this talk I will explore the intermediate NOx regime, focusing on the role of organic nitrates as a control over atmospheric NOx and HOx free radicals.

ATu4J.2 • 16:30
Transportable Dual-Modulation Faraday Rotation Spectrometer for Time-Multiplexed Nitric Oxide Isotope Ratiometry, Eric J. Zhang[1], Stacey Huang[1], Michael Silvernagel[2], Gerard Wysocki[1]; *[1]Electrical Engineering, Princeton Univ., USA; [2]Electrical Engineering, Univ. of Notre Dame, USA.* We present a transportable dual-modulation Faraday rotation spectrometer with minor isotope (15NO) detection sensitivity of 0.35 ppbv·Hz-1/2, corresponding to 1.4x the shot-noise limit. NO isotope line-switching is implemented for quasi-simultaneous time-multiplexed isotope measurements.

CLEO: Science & Innovations

16:00–18:00
STu4K • Biosensing
Presider: Ralph Jimenez; Univ. of Colorado at Boulder, USA

STu4K.1 • 16:00 Invited
Micro-Cavity based Force Sensors - A Novel and Simple Interferometric Tool for Cell-Mechanical Investigations, Nils M. Kronenberg[1], Philipp Liehm[1], Anja Steude[1], Malte C. Gather[1]; *[1]Univ. of St Andrews, UK.* We have developed a completely new approach to measure vertical and horizontal forces of biological cells cultured on 2D substrata by interferometrically detecting deformations of a soft micro-resonator with an elastic filling.

STu4K.2 • 16:30
Wide Dynamic Range Specific Detection of Therapeutic Drugs by Photonic Crystal Microcavity Arrays, Hai Yan[1], Chun-Ju Yang[1], Yi Zou[1], Naimei Tang[1,2], Swapnajit Chakravarty[2], Ray T. Chen[1,2]; *[1]The Univ. of Texas at Austin, USA; [2]Omega Optics Inc., USA.* Six orders of magnitude wide dynamic range (0.1ng/ml to over 100μg/ml), label-free detection of gentamicin small molecules with silicon photonic crystal microcavity biosensors multiplexed by multimode interference power splitters was experimentally demonstrated. Detection specificity was confirmed.

16:00–18:00
STu4L • Higher-Order Modes & Mode Coupling in Fiber
Presider: Poul Kristensen; OFS Fitel Denmark I/S, Denmark

STu4L.1 • 16:00 Invited
Astrophotonics: The Future of Astronomical Instrumentation, Joss Bland-Hawthorn[1]; *[1]Univ. of Sydney, Australia.* Astrophotonics has already made important contributions to astronomical and space instrumentation. The early developments built on technologies arising out of telecommunications but the field has begun to "give back" to traditional photonic fields.

STu4L.2 • 16:30
Input and Output Coupling in Higher Order Mode Fibers, Jeffrey Demas[1], Lars Rishoej[1], Siddharth Ramachandran[1]; *[1]Boston Univ., USA.* We convert higher order fiber modes into Gaussian beams using binary phase plates, and characterize the resulting M^2 and coupling efficiency to single-mode fiber (~64%). Reciprocally, the system is used to excite modes in multi-mode fiber with purity >13dB.

CLEO: Applications & Technology

CLEO: Science & Innovations

16:00–18:00
ATu4M • Novel Sources for Industrial Applications
Presider: Richard Solarz; KLA-Tencor Corp, USA

ATu4M.1 • 16:00 Invited
Lasers in the 2um SWIR spectral regime and their Applications, Tony Hoult[1]; [1]*IPG Photonics Corp, USA*. For a particular laser type to be widely adopted for industrial materials processing, a minimum laser power is required. The development of supra 100 watt thulium fiber lasers means that another laser type has now been added to that relatively short list.

ATu4M.2 • 16:30 Invited
High Power Laser-Sustained Plasma Lightsources for KLA-Tencor Broadband Inspection Tools, Ilya Bezel[1], Gil Delgado[1], Matthew Derstine[1], Ken Gross[1], Richard Solarz[1], Anatoly Shchemelinin[1], David Shortt[1]; [1]*KLA-Tencor Corp, USA*. For the last 8 years, the brightness of UV lightsources in KT Broadband inspection tools increased by orders of magnitude due to advances in LSP technology. Challenges of LSP in high-power regime are discussed here.

16:00–18:00
STu4N • Ultrafast Imaging and Spectroscopy
Presider: Cristian Manzoni; IFN-CNR, Italy

STu4N.1 • 16:00
Motion Picture Femtophotography with Sequentially Timed All-optical Mapping Photography, keiichi nakagawa[1], Atsushi Iwasaki[1], Yu Oishi[2], Ryoichi Horisaki[3], Akira Tsukamoto[4], Aoi Nakamura[5], Kenichi Hirosawa[5], Hongen Liao[1], Takashi Ushida[1], Keisuke Goda[1,6], Fumihiko Kannari[5], Ichiro Sakuma[1]; [1]*Univ. of Tokyo, USA;* [2]*RIKEN, Japan;* [3]*Osaka Univ., Japan;* [4]*National Defense Academy, Japan;* [5]*Keio Univ., Japan;* [6]*Univ. of California, Los Angeles, Armenia*. We present a method for motion-picture femtophotography that performs continuous, single-shot, burst image acquisition without the need for repetitive measurements. We capture the dynamics of laser ablation and phonon propagation with the imaging method.

STu4N.2 • 16:15
Ultrafast Imaging using Simultaneous Spatially and Temporally Resolved Wavelength-Multiplexed Photography (SSTWP), Takakazu Suzuki[1], Fumihiro Isa[1], Leo Fujii[1], Kenichi Hirosawa[1], Fumihiko Kannari[1]; [1]*Keio Univ., Japan*. We propose and experimentally demonstrate the simultaneous spatially and temporally resolved wavelength-multiplexed photography device (SSTWP) with a diffractive optical element and a band-pass filter. Using frequency chirped pulses, we realize ultrafast imaging.

STu4N.3 • 16:30
Imaging through permuted optical probes, Barmak Heshmat[1], IK Hyun Lee[1], Hisham Bedri[1], Ramesh Raskar[1]; [1]*MIT, USA*. Using time of flight we have enabled an optical brush to calibrate itself and image with its randomly positioned fibers, this offers a flexible field of view and is intrinsically multi-spectral. Therefore, it has potential application for endoscopy, imaging in turbid media and near-field probing.

16:00–18:00
STu4O • OPCPA Systems & Pump Lasers
Presider: Constantin Haefner; Lawrence Livermore National Lab, USA

STu4O.1 • 16:00 Invited
Scaling High Peak Powers to High Average Powers - Opportunities in Innovation and Technology, John L. Collier[1]; [1]*STFC Rutherford Appleton Lab, UK*. This talk will describe our programmes to scale diode pumped PW and parametric systems to high average power as a new basis for applications based on compact, efficient and reliable secondary sources.

STu4O.2 • 16:30 Invited
220mJ Ultrafast Thin-Disk Regenerative Amplifier, Sandro Klingebiel[1], Marcel Schultze[1], Catherine Y. Teisset[1], Robert Bessing[1], Matthias Haefner[1], Stephan Prinz[1], Martin Gorjan[2,3], Dirk H. Sutter[4], Knut Michel[1], Helena G. Barros[2], zsuzsanna Major[2,3], Ferenc Krausz[2,3], Thomas Metzger[1]; [1]*TRUMPF Scientific Lasers GmbH + Co. KG, Germany;* [2]*Dept. für Physik, Ludwig-Maximilians-Universität München, Germany;* [3]*Max-Planck-Institut für Quantenoptik, Germany;* [4]*Trumpf Laser GmbH, Germany*. We report on a chirped-pulse regenerative thin-disk amplifier generating 220 mJ pulse energy at 1 kHz repetition rate with a pulse duration of 1.9 ps for pumping few-cycle optical parametric amplifiers (OPA).

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CLEO: QELS-Fundamental Science

FTu4A • Fundamental Quantum Optics—Continued

FTu4A.4 • 16:45
Reducing the Free-Space Group Velocity of Single Photons by Transverse Structuring, Daniel Giovannini[1], Jacquiline Romero[1], Vaclav Potocek[1], Gergely Ferenczi[1], Fiona Speirits[1], Stephen Barnett[1], Daniele Faccio[2], Miles Padgett[1]; [1]*School of Physics and Astronomy, Univ. of Glasgow, UK;* [2]*School of Engineering and Physical Sciences, Heriot-Watt Univ., UK.* The group velocity of light in free space is decreased by controlling the transverse spatial structure of the beam. We present experimental results in the single-photon regime, supported by a simple geometric argument and a full theoretical treatment.

FTu4A.5 • 17:00
Hong-Ou-Mandel Interference between Transverse Spatial Waveguide Modes, Aseema Mohanty[1], Mian Zhang[1], Sven Ramelow[2], Paulo Nussenzveig[3], Michal Lipson[1,4]; [1]*School of Electrical and Computer Engineering, Cornell Univ., USA;* [2]*School of Applied and Engineering Physics, Cornell Univ., USA;* [3]*Instituto de Fisica, Universidade de Sao Paulo, Brazil;* [4]*Kavli Inst. at Cornell for Nanoscale Science, Cornell Univ., USA.* We demonstrate Hong-Ou-Mandel interference between different transverse spatial modes in a silicon nitride multimode waveguide. We show over 90% visibility between modes, providing a promising route for scalable on-chip quantum information processing.

FTu4A.6 • 17:15
Quantum Walk Coherences on a Dynamical Percolation Graph, Fabian Elster[1], Sonja Barkhofen[1], Thomas Nitsche[1], Jaroslav Novotný[2], Aurél Gábris[2,3], Igor Jex[2], Christine Silberhorn[1]; [1]*Applied Physics, Univ. of Paderborn, Germany;* [2]*Dept. of Physics, Faculty of Nuclear Sciences and Physical Engineering, Czech Technical Univ. in Prague, Czech Republic;* [3]*Dept. of Theoretical Physics, Univ. of Szeged, Hungary.* We implement a quantum walk on a percolation graph leveraging a time-multiplexed quantum walk architecture to create broken links between the graph nodes. We test our system by verifying non-Markovian signatures resulting from induced open system dynamics.

FTu4B • Light-matter Interaction in Graphene/Other Carbon-based Materials—Continued

FTu4B.4 • 16:45
Terahertz Generation by Dynamical Photon Drag Effect in Graphene, Juliette Mangeney[1], Jean Maysonnave[1], SImon Huppert[1], Feihu Wang[1], simon Maero[1], Claire Berger[2,4], Walt A. de Heer[2], Theodore B. Norris[3], Louis-Anne de Vaulchier[1], Sukhdeep Dhillon[1], Robson Ferreira[1], Jérôme Tignon[1]; [1]*Laboratoire Pierre Aigrain, Ecole Normale Supérieure-PSL Research Univ., CNRS, Université Pierre et Marie Curie-Sorbonne Universités, Université Paris Diderot-Sorbonne Paris Cité, France;* [2]*School of Physics, Georgia Inst. of Technology, USA;* [3]*Univ. of Michigan, USA;* [4]*Université Grenoble Alpes/CNRS, Institut Néel, France.* Room temperature terahertz generation is demonstrated in graphene under femtosecond optical excitation. This is induced by dynamical photon drag, which relies on the transfer of light momentum to the carriers by ponderomotive and magnetic forces.

FTu4B.5 • 17:00
Microscopic Origins of the Terahertz Carrier Relaxation and Cooling Dynamics in Graphene, Momchil T. Mihnev[1,2], Charles J. Divin[1,2], Faris Kadi[3], Torben Winzer[3], Seunghyun Lee[1], Che-Hung Liu[1], Zhaohui Zhong[1], Xiaohan Wang[4], Rodney S. Ruoff[4], Claire Berger[5], Walt A. de Heer[5], Ermin Malic[3], Andreas Knorr[3], Theodore B. Norris[1,2]; [1]*Dept. of Electrical Engineering and Computer Science, Univ. of Michigan, USA;* [2]*Center for Ultrafast Optical Science, Univ. of Michigan, USA;* [3]*Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Germany;* [4]*Dept. of Mechanical Engineering and the Materials Science and Engineering Program, The Univ. of Texas at Austin, USA;* [5]*School of Physics, Georgia Inst. of Technology, USA.* We combine ultrafast time-resolved THz spectroscopy and microscopic modeling to study the hot-carrier relaxation and cooling dynamics in graphene; we demonstrate that the dynamics are the result of the intricate interplay between carrier-carrier and carrier-phonon interactions.

FTu4B.6 • 17:15
Ultrabroadband THz Conductivity of Non-equilibrium Dirac Fermions in Graphene, Giacomo Coslovich[1], Ryan P. Smith[1], Sufei Shi[1,2], Jan H. Buss[1], Jeremy T. Robinson[3], Feng Wang[1,2], Robert A. Kaindl[1]; [1]*Lawrence Berkeley National Lab, USA;* [2]*Dept. of Physics, Univ. of California at Berkeley, USA;* [3]*Naval Research Lab, USA.* We employ ultrabroadband THz pulses to expose the high-frequency transport of non-equilibrium Dirac fermions in graphene. Tuning the Fermi level reveals a transient response characteristic of high-energy photo-excited carriers with strongly enhanced interactions.

FTu4C • Topological Photonics II—Continued

FTu4C.4 • 17:00
One-Way Topological Transitions in Magnetoplasmonic Hyperbolic Metamaterials, Binyamin Stein[1], Alex Leviyev[1], Tal Galfsky[3,2], Harish Krishnamoorthy[1,2], Igor L. Kuskovsky[1,2], Vinod M. Menon[3,2], Alexander B. Khanikaev[1,2]; [1]*Physics, Queens College of the City Univ. of New York, USA;* [2]*Physics, Graduate Center of the City Univ. of New York, USA;* [3]*Physics, The City College of New York, USA.* It is shown that hyperbolic metamaterials with reduced spatial symmetry and the time-reversal symmetry broken by magnetization exhibit multiple nonreciprocal hyperbolic regimes. Magnetization induced one-way topological phase transitions between elliptical and hyperbolic regimes are demonstrated.

FTu4C.5 • 17:15
Integrated impedance-matched photonic Dirac-cone metamaterials, Yang Li[1], Shota Kita[1], Philip Muñoz[1], Orad Reshef[1], Daryl Vulis[1], Marko Loncar[1], Eric Mazur[1]; [1]*Harvard Univ., USA.* We design and fabricate an on-chip Dirac-cone metamaterial with impedance-matched zero index at 1550 nm. This design can serve as an on-chip platform to implement applications of Dirac-cone metamaterials in integrated photonics, such as supercoupling.

FTu4D • Optical Filamentation and Compression—Continued

FTu4D.4 • 16:45
Transition between linear and nonlinear focusing regimes during filamentation, Khan Lim[1], Magali Durand[1], Matthieu Baudelet[1], Martin Richardson[1]; [1]*Univ. of Central Florida, CREOL, USA.* The transition between linear and nonlinear regimes of focusing for laser filamentation is described and shows the balance between plasma physics and nonlinear propagation for the stability of the laser filament and its properties.

FTu4D.5 • 17:00
Superfilamentation in water with tight focusing laser beams, Fedor V. Potemkin[1], Evgeniy I. Mareev[1], Alexey Podshivalov[1], Vyacheslav M. Gordienko[1]; [1]*M. V. Lomonosov Moscow State Univ., Russia.* We report whole life cycle of superfilament excited in tight focusing beams in water. Extreme energy delivery achieved under superfilamention is reflected in strong post-effects (cavitation bubbles and shock waves), which can completely characterize superfilament.

FTu4D.6 • 17:15
Generation and Enhancement of XUV Pulse from UV Filament Interaction in Argon, Di Wang[1], Wenxue Li[1], Liangen Ding[1], Heping Zeng[1]; [1]*East China Normal Univ., China.* We demonstrated the generation and enhancement of XUV pulse at 89 nm by non-collinear interaction between UV filaments in argon. The experimental result agrees well with the simulated data.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FTu4E • Plasmonic Nanoatennas for Sensing and Focusing—Continued

FTu4E.4 • 16:45
3D Plasmonic nanostar structures for recyclable SERS applications, Manohar Chirumamilla[2,1], Anisha Gopalakrishnan[2], Andrea Toma[2], Remo Proietti Zaccaria[2], Francesco De Angelis[2], Roman Krahne[2]; *[1]Dept. Of Physics and Nanotechnology, Aalborg Univ., Denmark; [2]Nanostructures, Istituto Italiano di Tecnologia, Italy.* Nanofabrication of metallic nanostructures/nanoparticles enables the detection of analyte molecules at ultra-low concentrations with the aid of plasmon induced hot-spots. Here we present a cost effective approach to recycle the SERS substrates for label free bio-sensing applications.

FTu4E.5 • 17:00
Plasmonics of Ultranarrow Gaps Shunted by Organic Conductive Junctions, Christos Tserkezis[1], Felix Benz[2], Lars O. Herrmann[2], Bart de Nijs[2], Alan Sanders[2], Daniel O. Sigle[2], Jeremy Baumberg[2], Javier Aizpurua[1]; *[1]Donostia International Physics Center and Centro de Fisica de Materiales CSIC-UPV/EHU, Spain; [2]Nanophotonics Centre, Cavendish Lab, Dept. of Physics, Univ. of Cambridge, UK.* The optical response of plasmonic cavities formed by metallic nanoparticles deposited on a metallic substrate separated by self-assembled monolayers of conductive organic molecules can be precisely controlled by the exact chemical composition of the monolayers.

FTu4E.6 • 17:15
Subwavelength Sensing Elements from Film-Coupled Silver Nanocubes, Alex Powell[1], Andrew Watt[1], Hazel Assender[1], Jason M. Smith[1]; *[1]Univ. of Oxford, UK.* By placing a moisture-sensitive polymer spacer between a silver nanocube and an Ag film, the extreme sensitivity of the plasmon resonance excited between them to spacer thickness is exploited to create a novel sub-wavelength sensing element.

STu4F • Components and Optical Interconnects—Continued

STu4F.4 • 17:00
Efficient III-V/Si Hybrid SOAs for Optical Interconnects, Stanley Cheung[1], Kuanping Shang[1], Yasumasa Kawakita[1]; *[1]Univ. of California Davis, USA.* We present 1.55 μm hybrid III-V/Si SOA designs and experimentally determine wall-plug-efficiency (*WPE*) values for 2 mW and 0.1 mW input power amplification. Flared SOAs yield *WPE* = 12.1% for output power > 10 mW and straight SOAs achieve *WPE* = 7.2%.

STu4F.5 • 17:15
56 Gb/s PAM-4 Data Transmission Over a 1 m Long Multimode Polymer Interconnect, Nikos Bamiedakis[1], Jinlong Wei[1], Jian Chen[1], Petter Westbergh[2], Anders Larsson[2], Richard V. Penty[1], Ian H. White[1]; *[1]Univ. of Cambridge, UK; [2]Chalmers Univ. of Technology, Sweden.* Advanced modulation formats can enable >40 Gb/s data rates in waveguide-based optical interconnects without the need for high-specification optoelectronic components. Record 56Gb/s PAM-4 data transmission is demonstrated over a 1 m-long multimode polymer waveguide.

STu4G • Cascade Lasers III—Continued

STu4G.4 • 16:45
Room Temperature Operation of a Photonic Crystal Quantum Cascade Laser, Romain Peretti[1], Valeria Liverini[1], Johanna Wolf[1], Christopher Bonzon[1], Sebastian Lourdudoss[2], Wondwosen Metaferia[2], Mattias Beck[1], Jerome Faist[1]; *[1]ETH Zurich, Switzerland; [2]Lab of Semiconductor Materials, School of ICT, KTH-Royal Inst. of Technology, Sweden.* We report on design, fabrication and investigation of a buried heterostructure photonic crystal quantum cascade laser operating in the mid-IR (8.5μm) at room temperature, leading to single mode emission on a 600μm by 600μm mesa.

STu4G.5 • 17:00 Invited
Perspectives for intersubband polariton lasers and Bose-Einstein condensation of intersubband polaritons, Raffaele Colombelli[1], Jean-Michel Manceau[1]; *[1]Univ. Paris Sud and CNRS, France.* Intersubband polaritons are mixed states, partially micro-cavity photon and partially intersubband excitation, which behave as bosons below a certain density. We discuss the perspectives toward the development of mid-IR and THz intersubband polariton bosonic lasers.

STu4H • THZ Spectroscopic Techniques—Continued

STu4H.4 • 16:45
Terahertz Response of Long-lived Photoexcited Electrons in Silicon Observed Using Single-shot Terahertz Spectroscopy, Ikufumi Katayama[1], Kaisei Masuda[1], Kohei Horiuchi[1], Yasuo Minami[1], Jun Takeda[1]; *[1]Yokohama National Univ., Japan.* We observed photoexcited carriers in silicon by using single-shot terahertz spectroscopy. This technique can significantly reduce the measurement time and repetition rate of pump pulses, enabling us to observe the dynamics of long-lived photoexcited carriers without a pileup effect.

STu4H.5 • 17:00
Real-Time Absolute Frequency Measurement of CW-THz Wave Based on a Free-Running THz Comb, Takashi Ogura[1], Kenta Hayashi[1], Hajime Inaba[4,2], Kaoru Minoshima[3,2], Takeshi Yasui[1,2]; *[1]Tokushima Univ., Japan; [2]ERATO Intelligent Optical Synthesizer Project, Japan; [3]The Univ. of Electro-Communications, Japan; [4]National Inst. of Advanced Industrial Science and Technology, Japan.* We demonstrated a real-time frequency measurement of CW-THz wave using a single free-running THz comb. The absolute frequency of the CW-THz wave is measured with an accuracy of $8.7*10^{-12}$ at a rate of 10 Hz.

STu4H.6 • 17:15
Generation and Stabilization of THz-waves with Extraordinary Low Line Width and Phase Noise, Stefan Preussler[1], Thomas Schneider[1], Hassanain Al-Taiy[1]; *[1]Institut für Hochfrequenztechnik, Technische Universität Braunschweig, Germany.* The generation and stabilization of high quality mm- and THz-waves via extraction of two lines from a fs-laser, with frequencies up to 3 THz, line width below 1 Hz and phase noise of -134 dBc/Hz is presented.

CLEO: Science & Innovations

STu4I • Mid-IR Photonics—Continued

STu4I.4 • 16:45
Near Field Optical Measurements of Silicon Waveguide in Mid-IR Regime Using Scanning Thermal Microscopy, Meir Y. Grajower[1], Yoel Sebbag[1], Alex Naiman[1], Boris Desiatov[1], Uriel Levy[1]; [1]*Hebrew Univ. of Jerusalem, Israel.* We observe for the first time the near field optical intensity distribution of silicon nanophotonic devices operating in the mid-IR spectrum using our scanning thermal microscopy and demonstrate its advantages over conventional NSOM technique.

STu4I.5 • 17:00
On-Chip Modulation in the Mid-Infrared with Silicon-on-Lithium-Niobate Photonics, Jeff Chiles[1], Sasan Fathpour[1]; [1]*CREOL, Univ. of Central Florida, USA.* Mid-infrared (3.39 μm) optical modulators are demonstrated for the first time on the silicon-on-lithium-niobate platform, with a $V_\pi \cdot L$ of 26 V·cm, extinction ratio of 8 dB, and on-chip insertion losses of 3.3 dB.

STu4I.6 • 17:15
Microscopic Analysis of Quantum-Confined Stark Effect of Group IV Quantum Wells for Mid-Infrared Si-Based Electroabsorption Modulators, Takeshi Fujisawa[1], Kunimasa Saitoh[1]; [1]*Graduate school of information science and technology, Hokkaido Univ., Japan.* Quantum-confined Stark effect of Ge(Sn)/SiGe(Sn) quantum wells (QWs) is analyzed by many-body theory. Calculated absorption spectra of Ge/SiGe-QWs are in good agreement with the experiment. Also, the effect of Sn-incorporation is investigated for mid-infrared applications.

CLEO: Applications & Technology

ATu4J • Environmental Sensing—Continued

ATu4J.3 • 16:45
Quantifying Primary Reactive Nitrogen Emissions Using Open-Path, Quantum Cascade Laser-Based Sensors, Kang Sun[1], Lei Tao[1], Da Pan[1], Levi Golston[1], Yue Tian[2], Ming-Fang Huang[2], Junqiang Hu[2], Ting Wang[2], Mark A. Zondlo[1]; [1]*Princeton Univ., USA;* [2]*NEC Labs America, USA.* A compact QCL-based open-path NO sensor is developed at 5.26 μm for high sensitivity and fast response. Combined with existing NH_3 and N_2O sensors, this system measures primary emissions of reactive nitrogen to the atmosphere.

ATu4J.4 • 17:00
Airborne Multi-Gas Sensor, David Bomse[1], Marwood N. Ediger[1], Andrei B. Vakhtin[1]; [1]*Mesa Photonics, USA.* Carbon dioxide and methane are detected simultaneously using two-tone frequency modulation spectroscopy. Detection limits are 1.5 ppm $Hz^{-1/2}$ and 3.5 ppb $Hz^{-1/2}$, respectively, over 0.1 to 100 s. External phase modulators apply the two tones.

ATu4J.5 • 17:15
CAMS - Compact Atmospheric Multi-Species Spectrometer, Dirk Richter[1], Petter Weibring[1], James Walega[1], Alan Fried[1], Scott M. Spuler[2], Matthew Taubman[3]; [1]*Univ. of Colorado, USA;* [2]*Earth Observing Lab, National Center for Atmospheric Research, USA;* [3]*Pacific Northwest National Lab, USA.* We present the design, development, and field performance of an airborne mid-IR spectrometer configured for the simultaneous sensitive detection of CH_2O (~40 pptv, 1 Hz) and C_2H_6 (~15 pptv, 1 Hz).

CLEO: Science & Innovations

STu4K • Biosensing—Continued

STu4K.3 • 16:45
Silicon Nitride Coupled-Resonator Optical-Waveguide-based Biosensors using Visible-Light-Scattering Pattern Recognition, Jiawei Wang[1], Andrew W. Poon[1]; [1]*Photonic Device Lab, Dept. of Electronics and Computer Engineering, Hong Kong Univ. of Science and Technology, China.* We demonstrate silicon nitride coupled-resonator optical-waveguide-based biosensors using visible-light-scattering pattern recognition with pixelized mode-field-intensity distributions. Our 16-microring sensor reveals 14 eigenstates. Our algorithm suggests an average sensitivity of ~ 372 RIU^{-1}.

STu4K.4 • 17:00
Phospholipid-functionalized microgoblet lasers for biomolecular detection, Uwe R. Bog[1], Falko Brinkmann[1], Sentayehu Fetene Wondimu[1], Tobias Wienhold[1], Sarah Kraemmer[1], Christian Koos[1], Heinz Kalt[1], Sebastian Koeber[1], Timo Mappes[3], Michael Hirtz[1], Harald Fuchs[2]; [1]*Karlsruher Institut für Technologie, Germany;* [2]*Westfaelische-Wilhelms Universitaet, Germany;* [3]*Carl Zeiss AG, Germany.* We present our latest results on microgoblet lasers as biosensors. Surface functionalization is performed with high resolution and throughput by aligned microcontact stamping. We show simultaneous device readout, the resulting cross-referencing capabilities and functionalization reconfiguration.

STu4K.5 • 17:15
193nm Lithography Fabricated High Sensitivity Photonic Crystal Microcavity Biosensors for Plasma Protein Detection in Patients with Pancreatic Cancer, Chun-Ju Yang[1], Naimei Tang[1,2], Hai Yan[1], Swapnajit Chakravarty[2], Donghui Li[3], Ray T. Chen[1,2]; [1]*The Univ. of Texas at Austin, USA;* [2]*Omega Optics Inc., USA;* [3]*UT MD Anderson Cancer Center, USA.* High sensitivity L13-type two-dimensional photonic crystal microcavities with nanoholes were fabricated by 193nm photolithography. 0.03 picomolar concentration pancreatic cancer biomarker in patient serum samples was experimentally detected to 10× lower dilution than ELISA.

STu4L • Higher-Order Modes & Mode Coupling in Fiber—Continued

STu4L.3 • 16:45
Large Mode Area Guidance in a Simple Fiber Structure, Lars Rishoej[1], Maxwell Jones[2], Jeffrey Demas[1], Gautam Prabhakar[1], Lu Yan[1], Thomas W. Hawkins[2], John Ballato[2], Siddharth Ramachandran[1]; [1]*Boston Univ., USA;* [2]*COMSET, Clemson Univ., USA.* We demonstrate higher-order-mode (A_{eff}~1800μm²) propagation in a 100-μm-OD pure-silica fiber with a low-index polymer jacket commonly used for fiber-laser pump-guidance. This simple structure obviates the need for complex designs deemed necessary for realizing large-mode-area fibers.

STu4L.4 • 17:00
High Energy Pulse Amplification in a Higher-Order Mode Fiber Amplifier with Axicon for Output Mode Conversion, Jeffrey W. Nicholson[1], John M. Fini[1], A. DeSantolo[1], Paul S. Westbrook[1], Robert Windeler[1], Tristan Kremp[1], Clifford Headley[1], David DiGiovanni[1]; [1]*OFS Labs, USA.* High energy, 700 μJ, one nanosecond pulses and 490 femtosecond, 50 μJ pulses are demonstrated in an Er-doped, higher-order-mode fiber amplifier. An axicon at the output enables efficient, nonlinearity-free reconversion to a low M^2 beam.

STu4L.5 • 17:15
Microstructured suspended core fiber for cylindrical vector beams propagation, Hong Ji[1], Yinlan Ruan[1], Heike Ebendorff-Heidepriem[1], Wen Qi Zhang[1], Shahraam Afshar[1], Tanya Monro[1]; [1]*the Univ. of Adelaide, Australia.* A suspended core fiber based on lead silicate glass has been fabricated to generate doughnut beams. Preliminary results demonstrated a potential to be a good candidate for fiber based cylindrical vector beams generation and propagation.

CLEO: Applications & Technology

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ATu4M • Novel Sources for Industrial Applications—Continued

ATu4M.3 • 17:00
High-energy, 34 fs, fiber source via nonlinear compression in hypocycloid-core Kagome fibe, Achut Giree[3,4], Florent Guichard[1,2], Yoann Zaouter[2], Marc Hanna[1], Guillaume Machinet[2], Benoît Debord[5], Frédéric Gérôme[5,6], Pascal Dupriez[7], Clemens Hoenninger[2], Eric Mottay[2], Fetah Benabid[5,6], Patrick Georges[1]; [1]*Lab Charles Fabry de l'Inst d'Optique, France;* [2]*Amplitude Systemes, France;* [3]*MBI, Germany;* [4]*Amplitude Technologies, France;* [5]*XLIM Inst., France;* [6]*GLO photonics, France;* [7]*Alphanov, France.* We report on the nonlinear compression of 330 fs and 70 µJ pulses from a high energy fiber amplifier system down to 34 fs and 50 µJ pulses using an air-filled 40 µm hypocycloid-core Kagome fiber.

ATu4M.4 • 17:15
1.75 kW CW Narrow Linewidth Yb-doped all-fiber Amplifiers for Beam Combining Application, YunFeng Qi[1], ming lei[1], chi liu[1], bing he[1], jun zhou[1]; [1]*Shanghai Inst of Optics and Fine Mech, USA.* We reported on a Yb-doped all-fiber amplifier when seeded with a 20 GHz line-width master oscillator. By using mode controlling technology, an output power of 1.75 kW with near-diffraction limited beam quality (M2=1.77) was observed.

STu4N • Ultrafast Imaging and Spectroscopy—Continued

STu4N.4 • 16:45
Coherent Diffraction Imaging with Absorption Contrast using Broadband Tabletop Soft X-ray Sources, Guido Cadenazzi[2], Brian K. McFarland[1], Nina R. Weisse-Bernstein[1], Matthew C. Tyson[1], George Rodriguez[1], Richard L. Sandberg[1]; [1]*Los Alamos National Lab, USA;* [2]*La Trobe Univ., Australia.* We demonstrate nanometer scale resolution with absorption contrast without the need for scanning wavelength as is typically done. This is accomplished by applying polychromatic coherent diffraction imagining with a tabletop, ultrafast, broadband high harmonic source.

STu4N.5 • 17:00
Probing Ultrafast Magnetization Dynamics using Bright Circularly Polarized High Harmonics, Dmitriy Zusin[1], Ronny Knut[1,3], Patrik Grychtol[1], Ofer Kfir[2], Christian Gentry[1], Hans Nembach[3], Justin Shaw[3], Tom Silva[3], Avner Fleischer[2,4], Oren Cohen[2], Henry C. Kapteyn[1], Margaret M. Murnane[1]; [1]*Dept. of Physics and JILA, Univ. of Colorado and NIST, USA;* [2]*Solid State Inst. and Physics Dept., Technion, Israel;* [3]*Electromagnetics Division, National Inst. of Standards and Technology, USA;* [4]*Dept. of Physics and Optical Engineering, Ort Braude College, Israel.* We generate bright circularly polarized high harmonics and use this new table-top light source to capture ultrafast magnetization dynamics for the first time by measuring laser-driven ultrafast demagnetization in a FeCr alloy.

STu4N.6 • 17:15
Attenuated total reflectance infrared spectroscopy with chirped-pulse upconversion, Takao Fuji[1], Hideto Shirai[1], Constance Duchesne[1,2], Yuji Furutani[1]; [1]*National Inst.s of Natural Sciences, Japan;* [2]*Chimie ParisTech, France.* Chirped-pulse upconversion technique has been applied to attenuated total reflectance infrared spectroscopy. The system was applied to observe the dynamics of exchanging process of buffers for biological tissues.

STu4O • OPCPA Systems & Pump Lasers—Continued

STu4O.3 • 17:00
Picosecond, 115 mJ Energy, 200 Hz Repetition Rate Cryogenic Yb:YAG Bulk-amplifier, Michaël Hemmer[1], Fabian Reichert[1], Kelly Zapata[1], Martin Smrz[2,1], Anne-Laure Calendron[1,3], Huseyin Cankaya[1,3], Kyung-Han Hong[4], Franz Kaernter[1,3], Luis E. Zapata[1]; [1]*Center for Free-Electron Laser Science (CFEL), Germany;* [2]*Hilase Center, Inst. of Physics AS CR, Czech Republic;* [3]*The Hamburg Center for Ultrafast Imaging and Dept. of Physics, Germany;* [4]*MIT, USA.* We report on a compact, high-energy, cryogenically-cooled Yb:YAG bulk-amplifier delivering energies > 100 mJ at 200 Hz repetition rate with excellent beam quality and spectrum supporting 5-ps pulses.

STu4O.4 • 17:15
100 mJ thin disk regenerative amplifier at 1 kHz as a pump for picosecond OPCPA, Jakub Novák[1,2], Pavel Bakule[1], Jonathan T. Green[1], Zbynek Hubka[1,2], Bedrich Rus[1]; [1]*ELI-Beamlines, Inst. of Physics ASCR, v. v. i. (FZU), Czech Republic;* [2]*Faculty of Nuclear Sciences and Physical Engineering, Czech Technical Univ., Czech Republic.* Stable operation with energy >100mJ of the Yb:YAG thin disk regenerative amplifier at 1kHz has been achieved. The amplifier is being developed as a pump for the picosecond OPCPA of the L1 beamline at ELI-Beamlines.

Conference Reception and Poster Session

Join us for this exciting event on Tuesday from 18:00–20:00 in the CLEO:Expo.

CLEO: QELS-Fundamental Science

FTu4A • Fundamental Quantum Optics—Continued

FTu4A.7 • 17:30
Efficient Boson Sampling Schemes using Dispersion and Pulse Shaping, Mihir Pant[1], Dirk R. Englund[1]; [1]*MIT, USA.* We present Boson Sampling schemes in the time-frequency basis that allow for more modes, fewer sources and detectors and are more tolerant to temporal mismatch than Boson Sampling schemes using photons in many spatial modes.

FTu4A.8 • 17:45
Repeat-Until-Success Cubic Phase Gate, Kevin A. Marshall[1], Raphael Pooser[2,3], George Siopses[3], Christian Weedbrook[4]; [1]*Univ. of Toronto, Canada;* [2]*Quantum Information Science Group, Oak Ridge National Lab, USA;* [3]*Dept. of Physics and Astronomy, The Univ. of Tennessee, USA;* [4]*QKD Corp., Canada.* Here we introduce an experimentally viable 'repeat-until-success' implementation of the cubic phase gate, required for universal quantum computation, using sequential photon subtractions. Our scheme offers benefits in the expected time until success, although we require a primitive quantum memory.

FTu4B • Light-matter Interaction in Graphene/Other Carbon-based Materials—Continued

FTu4B.7 • 17:30
Ultrafast Photo-Excitation Dynamics of Nitrogen-Vacancy Defects in Diamond, Ronald Ulbricht[1,2], Shuo Dong[2], Julian Schwartz[3], Hyeon-Deuk Kim[4], Yoshitaka Tanimura[4], Bala Murali Krishna Mariserla[5], Keshav M. Dani[5], Zhi-Heng Loh[2]; [1]*Dept. of Physics, Univ. of Colorado, USA;* [2]*Division of Chemistry and Biological Chemistry, Nanyang Technological Univ., Singapore;* [3]*Accelerator and Fusion Research Division, Lawrence Berkeley National Lab, USA;* [4]*Dept. of Chemistry, Kyoto Univ., Japan;* [5]*Femtosecond Spectroscopy Unit, Okinawa Inst. of Science and Technology, Japan.* We probe the ultrafast dynamics of the electronic excited state of nitrogen-vacancy defects in diamond for temperatures 10K-300K, observing vibrational relaxation times of 40fs and temperature-dependent bi-exponential anisotropy dynamics related to electron motion in Jahn-Teller-distorted orbitals.

FTu4B.8 • 17:45
Controlling Carbon Nanotube Mechanics with Optical Microcavities, Mian Zhang[1], Arthur Barnard[1], Paul McEuen[1], Michal Lipson[1]; [1]*Cornell Univ., USA.* We demonstrate optomechanically induced amplification of carbon nanotube (CNT) mechanical modes using optical microcavities. We also show direct imaging of the spatial profile of CNT mechanical modes using optical readout.

FTu4C • Topological Photonics II—Continued

FTu4C.6 • 17:30
Probing the Ultrathin Limit of Hyperbolic Meta-material: Nonlocality Induced Topological Transitions, Long Chen[1,2], Cheng Zhang[2], Jing Zhou[2], L. Jay Guo[1,2]; [1]*Applied Physics, Univ. of Michigan, USA;* [2]*Dept. of Electrical Engineering and Computer Science, Univ. of Michigan, USA.* Hyperbolic meta-materials based on ultrathin metal-dielectric multilayers have been studied by considering the nonlocal response of electrons in metal. We show that nonlocality will induce topological transitions of the iso-frequency surfaces and limit light-matter interactions.

FTu4C.7 • 17:45
Photonic Topological Edge Modes without an Edge, Yaniv Tenenbaum Katan[1], Yaakov Lumer[1], Yonatan Plotnik[1], Mikael Rechtsman[1], Mordechai Segev[1]; [1]*Technion, Israel.* We present photonic topological modes without a topological edge: topologically protected states which reside at a non-topological interface in the bulk of a photonic topological insulator (a honeycomb lattice of helical waveguides).

FTu4D • Optical Filamentation and Compression—Continued

FTu4D.7 • 17:30
Plasma density measurement along femtosecond laser filament via enhanced THz spectroscopy, Tie-Jun Wang[1]; [1]*SIOM, Chinese Adademy of Sciences, China.* We report on a longitudinally resolved measurement of plasma density along femtosecond laser filament in air via needlelike high-voltage DC electric field enhanced THz spectroscopy. Longitudinal distribution of plasma density of ~10^{15} cm^{-3} along laser filament has been successfully recorded.

FTu4D.8 • 17:45
Spatial Dependence of the Interaction between a Single Aerosol and a Laser Filament on its Reformation, Cheonha Jeon[1], Danielle Harper[1], Khan Lim[1], Magali Durand[1], Michael Chini[1], Matthieu Baudelet[1], Martin Richardson[1]; [1]*Univ. of Central Florida, CREOL, USA.* The analysis of the filament destruction and reformation as a single aerosol is positioned along the radial and longitudinal axes of the filament provides more understanding of the propagation of filaments in aerosol-containing media.

16:30–18:00 IEEE Journal of Quantum Electronics Celebrates 50 Years, *Willow Glen, Marriott*

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CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FTu4E • Plasmonic Nanoatennas for Sensing and Focusing—Continued

FTu4E.7 • 17:30
Efficient Integration of Sub-5-nm-gap Plasmonic Crystal Cavities with Plasmonic Waveguides, Myung-Ki Kim[1]; Yong-Hee Lee[1]; *[1]KAIST, Korea.* We propose a three-dimensionally tapered 2-nm-gap plasmonic crystal cavity which can efficiently couple to an integrated waveguide with over 90% efficiency. Along with the theoretical study, we successfully fabricated the 3D-tapered plasmonic crystal cavity integrated with a plasmonic waveguide.

FTu4E.8 • 17:45
Hybridisation of antenna and cavity modes in nanoparticle-on-mirror plasmonic nanocavities, Christos Tserkezis[1], Ruben Esteban[1], Daniel O. Sigle[2], Jan Mertens[2], Lars O. Herrmann[2], Jeremy Baumberg[2], Javier Aizpurua[1]; *[1]Donostia International Physics Center and Centro de Fisica de Materiales CSIC-UPV/EHU, Spain; [2]Nanophotonics Centre, Cavendish Lab, Dept. of Physics, Univ. of Cambridge, UK.* Longitudinal antenna and transverse cavity modes can be excited when bringing a faceted plasmonic nanoparticle close to a metallic substrate. Their interaction leads to a rich optical response, understandable in terms of the modal symmetry.

STu4F • Components and Optical Interconnects—Continued

STu4F.6 • 17:30
56 Gb/s, PAM-4 Transmission Over 25 km, Using IQ Modulator and Unequally Spaced Levels, Cristian Prodaniuc[1,2], Nebojsa Stojanovic[1], Fotini Karinou[1], Gernot Goeger[1], Zhang Qiang[1], Roberto Llorente Saez[2]; *[1]Optical Technologies, Huawei Technologies Düsseldorf GmbH, Germany; [2]Nanophotonics Technology Centre, Universidad Politécnica de Valencia, Spain.* We propose a PAM-4 modulation scheme with unequally spaced levels in order to mitigate chirp effects caused by IQ modulators. Experimental results of 56 Gb/s transmission over 25 km link demonstrate the robustness of this modulation concept.

STu4F.7 • 17:45
6.25 Gb/s POF Link Using GaN µLED Arrays and Optically Generated Pulse Amplitude Modulation, Xin Li[1], Nikos Bamiedakis[1], Jinlong Wei[1], Jonathan Mckendry[2], Enyuan Xie[2], Ricardo Ferreira[2], Erdan Gu[2], Martin Dawson[2], Richard V. Penty[1], Ian H. White[1]; *[1]Univ. of Cambridge, UK; [2]Dept. of Physics, Univ. of Strathclyde, UK.* Optically-generated PAM schemes using µLED arrays are implemented for high-speed POF links for the first time. 6.25Gb/s PAM-16 transmission is demonstrated using 4 µLEDs, exhibiting 3.8dB greater power-margin than a link with a single µLED.

STu4G • Cascade Lasers III—Continued

STu4G.6 • 17:30
Continuous Wave Room Temperature External Ring Cavity Quantum Cascade Laser, Michael Hemingway[1], Deivis Vaitiekus[1], John Cockburn[1], Nils Hempler[2], Gareth Maker[2], Graeme Malcolm[2], Dmitry G. Revin[1]; *[1]Univ. of Sheffield, UK; [2]M Squared Lasers, UK.* Mid infrared, tunable quantum cascade laser operating in free-space external ring cavity in continuous wave regime at room temperature is demonstrated for the first time. Out-coupled optical power up to 17 mW has been achieved.

STu4G.7 • 17:45
Monolithic Integration of Quantum Cascade Lasers and Passive Components, Juan Montoya[1], Christine A. Wang[1], Kevin Creedon[1], Anish Goyal[1], Jeffry Daulton[1], Joseph Donnelly[1], Leo Missaggia[1], Antonio Sanchez-Rubio[1], William Herzog[1]; *[1]Massachusetts Inst of Tech Lincoln Lab, USA.* We present a method to integrate quantum cascade lasers with passive components using proton implantation. Proton implantation reduces the intersubband and free-carrier absorption optical loss. We have measured a loss α=0.33 cm^{-1} in proton implanted waveguides.

STu4H • THZ Spectroscopic Techniques—Continued

STu4H.7 • 17:30
Transition from Plasmon Coupling to Plasmon-Microcavity Hybridization, Qinghua Song[1,2], Pin Chieh Wu[2], Weimiing Zhu[2], wu zhang[2], Zhongxiang shen[2], Qing Xuan Liang[3], Zhen Chuan Yang[4], Yu Feng Jin[4], Yilong Hao[4], Tarik Bourouina[5], Yamin Leprince-Wang[1], Ai-Qun LIU[2]; *[1]UPEM, Université Paris-Est, France; [2]Nanyang Technological Univ., Singapore; [3]School of Mechanical Engineering, Xi'an Jiangtong Univ., China; [4]National Key Lab of Science and Technology on Micro/Nano Fabrication, Inst. of Microelectronics, Peking Univ., China; [5]ESYCOM, ESIEE, Université Paris-Est, France.* We report a coupling mode transition from pure plasmon coupling to plasmon-microcavity hybridization in THz using liquid metal whose shape can be tuned, not only from disk to droplet, but also from 2D to 3D.

STu4H.8 • 17:45
Single Nanowire Terahertz Detectors, Kun Peng[1], Patrick Parkinson[2], Lan Fu[1], Qiang Gao[1], Nian Jiang[1], Ya-Nan Guo[1], Fan Wang[1], Hannah Joyce[2,3], Jessica Boland[2], Michael Johnston[2], Hark Tan[1], Chennupati Jagadish[1]; *[1]The Australian National Univ., Australia; [2]Univ. of Oxford, UK; [3]Univ. of Cambridge, UK.* Photoconductive terahertz detectors based on single GaAs/AlGaAs nanowire were designed, fabricated and incorporated into the pulsed time-domain technique, showing a promise for nanowires in terahertz applications such as near-field terahertz sensors or on-chip terahertz micro-spectrometers.

16:30–18:00 IEEE Journal of Quantum Electronics Celebrates 50 Years, *Willow Glen, Marriott*

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CLEO: Science & Innovations

STu4I • Mid-IR Photonics—Continued

STu4I.7 • 17:30
All-optical Modulation in Germanium-on-silicon Waveguides in the Mid-infrared, Li Shen[1], Noel Healy[1], Collin Mitchell[1], Jordi Penades[1], Milos Nedeljkovic[1], Goran Mashanovich[1], Anna C. Peacock[1]; [1]*Optoelectronics Research Centre, Univ. of Southampton, UK.* All-optical modulation is demonstrated in low loss germanium-on-silicon waveguides at mid-infrared wavelengths. The results indicate the suitability of this platform for optical signal processing in this long wavelength regime.

STu4I.8 • 17:45
Broadband Mid-Infrared Frequency Comb Generation in a Si_3N_4 Microresonator, Kevin Luke[1], Yoshitomo Okawachi[1], Michael Lamont[1], Alexander L. Gaeta[1], Michal Lipson[1]; [1]*Cornell Univ., USA.* We demonstrate broadband frequency comb generation in the mid-infrared from 2.3 to 3.5 μm in a Si_3N_4 microresonator with Q=850,000 fabricated using an optimized process for decreasing intrinsic losses and overcoming stress limitations.

CLEO: Applications & Technology

ATu4J • Environmental Sensing—Continued

ATu4J.6 • 17:30
Advancing a Deep Sea Near-Infrared Laser Spectrometer for Dual Isotope Measurements, Anna P. Michel[1], Scott Wankel[1], Jason Kapit[1], Peter Girguis[2], Manish Gupta[3]; [1]*Woods Hole Oceanographic Institution, USA;* [2]*Harvard Univ., USA;* [3]*Los Gatos Research, USA.* A deep-sea near-infrared laser-based sensor, utilizing off-axis integrated cavity output spectroscopy, was enhanced to achieve in situ sensing dual isotope sensing ($\delta^{13}CO_2$, $\delta^{13}CH_4$) of both fluid and bubble samples.

ATu4J.7 • 17:45
Advances in Diode Laser Based Lidar for Profiling Atmospheric Water Vapor, Scott M. Spuler[1], Kevin Repasky[2], Bruce Morley[1], Drew Moen[2], Tammy Weckwerth[1], Matthew Hayman[1], Amin Nehrir[3]; [1]*National Center for Atmospheric Research, USA;* [2]*Electrical and Computer Engineering, Montana State Univerity, USA;* [3]*NASA Langley Research Center, USA.* The design of an advanced diode laser based differential absorption lidar (DIAL) is discussed which is capable of operation over a wide range atmospheric conditions. The instrument was field tested for 50 days and the results were compared to collocated instrumentation.

CLEO: Science & Innovations

STu4K • Biosensing—Continued

STu4K.6 • 17:30
High Contrast Grating Resonator for Label-Free Biosensor, Tianbo Sun[1], Shu Kan[2], Gerard Marriott[2], Connie J. Chang-Hasnain[1]; [1]*EECS, Univ. of California, Berkeley, USA;* [2]*Bioengineering, Univ. of California, Berkeley, USA.* We present a novel label-free biosensor using Si-based high-contrast grating resonator with Q ~3000. The biosensor is coupled using a single-mode fiber and realizes high sensitivity in the specific detection of target proteins at 100pg/ml.

STu4K.7 • 17:45
On-chip Integrated Differential Optical Microring Biosensing Platform Based on a Dual Laminar Flow Scheme, Dongwan Kim[1], Paula Popescu[1]; [1]*Applied Physics, Caltech, USA.* We propose an on-chip integrated differential optical silicon nitride microring biosensing platform which uses a dual laminar flow scheme. This platform reduces the fabrication complexity involved in the fabrication of the reference resonator.

STu4L • Higher-Order Modes & Mode Coupling in Fiber—Continued

STu4L.6 • 17:30
Fano Resonance in Inhibited Coupling Kagome Fiber, Abhilash Amsanpally[1], Benoît Debord[1], Meshaal Alharbi[1], Ekaterina Ilinova[1], Luca Vincetti[2], Frédéric Gérôme[1], Fetah Benabid[1]; [1]*Xlim Research Inst., UMR CNRS 7252, Univ. of Limoges, France;* [2]*Dept. of Engineering, Univ. of Modena and Reggio Emilia, Italy.* We report on the first experimental observation of Fano resonances in inhibited- coupling guiding Kagome fiber. A high-spectral resolution fiber-transmission showed the typical Fano asymmetric feature and a high dynamic-range near-field imaging resolved the core-cladding coupling.

STu4L.7 • 17:45
Triple-cup Hypocycloid-Core Inhibited-Coupling Kagome Hollow-Core Photonic Crystal Fiber, Luca Vincetti[1,2], Benoît Debord[1], Meshaal Alharbi[1], Frédéric Gérôme[1], Fetah Benabid[1]; [1]*GPPMM Xlim Research Inst., UMR CNRS 7252, Univ. of Limoges, France;* [2]*Dept. of Engineering, Univ. of Modena and Reggio Emilia, Italy.* We report on design and fabrication of a new hypocycloid core-contour Kagome HC-PCF based on a triangular-like shaped core exhibiting smaller effective area and comparable confinement loss than previous hypocycloid core-contour Kagome fibers.

16:30–18:00 IEEE Journal of Quantum Electronics Celebrates 50 Years, *Willow Glen, Marriott*

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CLEO: Applications & Technology

ATu4M • Novel Sources for Industrial Applications—Continued

ATu4M.5 • 17:30 Invited

Status and Potential of Laser based EUV Sources, Akira Endo[1]; *[1]Inst. of Physics ASCR,, HiLase Center, Czech Republic.* The established EUV source for lithography is driven by a high average power pulsed CO_2 laser. Micro droplet of Tin is injected as the plasma source. Present average power is more than 100W, and the scaling potential to over kW is described regarding several physical limits.

CLEO: Science & Innovations

STu4N • Ultrafast Imaging and Spectroscopy—Continued

STu4N.7 • 17:30

Real-Time Averaging of Repetitive Optical Waveforms by Non-Integer Factors based on Temporal Self-Imaging, Luis Romero Cortés[1], Reza Maram Qartavol[1], José Azaña[1]; *[1]INRS-EMT, Canada*. We report a new method to divide the repetition-rate of a periodic waveform train by a fractional factor based on energy-preserving processes, implementing an equivalent real-time averaging of the input waveforms by the rate-division factor.

STu4N.8 • 17:45

Extreme localization of light with femtosecond subwavelength rogue waves, Changxu Liu[1], van der Wel Ruben[2], Nir Rotenberg[2], Kobus Kuipers[2], Thomas Krauss[3], Andrea Di Falco[4], Andrea Fratalocchi[1]; *[1]PRIMALIGHT, KAUST, Saudi Arabia; [2]Center for Nanophotonics, FOM Inst. AMOLF, Netherlands; [3]Dept. of Physics, Univ. of York, UK; [4]School of Physics and Astronomy, Univ. of St. Andrews, UK.* By using theory and experiments, we investigate a new mechanism based on spontaneous synchronization of random waves which generates ultrafast subwavelength rare events in integrated photonic chips.

STu4O • OPCPA Systems & Pump Lasers—Continued

STu4O.5 • 17:30

145 W, 3 kHz Picosecond Amplifier for OPCPA Pumping, Nathan Bodnar[1], Benjamin Webb[1], Michael Chini[1], Lawrence Shah[1], Martin Richardson[1]; *[1]Univ. of Central Florida, USA.* OPCPA laser systems require a high-quality, high-energy picosecond pump. The challenges of energy scaling in multi-kilohertz systems include thermal loads, depolarization and gain extraction. We address these issues for a high energy/average power MOPA System.

STu4O.6 • 17:45

High Contrast Broadband Seeder for Multi-PW Laser System, Olivier Chalus[1], Alain Pellegrina[1], Olivier Casagrande[1], Christophe Derycke[1], Laurent Boudjemaa[1], Christophe Simon-Boisson[1], Sebastien Laux[1], Francois Lureau[1], Daniel Sanchez[2], Jens Biegert[2], Jan Ahrens[3], Thomas Binhammer[3], Oliver Prochnow[3], Stefan Rausch[3]; *[1]Thales Optronique SA, France; [2]ICFO- The Inst. of Photonics Sciences, Spain; [3]VENTEON Laser Technologies GmbH, Germany.* A hybrid Ti:Sa CPA/BBO OPCPA system with a XPW filter inbetween the two has been developed to produce a broadband high contrast seeder of 10 mJ for the two 10 PetaWatt beamlines of ELI NP infrastructure.

16:30–18:00 IEEE Journal of Quantum Electronics Celebrates 50 Years, *Willow Glen, Marriott*

NOTES

18:00–20:00
JTu5A • Poster Session I and Conference Reception

JTu5A.1
Enhanced optical limiting effects in multi-photon absorbers using cylindrical vector beams, Gu Bing[1], Jia-Lu Wu[1], Ning Sheng[1], Dahui Liu[1], Yiping Cui[1]; [1]*Southeast Univ., China.* Optical limiting effects can be enhanced by designing nonlinear optical materials and by exploiting various limiting mechanisms. Here, we present the enhancement of optical limiting effects by manipulating the polarization distribution of the light field.

JTu5A.2
Multi-nonlinear Effects in a Two-crystal Optical Parametric Oscillator, Yuwei Jin[1], Simona M. Cristescu[1], Frans J. Harren[1], Julien Mandon[1]; [1]*Dept. of Molecular and Laser Physics, Radboud Univ. Nijmegen, Netherlands.* We present the observation of several nonlinear effects in a two-crystal femtosecond optical parametric oscillator. Unusual parametric processes are observed when the total cavity length is detuned up to 7.3~mm within this synchronously pumped optical parametric oscillator.

JTu5A.3
Observing the effects of Time Ordering in Single Photon Frequency Conversion, Nicolas Quesada[1], John E. Sipe[1]; [1]*Univ. of Toronto, Canada.* We show how time ordering effects in single photon frequency conversion (FC) can be revealed by using the fact that the joint conversion amplitude in FC is a nonlinear function of the pump electric field.

JTu5A.4
The Effect of Orbital Angular Momentum on Nondiffracting Optical Pulses, Marco Ornigotti[1], Claudio Conti[2,3], Alexander Szameit[1]; [1]*Friedrich-Schiller Univ IAP, Germany;* [2]*Inst. of Complex Systems ISC-CNR, Italy;* [3]*Dept. of Physics, Univ. Sapienza, Italy.* We study the effects of orbital angular momentum on a nondiffracting optical pulse, and show that there exist a limit on the amount of OAM that a pulse can carry without modifying its temporal properties.

JTu5A.5
Femtosecond dynamics of a spaser and unidirectional emission from a perfectly spherical nanoparticle, Juan Sebastian Totero Gongora[1], Andrey Miroshnichenko[2], Yuri S. Kivshar[2], Andrea Fratalocchi[1]; [1]*PRIMALIGHT, King Abdullah Univ. of Science and Technology (KAUST), Saudi Arabia;* [2]*Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National Univ., Australia.* We investigate the femtosecond dynamics of the spaser emission by combining ab-initio simulations and thermodynamic analysis. Interestingly, the emission is characterized by rotational evolution, opening to the generation of unidirectional emission from perfectly spherical nanoparticles.

JTu5A.6
Frequency Comb Generation on a Silicon Chip, Andrei Rogov[1], Evgenii Narimanov[1]; [1]*Purdue Univ., USA.* We present a new approach to achieving frequency comb generation on a silicon chip by means of optical switching in microring resonators.

JTu5A.7
A simple method for the measurement of the optical pulse width on-site the mass spectrometer, Tomoko Imasaka[1], Akifumi Hamachi[1], Tomoya Okuno[1], Totaro Imasaka[1]; [1]*Kyushu Univ., Japan.* The laser pulse width was measured on-site the mass spectrometer by scanning a dispersion in the pulse compressor. A pulse width of 49 fs measured was close to 35 fs calculated from the spectrum.

JTu5A.8
Radiation Pressure Induced Nonlinear Optofluidics in Liquid Whispering Gallery Mode Resonator, Aram Lee[1], Peng Zhang[2], Sunghwan Jung[2], Yong Xu[1]; [1]*Electrical and Computer Engineering, Virginia Tech, USA;* [2]*Biomedical Engineering and Mechanics, Virginia Tech, USA.* We analyze a nonlinear optofluidic process produced by radiation pressure of a high quality factor whispering gallery mode in a liquid droplet. Using liquid properties that are experimentally attainable, we find that such a process may lead to photon-photon interaction at single photon energy level.

JTu5A.9
Correlated Study of Terahertz Pulse Generation and Plasma Density During Two-Color Filamentation in Air, Jiayu Zhao[1], Yizhu Zhang[2], Tao Zeng[1], Jing Yang[1], Weiwei Liu[1]; [1]*Nankai Univ., China;* [2]*Shanghai Advanced Research Inst., China.* The variation of plasma density, which is sensitive to the BBO crystal rotation angle, is systematically investigated in this work. According to our results, the well-known photocurrent model could not reproduce the characteristics of the THz pulse generated in both polarization directions.

JTu5A.10
Internal Conical Diffraction of a Top-hat Beam, Ronan T. Darcy[1], James G. Lunney[1], John Donegan[1]; [1]*Trinity College Dublin, Ireland.* The evolution of a beam undergoing internal conical diffraction exhibits a sensitive dependence on the spatial profile of the incident beam. We investigate the case of a top-hat incident beam undergoing conical diffraction.

JTu5A.11
Generation of Versatile Vortex Linear Light Bullet, Xin Huang[1], Qian Cao[2,3], Han Li[1], Peiyun Li[1], Andy Chong[1,2]; [1]*Univ. of Dayton, USA;* [2]*Deutsches-Elektronen Synchrotron, Germany;* [3]*Dept. of Physics, Univ. of Hamburg, Germany.* We demonstrate a versatile vortex linear light bullet as a vortex Airy-Bessel wave packet for the first time. Its non-varying three-dimensional (3D) vortex field in linear propagation is verified by 3D measurements.

JTu5A.12
Photon pair generation in leaky coupled-resonator optical waveguides via spontaneous four-wave mixing, Mohsen Kamandar[1], Marc M. Dignam[1]; [1]*Queen's Univ. at Kingston, Canada.* A fully quantum mechanical formalism is developed to calculate photon pair detection probabilities in leaky coupled-resonator optical waveguide. Using our formalism we have studied the effect of loss on pair evolution as well as higher order pair generations in the system.

JTu5A.13
Surface enhanced nonlinear optics using lithography-free metasurfaces , Kai Liu[1], Tianmu Zhang[1], Dengxin Ji[1], Joseph Murphy[1], Haomin Song[1], Tim Thomay[1], Kebin Shi[2], Qiaoqiang Gan[1], Alexander Cartwright[1]; [1]*State Univ. of New York at Buffalo, USA;* [2]*Peking Univ., China.* We demonstrate a strong enhancement of second harmonic generation based on a three-layered super absorbing metasurface consisting of an ultrathin spacer layer sandwiched by an array of random metallic nanoparticles and a metal ground plate.

JTu5A.14
Measuring Orbital Angular Momentum of Light With a Single, Stationary Lens, Samuel N. Alperin[1], Mark E. Siemens[1], Robert D. Niederriter[2], Juliet Gopinath[3]; [1]*Dept. of Physics and Astronomy, Univ. of Denver, USA;* [2]*Dept. of Physics, Univ. of Colorado, Boulder, USA;* [3]*Dept. of Electrical, Computer, and Energy Engineering, Univ. of Colorado, Boulder, USA.* We demonstrate that average orbital angular momentum (OAM) can be measured with a simplified twist parameter measurement technique. This technique uses a stationary apparatus composed of only a cylindrical lens and a CCD.

JTu5A.15
Coherent Artifact Study of Multiphoton Intrapulse Interference Phase Scan, Michelle Rhodes[1], Rick Trebino[1]; [1]*Georgia Inst. of Technology, USA.* We study intensity-and-phase measurements of unstable trains of pulses using multiphoton intrapulse interference phase scan (MIIPS). MIIPS retrieves only a coherent artifact and so can under-estimates pulse lengths, but wider measured traces can indicate instability.

JTu5A.16
Parity-Time Anti-Symmetric Parametric Amplifier, Diana A. Antonosyan[1], Alexander S. Solntsev[1], Andrey A. Sukhorukov[1]; [1]*Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National Univ., Australia.* We predict that directional coupler of quadratically nonlinear and lossy waveguides can perform ultrafast signal switching and parametric amplification, using the pump-controlled breaking of the parity-time anti-symmetry associated with nonlinear wave mixing.

JTu5A.17
Spectral analysis of the optical pulses produced by the interaction of optical and THz pulses in a ZnTe crystal, Marion Cornet[1], Jérôme Degert[1], Emmanuel Abraham[1], Eric Freysz[1,2]; [1]*Université de Bordeaux, France;* [2]*LOMA, Université de Bordeaux, UMR 5798, CNRS, France.* The spectra of the optical pulses generated during the interaction of THz and optical pulses in a ZnTe crystal indicate that, besides sum and difference frequency mixing, spectral components associated to cross-phase modulation are produced.

JTu5A.18
Waves of constant intensity and their instabilities in non-Hermitian photonic structures, Konstantinos Makris[2,1], Ziad Musslimani[3], Demetrios N. Christodoulides[4], Stefan Rotter[2]; [1]*Princeton Univ., USA;* [2]*Inst. for Theoretical Physics, Vienna Univ. of Technology, Austria;* [3]*Mathematics, Florida State Univ., USA;* [4]*College of Optics-CREOL, Univ. of Central Florida, USA.* We study, for the first time, the modulation instability of a new class of *constant intensity* solutions (valid also for linear non-hermitian media) of nonlinear Schrödinger equation in the presence of a complex optical potential.

JTu5A.19
Composite multi-vortex diffraction-free beams and van Hove singularities in honeycomb lattices, Vassilis Paltoglou[1], Zhigang Chen[2], Nikolaos K. Efremidis[1]; [1]*Dept. of Mathematics and Applied Mathematics, Univ. of Crete, Greece;* [2]*Dept. of Physics and Astronomy, San Francisco State Univ., USA.* We find that honeycomb lattices support diffraction-free multi-vortices above the van-Hove singularity. Exact solutions for the spinor components are obtained in the Dirac limit. Right at the singularity the solutions become infinite extend stripes.

JTu5A.20
Hybrid Chalcogenide Microstructured Optical Fiber for Mid-infrared Soliton Self-frequency Shift, Tonglei Cheng[1], Yasuhire Kanou[1], Xiaojie Xue[1], Dinghuan Deng[1], Lei Zhang[1], Lai Liu[1], Morio Matsumoto[2], Hiroshige Tezuka[2], Takenobu Suzuki[1], Yasutake Ohishi[1]; [1]*ofmlab, Japan;* [2]*Furukawa Denshi Co., Ltd., Japan.* A hybrid $AsSe_2$-As_2S_5 microstructured optical fiber is fabricated by the rod-in-tube drawing technique. Soliton self-frequency shift with a soliton center wavelength from ~2.986 to 3.419 mm is observed at the pump wavelength of ~2.8 mm.

JTu5A.21
Tunable Pulse Compression by Nonlinear Cross-Phase Modulation using Cascaded Electro-Optic Effects, Guangzhen Li[1], Haowei Jiang[1], Xianfeng Chen[1], Yuping Chen[1]; [1]*Shanghai Jiaotong Univ., China.* We demonstrate the first pulse compression induced by cross-phase modulation through cascading Pockels effects. It provides first practically useful solutions for enhanced effective third-order nonlinearity independent of light intensity.

JTu5A.22
Second Harmonics of Phase Locked Laser Arrays, Chene Tradonsky[1], Nir Davidson[1], Vishwa Pal[1], Asher A. Friesem[1], Micha Nixon[1], Eitan Ronen[1], Ronen Chriki[1]; [1]*Weizmann Inst. of Science, Israel.* Second harmonic generation in coupled laser arrays is exploited to convert out-of-phase lasers into in-phase lasers and reveal hitherto unknown properties of some laser array geometries.

18:00–20:00
JTu5A • Poster Session I and Conference Reception

JTu5A.23
Tapered Seven-core Photonic Crystal Fiber for Flat Supercontinuum Generation, Xing Luo[1], Jinggang Peng[1], Lan Chen[1], Luyun Yang[1], Nengli Dai[1], Haiqing Li[1], Jinyan Li[1]; *[1]Wuhan National Lab for Optoelectronics, China.* We report the broadband supercontinuum (SC) generation in a tapered seven-core photonic crystal fiber (PCF). The introducing of a section of taper waist dramatically alters the group velocity and making the SC flatter.

JTu5A.24
Mechanism of THz Generation from Graphite, Yan Yin[3,1], Tong Ye[3], Yiwen E[3], Yuping Yang[2], Sheng Meng[3], Li Wang[3,1]; *[1]Cooperative Innovation Centre of Terahertz Science, China; [2]Central Univ. for Nationalities, China; [3]Inst. of Physics, CAS, China.* We employ an electric gating method to modulate the surface field of graphite and study the THz generation. The result reveals the mechanism, the similarities and differences to semiconductors, and the effective mass difference of electrons and holes.

JTu5A.25
Quantum Nanoantennas for Making Nonlinear and Self-Modulatable Metasurface, Mohamed Farhat[1], Pai-Yen Chen[2]; *[1]King Abdullah Univ of Science & Tech, Saudi Arabia; [2]Wayne State Univ., USA.* We investigate the plasmonic nanodipole antenna with sub-microscopic nanogap. Relevant quantum conductivities, including linear and nonlinear components, are observed due to the photon-assisted quantum tunneling, realizing optical nano-radiators with enhanced amplitude and frequency modulations.

JTu5A.26
All Periodically-poled Crystals Based Source of Tunable, Continuous-wave, Single-frequency, Ultraviolet Radiation, Aadhi A[1,2], Apurv Chaitanya N[1,2], Ravindra pratap singh[1], Goutam Kumar Samanta[1]; *[1]Physical Research Lab, India; [2]Indian Inst. of Technology-Gandhinagar, India.* We report on all periodically-poled crystals based singly-resonant optical parametric oscillator (SRO) generating continuous-wave, single-frequency, tunable UV radiation with maximum output power of 336mW in 18.5 MHz line-width at 399.2nm. It has tunability of 18nm.

JTu5A.27
A Novel Graphene-Silicon Hybrid Waveguide for Nonlinearity Enhancement in Near-Infrared Band, Qiang Jin[1], Jiamei Lu[1], Qiang Yan[1], Xibin Li[1], Qianyu Gao[1], Shiming Gao[1]; *[1]Zhejiang Univ., China.* A novel graphene-silicon hybrid waveguide is proposed to enhance the nonlinearity in near-infrared band using a MoO_3 overlayer for light confinement. A four-wave mixing efficiency of -27.3 dB is numerically obtained in a 25-μm-long waveguide.

JTu5A.28
Chemical Vapor Deposition (CVD) of Graphene for Four-Wave-Mixing (FWM) Based QPSK Wavelength Conversion, Xiao Hu[1], Andong Wang[1], Mengqi Zeng[2], Chengcheng Gui[1], Lei Fu[2], Jing Wang[1]; *[1]Wuhan National Lab for Optoelectronics, Huazhong Univ. of Science & Technology, China; [2]College of Chemistry and Molecular Science, Wuhan Univ., China.* We experimentally demonstrate FWM based wavelength conversion of a 10 Gbaud/s QPSK signal with graphene grown by CVD method. The observed OSNR penalty is around 1 dB for QPSK wavelength conversion.

JTu5A.29
Nonlinear Optical Properties Of A Graphene-Polyvinyl Alcohol Composite From 1550 nm To 2400 nm, Giorgos Demetriou[1], Fabio Biancalana[1], Henry T. Bookey[2,1], Ajoy Kar[1]; *[1]Inst. of Photonics and Quantum Sciences, Heriot Watt Univ., UK; [2]Fraunhofer CAP, UK.* The nonlinear optical properties of a graphene-Polyvinyl alcohol (G-PVA) composite are studied in the femtosecond temporal regime by employing the Z-scan technique. The nonlinear coefficients β_{eff}, I_{sat} and n_2 are calculated via numerical fitting.

JTu5A.30
1.2 W-average-power, Yb-fiber-pumped, Picosecond Ultraviolet Source at 355 nm Based on BiB_3O_6, Suddapalli Chaitanya Kumar[1], Enrique sanchez Bautista[1], Majid Ebrahim-Zadeh[1,2]; *[1]ICFO -The Inst. of Photonic Sciences, Spain; [2]Institucio Catalana de Recerca i Estudis Avancats (ICREA), Passeig Lluis Companys 23, Spain.* We report a compact, stable, 79.5-MHz, Yb-fiber-based, picosecond UV source generating 1.2-W of power at 355 nm with a stability better than 0.4% rms over 3 hours, and pointing stability <45 μrad in good spatial-beam-quality.

JTu5A.31
Kerr nonlinearity of Thulium-doped fiber near 2 μm, Svyatoslav Kharitonov[1], Adrien Billat[1], Ludovic Zulliger[1], Steevy Cordette[1], Armand Vedadi[1], Camille-Sophie Brès[1]; *[1]STI-IEL, Photonic Systems Lab (PHOSL), EPFL, Switzerland.* The nonlinear coefficient and group velocity dispersion of a thulium-doped fiber near 2μm are evaluated via four-wave mixing. Nonlinearity of thulium-doped fiber can be used for the design of doped-fiber lasers in this spectral region.

JTu5A.32
Impact of Higher-Order Dispersion on the Performance of a Kerr Frequency Comb as Affected by the Generated Dispersive Wave, Changjing Bao[1], Lin Zhang[2], Yan Yan[1], Andrey Matsko[3], Guodong Xie[1], Long Li[1], Lionel Kimerling[2], Jurgen Michel[2], Lute Maleki[3], alan willner[1]; *[1]Dept. of Electrical Engineering, Univ. of Southern California, USA; [2]Dept. of Materials Science and Engineering, MIT, USA; [3]OEwaves Inc., USA.* The dispersive wave generated from the higher-order dispersion perturbation is found to limit the Kerr comb performance in microring resonators. A negative fourth-order dispersion can potentially reduce the effect of dispersive wave.

JTu5A.33
1 MW peak power at 266 nm in nonlinear $YAl_3(BO_3)_4$ (YAB) single crystal, Lihe Zheng[1], jinlei ren[2], Pascal Loiseau[2], Gerard Aka[2], Takunori Taira[1], Daniel Rytz[3]; *[1]Inst. for Molecular Science, Japan; [2]PSL Research Univ., Inst. de Recherche de Chimie Paris IRCP, Chimie ParisTech, France; [3]FEE GmbH, Germany.* $YAl_3(BO_3)_4$ crystal enables the highest UV power of 1.8 MW and shortest pulse of 118 ps with power conversion efficiency of 37 % at 266 nm by using LBO crystal and Nd:YAG/Cr:YAG microchip laser.

JTu5A.34
Phase-matching properties of $GaS_{0.4}Se_{0.6}$ for difference-frequency generation in the 100.4-1030.6μm range, Kiyoshi Kato[1], Valentin Petrov[2], Nobuhiro Umemura[1]; *[1]Chitose Inst of Science and Technology, Japan; [2]Nonlinear optics and ultrafast spectroscopy, Max-Born Inst., Germany.* This paper reports the phase-matching properties of $GaS_{0.4}Se_{0.6}$ for DFG between a Nd:YAG laser and a Nd:YAG laser-pumped BBO/OPO in the 100.4-1030.6μm range and refines the Sellmeier equations for GaS_xSe_{1-x} (x=0, 0.4, and 1.0).

JTu5A.35
Real-time detection of formaldehyde using PPLN-based mid-infrared laser for study of sick house syndrome, Masaki Asobe[1], Yutato Takemiya[1], Shoutsu Rin[1], Yuhei Matsuya[1], Teruyo Aoki[1], Akira Katoh[1], Ryuta Someya[1], Akira Tokura[2], Hirokazu Takenouchi[2], Shigeru Yamaguchi[1]; *[1]Tokai Univ., Japan; [2]NTT Device Technology Labs, Japan.* We studied the detection of formaldehyde using a compact 3-mm DFG light source based on a PPLN waveguide. Single-pass DFG of laser diodes enables wavelength modulation spectroscopy and real-time detection.

JTu5A.36
2D Quadratic Nonlinear Photonic Crystal for Pulsed Orange Generation in a Dual-Wavelength Nd:YVO_4 Laser, Yen-Hung Chen[1], Wei-Kun Chang[1], Hung-Ping Chung[1], Pin-Yu Chou[1]; *[1]National Central Univ., Taiwan.* A novel $LiNbO_3$ 2D aperiodic nonlinear photonic crystal was constructed to work simultaneously as a dual-wavelength Q-switch and a sum frequency generator in a Nd:YVO_4 laser. ~531-W peak-power orange light was obtained with this laser.

JTu5A.37
Dynamic Instabilities of Self-Excited Oscillation in Optical Ring Resonator, Jianguo Huang[1,2], Bin Dong[2], Hong Cai[3], Yuandong Gu[3], Jiuhui Wu[1], Tianning Chen[1], Ai-Qun LIU[2]; *[1]Xian Jiaotong Univ., China; [2]Nanyang Technological Univ., Singapore; [3]Inst. of Microelectronics, A*STAR, Singapore.* We demonstrated the nonlinear dynamic instabilities in the self-excited oscillations in the silicon ring resonators. A hysteresis loop is observed both in forward and backward tuning of the input wavelength and the input power.

JTu5A.38
Low-threshold collinear parametric Raman comb generation in calcite, Michal Jelinek[1], Vaclav Kubecek[1], Helena Jelinkova[1], Sergei Smetanin[2]; *[1]Czech Technical Univ. in Prague, Czech Republic; [2]Prokhorov General Physics Inst. of Russian Academy of Sciences, Russia.* The optimal conditions of low-threshold collinear parametric Raman-comb generation in calcite from the 477-nm second anti-Stokes to 692-nm fourth Stokes component under 20-ps laser excitation at 532-nm are demonstrated in good agreement with theoretical model.

JTu5A.39
High-power silica-based Raman fiber amplifier at 2147 nm, Jiang Liu[1], Fangzhou Tan[1], Hongxing Shi[1], Pu Wang[1]; *[1]Beijing Univ. of Technology, China.* We demonstrated a silica-based Raman all-fiber amplifier delivering as much as 14.3W of output power at a wavelength of 2147nm. The conversion efficiency for the Raman fiber amplifier was 38.5% from 1963nm to 2147nm.

JTu5A.40
Raman scattering and Kerr shock induced breather soliton in Kerr frequency comb generation, Chengying Bao[1], Changxi Yang[1], Lin Zhang[2], Lionel Kimerling[2], Jurgen Michel[2]; *[1]Tsinghua Univ, USA; [2]MIT, USA.* We found Raman scattering and Kerr shock tend to induce breather soliton in Kerr frequency comb generation. They will also degrades the coherence property of the excited breather soliton.

JTu5A.41
Spatial and Spectral Ellipsometry of Light Filaments, Ladan Arissian[1], Shermineh Rostami[1], Jean-Claude Diels[1]; *[1]Univ. of New Mexico, USA.* Measuring the continuum polarization against pulse ellipticity of a laser filament is introduced as a new paradigm for quantifying nonlinearities in filamentation such as ionization paths, molecular alignment, nonlinear index and field intensity.

JTu5A.42
Broadband Phase-Matched Second-Harmonic Generation via Dielectric-Loaded Surface Plasmon Polariton Waveguide, Sangsik Kim[1], Minghao Qi[1]; *[1]School of Electrical and Computer Engineering and Birck Nanotechnology Center, Purdue Univ., USA.* We present the concept of broadband phase-matching for second-harmonic generation with a dielectric-loaded surface plasmon polariton waveguide. Nonlinear coupled mode analysis is conducted to evaluate the broadband response and the conversion efficiency of second-harmonic generation.

JTu5A.43
Chip-based frequency conversion by four-wave-mixing Bragg scattering in Si_3N_4 microrings, Qing Li[2,1], Marcelo I. Davanco[2], Kartik Srinivasan[2]; *[1]Maryland NanoCenter, Univ. of Maryland, USA; [2]National Inst. of Standards and Technology, USA.* We demonstrate frequency conversion via four-wave-mixing Bragg scattering in Si_3N_4 microrings. The intra-chip conversion efficiency in 40-μm-radius microrings is -17 dB, a >40 dB increased compared to 1.2-cm-long Si_3N_4 waveguides under equal pumping conditions.

18:00–20:00
JTu5A • Poster Session I and Conference Reception

JTu5A.44
Full (3+1)D Split-Step Technique for Spatial Mode Analysis of White Light Generation in Bulk Kerr-Media, Haider Zia[1], Aradhana Choudhuri[1], Ingmar Hartl[2], R.J. Dwayne Miller[1,3], Axel Ruehl[2]; [1]*Max Planck Inst. for the Structure and Dynamics of Matter, Germany;* [2]*Deutsches Elektronen-Synchrotron (DESY), Germany;* [3]*Dept.s of Chemistry and Physics, Univ. of Toronto, Canada.* We present a novel full (3+1)D split-step numerical model for white-light generation including all major physical effects. We present a detailed spatial mode analysis and derive imaging systems to re-shape the spatial distribution.

JTu5A.45
Silicon Waveguide based Two-Input Simultaneous Quaternary Hybrid Doubling/Subtraction (2A-B, 2B-A) Using Degenerate FWM and QPSK, Chengcheng Gui[1], Jian Wang[1]; [1]*Wuhan National Lab for Optoelectr, China.* By exploiting two degenerate four-wave mixing in a silicon waveguide and quadrature phase-shift keying (QPSK) signals, we experimentally demonstrate two-input (A, B) simultaneous optical quaternary hybrid doubling/subtraction (2A-B, 2B-A).

JTu5A.46
Efficient and ultra-compact computational metamaterials for integrated photonics and free-space applications, Bing Shen[1], Peng Wang[1], Randy C. Polson[1], Rajesh Menon[1]; [1]*Univ. of Utah, USA.* We applied nonlinear optimization to design metamaterials as free-space polarizers, integrated fiber couplers, polarization splitter/rotators, etc. Such devices exhibit at least comparable or better performance than their conventional counterparts, but occupy a much smaller size.

JTu5A.47
Photodetector based on lateral graphene p-n junction created by electron-beam irradiation, Xuechao Yu[1], Qi Jie Wang[1,2]; [1]*School of Electrical and Electronic Engineering, OPTIMUS, Photonics Centre of Excellence,, Singapore;* [2]*Centre for Disruptive Photonic Technologies, Nanyang Technological Univ., Singapore.* Graphene p-n junctions fabricated by electron irradiation method that induces n-type doping in the intrinsic p-type graphene are demonstrated. Photoresponse was obtained because the photoexcited electron-hole pairs can be separated in the graphene p-n junction by the built-in potential.

JTu5A.48
Light Confinement in Hyperuniform Photonic Slabs: High-Q Cavities and Low-Loss Waveguides, Timothy Amoah[1], Marian Florescu[1]; [1]*Univ. of Surrey, UK.* Using FDTD and band structure simulations, we demonstrate efficient confinement of TE radiation in high-Q optical-cavities and low-loss waveguides in planar hyperuniform-disordered architectures based on a design strategy that has potential to be a general purpose platform for optical microcircuits.

JTu5A.49
Tunable Spectral Engineering of Coupled Silicon Microcavities, Mario C. Souza[1], Luis A. Barea[1], Gustavo Wiederhecker[1], Antonio A. von Zuben[1], Newton C. Frateschi[1]; [1]*Universidade Estadual de Campinas, Brazil.* We demonstrate the generation and control of optical resonance mode-splitting arising from a single-notch resonances using coupled silicon microring resonators with electrically controlled counter-propagating mode excitation.

JTu5A.50
Efficiency Improvement of Crystalline-Si Solar Cell Using the Combination of Europium Doped Silicate Phosphors Down Shifting and SiO_2 Antireflective Coating, Guo-Chang Yang[1], Wen-Jeng Ho[1], Chien-Wu Yeh[1], Ruei-Siang Sue[1], Yu-Tang She[1], Chia-Hua Hu[1], Yu-Jie Deng[1]; [1]*National Taipei Univ. of Technology, Taiwan.* Impressive efficiency enhancement of 15.38% of crystalline-silicon solar-cell with Eu-doped silicate-phosphors and SiO_2-layer using spin-on technique is demonstrated. Reflectance, external quantum efficiency, and photovoltaic I-V characteristics are used to examine the down-shifting effectiveness.

JTu5A.51
High-index-contrast Grating Mirrors Implemented on the Polysilicon Gates of a Standard Bulk CMOS Process, Yung-Jr Hung[1], Ming-Chun Hsieh[1]; [1]*National Sun Yat-sen Univ., Taiwan.* High-index-contrast grating implemented in bulk CMOS can provide 95% surface reflectivity with 50 nm bandwidth for TE polarization. Higher reflectivity is achievable by creating air cavities beneath HCGs to avoid the optical leakage to the substrate.

JTu5A.52
A Compact Polarization Beam Splitter Based on Augmented Low Index Guiding Structure, Xiao Sun[1], Muhammad Z. Alam[1], J. Stewart Aitchison[1], Mo Mojahedi[1]; [1]*Univ. of Toronto, Canada.* A compact broadband polarization beam splitter based on the augmented low index guiding scheme is proposed. TM and TE modes are separated in two layers with the TM mode confined in the lower index layer.

JTu5A.53
Highly Compact Polarization Insensitive Strip-Slot Waveguide Mode Converter, Qingzhong Deng[1], Qiaojing Yan[1], Lu Liu[1], Xinbai Li[1], Zhiping Zhou[1]; [1]*State Key Lab of Advanced Optical Communication Systems and Networks, School of Electronics Engineering and Computer Science, Peking Univ., China.* A polarization insensitive strip-slot waveguide mode converter with large fabrication tolerance is proposed based on symmetric multimode interference (MMI). This converter can achieve efficient strip-slot waveguide coupling (TE:94.9%, TM:94.6%) while the dimensions are only 1.18μm×3μm.

JTu5A.54
Triple Metal-Film Subwavelength Gratings on Both Sides of a Silicon Substrate for Mid-Infrared polarizers, Kazuo Shiraishi[1], Shogo Higuchi[1], Hiroshi Kakinuma[1], Jun Shimizu[1], Hidehiko Yoda[1], Hiroshi Ohno[1]; [1]*Utsunomiya Univ., Japan.* Triple metal-film subwavelength gratings on both sides of a thin silicon substrate are fabricated for polarizers in the mid-infrared. An extinction ratio of higher than 30dB together with insertion loss of 2 dB is obtained.

JTu5A.55
Nanobump Microresonators at the Fiber Surface , Leonid A. Kochkurov[1], Misha Sumetsky[1]; [1]*Aston Univ., UK.* It is shown that an asymmetric nanometer-high bump at the fiber surface causes strong localization of whispering gallery modes. Our theory explains and describes the experimentally observed nanobump microresonators in Surface Nanoscale Axial Photonics.

JTu5A.56
Surface Mode in Photonic Crystal Fishbone Nanocavity for Highly Efficient Optical Sensing and Trapping, Tsan-Wen Lu[1], Po-Tsung Lee[1]; [1]*National Chiao Tung Univ., Taiwan.* A novel one-dimensional photonic crystal fishbone (*FB*) with surface wave is proposed. Via designing high quality *FB* nanocavity, high sensitivity for optical sensing and strong optical force for optical trapping in fluidics can be obtained.

JTu5A.57
Design of On-Chip Dielectric Elliptical Meta-Reflectarray for Bessel Beams Generation and N-Fold Orbital Angular Momentum (OAM) Multicasting, Jing Du[1], Zhidan Xu[1], Long Zhu[1], Shuhui Li[1], Jian Wang[1]; [1]*Huazhong Univ. of Sci. and Tech., China.* We design dielectric meta-reflectarrays to realize Bessel beams generation and OAM multicasting. The purities of generated Bessel beams are higher than 0.93 and the crosstalks between the multicasted OAM channels and their neighboring ones are less than -14 dB.

JTu5A.58
Microring resonator design with improved quality factors using quarter Bezier curves, Hamed Pishvai Bazargani[1], José Azaña[1], Lukas Chrostowski[2], Jonas Flueckiger[2]; [1]*INRS, Canada;* [2]*UBC, Canada.* A new design concept to improve the quality factor of ring resonators using quarter Bezier curves has been investigated. Quality factor improvements by 3 times have been achieved for a 3-μm radius ring resonator.

JTu5A.59
Optimized emission in nanorod arrays through quasi-aperiodic inverse design , Patrick Anderson[1], Michelle Povinelli[1]; [1]*Univ. of Southern California, EE, USA.* We investigate a new class of quasi-aperiodic nanorod structures for emission enhancement. Using inverse design we identify one optimized structure which produces a 1.48X enhancement in extracted power relative to a periodic array.

JTu5A.60
Lasing in optimized two dimensional iron-nail-shape nanorod photonic crystals, Soon-Yong Kwon[1], Seul-Ki Moon[1], Jae-Hyuck Choi[2], Se-Hwan Jang[2], Kwang-Yong Jeong[2], Hong-Gyu Park[2], Jin-Kyu Yang[1]; [1]*kongju National Univ., Korea;* [2]*Korea Univ., Korea.* We demonstrated lasing at the band edges in optimized two-dimensional iron-nail-shape nanorod photonic crystals by optical pumping at room temperature. The size of the nanorod gradually increased toward the edge of the pattern in order to reduce the optical loss in horizontal direction.

JTu5A.61
Optomechanical Crystal Cavity with Ultra-small Effective Motion Mass based on Split-nanobeam Structure, Yeping Zhang[1], Kaiyu Cui[1], Zhilei Huang[1], Xue Feng[1], Yidong Huang[1], Fang Liu[1], Wei Zhang[1]; [1]*Tsinghua Univ., China.* A split-nanobeam optomechanical crystal cavity is proposed. By adjusting the split width, an ultra-small effective motion mass as small as 5.2fg is realized with a high mechanical frequency of 7.55GHz.

JTu5A.62
Mode Conversion Based on Dielectric Metamaterial in Silicon, David Ohana[1], Boris Desiatov[1], Noa Mazurski[1], Uriel Levy[1]; [1]*The Hebrew Univ. of Jerusalem, Israel.* We design, analyze and experimentally demonstrate a novel mode converter in silicon waveguide based on a graded index co-directional grating coupler. Numerical simulations results and microscope images of modes' far field are presented and discussed.

JTu5A.63
Design of Integrated Circularly Polarized Orbital Angular Momentum (OAM) Beam Emitter Using Microring with Interleaved Tailored Angular Gratings, Jingwen Ma[1], Jing Du[1], Xiao Hu[1], Jian Wang[1]; [1]*Wuhan National Lab for Optoelectr, China.* By exploiting microring with interleaved tailored angular gratings, we present a simple design of integrated circularly polarized orbital angular momentum (OAM) beam emitter. The Stokes parameter S_3 is above 0.97 with high OAM purity of 99.84%.

JTu5A.64
Multifunctional, tunable and wideband all-fiber filter based on θ shaped microfiber resonator, Zhilin Xu[1], Qizhen Sun[1,2], Borui Li[1], Yiyang Luo[1], Wengao Lu[1], Haipeng Luo[1], Deming Liu[1], Lin Zhang[2]; [1]*Huazhong Univ of Science and Technology, China;* [2]*Aston Univ., UK.* A compact θ shaped microfiber resonator for multifunctional, tunable and wideband filter is proposed. The filtering performance of reflection and transmission spectra depending on coupling coefficients and cavity length is theoretically investigated and experimentally demonstrated.

JTu5A.65
Photocurrent Density Enhancement of a III-V Inverse Quantum Dot Intermediate Band Gap Photovoltaic Device, Jeongdong Kim[1], Xiaogang Chen[1], Xiuling Li[1], James Coleman[1]; [1]*Univ. of Illinois, USA.* We measured the photocurrent density of quantum well (QW) and inverse quantum dot (IQD) photovoltaic devices. The photocurrent per unit area of IQD was enhanced as the carrier confinement became stronger with increasing diameter.

18:00–20:00
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JTu5A.66
Plasmonic Mode-Evolution-based Polarization Rotator and Coupler, Sangsik Kim[1], Minghao Qi[1]; [1]*School of Electrical and Computer Engineering and Birck Nanotechnology Center, Purdue Univ., USA.* A plasmonic mode-evolution-based device rotates the TE mode in silicon waveguide and couples it to the hybrid plasmonic mode with a 92% peak coupling factor and ⊠-3 dB bandwidth of over 500 nm at near infrared.

JTu5A.67
Aluminum Micro-Patch Arrays for Highly-Sensitive Vibration Spectroscopy, Duk-Yong Choi[1], Barry Luther-Davies[1], Vivek R. Shrestha[2], Sang-Shin Lee[2]; [1]*The Australian National Univ., Australia;* [2]*Kwangwoon Univ., Korea.* We demonstrate collective plasmonic resonance from aluminum micro-patch arrays patterned on slide glass. This cost-efficient device can be applied in extremely sensitive vibration spectroscopy.

JTu5A.68
High Sensitivity Dark Mode Plasmonic Resonance of Gold Nanoantennas Arrays in Evanescent Waves, Kuo-Ping Chen[1], Yi-Hsun Chen[1], Yu-Lun Kuo[1], Zhen-hong Yang[1], Che-Yuan Chang[1]; [1]*National Chaio-Tung Univ., Taiwan.* Plasmonic dark modes of gold nanoantennas are observed in evanescent waves. Dark mode not only has a higher extinction coefficient but also achieves higher sensitivity to the surrounding environment. The sensitivity of the dark mode is 4.84 times that of the bright mode in figure of merit.

JTu5A.69
Optionally focusing with plasmonic vortex lens, Hailong Zhou[1], Jianji Dong[1], Yifeng Zhou[1], Xinliang Zhang[1]; [1]*Wuhan National Lab for Optoelectronics, China.* We present a specific plasmonic vortex lens (PVL) structure to focus the surface plasmon polariton wave on an arbitrary spatial position.

JTu5A.70
Ultrathin High Efficiency Photodetectors Based on Near Field Enhanced Optical Absorption, Moshe Zohar[1], Mark Auslender[1], Shlomo Hava[1]; [1]*Ben Gurion Univ. of the Negev, Israel.* Ultrathin photodetectors, comprising a thin film optical absorber between two transparent layers near a quarter-wave high refractive index one and subwavelength grating, are designed to attain ~100% peak spectral absorbance. Near-field enhancement mechanism of the absorption is demonstrated.

JTu5A.71
High visibility on-chip quantum interference of single surface plasmons, Yong-Jing Cai[1], Ming Li[1], Xifeng Ren[1], Chang-Ling Zou[1], Xiao Xiong[1], Hua-Lin Lei[1], Bi-Heng Liu[1], Guo-Ping Guo[1], Guang-Can Guo[1]; [1]*Univ of science and technology of China, China.* In this work, the on-chip quantum interference of two single surface plasmons was achieved and the high visibility (greater than 90%) proves the bosonic nature of single plasmons. The effect of intrinsic losses in plasmonic waveguides is also discussed.

JTu5A.72
Nanophotonic Modulator with Bismuth Ferrite as Low-loss Switchable Material, Viktoriia Babicheva[2,1], Sergei Zhukovsky[2,1], Andrei Lavrinenko[2]; [1]*ITMO Univ., Russia;* [2]*DTU Fotonik, Technical Univ. of Denmark, Denmark.* We propose a nanophotonic waveguide modulator with bismuth ferrite as a tunable material. Due to near-zero losses in bismuth ferrite, modulation with up to 20 dB/μm extinction ratio and 12 μm propagation length is achieved.

JTu5A.73
Optical Modulation of Graphene-Cladded Silicon Photonic Crystal Cavity, Lin Gan[1], Zhe Shi[1], Tinghui Xiao[1], Honglian Guo[1], Zhiyuan Li[1]; [1]*CAS Inst. of Physics, China.* We demonstrate all-optical tuning of a graphene-cladded silicon photonic crystal cavity. A continuous-wave laser is focused on the cavity and a large resonant shift is observed. Several physical reasons causing the shift are discussed in details.

JTu5A.74
Plasmonic Enhancement of Eu:Y_2O_3 Luminescence By Al Percolated Layer, Nora Abdellaoui[1], Antonio Pereira[1], Alice Berthelot[1], Bernard Moine[1], Nicholas Blanchard[1], Anne Pillonnet[1]; [1]*Institut Lumière Matière, France.* We propose the design of plasmonic nanostructure for Eu3+ luminescence enhancement. We control our crystalline structure with a nanosized precision thanks to Eu3+ crystalline probe and we show luminescence enhancement thanks to Al Plasmon in UV.

JTu5A.75
Second Harmonic Generation from Symmetric and Asymmetric Gold Nanoantennas, Wei-Liang Chen[1], Fan-Cheng Lin[2], Jer-Shing Huang[2], Yu-Ming Chang[1]; [1]*Center for Condensed Matter Sciences, National Taiwan Univ., Taiwan;* [2]*Dept. of Chemistry, National Tsing Hua Univ., Taiwan.* We measure second harmonic generation (SHG) from symmetric and asymmetric gold nanoantennas and find that asymmetric antennas in fundamental bonding resonance with excitation can lead to four time SHG enhancement than that of symmetric nanoantennas.

JTu5A.76
Phase change dispersion of plasmonic nano-objects, Xie Zeng[1], Haifeng Hu[1], Yongkang Gao[2], Dengxin Ji[1], Nan Zhang[1], Haomin Song[1], Kai Liu[1], Qiaoqiang Gan[1]; [1]*State Univ. of New York at Buffalo, USA;* [2]*Alcatel-Lucent Bell Labs, USA.* The phase change dispersion during the surface plasmon wave coupling process was extracted experimentally using a slit-groove interferometer and validated through numerical simulation, enriching the fundamental understanding of plamsonic subwavelength optics on a chip.

JTu5A.77
Near Field Measurements of the Scattering Phase Function with Evanescent Field Excitation, Roxana Rezvani Naraghi[1,2], Sergey Sukhov[1], Aristide Dogariu[1]; [1]*CREOL, The College of Optics and Photonics, Univ. of Central Florida, USA;* [2]*Dept. of Physics, Univ. of Central Florida, USA.* Scattering phase functions of spherical particles excited with evanescent waves are measured using near-field optical scanning microscopy. Polarization dependent cross-sections and asymmetry parameters are determined to improve the predictive capabilities of light transport models.

JTu5A.78
Ruby-Nanocrystal-Enhanced Random Dye Lasers, wan zakiah wan ismail[1], Wan Aizuddin Wan Razali[1], andrei zyagin[1], David Coutts[1], Ewa Goldys[1], Judith Dawes[1]; [1]*Macquarie Univ., Australia.* Rhodamine 6G random dye lasers are more efficient with ruby nanocrystal scatterers than with alumina, exhibiting reduced threshold despite the increased absorption of ruby nanocrystals.

JTu5A.79
Topological Darkness Revisited: a Four-dimensional Picture, Haomin Song[1], Xie Zeng[1], Dengxin Ji[1], Nan Zhang[1], Kai Liu[1], Qiaoqiang Gan[1]; [1]*The State Univ of New York at Buffalo, USA.* We present a complete description of "topological darkness" in a four-dimensional space regarding optical constants (i.e. *n* and *k*) of effective media, wavelengths and incident angles, which is essential for enhanced light-matter interaction in thin-films.

JTu5A.80
Plasmon Optical Trapping in Silicon Nitride Trench Waveguide, Qiancheng Zhao[1], Caner Guclu[1], Yuewang Huang[1], Filippo Capolino[1], Ozdal Boyraz[1]; [1]*Univ. of California, Irvine, USA.* Optical trapping by using bowtie antennas deposited on top of a microfluidic SiN trench waveguide is investigated. We show that the presence of plasmonic field enhancement boosts the vertical trapping force by 3 orders of magnitude.

JTu5A.81
Near Total Resonant Light Absorption in a Graphene Monolayer at Multiple Tunable Wavelengths with Aperiodic Multilayer Structures, Iman Zand[1], Ali Haddadpour[1], Christopher Granier[1], Jonathan Dowling[1], Georgios Veronis[1]; [1]*Louisiana State Univ., USA.* We investigate a one-dimensional system consisting of a graphene monolayer sandwiched between two aperiodic multilayer structures. We show that such a system can achieve near total resonant light absorption in graphene at multiple tunable wavelengths.

JTu5A.82
Visible Excitation of Surface Plasmon Polariton and Strengthened Nonlinearity in ITO coated Fe:LiNbO, Hua Zhao[1], liang li[1], Hao Wang[1], Jingwen Zhang[1,2]; [1]*Harbin Inst. of Technology, China;* [2]*Boston Applied Technologies, Inc., USA.* Anisotropic 2D diffraction orders were observed in ITO coated 1.0-mm thick iron-doped lithium noibate slabs, which can be satisfactorily by excitation of SPPs near ITO/LN interface modified by pyroelectric and bulk photovoltaic effects.

JTu5A.83
Enhancement of Single Quantum Emitters Using Ultra-Widely Tunable Nanofiber Bragg Cavities, Andreas W. Schell[2,1], Hideaki Takashima[3,2], Shunja Kamioka[4], Yasuko Oe[4,2], Shiro Fujita[2], Masazumi Fujiwara[1,4], Oliver Benson[1], Shigeki Takeuchi[2,3]; [1]*Humboldt-Universität zu Berlin, Japan;* [2]*Dept. of Electronic Science and Engineering, Kyoto Univ., Japan;* [3]*Research Inst. for Electronic Science, Hokkaido Univ., Japan;* [4]*The Inst. of Scientific and Industrial Research, Osaka Univ., Japan.* We introduce nanofiber Bragg cavities fulfilling three important requirements: small mode-volume, wide tuning-range, and efficient fiber-coupling. In a first application, we show enhancement of single quantum emitters such as quantum dots and nitrogen vacancy centers.

JTu5A.84
Surface Plasmonic Array Sensors (SPlAS): From Color Sensing to Surface Enhanced Raman Spectroscopy, Jaspreet Walia[1], Iman Khodadad[1], reza Khorasaninejad[1], Simarjeet Saini[1]; [1]*Univ. of Waterloo, Canada.* A periodic arrangement of gold crescents is shown to have very high Raman scattering enhancement factors, ~10^{-6}, as well as structural color generation properties. This opens up the possibly for a two-level sensing platform which could be tailored for a wide variety of applications.

JTu5A.85
High Temperature Plasmonics: Optical Effects on Different Nanostructures, Alessandro Alabastri[1], Andrea Toma[1], Mario Malerba[1], Francesco De Angelis[1], Remo Proietti Zaccaria[1]; [1]*Istituto Italiano di Tecnologia, Italy.* We show the effect of high temperature on the plasmonic properties of metallic nanospheres and nano-rods. It is found that the damping modifications due to temperature change, modify both the near and far field optical response.

JTu5A.86
Greatly Enhanced Kerr Nonlinearity Induced by Subwavelength-Confined Anisotropic Purcell Factors in Plasmonic Nanocavity, hongyi chen[1]; [1]*Peking Univ., China.* Combining the coherent effects in quantum optics and anisotropic Purcell factors given by surface plasmons, we theoretically investigate the greatly enhanced Kerr nonlinearity of double lambda atomic system with two vertical dipole moments.

JTu5A.87
A Photonic Crystal Explanation For a Butterfly Wing Color, Alessandro Alabastri[1], Hai Wang[1], Andrea Toma[1], Remo Proietti Zaccaria[1]; [1]*Istituto Italiano di Tecnologia, Italy.* We have theoretically explained the origin of the green/yellow colour emitted by the wings of the Teinopalpus Imperialis butterfly.The results well explain why the wings of this kind of butterfly reflect light in the green/yellow region of the optical spectrum.

18:00–20:00
JTu5A • Poster Session I and Conference Reception

JTu5A.88
Control of entanglement of two-level atoms using graphene, ANDREI NEMILENTSAU[1], Seyyed A. Hassani[1], George Hanson[1], Stephen Hughes[2]; [1]*Univ. of Wisconsin Milwaukee, USA;* [2]*Queen's Univ., Canada.* Dynamics of two-level atoms (TLAs) above lossy graphene are studied using a master equation model, and improvement of entanglement compared to the vacuum case is demonstrated. Entanglement can be controlled by graphene biasing.

JTu5A.89
Color Hologram Generation Using a Pancharatnam-Berry Phase Manipulating Metasurface, Sajid Choudhury[1], Amr Shaltout[1], Vladimir M. Shalaev[1], Alexandra Boltasseva[1], Alexander V. Kildishev[1]; [1]*Purdue Univ., USA.* We propose a new scheme to generate polychromatic holograms by manipulating the Pancharatnam-Berry phase. Using anisotropic transmission characteristics and tuning the resonant wavelengths of nanoslits, multicolor holograms can be produced for arbitrary RGB images.

JTu5A.90
Femtosecond Nanoplasmonic Dephasing of Individual Silver Nanoparticles, Rachel Glenn[1], Richa Mittal[1], Ilyas Saytashev[1], Vadmin Lozovoy[1], Marcos Dantus[1,2]; [1]*Dept. of Chemisty, Michigan State Univ., USA;* [2]*Dept. of Physics and Astronomy, Michigan State Univ., USA.* We detect the coherence of localized surface plasmon resonances in individual silver nanoparticles via accurately delayed femtosecond laser pulses. The Fourier transform of the time-resolved spectra reveals nanoplasmonic coherence components and their corresponding dephasing rates.

JTu5A.91
Fourier Plane Imaging Microscopy, Luis Grave de Peralta[1], Ayrton A. Bernussi[1]; [1]*Texas Tech Univ., USA.* Super-resolution images were obtained using a simple microscope formed by an ultrathin condenser and an objective lens. This was because the Fourier plane images carried more information about the object than real plane images do.

JTu5A.92
Room temperature lasing characteristics in metal-cavity GaN shallow grating and spiral structures, Liao Shu-Wei[1,2]; [1]*National Chiao Tung Univ., Taiwan;* [2]*Dept. of Photonics & Inst. of Electro-Optical Engineering, Taiwan.* We demonstrated a metal-cavity GaN spiral structure lasing at room temperature with the threshold power density about 17 W/cm^2 under circularly polarized pumping condition. The emission wavelength is approximately 363 nm.

JTu5A.93
Tuning metacavity modes by the symmetry breaking of metasurface, hui liu[1]; [1]*nanjing Univ., China.* A metacavity composed from metasurface is designed and experimentally demonstrated. Due to the symmetry breaking of the metasurface, the degeneracy of the different polarized cavity states is lifted. It shifts the resonating frequencies of two polarized cavity modes.

JTu5A.94
Phase control by Graphene metasurface, Zu-Bin Li[1]; [1]*Nankai Univ., China.* We numerically design and study graphene metasurface to modulate the phase of reflective light. And the phase shift from -π to π is achieved. By using graphene metasurface, we realize negative reflection and nano focusing.

JTu5A.95
Accurately Simulating Focusing Beams using Monte Carlo Techniques, Brett H. Hokr[1,2], Joel Bixler[1,3], Gabe Elpers[4], Byron Zollars[4], Robert Thomas[3], Vladislav Yakovlev[1], Marlan O. Scully[1,5]; [1]*Texas A&M Univ., USA;* [2]*TASC Inc., USA;* [3]*Bioeffects Division, Optical Radiation Branch, 711th Human Performance Wing, Human Effectiveness Directorate, USA;* [4]*Nanohmics, Inc., USA;* [5]*Baylor Univ., USA.* A simple method for accurately simulating focusing beams, which obey Gaussian optics, in the context of traditional Monte Carlo simulations is presented. This technique will allow rapid implementation into existing Monte Carlo codes.

JTu5A.96
Breaking Malus' Law: Enhancing Asymmetric Light Transmission with Metasurfaces, Cheng Zhang[1], Carl Pfeiffer[1], Taehee Jang[1], Vishva Ray[1], Anthony Grbic[1], L. Jay Guo[1]; [1]*Univ. of Michigan, USA.* A structure providing broadband asymmetric light transmission at 1.5 μm with a suppression ratio of 24:1 is achieved with a metasurface consisting of three cascaded layers of gold nano-wires, with a total thickness of λ/5.

JTu5A.97
Making Structured Metals Ultrabroadband Transparency by Surface Plasmons, Ruwen Peng[1], Ren-Hao Fan[1], Xian-Rong Huang[2], Mu Wang[1]; [1]*Nanjing Univ., China;* [2]*Argonne National Lab, USA.* We present theoretically and experimentally that one-dimensional and two-dimensional metallic gratings can become transparent and completely antireflective for extremely broadband electromagnetic waves by relying on surface plasmons or spoof surface plasmons.

JTu5A.98
Spacer-dependent coupled and decoupled super absorbing metasurfaces , Kai Liu[1], Nan Zhang[1], Dengxin Ji[1], Haomin Song[1], Xie Zeng[1], Qiaoqiang Gan[1]; [1]*State Univ. of New York at Buffalo, USA.* We differentiate the spacer-dependent peak shift in coupled and decoupled super absorbing metasurfaces based on magnetic resonance and interference mechanism, respectively, which was experimentally validated by low-cost structures fabricated by lithography-free processes.

JTu5A.99
Stadium Mushroom Metasurface for Electro-Optical Ignition of Gas Plasma, Ebrahim Forati[1], Shiva Piltan[1], Dan Sievenpiper[1]; [1]*Univ. of California San Diego, USA.* A metasurface is proposed to combine DC and laser induced discharges in micro scales. The structure is intended to be used as a platform for a new class of microplasma devices with electro-optical activation.

JTu5A.100
Dual-Band Metasurface Based Nano-Cavities, Amr Shaltout[1], Vladimir M. Shalaev[1], Alexander V. Kildishev[1]; [1]*Electrical and Computer Engineering, Purdue Univ., USA.* Fabry-Pérot nano-cavities with metasurface mirrors are developed to obtain multi-band resonances at the wavelengths that exceed the diffraction limit. Independently tuned resonance bands are thus not limited to the integer multiples of a fundamental tone.

JTu5A.101
Theoretical Demonstration of Weyl Points in 3D srs Photonic Crystals, Elena Goi[1,2], Benjamin P. Cumming[1,2], Min Gu[1,2]; [1]*Centre for Micro-Photonics and CUDOS, Australia;* [2]*Faculty of Science, Engineering and Technology, Swinburne Univ. of Technology, Australia.* We present the theoretical study of achiral 2-srs-networks and we show that these structures possess the frequency-isolated linear point degeneracies in their three-dimensional dispersion relations that define the Weyl points.

JTu5A.102
Ultra-broad Flat Band Light Absorber Based on Multi-sized Slow-wave Hyperbolic Metamaterial Thin-films, Fei Ding[1], Lei Mo[1]; [1]*Centre for Optical and Electromagnetic Research, Zhejiang Univ., China.* We realize a broadband absorber by using a hyperbolic metamaterial composed of alternating aluminum-alumina thin films based on superposition of multiple slow-wave modes. Our super absorber ensures broadband and polarization-insensitive light absorption in the visible and near-infrared regime.

JTu5A.103
Light Energy Trapping and Localization in RE^{3+} Doped PLZT Ceramics, Jingwen Zhang[1], Caixia Xu[1], Long Xu[1], Hua Zhao[1]; [1]*Harbin Inst. of Technology, China.* Single-pass gain over theoretical value and pulsation in amplified seeding light were observed in RE^{3+} doped PLZT ceramic plates. Theoretical consideration based on light energy trapping and localization was given to elucidate the findings.

JTu5A.104
Withdrawn

JTu5A.105
Tunable VO_2/Au hyperbolic metamaterial, Srujana Prayakrao[1], Brock Mendoza[2], Andrew Devine[2], Chan Kyaw[3], Robert Van Dover[2], Mikhail A. Noginov[1]; [1]*Norfolk State Univ., USA;* [2]*Cornell Univ., USA;* [3]*Morehouse College, USA.* We have fabricated and studied thin films of VO_2 and lamellar VO_2/Au metamaterials. Optical properties of the VO_2/Au metamaterials are consistent with the transition between the hyperbolic and metallic phases ocurring at elevated temperatures.

JTu5A.106
Miniaturization Resonators in Mimicking Electromagnetically Induced Transparency, Dejia Meng[1]; [1]*hust, China.* Electromagnetically induced transparency is mimicked by nested split ring resonators. The nested resonator offers a miniaturization with polarization-insensitive properties, high quality-factors and absorptions which may have essential applications in wireless communications and phased arrays

JTu5A.107
Negative-index Polarization-independent Metamaterial, Morteza Karami[1], Christopher Rosenbury[1], Steven Kitchin[1], Michael A. Fiddy[1]; [1]*Univ of North Carolina at Charlotte, USA.* We introduce a polarization-independent left-handed metamaterial. Mirrored S-shaped resonators are shown to exhibit negative refractive index; and a crossed design based on these resonators is demonstrated as a polarization insensitive metamaterial with negative index.

NOTES

CLEO: QELS-Fundamental Science

08:00–10:00
FW1A • Symposium on Cavity Quantum Electrodynamics I

Presider: Glenn Solomon; Joint Quantum Inst., USA

FW1A.1 • 08:00 Invited

James P. Gordon Memorial Speakership: Quantum State Control with Atoms and Cavities, Jean-Michel Raimond[1,2], Theo Rybarczyk[2], Bruno Peaudecerf[2], Mariane Penasa[2], Stefan Gerlich[2], Sebastien Gleyzes[2], Michel Brune[2], Serge Haroche[2], Igor Dotsenko[2]; [1]*Universite Pierre-et-Marie-Curie, France;* [2]*LKB, Collège de France, UPMC, CNRS, France.* We measure the photon number in a microwave cavity probed by circular Rydberg atoms using the Past Quantum State approach. It leads to a considerable noise reduction and allows us to access normally hidden information.

FW1A.2 • 08:30

Cavity-Modified Collective Rayleigh Scattering of Exactly Two Atoms, Rene Reimann[1], Wolfgang Alt[1], Tobias Kampschulte[1], Tobias Macha[1], Lothar Ratschbacher[1], Natalie Thau[1], Seokchan Yoon[1], Dieter Meschede[1]; [1]*Physics, Bonn Univ. - IAP, Germany.* We report on observing cooperative radiation of exactly two neutral atoms strongly coupled to an optical cavity. The roles of cavity backaction and of the relative atom-field coupling phases are discussed. Our results are important for the realization of phase-sensitive cavity QED protocols.

08:00–10:00
FW1B • Novel Sources for Attoscience

Presider: Oliver Muecke; Deutsches Elektronen Synchrotron, Germany

FW1B.1 • 08:00 Invited

Bright High Harmonics with Tunable Polarization, Oren Cohen[1]; [1]*Technion Israel Inst. of Technology, Israel.* Generation and application of bright phase-matched high-order harmonic with fully tunable polarization - from linear through elliptic to circular - is presented.

FW1B.2 • 08:30

Carbon K-edge NEXFAS spectroscopy from a table-top soft x-ray high harmonics source driven by sub-2-cycle, CEP stable, 1.85-μm 1-kHz laser pulses, Seth L. Cousin[1], Francisco Silva[1], Stephan Teichmann[1], Michael Hemmer[1], Barbara Buades[1], Jens Biegert[1,2]; [1]*ICFO -The Inst. of Photonic Sciences, Spain;* [2]*ICREA - Institució Catalana de Recerca i Estudis Avançats, Spain.* A high-flux table-top coherent soft x-ray high harmonic generation source, driven by sub-2-cycle, 1.85 μm, 1 kHz laser pulses, is applied to a condensed phase sample revealing the carbon binding orbitals of polyimide.

08:00–10:00
FW1C • Optics of Complex Media I

Presider: Alexey Yamilov; Missouri Univ of Science & Technology, USA

FW1C.1 • 08:00

Retrieving time-dependent Green's functions in optics with low-coherence interferometry, Amaury Badon[1], Geoffroy Lerosey[1], Claude Boccara[1], Mathias Fink[1], Alexandre Aubry[1]; [1]*Institut Langevin, France.* We report on the passive measurement of time-dependent Green's functions with low-coherence interferometry. We show how the mutual coherence function of an incoherent wavefield can directly yield the Green's functions between scatterers of a complex medium.

FW1C.2 • 08:15

Preferential emission into epsilon-near-zero metamaterial, Tal Galfsky[1,2], Zheng Sun[1,2], Zubin Jacob[3], Vinod M. Menon[1,2]; [1]*Physics, Graduate Center of the City Univ. of New York, USA;* [2]*Physics, City College of the City Univ. of New York, USA;* [3]*Dept. of Electrical and Computer Engineering, Univ. of Alberta, Canada.* We report preferential emission from ZnO nanoparticles into an epsilon near zero metamaterial. The structure is designed to have the parallel component of its dielectric constant approach zero at the maximum emission wavelength of ZnO.

FW1C.3 • 08:30

Topological Defect Lasers, Sebastian Knitter[1], Seng Fatt Liew[1], Wen Xiong[1], Mikhael I. Guy[2,4], Glenn S. Solomon[3,4], Hui Cao[1]; [1]*Dept. of Applied Physics, Yale Univ., USA;* [2]*Science & Research Software Core, Yale Univ., USA;* [3]*Joint Quantum Inst., Univ. of Maryland, USA;* [4]*National Inst. of Standards and Technology, USA.* We demonstrate topological defect lasers in a GaAs membrane with embedded InAs quantum dots. By introducing a disclination to a square-lattice of elliptical air holes, we obtain spatially confined lasing modes that support powerflow vortices.

08:00–10:00
FW1D • Integrated Nonlinear Devices

Presider: Luca Razzari; INRS-Energie Materiaux et Telecom, Canada

FW1D.1 • 08:00 Invited

Integrated Lithium Niobate Nonlinear Optical Devices, Cheng Wang[1], Michael J. Burek[1], zin lin[1], Haig A. Atikian[1], Vivek Venkataraman[1], I-chun Huang[1], Peter Stark[1], Marko Loncar[1]; [1]*Harvard Univ., USA.* We demonstrate robust and scalable fabrication of lithium niobate nanophotonic devices including microdisk and microring resonators. Our devices feature optical quality factors over 10^5 and are promising for nonlinear optical applications.

FW1D.2 • 08:30

A Nonlinear Polymer Waveguide Implemented Using an Augmented Low Index Guide, Muhammad Z. Alam[1], Xiao Sun[1], Mo Mojahedi[1], J. Stewart Aitchison[1]; [1]*Univ. of Toronto, Canada.* We propose a new scheme which is easy to implement and can be used to integrate low index nonlinear materials with silicon photonics to achieve high nonlinearly without suffering nonlinear losses.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

08:00–10:00
FW1E • Quantum Emission and Plasmonics
Presider: Nanfang Yu; Columbia Univ., USA

FW1E.1 • 08:00
Propagation of quantum signal in plasmonic waveguides, Xifeng Ren[1,2], Yong-Jing Cai[1,2], Ming Li[1,2], Chang-Ling Zou[1,2], Xiao Xiong[1,2], Hua-Lin Lei[1,2], Bi-Heng Liu[1,2], Guo-Ping Guo[1,2], Guang-Can Guo[1,2]; [1]*Key Lab of quantum information, Univ. of science and technology of China, China;* [2]*Synergetic Innovation Center of Quantum Information and Quantum Physics, Univ. of Science and Technology of China, China.* Here we introduce two works on quantum plasmonics: high-visibility on-chip quantum interference of single surface plasmons and transmission of quantum polarization entanglement in a nanoscale hybrid plasmonic waveguide. Our works can bridge nanophotonics and quantum optics.

FW1E.2 • 08:15
Plasmonic Nanopatch Antennas for Large Purcell Enhancement, Gleb M. Akselrod[1,2], Christos Argyropoulos[1,3], Thang B. Hoang[1,4], Cristian Ciraci[1,5], Chao Fang[2], Jiani Huang[1,4], David R. Smith[1,2], Maiken H. Mikkelsen[1,2]; [1]*Center for Metamaterials and Integrated Plasmonics, Duke Univ., USA;* [2]*Electrical and Computer Engineering, Duke Univ., USA;* [3]*Dept. of Electrical and Computer Engineering, Univ. of Nebraska-Lincoln, USA;* [4]*Dept. of Physics, Duke Univ., USA;* [5]*Center for Biomolecular Nanotechnologies, Istituto Italiano di Tecnologia, Italy.* We demonstrate Purcell enhancements of ~1000 from fluorescent molecules embedded in a plasmonic antenna with sub-10 nm gap between metals. Simulations and experiments reveal the high radiative efficiency and directionality of the antenna.

FW1E.3 • 08:30
Enhanced Single Photon Emission from Quantum Dots Coupled to Localized Surface Plasmons, Brandon Demory[1], Tyler Hill[2], chu-hsiang teng[1], Lei Zhang[2], Hui Deng[2], Pei-Cheng Ku[1]; [1]*Electrical Engineering and Computer Science, Univ. of Michigan, USA;* [2]*Physics, Univ. of Michigan, USA.* The coupling between excitons and localized surface plasmons in two-level systems can lead to enhanced spontaneous emission and was studied using site-controlled InGaN quantum dots. The dynamics and the Purcell effect were measured and analyzed.

08:00–10:00
SW1F • Surface Emitting Semiconductors Lasers
Presider: Weidong Zhou; Univ. of Texas at Arlington, USA

SW1F.1 • 08:00
Position-modulated Photonic-crystal Lasers and Control of Beam Direction and Polarization, Tsuyoshi Okino[1], Kyoko Kitamura[1], Daiki Yasuda[1], Yong Liang[1], Susumu Noda[1]; [1]*Kyoto Univ., Japan.* We propose and demonstrate position-modulated photonic-crystal lasers which can control the output-beam directions two-dimensionally and have various polarizations. The results promise to greatly enhance the range of possible laser-scanning applications.

SW1F.2 • 08:15
Compact Vortex Beam Emitter Laterally Integrated with VCSEL Array, Kenji Tanabe[1], Xiaodong GU[1], Akihiro Matsutani[1], Fumio Koyama[1]; [1]*Tokyo Inst. of Technology, Japan.* We demonstrate the integration of VCSEL array and vortex-beam-emitters, composed of double-ring-shaped Bragg-reflector waveguides functioning as diffraction element. A possibility of compact VCSEL-based emitters, creating and multiplexing vortex beams with different orbital momentums is suggested.

SW1F.3 • 08:30
Resonance Tuning and Coherent Operation in Anti-Guided Vertical-Cavity Laser Arrays, Stewart Fryslie[1], Meng P. Tan[2], Matthew Johnson[3], Kent D. Choquette[1]; [1]*Univ. of Illinois Urbana-Champaign, USA;* [2]*Intel Corp., USA;* [3]*U.S. Air Force, USA.* We demonstrate that photonic crystal anti-guided VCSEL arrays can be tuned to coherent operation by control of the cavity resonance by independent control of the bias currents.

08:00–10:00
SW1G • Optical Frequency Comb Spectroscopy
Presider: Mark Phillips; Pacific Northwest National Lab, USA

SW1G.1 • 08:00
Mid-Infrared frequency comb for rapid detection of CH_4 and H_2O in open air, Lora Nugent-Glandorf[1], Fabrizio R. Giorgetta[1], Scott A. Diddams[1]; [1]*NIST, USA.* We present open-air trace-gas spectroscopy utilizing a mid-infrared frequency comb. The MIR beam spanning 300 nm propagates through 26 m of atmosphere and absorption spectra are collected in 2 ms with a Virtual-Image Phased-Array spectrometer.

SW1G.2 • 08:15
Dual-Frequency Comb Measurements of Atmospheric Absorption: Comparison with HITRAN Database Parameters, Gregory B. Rieker[1,2], Fabrizio R. Giorgetta[2], William C. Swann[2], Laura C. Sinclair[2], Christopher L. Cromer[2], Esther Baumann[2], Ian R. Coddington[2], Nathan R. Newbury[2]; [1]*Univ. of Colorado at Boulder, USA;* [2]*National Inst. of Standards & Technology, USA.* Near-infrared frequency-comb spectroscopy is used to measure CO_2 absorption over a 2-km outdoor path under well-mixed atmospheric conditions. We compare integrated area, linecenter, and Lorentz widths extracted from Voigt fits to the data with HITRAN.

SW1G.3 • 08:30
Dual-Comb Spectroscopy based on Quantum Cascade Laser Frequency Combs, Gustavo Villares[1], Francesco Cappelli[1,2], Andreas Hugi[1,3], Stéphane Blaser[4], Jerome Faist[1]; [1]*IQE, Physics Dept., ETH Zurich, Switzerland;* [2]*CNR-INO and LENS, Italy;* [3]*IRsweep GmbH, Switzerland;* [4]*Alpes Lasers SA, Switzerland.* Mid-infrared dual-comb spectroscopy by means of quantum cascade laser frequency combs is demonstrated. Broadband high resolution molecular spectroscopy is performed, showing the potential of quantum cascade laser combs as a compact, all solid-state, chemical sensor.

08:00–10:00
SW1H • Ultrashort Pulse Characterization
Presider: Takao Fuji; National Inst. of Natural Sciences, Japan

SW1H.1 • 08:00 Invited
Solid State Light Field Sampling and Light Phase Detection, Tim Paasch-Colberg[1]; [1]*Max-Planck-Institut fur Quantenoptik, Germany.* The conductivity of a solid state device is reversibly increased by several orders of magnitude on a femtosecond timescale using the instantaneous electric field of an intense few-cycle laser pulse to create ultrafast detectable currents.

SW1H.2 • 08:30
Electro-optic Sampling of Mid-to-Near-Infrared Waveforms, Sabine Keiber[1,2], Shawn Sederberg[1], Alexander Schwarz[1], Olga Razskazovskaya[1,2], Michael K. Trubetskov[1,3], Vladimir Pervak[1,2], Ferenc Krausz[1,2], Nicholas E. Karpowicz[1]; [1]*Max-Planck-Institut für Quantenoptik, Germany;* [2]*Dept. für Physik, Ludwig-Maximilians-Universität, Germany;* [3]*Moscow State Univ., Russia.* Electro-optic sampling is a valuable tool in the terahertz range for sensitive, time-resolved electric field measurement. We show that this technique can be extended to the near infrared for unambiguous measurement of broadband, phase-locked pulses.

CLEO: Science & Innovations

08:00–10:00
SW1I • Micro & Nanophotonics
Presider: To be Determined

SW1I.1 • 08:00 Invited
Integrated Photonic Devices with Single Quantum Dots, A. Mark Fox[1], Edmund Clarke[2], Rikki Coles[1], James Dixon[1], Isaac J. Luxmoore[1], Maxime Hugues[2], Maxim Makhonin[1], John O'Hara[1], Nikola Prtljaga[1], Andrew Ramsay[1], Ben Royall[1], Nicholas Wasley[1], Maurice S. Skolnick[1]; [1]*Physics & Astronomy, Univ. of Sheffield, UK;* [2]*EPSRC National Centre for III-V Technologies, Univ. of Sheffield, UK.* The integration of InAs quantum dots as on-chip single-photon sources in GaAs photonic circuits is reviewed. A Hanbury Brown-Twiss effect is demonstrated using a monolithic directional coupler, together with coherent emission under resonant excitation.

SW1I.2 • 08:30
Observation of Einstein's Rings and Optical Gravitational Collimation, Chong Sheng[2], Rivka Bekenstein[1], hui liu[2], Shining Zhu[2], Mordechai Segev[1]; [1]*Technion Israel Inst. of Technology, Israel;* [2]*National Lab of solid State Microstructures & Dept. and Physics, Collaborative Innovation Center of Advanced Microstructures, Nanjing Univ., China*. We experimentally observe Einstein's Rings caused by gravitational lensing by designing a refractive index profile analogous to the curvature of a star. We employ the experiment to produce collimated optical beams in homogenous media.

CLEO: Applications & Technology

08:00–10:00
AW1J • Biomedical Imaging and Sensing I
Presider: Xuan Liu; New Jersey Inst. of Technology, USA

AW1J.1 • 08:00 Invited
Multipurpose Information Encoding using interleaved Optical Coherence Tomography, Audrey Ellerbee[1]; [1]*Stanford Univ., USA.* We present interleaved OCT as a unique strategy to exploit long coherence lengths for novel spectral multiplexing schemes that permit multi-purpose information encoding and streamlined image acquisition.

AW1J.2 • 08:30 Invited
Quantitative Imaging of Tissue Polarization Property by Jones Matrix Optical Coherence Tomography, Yoshiaki Yasuno[1]; [1]*Univ. of Tsukuba, Japan*. A quantitative polarization sensitive optical coherence tomography which measures tissue Jones matrix is presented. Jones matrix based signal processing is applied to obtain quantitative birefringence. Its clinical utility is examined by measuring in vivo human eyes.

CLEO: Science & Innovations

08:00–10:00
SW1K • Laser-Induced Structuring in Bulk Material
Presider: Richard Haglund; Vanderbilt Univ., USA

SW1K.1 • 08:00
Fabrication of complex three-dimensional metallic microstructures based on femtosecond laser micromachining, Feng Chen[1], Qing Yang[1], Chao Shan[1]; [1]*Xi'an Jiaotong Univ., China*. The fabrication of complex metallic microstructures based on femtosecond laser micromachining and metal microsolidify process is demonstrated. This method is beneficial for building complex embedded 3D metal microstructures, electronic components, and hybrid electronic-microfluidic devices.

SW1K.2 • 08:15
Fs-laser Induced Optical Changes in Zinc Aluminum Phosphate Glasses, Javier Hernandez Rueda[1], Charmayne E. Smith[2], Richard K. Brow[2], Denise M. Krol[1]; [1]*Univ. of California Davis, USA;* [2]*Missouri Univ. of Science and Technology, USA*. The fs-laser induced refractive index change in zinc aluminum phosphate glasses and its underneath structural modifications have been investigated both at the surface and in bulk.

SW1K.3 • 08:30 Invited
Optical Aspect of Ultrafast Laser Ablation on Transparent Dielectrics: Ciliary White Light, Yi Liu[1], Yohann Brelet[1], Zhanbing He[2], Linwei Yu[3], Yue Zhong[4], Zhinan Zeng[4], Ruxin Li[4], Aurelien Houard[1], Arnaud Couairon[5], Andre Mysyrowicz[1]; [1]*Laboratoire d'Optique Appliquée, ENSTA/CNRS/Ecole Polytechnique, France;* [2]*Electron Microscopy for Materials Research (EMAT), Univ. of Antwerp, Belgium;* [3]*Laboratoire de Physique des Interfaces et des Couches Minces, Ecole Polytechnique, France;* [4]*Shanghai Inst. of Optics and Fine Mechanics, China;* [5]*Centre de Physique Théorique, Ecole Polytechnique, France.* We report on a new nonlinear optical phenomenon during laser ablation on transparent dielectrics, coined as ciliary white light. It is universally observed on 14 different dielectrics with femtosecond pulses at 800 nm and 1.8 μm.

08:00–10:00
SW1L • Mid-IR & Supercontinum Fiber Sources
Presider: Fetah Benabid; Xlim Research Insititute, France

SW1L.1 • 08:00 Invited
Multimaterial Chalcogenide Fibers and Devices for the Mid-IR, Ayman F. Abouraddy[1]; [1]*Univ. of Central Florida, CREOL, USA.* Chalcogenide glass fibers offer a fruitful playground for mid-infrared nonlinear optics but are hampered by mechanical fragility and high chromatic dispersion. I review recent efforts on novel of chalcogenide fibers that address these perennial issues.

SW1L.2 • 08:30
Tunable Single Longitudinal Mode Tm-doped Fiber Ring Laser, Jae-Keun Yoo[1,2], Sun Do Lim[1,2], Seung Kwan Kim[1]; [1]*Physical Metrology, Korea Research Inst. of Standards and Science, Korea;* [2]*Measurement Science, Korea Univ. of Science and Technology, Korea.* We present a tunable single longitudinal mode Tm-doped fiber ring laser incorporating a self-constructed saturable absorption grating and a blazed grating with wavelength tunability of over 100 nm. The spectral and temporal characteristics of the laser output are described.

CLEO: Science & Innovations

08:00–10:00
SW1M • Coherent Communications
Presider: Takashi Sugihara; Mitsubishi Electric Corporation, Japan

SW1M.1 • 08:00
Phase Diversity Method for Optical Coherent Receiver, Thang M. Hoang[1], Mohamed Osman[1], Mathieu Chagnon[1], Qunbi Zhuge[1], David Patel[1], David Plant[1]; [1]*McGill Univ., Canada.* We present the first phase-diversity coherent receiver for an arbitrary hybrid. Colorless experiment of 10x132-Gb/s PDM-QPSK is demonstrated with reduced components and with less than 0.5 dB in OSNR penalty compared to traditional coherent receivers.

SW1M.2 • 08:15
Multi-Gigabit Coherent Communications Using Low-Rate FEC to Approach the Shannon Capacity Limit, David J. Geisler[1], Venkat Chandar[1,2], Timothy M. Yarnall[1], Mark L. Stevens[1], Scott A. Hamilton[1]; [1]*Massachusetts Inst of Tech Lincoln Lab, USA;* [2]*D. E. Shaw and Co., USA.* Combining a rate-¼ forward error-correcting code, a coherent receiver, and an optical phase-locked loop yields near error-free performance with 2-dB photon-per-bit sensitivity, which is <3-dB from the Shannon limit for a rate-¼, pre-amplified, coherent receiver.

SW1M.3 • 08:30
Phase Noise-Robust LLR Calculation with Linear/Bilinear Transform for LDPC-Coded Coherent Communications, Toshiaki Koike-Akino[1], David S. Millar[1], Keisuke Kojima[1], Kieran Parsons[1]; [1]*Mitsubishi Electric Research Labs, USA.* We propose a modified log-likelihood ratio (LLR) calculation for an LDPC decoder to be robust against residual phase noise at the demodulator. The proposed scheme is based on a linear/bilinear transform offers 1 to 2dB gain in the presence of large phase noise.

08:00–10:00
SW1N • Applications of Optical Resonators
Presider: Lin Zhu; Clemson Univ., USA

SW1N.1 • 08:00
Single ring resonator QPSK modulator, Binhuang Song[1], Leimeng Zhuang[1], Chen Zhu[1], Bill Corcoran[1,2], Arthur Lowery[1,2]; [1]*Monash Univ., Australia;* [2]*Centre for Ultrahigh-bandwidth Devices for Optical Systems (CUDOS), Australia.* We propose a new implementation of a QPSK modulator using a simple single ring resonator. That requires only $< \pi/10$ phase shift. Signal generated have a better dispersion tolerance than from a single phase modulator.

SW1N.2 • 08:15
Automated Calibration of High-Order Microring Filters, Jason Mak[1], Wesley Sacher[1], Jared Mikkelsen[1], Tianyuan Xue[1], Zheng Yong[1], Joyce Poon[1]; [1]*Edward S. Rogers Sr. Dept. of Electrical & Computer Engineering, Univ. of Toronto, Canada.* We demonstrate the automated calibration of a 5th-order silicon microring filter using an optimization algorithm. The procedure only requires a single input wavelength and was implemented on a microcontroller with simple ADC and DAC circuitry.

SW1N.3 • 08:30 Tutorial
Selected Applications of Ultra-high Q Whispering Gallery Mode Resonators, Lute Maleki[1]; [1]*OEwaves Inc, USA.* Emerging applications aided by advances in physics and technology of Whispering Gallery Mode microresonators will be discussed.

Lute Maleki is a Founder and President & CEO of OEwaves, Inc. Previously at the Jet Propulsion Lab he created and led the Quantum Sciences and Technologies Group. Dr. Maleki's research includes study and development of ultra-stable photonic oscillators; whispering gallery mode optical microresonators; atomic clocks based on ion traps and laser cooled atoms; quantum sensors. He has over 50 U.S. Patents, authored 150 refereed publications, serves on technical program committees, is a Fellow of the IEEE, American Physical Society and The Optical Society. He received the IEEE Rabi Award, NASA's Exceptional Engineering Achievement Medal and IEEE UFFC Sawyer Award.

08:00–10:00
SW1O • Ultrafast Technologies Based on Aperiodical Quasi-Phase Matching
Presider: Yen-Hung Chen; National Central Univ., Taiwan

SW1O.1 • 08:00 Tutorial
Tailoring Nonlinear Interactions with Aperiodic QuasiPphasmeatching, Martin M. Fejer[1]; [1]*Stanford Univ., USA.* The evolution of three-wave mixing processes can be controlled with aperiodic QPM structures. We describe underlying concepts, engineering of spectral amplitude and phase, and adiabatic processes, illustrated with examples including few-cycle OPCPA, octave spanning frequency combs, and quantum frequency conversion.

Martin Fejer is Professor of Applied Physics, and was Senior Associate Dean of Humanities and Sciences and Chair of the Applied Physics department at Stanford Univ.. He received his B.A. in Physics from Cornell Univ., and his M.S. and Ph.D. in Applied Physics from Stanford Univ.. His current research interests are in nonlinear optical materials and devices, guided wave optics, microstructured ferroelectrics and semiconductors, ultrafast optics, classical and quantum optical signal processing, and materials with low dissipation. He has published over 400 papers in these areas, and holds over 30 patents. Fejer is a fellow of IEEE and The Optical Society (OSA). He was awarded OSA's R. W. Wood Prize and has been a member of the OSA Board of Directors and the Board of Governors of IEEE-LEOS.

CLEO: QELS-Fundamental Science

FW1A • Symposium on Cavity Quantum Electrodynamics I—Continued

FW1A.3 • 08:45 Invited
Photonic Quantum-Information Processing with Quantum Dots in Photonic Crystals, Peter Lodahl[1]; *[1]Univ. of Copenhagen, Denmark*. Quantum dots in photonic crystals have proven to be a very suitable platform for quantum-information processing. We review current progress on the ability to deterministically interface single photons and single quantum dots in photonic crystal waveguides and the chiral spin-photon interfaces.

FW1A.4 • 09:15
An ultrasmall mode volume cantilever-based Fabry-Pérot microcavity, Hrishikesh Kelkar[1], Daqing Wang[1,2], Björn Hoffmann[1], Silke Christiansen[3,1], Stephan Götzinger[2,1], Vahid Sandoghdar[1,2]; *[1]Max Planck Inst. for the Science of, Germany; [2]Friedrich Alexander Univ. Erlangen-Nuremberg, Germany; [3]Helmholtz Centre Berlin for Materials and Energy, Germany.* A tunable Fabry-Pérot microcavity consisting of a 2.6 μm curvature mirror and 0.4 numerical aperture is fabricated. We study the effect of a nanoparticle on the cavity modes and discuss the coupling of single molecules to it.

FW1B • Novel Sources for Attoscience—Continued

FW1B.3 • 08:45
Suppression of Resonant-induced Harmonics of Tin with Tunable Laser Wavelengths, Muhammad Ashiq Fareed[1], Sudipta Mondal[1], Nicolas Thiré[1], Maxime Boudreau[1], yoann pertot[1], Bruno E. Schmidt[1], François Légaré[1], Tsuneyuki Ozaki[1]; *[1]INRS-EMT, Canada*. We investigate the behavior of resonant-induced harmonics from tin using driving lasers with tunable wavelengths. The intensity of the resonant harmonic is suppressed by the tuning laser wavelength around 1.8μm to understand the interaction dynamics of continuum electron with the autoionizing state.

FW1B.4 • 09:00
Control of attosecond pulse and XUV high-order harmonic generation with spatially-chirped laser pulses, Carlos Hernandez-Garcia[1,2], Agnieszka Jaron-Becker[1], Andreas Becker[1], Charles G. Durfee[3]; *[1]JILA, Univ. of Colorado, USA; [2]Universidad de Salamanca, Spain; [3]Physics, Colorado School of Mines, USA*. We present a technique to drive high-order harmonics with angularly spatially chirped pulses. Our calculations show that each harmonic is emitted with angular chirp, leading to dramatically improved control of spectral and temporal spatial resolution.

FW1B.5 • 09:15
Relativistic High Harmonics Driven by Two-Color Incident Fields, Matthew Edwards[1], Julia Mikhailova[1]; *[1]Princeton Univ., USA*. Particle-in-cell simulations suggest that relativistic high-harmonic generation using overdense plasmas will be substantially enhanced by adding second harmonic to the incident laser field. This mechanism also offers a new diagnostic of the laser-plasma interaction.

FW1C • Optics of Complex Media I—Continued

FW1C.4 • 08:45
Localization of Light at Vanishingly Small Disorder-Levels with Heavy Photons, Alexandre Baron[1], Rémi Faggiani[2], Xiaorun Zang[2], Loïc Lalouat[3], Sebastian A. Schulz[4], Kévin Vynck[2], Bryan O'Regan[5], Benoit Cluzel[3], Frédérique de Fornel[3], Thomas Krauss[5], Philippe Lalanne[2]; *[1]Duke Univ., USA; [2]Université de Bordeaux, France; [3]Université de Bourgogne, France; [4]Univ. of Ottawa, Canada; [5]Univ. of York, UK*. We investigate the formation of localized modes in randomly-perturbed photonic-crystal waveguides near the photonic band-edge. We show that the key parameter driving the formation process is the effective photon mass rather than the group index.

FW1C.5 • 09:00 Invited
Coherent Perfect Absorbers and Coherent Enhancement of Absorption, A. Douglas Stone[1], Hui Cao[1], Yidong Chong[2], Li Ge[3], Sebastien Popoff[4], Arthur Goetschy[5]; *[1]Yale Univ., USA; [2]Nanyang Technical Univ., Singapore; [3]CUNY Staten Island, USA; [4]CNRS-LTCI, France; [5]Institut Langevin, France*. Coherent illumination and wave-front shaping can be used to make a weakly absorbing cavity perfectly absorbing and to enhance strongly the absorption of a multiple scattering medium.

FW1D • Integrated Nonlinear Devices—Continued

FW1D.3 • 08:45
Pump-Degenerate Phase-Sensitive Amplification in Amorphous Si Waveguides, Hongcheng Sun[1], Ke-Yao Wang[1], Amy C. Foster[1]; *[1]Johns Hopkins Univ., USA*. We demonstrate phase-sensitive amplification in hydrogenated amorphous silicon waveguides based on pump-degenerate four-wave mixing at 90 MHz and 10 GHz. An 11.7 dB (6.6 dB) phase-sensitive extinction ratio is achieved at 90 MHz (10 GHz).

FW1D.4 • 09:00
Nonlinear Silicon Photonics and the Moment Method, Simon Lefrancois[1], Chad A. Husko[1], Andrea Blanco-Redondo[1,2], Benjamin J. Eggleton[1]; *[1]Univ. of Sydney, Australia; [2]Tecnalia, Spain*. We develop a moment method theory for nonlinear propagation in silicon waveguides. Expressions for pulse parameters, free-carrier blueshift and acceleration are derived. We apply this to propagation in silicon photonic crystal waveguides and nanowires.

FW1D.5 • 09:15
Low Power All-Optical Switching in a Gallium Arsenide Photonic Molecule, Ranojoy Bose[1], Jason Pelc[1], Charles Santori[1], Raymond Beausoleil[1]; *[1]Hewlett Packard Labs, USA*. We demonstrate low power all-optical switching in a gallium arsenide (GaAs) photonic molecule with resonances near the material band edge. The enhanced nonlinear effects in this spectral region result in a low estimated switching energy of a few femtojoules with 45% transmission contrast.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FW1E • Quantum Emission and Plasmonics—Continued

FW1E.4 • 08:45
Plasmonic Giant Semiconductor Nanocrystals with Enhanced Light Output and Suppressed Blinking for Biomedical Applications, sid sampat[1], Niladri karan[2], Aaron Keller[2], Andrei Piryatinski[3], Oleksiy Roslyak[4], Christina Hanson[2], Yagnaseni Ghosh[2], han htoon[2], jennifer hollingsworth[2], anton malko[1]; *[1]U Texas at Dallas, USA; [2]Material Physics and Applications Division, CINT, Los Alamos National Lab, USA; [3]Theoreical Division: Physics of Condensed Matter and Complex Systems, Los Alamos National Lab, USA; [4]Physics, Fordham Univ., USA.* We study single particle PL emission signatures of giant semiconductor nanocrystals overcoated with silica shells and ultrathin gold layers. We observe complex metal/semiconductor coupling and plasmonic interactions leading to either emission quenching or photobrightening.

FW1E.5 • 09:00
Quantum Model of Plasmon-Quantum Emitter Interaction in the Strong-Coupling Regime, Roderick Davidson[1,2], Pavel Lougovski[2], Benjamin Lawrie[2]; *[1]Physics, Vanderbilt Univ., USA; [2]Quantum Information Sciences, Oak Ridge National Lab, USA.* A full quantum model incorporating realizable materials properties is developed for interactions between a plasmonic resonator and a single two-level quantum emitter, enabling fabrication of plasmonic nanostructures for the strong coupling regime of cavity-quantum-electrodynamics.

FW1E.6 • 09:15
Efficient Fiber Collection of Nitrogen-Vacancy Center Emission from Diamond Nano Beams, Harishankar Jayakumar[1], Behzad Khanaliloo[1,2], Paul E. Barclay[1,2]; *[1]Univ. of Calgary, Canada; [2]National Research Center-National Inst. for Nanotechnology, Canada.* We present tapered diamond nano beams, which allows efficient collection of diamond nitrogen vacancy emission through phase-matched coupling to a tapered optical fiber.

SW1F • Surface Emitting Semiconductors Lasers—Continued

SW1F.4 • 08:45
Effect of In-plane Mirror Dispersion on Vertical Cavities Based on High-Contrast Grating Mirrors, Alireza Taghizadeh[1], Jesper Mork[1], Il-Sug Chung[1]; *[1]Technical Univ. of Denmark, Denmark.* We report how the in-plane dispersion of a high-index-contrast grating reflector influences the transverse mode properties such as shorter wavelengths for lower-order transverse modes and different transverse-mode wavelength spacings for modes with the same size.

SW1F.5 • 09:00
Smooth lasing transition in high β buried multiple-quantum-well 2D photonic crystal lasers, Masato Takiguchi[1,2], Hideaki Taniyama[1,2], Hisashi Sumikura[1,2], Danang M. Birowosuto[1,2], Eiichi Kuramochi[1,2], Akihiko Shinya[1,2], Tomonari Sato[1,3], Koji T. Takeda[1,3], Shinji Matsuo[1,3], Masaya Notomi[1,2]; *[1]NTT Nanophotonics Center, NTT Corporation,, Japan; [2]NTT Basic Research Labs, NTT Corporation, Japan; [3]NTT Device Technology Labs, NTT Corporation, Japan.* By adopting high β buried-multiple-quantum-well photonic crystal nanocavities, we have demonstrated smooth lasing operation, which indicates thresholdless-like lasing theoretically predicted, by mean of light-in vs light-out curve analysis, linewidth analysis, and photon correlation measurements.

SW1F.6 • 09:15
Broadband Self-Swept High Contrast Grating VCSEL, Stephen Gerke[1], Weijian Yang[1], Kar Wei Ng[1], Christopher Chase[2], Yi Rao[2], Connie J. Chang-Hansnain[1]; *[1]Univ. of California Berkeley, USA; [2]Bandwidth10 Inc., USA.* We demonstrate a 1550 nm broadband self-swept VCSEL with 23-nm wavelength range at 131 kHz sweep rate. The mechanical oscillation of the ultra-lightweight HCG top mirror is excited optomechanically by photons inside the lasing cavity.

SW1G • Optical Frequency Comb Spectroscopy—Continued

SW1G.4 • 08:45
Noise properties in multi-heterodyne spectrometers based on quantum- and interband-cascade lasers, Andreas Hangauer[1], Jonas Westberg[1], Michael Soskind[2,1], Eric J. Zhang[1], Gerard Wysocki[1]; *[1]Princeton Univ., USA; [2]Rutgers, USA.* The noise properties of two multi-heterodyne spectrometers based on multi-mode semiconductor lasers (QCLs and ICLs) are investigated to determine their performance limitations. Both technologies provide well-defined multi-heterodyne beatnote structures suitable for spectroscopic measurements.

SW1G.5 • 09:00
Multiheterodyne Spectroscopy with Electro-Optic Frequency Combs, David Long[1], Adam J. Fleisher[1], Joseph T. Hodges[1], David F. Plusquellic[1]; *[1]NIST, USA.* Waveguide-based, electro-optic modulators were used to generate pitch-agile, optical frequency combs from a single continuous-wave laser. These combs are then detected via a multi-heterodyne approach where the absorption information is down-converted into the radiofrequency domain.

SW1G.6 • 09:15
Broadband, Comb-resolved, High-Finesse Enhancement Cavity Spectrometer with Graphene Modulator, Kevin F. Lee[1], Grzegorz Kowzan[1,2], Chien-Chung Lee[3], C. Mohr[1], Jie Jiang[1], Thomas R. Schibli[3], Piotr Maslowski[2], M. E. Fermann[1]; *[1]IMRA America, Inc., USA; [2]Nicolaus Copernicus Univ., Poland; [3]Univ. of Colorado, USA.* We transmit a frequency comb through an enhancement cavity by PDH locking with a graphene modulator. We comb-resolve the 1940 to 2115 nm spectrum with stable repetition rate and offset frequency via Fourier transform spectrometry.

SW1H • Ultrashort Pulse Characterization—Continued

SW1H.3 • 08:45
Cross-Correlation Frequency-Resolved Optical Gating for Characterization of A Train of Monocycle Optical Pulses, Yuta Nakano[1], Yuichiro Kida[1], Kazuya Motoyoshi[1], Totaro Imasaka[1,2]; *[1]Dept. of Applied Chemistry, Kyushu Univ.,Graduate School of Engineering, Japan; [2]Division of Optoelectronics and Photonics, Kyushu Univ., Center for Future Chemistry, Japan.* A cross-correlation frequency-resolved optical gating is developed for the characterization of an optical pulse train consisting of monocycle pulses. An optical beat is employed for resolving the ultrafast temporal intensity variation in the train.

SW1H.4 • 09:00
A Spectrally Resolved Lateral-Shearing Interferometer for Measurement of Relative Group Delay Using a Periodic Entrance Slit in a Spectrometer, Seung-Whan Bahk[1], Christophe Dorrer[1], Rick Roides[1], Jake Bromage[1]; *[1]Univ. of Rochester, USA.* A concept for a spectrally resolved lateral-shearing interferometer is proposed to measure pulse front and radial group delay. A periodic slit in a spectrometer enables a simpler spatial interference scheme than a Mach-Zehnder interferometer.

SW1H.5 • 09:15
Pulse Characterization in Ultrafast Microscopy: a Comparison of FROG, MIIPS and G-MIIPS, Alberto Comin[1], Michelle Rhodes[2], Richard Ciesielski[1], Rick Trebino[2], Achim Hartschuh[1]; *[1]Dept. Chemie, Ludwig-Maximilians-Universitaet Muenchen, Germany; [2]Georgia Inst. of Technology, USA.* MIIPS is a popular method for compressing femtosecond pulses. It is not ideal for complex pulses, like those produced by self-phase modulation. We show that several limitations are fixed by an improvement called G-MIIPS.

CLEO: Science & Innovations

SW1I • Micro & Nanophotonics—Continued

SW1I.3 • 08:45
Theory and Practice of Resonant Antireflection, Ken Xingze Wang[1], Shanhui Fan[1]; [1]*Stanford Univ., USA.* Antireflection can be achieved using optical resonances. We show theoretically that complete resonant antireflection is possible if the resonances radiate in a balanced manner and the periodicity of the structure is subwavelength for normal incidence.

SW1I.4 • 09:00
Silicon Super-Resolution in the Visible, Asaf David[1], Bergin Gjonaj[1], Guy Bartal[1]; [1]*Technion Israel Inst. of Technology, Israel.* Planar Silicon waveguides provide up to 4 times wavelength compression, yielding sub-100nm focusing for visible light. Our near-field measurements for red light (671nm) show both wavelength compression (280nm) and super-focusing (80nm, bright and dark spots).

SW1I.5 • 09:15
Design Rule of 2D High Contrast Gratings and Engineering of Orbital Angular Momentum of Light, Pengfei Qiao[1,2], Li Zhu[2], Connie J. Chang-Hansnain[2]; [1]*Univ of Illinois at Urbana-Champaign, USA;* [2]*Univ. California at Berkeley, USA.* A design rule to obtain broadband high reflection and transmission in 2D high contrast gratings is proposed. Our design method is convenient for engineering the orbital angular momentum of light using 2D grating array.

CLEO: Applications & Technology

AW1J • Biomedical Imaging and Sensing I—Continued

AW1J.3 • 09:00 Invited
The Ultimate Road to Real Time 3D Optical Coherence Tomography Imaging, Tiancheng Huo[1], Xiao Zhang[1], Chengming Wang[1], Tianyuan Chen[1], Wenchao Liao[1], Wenxin Zhang[1], Shengnan Ai[1], Jui-Cheng Hsieh[1], Ping Xue[1]; [1]*State Key Lab of Low-dimensional Quantum Physics and Dept. of Physics, Tsinghua Univ. and Collaborative Innovation Center of Quantum Matter, China.* We have presented linear-in-wavenumber swept laser and all-optical 40MHz swept-source as the optical source, and compressed sensing and time serial optical computing to process the massive imaging data for real time 3D optical coherence tomography imaging.

CLEO: Science & Innovations

SW1K • Laser-Induced Structuring in Bulk Material—Continued

SW1K.4 • 09:00
Formation of nanogratings in porous glass initiated by excitation of plasma waves at interfaces, Yang Liao[1], Jielei Ni[1], Lingling Qiao[1], Min Huang[2], Ya Cheng[1]; [1]*Shanghai Inst of Optics and Fine Mech, China;* [2]*Sun Yat-sen Univ., China.* The evolution of nanogratings in a porous glass was directly observed, revealing that the nanogratings origin from the standing plasma waves at the interfaces excited by femtosecond laser pulses.

SW1K.5 • 09:15
Board-Level Optical Interconnect Using Glass, sheng huang[1], Kevin P. Chen[1], Ming-Jun Li[2]; [1]*Univ. of Pittsburgh, USA;* [2]*Corning Inc., USA.* This paper reports ultrafast laser fabrication of waveguide circuits and 45° vertical coupling micromirrors in fused silica for board-level optical interconnect applications. Excellent micromirror surface quality was obtained and 0.24-dB per reflection at l=632nm was demonstrated.

SW1L • Mid-IR & Supercontinum Fiber Sources—Continued

SW1L.3 • 08:45
Resonantly Pumped Amplification in a Thulium-doped Large Mode Area Photonic Crystal Fiber, Alex Sincore[1], Lawrence Shah[1], Martin Richardson[1]; [1]*Univ. of Central Florida, USA.* We demonstrate resonantly pumped amplification in a thulium-doped photonic crystal fiber. This enables greatly increased efficiencies compared to 795nm or 1550nm pumping and is attractive for pulsed amplification.

SW1L.4 • 09:00
Tunable Single-Frequency DFB Fiber Laser at 2.8 µm, Vincent Michaud-Belleau[1], Martin Bernier[1], Vincent Fortin[1], Jerome Genest[1], Réal Vallée[1]; [1]*Centre d'optique, photonique et laser, Universite Laval, Canada.* We report a tunable single-frequency laser emission near 2.8 µm from an all-fiber distributed feedback laser. A 20 kHz linewidth is measured with a tunability of ~1 nm at a step resolution of 3 pm.

SW1L.5 • 09:15
Wavelength Tunable Mid-infrared Er^{3+}:ZBLAN Fiber Laser at 3.5 µm using Dual Wavelength Pumping, Ori Henderson-Sapir[1], Jesper Munch[1], David J. Ottaway[1]; [1]*Univ. of Adelaide, Australia.* An Er^{3+}ZBLAN glass fiber laser which lases at 3.5 µm and produces 370 mW when operated at room temperature is reported. Good efficiency is obtained using a dual wavelength pumping scheme. Over 200 nm of wavelength tuning is demonstrated using a three mirror resonator configuration.

CLEO: Science & Innovations

SW1M • Coherent Communications—Continued

SW1M.4 • 08:45
FPGA-based Non-binary QC-LDPC Coding for High-Speed Coherent Optical Transmission, Ding Zou[1], Ivan B. Djordjevic[1]; *[1]Univ. of Arizona, USA.* We present a large-girth-non-binary QC-LDPC code suitable for beyond 100 Gb/s optical transmission and describe its implementation in FPGA. Great performance with Q-limit of 5.0 dB at BER of 10-10 has been found, which corresponds to NCG of 11.95 dB at 10-15.

SW1M.5 • 09:00
Experimental Demonstration of Simultaneous Phase Noise Suppression and Automatically Locked Tunable Homodyne Reception for a 20-Gbaud QPSK Signal, Amirhossein Mohajerin Ariaei[1], Morteza Ziyadi[1], ahmed almaiman[1], yinwen cao[1], Mohammad-Reza Chitgarha[1], Youichi akasaka[2], Jeng-Yuan Yang[2], motoyoshi sekiya[2], joseph touch[3], Moshe Tur[5], carsten langrock[4], Martin M. Fejer[4], alan willner[1]; *[1]Univ. of Southern California (USC), USA; [2]Fujitsu Labs of America, USA; [3]Information Sciences Inst., USA; [4]Stanford Univ-Edward L. Ginzton Lab, USA; [5]Tel Aviv Univ., Israel.* We experimentally demonstrate simultaneous phase-noise suppression and automatically locked homodyne reception for 20-Gbaud QPSK signal. The phase noise deviation can be reduced by a factor ~3. Open I/Q eyes are obtained after the noise mitigation.

SW1M.6 • 09:15
Enhanced Spectral Efficiency of 2.36 bits/s/Hz using Multiple Layer Overlay Modulation for QPSK over a 14-km Single Mode Fiber Link, Guodong Xie[1], Long Li[1], Yongxiong Ren[1], Hao Huang[1], Zhe Zhao[1], peicheng liao[1], ahmed almaiman[1], yinwen cao[1], Yan Yan[1], Changjing Bao[1], Nisar Ahmed[1], Zhe Wang[1], Nima Ashrafi[2,3], Solyman Ashrafi[2], moshe tur[4], alan willner[1]; *[1]U. of Southern California, USA; [2]NxGen Partners, USA; [3]Univ. of Texas at Dallas, USA; [4]Tel Aviv Univ., Israel.* A multiple-layer-overlay (MLO) modulation format is employed for a 14-km optical fiber link and an enhanced spectral efficiency of 2.36 bits/s/Hz is achieved by multiplexing 3-layer signals with each layer carrying a 2-Gbit/s QPSK signal.

SW1N • Applications of Optical Resonators—Continued

(see page 137 for SW1N.4)

SW1O • Ultrafast Technologies Based on Aperiodical Quasi-Phase Matching—Continued

SW1O.2 • 09:00
Chirped Quasi-Phase-Matching Grating Design for Broad-Bandwidth, Engineerable-Phase Adiabatic Second-Harmonic Generation, Yu-Wei Lin[1], Chris Phillips[2], Martin M. Fejer[1]; *[1]Stanford Univ., USA; [2]ETH Zurich, Switzerland.* The use of adiabatic conversion for broadband, efficient, and robust second-harmonic generation with engineerable spectral phase is analyzed theoretically and numerically, and verified by experiment. The advantages compared with conventional methods are also discussed.

SW1O.3 • 09:15
Toward Multi-Octave Pulse Shaping by Adiabatic Frequency Conversion, Peter Krogen[1], Haim Suchowski[2], Houkun Liang[1], Franz X. Kaertner[1,3], Jeffrey Moses[4,1]; *[1]Dept. of Electrical Engineering and Computer Science and Research Lab of Electronics, MIT, USA; [2]Raymond and Beverly Sackler School of Physics and Astronomy, Tel Aviv Univ., Israel; [3]Center for Free-Electron Laser Science, DESY and Physics Dept., Univ. of Hamburg, Germany; [4]School of Applied and Engineering Physics, Cornell Univ., USA.* We demonstrate complex mid-IR spectral phase and amplitude shaping spanning 2.5-5 um, based on down-conversion of a shaped near-IR source, using chirped-pulse adiabatic difference frequency generation. The technique can be extended to multi-octave bandwidths.

CLEO: QELS-Fundamental Science

FW1A • Symposium on Cavity Quantum Electrodynamics I—Continued

FW1A.5 • 09:30 Invited

Towards Scalable Quantum Networks of Spin Qubits in Photonics Integrated Circuits, Dirk R. Englund[1], Luozhou Li[1], Tim Schroder[1], Edward Chen[1], Michael Walsh[1], Igal Bayn[1], Sara L. Mouradian[1], Matthew E. Trusheim[1], Ming Lu[3], Mircea Cotlet[3], Matthew Markham[2], Daniel Twitchen[2], Michal Lipson[4], Karl K. Berggren[1]; *[1]MIT, USA; [2]Element 6, USA; [3]Center for Functional Nanomaterials, Brookhaven National Lab, USA; [4]School of Electrical and Computer Engineering, Cornell Univ., USA.* We discuss progress towards the development of on-chip quantum networks of multiple spin qubits in nitrogen vacancy (NV) centers in diamond. We report NV-nanocavity systems in the strong Purcell regime; implantation of NVs with nanometer-scale apertures, including into cavity field maxima; hybrid on-chip networks for integration of multiple functional NV-cavity systems; and scalable integration of superconducting nanowire single photon detectors on-chip.

FW1B • Novel Sources for Attoscience—Continued

FW1B.6 • 09:30

All-Optical, Three-Dimensional Electron Pulse Compression, Liang Jie Wong[2,1], Byron Freelon[1], TImm Rohwer[1], Nuh Gedik[1], Steven Johnson[1]; *[1]MIT, USA; [2]Singapore Inst. of Manufacturing Technology, Singapore.* We propose a method of compressing and focusing electron pulses to attosecond durations and sub-micrometer-dimensions using the optical ponderomotive force. Applications include ultrafast electron diffraction, flat electron beam creation, and free-electron-based coherent terahertz emission schemes.

FW1B.7 • 09:45

Femtosecond Stark-Chirped Rapid Adiabatic Passage by Single Spectrally Shaped Pulse, Hangyeol Lee[1], Hyosub Kim[1], Hanlae Jo[1], Jaewook Ahn[1]; *[1]KAIST, Korea.* Complete population inversion of two-level atoms in a magneto-optical trap is demonstrated by off-resonant two laser pulses shaped from a single ultrafast laser pulse. The observed phenomenon is explained in the context of femto-second laser version of Stark-chirped rapid adiabatic passage.

FW1C • Optics of Complex Media I—Continued

FW1C.6 • 09:30

Efficient Thermal-Light and Light-Thermal Conversion by a Selective Emitter/Absorber, Jing Zhou[1], Xi Chen[1], L. Jay Guo[1]; *[1]Univ. of Michigan, USA.* We use a diluted refractory metal as a selective emitter/absorber to enhance the efficiencies of thermal-light and light-thermal conversions. The absorptivity (emissivity) was measured at high temperatures up to 750°C.

FW1C.7 • 09:45

Microcavity Laser Linewidth Theory, Adi Pick[1], Alex Cerjan[3], David Liu[2], Alejandro Rodriguez[4], Yidong Chong[5], A. Douglas Stone[3], Steven Johnson[2]; *[1]Physics, Harvard Univ., USA; [2]MIT, USA; [3]Yale Univ., USA; [4]Princeton Univ., USA; [5]Nanyang Technological Univ., Singapore.* We present a multimode laser-linewidth formula that generalizes previous theories, including corrections for cavity losses, nonlinear gain and dispersion, but is derived in a more general setting and is therefore applicable to complex wavelength-scale lasers.

FW1D • Integrated Nonlinear Devices—Continued

FW1D.6 • 09:30

Single Mode Broad Area PT-Symmetric Microring Lasers, William Hayenga[1], Mohammad-Ali Miri[1], Hossein Hodaei[1], Absar Ulhassan[1], Mathias Heinrich[1], Demetrios N. Christodoulides[1], Mercedeh Khajavikhan[1]; *[1]Univ. of Central Florida, CREOL, USA.* Single-transverse and longitudinal mode lasing is demonstrated in a PT-symmetric semiconductor microring arrangement. The proposed scheme is versatile, robust to fabrication errors, and allows for high brightness operation while maintaining spectral purity.

FW1D.7 • 09:45

Spontaneous mirror-symmetry breaking in two coupled nanolasers, Philippe Hamel[1], Samir Haddadi[1], fabrice raineri[1], Paul Monnier[1], grégoire beaudoin[1], Isabelle Sagnes[1], Ariel Levenson[1], Alejandro M. Giacomotti[1]; *[1]CNRS/LPN, France.* We experimentally show spontaneous breaking of mirror-symmetry in two evanescently coupled photonic crystal nanocavity-lasers. A transition from a delocalized mode, to two spatially localized states is observed. Coexistence of these states is demonstrated.

10:00–18:30 Exhibition Open, *Exhibit Halls 1 & 2*

10:00–10:30 Coffee Break, *Exhibit Hall*

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FW1E • Quantum Emission and Plasmonics—Continued

FW1E.7 • 09:30
Carrier Multiplication in a Single Semiconductor Nanocrystal, Fengrui Hu[1], Bihu Lv[1], Chunfeng Zhang[1], Xiaoyong Wang[1], Min Xiao[1]; [1]*Nanjing Univ.*. The UV-excited photoluminescence was measured for single CdSe nanocrystals and an average carrier multiplication efficiency of ~13.1% was obtained when the excitation photon energy was set at ~2.46 times of the nanocrystal energy gap.

FW1E.8 • 09:45
Spin Control in Charged Quantum Dots by Twisted Light, Guillermo Quinteiro[1], Tilmann Kuhn[2]; [1]*Universidad de Buenos Aires, Argentina;* [2]*Universitat Muenster, Germany.* Strongly focused twisted light may have strong field components in the propagation direction. By manipulating light-hole excitons in a charged quantum dot with such beams the spin of an excess electron can be efficiently controlled.

SW1F • Surface Emitting Semiconductors Lasers—Continued

SW1F.7 • 09:30
Printed Photonic Crystal Bandedge Surface-emitting Lasers on Silicon, Shihchia Liu[1], Deyin Zhao[1], Hongjun Yang[1], Zhenqiang Ma[2], Carl Reuterskiöld-Hedlund[3], Mattias Hammar[3], Weidong Zhou[1]; [1]*Univ. of Texas at Arlington, USA;* [2]*Electrical and Computer Engineering, Univ. of Wisconsin-Madison, USA;* [3]*School of Information and Communication Technology, KTH-Royal Inst. of Technology, Sweden.* We report experimental demonstration of a hybrid III-V/Si photonics crystal surface-emitting laser (PCSEL) based on membrane transfer printing technique. Single mode operation was observed with linewidth of 5 Å and side-mode suppression ratio (SMSR) greater than 20 dB.

SW1F.8 • 09:45
Electrically Tunable Organic Vertical Cavity Surface Emitting Laser, Wendi Chang[1], Apoorva Murarka[1], Annie Wang[1], Vladimir Bulovic[1], Jeffrey H. Lang[1]; [1]*Electrical Engineering and Computer Science, MIT, USA.* Using solvent-free composite membrane transfer, we demonstrate an electrically tunable organic visible light-emitting laser with reversible tuning range of 10nm under 6V actuation. Large-area scalability of utilized fabrication methods suggests potential use in all-optical pressure-sensing surfaces.

SW1G • Optical Frequency Comb Spectroscopy—Continued

SW1G.7 • 09:30
Optical Frequency Combs of Multi-GHz Line-spacing for Real-time Multi-heterodyne Spectroscopy, Atsushi Ishizawa[1], Tadashi Nishikawa[2,3], Ming Yan[3,4], Guy Millot[5], HIdeki Gotoh[1], Theodor Hänsch[3,4], Nathalie Picqué[3,4]; [1]*NTT Basic Research Labs, Japan;* [2]*Tokyo Denki Univ., Japan;* [3]*Max-Planck-Institut für Quantenoptik, Germany;* [4]*Ludwig-Maximilians-Universität München, Germany;* [5]*Laboratoire Interdisciplinaire Carnot de Bourgogne, France.* Dual-comb spectroscopy using electro-optic-modulator-based frequency combs broadened in a highly nonlinear fiber opens up new opportunities for analytical spectroscopy. One hundred thousand spectra per second are measurable with a 10-THz span and a 157-GHz resolution.

SW1G.8 • 09:45
Mid-Infrared Optical Frequency Combs based on Difference Frequency Generation for Dual-Comb Spectroscopy, Flavio C. Cruz[2,1], Daniel L. Maser[2], Todd Johnson[2], Gabriel Ycas[2], Andrew Klose[2], Laura C. Sinclair[2], Ian Coddington[2], Nathan R. Newbury[2], Scott Diddams[2]; [1]*Universidade Estadual de Campinas, Brazil;* [2]*Time & Frequency Division, National Inst. of Standards and Technology, USA.* Dual optical frequency combs at 2.8-3.4 μm with powers >210 mW were produced with femtosecond fiber-lasers and difference frequency generation. Interferograms between the combs have been demonstrated as a step towards mid-infrared dual-comb spectroscopy.

SW1H • Ultrashort Pulse Characterization—Continued

SW1H.6 • 09:30
Ultrafast Graphene Photodetector for On-chip Broadband Auto-correlator, Ren-Jye Shiue[1], Yuanda Gao[2], james Hone[2], Dirk R. Englund[1]; [1]*MIT, USA;* [2]*Mechanical Engineering, Columbia Univ., USA.* We report an integrated graphene photodetector on top of a silicon waveguide with a maximum responsivity of 0.36 A/W and a 3dB high-speed cut-off frequency of 42 GHz. Furthermore, nonlinear photocurrent in graphene under pulse excitation enables direct on-chip characterization of ultrafast pulses.

SW1H.7 • 09:45
Quantitative Characterization of Polarization States of Axisymmetrically Polarized Pulses Generated by Coherent Beam Combining, Masato Suzuki[1], Keisaku Yamane[1,2], Kazuhiko Oka[1], Yasunori Toda[1,2], Ryuji Morita[1,2]; [1]*Hokkaido Univ., Japan;* [2]*JST, CREST, Japan.* By using the extended Stokes parameters and the degree of polarization defined for the spatial distribution (DOP-SD), we fully quantitatively characterize the polarization states of arbitrary (DOP-SD>0.96) axisymmetrically-polarized femtosecond pulses generated by coherent beam combining.

10:00–18:30 Exhibition Open, *Exhibit Halls 1 & 2*

10:00–10:30 Coffee Break, *Exhibit Hall*

CLEO: Science & Innovations

SW1I • Micro & Nanophotonics—Continued

SW1I.6 • 09:30
Cloaking of Metal Contacts on Solar Cells, Martin F. Schumann[1,2], Samuel Wiesendanger[3], Jan-Christoph Goldschmidt[4], Karsten Bittkau[5], Ulrich W. Paetzold[5], Alexander Sprafke[6], Ralf B. Wehrspohn[6], Carsten Rockstuhl[2,7], Martin Wegener[1,2]; *[1]Inst. of Applied Physics, Karlsruhe Inst. of Technology, Germany; [2]Inst. of Nanotechnology, Karlsruhe Inst. of Technology, Germany; [3]Inst. of Condensed Matter Theory and Solid State Optics, Friedrich-Schiller-Universität Jena, Germany; [4]Fraunhofer Inst. for Solar Energy Systems ISE, Germany; [5]Institut für Energie- und Klimaforschung (IEK-5), Forschungszentrum Jülich GmbH, Germany; [6]Inst. of Physics, Martin Luther Univ. Halle-Wittenberg, Germany; [7]Inst. of Theoretical Solid-State Physics, Karlsruhe Inst. of Technology, Germany.* We design by transformation optics, fabricate by three-dimensional direct laser writing, and characterize experimentally polymer-based cloaks for 20 μm wide gold-wire contacts on a silicon wafer. The contact shadowing effect is reduced by 90%.

SW1I.7 • 09:45
Photovoltaic performance Improvement of Si HIT Solar Cell by Incorporating Flower-Like light trapping Structures, Sheng-Han Tsai[1], Ming-Lun Lee[2], Vin-Cent Su[2], Chien-Hsiung Hsu[2], Yao-Hong You[2,3], Po-Hsun Chen[2,3], Yen-Pu Chen[2], Zheng-Hung Hung[1], Chieh-Hsiung Kuan[1,2]; *[1]Graduate Inst. of Photonics and Optoelectronics, National Taiwan Univ., Taiwan; [2]Graduate Inst. of Electronics Engineering, National Taiwan Univ., Taiwan; [3]R&D Division, Kingwave Corporation, Taiwan.* We implemented the flower-like light trapping structures on the surface of HIT solar cell to achieve a great reflectance reduction and effectively improve the J_{SC} from 34.32 mA/cm^2 to 39.4 mA/cm^2 compared to the reference.

AW1J • Biomedical Imaging and Sensing I—Continued

AW1J.4 • 09:30
Differential Mueller-matrix formalism for polarization sensitive optical coherence tomography, Martin Villiger[1,2], Norman Lippok[1,2], Brett Bouma[1,2]; *[1]Wellman Center for Photomedicine, USA; [2]Harvard Medical School, USA.* The differential Mueller matrix offers useful insight into the polarization properties of biological tissue imaged with polarization sensitive optical coherence tomography. We present the theory and experimentally demonstrate local depolarization in addition to local retardation.

AW1J.5 • 09:45
Effects of Wavelength and Side Lobes on Airy Beam for Optical Coherence Tomography, Miao Zhang[1], Ping Yu[1], Zhijun Ren[2]; *[1]Univ. of Missouri-Columbia, USA; [2]Zhejiang Normal Univ., China.* Optical coherence tomography system using a broad wavelength band Airy beam generated by a transmissive cubic phase mask. We experimentally show that the detrimental effects from the side lobes and wavelength dependent curvature are negligible.

CLEO: Science & Innovations

SW1K • Laser-Induced Structuring in Bulk Material—Continued

SW1K.6 • 09:30
Direct Laser Writing of 3D Gratings and Diffraction Optics, Michael Moebius[1], Kevin Vora[1], SeungYeon Kang[1], Phil Muñoz[1], Guoliang Deng[1], Eric Mazur[1]; *[1]Harvard Univ., USA.* We fabricate 3D gratings and diffraction optics using direct laser writing. Diffraction patterns of gratings agree with Laue theory. We demonstrate zone plates for visible wavelengths. Direct laser writing is promising for integrated diffraction optics.

SW1K.7 • 09:45
Harnessing Polarization Spatio-Temporal Coupling: A New Degree of Freedom in Ultrafast Laser Material Processing, Aabid Patel[1], Martynas Beresna[1], Peter Kazansky[1]; *[1]Univ. of Southampton, UK.* Polarization spatio-temporal coupling reveals new degree of freedom in ultrafast laser material processing. Control of modification in fused silica is demonstrated with the use of prism compressors and polarization azimuth of ultrashort pulse laser beam.

SW1L • Mid-IR & Supercontinuum Fiber Sources—Continued

SW1L.6 • 09:30
Power Scaling of 2.94 μm Fiber Lasers, Vincent Fortin[1], Martin Bernier[1], Réal Vallée[1]; *[1]Centre d'optique, photonique et laser, Université Laval, Canada.* Recent advances in high power erbium-doped fluoride fiber lasers near 2.94 μm are reviewed. Based on an all-fiber architecture, a 20 W record output power was achieved at this wavelength of interest for medical applications.

SW1L.7 • 09:45
Two-Octave Mid-Infrared Supercontinuum Generation in As-Se Suspended Core Fibers, Uffe Møller[1], Christian R. Petersen[1], Irnis Kubat[1], Yi Yu[2], Xin Gai[2], Laurent Brilland[3], David Méchin[3], Celine Caillaud[4], Johann Troles[4], Barry Luther-Davies[2], Ole Bang[1,5]; *[1]DTU Fotonik, Dept. of Photonics Engineering, Technical Univ. of Denmark, Denmark; [2]Centre for Ultrahigh bandwidth Devices for Optical Systems, Laser Physics Centre, Australian National Univ., Australia; [3]R&D Platform of Photonics Bretagne, Perfos, France; [4]Institut des Sciences Chimiques de Rennes, Université de Rennes 1, France; [5]NKT Photonics, Denmark.* A more than two-octave mid-infrared supercontinuum with an average output power of 15.6 mW covering 1.7-7.5 μm (1333-5900 cm^{-1}) is generated in a low-loss $As_{38}Se_{62}$ suspended core fiber with core diameter of 4.5 μm.

10:00–18:30 Exhibition Open, *Exhibit Halls 1 & 2*

10:00–10:30 Coffee Break, *Exhibit Hall*

CLEO: Science & Innovations

SW1M • Coherent Communications—Continued

SW1M.7 • 09:30 Invited

DSP-complexity Reduction of QAM-based Coherent Optical Networks Enabled by Seed Lightwave Distribution, Jun Sakaguchi[1], Motohiro Kumagai[1], Ying Li[1], Tetsuya Ido[1], Yoshinari Awaji[1], Naoya Wada[1]; [1]*NICT, Japan*. A new network scheme employing stable seed lightwave distribution is investigated for reducing QAM demodulation complexity. We perform 150 km seed distribution before 100 km WDM-PDM-64QAM transmission and achieve simple demodulation without phase estimation.

SW1N • Applications of Optical Resonators—Continued

SW1N.4 • 09:30

Silicon Photonic Filters for Compact High Extinction Ratio Power Efficient (CHERPe) Transmitters, Steven Spector[1], Jeffrey M. Knecht[1], Robert T. Schulein[1], David O. Caplan[1]; [1]*Massachusetts Inst of Tech Lincoln Lab, USA*. We experimentally investigate integrated photonic microring resonator filters as frequency windows in CHERPe transmitters. The impact of filter-order on optical loss, power handling, modulation extinction ratio enhancement, and waveform distortion is assessed.

SW1N.5 • 09:45

28 Gb/s BPSK Modulation in a Coupling-tuned Silicon Microring Resonator, Rui Yang[1], Linjie Zhou[1], haike zhu[1], Jianping Chen[1]; [1]*Shanghai Jiao Tong Univ., China*. We demonstrate 28 Gb/s binary phase-shift keying modulation in a silicon microring integrated with a Mach-Zehnder coupler. The BPSK signal has a Q-factor of 6.3 dB and an EVM of 23.3% with 3 V drive voltage.

SW1O • Ultrafast Technologies Based on Aperiodical Quasi-Phase Matching—Continued

SW1O.4 • 09:30

Soliton Modelocking With Normal Dispersion via Adiabatic Excitation of $\chi^{(2)}$ Solitons in Apodized Fanout PPLN Devices, Christopher R. Phillips[1], Aline Sophie Mayer[1], Alexander Klenner[1], Ursula Keller[1]; [1]*ETH Zurich, Switzerland*. We demonstrate soliton modelocking of a Yb:CALGO laser via cascaded second-order nonlinearities whereby the second-harmonic is adiabatically excited/de-excited in an apodized-fanout-PPLN crystal. We obtain 100-fs pulses at 540 MHz with 760 mW average power.

SW1O.5 • 09:45

Fast Tunable Picosecond Optical Parametric Oscillator Based on Chirped Quasi-Phase Matching, Delphine Descloux[1], Jean-Baptiste Dherbecourt[1], Jean-Michel Melkonian[1], Myriam Raybaut[1], Cyril Drag[2], Antoine Godard[1]; [1]*Onera, France;* [2]*Laboratoire Aimé Cotton, France*. We report on a picosecond OPO combining an aperiodically poled nonlinear crystal and a rapidly tunable intracavity spectral filter. Fast tuning over 80 nm around 3.84 μm is carried out in less than few milliseconds.

10:00–18:30 Exhibition Open, *Exhibit Halls 1 & 2*

10:00–10:30 Coffee Break, *Exhibit Hall*

10:00–12:00
JW2A • Poster Session II

JW2A.1
Withdrawn

JW2A.2
Entanglement Diversity in MonolithicWaveguides, Dongpeng Kang[1], Minseok Kim[1], Haoyu He[1], Amr S. Helmy[1]; [1]*Univ. of Toronto, Canada*. The simultaneous generation of both co-polarized and cross-polarized polarization entangled photons from a monolithic semiconductor chip is demonstrated. High quality entanglement is achieved with no use of any off-chip compensation, interferometry or filtering.

JW2A.3
Avoiding Entanglement Sudden Death Using Quantum Measurement Reversal on Single-qubit, Hyang-Tag Lim[1], Jong-Chan Lee[1], Kang-Hee Hong[1], Yoon-Ho Kim[1]; [1]*Pohang Univ of Sci & Tech (POSTECH), USA*. Decoherence on two-qubit systems degrades entanglement, and sometimes even causes entanglement sudden death (ESD). We show quantum measurement reversal on only one subsystem can avert ESD, providing methods for practical entanglement distribution under decoherence.

JW2A.4
Measurement of Energy Correlations of Photon Pairs Generated in Silicon Ring Resonators, Davide Grassani[1], Angelica Simbula[1], Matteo Galli[1], Stefano Pirotta[1], Tom Baher-Jones[2], Michael Hochberg[2], Nicholas Harris[3], Christophe Galland[4], John E. Sipe[5], Daniele Bajoni[6], Marco Liscidini[1]; [1]*Physics, Universita degli Studi di Pavia, Italy;* [2]*East West Photonics Pte Ltd, Singapore;* [3]*Electrical Engineering and Computer Science, MIT, USA;* [4]*Stuttgart Univ., Germany;* [5]*Physics, Univ. of Toronto, Canada;* [6]*Ingegneria Industriale e dell'Informazione, Università degli Studi di Pavia, Italy.* With unprecedented resolution we measure the joint spectral density of photon pairs that would be generated by spontaneous four-wave-mixing in a silicon ring resonator, and show how the quantum correlations can be tailored.

JW2A.5
Quantum information interface for orbital angular momentum photons, Ruikai Tang[1], Xiongjie Li[1], Wenjie Wu[1], Haifeng Pan[1], Heping Zeng[1], E Wu[1]; [1]*East China Normal Univ., China*. We have demonstrated a quantum interface based on the frequency upconversion for photons carrying orbital angular momentum (OAM) states from telecom wavelength to visible regime by sum-frequency generation with high quantum conversion efficiency.

JW2A.6
Generation and Characterization of Continuous Variable Quantum Correlations Using a Fiber Optical Parametric Amplifier, Xueshi Guo[1], Xiaoying Li[1], Nannan Liu[1], Yuhong Liu[1]; [1]*College of Precision Instrument and Opto-electronics Engineering, Tianjin Univ., China*. We generate the quadrature entanglement and the Gaussian discord using a fiber optical parametric amplifier, and investigate the factors influencing the values of inseparability *I* and discord *D*, respectively.

JW2A.7
Fortifying Single Photon Detectors to Quantum Hacking Attacks by Using Wavelength Upconversion, Gregory S. Kanter[1,2]; [1]*NuCrypt, USA;* [2]*Center for Photonic Communication and Computing, Northwestern Univ., USA*. Upconversion detection can isolate the temporal and wavelength window over which light can be efficiency received. Using appropriate designs the ability of an eavesdropper to damage, measure, or control QKD receiver components is significantly constricted.

JW2A.8
A Controlled-NOT (CNOT) Gate Based on Quantum Interference in Cascaded Silicon Dual-ring Resonators, Lei Zhang[1,2], Zhanshi Yao[1], Lin Yang[2], Andrew W. Poon[1]; [1]*Photonic Device Lab, Dept. of Electronic and Computer Engineering, The Hong Kong Univ. of Science and Technology, China;* [2]*State Key Lab on Integrated Optoelectronics, Inst. of Semiconductors, Chinese Academy of Sciences, China*. We propose a controlled-NOT (CNOT) gate based on two-photon quantum interference in cascaded silicon dual-ring resonators with Mach-Zehnder interferometer-assisted coupling. We illustrate the working principle and the design parameters of the device by theoretical modeling.

JW2A.9
Photonic Quantum Walks on Finite Graphs and with Non-Localised Initial States, Sonja Barkhofen[1], Fabian Elster[1], Thomas Nitsche[1], Jaroslav Novotný[2], Aurél Gábris[2,3], Igor Jex[2], Christine Silberhorn[1]; [1]*Applied Physics, Univ. of Paderborn, Germany;* [2]*Dept. of Physics, Faculty of Nuclear Sciences and Physical Engineering, Czech Technical Univ. in Prague, Czech Republic;* [3]*Dept. of Theoretical Physics, Univ. of Szeged, Hungary.* We present a time-multiplexed quantum walk in a fibre loop setup and introduce a fast switching electro optic modulator. Hence we can limit the spread of the wavefunction by choice and study the evolution of non-localized initial states.

JW2A.10
Multi-party Agile QKD Network with a Fiber-based Entangled Source, Eric Y. Zhu[1], Costantino Corbari[2], Alexey V. Gladyshev[3], Peter Kazansky[2], Hoi-Kwong Lo[1], Li Qian[1]; [1]*Univ. of Toronto, Canada;* [2]*Univ. of Southampton, UK;* [3]*Fiber Optics Research Center of the Russian Academy of Sciences, Russia*. A multi-party quantum key distribution scheme is demonstrated by utilizing a poled fiber-based broadband polarization-entangled source and dense wavelength-division multiplexing. Entangled photon pairs are delivered over 40-km of fiber, with secure key rates of more than 20 bits/s observed.

JW2A.11
Spectral Engineering and Entanglement Generation in Poled Optical Fibers, Eric Y. Zhu[1], Costantino Corbari[2], Alexey V. Gladyshev[3], Alexey Kosolapov[3], Mikhail Yashkov[4], Peter Kazansky[2], Li Qian[1]; [1]*Univ. of Toronto, Canada;* [2]*Optoelectronics Research Centre, Univ. of Southampton, UK;* [3]*Fiber Optics Research Center of the Russian Academy of Sciences, Russia;* [4]*Inst. of Chemistry of High-Purity Substances of the Russian Academy of Sciences, Russia*. The joint spectra of the two type-II phase-matchings that add coherently to give rise to the generation of polarization-entangled photon pairs in a poled fiber are measured. Optimal parameters are identified for the generation of high-quality entanglement.

JW2A.12
Divide-and-Conquer Integrated Photon-Counting Device, Armando P. Leija[1], Jan Sperling[2], Markus Graefe[1], Rene Heilmann[1], Mathias Heinrich[1], Werner Vogel[2], Stefan Nolte[1], Alexander Szameit[1]; [1]*Friedrich-Schiller-Universität Jena, Germany;* [2]*Institut für Physik, Rostock Univ., Germany.* In this work we experimentally demonstrate a fully integrated photon-counting device based on a divide-and-conquer technique using linear optics in combination with on-off detectors. Our scheme is based on click-counting statistics instead of photon-counting statistics.

JW2A.13
High-Q Microresonator as a Five-Partite Entanglement Generator via Cascaded Parametric Processes, Yutian Wen[1], Qiang Lin[2], Guangqiang He[1]; [1]*Dept. of Electronic Engineering, Shanghai Jiaotong Univ., China;* [2]*Dept. of Elctrical and Computer Engineering, Univ. of Rochester, USA*. We propose to produce five-partite entanglement via cascaded four-wave mixing in a high-Q microresonator that may become a key to future one-way quantum computation on chip.

JW2A.14
Integrated-photonic generation of general EPR-states, Markus Graefe[1], René Heilmann[1], Stefan Nolte[1], Alexander Szameit[1]; [1]*Inst. of Applied Physics, Germany.* We present a novel method to generate arbitrary path-encoded EPR- states on-chip by a single operation only. Such states can be utilized to mimic the quantum statistics of fermions, bosons, and anyons.

JW2A.15
Secure Communication App on Mobile Phone Enabled by Sharing Quantum Random Numbers, Lu-Feng Qiao[1,2], Long Li[1], Xiao-Feng Lin[1,2], Xianmin Jin[1,2]; [1]*State Key Lab of Advanced Optical Communication Systems and Networks, Dept. of Physics and Astronomy, Shanghai Jiao Tong Univ., China;* [2]*Synergetic Innovation Center of Quantum Information and Quantum Physics, Univ. of Science and Technology of China, China*. We develop a mobile phone app for secure communication in which all data including text, voice, email and any other files are all encrypted and decrypted with shared quantum random numbers.

JW2A.16
Quantum Repeater with Quantum Frequency Conversion, Xiao Li[1], Neal Solmeyer[2], Qudsia Quraishi[2]; [1]*Joint Quantum Inst., USA;* [2]*U.S. Army Research Lab, USA*. We report the progress of a quantum repeater with quantum frequency conversion to telecom wavelengths, which allows for quantum communication over long distances.

JW2A.17
Quantum State Engineering in Integrated Couplers, Ryan P. Marchildon[1], Amr S. Helmy[1]; [1]*Univ. of Toronto, Canada*. The utilization of integrated couplers beyond their function as 50:50 splitters is examined. Their dispersive properties offer novel possibilities for state engineering, interference visibility behaviour, and entanglement sensitivity. Implications for photon pair separation are explored.

JW2A.18
Compressive Imaging of Broadband Single-Photon Sources With Superconducting Detectors, Jason Schaake[1]; [1]*Univ. of Tennessee at Knoxville, USA*. We experimentally characterize the spatio-spectral properties of photon pairs generated by spontaneous parametric down-conversion in a Type-0 PPKTP waveguide using compressive imaging techniques combined with superconducting single photon detectors and dispersive fiber spectrometer.

JW2A.19
Simulation Study of the Stability of Polarization Structure in Disordered Photonic Crystal Waveguides, Ben Lang[1], Ruth Oulton[1], Daryl Beggs[1], John Rarity[1], Andrew Young[1]; [1]*Univ. of Bristol, UK*. The effects of short range disorder on the polarization characteristics of light in W1 photonic crystal waveguides were simulated. It was found that points of local circular polarization were robust in both quantity and location.

JW2A.20
Two-photon evolution equation for multiport optical systems, Armando P. Leija[1], Markus Graefe[1], Rene Heilmann[1], Maxime N. Lebugle[1], Stefan Nolte[1], Hector Moya-Cessa[2], Demetrios N. Christodoulides[3], Alexander Szameit[1]; [1]*Friedrich-Schiller-Universität Jena, Germany;* [2]*Optics Dept., INAOE, Mexico;* [3]*CREOL, Univ. of Central Florida, USA*. In this work we demonstrate, theoretically and experimentally, that two-photon probability amplitudes describing propagation of light in any two-photon state are governed by an evolution equation identical to a 2D tight-binding equation.

10:00–12:00
JW2A • Poster Session II

JW2A.21
Optical and Microwave Properties of Focused Ion Beam Implanted Erbium Ions in Y_2SiO_5 Crystals, Nadezhda Kukharchyk[1], Sebastian Probst[2], Shovon Pal[1], Kangwei Xia[3], Roman Kolesov[3], Arne Ludwig[1], Alexey V. Ustinov[2], Pavel Bushev[4], Andreas D. Wieck[1]; [1]*Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany;* [2]*Physikalisches Institut, Karlsruhe Inst. of Tachnology, Germany;* [3]*Physikalisches Institut, Universität Stuttgart, Germany;* [4]*Experimentalphysik, Universität des Saarlandes, Germany.* We present focused ion beam implantation as a prospective tool for realizing a patterned rare-earth spin-ensemble in a solid-state substrate. We demonstrate a successful implantation with 20% of luminescent ion activation for Erbium ions in Y_2SiO_5 crystals.

JW2A.22
Efficient Collisional Blockade Single Atom Loading in Tight Optical Microtraps, Yin Hsien Fung[1], Mikkel Andersen[1]; [1]*Jack Dodd Centre for Quantum Technology, Univ. of Otago, New Zealand.* Collisional blockade loading of single atom in tight FORT has about 50% efficiency in previous works. We experimentally observe an enhancement to about 80% by inducing controlled inelastic collisions during loading, which is supported by an analytical theory.

JW2A.23
Preservation of Transverse Spatial Coherence of an Optical Pulse in Atomic Vapor Quantum Memory, Jong-Chan Lee[1], Kwang-Kyoon Park[1], Young-Wook Cho[1], Yoon-Ho Kim[1]; [1]*Physics, Pohang Univ. of Science and Technology, Korea.* We report preservation of transverse spatial coherence of an optical pulse stored in atomic vapor quantum memory. Using Young-type spatial interference, it is clearly demonstrated that the atomic vapor quantum memory preserves transverse spatial coherence.

JW2A.24
Withdrawn

JW2A.25
Coulomb Interaction and Delocalized States in Self-assembled InGaAs Lateral Quantum Dot Molecules, Xinran Zhou[1], Miquel Royo[2], Weiwen O. Liu[1], Jihoon Lee[3,4], Gregory Salamo[4], Juan Climente[2], Matthew Doty[1]; [1]*Univ. of Delaware, USA;* [2]*Departament de Quimica Fisica i Analitica, Universitat Jaume I, Spain;* [3]*School of Electronics and Information, Kwangwoon Univ., Korea;* [4]*Inst. of Nanoscale Science and Engineering, Univ. of Arkansas, USA.* We study self-assembled lateral quantum dot molecules (LQDMs) under varying electric and magnetic fields and deduce the electronic structure, charge configurations and delocalized states that lead to the observed photoluminescence spectra.

JW2A.26
Resonance Fluorescence Spectrum from a Quantum Dot Driven by a Periodically-Pulsed Laser, kumarasiri konthasinghe[1], Manoj Peiris[1], Ben Petrak[1], Ying yu[2], Zhichuan Niu[2], Andreas muller[1]; [1]*Physics, Univ. of South Florida, USA;* [2]*Chinese Academy of Sciences, China.* We report the measurement of the resonance fluorescence spectrum from a quantum dot under periodically-pulsed excitation. The evolution of multiple sidebands and Rabi oscillations for coherently and incoherently scattered light were observed.

JW2A.27
Withdrawn

JW2A.28
Deterministic Generation of a Triexciton in a Quantum Dot, Emma Schmidgall[1], Ido Schwartz[1], Liron Gantz[1], Dan Cogan[1], David Gershoni[1]; [1]*Technion, Israel.* We demonstrate deterministic generation of a quantum dot-confined triexciton in a well-defined coherent state using a sequence of three laser pulses.

JW2A.29
Bright phonon-tuned single-photon source, Simone L. Portalupi[1], Gaston Hornecker[2], Valérian Giesz[1], Thomas Grange[2], Aristide Lemaître[1], Justin Demory[1], Isabelle Sagnes[1], Norberto D. Lanzillotti-Kimura[1], Loic Lanco[1,3], Alexia Auffèves[2], Pascale Senellart[1,4]; [1]*CNRS-LPN Laboratoire de Photonique et de Nanostructures, France;* [2]*CEA/CNRS/UJF joint team "Nanophysics and Semiconductors", Institut Néel-CNRS, France;* [3]*Département de physique, Université Paris Diderot, France;* [4]*Département de physique, Ecole Polytechnique, France.* We studied experimentally and theoretically a single-photon source consisting of a quantum dot coupled to a micropillar cavity. The influence of the LA-phonon bath on the brightness of the source and the indistinguishability of the emitted photons will be discussed.

JW2A.30
Interactions of Space Variant Polarization Beams with Zeeman-shifted Rubidium Vapor , Anat Szapiro[1], Liron Stern[1], Uriel Levy[1]; [1]*hebrew Univ. of Jerusalem, Israel.* We experimentally demonstrate the interaction between space variant polarization beams with a Zeeman shifted rubidium vapor operating as a controlled circular birefringence and dichroism media. Full Stokes parameters measurements allows for mapping the polarization distribution.

JW2A.31
A Subluminal Laser with Extreme Insensitivity to Cavity Length Change, Zifan Zhou[1], Joshua Yablon[1], Ye Wang[1], Jacob Scheuer[2], Selim M. Shahriar[1]; [1]*Northwestern Univ., USA;* [2]*School of Electrical Engineering, Tel Aviv Univ., Israel.* With a narrow peak on top of a broad-band gain profile in a laser, the group-velocity of light becomes significantly subluminal. The lasing frequency becomes extremely insensitive to cavity length change in such a laser.

JW2A.32
Simple and Efficient Filter for Single Photons from a Cold Atom Quantum Memory, Daniel T. Stack[1], Qudsia Quraishi[1]; [1]*US Army Research Lab, USA.* Filtering unwanted light signals is critical to the operation of neutral atom quantum memories. The addition of a novel frequency filter increases the non-classical correlations and readout efficiency of our quantum memory by ≈ 35%.

JW2A.33
Optimized scalable circular grating with efficient photon extraction for Nitrogen Vacancy centers in a bulk diamond, Jiabao Zheng[1,2], Edward Chen[2], Luozhou Li[2], Florian Dolde[2], Dirk R. Englund[2]; [1]*Dept. of Electrical Engineering, Columbia Univ., USA;* [2]*Dept. of Electrical Engineering and Computer Science, MIT, USA.* We numerically demonstrate an optimized circular grating for Nitrogen-Vacancy centers with collection efficiency of 35.8% for Zero-Phonon emission into NA within 0.5, which is improved to 63.9% by adding a conductive layer. The optimal structure is fabricated using transferred hard mask lithography.

JW2A.34
Withdrawn

JW2A.35
A New Algorithm for Attosecond Pulse Characterization, Phillip D. Keathley[1], Siddharth Bhardwaj[1], Jeffrey Moses[1], Guillaume Laurent[1], Franz X. Kaertner[1,2]; [1]*Electrical Engineering and Computer Science and Research Lab of Electronics, MIT, USA;* [2]*Center for Free-Electron Laser Science and Dept. of Physics, DESY and Univ. of Hamburg, Germany.* An algorithm for characterizing attosecond EUV pulses which is not bandwidth-limited, requires no interpolation of the experimental data, and makes no approximations beyond SFA while fully retrieving both the IR and EUV pulses is introduced.

JW2A.36
Versatile Simulation Package for Ultrafast Pulse Propagation and High Harmonic Generation, Gregory J. Stein[1], Chien-Jen Lai[1], Phillip D. Keathley[1], Peter R. Krogen[1], Houkun Liang[1], Chun-Lin L. Chang[1], Kyung-Han Hong[1], Guillaume Laurent[1], Franz X. Kaertner[1,2]; [1]*MIT, USA;* [2]*CFEL, Germany.* A simulation package for 3D pulse propagation and HHG is reported. Our package is capable of emulating pulse propagation for a host of geometries and nonlinear effects, and has been employed to reproduce experimental HHG spectra.

JW2A.37
Towards Observing Dynamical Localization within the Quantum Linear Rotor, andrei kamalov[1,2], Doug Broege[1,2], Philip H. Bucksbaum[2,1]; [1]*Stanford Univ., USA;* [2]*PULSE Inst., SLAC National Accelerator Lab, USA.* We discuss novel approaches towards observation of dynamical localization, a phenomenon believed to occur in the periodically δ-kicked quantum linear rotor and is related to one-dimensional Anderson localization.

JW2A.38
Ultrafast Rotational Spectroscopy Based on a Free-space Nitrogen Ion Laser, Hongqiang Xie[1], Bin Zeng[1], Haisu Zhang[1], Guihua Li[1], Wei Chu[1], Jinping Yao[1], Chenrui Jing[1], Jielei Ni[1], Ya Cheng[1]; [1]*Shanghai Inst. of Optics and Fine Mechanics, China.* We demonstrated that ultrafast rotational spectroscopy can be performed with a cavityless nitrogen ion laser with both high temporal and spectral resolutions. Quantum beating between the molecular rotational wave packets have been observed.

JW2A.39
Highly Efficient High-order Harmonics with Large Cutoff from Carbon Molecules using Various Laser Wavelengths, Muhammad Ashiq Fareed[1], Nicolas Thiré[1], Sudipta Mondal[1], yoann pertot[1], Maxime Boudreau[1], Bruno E. Schmidt[1], François Légaré[1], Tsuneyuki Ozaki[1]; [1]*INRS-EMT, Canada.* Carbon molecules are used to generate intense high-order harmonics using driving lasers with 0.8 μm - 1.71 μm wavelengths. By driving plasma of reduced size (~200μm) with 1.71μm laser, we could extend the cutoff to ~70eV, while reducing the peak intensity by only ~31%.

JW2A.40
Interaction of Metal Oxide Nanoparticles, Generated via Microparticle Ablation, with Intense XUV Pulses, Sandra Bruce[1,2], Ahmed M. Helal[1,2], Thanh Ha[1,2], Hernan J. Quevedo[1,2], Aaron C. Bernstein[1,2], John Keto[1,2], Todd Ditmire[1,2]; [1]*Center for High Energy Density Science, USA;* [2]*Physics, The Univ. of Texas at Austin, USA.* We have designed and assembled an experiment to evaluate the role of continuum lowering in XUV nanocluster ionization. Metal oxide nanoparticles, generated via laser ablation of microparticles, will be irradiated by intense coherent XUV pulses.

JW2A.41
Electron Heating by Ultra-Fast, Ultra-Intense Laser Irradiation of Wavelength-Scale Wires, Kristina Serratto[1], Franki Aymond[1], Brandon Simon[1], Aaron C. Bernstein[1], Todd Ditmire[1]; [1]*The Univ. of Texas at Austin, USA.* Wavelength-scale platinum wires were irradiated by a 1-micron wavelength laser at relativistic intensities, accelerating electrons in the laser-matter interaction. Wire diameters and angles relative to laser polarization were varied, and emitted electron distributions were measured.

JW2A.42
Generation of High-Density, Thin Gas Targets for Intense Laser Interaction at 1 kHz Repetition Rates, Yan Tay[1], Donghoon Kuk[1], Luke Hahn[1], Howard Milchberg[1], Ki-Yong Kim[1]; [1]*Univ. of Maryland at College Park, USA.* We report the production of high-density, thin gas targets (90 ~ 500 microns) with cryogenic cooling in continuous gas flow. Multiple nozzles are also demonstrated to produce corrugated plasma waveguides at 1 kHz repetition rates.

10:00–12:00
JW2A • Poster Session II

JW2A.43
Density-chopped Far-infrared Transmission Spectroscopy to Probe Subband-Landau Splittings and Tune Intersubband Transitions, Shovon Pal[1,2], Hanond Nong[2], Sascha R. Valentin[1], Nadezhda Kukharchyk[1], Arne Ludwig[1], Nathan Jukam[2], Andreas D. Wieck[1]; *[1]Lehrstuhl für Angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany; [2]AG Terahertz Spektroskopie und Technologie, Ruhr-Universität Bochum, Germany.* We study the half-field subband-Landau resonant splitting of a two-dimensional electron gas and demonstrate the possibility to tune the intersubband spacings via density-chopped far-infrared transmission spectroscopy in the absence of external magnetic field.

JW2A.44
Withdrawn

JW2A.45
Optical Generation of High Spin Polarization in GaSe Nanoslabs, Yanhao Tang[1], Wei Xie[1], Krishna C. Mandal[2], John A. McGuire[1], Chih-Wei Lai[1]; *[1]Michigan State Univ., USA; [2]Univ. of South Carolina, USA.* We report nearly complete preservation of "spin memory" between optical absorption and photoluminescence under excitation >0.2 eV above the band gap in nanometer GaSe slabs.

JW2A.46
Control of Energy Relaxation Pathways in Graphene: Carrier-Carrier Scattering vs Phonon Emission, Zoltan Mics[1], Soren Jensen[1], Ivan Ivanov[1], Samet Varol[1], Dmitry Turchinovich[1], Frank Koppens[2], Mischa Bonn[1], Klaas-Jan Tielrooij[2]; *[1]Max Planck Inst. f. Polymer Research, Germany; [2]ICFO The Inst. of Photonic Sciences, Spain.* We investigate the relaxation pathways of photoexcited carriers in graphene. These carriers relax their energy through either carrier-carrier scattering or phonon emission, depending on photoexcitation conditions and the Fermi level.

JW2A.47
Withdrawn

JW2A.48
Exciton States in InGaN Nano-disks in GaN Nanowires Revealed Using Nonlinear Laser Spectroscopy, Cameron Nelson[1], Albert Liu[1], Saniya Desphande[1], Shafat Jahangir[1], Pallab K. Bhattacharya[1], Duncan G. Steel[1]; *[1]Univ. of Michigan, USA.* Linear and coherent non-linear resonant high resolution laser spectroscopy was used to characterize $In_{0.54}Ga_{0.46}N$ disks in nanowires. Nonlinear optical spectroscopy and PLE reveal narrow excitonic resonances and evidence of coupling between separate excited states.

JW2A.49
Many-Body Interactions Between Excitons in GaAs Quantum Wells Quantified Using Two-Dimensional Coherent Spectroscopy, Rohan Singh[1], Travis Autry[1], Galan Moody[2], Gael Nardin[1], Bo Sun[1], Takeshi Suzuki[1], Steven Cundiff[1]; *[1]JILA, Univ. of Colorado/NIST, USA; [2]NIST, USA.* We have quantified excitonic many-body interaction energies in GaAs quantum wells using two-dimensional coherent spectroscopy. The anharmonic oscillator model for excitons is used to extract the inter- and intra-mode interaction energies from 2D spectra.

JW2A.50
Optical Pump - Multi-THz Probe Spectroscopy of a Single Crystal Organic Hybrid Lead Halide Perovskite, David A. Valverde-Chavez[1], Carlito Ponseca[2], Constantinos Stoumpos[3], Arkady Yartsev[2], Mercouri Kanatzidis[3], Villy Sundström[2], David G. Cooke[1]; *[1]Physics, McGill Univ., Canada; [2]Chemical Physics, Lund Univ., Sweden; [3]Chemistry, Northwestern Univ., USA.* We analyzed ultrafast photocarrier generation in single crystal $CH_3NH_3PbI_3$ perovskite through time-resolved terahertz spectroscopy. We find a Drude-Lorentz type conductivity spectra with a carrier mobility of 35 cm^2/Vs and a Lorentzian component at 45 meV possibly due to intra-excitonic transitions.

JW2A.51
THz transient non-perturbative detection of spin reorientation transition in $NdFeO_3$ single crystal, Guo-Hong Ma[1]; *[1]Shanghai Univ., China.* Magnetic field-induced spin switching of NdFeO3 crystal was demonstrated with TDS spectroscopy. The critical magnetic field to achieve the magnetic phase transition is modulated by temperature. A useful one-way spin switching has been found in NdFeO3 crystal.

JW2A.52
Ultrafast Laser-Induced Field Emission from a Single Carbon Nanotube Based Nanotip, Mina Bionta[1], Benoit Chalopin[1], Marc Delmas[2], Florent Houdellier[2], Aurelien Masseboeuf[2], Julien Mauchain[1], Beatrice Chatel[1]; *[1]LCAR-IRSAMC Université Paul Sabatier, France; [2]CEMES, France.* We present the first demonstration of ultrafast laser-induced field emission from a carbon nanotube based nanotip, and measurement of the energy distribution of the electrons.

JW2A.53
Laser Assisted Electron Emission from Free Standing Carbon Nanotube Paper, Ryan Hendrix[1], Jason A. Deibel[1], Steven B. Fairchild[2], Benji Maruyama[2], Augustine Urbas[2], Mark Walker[2], Dean Brown[3]; *[1]Wright State Univ., USA; [2]Materials and Manufacturing Directorate, Air Force Research Lab, USA; [3]UES, Air Force Research Lab, USA.* Laser assisted electron emission from a free standing, non-aligned carbon nanotube film is observed with low power (<100 mW) continuous wave (785 nm) laser excitation. An increase in emission current by 330 times is realized.

JW2A.54
Two Dimensional Coherent Spectroscopy of CdSe/ZnS Colloidal Quantum Dots at Cryogenic Temperatures, Bo Sun[1], Diogo B. Almeida[1], Rohan Singh[1,2], Geoffrey M. Diederich[3], Mark E. Siemens[3], Lazaro A. Padilha[4], Wan K. Bae[5], Jeffrey Pietryga[6], Victor Klimov[6], Steven Cundiff[1,2]; *[1]JILA, National Inst. of Standards and the Univ. of Colorado, USA; [2]Physics, Univ. of Colorado, USA; [3]Dept. of Physics and Astronomy, Univ. of Denver, USA; [4]Instituto de Fisica, Universidade Estadual de Campinas, Brazil; [5]Photo-Electronic Hybrid Research Center, Korea Inst. of Science and Technology, Korea; [6]Chemistry Division, Los Alamos National Lab, USA.* We demonstrate 2D coherent spectroscopy of CdSe/ZnS nanocrystals and measure the exciton homogeneous linewidth as a function of temperature from 10K to 300K. The specra reveal contributions to the linewidth from discrete acoustic phonon modes.

JW2A.55
Hybrid Metal Wire-Dielectric THz Fibers: Design and Perspectives, Andrey Markov[1], Hichem Guerboukha[1], Maksim Skorobogatiy[1]; *[1]Ecole Polytechnique de Montreal, Canada.* We investigate the optical characteristics of terahertz two-wire plasmonic waveguides, porous, and foam-based dielectric waveguides. Our group demonstrates a low-loss and low-dispersion hybrid metal wire-dielectric fiber resulting from fusion of the aforementioned types of waveguides.

JW2A.56
Graded Index Porous Optical Fibers - Dispersion Management in Terahertz Range, Andrey Markov[1], Tian Ma[1,2], Maksim Skorobogatiy[1]; *[1]Ecole Polytechnique de Montreal, Canada; [2]Xi'an Inst. of Optics and Precision Mechanics of CAS, China.* Graded index porous fiber incorporating an air-hole array featuring variable air-hole diameters and inter-hole separations is proposed. We experimentally demonstrate smaller pulse distortion, larger bandwidth and higher excitation efficiency compared to fibers with uniform porosity.

JW2A.57
Efficiency Scaling of Narrowband Terahertz Wave Generation in PPLN by Optimizing the Pump-Pulse Format, Jan Schulte[1,2], Sergio Carbajo[1,2], Koustuban Ravi[3], Damian N. Schimpf[1], Franz Kaernter[1,3]; *[1]Center for Free-Electron Laser Science, Deutsches Elektronen-Synchrotron (DESY), Germany; [2]Dept. of Physics, Univ. of Hamburg, Germany; [3]Dept. of Electrical Engineering and Computer Science, MIT, USA.* We demonstrate a 1.5×10^{-4} room temperature conversion efficiency and 0.29 µJ pulse energy for narrowband terahertz generation in PPLN pumped with ultrafast pulses at 800nm by experimentally and numerically optimizing the pump-pulse format.

JW2A.58
Ultra High Dynamic Range Electro Optic Sampling for Terahertz Detection Using Fiber Based Spectral Domain Interferometry, Akram Ibrahim[1], Denis Férachou[1], Gargi Sharma[2], Kanwarpal (KP) Singh[3], Tsuneyuki Ozaki[1]; *[1]INRS-EMT, Advanced Laser Light Source, Université du Québec, 1650 boul. Lionel- Boulet, J3X 1S2, Canada; [2]Univ. of Massachusetts Lowell, 1 Univ. Avenue, 01854, USA; [3]Harvard Medical School, Massachusetts General Hospital, 40 Blossom Street, 02114, USA.* We demonstrate a novel fiber-based spectral-domain interferometry (SDI) technique for terahertz electric field measurement. Signal-to-noise ratio is enhanced by more than four folds while the scanning window is extended to >30 picoseconds compared to conventional SDI techniques.

JW2A.59
Freestanding Terahertz Metamaterials Fabricated by Laser Beam Machining, Norman Born[1], Jan C. Balzer[1], Ralf Gente[1], Ibraheem Al-Naib[2], Martin Koch[1]; *[1]Philipps Universitat Marburg, Germany; [2]Dept. of Physics, Queen's Univ., Canada.* We demonstrate freestanding terahertz metamaterials, fabricated by laser-beam machining of commercial Aluminum-foil. This method allows for cost-efficient and rapid prototyping. Low insertion losses and outstanding transmission characteristics render the samples as high performance filters.

JW2A.60
Nano-holes vs Nano-cracks in Thin Gold Films: What Causes Anomalous THz Transmission?, Dmitry Turchinovich[1], Keno Krewer[1], Ke Jiang[1], Zoltan Mics[1], Zuanming Jin[1], Karina Bley[1], Hans-Joachim Elmers[1], Katharina Landfester[1], Mischa Bonn[1]; *[1]Max Planck Inst. for Polymer Research, Germany.* Nano-structuring materials can change their properties extraordinarily, but so can defects caused by manufacturing. We study the effect of capacitive defects on terahertz transmission in golden nanomeshes, and find their influence crucial.

JW2A.61
Evaluation of trace amounts of liquid using THz waves, Kazunori Serita[1], Eiki Matsuda[1], Iwao Kawayama[1], Hironaru Murakami[1], Masayoshi Tonouchi[1]; *[1]Osaka Univ., Japan.* We demonstrated terahertz near-field measurements of trace amounts of liquid. The obtained data show that the information of the solute less than nanogram in the trace amounts of liquid can be sensitively detected.

JW2A.62
Measurement of Terahertz Spectrum Using Heterodyne Technique with LO signal Generated by an MZM-Based Flat Comb Source, Isao Morohashi[1], Yoshihisa Irimajiri[1], Motohiro Kumagai[1], Akira Kawakami[1], Takahide Sakamoto[1], Norihiko Sekine[1], Tetsuya Kawanishi[1], Akifumi Kasamatsu[1], Iwao Hosako[1]; *[1]NICT, Japan.* We demonstrated rapid measurement of spectra of terahertz (THz) radiation from a quantum cascade lasers. THz waves generated by photonic down-conversion using Mach-Zehnder-modulator-based flat comb generator were used for local oscillator signals.

JW2A.63
Effects of Photoexcitation on Intense Terahertz Field-induced Nonlinearity in Monolayer Epitaxial Graphene, Hassan Hafez Eid[1]; *[1]INRS-EMT, Canada.* Terahertz field-induced transmission enhancement in monolayer epitaxial graphene is observed with increasing terahertz field. Photoexcitation leads to further transmission enhancement that is found to be less for the higher terahertz field amplitudes.

JW2A.64
Synthesis and all-optical self-referenced measurement of vectorial optical arbitrary waveform, Chi-Cheng Chen[1], Shang-Da Yang[1]; *[1]Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan.* We demonstrated an integrated system that can manipulate and measure vectorial field spanning up to the entire repetition period without ambiguity, iteration, and reference.

10:00–12:00
JW2A • Poster Session II

JW2A.65
Large Time-Bandwidth Product Integrated Microwave Photonic Hilbert Transformer, Bolan Liu[1], Chaotan Sima[1,2], WEI YANG[1], Deming Liu[1], YU YU[2], JAMES C. GATES[3], Christopher Holmes[3], Michalis Zervas[3], Peter Smith[3]; [1]*Next Generation Internet Access National Engineering Lab (NGIA), Huazhong Univ of Science and Technology, China;* [2]*Wuhan National Lab for Optoelectronics, China;* [3]*Optoelectronics Research Centre, Univ. of Southampton, UK.* We demonstrate an integrated largest time-bandwidth product (TBP) microwave photonic Hilbert transformer, using synthesized Bragg grating design and fabrication techniques. Devices operate from 50 GHz to 2.5 THz, with the TBP approaching 50.

JW2A.66
Two-dimensional Nanomaterial Tungsten Disulfide (WS_2) As Saturable Absorber for Mode-locked Laser Near 1550 nm, Kan Wu[1], Xiaoyan Zhang[2], Jung Wang[2], Xing Li[1], Jianping Chen[1]; [1]*Shanghai Jiao Tong Univ., China;* [2]*Shanghai Inst. of Optics and Fine Mechanics, CAS, China.* Saturable absorption has been discovered in two-dimensional nanomaterial tungsten disulfide (WS_2) near 1550nm. The mode-locked laser based on WS_2 saturable absorber have been demonstrated, which indicates the potential of WS_2 for ultrafast photonic applications.

JW2A.67
Improved Multiple Pulse Reconstruction from SHG FROG Spectrograms, Alexander Hause[1], Fedor Mitschke[1]; [1]*Univ. of Rostock, Germany.* A modified algorithm is presented which significantly reduces the rate of false reconstructions of SHG FROG spectrograms. A procedure to obtain error bars is given; they allow to gauge the quality of the reconstruction.

JW2A.68
Twisted-Nematic Liquid Crystal Polarization Rotators for Broadband Laser Applications, Peter Fiala[1], Christophe Dorrer[1], Kenneth Marshall[1]; [1]*Univ. of Rochester, USA.* Liquid crystal twisted-nematic polarization rotators in the Mauguin condition are shown to be more achromatic, less prone to high-frequency modulations caused by internal reflections than compound wave plates, and can be fabricated cost effectively at multi-inch apertures.

JW2A.69
Incoherent-light implementation of the photonic time stretch concept, Bo Li[1,2], Shuqin Lou[2], José Azaña[1]; [1]*INRS - Energie, Canada;* [2]*School of Electronic and Information Engineering, Beijing Jiaotong Univ., China.* We propose and experimentally demonstrate photonic time stretch of radio-frequency signals by using a time-gated (pulsed) incoherent light source, with time-stretch factors of 0.83 and 8.66, and a time-bandwidth product of > 340.

JW2A.70
Nonstoichiometric $Si_{1-x}Ge_x$ Based Tunable Saturable Absorber for Mode-Locked Erbium-doped Fiber Laser, Chi-Cheng Yang[1], Yung-Hsiang Lin[1], Gong-Ru Lin[1]; [1]*National Taiwan Univ., Taiwan.* Free-standing thin-film flexible $Si_{1-x}Ge_x$ saturable absorber with Si/Ge composition-ratio dependent saturable absorbance is demonstrated to passively mode-lock the erbium-doped fiber laser for delivering a pulsewidth of 330 fs at a modulation depth of 16%.

JW2A.71
16 W All-Normal-Dispersion Mode-Locked Yb-Doped Fiber Laser With Large Core Diameter, Zhiguo Lv[1], Hao Teng[2], Lina Wang[2], Zhiyi Wei[2]; [1]*School of Physics and Optoelectronic Engineering, Xidian Univ., China;* [2]*Beijing National Lab for Condensed Matter Physics, Inst. of Physics, Chinese Academy of Sciences, Beijing 100190, China, Beijing National Lab for Condensed Matter Physics, Inst. of Physics, Chinese Academy of Sciences, Beijing 100190, China, China.* A mode-locked all-normal-dispersion rod-fiber laser with large core diameter was demonstrated. Output power of 16 W with 270 fs pulse duration is generated. To best knowledge this is the first laser operation with 85 mm core fiber.

JW2A.72
Time Resolved Measurements of Relativistic Laser Hole Boring Using Broadband Relay Imaged GRENOUILLE, Craig Wagner[1], Aaron C. Bernstein[1], Gilliss M. Dyer[1], Todd Ditmire[1]; [1]*Center for High Energy Density Science, Univ. of Texas at Austin, USA.* To measure relativistic laser hole boring velocities up to 0.18c, an ultra-broadband diagnostic capable of retrieving the full time resolved pulse phase is required. The design of such a device based on GRENOUILLE is presented.

JW2A.73
Single-Shot Measurement of High-Harmonic Generation Intensity Waveforms by Spatially Encoded Transmission Switching, Hsu-hsin Chu[1], Chi-Hsiang Yang[1], Shih-Cheng Liu[1], Jyhpyng Wang[1,2]; [1]*National Central Univ., Taiwan;* [2]*Inst. of Atomic and Molecular Sciences, Academia Sinica, Taiwan.* Single-shot measurement of high-harmonic generation intensity waveforms is demonstrated by utilizing tunneling ionization of H_2 gas for transmission switching. This method can be applied to different kinds of ultrashort coherent extreme-UV sources.

JW2A.74
Passively Mode-locked Fiber Laser based on CVD WS_2, Reza Khazaeinezhad[1], Sahar Hosseinzadeh Kassani[1], Hwanseong Jeong[2], Dong-Il Yeom[2], Kyunghwan Oh[1]; [1]*Yonsei Univ., USA;* [2]*Ajou Univ., Korea.* We investigated nonlinear characteristics and applications of WS_2 for mode-locked fiber laser. The saturable absorber was prepared by transferring the synthesized CVD WS_2 onto a fabricated side-polished fiber. WS_2 showed promising potential for ultrafast-pulse generation.

JW2A.75
Real-time and Ultrafast Phase Retrieval in Optical Time-stretch Using a Modified Gerchberg-Saxton Algorithm, Yiqing Xu[1], Zhibo Ren[1], Kenneth K. Y. Wong[1], Kevin K. Tsia[1]; [1]*The Univ. of Hong Kong, USA.* We report a new and practical scheme of using optical time-stretch with Gerchberg Saxton (GS)-like algorithm for ultrafast real-time phase retrieval, with the phase error significantly suppressed even at a wide signal bandwidth.

JW2A.76
$\chi^{(2)}$-Lens Mode-Locking of a Nd:YVO_4 Laser with High Average Power and Repetition Rate up to 600 MHz, Veselin S. Aleksandrov[1], Hristo Iliev[2], Ivan Buchvarov[1]; [1]*Sofia Univ. St. Kliment Ohridski, Bulgaria;* [2]*Binovation Ltd., Bulgaria.* We demonstrate $\chi^{(2)}$-lens mode-locking of a diode pumped Nd:YVO_4 laser. The output power is 6 W, the pulse duration is 6 ps for repetition rates from 110 MHz up to 600 MHz.

JW2A.77
Deviations from Theory by Femtosecond Lasers due to Noise, Gennady Rasskazov[1], Vadim Lozovoy[1], Marcos Dantus[1]; [1]*Michigan State Univ., USA.* We compare deviations from theory in the yield of second harmonic generation in order to characterize high-repetition rate femtosecond laser sources where the amplitude and phase differs from pulse to pulse. Experimental results are presented for cases with phase noise and a post-pulse.

JW2A.78
Vertically Stacked AllPolymer Whispering-Gallery Mode Lasers for Biosensing Applications, Sentayehu Fetene Wondimu[1], Tobias Siegle[3], Uwe Bog[1,4], Sarah Kraemmer[3], Heinz Kalt[3], Timo Mappes[1,2], Sebastian Koeber[1,5], Tobias Wienhold[1], Christian Koos[1,5]; [1]*Inst. of Microstructure Technology (IMT), Karlsruhe Inst. of Technology, Germany;* [2]*Corporate Research and Technology, Carl Zeiss AG, Germany;* [3]*Inst. of Applied Physics (APH), Karlsruhe Inst. of Technology, Germany;* [4]*Inst. of Nanotechnology (INT), Karlsruhe Inst. of Technology, Germany;* [5]*Inst. of Photonics and Quantum Electronics (IPQ), Karlsruhe Inst. of Technology, Germany.* We report on the fabrication of polymeric whispering-gallery mode (WGM) lasers. Our approach enables high packing density by vertical stacking and multiplexed readout of resonators and lends itself to signal referencing or multi-target sensing.

JW2A.79
Fiber Optical Tweezers for Simultaneous Force Exertion and Measurements in a 3D Hydrogel Compartment, Chaoyang Ti[1], Gawain M. Thomas[2], Qi Wen[2], Yuxiang Liu[1]; [1]*Mechanical Engineering Dept., Worcester Polytechnic Inst., USA;* [2]*Physics Dept., Worcester Polytechnic Inst., USA.* We developed an inclined dual fiber optical tweezers (DFOTs) for simultaneous force application and measurements in a 3D hydrogel matrix. The inclined DFOTs provide a potential solution for cell mechanics study in a three-dimensional matrix.

JW2A.80
Implementation of optical multiplicative spike-timing-dependent plasticity with adaptive current feedback of semiconductor optical amplifiers, Yaolin Zhang[1], Quansheng Ren[1], Jy Zhao[1]; [1]*Peking Univ., China.* We present the optical multiplicative spike-timing-dependent-plasticity (STDP) by adaptive control of current injection to the semiconductor optical amplifiers. As a result, we can mimic the behavior of biological STDP synapses more realistically.

JW2A.81
Resonantly-Enhanced Sensing Using Surface Plasmon Polaritons in a Sagnac Interferometer, Brian Hake[1], Herbert Grotewohl[1], Miriam Deutsch[1]; [1]*Univ. of Oregon, USA.* We present analysis of a resonantly enhanced Sagnac interferometer. While one output port is highly sensitive to nonreciprocal phenomena and robust to reciprocal fluctuations, the complementary output can be used to simultaneously monitor reciprocal drifts.

JW2A.82
60-MHz wavelength-encoded tomography (WET), Bowen Li[1], Chi Zhang[2], Sisi Tan[1], Xiaoming Wei[1], Yiqing Xu[1], Kevin K. Tsia[1], Kenneth K. Y. Wong[1]; [1]*The Univ. of Hong Kong, Hong Kong;* [2]*Huazhong Univ. of Science and Technology, China.* Wavelength-encoded tomography (WET) is upgraded to a triple-time-lens system to perform ultrafast cross-sectional imaging through 68.4x-temporal magnification. 60-MHz A-scan rate is demonstrated by imaging a glass sample with 180-μm axial resolution.

JW2A.83
Manipulation of Nanoparticles using Quadrangular Microlens, Yuzhi Shi[1,2], Lip Ket Chin[2], Jiuhui Wu[1], Tianning Chen[1], Ai-Qun LIU[2]; [1]*School of Mechanical Engineering, Xi'an Jiaotong Univ., China;* [2]*School of Electric and Electronic Engineering, Nanyang Technological Univ., Singapore.* We present an optical element, quadrangular microlens, for the generation of Bessel beam, bottle beams, slowly divergent self-healing beam and the discrete interference pattern. Thus, it can be used for the transporting, trapping, cooling, sorting and patterning of nanoparticles.

JW2A.84
Hologram Acquisition by Using Time Resolved Heterodyne Method in Optical Scanning Holography, Munseob Lee[1], Gihyeon Min[1], Nacwoo Kim[1], Byung-Tak Lee[1]; [1]*ETRI, Korea.* We propose the new hologram acquisition method based on the time resolved heterodyne analysis in optical scanning holography. By applying the FFT or four phase picking algorithm method, we obtain complex hologram without reference signal.

JW2A.85
Hybrid Mid-IR OCT System for Imaging and Spectroscopy Using New High Power Low-Coherence Quantum Cascade Superluminescent Emitters, Deborah Varnell[1], Mei Chai Zheng[1], Nyan L. Aung[1], Ahmed Musse[1], Samantha Lee[1], Claire F. Gmachl[1]; [1]*Princeton Univ., USA.* We have successfully constructed and tested a new mid-infrared optical coherence tomography imaging system capable of simultaneous imaging and spatial spectroscopy using new quantum cascade superluminescent emitters.

10:00–12:00
JW2A • Poster Session II

JW2A.86
Ellipsometry-based opto-fluidic platform for characterizing 10,000 biomolecular reactions on solid supports in real time and for identifying inhibitors against specific protein-receptor interactions, Xiangdong Zhu[1]; *[1]Univ. of California at Davis, USA.* We developed an optical detection platform based on nulling ellipsometry for simultaneously characterizing 10,000 biomolecular reactions on solid supports and for highly efficient identification of inhibitory molecules against specific protein-protein interactions from large compound libraries.

JW2A.87
Optical Measurement on Cell Membrane Roughness Influenced by Paclitaxel and Gold Nanoparticles, Chau-Hwang Lee[1,2], Lan-Lin Jang[1], Huei-Jyuan Pan[1]; *[1]Research Center for Applied Sciences, Academia Sinica, Taiwan; [2]Inst. of Biophotonics, National Yang-Ming Univ., Taiwan.* We measured the membrane roughness of neuroblastoma cells under the treatments of gold nanoparticles and paclitaxel. The stabilization of microtubules by paclitaxel reduced the membrane roughness. The positive charges on nanoparticles led to similar results.

JW2A.88
Improvement in In-Plane Localization Precision of Nanoparticles Using Interference Analysis, Amihai Meiri[1], Carl Ebeling[1], Jason Martineau[1], Zeev Zalevsky[2], Jordan Gerton[1], Rajesh Menon[1]; *[1]Univ. of Utah, USA; [2]Bar Ilan Univ., Israel.* We present a method to improve the localization precision of nanoparticles over Gaussian fitting by imposing an interference pattern on the Point-Spread-Function. Localization precision of 0.1nm for a single emitter was obtained.

JW2A.89
Optofluidic Detection for Virus Infection Monitoring using Effective Refractive Index, Patricia Yang Liu[1,2], Lip Ket Chin[2], Wee Ser[2], Teck Choon Ayi[3], Eric Peng Huat Yap[3], Tarik Bourouina[1], Yamin Leprince-Wang[1]; *[1]Université Paris-Est, France; [2]Nanyany Technological Univ., Singapore; [3]DSO National Labs, Singapore.* This paper presents an optofluidic imaging system to detect influenza virus infection via the change of refractive index based on scattering signature. This method allows for a direct monitor of the influenza flu virus.

JW2A.90
Virtual Acousto-optic Beam Paths for Steerable Deep-tissue Optical Stimulation and Imaging, Maysamreza Chamanzar[1], Minyoung Huh[1], NINH DO[1], M. Reza Alam[1], Michel Maharbiz[1]; *[1]Univ. of California Berkeley, USA.* Here we present the first non-invasive methodology for optical delivery and steering deep inside the brain through creating reconfigurable light paths by ultrasonic waves via modulating the refractive and diffractive properties of the medium.

JW2A.91
Ce-doped Fibers with High Axial Resolution for Optical Coherence Tomography Applications, Liu Chun-Nien[1], Yi-Chung Huang[2], Pi-Ling Huang[1], Sheng-Lung Huang[3], Wood-Hi Cheng[1]; *[1]Dept. of Photonics, National Sun Yat-Sen Univ., Taiwan; [2]CEO office, Brogent Technologies Inc., Taiwan; [3]Graduate Inst. of Photonics and Optoelectronics, National Taiwan Univ., Taiwan.* The fabrication of CeDFs with drawing-tower is demonstrated. The CeDFs exhibited a 160-nm broadband emission with 1.47-μm axial resolution. This CeDF may be functioned as a high- resolution light source for OCT applications.

JW2A.92
Noninvasive flow cytometry by heterodyne self-mixing interferometry, Olivier Hugon[1], Mehdi Inglebert[1], Olivier Jacquin[1], Hugues Guillet de Chatellus[1], Eric Lacot[1], Chaouqi Misbah[1], Boudewijn Van Der Sanden[2]; *[1]LIPhy, France; [2]Clinatec, France.* We present a device for characterizing red blood cells flows in capillaries (speed, hematocrit, aggregation, …) . We've used the LOFI technique on a microfluidic system that mimics the human skin and subcutaneous tissues.

JW2A.93
All-Fiber Tunable Ring Laser Based on an Acousto-Optic Tunable Coupler, Ligang Huang[1], Wending Zhang[2], Dong Mao[2], Feng Gao[1], Weihua Peng[1], Fang Bo[1], Guoquan Zhang[1], Jingjun Xu[1]; *[1]Nankai Univ., China, China; [2]Northwestern Polytechnical Univ., China.* An all-fiber tunable ring laser consisted of an acousto-optic tunable notch filter and a tapered fiber was demonstrated with a tunable wavelength range from 1532.1 nm to 1570.4 nm and a linewidth of 0.2 nm.

JW2A.94
Supercontinuum Generated by Noise-like Pulses for Spectral-domain Optical Coherence Tomography, Yi-Jing You[1], Chengming Wang[2], Ping Xue[2], Alexey Zaytsev[3], Ci-Ling Pan[1,3]; *[1]Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan; [2]State Key Lab of Low-dimensional Quantum Physics, Dept. of Physics, Tsinghua Univ., China; [3]Dept. of Physics, National Tsing Hua Univ., Taiwan.* A supercontinuum with over 420-nm of spectral bandwidth is generated in a single-mode-fiber pumped by noise-like-pulses from an Yb-doped fiber laser. The supercontinuum source is successfully employed in a spectral-domain optical coherence tomography imaging system.

JW2A.95
Annular Cladding Erbium-Doped Multi-Core Fiber for SDM Amplification, Cang Jin[1,2], Bora Ung[3], Younès Messaddeq[4,2], Sophie LaRochelle[1,2]; *[1]Département de Génie Électrique et de Génie Informatique, Université Laval, Canada; [2]Centre D'optique, Photonique et Laser, Canada; [3]Département de Génie Électrique, École De Technologie Supérieure, Canada; [4]Département de Physique, De Génie Physique et D'optique, Université Laval, Canada.* An annular cladding ED-MCF is proposed to enhance pump power efficiency. Simulations suggest single core amplification with over 29 dB gain and less than 7.5 dB at 1550 nm using a single Watt-level pump.

JW2A.96
Transition Profile Control for Broadband Visible Supercontinuum Generation in Tapered PCF, Tongxiao Jiang[1], Aimin wang[1], Fuzeng Niu[1], Wei Zhang[1], Yawei Chang[1], Zhigang Zhang[1]; *[1]Peking Univ., China.* Tapered photonic crystal fibers with different transition profiles were designed and fabricated to control the visible dispersive wave generation process, and broadband visible supercontinuum (350-700 nm) was achieved.

JW2A.97
Design of Supermode Fiber for Orbital Angular Momentum (OAM) Multiplexing, Shuhui Li[1], Jian Wang[1]; *[1]Wuhan National Lab for Optoelectronics, China.* We present a supermode fiber to support orbital angular momentum (OAM) multiplexing. The designed supermode fiber can guide multiple OAM modes with favorable performance of low mode coupling, low nonlinearity, and low modal dependent loss.

JW2A.98
Widely tunable Raman laser in a tellurite fiber ring cavity, Dinghuan Deng[1], Lai Liu[1], Tonglei Cheng[1], Xiaojie Xue[1], Lei Zhang[1], Makoto Yamada[2], Takenobu Suzuki[1], Yasutake Ohishi[1]; *[1]Toyota Technological Inst., Japan; [2]Osaka Prefecture Univ., Japan.* A widely tunable Raman laser covering a 170-nm bandwidth was demonstrated using a single-mode tellurite fiber embedded in a ring cavity.

JW2A.99
Small signal gain for Nd/Cr:YAG ceramics at high temperature, Yoshiyuki Honda[1], Shinji Motokoshi[2], Takahisa Jitsuno[1], Noriaki Miyanaga[1], Kana Fujioka[1], Masahiro Nakatsuka[2], Minoru Yoshida[3]; *[1]Osaka Univ., Japan; [2]Inst. for Laser Technology, Japan; [3]Kinki Univ., Japan.* The gain coefficient of the Nd/Cr:YAG ceramics excited by the absorption line of Cr^{3+} increased with increasing temperature up to 400 K.

JW2A.100
Simulated Tempering Markov Chain Monte Carlo for Full Waveform Analysis, Weiji He[1], Wenye Yin[1], Feng Shi[2], Guohua Gu[1], Qian Chen[1]; *[1]Nanjing Univ of Science and Technology, China; [2]Science & Technology on Low-light-level Night Vision Lab, China.* A new approach of Simulated Tempering Markov Chain Monte Carlo(STMCMC) for full waveform LIDAR signal analysis was proposed and demonstrated. We present the theory, algorithm as well as the practical examples.

JW2A.101
Withdrawn

JW2A.102
Hybrid White Light-emitting Diodes by Organic-Inorganic materials, Kuo-Ju Chen[1], Yi-Chun Lai[1], Bin-Cheng Lin[1], Chien-Chung Lin[1], Sheng-Huan Chiu[1], Zong-Yi Tu[1], Min-Hsiung Shih[2], Peichen Yu[1], Po-Tsung Lee[1], Xiuling Li[3], Hsin-Fei Meng[1], Gou-chung Chi[1], Teng-Ming Chen[1], Hao-Chung Kuo[1]; *[1]National Chiao Tung Univ., Taiwan; [2]Research Center for Applied Sciences, Taiwan; [3]Dept. of Electrical and Computer Engineering, Univ. of Illinois at Urbana-Champaign Urbana, USA.* This study demonstrated the high uniformity hybrid white light-emitting didoes with polyfluoren (PFO) polymer and quantum dot (QD) with different CCT range from 3000K to 9000K.

JW2A.103
Flat-Plate Photovoltaics with Solar-Tracking Origami Micro-Concentrator Arrays, Chih-Wei Chien[1], Kyusang Lee[1], Matthew Shlian[2], Stephen Forrest[1], Max Shtein[3], Pei-Cheng Ku[1]; *[1]Dept. of Electrical Engineering and Computer Science, Univ. of Michigan, USA; [2]School of Art and Design, Univ. of Michigan, USA; [3]Dept. of Materials Science and Engineering, Univ. of Michigan, USA.* A new PV architecture combining the advantages of concentration and flat-plate PVs is shown. Using origami techniques, fabrication and solar tracking of micro-concentrators were achieved with minimally added complexity to the existing flat-plate PVs.

JW2A.104
Application of Fractional Fourier Transform for Interferometry, Ming-Feng Lu[1], Feng Zhang[1], Ran Tao[1], Guo-Qiang Ni[1], Ting-Zhu Bai[1]; *[1]Beijing Inst. of Technology, China.* The Fractional Fourier transform can be understood as a chirp-based decomposition. Accordingly it can be used to process fringe patterns with quadratic phase, including denoising, quantization error reduction, sampling and reconstruction, and phase derivative estimation.

10:30–12:30 Market Focus: Precision Manufacturing Using Ultrafast Lasers, *Exhibit Hall Theater*

12:00–13:00 Lunch and Unopposed Exhibit Only Time, *Exhibit Halls 1 & 2 (concessions available)*

12:30–13:30 VIP Industry Leaders Networking Event, *Exhibit Hall 3*
(lunch provided, registration required)

12:30–15:30 OSA Members, Family and Friends Event
(Visit the OSA booth to register, as registration is required)

NOTES

CLEO: QELS-Fundamental Science

13:00–15:00
FW3A • Symposium on Cavity Quantum Electrodynamics II
Presider: Pascale Senellart; CNRS-Laboratoire de Photonique et Nanost, France

FW3A.1 • 13:00 Invited
Cavity-QED with a Trapped Ion in an Optical Fiber Cavity, Michael Köhl[1]; [1]*Universitat Bonn, Germany.* We report on cavity-QED experiments with trapped ions in fiber-based high-finesse optical cavities. We observe single photon emission and absorption and, in particular, demonstrate coupling to a semiconductor quantum dot by exchange of a single photon between the atomic and solid state quantum emitters.

FW3A.2 • 13:30
Fiber-Based Cavities for Ion-Trap Quantum Networks, Tracy Northup[1], Klemens Schüppert[1], Florian Ong[1], Bernardo Casabone[1], Konstantin Friebe[1], Moonjoo Lee[1], Jakob Reichel[2], Rainer Blatt[1,3]; [1]*Univ. of Innsbruck, Austria;* [2]*ENS/UPMC-Paris 6/CNRS, France;* [3]*Inst. for Quantum Optics and Quantum Information, Austria.* Fiber-based cavities offer a promising route toward the strong-coupling regime of cavity QED. I will discuss the development of a fiber-cavity experiment for single trapped calcium ions, focusing on mirror characterization and quantum-network prospects.

FW3A.3 • 13:45
Nanophotonic Quantum Memory Based on Rare-Earth-Ions Coupled to an Optical Resonator, Tian Zhong[1], Jonathan Kindem[1], Evan Miyazono[1], Andrei Faraon[1]; [1]*California Inst. of Technology, USA.* We demonstrate optical photon storage in a Nd:YSO nano-resonator using multi-mode stimulated photon echo and atomic frequency comb protocols. Current results indicate strong prospects for on-chip nanophotonic quantum memories using rare-earth-ions.

13:00–15:00
FW3B • Novel Approach for Studying Condensed Matter
Presider: Giacomo Coslovich; Lawrence Berkeley National Lab, USA

FW3B.1 • 13:00 Invited
Attosecond Sources for Time-Bandwidth Balanced Spectroscopy, Alberto Simoncig[1], Sebastian Schulz[1], Ivanka Grguras[3], Sasa Bajt[2], Adrian L. Cavalieri[1,3]; [1]*MPI-Structure and Dynamics of Matter, Germany;* [2]*DESY, Germany;* [3]*Univ. of Hamburg, Germany.* Spectral bandwidth in attosecond pulses can span multiple energy levels simultaneously, complicating time-resolved photoemission applications. We seek to adapt attosecond sources to study condensed-matter dynamics with sub-eV resolution, unfolding on the corresponding femtosecond timescale.

FW3B.2 • 13:30
Experimental Distinction between Femtosecond Transient Demagnetization and Spin Current Dynamics in Metals, Zuanming Jin[1], Jacek Arabski[2], Guy Schmerber[2], Eric Beaurepaire[2], Mischa Bonn[1], Dmitry Turchinovich[1]; [1]*MPI for Polymer Research, Germany;* [2]*Institut de Physique et Chimie des Matériaux de Strasbourg (IPCMS), UMR 7504 CNRS - Université de Strasbourg, France.* Using terahertz emission spectroscopy we probe the elementary spin dynamics in ferromagnetic metal on a femtosecond timescale, and distinguish between the two major contributions - transient demagnetization and spin current by hot electrons.

FW3B.3 • 13:45
Ultrafast Pump-probe Spectroscopy in Gallium Arsenide at 25 Tesla , Jeremy Curtis[1], Takahisa Tokumoto[1], Nicholas Nolan[1], Luke McClintock[1], Judy Cherian[2], Stephen McGill[2], David J. Hilton[1]; [1]*Univ. of Alabama at Birmingham, USA;* [2]*National High Magnetic Field Lab, USA.* We have conducted pump-probe spectroscopy of bulk GaAs in the Split Florida- Helix at 15 K and 25 T. We observe an electronic rise followed by a slower decay with a superimposed oscillatory response.

13:00–15:00
FW3C • Optics of Complex Media II
Presider: Hui Cao; Yale Univ., USA

FW3C.1 • 13:00 Invited
Spatial Coherence of Random Raman Lasing Emission, Brett H. Hokr[1,2], Morgan Schmidt[3], Joel Bixler[1,3], Phillip Dyer[2], Gary Noojin[2], Brandon Redding[4], Robert Thomas[3], Benjamin Rockwell[3], Hui Cao[4], Vladislav Yakovlev[1], Marlan Scully[1,5]; [1]*Texas A&M Univ., USA;* [2]*TASC Inc., USA;* [3]*Bioeffects Division, Optical Radiation Branch, 711th Human Performance Wing, Human Effectiveness Directorate, USA;* [4]*Yale Univ., USA;* [5]*Baylor Univ., USA.* Random Raman laser emission is demonstrated to be an excellent source of narrow-band, high intensity, short duration light for speckle-free imaging. Spatial coherence measurement and strobe photography of cavitation bubbles are presented.

FW3C.2 • 13:30
Critical States Embedded in the Continuum, Milan Koirala[1], Alexey G. Yamilov[1], Ali Basiri[3], Yaron Bromberg[2], Hui Cao[2], Tsampikos Kottos[3]; [1]*Physics, Missouri Univ. of Science and Technology, USA;* [2]*Applied Physics, Yale Univ., USA;* [3]*Physics, Wesleyan Univ., USA.* We introduce a class of critical states which are embedded in the continuum (CSC) of one-dimensional optical waveguide array with a non-Hermitian defect.

FW3C.3 • 13:45
Quantitative test of the ab initio intrinsic laser linewidth theory, Alexander Cerjan[1], Adi Pick[2], Yidong Chong[3], Alejandro Rodriguez[4], Steven Johnson[5], A. Douglas Stone[1]; [1]*Yale Univ., USA;* [2]*Physics, Harvard Univ., USA;* [3]*Division of Physics and Applied Physics, Nanyang Technological Univ., Singapore;* [4]*Applied Physics, Princeton, USA;* [5]*Applied Math, MIT, USA.* Direct FDTD simulations of the Maxwell-Bloch equations coupled to Langevin noise equations are shown to quantitatively agree with a recent analytic linewidth formula and predicted scaling relations.

13:00–15:00
FW3D • New Effects in Nanostructures and Semiconductors
Presider: Dragomir Neshev; Australian National Univ., Australia

FW3D.1 • 13:00 Invited
Nonlinear Effects Driven by Optically-induced Magnetic Response, Yuri S. Kivshar[1]; [1]*Australian National Univ., Australia.* We discuss novel nonlinear effects in nanostructured metasurfaces driven by optically-induced electric and magnetic responses associated with Mie-type resonances of their metallic and dielectric structural elements including the generation of multipole harmonics and substantial power enhancement.

FW3D.2 • 13:30
Studying the Interplay of Electric and Magnetic Resonance-Enhanced Second Harmonic Generation: Theory and Experiments, Rohith Chandrasekar[1], Naresh K. Emani[1], Alexei Lagutchev[1], Vladimir M. Shalaev[1], Cristian Ciraci[2,3], David R. Smith[2], Alexander V. Kildishev[1]; [1]*Electrical and Computer Engineering, Purdue Univ., USA;* [2]*Electrical and Computer Engineering, Duke Univ., USA;* [3]*Center for Biomolecular Nanotechnologies, Istituto Italiano di Tecnologia, Italy.* We present an experimental study of a metasurface, which exhibits electric and magnetic resonances, in order to understand their independent contributions to second-harmonic generation. A hydrodynamic model framework is used to match experimental results.

FW3D.3 • 13:45
Semiconductor-Superconductor Two-Photon Amplifier, Raja Marjieh[1], Evyatar Sabag[1], Alex Hayat[1]; [1]*Technion, Israel.* We study a new effect of Cooper-pair-based two-photon gain in semiconductor-superconductor structures, showing broadband enhancement of singly- and fully-stimulated ultrafast two-photon gain. These effects can have important implications in optoelectronics and in coherent-control applications.

CLEO: QELS-Fundamental Science

13:00–15:00
FW3E • Active Plasmonics and Nanolasers
Presider: Jie Yao; Berkeley Univ., USA

FW3E.1 • 13:00
Quantum-Coherently Assisted Deep-UV Localization of Photonic States in Active Stopped-Light Plasmonic Heterostructures, Kosmas Tsakmakidis[1], Pankaj K. Jha[1], Yuan Wang[1], Xiang Zhang[1]; *[1]UC Berkeley, USA.* We introduce a new method to localize light-waves. We show how the interaction of a gain medium with a planar deep-UV plasmonic heterostructure, at its zero-v_g point, *strongly* localizes light. A quantum-coherent drive provides a means to control the localization and dramatically improve the dynamics.

FW3E.2 • 13:15
Optical Switching of Mid-Infrared Plasmonic Nanoantennas Based on Germanium, Marco Patrick Fischer[1], Christian Schmidt[1], Johannes Stock[1], Emilie Sakat[2], Antonio Samarelli[3], Jacopo Frigerio[4], Paolo Biagioni[2], Douglas J. Paul[3], Giovanni Isella[4], Alfred Leitenstorfer[1], Daniele Brida[1]; *[1]Dept. of Physics and Center for Applied Photonics, Universität Konstanz, Germany; [2]Dipartimento di Fisica, Politecnico di Milano, Italy; [3]School of Engineering, Univ. of Glasgow, UK; [4]L-NESS, Dipartimento di Fisica, Politecnico di Milano, Italy.* Germanium nanoantennas are activated by triggering a mid-infrared plasma response via ultrafast interband excitation. Femtosecond control of the intrinsic semiconductor allows complete activation of the plasmonic resonance for hundreds of picoseconds.

FW3E.3 • 13:30
Enhanced Near- and Far-Field Faraday Rotation with a Monolayer Array of Core-Shell Nanoparticles, Arthur Davoyan[1], Nader Engheta[1]; *[1]Univ. of Pennsylvania, USA.* We study Faraday rotation by magnetized core-shell nanoparticles. We theoretically show enhanced polarization rotation in the near-zone and several-fold increase of the Faraday effect in the far-zone for a periodic array of nanoparticles.

FW3E.4 • 13:45
Plasmon-mediated emission in the strong coupling regime, Thejaswi Tumkur[1], Guohua Zhu[1], Devon Courtwright[1], Mikhail A. Noginov[1]; *[1]Norfolk State Univ., USA.* We demonstrate the strong coupling of SPPs and localized plasmons to dye molecules, characterized by splitting of the dispersion curve. We further observe an anomalous behavior in the emission of molecules strongly coupled to plasmons.

CLEO: Science & Innovations

13:00–15:00
SW3F • III-V Lasers on Silicon
Presider: John Bowers; Univ. of California Santa Barbara, USA

SW3F.1 • 13:00
Electrically Pumped 1.3-μm InAs/GaAs Quantum Dot Laser Monolithically Grown on Si Substrate Lasing up to 111°C, Siming chen[1], Mingchu Tang[1], Qi Jiang[1], Jiang Wu[1], Vitaliy Dorogan[2], Mourad Benamara[2], Yuriy Mazur[2], Gregory Salamo[2], Alwyn Seeds[1], Huiyun Liu[1]; *[1]Univ. College London, UK; [2]Univ. of Arkansas, USA.* A silicon-based InAs/GaAs quantum dot laser that lases up to 111°C, with a threshold current density of 200 A/cm^2 and an output power exceeding 100 mW at room temperature, has been achieved.

SW3F.2 • 13:15
Hybrid III-V/SOI single-mode vertical-cavity laser with in-plane emission into a silicon waveguide, Gyeong C. Park[1], Weiqi Xue[1], Elizaveta Semenova[1], Jesper Mork[1], Il-Sug Chung[1]; *[1]Technical Univ. of Denmark, Denmark.* We report a III-V-on-SOI vertical-cavity laser emitting into an in-plane Si waveguide fabricated by using CMOS-compatible processes. The fabricated laser operates at 1.54 mm with a SMSR of 33 dB and a low threshold.

SW3F.3 • 13:30
Ultra-compact Wavelength Tunable Quantum Dot Laser with Silicon Photonic External Cavity, Tomohiro Kita[1], Naokatsu Yamamoto[2], Tetsuya Kawanishi[2], Hirohito Yamada[1]; *[1]Tohoku Univ., USA; [2]National Inst. of Information and Communications Technology, Japan.* Ultra-compact wavelength tunable laser diode with wide tunability was successfully developed with combining quantum dot optical amplifier and silicon micro-ring filters. The single mode laser oscillation was demonstrated with 25 nm wavelength tuning range.

SW3F.4 • 13:45
1.3-μm InAs/GaAs Quantum Dot Lasers on Silicon-on-Insulator Substrates by Metal-Stripe Bonding, Yuan-Hsuan Jhang[1], Katsuaki Tanabe[2], Satoshi Iwamoto[1,2], Yasuhiko Arakawa[1,2]; *[1]Inst. of Industrial Science, Univ. of Tokyo, Japan; [2]Inst. for Nano Quantum Information Electronics, Univ. of Tokyo, Japan.* We demonstrate InAs/GaAs quantum dot lasers on silicon-on-insulator substrates by metal-stripe wafer bonding technology. Our III-V-on-Si bonded laser exhibits room-temperature lasing at 1.3 μm with current injection through the bonding metal stripe.

13:00–15:00
SW3G • Precision Spectroscopy
Presider: R. Jason Jones; Univ. of Arizona, USA

SW3G.1 • 13:00
Dual-Comb Femtosecond Enhancement Cavity for Precision Measurements of Plasma Dynamics and Spectroscopy in the XUV, David R. Carlson[1], Tsung-Han Wu[1], R. Jason Jones[1]; *[1]Univ. of Arizona, USA.* We show two high power 100 fs frequency combs can be coupled to the same enhancement cavity for performing time-resolved measurements of optical nonlinearities and for simplifying dual-comb spectroscopy in the XUV.

SW3G.2 • 13:15
Broadband Dual-comb Spectroscopy with Cascaded-electro-optic-modulator-based Frequency Combs, Tadashi Nishikawa[1], Atushi Ishizawa[2], Ming Yan[1,3], HIdeki Gotoh[2], Theodor Hänsch[1,3], Nathalie Picqué[1,3]; *[1]Max-Planck-Institut für Quantenoptik, Germany; [2]NTT Basic Research Labs, Japan; [3]Ludwig-Maximilians-Universität München, Germany.* Dual-comb spectroscopy without mode-locked lasers is demonstrated in the telecommunication region. As a proof-of-principle, we measure Doppler-limited rovibrational spectra of the $2v_3$ band of $H^{13}C^{14}N$ spanning more than 4 THz with resolved comb lines.

SW3G.3 • 13:30 Invited
Ramsey-comb Spectroscopy: Power and Precision Combined, Robert K. Altmann[1], Laura S. Dreissen[1], Sandrine A. Galtier[1], Kjeld S. Eikema[1]; *[1]LaserLaB, VU Univ. (FEW), Netherlands.* Ramsey-comb spectroscopy enables ultra-high precision spectroscopy with amplified pairs of high-power frequency comb laser pulses, and we extended it to the deep-UV for precision spectroscopy in krypton and molecular hydrogen.

CLEO: Applications & Technology

13:00–15:00
AW3H • A&T Topical Review on Advances in Molecular Imaging I
Presider: Melissa Skala; Vanderbilt Univ., USA

AW3H.1 • 13:00 Invited
Label-Free Optical Molecular Imaging for Clinical Tissue Diagnostics, Mary-Ann Mycek[1]; *[1]Univ. of Michigan, USA.* Label-free nonlinear optical molecular imaging methods could enable the rapid, reliable, and non-invasive assessment of living tissue-engineered constructs, potentially addressing a critical regulatory requirement in tissue engineering and regenerative medicine.

AW3H.2 • 13:30 Invited
Wide-Field Lifetime-Based Förster Resonance Energy Transfer in Live Animals, Xavier Intes[1]; *[1]Biomedical Engineering, Rensselaer Ploytechnic Inst., USA.* A new whole-body Fluorescence Molecular Tomography approach based on wide-field time-resolved structured illumination will be presented. Current instrumental, theoretical and experimental efforts will be summarized as well as its application to image FRET *in vivo*.

CLEO: Science & Innovations

13:00–15:00
SW3I • Metamaterials & Metasurfaces
Presider: Ilya Goykhman; Hebrew University of Jerusalem, Israel

SW3I.1 • 13:00 Tutorial
Nanophotonics based on Metasurfaces, Federico Capasso[1]; [1]*School of Engineering and Applied Sciences, Harvard Univ., USA.* Metasurfaces enable new phenomena that are distinctly different from those observed in 3D metamaterials, providing us with unique capabilities to fully control wavefront and surface wave propagation with planar elements and thus realize "flat photonics".

Federico Capasso is Professor of Applied Physics at Harvard, following 27 years at Bell Labs. His contributions include bandstructure engineering and the quantum cascade laser; the first measurement of the repulsive Casimir force; the generalized Snell laws for metasurfaces and their applications to flat photonics. He is a member of NAE, NAS and received the King Faisal Prize, the APS Schawlow Prize and the IEEE Edison Medal.

CLEO: Applications & Technology

13:00–15:00
AW3J • Symposium on Photonics in Surgery I
Presider: Nicusor Iftimia; Physical Sciences Inc., USA

AW3J.1 • 13:00 Invited
Molecular Guided Surgery - Quantitative Immunologic Guidance with Optical Imaging, Brian W. Pogue[2,1]; [1]*Wellman Center for Photomedicine, Massachusetts General Hospital, USA;* [2]*Thayer School of Engineering, Dartmouth College, USA.* Molecular guided surgery is just now reaching substantial clinical trials stage, with multiple imaging systems, and a groundswell of GMP fluorescent molecular probes. Quantifying receptor expression is one potential way to guide cancer surgery.

AW3J.2 • 13:30 Invited
Clinical Potential of Light-Activated Tissue Crosslinking, Robert Redmond[2,1], Irene E. Kochevar[2,1], Michael C. McCormack[3,1], William G. Austen[3,1]; [1]*Harvard Medical School, USA;* [2]*Wellman Center for Photomedicine, Massachusetts General Hospital, USA;* [3]*Surgery, Massachusetts General Hospital, USA.* Photocrosslinking can alter biomechanical and biological properties of tissue and close surgical wounds. This contribution focuses on potential clinical applications in vascular surgery and plastic surgery.

13:00–15:00
AW3K • A&T Topical Review on Optofluidics Microsystems I
Presider: Ai-Qun Liu; Nanyang Technological Univ., Singapore

AW3K.1 • 13:00 Invited
Fluid Coupled Optomechanical Oscillators, Hong Tang[1]; [1]*Yale Univ., USA.* We demonstrate an optomechanical resonator operating in transparency window of water with optical Q beyond 1.5 million, which allows the detection of mechanical motion at 15am/rtHz resolution with attogram mass sensitivity in liquid environment.

AW3K.2 • 13:30
Surface Sensitive Microfluidic Optomechanical Ring Resonator Sensors, Kyu Hyun Kim[1], Xudong Fan[1]; [1]*Univ. of Michigan, USA.* Sensitivity of the optomechanical resonator to the surface mass change is demonstrated to be 1.2 Hz per pg/mm^2 by gradually removing SiO_2 molecules from the resonator surface. A detection limit of 83 pg/mm^2 is achieved.

AW3K.3 • 13:45
Single Molecule Detection with an Optomechanical Nanosensor, Wenyan Yu[1], Wei Jiang[3], Qiang Lin[3,2], Tao Lu[1]; [1]*Univ. of Victoria, Canada;* [2]*Electrical and Computer Engineering, Univ. of Rochester, USA;* [3]*Inst. of Optics, Univ. of Rochester, USA.* We report 50-milli-Hertz-linewidth optomechanical oscillation of a silica microsphere immersed in a buffer solution. Using the microsphere as a nanosensor, single 10-nm-radius silica beads and Bovine serum albumin (BSA) protein molecules were detected.

CLEO: Science & Innovations

13:00–15:00
SW3L • Nonlinear Effects in Waveguides
Presider: Peter Dragic; Univ. of Illinois at Urbana-Champaign, USA

SW3L.1 • 13:00 Tutorial
New Directions for Chip-based Nonlinear Optics, Benjamin J. Eggleton[1]; [1]*Univ. of Sydney, Australia.* I review recent progress in chip-based nonlinear optics with a focus on emerging applications in quantum information processing, microwave photonics and midinfrared photonics.

Benjamin Eggleton is an ARC Laureate Fellow and Professor of Physics at the Univ. of Sydney and Director of the ARC Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS). He obtained his Ph.D. degree in Physics from the Univ. of Sydney. Eggleton joined Bell Laboratories, Lucent Technologies as a Postdoctoral Member of Staff after graduation and was promoted to Research Director within the Specialty Fiber Business Division of Bell Laboratories. Eggleton has published more than 390 journal publications and over 150 invited presentations. He is a Fellow of the OSA and IEEE. He was President of the Australian Optical Society and is currently Editor-in-Chief for Optics Communications.

CLEO: Science & Innovations

13:00–15:00
SW3M • Space-Division Multiplexing
Presider: Nicolas Fontaine; Alcatel-Lucent Bell Labs, USA

SW3M.1 • 13:00
Microwave Photonics Mixer based on Polarization Rotation in Semiconductor Optical Amplifier, Qi Zhou[1], Mable P. Fok[1]; [1]*Univ. of Georgia, USA*. A wideband microwave photonics mixer is experimentally demonstrated based on the use of phase coherent orthogonal carriers, generated from single sideband modulation in dual drive Mach-Zehnder modulator and polarization-rotation in semiconductor optical amplifier.

SW3M.2 • 13:15
Photonically-Enabled Phase Shift Keying of 50 GHz Bandwidth Radio-Frequency Arbitrary Waveforms, Amir Rashidinejad[1], Daniel E. Leaird[1], Andrew M. Weiner[1]; [1]*Purdue Univ., USA*. We experimentally realize phase shift keying of ultrabroadband radio-frequency arbitrary waveforms. BPSK, QPSK and 16-PSK modulation are demonstrated for 50-GHz-bandwidth spread spectrum RF waveforms.

SW3M.3 • 13:30
Dispersion Compensation Scheme for Ultra-Wideband Coherent Matched Detection, Takahide Sakamoto[1]; [1]*National Inst. of Information and Communications Technology, Japan*. We propose and investigate a digital processing technique for dispersion compensation in coherent matched detectors, by which ultra-wideband multi-carrier signals beyond electrical bandwidth are orthogonally demultiplexed and demodulated, fully electrically dispersion compensated.

SW3M.4 • 13:45
Widely Tunable Optoelectronic Oscillator Utilizing an Optical Notch Filter Based on the Deamplification of Stimulated Brillouin Scattering, Huanfa Peng[1], Yongchi Xu[1], Cheng Zhang[1], Peng Guo[1], Lixin Zhu[1], Weiwei Hu[1], Zhangyuan Chen[1]; [1]*Peking Univ., China*. A novel tunable optoelectronic oscillator utilizing an optical notch filter based on stimulated Brillouin scattering is demonstrated. Tunable 3.36 to 31.4 GHz signals with phase noise of -120 dBc/Hz at 10 kHz offset are obtained.

13:00–15:00
SW3N • Integrated Optical Modulators
Presider: Mark Foster; Johns Hopkins Univ., USA

SW3N.1 • 13:00
High-speed Energy-efficient Silicon-polymer Hybrid Integrated Slot Photonic Crystal Waveguide Modulator, Xingyu Zhang[1], Amir Hosseini[2], Harish subbaraman[2], Jingdong Luo[3], Alex K. Jen[3], Chi-jui Chung[1], Robert Nelson[4], Ray T. Chen[1]; [1]*Univ. of Texas at Austin, USA;* [2]*Omega Optics, Inc., USA;* [3]*Univ. of Washington, USA;* [4]*Air Force Research Lab at Wright Patterson, USA*. We present a high-performance silicon-polymer hybrid integrated slot photonic crystal waveguide modulator. A record-high effective in-device r_{33} of 1230pm/V, $V_\pi \times L$ of 0.282V×mm, 3-dB bandwidth of 15GHz, and energy consumption of 94.4fJ/bit are experimentally demonstrated.

SW3N.2 • 13:15
WDM Transmitter Using Si Photonic Crystal Optical Modulators, Hiroyuki Ito[1], Yosuke Terada[1], Norihiro Ishikura[1], Toshihiko Baba[1]; [1]*Yokohama National Univ., Japan*. We fabricated a WDM transmitter consisting of Si photonic crystal MZ modulators, triangular-shaped coupled-microring multiplexers and optical switches. 25 Gbps/ch operation and hitless switching of channel wavelength were successfully obtained.

SW3N.3 • 13:30
A 41 GHz Slow-Wave Series Push-Pull Silicon Photonic Modulator, David Patel[1], Venkat Veerasubramanian[1], Alireza Samani[1], Samir Ghosh[1], Mathieu Chagnon[1], Mohamed Osman[1], David Plant[1]; [1]*McGill Univ., Canada*. We present a silicon modulator with a measured E-O bandwidth of 41 GHz at -4 V bias. Open eye diagrams are visible up to 60 Gbps. With DSP, 112 Gbps PAM-4 transmission below FEC threshold is demonstrated.

SW3N.4 • 13:45
OOK and QPSK Operation with Wide Working Spectrum in 200-300 μm Si Photonic Crystal Slow Light Modulators, Yosuke Terada[1], Yosuke Hinakura[1], Keiko Hojo[1], Naoya Yazawa[1], Tomohiko Watanabe[1], Toshihiko Baba[1]; [1]*Yokohama National Univ., Japan*. 25 Gbps error-free operation and 16-nm working spectrum were obtained in 200-μm photonic crystal slow light MZ OOK modulators. QPSK modulation was also obtained in a 300-μm device (1.0 × 0.5 mm^2 footprint).

13:00–15:00
SW3O • Parametric Sources for Coherent Infrared Light Generation
Presider: Shekhar Guha; US Air Force Research Lab., USA

SW3O.1 • 13:00
First OPO Based on Orientation-Patterned Gallium Phosphide (OP-GaP), Peter G. Schunemann[1], Leonard A. Pomeranz[1], Daniel J. Magarrell[1]; [1]*BAE Systems Inc, USA*. Optical parametric oscillation was achieved for the first time in OP-GaP. Tm-fiber-pumped Ho:YAG (2090nm, 20W, 20kHz, 12ns) generated 350 mW signal (3.54-microns) plus idler (5.1-microns) from a 92.7-micron grating period crystal in a linear DRO.

SW3O.2 • 13:15
Multi-Milliwatt, Continuous-Wave, Mid-Infrared Source for the 6.4-7.5 μm Spectral Range Based on Orientation-Patterned GaAs, Kavita Devi[1], Peter G. Schunemann[2], Majid Ebrahim-Zadeh[1,3]; [1]*ICFO -The Inst. of Photonic Sciences, Spain;* [2]*BAE Systems, USA;* [3]*Institucio Catalana de Recerca i Estudis Avancats (ICREA), Spain*. We report a cw mid-infrared source based on OP-GaAs, tunable across 6460-7517nm, providing 51.1mW at 6790nm, with passive power stability of ~2.3% rms (>1 hour) and frequency stability of 1.8GHz (>1 minute), in high-beam quality.

SW3O.3 • 13:30 Invited
High Power and High Energy Infrared Parametric Sources, Espen Lippert[1]; [1]*Forsvarets Forskningsinstitutt, Norway*. We report on $ZnGeP_2$-based parametric sources pumped by holmium lasers which are resonantly pumped by thulium fiber lasers. Using this scheme, we have built one source with up to 22 W average power and another with more than 0.2 J pulse energy in the mid-infrared region.

CLEO: QELS-Fundamental Science

FW3A • Symposium on Cavity Quantum Electrodynamics II—Continued

FW3A.4 • 14:00
A Solid-State Spin-Photon Transistor, Shuo Sun[1], Hyochul Kim[1], Glenn S. Solomon[2,3], Edo Waks[1,3]; *[1]Inst. for Research in Electronics and Applied Physics, Univ. of Maryland, USA; [2]NIST, USA; [3]Joint Quantum Inst., Univ. of Maryland, USA.* We experimentally realize a solid-state spin-photon transistor using a quantum dot strongly coupled to a photonic crystal cavity. We are able to control the light polarization through manipulation of the quantum dot spin states.

FW3A.5 • 14:15
Nanoscale Optical Positioning of Single Quantum Dots for Efficient Quantum Photonic Devices, Luca Sapienza[1,3], Marcelo I. Davanco[1], Antonio Badolato[2], Kartik Srinivasan[1]; *[1]Center for Nanoscale Science and Technology, National Inst. of Standards and Technology, USA; [2]Dept. of Physics and Astronomy, Univ. of Rochester, USA; [3]School of Physics and Astronomy, Univ. of Southampton, UK.* We locate single quantum dots with nanoscale accuracy through photoluminescence imaging. This enables nanophotonic device fabrication with engineered light-matter coupling, enabling bright (48±5% extraction efficiency), Purcell-enhanced (≈3), on-demand single-photon emission with >99% purity.

FW3A.6 • 14:30 Invited
Exploring Cavity QED with Superconducting Circuits, Andreas Wallraff[1]; *[1]ETH Zurich, Switzerland.* Using modern micro and nanofabrication techniques we realize superconducting quantum electronic circuits based on which we probe fundamental quantum effects of microwave radiation and develop components for applications in quantum technology.

FW3B • Novel Approach for Studying Condensed Matter—Continued

FW3B.4 • 14:00
Dynamical Driving and Probing of Quantum Phase Transitions on the Nanoscale, Sven Doenges[1], Brian T. O'Callahan[1], Joanna M. Atkin[1], Omar Khatib[1], Markus B. Raschke[1]; *[1]Univ. of Colorado Boulder, USA.* We extended the characterization of photoinduced quantum phase transitions into the nanoscale. We demonstrate this for VO_2 by accessing spatial inhomogeneities in the insulator-to-metal transition due to local strain and defects.

FW3B.5 • 14:15
Ultrafast Dynamics of the Skyrmion and Conical Phases in Cu_2OSeO_3, Matt Langner[1], Sujoy Roy[1], S. Mishra[1], J.C.T. Lee[1], X. W. Shi[1], M. A. Hossain[1], Y.-D. Chuang[1], S. Seki[2,3], Y. Tokura[4,3], S. D. Kevan[1], R. W. Schoenlein[1]; *[1]Lawrence Berkeley National Lab, USA; [2]Center for Emergent Matter Science, RIKEN, Japan; [3]PRESTO, Japan Science and Technology Agency, Japan; [4]Univ. of Tokyo, Japan.* We study the skyrmion structure in Cu_2OSeO_3 using resonant x-ray spectroscopy. The skyrmion structure shows long range fluctuations of ferrimagnetic ordering, and above-gap optical excitation reduces the magnetic ordering on a 40 picosecond timescale.

FW3B.6 • 14:30
Ultrafast terahertz spectroscopy of the inverse giant piezoresistance effect in silicon nanomembranes, Jaeseok Kim[1], Houk Jang[1], Min-Seok Kim[4], Jeong Ho Cho[3,2], Jong-Hyun Ahn[1], Hyunyong Choi[1]; *[1]Yonsei Univ., Korea; [2]School of Chemical Engineering, Sungkyunkwan Univ., Korea; [3]SKKU Advanced Inst. of Nanotechnology (SAINT), Sungkyunkwan Univ., Korea; [4]Center for Mass Related Quantities, Korea Research Inst. of Standards and Science, Korea.* We observe the clear inverse piezoresistance effect in the silicon nanomembranes. Thickness-dependent optical-pump terahertz spectroscopy strongly corroborate that the effect originates from the carrier-concentration changes via charge carrier trapping into strain-induced defect states.

FW3B.7 • 14:45
Tailored Light-Matter Interaction through Epsilon-Near-Zero Modes, Salvatore Campione[2,1], Sheng Liu[2,1], Alexander Benz[2,1], John F. Klem[1], Michael B. Sinclair[1], Igal Brener[2,1]; *[1]Sandia National Labs, USA; [2]Center for Integrated Nanotechnologies, Sandia National Labs, USA.* We use epsilon-near-zero modes in semiconductor nanolayers to design a system whose spectral properties are controlled by their interaction with multi-dipole resonances. This design flexibility renders our platform attractive for efficient nonlinear composite materials.

FW3C • Optics of Complex Media II—Continued

FW3C.4 • 14:00
Opportunities for Imaging in Heavily Scattering Random Media with Spatial Intensity Correlations, Kevin J. Webb[1], Jason A. Newman[1]; *[1]Purdue Univ., USA.* We describe a method that allows imaging of objects moving within heavily scattering random media. This should prove valuable in biological imaging and other applications.

FW3C.5 • 14:15
Optical Detection and Imaging in Complex Media: How the Memory Effect Can Help Overcome Multiple Scattering, Amaury Badon[1], Dayan Li[1], Geoffroy Lerosey[1], Claude Boccara[1], Mathias Fink[1], Alexandre Aubry[1]; *[1]Institut Langevin, France.* We report on optical imaging through turbid media. Our approach is based on the measurement of a reflection matrix and a separation of the single scattering and multiple scattering contributions based on the memory effect.

FW3C.6 • 14:30
Device design using the steady-state ab initio laser theory, Alexander Cerjan[1], Brandon Redding[1], Hui Cao[1], A. Douglas Stone[1]; *[1]Yale Univ., USA.* We present a method for designing highly multimode lasers for use as effectively incoherent light sources in optical imaging techniques.

FW3C.7 • 14:45
Correlation effects in Anderson localization and light transport in a 2D photonic disorder, Julien Armijo[1], Martin Boguslawski[2], Raphael Allio[1,4], Laurent Sanchez-Palencia[3], Cornelia Denz[2]; *[1]Universidad de Chile, Chile; [2]Univ. of Muenster, Germany; [3]Laboratoire Charles Fabry, Institut d'Optique, France; [4]Univ. of Rennes I, France.* We study the propagation of tailored wave packets in a computer controlled photo-induced disorder. Disorder correlations cause in real space a ballistic front of exponential Anderson Localization, and novel effects are observed in Fourier space.

FW3D • New Effects in Nanostructures and Semiconductors—Continued

FW3D.4 • 14:00
Four-fold Enhancement of Transverse Optical Magnetism in Unstructured Solids, Ayan Chakrabarty[1], Alexander Fisher[1], Elizabeth F. Dreyer[1], Stephen C. Rand[1]; *[1]Univ. of Michigan, USA.* Scattering experiments on second-order induced magnetization in transparent Gadolinium Gallium Garnet (GGG) crystals show four times the maximum magnetic response measured previously in liquids.

FW3D.5 • 14:15
Ultrafast Magneto-Photocurrents in GaAs: Separation of Surface and Bulk Contributions, Christian B. Schmidt[1], Shekhar Priyadarshi[1], Mark Bieler[1]; *[1]Physikalisch-Technische Bundesanstalt, Germany.* We generate ultrafast magneto-photocurrents in bulk GaAs and non-invasively separate surface and bulk contributions to the overall current. This method enables the investigation of processes such as anisotropic-distribution relaxation and the inverse Spin Hall effect.

FW3D.6 • 14:30
Analysis of soliton fission induced by free-carriers, Chad A. Husko[1], Simon Lefrancois[1], Matthias Wulf[2], Sylvain Combrie[3], Alfredo De Rossi[3], Lorenz Kobus Kuipers[2], Benjamin J. Eggleton[1]; *[1]Univ. of Sydney, Australia; [2]FOM Inst. AMOLF, Netherlands; [3]Thales Research and Technology, France.* Previously we presented measurements of soliton fission induced by free-carriers. Here we report the derivation of a normalized free-carrier perturbation parameter to describe both those experiments and to extract more general properties of this mechanism.

FW3D.7 • 14:45
Beam Deflection Measurements of Nondegenerate Nonlinear Refractive Indices in Direct-gap Semiconductors, Peng Zhao[1], Matthew Reichert[1], Trenton Ensley[1], David J. Hagan[1], Eric W. Van Stryland[1]; *[1]CREOL Univ. of Central Florida, USA.* We use the beam-deflection method to measure nondegenerate nonlinear refractive indices of ZnO and ZnSe and show, in agreement with theory, extremely nondegenerate nonlinear refraction is significantly larger than in the degenerate or near-degenerate case.

15:00–15:30 Coffee Break and Unopposed Exhibit Only Time, *Exhibit Hall*

15:00–17:00 Market Focus: Optics and Photonics Market Overview Panel, *Exhibit Hall Theater*

CLEO: QELS-Fundamental Science

FW3E • Active Plasmonics and Nanolasers—Continued

FW3E.5 • 14:00
Time-Domain Model of 4-Level Gain System Fitted to Nanohole Array Lasing Experiment, Jieran Fang[1], Jingjing Liu[1], Zhuoxian Wang[1], Xiangeng Meng[1], Ludmila Prokopeva[1], Vladimir M. Shalaev[1], Alexander V. Kildishev[1]; [1]*Birck Nanotechnology Center, School of Electrical and Computer Engineering, Purdue Univ., USA.* We developed an accurate three dimensional time domain model of a 4-level gain system fitted to lasing experiment with a silver nanohole array. The simulated emission intensity showed clear lasing effects confirmed by optical experiments.

FW3E.6 • 14:15
Room Temperature Continuous Wave Blue Lasing in High Quality Factor III-Nitride Nanobeam Cavity on Silicon, Noelia Vico Triviño[1], Raphael Butte[1], Jean-François Carlin[1], Nicolas Grandjean[1]; [1]*Ecole Polytechnique Federale de Lausanne, Switzerland.* Lasing is demonstrated in III-nitride photonic crystal nanobeam cavities grown on silicon. Laser characteristics are well accounted for by the large spontaneous emission coupling factor inherent to nanobeams and the InGaN quantum well material gain.

FW3E.7 • 14:30
Plasmonic Random Lasing in Strongly Scattering Regime with Slanted Silver Nanorod Array, Zhuoxian Wang[1], Xiangeng Meng[1], Seung Ho Choi[2], Young L. Kim[2], Vladimir M. Shalaev[1], Alexandra Boltasseva[1]; [1]*School of Electrical & Computer Engineering and Birck Nanotechnology Center, Purdue Univ., USA;* [2]*Weldon School of Biomedical Engineering, Purdue Univ., USA.* We present a plasmonic approach employing a slanted silver nanorod array for achieving controllable random lasing in a strongly scattering regime. Such random lasers can serve as a bright optical source for speckle-free imaging.

FW3E.8 • 14:45
Blackbody metamaterial lasers, Changxu Liu[1], Jianfeng Huang[2], Silvia Masala[3], Erkki Alarousu[3], Yu Han[2], Andrea Fratalocchi[1]; [1]*PRIMALIGHT, KAUST, Saudi Arabia;* [2]*Advanced Membranes and Porous Materials Center, Division of Physical Sciences and Engineering, KAUST, Saudi Arabia;* [3]*Solar and Photovoltaics Engineering Research Center, Division of Physical Sciences and Engineering, KAUST, Saudi Arabia.* We investigate both theoretically and experimentally a new type of laser, which exploits a broadband light "condensation" process sustained by the stimulated amplification of an optical blackbody metamaterial.

CLEO: Science & Innovations

SW3F • III-V Lasers on Silicon—Continued

SW3F.5 • 14:00
High Temperature Hybrid Silicon Micro-ring Lasers with Thermal Shunts, Chong Zhang[2,1], Di Liang[2], Geza Kurczveil[2], John Bowers[1], Raymond Beausoleil[2]; [1]*UCSB, USA;* [2]*HP Labs, USA.* We demonstrate a hybrid silicon micro-ring laser design with novel thermal shunts. With this technique the hybrid silicon ring lasers with a 50 mm diameter operate continuous wave up to 105 °C.

SW3F.6 • 14:15
High-Q Silicon Resonators For High-Coherence Hybrid Si/III-V Semiconductor Lasers, Christos Santis[1], Amnon Yariv[1]; [1]*California Inst. of Technology, USA.* We report on the design and experimental demonstration of high-Q Si resonators with Q ~ 10^6, a fundamental figure of merit of the phase coherence of hybrid Si/III-V semiconductor lasers.

SW3F.7 • 14:30
Si-SOA Hybrid Wavelength Tunable Laser with a Tunable Coupler for High-Power Operation, Yuriko Kawamura[1], Hiroshi Yamazaki[1], Yuta Ueda[2], Shin Kamei[2], Toshikazu Hashimoto[1]; [1]*NTT Device Technology Labs, Japan;* [2]*NTT Device Innovation Center, Japan.* We devised an output configuration for the Si-SOA hybrid laser which is suitable for high-power operation in terms of slope efficiency and suppression of nonlinear effects. These advantages were theoretically evaluated. A proof-of-concept experiment demonstrated.

SW3F.8 • 14:45
Passively Mode-locked III-V/Silicon Lasers with Low Time Jitter Using CW Optical Injection, Yuanbing Cheng[1], Xianshu Luo[2], Junfeng Song[2], Tsung-Yang Liow[2], Guo-Qiang Lo[2], Yulian Cao[1], Xiaonan Hu[1], Peng Huei Lim[3], Qijie Wang[1]; [1]*Nanyang Technological Univ., Singapore;* [2]*Inst. of microelectronics,a*star, Singapore;* [3]*DSO National Lab,Singapore, Singapore.* We demonstrate 30 GHz mode-locked quantum well lasers on silicon platform using continuous-wave optical injection, which emit at the L-band wavelength with integrated root-mean-square time jitter of 1.0 ps and radio-frequency-linewidth of 150 kHz.

SW3G • Precision Spectroscopy—Continued

SW3G.4 • 14:00
Measuring Part-per-Billion Line Shifts and Frequencies with Direct-Frequency-Comb Vernier Spectroscopy, Pablo Cancio Pastor[1], Mario Siciliani de Cumis[1], Roberto Eramo[1], Paolo De Natale[1], Nicola Coluccelli[2], Marco Cassinerio[2], Gianluca Galzerano[2], Paolo Laporta[2]; [1]*INO-CNR, Italy;* [2]*Politecnico di Milano, Italy.* Accurate frequency measurements of CO2 transitions around 2 mum are performed by direct frequency-comb Vernier spectroscopy. Measurements of pressure line shifts at the ppb. accuracy level demonstrates the application of comb sources in precision molecular spectroscopy.

SW3G.5 • 14:15
Dual-Comb Modelocked Lasers, Sandro M. Link[1], Alexander Klenner[1], Mario Mangold[1], Matthias Golling[1], Bauke W. Tilma[1], Ursula Keller[1]; [1]*Inst. for Quantum Electronics, ETH Zurich, Switzerland.* We present the first semiconductor disk laser simultaneously emitting two gigahertz modelocked pulse trains. This simply allows to establish a link from the optical domain to a microwave frequency comb. The relative carrier-envelope-offset frequency can be accessed directly.

SW3G.6 • 14:30
Discrete Fourier Transform Infrared Spectroscopy Using Precisely Periodic Pulse, YI-DA HSIEH[1,2], Sho Okubo[2,3], Hajime Inaba[2,3], Mamoru Hashimoto[4], Takeshi Yasui[1,2]; [1]*Tokushima Univ., Japan;* [2]*ERATO Intelligent Optical Synthesizer Project, Japan;* [3]*National Inst. of Advanced Industrial Science and Technology, Japan;* [4]*Osaka Univ., Japan.* A stabilized Fabry-Perot cavity with a 2.2 MHz-linewidth resonance-mode and a 566MHz FSR was fully characterized over the spectral range from 186 to 200 THz by discrete Fourier transform infrared spectroscopy using precisely periodic pulse.

SW3G.7 • 14:45
A compact iodine-stabilized diode laser at 531 nm, Takumi Kobayashi[1], Daisuke Akamatsu[1], Kazumoto Hosaka[1], Hajime Inaba[1], Sho Okubo[1], Takehiko Tanabe[1], Masami Yasuda[1], Atsushi Onae[1], Feng-Lei Hong[1]; [1]*NMIJ, Japan.* A compact iodine-stabilized laser at 531 nm is developed with a frequency stability at the 10^{-12} level using a coin-sized diode laser module. This laser will be used for applications including interferometic measurements.

CLEO: Applications & Technology

AW3H • A&T Topical Review on Advances in Molecular Imaging I—Continued

AW3H.3 • 14:00 Invited
Molecular Imaging with Sum-frequency Generation Microscopy, Yang Han[1], julie hsu[1], Nien-Hui Ge[1], Eric O. Potma[1]; [1]*Chemistry, Univ. of California, Irvine, USA.* We present an overview of the recent developments and biological imaging applications of sum-frequency generation (SFG) microscopy.

AW3H.4 • 14:30 Invited
Fluorescence lifetime imaging of cellular heterogeneity in cancer drug response, Melissa Skala[1]; [1]*Vanderbilt Univ., USA.* Cancer is a heterogeneous disease, and subpopulations of cells can drive drug resistance. Fluorescence lifetime imaging of metabolic co-factors is used to monitor drug response on a cellular level, to optimize treatment strategies for patients.

15:00–15:30 Coffee Break and Unopposed Exhibit Only Time, *Exhibit Hall*

15:00–17:00 Market Focus: Optics and Photonics Market Overview Panel, *Exhibit Hall Theater*

CLEO: Science & Innovations

SW3I • Metamaterials & Metasurfaces—Continued

SW3I.2 • 14:00
Simultaneous and Complete Control of Light Polarization and Phase using High Contrast Transmitarrays, Amir Arbabi[1], Yu Horie[1], Mahmood Bagheri[2], Andrei Faraon[1]; [1]*T. J. Watson Lab of Applied Physics, California Inst. of Technology, USA;* [2]*Jet Propulsion Lab, California Inst. of Technology, USA*. We report an efficient dielectric metasurface platform for complete control over polarization and phase of light with subwavelength spatial resolution. Using this platform, we experimentally demonstrate polarization switchable phase holograms and vector beam generators.

SW3I.3 • 14:15
Liquid Crystal Tunable Plasmonic Color, Daniel Franklin[1], Debashis Chanda[1]; [1]*Univ. of Central Florida, USA*. We demonstrate a liquid crystal-tunable reflective surface where the color of the metasurface is changed as a function of applied voltage. Reflection spectra are compared with finite-difference time-domain numeric simulations.

SW3I.4 • 14:30 Invited
Nanophotonic Metastructures: Functionality at the Extreme, Nader Engheta[1]; [1]*Univ. of Pennsylvania, USA*. We have been exploring the light-matter interaction in metastructures with scenarios that include extreme dimensionality, processing at nanoscales, extreme parameter values, unusual topology, and extreme near zones. We give an overview of our ongoing study.

CLEO: Applications & Technology

AW3J • Symposium on Photonics in Surgery I—Continued

AW3J.3 • 14:00 Invited
Optical Surgical Navigation for Medulloblastoma, Christopher Contag[1]; [1]*Stanford Univ., USA*. We have developed miniaturized confocal microscope designs coupled with wide-field fluorescence micorendocopes scopes for the detection of molecular probes to improve resection of medulloblastoma of children.

AW3J.4 • 14:30 Invited
Recent Advance in Visible Spectrum Surgical Navigation, Victor Yang[1]; [1]*Sunnybrook Health Sciences Centre, Canada*. Technological over-kill may not be the most efficient path towards medical device adoption. In this talk, we distill the work flow requirement of surgical navigation and examine the recent advances in 3D visible spectrum imaging with applications in neurosurgery.

AW3K • A&T Topical Review on Optofluidics Microsystems I—Continued

AW3K.4 • 14:00 Invited
Real-time Size/Mass Spectrometry in Solution using Whispering Gallery Micro-Global Positioning, Stephen Arnold[1], David Keng[1]; [1]*NYU Polytechnic School of Engineering, USA*. The goal of real-time nano-particle size/mass spectrometry by a microcavity in solution has been illusive for lack of binding position metrology. We demonstrate through Reactive Sensing theory and experiment that this limitation has been overcome.

AW3K.5 • 14:30
Plasmon-Assisted Optoelectrofluidics, Justus C. Ndukaife[1,2], Alexander V. Kildishev[1], A. G. Agwu Nnanna[2], Steven T. Wereley[1], Vladimir M. Shalaev[1], Alexandra Boltasseva[1]; [1]*Purdue Univ., USA;* [2]*Purdue Calumet Water Inst., USA*. By harnessing the photo-induced heating of a single plasmonic nanostructure and AC E-field in our research at the interface between plasmonics and optofluidics we demonstrate *on-demand* fluid flow control with unparalleled micron per second-scale velocities.

AW3K.6 • 14:45
Spontaneous Light-driven Heat Cycles in Metallic Nanofluids with Nanobubbles, J. Luis Dominguez[1], Matthew Moocarme[1,2], Luat Vuong[1,2]; [1]*Physics, Queens College of CUNY, USA;* [2]*Physics, Graduate Center of CUNY, USA*. We present the first experiments of spontaneous oscillatory behavior in binary-solvent nanofluids, which occurs when collimated light grazes menisci. The robust heat cycles identify nanobubbles, new mechanisms for probing nanoparticle-solvent chemistry, and novel thermo-mechanical dynamics.

CLEO: Science & Innovations

SW3L • Nonlinear Effects in Waveguides—Continued

SW3L.2 • 14:00
Phase-iinsensitive fiber parametric amplifier system with clampled output phase, Kyo Inoue[1]; [1]*Osaka Univ., Japan*. This paper proposes a phase-insensitive fiber parametric amplifier system that outputs a phase-clamped signal. It consists of an orthogonally pumped fiber with polarization-aligned signal and a fiber loop with a polarization beam splitter.

SW3L.3 • 14:15
Spectral Narrowing of CW Light in Optical Fibers with Normal Dispersion, Serguei Papernyi[1], Anastasia Bednyakova[2], Sergei Tyritsyn[3]; [1]*Lasers, MPB Communications Inc, Canada;* [2]*Novosibirsk State Univ., Russia;* [3]*Aston Inst. of Photonic Technologies, UK*. Spectrum narrowing of CW light was observed experimentally in optical transmission fibers with normal dispersion. The effect's theoretical interpretation as an effective self-pumping parametric amplification of the spectrum's central part is confirmed by numerical modeling.

SW3L.4 • 14:30
Dual-peaked Laser Spectral Compression Generated in a Dispersion-increasing Fiber, Yu-Hsiang Lin[1], Chen-Bin Huang[1]; [1]*National Tsing Hua Univ., Taiwan*. Adiabatic pulse propagation in a dispersion-increasing fiber is used to generate dual spectrally compressed peaks with tunable amplitudes. Our experimental results are in excellent agreements as compared to numerical calculations.

SW3L.5 • 14:45
Raman-Enhanced Phase-Sensitive Fiber Optical Parametric Amplifier, Xuelei Fu[1], Xiaojie Guo[1], Chester Shu[1]; [1]*Chinese Univ. of Hong Kong, Hong Kong*. Backward Raman amplification is applied to enhance the performance of phase-sensitive fiber optical parametric amplification. The gain extinction ratio and the maximum signal gain are increased by 9.2 and 18.7 dB, respectively.

15:00–15:30 Coffee Break and Unopposed Exhibit Only Time, *Exhibit Hall*

15:00–17:00 Market Focus: Optics and Photonics Market Overview Panel, *Exhibit Hall Theater*

CLEO: Science & Innovations

SW3M • Space-Division Multiplexing—Continued

SW3M.5 • 14:00 Invited

Experimental Demonstration of Optical Switching of Tbit/s Data Packets for High Capacity Short-Range Networks, Ashenafi Kiros Medhin[1], Valerija Kamchevska[1], Hao Hu[1], Michael Galili[1], Leif K. Oxenløwe[1]; [1]*Technical Univ. of Denmark, Denmark*. Record-high 1.28-Tbit/s optical data packets are experimentally switched in the optical domain using a $LiNbO_3$ switch. An in-band notch-filter labeling scheme scalable to 65,536 labels is employed and a 3-km transmission distance is demonstrated.

SW3M.6 • 14:30

High speed and high resolution demodulation system for hybrid WDM/FDM based fiber microstructure sensor network by using Fabry-Perot filter, Qizhen Sun[1], Jianwei Cheng[1], Fan Ai[1]; [1]*Huazhong Univ of Science and Technology, China*. Hybrid WDM/TDM enabled microstructure based optical fiber sensor network with large capacity is proposed. Assisted by Fabry-Perot filter, the demodulation system with high speed of 500Hz and high wavelength resolution less than 4.91pm is realized.

SW3M.7 • 14:45

Simple and Efficient Detection Scheme for Continuous Variable Quantum Key Distribution with m-ary Phase-Shift-Keying, Sebastian Kleis[1], Reinhold Herschel[1], Christian G. Schäffer[1]; [1]*Helmut-Schmidt-Univ., USA*. A detection scheme for discriminating coherent states in quantum key distribution systems employing PSK is proposed. It is simple and uses only standard components. Its applicability at extremely low power levels of as low as 0.045 photons per symbol is experimentally verified.

SW3N • Integrated Optical Modulators—Continued

SW3N.5 • 14:00

Linear silicon PN junction phase modulator, Yoon Ho Daniel Lee[1], Jaime Cardenas[1], Michal Lipson[1]; [1]*Cornell Univ., USA*. We propose a method for linearizing the response of depletion-mode silicon waveguide modulator based on the engineering of modal overlap with the depletion region. Simulations show suppression of nonlinearities in index-voltage transfer function, enabling SFDR of 116 dB/$Hz^{2/3}$ in MZM configuration.

SW3N.6 • 14:15

Linearity Measurement of a Silicon Single-Drive Push-Pull Mach-Zehnder Modulator, Yanyang Zhou[1], Linjie Zhou[1], Feiran Su[1], Jingya Xie[1], Haike Zhu[1], Xinwan Li[1], Jianping Chen[1]; [1]*Shanghai Jiao Tong Univ., USA*. We investigate the linearity of a silicon Mach-Zehnder modulator with single-drive push-pull configuration. The spurious free dynamic range for second harmonic distortion ($SFDR_{SHD}$) is 86 dB·$Hz^{1/2}$ with 4 dB improvement over previous best result.

SW3N.7 • 14:30

64 Gb/s silicon QPSK modulator with single-drive push-pull traveling wave electrodes, haike zhu[1], Linjie Zhou[1], Tao Wang[2], Lei Liu[2], Chiyan Wong[2], Yanyang Zhou[1], jinting wang[1], qianqian wu[1], anbang xie[1], Rui Yang[1], zuxiang li[1], Xinwan Li[1], Jianping Chen[1]; [1]*shanghai jiao tong Univ., USA;* [2]*Huawei, China*. We demonstrate a silicon QPSK modulator consisting of two nested Mach-Zehnder interferometers with 3.5 mm long traveling-wave electrodes. 64 Gb/s QPSK modulation is achieved with an EVM of 24.4% and power consumption of 7.1 pJ/bit.

SW3N.8 • 14:45

Monolithically Integrated Quantum Dot Optical Modulator with Semiconductor Optical Amplifier for High-speed Optical Data Generation, Naokatsu Yamamoto[1], Kouichi Akahane[1], Toshimasa Umezawa[1], Tetsuya Kawanishi[1]; [1]*National Inst Information & Comm Tech, Japan*. High-speed optical data signal generation of >6.8 Gb/s with an error-free operation was successfully demonstrated using newly developed monolithically integrated quantum dot optical modulator and semiconductor optical amplifier operated in an ultra-broad optical frequency bandwidth.

SW3O • Parametric Sources for Coherent Infrared Light Generation—Continued

SW3O.4 • 14:00

1064-nm-Pumped Mid-Infrared Optical Parametric Oscillator Based on Orientation-Patterned Gallium Phosphide (OP-GaP), Leonard A. Pomeranz[1], Peter G. Schunemann[1], Daniel J. Magarrell[1], John C. McCarthy[1], Kevin Zawilski[1], David E. Zelmon[2]; [1]*BAE Systems Inc, USA;* [2]*AFRL/RXAP, US Air Force Research Lab, USA*. The first 1064-nm-pumped OP-GaP OPO was successfully demonstrated. A Q-switched Nd:YVO_4 laser (~1W, 3.3ns, 10kHz) pumped OP-GaP (16.5-mm-long, 20.8-micron grating period) yielded temperature-tunable signal and idler output wavelengths of 1385-1361 nm and 4591-4876 nm respectively.

SW3O.5 • 14:15

Long-Wave Infrared Single-Frequency OP-GaAs OPO Pumped by a Pulsed Tm:YAP Microlaser, Quentin Clement[1], Jean-Michel Melkonian[1], Jean-Baptiste Dherbecourt[1], Myriam Raybaut[1], Antoine Godard[1], Arnaud Grisard[2], Eric Lallier[2], Bertrand Gerard[3], Basile Faure[4], Grégoire Souhaité[4]; [1]*ONERA The French Aerospace Lab, France;* [2]*Thales Research & Technology, France;* [3]*Alcatel-Thales III-V Lab, France;* [4]*Teem Photonics, France*. We report on a single-frequency nested cavity OPO based on OP-GaAs, pumped by a pulsed Tm:YAP microlaser. A threshold energy of 10 µJ has been measured and temperature tuning enables to cover the 10.3-10.9 µm range.

SW3O.6 • 14:30

Electro-Optically Spectrum Tailorable, Aperiodically Poled Lithium Niobate Optical Parametric Oscillators, Yen-Hung Chen[1], Hung-Ping Chung[1], Wei-Kun Chang[1], Chien-Hao Tseng[1]; [1]*National Central Univ., Taiwan*. An electro-optically spectrum tailorable intracavity optical parametric oscillator (IOPO) was built based on a novel integrated aperiodically poled lithium niobate. Spectral narrowing and manipulation of the IOPO signal was demonstrated simply by electro-optic control.

SW3O.7 • 14:45

Widely tunable 1µm optical vortex laser, Aizitiaili Abulikemu[1], Taximaiti Yusufu[1], Katsuhiko Miyamoto[1], Takashige Omatsu[1,2]; [1]*Chiba Univ., Japan;* [2]*JST, CREST, Japan*. We developed a widely tunable 1-µm optical vortex laser formed of a 0.5-µm vortex pumped optical parametric oscillator by employing non-critical phase-matching LiB_3O_5 crystals. Tunable vortex output was obtained in the wavelength range of 880-1345nm.

15:00–15:30 Coffee Break and Unopposed Exhibit Only Time, *Exhibit Hall*

15:00–17:00 Market Focus: Optics and Photonics Market Overview Panel, *Exhibit Hall Theater*

CLEO: QELS-Fundamental Science

15:30–17:30
FW4A • Quantum Computing
Presider: James Franson; Univ. of Maryland Baltimore County, USA

FW4A.1 • 15:30
Implementation of the Classical and Quantum Fourier Transform in Photonic Lattices, Steffen Weimann[1], Armando Perez-Leija[1], Maxime Lebugle[1], Alexander Szameit[1]; [1]*Institut für angewandte Physik, Germany.* We report on the experimental realization of an optical version of the fractional and standard Fourier transform using discrete photonic lattices. Our approach is fully integrated and free of bulk optical components. We investigate the transformation of classical and quantum light.

FW4A.2 • 15:45
Programmable Nanophotonic Processor for Arbitrary High Fidelity Optical Transformations, Gregory Steinbrecher[1], Nicholas C. Harris[1], Jacob Mower[1], Mihika Prabhu[1], Dirk R. Englund[1]; [1]*Research Lab of Electronics, MIT, USA.* We present an architecture for programmable nanophotonic processors capable of arbitrary discrete transformations for quantum and classical applications. A method to combat fabrication imperfections with high fidelity is discussed along with initial experimental results.

FW4A.3 • 16:00 Invited
A Fermionic Quantum Computer with Ultracold Atoms, Julio T. Barreiro[1]; [1]*Univ. of California, San Diego, USA.* I will discuss how state-of-the-art experiments with ultracold atoms in optical lattices can be extended to realize fermionic quantum computations for chemistry, achieved by engineering arbitrary hoping and specific many-body interactions of fermions.

15:30–17:30
FW4B • Integrated Structures for Quantum Optics
Presider: Glenn Solomon; Joint Quantum Inst., USA

FW4B.1 • 15:30
Enhanced Multi-Photon Emission from Single NV Center Coupled to Graphene by Laser-Shaping, Jing Liu[1,2], Yaowu Hu[3], Prashant Kumar[3], Mikhail Y. Shalaginov[2,4], Alexei Lagutchev[2,4], Vladimir M. Shalaev[2,4], Gary Cheng[3], Joseph M. Irudayaraj[1,2]; [1]*Dept. of Agricultural and Biological Engineering, Purdue Univ., USA;* [2]*Birck Nanotechnology Center, Purdue Univ., USA;* [3]*School of Industrial Engineering, Purdue Univ., USA;* [4]*School of Electrical and Computer Engineering, Purdue Univ., USA.* We experimentally demonstrated the enhanced multi-photon emission from single NV center coupled to 2D and 3D graphene by a nanoscale laser-shaping technique. Our results provide new non-classical light source for quantum optics and light harvesting.

FW4B.2 • 15:45 Invited
Fully-tunable, Purcell-enhanced On-chip Quantum Emitters, Maurangelo Petruzzella[1], Tian Xia[1], Francesco Pagliano[1], Simone Birindelli[1], Leonardo Midolo[1], Zarko Zobenica[1], Li Lianhe[2], Edmund Linfield[2], Andrea Fiore[1]; [1]*Eindhoven Univ. of Technology, Netherlands;* [2]*Univ. of Leeds, UK.* We report the all-electrical control over cavity-emitter systems, consisting in Stark-tunable quantum dots embedded in mechanically reconfigurable photonic crystal membranes. Purcell-effect from a single dot is demonstrated at distinct wavelengths.

15:30–17:30
FW4C • Novel Optics
Presider: Sebastian Knitter; Yale Univ., USA

FW4C.1 • 15:30
Control of Coherent Backscattering in a Multimode Fiber Using Nonreciprocal Phase Modulation, Yaron Bromberg[1], Brandon Redding[1], Hui Cao[1]; [1]*Dept. of Applied Physics, Yale Univ., USA.* We used a magneto-optical effect to control coherent backscattering in a multimode fiber. A continuous transition from a backscattered peak to a dip was realized by manipulating the relative phase between reciprocal paths.

FW4C.2 • 15:45
Casimir forces in inhomogeneous media: towards a workable regularization, Ulf Leonhardt[1], Itay Griniasty[1]; [1]*Weizmann Inst. of Science, Israel.* The most sophisticated theory of Casimir forces in realistic materials, Lifshitz theory, diverges in inhomogeneous media. Inspired by transformation optics, we have constructed a regularization procedure that appears to converge in planar materials.

FW4C.3 • 16:00
All-Solid-State Invisibility Cloak for Diffuse Light, Robert Schittny[1], Andreas Niemeyer[1], Muamer Kadic[1], Tiemo Bückmann[1], Andreas Naber[1], Martin Wegener[1]; [1]*Karlsruhe Inst. of Technology, Germany.* We realize an all-solid-state version of a macroscopic broadband omnidirectional invisibility cloak for diffuse visible light based on polydimethylsiloxane doped with titania nanoparticles. This cloak is portable, easy to handle, and suitable for school demonstrations.

15:30–17:30
FW4D • Nonlinear Fiber Effects
Presider: Mark Foster; Johns Hopkins Univ., USA

FW4D.1 • 15:30
Spatiotemporal Dynamics of Multimode Optical Solitons, Logan Wright[1], William H. Renninger[1], Demetrios N. Christodoulides[2], Frank W. Wise[1]; [1]*Cornell Univ., USA;* [2]*College of Optics and Photonics, CREOL, Univ. of Central Florida, USA.* We study multimode optical solitons with up to roughly 10 spatial modes. This work provides the first evidence for solitons involving more than a few modes, and for spatiotemporal multimode soliton fission and Raman shifting.

FW4D.2 • 15:45
Dynamics of Rogue Wave and Soliton Emergence in Spontaneous Modulation Instability, Shanti Toenger[1], Thomas Godin[1], Cyril Billet[1], Frédéric Dias[2], Miro Erkintalo[3], Göery Genty[4], John Dudley[1]; [1]*Institut FEMTO-ST, Université de Franche-Comté, France;* [2]*School of Mathematical Sciences, Univ. College Dublin, Ireland;* [3]*Physics Dept., Univ. of Auckland, New Zealand;* [4]*Tampere Univ. of Technology, Optics Lab, Finland.* Numerical simulations of spontaneous modulation instability show that localized structures in the chaotic instability field are well-described by analytic elementary and higher order soliton on finite background solutions of the nonlinear Schrödinger equation.

FW4D.3 • 16:00
Multiple Raman Soliton Generation in a Birefringence Tellurite Microstructured Optical Fiber, Lei Zhang[1], Tonglei Cheng[1], Dinghuan Deng[1], Daisuke Sega[1], Lai Liu[1], Takenobu Suzuki[1], Yasutake Ohishi[1]; [1]*Toyota Technological Inst., Japan.* Based on a birefringence tellurite microstructured optical fiber, multiple solitons are generated by tuning the pump power and the polarization orientation. The central wavelength of the first soliton can be tuned over about 680 nm.

CLEO: QELS-Fundamental Science

15:30–17:30
FW4E • Plasmonic Metasurfaces and Metamaterials
Presider: Nanfang Yu; Columbia Univ., USA

FW4E.1 • 15:30 Invited
Photon Spin Induced Collective Electron Motion on a Metasurface, Xingjie Ni[1], Jun Xiao[1], Sui Yang[1,2], Yuan Wang[1], Xiang Zhang[1,2]; *[1]Univ. of California, Berkeley, USA; [2]Lawrence Berkeley National Lab, USA*. Strong spin-orbit interaction can be induced by light-bending metasurfaces. We show that the photon spin momentum can be directly transferred to collective motion of electrons on a conductive metasurface with this interaction.

FW4E.2 • 16:00
Active Epsilon-Near-Zero Infrared Metamaterials, Nihal Arju[1], Tzuhsuan Ma[1], Simeon Trendafilov[1], JONGWON LEE[1], Mikhail A. Belkin[1], Gennady Shvets[1]; *[1]Univ. of Texas at Austin, USA*. Metal-insulator-metal based epsilon-near-zero (ENZ) metamaterials are shown to support optical modes localized in the vicinity of a polarizable defect. ENZ-based infrared absorbers are fabricated using SiC and electrically controlled quantum wells structures.

CLEO: Science & Innovations

15:30–17:30
SW4F • Micro and Nano Lasers
Presider: Kent Choquette; Univ. of Illinois, USA

SW4F.1 • 15:30
Opening up spectrum with InPAs quantum dot lasers, Ivan Karomi[1,3], Sam Shutts[1], Peter M. Smowton[1], Andrey Krysa[2]; *[1]Cardiff Univ., UK; [2]Sheffield Univ., UK; [3]Univ. of Mosul, Iraq.* Electrically injected MOVPE grown InPAs quantum dot lasers emitting at wavelengths longer than 770nm are demonstrated with 300K threshold current density of 260Acm^{-2} for 2mm long uncoated facet devices and operation up to 370K.

SW4F.2 • 15:45
Quantum Cascade Laser-based Kerr Frequency Comb Generation, Caroline Lecaplain[1], Clément Javerzac-Galy[1], Erwan Lucas[1], John D. Jost[1], tobias kippenberg[1]; *[1]EPFL, Switzerland*. We report mid-infrared Kerr comb generation based on a quantum cascade laser pumping a crystalline microresonator. For the first time QCL light is coupled into a microresonator via a tapered chalcogenide fiber allowing mid-IR Kerr comb generation.

SW4F.3 • 16:00 Invited
Very Small Lasers and Resonators, Yong-Hee Lee[1], Hoon Jang[1]; *[1]Physics, Korea Advanced Inst of Science & Tech, Korea*. Evolution of small resonant lasers/cavities, from 1D vertical cavity surface emitting lasers to 2D photonic crystal lasers and back to 1D nanobeam lasers, will be discussed. Emphases will be placed on ultra-low threshold nanobeam lasers.

15:30–17:30
SW4G • Comb Technology
Presider: Brian Washburn; Kansas State Univ., USA

SW4G.1 • 15:30
Octave Spanning Frequency Comb Generation in a Dispersion-Controlled Short Silicon-Wire Waveguide with a Fiber Laser Oscillator, Takahiro Goto[1,2], Atushi Ishizawa[2], Rai Kou[3,4], Tai Tsuchizawa[3,4], Nobuyuki Matsuda[2,3], Kenichi Hitachi[2], Tadashi Nishikawa[1], Koji Yamada[3,4], Tetsuomi sogawa[2], HIdeki Gotoh[2]; *[1]Tokyo Denki Univ., Japan; [2]NTT Basic Research Labs, NTT Corporation, Japan; [3]NTT Nanophotonics Center, NTT Corporation, Japan; [4]NTT Device Technology Labs, NTT Corporation, Japan*. We demonstrate on-chip frequency comb generation spanning from 900 to 2300 nm, the widest bandwidth with a laser oscillator (only 50-pJ pulse energy), by controlling dispersion and propagation distance of silicon-wire waveguides.

SW4G.2 • 15:45
A Hybrid III-V-Graphene Device for Modelocking and Noise Suppression in a Frequency Comb, Chien-Chung Lee[1], Kevin Silverman[2], Ari Feldman[2], Todd Harvey[2], Richard P. Mirin[2], Thomas R. Schibli[1,3]; *[1]Physics, Univ. of Colorado at Boulder, USA; [2]National Inst. of Standards and Technology, USA; [3]JILA, National Inst. of Standards and Technology and Univ. of Colorado, USA*. We demonstrate a device that integrates a III-V semiconductor saturable absorber mirror with a graphene electro-optic modulator, which provides a monolithic solution to modelocking and noise suppression in a frequency comb.

SW4G.3 • 16:00
A Robust 2*f*-to-3*f* Collinear Interferometer with a Dual-Pitch Periodically Poled Lithium Niobate Ridge Waveguide, Kenichi Hitachi[1], Atsushi Ishizawa[1], Osamu Tadanaga[2], Hiroki Mashiko[1], Tadashi Nishikawa[3], Tetsuomi Sogawa[1], HIdeki Gotoh[1]; *[1]NTT Basic Research Labs, Japan; [2]NTT Device Technology Labs, Japan; [3]Tokyo Denki Univ., Japan*. We demonstrated that a 2*f*-to-3*f* collinear interferometer is robust against environmental noise. The out-of-loop Allan deviation of the collinear interferometer is 7x10^{-15} at gate time of 1 s, irrespective of environmental perturbation.

CLEO: Applications & Technology

15:30–17:30
AW4H • A&T Topical Review on Advances in Molecular Imaging II
Presider: Brian Applegate; Texas A&M Univ., USA

AW4H.1 • 15:30 Invited
Molecular Contrast in Interferometric Imaging, Adam Wax[1]; *[1]Bioemedical Engineering, Duke Univ., USA*. Interferometric imaging offers many advantages for biomedical applications such as optical sectioning/depth resolution. Inclusion of molecular contrast information improves utility but requires additional efforts to either isolate spectroscopic information or detect contrast agents.

AW4H.2 • 16:00 Invited
Multi-Scale Optical Molecular Imaging, Yu Chen[1]; *[1]Univ. of Maryland at College Park, USA*. An array of fluorescence molecular imaging technologies for multi-scale imaging will be presented, including planar fluorescence for macroscopic samples, fluorescence laminar optical tomography for mesoscopic samples, and two-photon fluorescence microscopy for intravital imaging.

CLEO: Science & Innovations

15:30–17:30
SW4I • Novel Materials for On-chip Photonics
Presider: Federico Capasso; Harvard Univ., USA

SW4I.1 • 15:30
Microdisk Cavity-Coupled MoS_2 with Tunable Narrowband Emission, Jason C. Reed[1], Alexander Y. Zhu[1], Hai Zhu[1], Ertugrul Cubukcu[1]; [1]*Univ. of Pennsylvania, USA.* We incorporate monolayer MoS_2 into a microdisk optical resonator cavity to produce narroband emission with quality-factors of 900. The integrated photonic device has high spatial and temporal coherence and is wavelength tunable.

SW4I.2 • 15:45
Fabrication of 1D Photonic Crystal on a Single Erbium Chloride Silicate Nanowire and Microcavity Laser Design, Zhicheng Liu[1], Hao Sun[2], Yongzhuo Li[2], Jianxing Zhang[2], Cun-Zheng Ning[1,2]; [1]*School of Electrical, Computer, and Energy Engineering, Arizona State Univ., USA;* [2]*Dept. of Electronic Engineering, Tsinghua Univ., China.* We report on fabrication and characterization of 1D photonic crystal on a single erbium chloride silicate nanowire. Design and simulation show that a microcavity laser with Q-factor over 10000 is feasible from a single nanowire.

SW4I.3 • 16:00 Invited
Two-Dimensional Material Nanophotonics, Fengnian Xia[1]; [1]*Yale Univ., USA.* We discuss optical properties of two-dimensional materials ranging from insulating hexagonal boron nitride, semiconducting transition metal dichalcogenides such as molybdenum disulfide and black phosphorus, to semi-metallic graphene. We also cover their potential applications in photonics.

CLEO: Applications & Technology

15:30–17:30
AW4J • Symposium on Photonics in Surgery II
Presider: Jin Kang; Johns Hopkins Univ., USA

AW4J.1 • 15:30 Invited
Photosurgery for the skin: Younger, Healthier and Easier, Boncheol L. Goo[1,2]; [1]*Lutronic Corporation, Korea;* [2]*Clinique L Dermatology, Korea.* Surgeons use sophisticated but imperfect clinical algorithms to analyze visible skin conditions for precise decision making. Algorithmic approaches, current limitations and future ideas will be discussed.

AW4J.2 • 16:00
Delineation of Basal Cell Carcinoma Margins with Combined RCM/OCT Imaging, Nicusor Iftimia[1]; [1]*Physical Sciences Inc., USA.* We demonstrate a novel approach for delineation of basal cell carcinoma (BCC) margins based on combined Reflectance Confocal Microscopy (RCM)/ Optical Coherence Tomography (OCT) imaging. BCC margins delineation f is very important for both disease staging and therapy guidance.

15:30–17:30
AW4K • A&T Topical Review on Optofluidics Microsystems II
Presider: Xudong Fan; Univ. of Michigan, USA

AW4K.1 • 15:30 Invited
Photonic Crystal Enhanced Microscopy, Brian T. Cunningham[1,2], weili chen[1], kenneth D. long[2], Yue Zhuo[2], Ji S. Choi[3], Brendan A. Harley[3]; [1]*Electrical and Computer Engineering, Univ. of Illinois at Urbana-Champaign, USA;* [2]*Dept. of Bioengineering, Univ. of Illinois at Urbana-Champaign, USA;* [3]*Dept. of Chemical and Biological Engineering, Univ. of Illinois at Urbana-Champaign, USA.* By modifying a microscope to perform hyperspectral imaging of reflectance from a photonic crystal, we describe a new microscopy approach that enables quantitative, spatially resolved imaging of the interaction of cells and nanoparticles with surfaces.

AW4K.2 • 16:00 Invited
Microfluidic Isolation and Fluorescence Microscopy in a Fully Automated Digital Diagnostic Instrument (SIMOA HD-1), William McGuigan[1], David C. Duffy[1]; [1]*STRATEC Biomedical USA, Inc., USA.* Quanterix and Stratec Biomedical have developed an automated analyzer that enables the measurement of subfemtomolar concentrations of proteins. The development of this technology focusing on the custom optical module and microfluidic disc is outlined below.

CLEO: Science & Innovations

15:30–17:30
SW4L • Nonlinear Fiber Optics
Presider: Sze Yun Set; Alnair Labs Corporation, Japan

SW4L.1 • 15:30 Invited
Towards Nonlinear Optics with Cold Rydberg Atoms Inside a Hollow Core Fiber, Maria Langbecker[1], Mohammad Noaman[1], Patrick Windpassinger[1]; [1]*Johannes Gutenberg Universitat Mainz, Germany.* We present an experimental setup for studying strongly nonlinear light-matter interactions using cold atoms inside a hollow core fiber. A Rydberg EIT process can potentially be used to generate strong and tunable effective photon-photon interactions.

SW4L.2 • 16:00
SBS Suppression in Nanosecond Fiber Amplifier with Controlled Frequency Chirp, Pavel Ionov[1], Fabio Di Teodoro[1], Todd Rose[1]; [1]*The Aerospace Corporation, USA.* We observe a nearly 9-fold increase in the SBS threshold for a pulsed Yb fiber amplifier by applying a linear frequency-chirp to the input seed pulse. The chirp is achieved by pulse driving a phase modulator. SBS threshold data and transient SBS gain for various degrees of chirp are reported.

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CLEO: Science & Innovations

15:30–17:15
SW4M • SDM, OAM & Free-Space Communications
Presider: Christian Malouin; Juniper Networks Inc., USA

SW4M.1 • 15:30 Invited
Dense Space Division Multiplexed Transmission Technology, Takayuki Mizuno[1], Hidehiko Takara[1], Akihide Sano[1], Yutaka Miyamoto[1]; [1]*NTT Network Innovation Labs, Japan.* We review recent progress in ultra-high capacity transmission based on dense space division multiplexing (DSDM) for future scalable optical transport networks, and present the latest multi-core multi-mode fiber, spatial multi/demultiplexers, and MIMO signal processing technique.

SW4M.2 • 16:00
Experimental Demonstration of N-Dimensional 1-to-1100 Multicasting (25 Wavelengths x 22 Orbital Angular Momentum Modes x 2 Polarizations) of OFDM-mQAM Signal, Jian Wang[1], Shuhui Li[1], Jun Liu[1], Chao Li[1], Long Zhu[1], Jing Du[1], Ming Luo[2], Qi Yang[2], Shaohua Yu[2]; [1]*Wuhan National Lab for Optoelectronics, School of Optical and Electronic Information, Huazhong Univ. of Science and Technology, China;* [2]*State Key Lab of Optical Comm. Technologies and Networks, China.* We present N-dimensional multicasting exploiting wavelength, orbital angular momentum (OAM) and polarization dimensions. 1-to-1100 multicasting (25 wavelengths x 22 OAM modes x 2 polarizations) of OFDM-16/32QAM signal is demonstrated. All 1100-fold channels achieve BER <2e-3.

15:30–17:30
SW4N • Novel Devices for Communications and Signal Processing
Presider: Takahide Sakamoto; NICT, Japan

SW4N.1 • 15:30
Scaling Zero-Change Photonics: An Active Photonics Platform in a 32 nm Microelectronics SOI CMOS Process, Mark T. Wade[1], Fabio Pavanello[1], Jason Orcutt[2], Rajesh Kumar[1], Jeffrey Shainline[1], Vladimir Stojanovic[3], Rajeev Ram[2], Milos Popovic[1]; [1]*Univ. of Colorado at Boulder, USA;* [2]*MIT, USA;* [3]*Univ. of California, USA.* We demonstrate photonics monolithically integrated in a 32nm SOI microelectronics process, including grating couplers, tunable filters, and modulators, the first migration of zero-change CMOS photonics moving down the microelectronics technology-node ladder, from the 45nm node.

SW4N.2 • 15:45
III-V Nanopillar Phototransistor Directly Grown on Silicon, Indrasen Bhattacharya[1], Wai Son Ko[1], Fanglu Lu[1], Stephen Gerke[1], Connie J. Chang-Hansnain[1]; [1]*Univ. of California Berkeley, USA.* We demonstrate InP nanopillar bipolar junction phototransistors monolithically integrated on a Silicon substrate. With a responsivity of 4 A/W and bandwidth of 7.5 GHz, these receivers indicate a route towards efficient on-chip optical interconnects.

SW4N.3 • 16:00
Performance Evaluation of GaN/InGaN Heterojunction Phototransistors, Tsung-Ting Kao[1], Jeomoh Kim[1], Yi-Che Lee[1], Mi-Hee Ji[1], A. Saniul Haq[1], Theeradetch Detchprohm[1], Russell D. Dupuis[1], Shyh-Chiang Shen[1]; [1]*Georgia Inst. of Technology, USA.* We present a high-performance InGaN/GaN heterojunction phototransistor with the responsivity (R_v)> 8 (A/W), low noise-equivalent-power (NEP)< 1.1×10^{-17} (W-Hz$^{-0.5}$) and high detectivity (D^*)> 1.2×10^{14} (cm-Hz$^{0.5}$-W^{-1}).

15:30–17:30
SW4O • Broadband and Ultrafast Parametric Sources
Presider: Jeffrey Moses; Cornell Univ., USA

SW4O.1 • 15:30
High-average-power, Mid-infrared Femtosecond Optical Parametric Oscillator at 7 µm Based on $CdSiP_2$, Suddapalli Chaitanya Kumar[1], Joachim Krauth[2], K. T. Zawilski[3], Peter G. Schunemann[3], Harald W. Giessen[2], Majid Ebrahim-Zadeh[1,4]; [1]*ICFO -The Inst. of Photonic Sciences, Spain;* [2]*4th Physics Inst. and Research Center SCOPE, Univ. of Stuttgart, Germany;* [3]*BAE Systems, USA;* [4]*Institucio Catalana de Recerca i Estudis Avancats (ICREA), Spain.* We report a mid-infrared femtosecond OPO based on $CdSiP_2$ tunable across 6786-7069 nm, generating record power of 110-mW at 7 mm, with passive power and wavelength stability below 3% rms (1-hour) and 0.1% rms (15-min), respectively.

SW4O.2 • 15:45
Cr:ZnS Laser-pumped Subharmonic GaAs OPO with an Instantaneous Bandwidth 3.6-5.6 µm, Viktor O. Smolski[1], Sergey Vasilyev[2], Peter G. Schunemann[3], Sergey B. Mirov[2,4], Konstantin Vodopyanov[1]; [1]*CREOL, Univ. of Central Florida, USA;* [2]*Mid-IR Lasers, IPG Photonics, USA;* [3]*BAE Systems, USA;* [4]*Dept. of Physics, Univ. of Alabama at Birmingham, USA.* High-power (110mW) mid-IR output suitable for ultra-broadband frequency comb generation was produced in a low-threshold (20mW) subharmonic GaAs optical parametric oscillator that was synchronously pumped (175MHz) by a compact 0.5-W femtosecond Cr:ZnS (2.38µm) oscillator.

SW4O.3 • 16:00
Mid-Infrared Femtosecond Optical Parametric Oscillator Synchronously-Pumped Directly by a Ti:sapphire laser, Majid Ebrahim-Zadeh[1,2]; [1]*Nonlinear Optics, ICFO-Inst. of Photonic Sciences, Spain;* [2]*ICREA-Catalan Inst. of Research and Advanced Studies, Spain.* We report a deep-mid-IR femtosecond OPO based on $CdSiP_2$ using direct synchronous pumping by a Ti:sapphire laser, providing continuous wavelength coverage across 6-8 µm under rapid static cavity delay tuning with high output stability.

CLEO: QELS-Fundamental Science

FW4A • Quantum Computing—Continued

FW4A.4 • 16:30
Topological Protection of Path Entanglement in Photonic Quantum Walks, Mikael Rechtsman[1], Yaakov Lumer[2], Yonatan Plotnik[2], Armando Perez-Leija[3], Alexander Szameit[3], Mordechai Segev[2]; *[1]Physics Dept., The Pennsylvania State Univ., USA; [2]Physics Dept., Technion Israel Inst. of Technology, Israel; [3]Inst. of Applied Physics, Friedrich-Schiller-Universität Jena, Germany.* We show that entangled photons propagating along the edge of a photonic topological insulator preserve their entanglement despite edge defects of any kind. This represents a novel methodology for the transport of quantum information.

FW4A.5 • 16:45
Quantum Random Walks in a Programmable Nanophotonic Processor, Nicholas C. Harris[1], Greg Steinbrecher[1], Jacob Mower[1], Yoav Lahini[1], Dirk R. Englund[1]; *[1]MIT, USA.* We present our recent theoretical and preliminary experimental results on the role of disorder and decoherence in quantum random walks implemented in a large-scale, programmable nanophotonic processor.

FW4B • Integrated Structures for Quantum Optics—Continued

FW4B.3 • 16:15
Single NV Zero-Phonon Line Emission into Waveguide-Coupled GaP-on-Diamond Disk Resonators, Michael Gould[1], Nicole K. Thomas[1], Yuncheng Song[2], Minjoo Larry Lee[2], Kai-Mei Fu[3]; *[1]Electrical Engineering, Univ. of Washington, USA; [2]Electrical Engineering, Yale Univ., USA; [3]Physics, Univ. of Washington, USA.* We present results from waveguide-coupled GaP-on-diamond disk resonators coupled to single nitrogen-vacancy centers in diamond. We estimate zero-phonon line emission rates into one direction of a bus waveguide as high as 1.2×10^4 s^{-1}.

FW4B.4 • 16:30
Tunable Squeezing Using Coupled Ring Resonators on a Silicon Nitride Chip, Avik Dutt[1], Steven Miller[1], Kevin Luke[1], Alexander L. Gaeta[1], Paulo Nussenzveig[2], Michal Lipson[1]; *[1]Cornell Univ., USA; [2]Universidade de São Paulo, Brazil.* We demonstrate continuous tuning of the degree of squeezing from 0.5 to 2 dB (0.9 to 4 dB inferred on chip) by externally controlling the coupling condition of a Si_3N_4 double ring OPO using integrated microheaters.

FW4B.5 • 16:45
Effect of Pure Dephasing and Phonon Scattering on the Coupling of Semiconductor Quantum Dots to Optical Cavities, Clément Jarlov[1], Etienne Wodey[1], Alexey Lyasota[1], Milan Calic[1], Pascal Gallo[1], Benjamin Dwir[1], Alok Rudra[1], Elyahou Kapon[1]; *[1]Ecole Polytechnique Fédérale de Lausanne, Switzerland.* We investigate the effect of decoherence mechanisms in semiconductor quantum dot-cavity systems by performing photoluminescence measurements of InGaAs/GaAs site-controlled quantum dots coupled to photonic crystal cavities and comparing the results to a theoretical model.

FW4C • Novel Optics—Continued

FW4C.4 • 16:15
Metasurface Optical Antireflection Coatings, Hou-Tong Chen[1], Boyang Zhang[2], Junpeng Guo[2], Joshua Hendrickson[3], Nima Nader[3]; *[1]Los Alamos National Lab, USA; [2]Univ. of Alabama in Huntsville, USA; [3]Air Force Research Lab, USA.* We demonstrate a new strategy of optical antireflection coatings employing metasurfaces with designer surface properties in the mid-wave infrared. It has very little requirement on the choice of materials and is scalable to other wavelengths.

FW4C.5 • 16:30
Analytic Modeling of Metmaterial Absorbers, Patrick Bowen[1], Alexandre Baron[1], David R. Smith[1]; *[1]Duke Univ., USA.* We present a fully analytical model that describes ideal absorbing metasurfaces composed of film-coupled optical nanoantennas. The model predicts the spectrum and the angular dependence of the absorption and is compared to full-wave numerical simulations.

FW4C.6 • 16:45
Highly Efficient Modulation of THz Metamaterials Using Graphene Surface Plasmons, Isaac J. Luxmoore[1], Peter Q. Liu[2], Sergey A. Mikhailov[3], Nadja A. Savostiyanova[3], Federico Valmorra[2], Jerome Faist[2], Geoffrey R. Nash[1]; *[1]Univ. of Exeter, USA; [2]ETH Zurich, Switzerland; [3]Univ. of Augsburg, Germany.* We introduce hybrid metamaterials consisting of split ring resonators and a graphene nanoribbon array. Electrostatic control of the graphene plasmon resonance provides dynamic control of the transmission of THz radiation with modulation depth of ~50%.

FW4D • Nonlinear Fiber Effects—Continued

FW4D.4 • 16:15
Polarization dynamics of dissipative solitons in a erbium doped fiber laser passively mode locked by carbon nanotube polymer composite, Chengbo Mou[1], Sergey Sergeyev[1], Stanislav Kolpakov[1], Raz Arif[1], Alex Rozhin[1], Maria Chernysheva[1], Sergei Turitsyn[1]; *[1]Aston Inst. of Photonic Technologies, UK.* Here we present first investigation of polarization dynamics from a carbon nanotube mode locked erbium doped fiber laser. Both vector and polarization switching dissipative soliton have been observed.

FW4D.5 • 16:30
How Optical Spectrum of Random Fiber Laser is Formed, Dmitry V. Churkin[1,3], Igor Kolokolov[4,5], Evgeniy V. Podivilov[2,3], Ilya Vatnik[2,3], Maxim Nikulin[2], Sergey Vergeles[4], Ivan Terekhov[3,6], Vladimir Lebedev[4,5], Gregory Falkovich[7,8], Sergey A. Babin[2,3], Sergei Turitsyn[1,3]; *[1]Aston Inst. of Photonic Technologies, UK; [2]Inst. of Automation and Electrometry, Russia; [3]Novosibirsk State Univ., Russia; [4]Landau Inst. for Theoretical Physics, Russia; [5]Moscow Inst. of Physics and Technology, Russia; [6]The Budker Inst. of Nuclear Physics, Russia; [7]Weizmann Inst. of Science, Israel; [8]Inst. for Information Transmission Problems, Russia.* We experimentally and theoretically describe formation of random fiber laser's optical spectrum. We propose a new concept of active cycled wave kinetics from which we derive first ever nonlinear kinetic theory describing laser spectrum.

FW4D.6 • 16:45
Graphene Coated Microfiber For Cascaded Four-Wave-Mixing Generating, Baicheng Yao[1], Yu Wu[1], Qiuyan Feng[1], Zegao Wang[1,2], Yunjiang Rao[1], Yuanfu Chen[1], Kin S. Chiang[1,3]; *[1]UESTC, China; [2]Aarhus Univ., Denmark; [3]City Univeristy of Hong Kong, Hong Kong.* Cascaded four-wave-mixing was effectively demonstrated in a graphene-coated-microfiber, by using a pulsed pump at 1550 nm, which may be useful for realization of graphene based fiber-optic nonlinear devices, e.g. lasers, filters, modulators and regenerators.

CLEO: QELS-Fundamental Science

FW4E • Plasmonic Metasurfaces and Metamaterials—Continued

FW4E.3 • 16:15
Negative refraction due to discrete plasmon diffraction, Arian Kriesch[1,2], Ho Wai H. Lee[2], Daniel Ploss[1], Stanley P. Burgos[2], Hannes Pfeifer[3,1], Jakob Naeger[1], Harry Atwater[2], Ulf Peschel[1]; *[1]Inst. of Opt., Information and Photonics (IOIP), Cluster of Excellence Engineering of Adv. Opt. Mat. (EAM) and Graduate School in Adv. Opt. Tech. (SAOT) and MPL, Friedrich Alexander Univ. Erlangen-Nuremberg, Germany; [2]Applied Physics and Material Sciences, California Inst. of Technology, USA; [3]Max-Planck-Inst Physik des Lichts, Germany.* We experimentally demonstrate spectrally broad (λ_0=1200-1800 nm) in-plane negative diffraction of SPPs in an array of gap-plasmonic waveguides with negative mutual coupling resulting in negative refraction on the array's interface and refocusing in an adjacent metal layer.

FW4E.4 • 16:30
Controlled steering of Cherenkov surface plasmon wakes with a one-dimensional metamaterial, Patrice Genevet[1], Daniel Wintz[1], Antonio Ambrosio[1], Alan She[1], Romain Blanchard[1], Federico Capasso[1]; *[1]Harvard Univ., USA.* We show that by creating a running wave of polarization along a 1D metallic nanostructure consisting of subwavelength spaced rotated apertures that propagates faster than the surface plasmon phase velocity, we can generate surface plasmon wakes, which are the 2D analogue of Cherenkov radiation.

FW4E.5 • 16:45
Three-Dimensional Metasurface Carpet Cloak, Xingjie Ni[1], Zi Jing Wong[1], Yuan Wang[1], Xiang Zhang[1,2]; *[1]Univ. of California, Berkeley, USA; [2]Lawrence Berkeley National Lab, USA.* We experimentally demonstrate a three-dimensional ultra-thin metasurface carpet cloak can cover on an arbitrary-shaped object and make it undetectable by the visible light owing to the phase control capability of the metasurface.

CLEO: Science & Innovations

SW4F • SW4F • Micro and Nano Lasers—Continued

SW4F.4 • 16:30
Waveguide-integrated Unidirectional-Emission Microspiral Lasers for Optical Interconnects, Yu Zhang[1], Andrew W. Poon[1]; *[1]Photonics Device Lab, Dept. of Electronic and Computer Engineering, The Hong Kong Univ. of Science and Technology, China.* We demonstrate a room-temperature continuous-wave electrically injected unidirectional-emission AlGaInAs/InP multiple-quantum-well microspiral disk laser with a 44mA threshold current. Above 130 mA, the laser shows a unidirectional emission from the waveguide butt-coupled to the microspiral notch.

SW4F.5 • 16:45
Room Temperature UV-C Lasers with Nitride Microdisks on Silicon, Philippe Boucaud[1], Julien Sellés[2], Christelle Brimont[2], Thierry Guillet[2], Guillaume Cassabois[2], Bruno Gayral[3], Meletios Mexis[4], Fabrice Semond[4], Iannis Roland[1], Yijia Zeng[1], Xavier Checoury[1]; *[1]IEF-CNRS-Univ Paris Sud, France; [2]L2C-Univ. Montpellier 2, France; [3]Univ. Grenoble Alpes, INAC-SP2M, CEA-CNRS, France; [4]CRHEA-CNRS, France.* We demonstrate room temperature lasing in the UV-C spectral range (~275 nm) with nitride microdisks. The nitride materials are directly grown on a silicon substrate. The active region consists of ultra-thin GaN/AlN quantum wells.

SW4G • Comb Technology—Continued

SW4G.4 • 16:15
Ultra low noise all polarization-maintaining fiber-based Er optical frequency combs, Naoya Kuse[1], Chien-Chung Lee[2], Jie Jiang[1], C. Mohr[1], Thomas R. Schibli[2], M. E. Fermann[1]; *[1]IMRA America Inc, USA; [2]Dept. of Physics, Univ. of Colorado, USA.* We demonstrated all polarization-maintaining (PM) Er fiber frequency combs with record-low noise by using two fast actuators, a graphene-based EOM and a bulk EOM.

SW4G.5 • 16:30
Thin-Disk Lasers for Multi-100-W Average Power Frequency Combs: Challenges and Analysis, Andreas Diebold[1], Florian Emaury[1], Alexander Klenner[1], Clara J. Saraceno[1,2], Stephane Schilt[2], Thomas Sudmeyer[2], Ursula Keller[1]; *[1]Dept. of Physics, ETH Zurich, Switzerland; [2]Laboratoire Temps-Frequence, Universite de Neuchatel, Switzerland.* We compare the noise characteristics and cavity dynamics of a CEOstabilized 80fs Yb:CALGO SESAM-modelocked thin-disk-laser (TDL) and a 140W SESAMmodelocked Yb:YAG TDL with CEO detection. Guidelines towards tight CEOlocking in the >100-W regime are presented.

SW4G.6 • 16:45
Highly Efficient Self-Referencing of a 1-GHz Diode-Pumped Solid-State Laser Using a Silicon Nitride Chip, Aline Sophie Mayer[1], Alexander Klenner[1], Adrea R. Johnson[2], Kevin Luke[2], Michael R. Lamont[2], Yoshitomo Okawachi[2], Michal Lipson[2], Alexander L. Gaeta[2], Ursula Keller[1]; *[1]ETH Zurich, Switzerland; [2]Cornell Univ., USA.* We present the first carrier-envelope-offset (CEO) frequency detection based on multi-octave-spanning supercontinuum generation in a CMOS-compatible Si_3N_4 waveguide. Strong CEO-beat-signals (>30 dB) of a gigahertz-Yb:CALGO-laser were obtained with only 36 pJ of coupled pulse energy.

CLEO: Applications & Technology

AW4H • A&T Topical Review on Advances in Molecular Imaging II—Continued

AW4H.3 • 16:30 Invited
Fiber-optic Endomicroscopy for Label-free Optical Histology, Xingde Li[1]; *[1]Johns Hopkins Univ., USA.* We report on recently developed high-resolution, fiber-optic scanning endomicroscopy technology and its capability of performing label-free optical histologic imaging *in vivo* and *in situ*. Technological advances and examples of biological tissue imaging will be presented.

CLEO: Science & Innovations

SW4I • Novel Materials for On-chip Photonics—Continued

SW4I.4 • 16:30
30 GHz Zeno-based Graphene Electro-optic Modulator, Christopher T. Phare[1], Yoon Ho Daniel Lee[1], Jaime Cardenas[1], Michal Lipson[1]; [1]*Cornell Univ., USA.* We experimentally demonstrate the first ultrafast graphene modulator by exploiting Zeno coupling effects in a graphene-on-silicon-nitride ring resonator.

SW4I.5 • 16:45
Small Footprint Barium Titanate Photonic Crystal Modulators for Photonic Integrated Circuits, Peter Girouard[2], Pice Chen[2], Yongming Tu[1], Young Kyu Jeong[2], Zhifu Liu[2], Seng Tiong Ho[1], Bruce W. Wessels[2]; [1]*Electrical Engineering and Computer Science, Northwestern Univ., USA;* [2]*Materials Science and Engineering, Northwestern Univ., USA.* We report on the design, fabrication, and characterization of photonic crystal phase modulators on epitaxial barium titanate thin films. Modeling indicates that >50 GHz bandwidth and 0.25 V·cm voltage-length product are achievable in sub-millimeter long devices.

CLEO: Applications & Technology

AW4J • Symposium on Photonics in Surgery II—Continued

AW4J.3 • 16:15
Simple optical configuration for continuous curvilinear capsulorhexis, Heechul Lee[1], Jong Woon Choi[1], Yong Pyung Kim[2]; [1]*Lutronic Center, Korea;* [2]*Kyunghee Univ., Korea.* A simple optical system using a wedge prism instead of a scanner for continuous curvilinear capsulorhexis [CCC] was studied.

AW4J.4 • 16:30 Invited
Clinical Embodiments of Laser Speckle Imaging for Real-Time Blood-Flow Monitoring, Bernard Choi[1,2]; [1]*Surgery and Biomedical Engineering, Univ. of California, Irvine, USA;* [2]*Beckman Laser Inst. and Medical Clinic, USA.* Laser Speckle Imaging (LSI) is used widely in preclinical studies of blood flow, especially in neurobiology. However, clinical application of LSI remains underexplored. Here, I describe our experiences in developing clinic-friendly embodiments of LSI.

AW4K • A&T Topical Review on Optofluidics Microsystems II—Continued

AW4K.3 • 16:30
Optofluidic Microreactors for Visible-Light Photocatalysis, Xuming Zhang[1]; [1]*Hong Kong Polytechnic Univ., Hong Kong.* Photocatalysis and optofluidics have an intrinsic synergy as both deal with the same objects - light, fluids and solvents. This study presents different designs of optofluidic microreactors to solve some major problems of current photocatalytic technology.

AW4K.4 • 16:45
Electrowetting-Based Variable Tuning Prism, Soraya Terrab[1], Alexander Watson[1], Kevin Dease[1], Juliet Gopinath[1], Victor Bright[1]; [1]*Univ. of Colorado Boulder, USA.* We demonstrate an electrowetting-based variable prism with dual prism-lens operation. A prism apex angle change of 19° at 35 V and curvature change to infinite focal length at 18.9 V are demonstrated.

CLEO: Science & Innovations

SW4L • Nonlinear Fiber Optics—Continued

SW4L.3 • 16:15
Stimulated Forward Brillouin Scattering in Hollow-core Photonic Crystal Fiber, William H. Renninger[1], Heedeuk Shin[1], Ryan O. Behunin[1], Prashanta Kharel[1], Eric Kittlaus[1], Peter T. Rakich[1]; [1]*Yale Univ., USA.* Stimulated forward Brillouin scattering is observed in hollow-core photonic bandgap fiber. Multiple acoustic closely-spaced resonances exist below 100 MHz. A quality factor enhancement is observed when air is evacuated from the fiber.

SW4L.4 • 16:30
Long-distance Superluminal Propagation Using a Single-longitudinal-mode Long-cavity Brillouin Fiber Laser, Liang Zhang[1], Li Zhan[1], Minglei Qin[1], Jinmei Liu[1,2]; [1]*Shanghai Jiao Tong Univ., China;* [2]*East China Normal Univ., China.* We propose and experimentally validate superluminal propagation using a single-longitudinal-mode long-cavity Brillouin fiber laser with a saturable absorber. The transmission distance of Brillouin-induced superluminal propagation is stretched to 100m in optical fibers.

SW4L.5 • 16:45
Crosstalk Reduction by Backward Raman Pumping in Multi-Wavelength Fiber Optical Parametric Amplification, Xiaojie Guo[1], Chester Shu[1]; [1]*Chinese Univ. of Hong Kong, Hong Kong.* Reduction of four-wave-mixing crosstalk in multi-wavelength amplification is achieved using a backward Raman pump in a fiber optical parametric amplifier. The receiver sensitivity is improved by 1.6 dB in the amplification of three data channels.

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CLEO: Science & Innovations

SW4M • SDM, OAM & Free-Space Communications—Continued

SW4M.3 • 16:15
Q-plates for Switchable Excitation of Fiber OAM Modes, Patrick Gregg[1], Mohammad Mirhosseini[2], Andrea Rubano[3], Lorenzo Marrucci[3], Ebrahim Karimi[4], Robert W. Boyd[4,2], Siddharth Ramachandran[1]; *[1]Boston Univ., USA; [2]Univ. of Rochester, USA; [3]Universita di Napoli Federico II, Italy; [4]Univ. of Ottawa, Canada.* We demonstrate that a |q|=1/2 plate plus polarization optics can tunably excite all linear combinations of |L|=1 fiber OAM modes with up to ~30 dB purity, enabling switch fabrics in fiber-OAM networks and disentangling of degenerate mode mixing effects in long fibers.

SW4M.4 • 16:30 Invited
160 Gbaud Single Nyquist Channel Transmission through Emulated 4 km Free-space Turbulence Link, Deming Kong[1], Jian Wu[1], Tong Xu[1], Yan Li[1], Miao Yu[1], Donghao Zheng[1], Yong Zuo[1], Yue Lei[1], Wei Li[1], Hongxiang Guo[1], Jintong Lin[1]; *[1]State Key Lab of Information Photonics and Optical Communications, Beijing Univ. of Posts and Telecommunications, China.* A single 160 Gbaud Nyquist channel transmission based on coherent matched sampling under 4 km lab-emulated free-space turbulence link is demonstrated. Turbulence induced power fluctuation is found to be main reason of performance deterioration.

SW4N • Novel Devices for Communications and Signal Processing—Continued

SW4N.4 • 16:15
Photocurrent gain in graphene-silicon *p-i-n* junction, Tingyi Gu[1,2], Nick Petrone[1], Arend van der Zande[1], yilei li[1], Tony Heinz[1], Philip Kim[3,1], james Hone[1], Chee Wei Wong[1], Charles M. Santori[2], Raymond Beausoleil[2]; *[1]Columbia Univ., USA; [2]Hewlett-Packard Lab, USA; [3]Physics, Harvard Univ., USA.* We demonstrate single atomic cladding layer of graphene enhance the photocurrent profile of the monolithic silicon p-i-n junction, by spatially- and spectrally- resolved photocurrent measurement.

SW4N.5 • 16:30
First Demonstration of an Integrated Photonic Phase-Sensitive Amplifier, Wangzhe Li[1], Mingzhi Lu[3], Leif Johansson[2], Milan Mashanovitch[2], Danilo Dadic[1], Shamsul Arafin[1], Larry Coldren[1]; *[1]ECE, Univ. of California, Santa Barbara, USA; [2]freedomphotonics, USA; [3]infinera, USA.* For the first time, an integrated photonic phase-sensitive amplifier is reported. Approximately 6.3 dB extinction of on-chip phase-sensitive gain based on a signal-degenerate dual pump four-wave mixing architecture has been achieved.

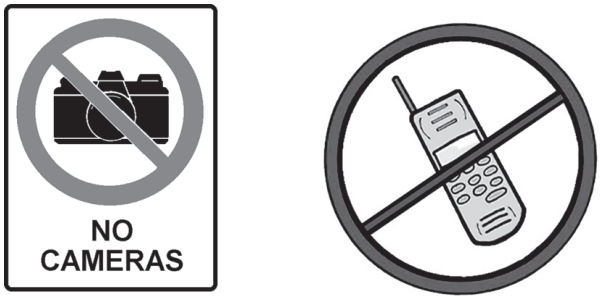
SW4N.6 • 16:45
Polarization Transparency for Silicon Photonics, Jan Niklas Caspers[1,2], Jonathan St-Yves[3], Lukas Chrostowski[4], Wei Shi[3], Mo Mojahedi[1]; *[1]Univ. of Toronto, Germany; [2]Robert Bosch GmbH, Germany; [3]Dept. of Electrical and Computer Engineering and the Center for Optics, Photonics, and Lasers (COPL), Université Laval, Canada; [4]Dept. of Electrical and Computer Engineering, Univ. of British Columbia, Canada.* We experimentally demonstrate the ability to couple any polarization state from a fiber to the TE-mode of a single waveguide in an integrated silicon photonics circuit. We obtain less than ±0.6 dB standard deviation across all input polarization states at a wavelength of 1.55 μm.

SW4O • Broadband and Ultrafast Parametric Sources—Continued

SW4O.4 • 16:15
Sub-100fs Fiber Feedback Synchronously Pumped Degenerate Optical Parametric Oscillator, Kirk A. Ingold[1], Alireza Marandi[1], Michel J. Digonnet[1], Robert L. Byer[1]; *[1]Stanford Univ., USA.* We report on a synchronously pumped degenerate OPO operated at 250 MHz that generates 280 mW of transform-limited sub-100fs pulses at 2.09μm using a compact dispersion-compensated fiber feedback cavity.

SW4O.5 • 16:30
Broadband 7 μm OPCPA pumped by a 2 μm picosecond Ho:YLF CPA system, Daniel Sanchez[1], Michael Hemmer[1], Matthias Baudisch[1], Seth L. Cousin[1], Kevin Zawilski[2], Peter G. Schunemann[2], Vadim Smirnov[3], Heinar Hoogland[4,5], Ronald Holzwarth[4], Olivier Chalus[6], Christophe Simon-Boisson[6], Jens Biegert[1,7]; *[1]ICFO-Institut de Ciences Fotoniques, Spain; [2]BAE Systems, USA; [3]OptiGrate Corp., USA; [4]Menlo Systems GmbH, Germany; [5]Dept. of Physics, Friedrich-Alexander Univ. Erlangen, Germany; [6]THALES Optronique S.A.S., Laser Solutions Unit, France; [7]Institució Catalana de Recerca i Estudis Avançats (ICREA), Spain.* We generate 260 μJ energy optical pulses at 7 μm with an OPCPA pumped by an optically synchronized 2 μm picosecond CPA system. The mid-IR pulses exhibit a bandwidth supporting sub-4 optical cycle duration.

SW4O.6 • 16:45
High Power, Phase-Coherent Multi-Color Source from UV to Mid-IR for Femtosecond-Resolved Pump-Probe Experiments, Matthias Baudisch[1], Michael Hemmer[1], Jens Biegert[1,2]; *[1]ICFO - Institut de Ciencies Fotoniques, Spain; [2]ICREA - Institució Catalana de Recerca i Estudis Avançats, Spain.* We present a parametric source operating at 160 kHz repetition rate providing simultaneously phase-coherent, femtosecond pulses at 3100, 1620, 810, 405 and 270 nm wavelengths with energies suitable for strong-field pump-probe experiments.



CLEO: QELS-Fundamental Science

FW4A • Quantum Computing—Continued

FW4A.6 • 17:00
Discorrelated Quantum States, Tim J. Bartley[1,2], Evan Meyer-Scott[3], Lynden Shalm[1]; [1]*National Insititute of Standards and Technology, USA;* [2]*Applied Physics, Univ. of Paderborn, Germany;* [3]*Inst. for Quantum Computing and Dept. of Physics & Astronomy, Univ. of Waterloo, Canada*. Using the building blocks of quantum optics - single photons, coherent states, beam splitters and projective measurement - we construct a two-mode quantum state for which coincident photon number terms in each mode are removed.

FW4A.7 • 17:15
Hybridization: When two wrongs make a right, William Munro[1], Yuichiro Matsuzaki[1], Hiraku Toida[1], Kosuke Kakuyanagi[1], Norikazu Mizuochi[3], Kae Nemoto[2], Kouichi Semba[2], Hiroshi Yamaguchi[1], Shiro Saito[1]; [1]*NTT Basic Research Labs, Japan;* [2]*National Inst. of Informatics, Japan;* [3]*Univ. of Osaka, Japan*. We show in this presentation how the coherence properties of single electron spins (or ensembles) can be dramatically increased just by it coupling with the superconducting qubit, that is two systems with limited coherence properties can form a combined system with a much longer coherence time.

FW4B • Integrated Structures for Quantum Optics—Continued

FW4B.6 • 17:00
Proposed Method of Optical Spin Readout in a Quantum Dot using the AC Stark Effect, Edward Flagg[1]; [1]*Dept. of Physics and Astronomy, West Virginia Univ., USA.* We propose a method to read-out the spin-state of an electron in a quantum dot in a Voigt geometry magnetic field via cycling transitions induced by the AC Stark effect.

FW4B.7 • 17:15
Measurement of Nonlinear Polariton Dispersion Curves Reveals the Tavis-Cummings Quantum Ladder, Travis Autry[1,2], Gael Nardin[1], Daniele Bajoni[3], Aristide Lemaître[4], Sophie Bouchoule[4], Jacqueline Bloch[4], Steven Cundiff[1,2]; [1]*JILA, USA;* [2]*Physics, Univ. of Colorado, USA;* [3]*Dipartimento di Ingegneria Industriale e dell'Informazione, Università di Pavia, Italy;* [4]*Laboratoire de Photonique et Nanostructures, NRS, France*. The nonlinear dispersion curves of the Tavis-Cummings quantum ladder are measured for exciton-polaritons. This quantum ladder remixes the exciton-cavity system in a manner analogous to a quantum beam splitter, realizing a light-matter n=2 nOOn state.

FW4C • Novel Optics—Continued

FW4C.7 • 17:00
Dielectric Metasurface Analogue of Electromagnetically Induced Transparency, Yuanmu Yang[1], Ivan I. Kravchenko[2], Dayrl Briggs[2], Jason Valentine[1]; [1]*Vanderbilt Univ., USA;* [2]*Center for Nanophase Materials Sciences, Oak Ridge National Lab, USA*. We present an experimental demonstration of a metasurface analogue of electromagnetically induced transparency based on silicon instead of lossy plasmonic metal, therefore achieved a record-high quality factor of 483 and a sensing figure-of-merit of 103.

FW4C.8 • 17:15
Plasmonic Metasurface for Efficient Laser-Driven Particle Acceleration, Doron Bar-Lev[1], Jacob Scheuer[1]; [1]*Dept. of Physical Electronics, School of Electrical Engineering, Tel Aviv Univ., Israel.* A laser-driven particle accelerator based on plasmonic metasurfaces is proposed and analyzed. The concept utilizes a unique slot-patch nanoantennas combination and is shown to support ultra-short laser pulses while providing high acceleration gradients reaching 11.6GV/m.

FW4D • Nonlinear Fiber Effects—Continued

FW4D.7 • 17:00 Invited
Temporal cloaking enhancements for optical communication, Joseph M. Lukens[1], Andrew J. Metcalf[1], Daniel E. Leaird[1], Andrew M. Weiner[1]; [1]*Purdue Univ., USA*. We demonstrate a temporal cloak with the capability to simultaneously hide and transmit optical data, as well as prevent corruption by an interfering event. Our results significantly expand the potential of time cloaking in telecommunications.

16:30–18:30 Exhibit Happy Hour and International Year of Light Celebration, *Exhibit Hall*

18:30–20:30 JW5A • Plenary Session III: International Year of Light Celebration and Awards Ceremony, *Grand Ballroom*

INTERNATIONAL YEAR OF LIGHT 2015

CLEO: QELS-Fundamental Science

FW4E • Plasmonic Metasurfaces and Metamaterials—Continued

FW4E.6 • 17:00
Metasurface Engaged with a Plasmonic Spiral Achieve Super Functional Lensing, Grisha Spektor[1], Asaf David[1], Guy Bartal[1], Meir Orenstein[1]; [1]*Technion, Israel Inst. of Technology, Israel*. We realized metasurface spiral plasmonic lenses, mitigating efficiency and functionality issues of conventional plasmonic lenses. The lens enhances the efficiency of linear-polarization-invariant focusing and enhances even further the efficiency of high contrast, circular dichroic detection.

FW4E.7 • 17:15
Creating Surface Plasmon Orbital Angular Momentum in a Gold Metasurface, Ching-Fu Chen[1], Chen-Ta Ku[1], Ming-Yang Pan[2], Pei-Kuen Wei[2], Chen-Bin Huang[1]; [1]*Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan;* [2]*Research Center for Applied Sciences, Academia Sinica, Taiwan*. Nanocavities inscribed in a gold thin film is optimized and arranged to form a metasurface. We demonstrate both numerically and experimentally that surface plasmon vortex carrying orbital angular momentum can be generated under linearly-polarized optical excitation.

CLEO: Science & Innovations

SW4F • SW4F • Micro and Nano Lasers—Continued

SW4F.6 • 17:00
Wide and reversible tuning of an individual nanowire laser using hydrostatic pressure, Sheng Liu[1,2], Changyi Li[3], Jeffrey Figiel[1], Igal Brener[1,2], Steven Brueck[3], George Wang[1]; [1]*Sandia National Labs, USA;* [2]*The Center for Integrated Nanotechnologies, USA;* [3]*Center for High Technology Materials, USA*. We report wide, continuous, and reversible tunable lasing between 367-337nm from single GaN nanowires by applying hydrostatic pressure up to ~7GPa. The pressure coefficients observed are 40% larger compared with bulk GaN or GaN microstructures.

SW4F.7 • 17:15
Room Temperature Continuous Operation of Sub-μW Threshold Nanobeam Laser, Hoon Jang[1], Indra Karnadi[1], Putu Pramudita[1], Yong-Hee Lee[1]; [1]*Physics, KAIST, Korea*. Nanobeam laser with threshold 230 nW is demonstrated in continuous-wave operation at room-temperature. This is achieved by reducing the size of active medium to 1.5×0.3×0.02 μm^3 via selective wet-etching of a single quantum well layer.

SW4G • Comb Technology—Continued

SW4G.7 • 17:00
Spectrally Flattened, Broadband Astronomical Frequency Combs, Rafael Probst[1], Yuanjie Wu[1], Tilo Steinmetz[2], Sebastian Stark[2], Theodor Hänsch[1], Thomas Udem[1], Ronald Holzwarth[1,2]; [1]*Max-Planck-Institut für Quantenoptik, Germany;* [2]*Menlo Systems GmbH, Germany*. We demonstrate the generation of broadband, visible astronomical frequency combs with flattened spectral envelopes. The flat-top region of the spectrum ranges from about 450 to 730 nm, at mode spacings of 18 and 25 GHz.

SW4G.8 • 17:15
A low-dispersion Fabry-Perot cavity for generation of a 30 GHz astrocomb spanning 140 nm, Daniel Hackett[1,2], Gabriel Ycas[1,2], Scott Diddams[2,1]; [1]*Univ. of Colorado Boulder, USA;* [2]*National Inst. of Standards and Technology, Boulder, USA*. For broadband filtering of a frequency comb, ultra-low dispersion mirrors with reflectivity 99.2 - 99.6% are fabricated and characterized. A Fabry-Perot cavity is constructed, and used to filter 140 nm of optical bandwidth to 30 GHz.

CLEO: Applications & Technology

AW4H • A&T Topical Review on Advances in Molecular Imaging II—Continued

AW4H.4 • 17:00 Invited
Ultra High-Resolution Photoacoustic Microscopy Using a Novel Transient Absorption Technique, Brian E. Applegate[1]; [1]*Texas A&M Univ., USA*. We have recently harnessed transient absorption for ultrahigh resolution photoacoustic microscopy, achieving nearly an order of magnitude improvement in axial resolution. We will discuss recent progress in system development and time resolved measurements for hemoglobin oxygen saturation.

16:30–18:30 Exhibit Happy Hour and International Year of Light Celebration, *Exhibit Hall*

18:30–20:30 JW5A • Plenary Session III: International Year of Light Celebration and Awards Ceremony, *Grand Ballroom*

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CLEO: Science & Innovations

SW4I • Novel Materials for On-chip Photonics—Continued

SW4I.6 • 17:00
Electrically Controllable Extraordinary Optical Transmission in Metallic Surface Gratings on VO_2, Junho Jeong[1], Arash Joushaghani[1], Suzanne Paradis[2], David Alain[2], Joyce K. Poon[1]; *[1]Univ. of Toronto, USA; [2]Defence Research and Development Canada, Canada.* We present metallic gratings on a VO_2 film with electrical control of the transmission spectrum. The extraordinary optical transmission was tunable by up to a factor of 2.75X to achieve an extinction ratio of 26 dB/μm.

SW4I.7 • 17:15
Lithium Niobate on Insulator (LNOI) Grating Couplers, Mohamed Mahmoud[1], Siddhartha Ghosh[1], Gianluca Piazza[1]; *[1]Carnegie Mellon Univ., USA.* One-dimensional grating couplers and waveguides are fabricated in 500 nm X-cut Lithium Niobate thin film making use of the Lithium Niobate on Insulator (LNOI) platform. Single coupler exhibit -12 dB peak insertion loss.

CLEO: Applications & Technology

AW4J • Symposium on Photonics in Surgery II—Continued

AW4J.5 • 17:00
Towards Endoscopic Image-Guided Laser Coagulation Using a Double-Clad Fiber Coupler, Kathy Beaudette[1,2], Jian Ren[2], Martin Villiger[2], Mathias Strupler[1], Wendy-Julie Madore[1], Milen Shishkov[2], Nicolas Godbout[1], Brett Bouma[2,3], Caroline Boudoux[1]; *[1]Ecole Polytechnique de Montreal, Canada; [2]Wellman Center for Photomedicine, Harvard Medical School and Massachusetts General Hospital, USA; [3]Division of Health Sciences and Technology, Harvard-MIT, USA.* We demonstrate a double-clad fiber (DCF) based system using a novel DCF coupler to simultaneously combine optical coherence tomography and laser coagulation. Such a system allows monitoring of dynamic thermal processes during laser irradiation, thus enabling image-guided laser marking and therapy.

AW4J.6 • 17:15
Wide-field Imaging of Pathology Slides using Lensfree On-chip Microscopy, Yibo Zhang[1], Alon Greenbaum[1], Alborz Feizi[1], Ping-Luen Chung[1], Wei Luo[1], Shivani R. Kandukuri[1], Aydogan Ozcan[1]; *[1]UCLA, USA.* Three-dimensional lensfree imaging of pathology slides over a large field-of-view is achieved using multi-height phase recovery that incorporates transport-of-intensity equation and rotational field transformations to overcome stagnation in iterative image reconstruction.

AW4K • A&T Topical Review on Optofluidics Microsystems II—Continued

AW4K.5 • 17:00 Invited
What Is the Microfluidics Doing in Electrowetting Displays?, Tao He[1], mingliang jin[1], xia chen[1], guofu zhou[1], Lingling Shui[1]; *[1]Inst. of Electronic Paper Displays, South China Academy of Advanced Optoelectronics, South China Normal Univ., China.* Electrowetting display (EWD) is realized by electrically driven fluidic flow in micro-pixels. The fluidic properties including interfacial tension, viscosity and conductivity have been investigated to understand the dual-phase microfluidic behavior in micro-pixels of EWDs.

CLEO: Science & Innovations

SW4L • Nonlinear Fiber Optics—Continued

SW4L.6 • 17:00
Addressing a cavity with patterns at ultra-wideband detune, Xiaoming Wei[1], Yiqing Xu[1], Sisi Tan[1], Shanhui Xu[2], Zhongmin Yang[2], Kevin K. Tsia[1], Kenneth K. Y. Wong[1]; *[1]Dept. of Electrical and Electronic Engineering, The Univ. of Hong Kong, Hong Kong; [2]Inst. of Optical Communication Materials and State Key Lab of Luminescent Materials and Devices, South China Univ. of Technology, China.* We demonstrate an amplified fiber ring cavity at telecommunication window addressed by optical pattern at 1.0 μm. A storage time longer than 38 μs and an ultra-wideband wavelength conversion of ~500 nm have been obtained.

SW4L.7 • 17:15
Critical Review of the Gain Factor of 16 for Calculation of the Raman Threshold in Fibers, Rainer Engelbrecht[1]; *[1]Inst. of Microwaves and Photonics, Friedrich-Alexander-Univ. Erlangen-Nuremberg (FAU), Germany.* Analytic approximations yielding the well-known gain factor of 16 in formulas for SRS threshold in fibers are compared to rigorous simulations. This factor is shown to be larger for short and modern fibers, as used for high-power lasers.

16:30–18:30 Exhibit Happy Hour and International Year of Light Celebration, *Exhibit Hall*

18:30–20:30 JW5A • Plenary Session III: International Year of Light Celebration and Awards Ceremony, *Grand Ballroom*

INTERNATIONAL YEAR OF LIGHT 2015

CLEO: Science & Innovations

SW4M • SDM, OAM & Free-Space Communications—Continued

SW4M.5 • 17:00
Experimental Demonstration of a 400-Gbit/s Free Space Optical Link Using Multiple Orbital-Angular- Momentum Beams with Higher Order Radial Indices, Long Li[1], Guodong Xie[1], Yan Yan[1], Yongxiong Ren[1], peicheng liao[1], Nisar Ahmed[1], Zhe Zhao[1], Changjing Bao[1], Zhe Wang[1], Nima Ashrafi[2,3], Solyman Ashrafi[2], moshe tur[4], alan willner[1]; *[1]Univ. of Southern California, USA; [2]NxGen Partners, USA; [3]Univ. of Texas at Dallas, USA; [4]Tel Aviv Univ., Israel*. We report a transmission of 400 Gbit/s signal over a four-channel, 1-meter mode-division-multiplexed free space optical communication link using multiple orbital-angular-momentum beams with non-zero radial indices, achieving a power penalty less than 6 dB.

SW4N • Novel Devices for Communications and Signal Processing—Continued

SW4N.7 • 17:00
Thermal-tuned optical pulse shaper for arbitrary waveform generation with integrated waveguides, Shasha Liao[1], Yunhong Ding[2], Ting Yang[1], Hailong Zhou[1], Xiaolin Chen[1], Jianji Dong[1], Xinliang Zhang[1]; *[1]Wuhan National Lab for Optoelectronics, China; [2]Technical Univ. of Denmark, Denmark*. We demonstrate an on-chip thermal-tuned optical pulse shaper based on the four-path finite impose response (FIR). Four typical waveform are demonstrated by tuning the phase and amplitude of each path.

SW4N.8 • 17:15
All-Optical Flip-Flop Memory Based on V-cavity Laser, Yingchen Wu[1], Yu Zhu[1], Xiaolu Liao[1], Jian-Jun He[1]; *[1]Zhejiang Univ., China*. We experimentally demonstrate an all-optical flip-flop memory based on the bistability of tunable V-cavity laser with short storing and erasing response time of about 150ps and 159ps, respectively.

SW4O • Broadband and Ultrafast Parametric Sources—Continued

SW4O.7 • 17:00
Front-End of Yb-based High-Energy Optical Waveform Synthesizer, Huseyin Cankaya[1,2], Anne-Laure Calendron[1,2], Giovanni Cirmi[1,2], Franz Kaertner[1,3]; *[1]Center for Free-Electron Laser Science (CFEL), Deutsches Elektronen Synchrotron (DESY), Germany; [2]Centre for Ultrafast Imaging and Dept. of Physics, Universitaet Hamburg, Germany; [3]Dept. of Electrical Engineering and Computer Science and Research Lab of Electronics, MIT, USA*. We demonstrate a front-end of an Yb-based passively CEP-stable, two-octave wide, two-channel optical parametric synthesizer driven by slightly sub-picosecond pump pulses from a multi-mJ regenerative amplifier at 1 kHz.

SW4O.8 • 17:15
Quarter-harmonic generation of femtosecond pulses at 4.18 μm from a mode-locked Yb:fiber laser, Alireza Marandi[1], Kirk Ingold[1], Robert L. Byer[1]; *[1]Stanford Univ., USA*. We report generation of 104 mW of 110-fs pulses at 4.18 μm using two cascaded sub-harmonic PPLN-based optical parametric oscillators pumped by a 950-mW Yb:fiber mode-locked laser at 250 MHz with expected intrinsic phase-locking.

16:30–18:30 Exhibit Happy Hour and International Year of Light Celebration, *Exhibit Hall*

18:30–20:30 JW5A • Plenary Session III: International Year of Light Celebration and Awards Ceremony, *Grand Ballroom*

Executive Ballroom 210A	Executive Ballroom 210B	Executive Ballroom 210C	Executive Ballroom 210D

CLEO: QELS-Fundamental Science

08:00–10:00
FTh1A • Quantum Entanglement III
Presider: Antonio Acin; ICFO - Inst. of Photonic Sciences, Spain

FTh1A.1 • 08:00
Noise Figure Improvement and Quantum Information Tapping in a Fiber Optical Parametric Amplifier with Correlated Quantum Fields, Xiaoying Li[1], Xueshi Guo[1], Nannan Liu[1], Yuhong Liu[1], Z. Y. Ou[2]; *[1]Tianjin Univ., China; [2]Indiana Univ.-Purdue Univ., USA*. We demonstrate a low noise fiber-optical parametric amplifier (FOPA), with noise figure 0.7dB lower than a regular FOPA having vacuum at the unused input port. The scheme can be used as a quantum information tap.

FTh1A.2 • 08:15
Propagation of Two-qubit States using Interference in a Distributed Phase Sensitive Amplifier, Anjali Agarwal[1], James M. Dailey[1], Paul Toliver[1], Nicholas A. Peters[1]; *[1]Applied Communication Sciences, USA*. We experimentally demonstrate transmission of non-orthogonal two-qubit states in a $\chi^{(3)}$-based optical phase-sensitive amplifier (OPSA). State analysis shows that the OPSA improves the transmission probability of both non-orthogonal states without measurable degradation in two-photon visibility.

FTh1A.3 • 08:30
Effects of Distributed Amplifiers on Quantum Coherence, James D. Franson[1], Brian T. Kirby[1]; *[1]Univ. of Maryland Baltimore County, USA*. The propagation of coherent states using a network of distributed amplifiers is analyzed. This technique can be used to calculate the coherence of other quantum states such as Schrodinger cats.

08:00–10:00
FTh1B • Quantum Control and Precision Measurements
Presider: Tessa Champion, Univ. of Oxford, UK

FTh1B.1 • 08:00
Quantum Zeno Dynamics with Rydberg Atoms, Adrien FACON[1]; *[1]Lab. Kastler Brossel, Collège de France, CNRS, ENS-PSL Research Univ., UPMC-Sorbonne, France*. The back-action of a quantum measurement with a degenerate eigenvalue confines the evolution of the system inside the corresponding eigenspace. Using the Stark sublevels of a Rydberg atom, we report the first observation of such quantum Zeno dynamics in a non-trivial 51-dimension Hilbert space.

FTh1B.2 • 08:15
Feedback Cooling of a Nanomechanical Oscillator to Near its Quantum Ground State, dalziel wilson[1], tobias kippenberg[1], Vivishek Sudhir[1], Nicolas Piro[1], Ryan Schilling[1]; *[1]epfl, Switzerland*. Cavity-enhanced interferometry is used to resolve the displacement of a 4.3 MHz nanobeam oscillator with an imprecision 40 dB below that at the standard quantum limit. Employing this measurement as an error signal, radiation pressure is used to feedback cool the oscillator to 5.3 mechanical quanta.

FTh1B.3 • 08:30
Search For a Permanent Electric Dipole Moment (EDM) of ^{225}Ra Atom, Mukut Kalita[1,3], Michael Bishof[1], Kevin Bailey[1], matthew Dietrich[5], John Greene[1], Roy Holt[1], Wolfgang Korsch[3], Zheng-Tian Lu[1,2], Nathan Lemke[1], Peter Mueller[1], Thomas O'Connor[1], Richard Parker[1,2], Jaideep Taggart Singh[4]; *[1]Argonne National Lab, USA; [2]Univ. of Chicago, USA; [3]Univ. of Kentucky, USA; [4]Michigan State Univ., USA; [5]Northwestern Univ., USA*. We are searching for a permanent EDM of the ^{225} Ra atom. Recently we have observed spin precession of ^{225} Ra atoms in parallel electric and magnetic fields.

08:00–10:00
FTh1C • High-field and XFEL Physics
Presider: Todd Ditmire; Univ. of Texas Austin, USA

FTh1C.1 • 08:00 Invited
Getting Beyond Unity Fusion Fuel Gain in an Inertially Confined Fusion Implosion, Omar Hurricane[1]; *[1]Lawrence Livermore National Lab, USA*. In this talk, we will discuss the progress towards ignition on the National Ignition Facility (NIF) at Lawrence Livermore National Lab (LLNL) in Northern California. We will cover the some of the setbacks encountered during the progress of the research at NIF, but also cover the great advances that have been made including the achievements of greater than unity fusion 'fuel gain' and alpha-heating dominated fusion plasmas. The research strategy for the future will also be discussed.

FTh1C.2 • 08:30
Laser Generation of Scaled Astrophysical Blast Waves in a Dynamically-Significant Magnetic Field, Nathan Riley[1], Matt Wisher[1,2], Sean Lewis[1,2], Craig Wagner[1], Vincent Minello[1], Roger Bengtson[1], Todd Ditmire[1]; *[1]Univ. of Texas at Austin, USA; [2]Sandia National Labs, USA*. We report preliminary results on the stability of a magnetized laser-launched blast wave scaled to simulate a supernova remnant. Magnetic fields appear to suppress the Vishniac overstability at high mode numbers, possibly facilitating gravitational star formation.

08:00–10:00
FTh1D • Nonlinear Resonators and Optical Frequency Combs
Presider: Marco Peccianti; Univ. of Sussex, UK

FTh1D.1 • 08:00 Invited
Temporal Cavity Solitons: From Fiber Resonators to Microresonators, Stephane Coen[1], Jae K. Jang[1], Stuart G. Murdoch[1], Miro Erkintalo[1]; *[1]Univ. of Auckland, New Zealand*. We will present our latest experiments with temporal cavity solitons, including writing/erasing, temporal tweezing, merging, annihilation, and spontaneous excitation. We will also highlight their relevance in the context of microresonator Kerr frequency combs.

FTh1D.2 • 08:30
Monolithic microresonator for simultaneous lasing feedback and intracavity hyperparametric oscillation, Zhenda Xie[2,1], wei liang[3], Anatoliy A. Savchenkov[3], James Mcmillan[1], jan Burkhart[1], Vladimir S. Ilchenko[3], Andrey B. Matsko[3], Lute Maleki[3], Chee Wei Wong[2,1]; *[1]Columbia Univ., USA; [2]Univ. of California, Los Angeles, USA; [3]OEwaves Inc., USA*. We demonstrate simultaneous lasing and parametric oscillation with high-Q (> 10^{10}) MgF_2 monolithic microresonators. Stable lasing around 698nm is achieved with sub-25kHz linewidth and 8.8nm tuning range. Multi-pair hyperparametric oscillation is observed over 137.2THz span.

Executive Ballroom 210E	Executive Ballroom 210F	Executive Ballroom 210G	Executive Ballroom 210H
CLEO: QELS-Fundamental Science	CLEO: Science & Innovations		

08:00–10:00
FTh1E • Electron and Ultrafast Probing of Plasmonic Nanostructures

Presider: Christoph Lienau; Carl V. Ossietzky Univ. Oldenburg, Germany

FTh1E.1 • 08:00
Interferometric Plasmon Propagation and Lensing with Nanohole Arrays in Gold Films: Visualization by Nonlinear Photoemission Electron Microscopy, Wayne Hess[1]; [1]*Pacific Northwest National Lab, USA.* Nonlinear photoemission electron microscopy, of nanohole arrays litho-graphically etched in gold films, is used to map propagating surface plasmon polaritons (SPPs). The recorded photoemission patterns are attributed to interferences between SPPs launched from the individual nanoholes.

FTh1E.2 • 08:15
Advanced Disc-Ring Optical Nanoantennas Investigated by Photoelectron Emission Microscopy (PEEM), Thomas Kaiser[1,2], Matthias Falkner[1,2], Jing Qi[3,2], Michael Steinert[1,2], Christoph Menzel[1,2], Carsten Rockstuhl[4,5], Thomas Pertsch[1,2]; [1]*Inst. of Applied Physics, Friedrich-Schiller-Universität, Germany;* [2]*Abbe Center of Photonics, Friedrich-Schiller-Universität, Germany;* [3]*Inst. of Condensed Matter Theory and Solid State Optics, Friedrich-Schiller-Universität, Germany;* [4]*Inst. of Theoretical Solid State Physics, Karlsruhe Inst. of Technology, Germany;* [5]*Inst. of Nanotechnology, Karlsruhe Inst. of Technology, Germany.* We theoretically and experimentally investigate circular plasmonic disc nanoantennas enhanced in their performance by a surrounding Bragg grating ring structure. PEEM investigations are demonstrated to provide unprecedented insights into the field localization and enhancement.

FTh1E.3 • 08:30 Invited
Electron-Light Interaction in Optical Near-Fields studied by Ultrafast Transmission Electron Microscopy, Armin Feist[1], Katharina E. Echternkamp[1], Jakob Schauss[1], Sergey V. Yalunin[1], Sascha Schäfer[1], Claus Ropers[1]; [1]*IV. Physical Inst., Univ. of Göttingen, Germany.* Photon-induced scattering of swift electrons with confined light is studied by ultrafast transmission electron microscopy (UTEM) and employed to locally map optical near-fields. Fluence-dependent kinetic energy spectra reveal quantum coherent scattering features.

08:00–10:00
STh1F • Mode Division Multiplexing

Presider: Takahide Sakamoto; NICT, Japan

STh1F.1 • 08:00
Efficient silicon PIC mode multiplexer using grating coupler array with aluminum mirror for few-mode fiber, Yunhong Ding[1], Kresten Yvind[1]; [1]*DTU Fotonik, Dept. of Photonics Engineering, Technical Univ. of Denmark, Denmark.* We demonstrate a silicon PIC mode multiplexer using grating couplers. An aluminum mirror is introduced for coupling efficiency improvement. A highest coupling efficiency of -10.6dB with 3.7dB mode dependent coupling loss is achieved.

STh1F.2 • 08:15
Integrated Switch for Mode-Division Multiplexing (MDM) and Wavelength-Division Multiplexing (WDM), Brian Stern[1], Xiaoliang Zhu[2], Christine Chen[2], Lawrence Tzuang[1], Jaime Cardenas[1], Keren Bergman[2], Michal Lipson[1,3]; [1]*Cornell Univ., USA;* [2]*Columbia Univ., USA;* [3]*Kavli Inst. at Cornell for Nanoscale Science, USA.* We demonstrate the first integrated switch for mode-division multiplexing (MDM) and wavelength-division multiplexing (WDM). We show on-chip routing of four 10 Gb/s channels with <-20 dB crosstalk and 0.5-1.4 dB power penalty.

STh1F.3 • 08:30
Mode division multiplexing using chip-scale silicon coupled vertical gratings, George F. Chen[1], Ting Wang[1], Kelvin J. Ooi[1], Arthur K. Chee[2], Lay Kee Ang[1], D. T. H. Tan[1]; [1]*Singapore Univ of Technology and Design, Singapore;* [2]*Massachusetts Insitute of Technology, USA.* Mode division multiplexing of modes in a silicon waveguide supporting three optical modes is demonstrated in the silicon on insulator platform. The extinction ratio is also observed to increase from 5 dB to 15dB and >25dB as mode order increases, implying an increasing cross coupling coefficient.

08:00–10:00
STh1G • Glass and Rare Earth Doped Materials

Presider: Thomas Murphy; Univ. of Maryland at College Park, USA

STh1G.1 • 08:00
Properties of Gallium Lanthanum Sulphide Glass, Paul Bastock[1], Chris Craig[1], Khouler Khan[1], Ed Weatherby[1], Jin Yao[1], Daniel W. Hewak[1]; [1]*Univ. of Southampton, UK.* A series of gallium lanthanum sulphide (GLS) glasses has been studied in order to ascertain properties across the entire glass forming region. This is the first comprehensive study of GLS glass over a wide compositional range.

STh1G.2 • 08:15
Fluorescence in Erbium Doped Gallium Lanthanum Sulphide: Potential for mid-IR Waveguide Laser, Giorgos Demetriou[1], Fiona Thorburn[1], Adam Lancaster[1], Chris Craig[2], Ed Weatherby[2], Daniel W. Hewak[2], Ajoy Kar[1]; [1]*Inst. of Photonics and Quantum Sciences, Heriot Watt Univ., UK;* [2]*Optoelectronics Research Centre, Univ. of Southampton, UK.* Fluorescence is reported in waveguides fabricated via the ultrafast laser inscription technique in Erbium doped Gallium Lanthanum Sulphide (Er^{3+}:GLS) for mid-infrared laser applications. The pump wavelength was 980nm leading to mid-infrared transition at 2.75 μm.

STh1G.3 • 08:30
Photo-Induced Tuning of Chalcogenide-on-Silicon Photonic Integrated Circuits, Ran Califa[1], Hadar Genish[1], Dvir Munk[1], Yuri Kaganovskii[1], Idan Bakish[1], Michael Rosenbluh[1], Avi Zadok[1]; [1]*Bar-Ilan Univ., Israel.* Silicon photonic devices are tuned by selective photo removal of upper chalcogenide glass layers. Phase delays in cascaded interferometer filters and couplers of ring resonators are arbitrarily adjusted. Responses remain stable following trimming.

08:00–10:00
STh1H • Nonlinear Optics for Advanced Measurements and Characterization

Presider: Derryck Reid; Heriot-Watt Univ., UK

STh1H.1 • 08:00
Direct Measurement of Plasma Mirror Expansion for Controlled Laser Driven Electron and Harmonic Beams, Maimouna Bocoum[1], Frederick Bohle[1], Benoit beaurepaire[1], Aline Vernier[1], Aurelie Jullien[1], Jérôme Faure[1], Rodrigo B. Lopez-Martens[1]; [1]*91762, Laboratoire d'Optique Appliquée, France.* We present a new method of visualizing plasma expansion at the surface of a plasma mirror over a few fractions of laser wavelength and validate it by selectively generating high-order harmonics or fast electrons.

STh1H.2 • 08:15
Ultrabroadband Mid-Infrared Pump-Probe Spectroscopy using Chirped-Pulse Upconversion, Hideto Shirai[1], Tien Tien Yeh[2], Yutaka Nomura[1], Chih Wei Luo[2], Takao Fuji[1]; [1]*Inst. for Molecular Science, Japan;* [2]*Dept. of Electrophysics, National Chiao Tung Univ., Taiwan.* We demonstrated ultrabroadband mid-infrared pump-probe spectroscopy combined with chirped-pulse upconversion in a gas. Ultrafast reflectivity-change signal of an intrinsic germanium was observed in the region from 200 to 5000 cm^{-1}.

STh1H.3 • 08:30
Relaxation dynamics of the OH stretching overtones in isolated HDO molecules observed by IR pump-repump-probe spectroscopy, Daniel Hutzler[1], Jasper Werhahn[1], Rupert Heider[1], Maximilian Bradler[2], Reinhard Kienberger[1], Eberhard Riedle[2], Hristo Iglev[1]; [1]*Technische Universität München, Germany;* [2]*Ludwig-Maximilian-Universität München, Germany.* We report on a novel, purely vibrational pump-repump-probe spectroscopy technique to access the overtones of the OH stretching in isolated HDO molecules. Approaching higher-lying states, a continuous decrease of the energy separation and a reduction of the respective lifetimes is observed.

Meeting Room 211 B/D

CLEO: Science & Innovations

08:00–10:00
STh1I • Photodetectors
Presider: To be Determined

STh1I.1 • 08:00
Tandem Photodetectors Containing Silicon Nanowires with Selective Spectral Absorption, Hyunsung Park[1], Kenneth B. Crozier[1,2]; *[1]School of Engineering and Applied Sciences, Harvard Univ., USA; [2]Dept. of Electrical and Electronic Engineering, Univ. of Melbourne, Australia.* We fabricate a vertically stacked photodetector device containing silicon nanowire photodetectors formed above a silicon substrate that also contains a photodetector. The substrate photodetector converts light not absorbed by the nanowires to photocurrent.

STh1I.2 • 08:15
Waveguide-Coupled Superconducting Nanowire Single-Photon Detectors, Andrew Beyer[1], Ryan Briggs[1], Francesco Marsili[1], Justin D. Cohen[2], Sean M. Meenehan[2], Oskar J. Painter[2], Matthew Shaw[1]; *[1]Jet Propulsion Lab, USA; [2]California Inst. of Technology, USA.* We have demonstrated WSi-based superconducting nanowire single-photon detectors coupled to SiN_x waveguides with integrated ring resonators. This photonics platform enables the implementation of robust and efficient photon-counting detectors with fine spectral resolution near 1550 nm.

STh1I.3 • 08:30
Series-Nanowire Photon Number Resolving Detector Counting up to 24 Photons, Francesco Mattioli[1], Zili Zhou[2], Alessandro Gaggero[1], Rosalinda Gaudio[2], Roberto Leoni[1], Andrea Fiore[2]; *[1]Ist di Fotonica e Nanotecnologie-IFN CNR, Italy; [2]Univ. of Technology, COBRA Research Inst., Netherlands.* A 24-pixel photon-number-resolving-detector (PNRD) based on superconducting nanowires in a series configuration is demonstrated. Distinct output levels corresponding to the detection of 0-25 photons are observed, due to the high signal-to-noise ratio.

Meeting Room 212 A/C

CLEO: Applications & Technology

08:00–09:45
ATh1J • Biomedical Imaging and Sensing II
Presider: Audrey Ellerbee; Stanford Univ., USA

ATh1J.1 • 08:00
Label-free imaging of biological tissues with nonlinear photothermal microscopy, JinPing He[1,2], Jun Miyazaki[1,2], Nan Wang[1,2], Takayoshi Kobayashi[1,2]; *[1]Univ. of Electro-Communications, Japan; [2]JST,CREST, Japan.* Nonlinear photothermal microscopy has been applied in imaging of mouse melanoma and spinal cord without any staining. The resolution is higher compared with linear mechanism.

ATh1J.2 • 08:15
Transmittance of *Ex vivo* Bovine Lens Capsule from 800 cm^{-1} to 40000 cm^{-1}, Hanh N. Le[1], Do-Hyun Kim[2], Moinuddin Hassan[2], William Calhoun[2], Yong Huang[1], Ilko Ilev[2], Jin U. Kang[1]; *[1]Johns Hopkins Univ., USA; [2]Food and Drug Administration, Center for Devices and Radiological Health, USA.* Here we present detailed transmission measurements of ex-vivo lens capsules from 40,000 cm^{-1} to 800 cm^{-1}. Time-dependent measurements were also performed to eliminate water absorption.

ATh1J.3 • 08:30
MEMS-Based Shadowless-illuminated variable-angle TIRF (SIVA-TIRF), Xiaoshuai Huang[1]; *[1]Inst of Molecular Medicine, Peking Univ, USA.* We demonstrate a new MEMS-Based Shadowless-illuminated variable-angle TIRF (SIVA-TIRF), which can realize two-plane, two-color TIRF imaging at the speed of 25Hz.

Meeting Room 212 B/D

08:00–09:45
ATh1K • Spectroscopy and Metrology
Presider: To be Determined

ATh1K.1 • 08:00 Invited
Monolithic Quantum Cascade Laser Arrays for Broadband Portable Infrared Spectroscopy, Mark F. Witinski[2,1], Christian Pflügl[2]; *[1]Harvard Univ., USA; [2]Eos Photonics, USA.* Eos manufactures arrays of DFB QCLs, with each element at a different wavelength than its neighbor. In spectroscopy systems, such as standoff and in situ analyzers, this increases sensitivity, allowing for fast all-electronic wavelength tuning.

ATh1K.2 • 08:30
Enhancement of Signal to Noise in Mid-IR Photothermal Spectroscopy by Optimization of Fiber Probe Lasers, Atcha Totachawattana[1], Hui Liu[1], Shyamsunder Erramilli[1], Michelle Y. Sander[1]; *[1]Boston Univ., USA.* Continuous-wave and mode-locked fiber lasers are incorporated into label-free mid-IR photothermal spectroscopy. Optimization of probe laser parameters leads to significant enhancement in the signal to noise ratio and the peak-to-baseline contrast.

Marriott Salon I & II

CLEO: Science & Innovations

08:00–10:00
STh1L • Mode-Locked Fiber Lasers
Presider: Andy Chong; University of Dayton, USA; Deutsched Elektronen Syncrhtron (DESY); Germany

STh1L.1 • 08:00 Invited
Ultralow-Jitter Mode-Locked Fiber Lasers and Their Applications, Jungwon Kim[1]; *[1]Korea Advanced Inst of Science & Tech, Korea.* We present the most recent progress in the design and implementation of sub-femtosecond timing jitter mode-locked fiber lasers and their applications in ultralow-noise microwave signal generation, synchronization and remote transfer.

STh1L.2 • 08:30
High power synchronously pumped femtosecond Raman fiber laser, Dmitriy Churin[1], Joshua Olson[1], Robert Norwood[1], Nasser Peyghambarian[1], Khanh Kieu[1]; *[1]Univ. of Arizona, USA.* We report a synchronously pumped femtosecond Raman fiber laser operating in normal dispersion regime. The laser produces chirped pulses with up to 18nJ energy, 0.76W average power, 88% efficiency, and pulse duration ~133fs after external compression.

Marriott Salon III	Marriott Salon IV	Marriott Salon V & VI

CLEO: Science & Innovations

08:00–10:00
STh1M • Beam Shaping for Optimized Laser-matter Interaction
Presider: Ya Cheng; Shanghai Inst. of Optics and Fine Mech., China

STh1M.1 • 08:00 Invited
Materials Processing based on Unconventional Femtosecond Laser Beams, Cyril Hnatovsky[1], Vladlen Shvedov[1], Wieslaw Krolikowski[1,2]; [1]*Australian National Univ., Australia;* [2]*Texas A & M Univ. at Qatar, Qatar.* We demonstrate the generation of femtosecond vector beams using a combination of a uniaxial and a biaxial crystal. The proposed beam synthesizer is achromatic and can withstand high light intensities.

STh1M.2 • 08:30
Tuning into Tyndall Windows, Benedikt Grover[1], Barmark Heshmat[1], Ramesh Raskar[1]; [1]*MIT, USA.* We report certain liquid mixtures that exhibit exotic Tyndall effects due to large contrast in refractive index modulation of their components. A sharp minimum in scattering enables these mixtures to notably modulate their optical diffusion. This can be applied in imaging, sensing, and displays.

08:00–10:00
STh1N • Frequency Conversion of Combs
Presider: Axel Ruehl; Deutsches Elektronen Synchrotron, Germany

STh1N.1 • 08:00
A Passively Phase-Locked Er:Fiber Frequency Comb:Free-Running Performance and Active Linewidth Narrowing, David Fehrenbacher[1], Philipp Sulzer[1], Denis Seletskiy[1], Alfred Leitenstorfer[1]; [1]*Dept. of Physics and Center for Applied Photonics, Univ. of Konstanz, Germany.* An offset-free frequency comb generated by difference frequency mixing is established and characterized. mHz-level direct locking of the repetition rate to ^{85}Rb and reference-limited linewidth narrowing via an extra-cavity electro-optic modulator are demonstrated.

STh1N.2 • 08:15
Offset-free supercontinuum frequency comb for optical clocks, Takuma Nakamura[1], Isao Ito[1,2], Alissa Silva[1,2], Shuntaro Tani[1], Yohei Kobayashi[1,2]; [1]*The Inst. for Solid State Physics, Japan;* [2]*Exploratory Research for Advanced Technology, Japan*. Difference-frequency mixing two portions of a broadened Yb:fiber laser spectrum leads to an offset-free supercontinuum. To demonstrate full phase stabilization of the comb, a single comb mode was locked to an optical reference.

STh1N.3 • 08:30
Visible to Mid-Infrared Frequency Comb Generation Using a Waveguide PPLN, Kana Iwakuni[1,2], Sho Okubo[2], Osamu Tadanaga[3], Hajime Inaba[2], Atsushi Onae[2], Feng-Lei Hong[2,4], Hiroyuki Sasada[1]; [1]*Keio Univ., Japan;* [2]*National Metrology Inst. of Japan (NMIJ), National Inst. of Advanced Industrial Science and Technology (AIST), Japan;* [3]*NTT Device Technology Labs, Japan;* [4]*Dept. of Physics, Yokohama National Univ., Japan.* We succeeded in generating a coherent optical frequency comb covering more than 3 octaves from visible to mid-infrared with a waveguide-type PPLN. The generated comb is demonstrated to be useful for metrology and spectroscopic applications.

08:00–10:00
STh1O • All Optical Signal Processing
Presider: Masaki Asobe; Tokai Univ., Japan

STh1O.1 • 08:00
A High Speed All-Optical NAND Logic Gate Using Four-Wave Mixing, Kangmei Li[1], Hong-Fu Ting[1], Mark A. Foster[1], Amy C. Foster[1]; [1]*Johns Hopkins Univ., USA.* We demonstrate a high speed all-optical NAND gate based on four-wave mixing Bragg scattering in highly nonlinear fiber. A 15.2-dB depletion of the signal is obtained and time domain measurements show 10-Gb/s NAND operation.

STh1O.2 • 08:15
Kerr Nonlinear Switching in a Core-shell Microspherical Resonator Fabricated From the Silicon Fiber Platform, Fariza Hanim Suhailin[1,2], Noel Healy[1], Misha Sumetsky[3], John Ballato[4], Andrew Dibbs[5], Ursula Gibson[5], Anna C. Peacock[1]; [1]*Optoelectronics Research Centre, Univ. of Southampton, UK;* [2]*School of Fundamental Science, Universiti Malaysia Terengganu, Malaysia;* [3]*Engineering and Applied Science, Aston Univ., UK;* [4]*COMSET, School of Materials Science and Engineering, Clemson Univ., USA;* [5]*Dept. of Physics, Norwegian Univ. of Science and Technology, Norway.* We investigate the Kerr nonlinearity in a core-shell microspherical resonator fabricated from a silicon fiber. By exploiting the ultrafast wavelength shifting, sub-picosecond modulation is demonstrated.

STh1O.3 • 08:30
High-accuracy heterodyne detection of THz radiation exploiting telecommunication technologies, Thomas Folland[1], Antonio ramospulido[1], Owen marshall[1], Harvey Beere[2], David Ritchie[2], Subhasish Chakraborty[1]; [1]*Univ. of Manchester, UK;* [2]*Univ. of Cambridge, UK.* We report the first open-loop heterodyne technique using standard telecom optical fibre components for spectral characterization of THz semiconductor lasers. This allows the measurement of continuous modal tuning with sub-GHz accuracy and 20dB dynamic range.

CLEO: QELS-Fundamental Science

FTh1A • Quantum Entanglement III—Continued

FTh1A.4 • 08:45
Enhanced Photon-Pair Detection Using Phase-Sensitive Pre-amplification, James M. Dailey[1], Anjali Agarwal[1], Paul Toliver[1], Nicholas A. Peters[1]; [1]*Applied Communication Sciences, USA*. We describe an experimental demonstration of fiber-based optical phase-sensitive amplification for improved detection of correlated single-photon pairs. A measured coincidence gain of 4.5dB provides 3dB improvement in the detection system signal-to-noise ratio.

FTh1A.5 • 09:00
Engineering large-scale entanglement in the quantum optical frequency comb, Pei Wang[1], Wenjiang Fan[1], Moran Chen[1], Olivier Pfister[1]; [1]*Univ. of Virginia, USA*. We report on experimental progress toward scaling our recent 60-entangled-qumode experiment [1] to thousands of qumodes in the quantum optical frequency comb. We present a model which predicts that 3,200 entangled modes can be achieved.

FTh1A.6 • 09:15
Frequency-Resolved Reconstruction of the Biphoton Polarization State via Stimulated Emission Tomography, Bin Fang[1], Marco Liscidini[2], John E. Sipe[3], Virginia Lorenz[1]; [1]*Dept. of Physics and Astronomy, Univ. of Delaware, USA;* [2]*Dept. of Physics, Univ. of Pavia, Italy;* [3]*Dept. of Physics and Inst. for Optical Sciences, Univ. of Toronto, Canada*. We reconstruct the polarization-entangled state of individual frequency components of the biphoton wave function by stimulated emission tomography. The frequency-resolved polarization state enables new insight into frequency-polarization correlations of the quantum process.

FTh1B • Quantum Control and Precision Measurements—Continued

FTh1B.4 • 08:45
Nonlinear optical magnetometry with accessible in situ optical squeezing, Nils Otterstrom[1,2], Raphael Pooser[2], Benjamin Lawrie[2]; [1]*Dept. of Physics and Astronomy, Brigham Young Univ., USA;* [2]*Quantum Information Science Group, Computational Science and Engineering Division, Oak Ridge National Lab, USA*. We demonstrate compact and accessible squeezed-light magnetometry using four-wave-mixing in a single hot rubidium vapor cell. This framework enables 4.7 dB of quantum-noise-reduction while simultaneously adding nonlinear-magneto-optical-rotation(NMOR) signals from the probe and conjugate fields.

FTh1B.5 • 09:00 Tutorial
Making the World's Best Atomic Clock, Jun Ye[1]; [1]*Univ. of Colorado at Boulder JILA, USA*. I will report our recent effort towards realizing the full potential of a many-particle clock with a state-of-the-art stable laser. We have achieved fractional stability of 2.2×10^{-16} at 1 s for the JILA Sr optical atomic clock. We have also reduced the total uncertainty of our clock to 2.1×10^{-18} in fractional frequency units. Both represent new records for the performance of an atomic clock.

Jun Ye is a Fellow of JILA, NIST and University of Colorado. His research focuses on the frontier of light-matter interactions and includes precision measurement, quantum physics and ultracold matter, optical frequency metrology, and ultrafast science. He has co-authored over 280 technical papers and has delivered over 400 invited talks. Ye is a Fellow of the American Physical Society, The Optical Society and a member of the National Academy of Sciences.

FTh1C • High-field FTh1C • High-field and XFEL Physics—Continued

FTh1C.3 • 08:45
Laser Acceleration and Deflection of 96.3keV Electrons with a Silicon Dielectric Structure, Kenneth Leedle[1], Fabian Pease[1], Robert L. Byer[1], James S. Harris[1]; [1]*Stanford Univ., USA*. Dielectric laser accelerators are a compact and scalable alternative to radio frequency accelerators. We present the first demonstration of over 200 MeV/m acceleration and deflection gradients with a silicon structure at 96.3keV electron energy.

FTh1C.4 • 09:00
He Ion Acceleration in Near Critical Density Plasma, Sergei Tochitsky[1], Chao Gong[1], Jeremy Pigeon[1], Frederico Fiuza[2], Chan Joshi[1]; [1]*Univ. of California Los Angeles, USA;* [2]*Lawrence Livermore National Lab, USA*. The CO_2 laser-plasma interactions are uniquely placed for Shock Wave Acceleration of He or other light ions. We report on experimental and numerical studies of He ion acceleration in a gas jet plasma.

FTh1C.5 • 09:15
Difference-Frequency Generation of Optical Radiation from Two-Color X-Ray Pulses, Eliyahu Shwartz[1], Sharon Shwartz[1,2]; [1]*Physics, Bar Ilan Univ., Israel;* [2]*The Inst. for Nanotechnology and Advanced Materials, Bar Ilan Univ., Israel*. We describe the process of difference-frequency generation of optical radiation from X-ray pulses. We find that the efficiency is orders of magnitude higher than similar effects, and highlight its potential application to probe atomic-scale structures.

FTh1D • Nonlinear Resonators and Optical Frequency Combs—Continued

FTh1D.3 • 08:45
Silicon Carbide Microresonators with High Optical Q and Large Kerr Nonlinearity for Nonlinear Optics, Xiyuan Lu[1], Jonathan Y. Lee[1], Steven Rogers[1], Qiang Lin[1]; [1]*Univ. of Rochester, USA*. We demonstrate an amorphous silicon carbide (a-SiC) microresonator with optical Q up to 1.3×10^5. This enables us to characterize the third-order nonlinearity of a-SiC with $n^2 = (5.9 \pm 0.7) \times 10^{-15}$ cm^2/W.

FTh1D.4 • 09:00
Frequency Comb-enhanced Coupling in Silicon Nitride Microresonators, Pei-Hsun Wang[1], Yi Xuan[1], Xiaoxiao Xue[1], Yang Liu[1], Jian Wang[1], Daniel E. Leaird[1], Minghao Qi[1], Andrew M. Weiner[1]; [1]*Purdue Univ., USA*. We investigate enhanced coupling of the pump laser as a result of power transfer to the frequency comb in a silicon nitride microring designed with an over-coupled bus-waveguide.

FTh1D.5 • 09:15
Tunable Frequency Combs based on Dual Microring Resonators, Steven Miller[1], Yoshitomo Okawachi[2], Kevin Luke[1], Alexander L. Gaeta[2,3], Michal Lipson[1,3]; [1]*School of Electrical and Computer Engineering, Cornell Univ., USA;* [2]*School of Applied and Engineering Physics, Cornell Univ., USA;* [3]*Kavli Inst. at Cornell for Nanoscale Science, Cornell Univ., USA*. We demonstrate tunable coupling condition of a silicon nitride microresonator frequency comb. Using a dual-coupled resonator geometry and integrated microheaters, we achieve 13.3 dB of extinction tuning and observe 10-fold increase in generated power.

Executive Ballroom 210E	Executive Ballroom 210F	Executive Ballroom 210G	Executive Ballroom 210H
CLEO: QELS-Fundamental Science	CLEO: Science & Innovations		

FTh1E • Electron and Ultrafast Probing of Plasmonic Nanostructures—Continued

FTh1E.4 • 09:00
Ultrafast pump-probe photo-induced force microscopy at nanoscale, Junghoon Jahng[1], Jordan Brocious[1], Dmitry Fishman[1], Eric O. Potma[1]; *[1]Univ. of California, Irvine, USA.* We perform time-resolved pump-probe microscopy measurements by recording the local force between a sharp tip and the photo-excited sample as a readout mechanism for the material's nonlinear polarization.

FTh1E.5 • 09:15
Spatially-Resolved, Three-Dimensional Investigation of Surface Plasmon Resonances in Complex Nanostructures, Jordan Hachtel[1,2], Daniel Mayo[3,4], Anas Mouti[2], Claire Marvinney[3], Richard Mu[4], Richard F. Haglund[1,3], Andrew Lupini[2], Matthew Chisholm[2], Sokrates Pantelides[1,2]; *[1]Dept. of Physics and Astronomy, Vanderbilt Univ., USA; [2]Materials Science and Technology Division, Oak Ridge National Lab, USA; [3]Interdisciplinary Materials Science Program, Vanderbilt Univ., USA; [4]Dept. of Physics, Fisk Univ., USA.* We report a three-dimensional study of surface plasmons in random-morphology nanoparticles by combining spatially resolved electron energy loss spectroscopy, which probes optical excitations, and cathodoluminescence, which probes radiative decay, in a scanning transmission electron microscope.

STh1F • Mode Division Multiplexing—Continued

STh1F.4 • 08:45
Mode Multiplexer Based on Integrated Horizontal and Vertical Polymer-Waveguide Directional Couplers, Kin S. Chiang[1], Jiangli Dong[1], Wei Jin[1]; *[1]City Univ. of Hong Kong, Hong Kong.* We propose an integrated polymer-waveguide mode (de)multiplexer based on cascaded horizontal and vertical directional couplers for combining/separating the three lowest-order modes. Our experimental device shows crosstalks lower than -15.6 dB in the C-band.

STh1F.5 • 09:00
Photonics Integrated Circuit for WDM Mode Division Multiplexing with Phase to Intensity Demodulation, Mengyuan Ye[1], Yu Yu[1], Guanyu Chen[1], Yuchan Luo[1], Lei Shi[1], Xinliang Zhang[1]; *[1]Wuhan National Lab for Optoelectronics, China.* We demonstrate an on-chip WDM-compatible mode multiplexing system with function of phase demodulation. The proposed scheme can be useful at the interface of long-haul and on-chip communication systems, which prefer phase and intensity modulated formats respectively.

STh1F.6 • 09:15
Demonstration of Distance Emulation for an Orbital-Angular-Momentum Beam, Nisar Ahmed[1], Martin P. Lavery[2,1], peicheng liao[1], Guodong Xie[1], Hao Huang[1], Long Li[1], Yongxiong Ren[1], Yan Yan[1], Zhe Zhao[1], Zhe Wang[1], Nima Ashrafi[3,4], Solyman Ashrafi[4], Moshe Tur[5], alan willner[1]; *[1]Univ. of Southern California, USA; [2]Univ. of Glasgow, UK; [3]Univ. of Texas at Dallas, USA; [4]NxGen Partners, USA; [5]Tel Aviv Univ., Israel.* We design and experimentally demonstrate a free-space distance emulator for propagating OAM beams over long distances in a lab environment. The performance of the system is assessed by measuring spot radius and radius of curvature of propagated beams.

STh1G • Glass and Rare Earth Doped Materials—Continued

STh1G.4 • 08:45
Visible up-conversion luminescence in $(ErSc)_2O_3$ epitaxial thin films and its suppression by photonic band-gap, Takehiko Tawara[1,2], Thomas McManus[1,3], Yoshihiro Kawakami[4], Hiroo Omi[1,2], Adel Najar[1], Reina Kaji[4], Satoru Adachi[4], HIdeki Gotoh[1]; *[1]NTT Basic Research Labs, Japan; [2]NTT Nanophotonics Center, Japan; [3]Univ. of Bath, UK; [4]Hokkaido Univ., Japan.* Visible up-conversion luminescence induced by 1535-nm excitation in $(ErSc)_2O_3$ epitaxial layers are observed. We investigate fast up-conversion rate and propose its suppression structure by photonic band-gap for realizing higher optical gain devices on Si wafers.

STh1G.5 • 09:00
Highly Yb-doped $KGd(WO_4)_2$ Thin-film Amplifier, Yean-Sheng Yong[1,2], Shanmugam Aravazhi[1], Sergio A. Vázquez-Córdova[1,2], Sonia M. García-Blanco[1,2], Markus Pollnau[1,3]; *[1]Integrated Optical MicroSystems Group, MESA+ Inst. for Nanotechnology, Univ. of Twente, Netherlands; [2]Optical Sciences Group, MESA+ Inst. for Nanotechnology, Univ. of Twente, Netherlands; [3]Dept. of Materials and Nano Physics, School of Information and Communication Technology, KTH–Royal Inst. of Technology, Sweden.* We report record-high small-signal gain of 1050 dB/cm at 981 nm wavelength in a $KGd_{0.425}Yb_{0.575}(WO_4)_2$ thin film. The sensitivity of gain to the shift of beam-focus position, which is critical under non-waveguiding conditions, is investigated.

STh1G.6 • 09:15
Extremely Low-Loss Chalcogenide Photonics Devices with Chlorine-Based Plasma Etching, Jeff Chiles[1], Marcin Malinowski[1], Ashutosh Rao[1], Spencer Novak[1,3], Kathleen Richardson[1,3], Sasan Fathpour[1,2]; *[1]Univ. of Central Florida, CREOL, USA; [2]Dept. of Electrical Engineering and Computer Science, Univ. of Central Florida, USA; [3]School of Materials Science and Engineering, Clemson Univ., USA.* Chlorine-based plasma is employed to produce extremely low propagation loss as low as 0.42 dB/cm in chalcogenide waveguides, record-high intrinsic Q-factors of 450,000 microring resonators and fiber-to-waveguide grating couplers with a coupling efficiency of 37%.

STh1H • Nonlinear Optics for Advanced Measurements and Characterization—Continued

STh1H.4 • 08:45
Tunable All-Optical Modulation by Period Multiplication in a Synchronously-Pumped Optical Parametric Oscillator, Tobias Steinle[1], Vikas Kumar[2], Andy Steinmann[1], Marco Marangoni[2], Giulio Cerullo[2], Harald W. Giessen[1]; *[1]4th Physics Inst., Univ. of Stuttgart, Germany; [2]IFN-CNR, Dipartimento di Fisica, Politecnico di Milano, Italy.* We present the first observation of period multiplication in a synchronously-pumped OPO, enabling tunable all-optical modulation for ultrafast pulses beyond 10 MHz. Elegant pump-probe spectroscopy without external modulation is demonstrated by stimulated Raman scattering.

STh1H.5 • 09:00
Two-crystal Optical Parametric Oscillator for Broadband Dual-comb Spectroscopy, Yuwei Jin[1], Simona M. Cristescu[1], Frans J. Harren[1], Julien Mandon[1]; *[1]Dept. of Molecular and Laser Physics, Radboud Univ. Nijmegen, Netherlands.* We present a broadband two-crystal optical parametric oscillator for mid-infrared dual-comb spectrosocpy. The measured absorption and dispersion spectra of methane between 2850 cm^{-1} and 3200 cm^{-1} are demonstrated with a 0.2 cm^{-1} spectral resolution.

STh1H.6 • 09:15
Visualization of the Internal Structure of Orientation-Patterned III-V Semiconductors, Pawel karpinski[1,2], Xin Chen[1], Vladlen Shvedov[1], Cyril Hnatovsky[1], Arnaud Grisard[3], Eric Lallier[3], Barry Luther-Davies[1], Wieslaw Krolikowski[1,4], Yan S[1]; *[1]Laser Physics Centre, Research School of Physics and Engineering, Australian National Univ., Australia; [2]Wroclaw Univ. of Technology, Poland; [3]Thales Research and Technology, France; [4]Texas A & M Univ. at Qatar, Qatar.* We investigate nonlinear diffraction in orientation-patterned semiconductors and identify Čerenkov second harmonic generation in a transverse geometry of interaction. Čerenkov second harmonic allows nondestructive 3D visualization of the internal structure of orientation-patterned semiconductor.

Meeting Room 211 B/D

CLEO: Science & Innovations

STh1I • Photodetectors—Continued

STh1I.4 • 08:45
High Responsivity Silicon-Graphene Schottky Avalanche Photodetectors for Visible and Telecom Wavelengths, Ilya Goykhman[1], Anna Eiden[1], Domenico De Fazio[1], Ugo Sassi[1], Matteo Barbone[1], Andrea C. Ferrari[1]; [1]*Cambridge Graphene Centre, Univ. of Cambridge, UK.* We design, optimize and demonstrate a silicon-graphene avalanche Schottky photodetector with photoresponsivities of 1A/W and 0.5A/W for visible and telecom wavelengths respectively.

STh1I.5 • 09:00
Graphene on Silicon-on-Sapphire Waveguide Photodetectors, Zhenzhou Cheng[1], Jiaqi Wang[1], Ke Xu[1], Hon Ki Tsang[1], Chester Shu[1]; [1]*The Chinese Univ. of Hong Kong, Hong Kong.* We describe the transfer of chemical vapor deposition grown graphene onto silicon-on-sapphire waveguides to form heterostructure waveguide photodetectors which had responsivities of 0.9 mA/W and 4.5 mA/W at 1.55 μm and 2.75 μm wavelengths, respectively.

STh1I.6 • 09:15
A CMOS-Compatible Plenoptic Sensor for Smart Lighting Applications, Javad Ghasemi[1], Alexander Neumann[1], Shima Nezhadbadeh[1], Xiangyu Nie[1], Payman Zarkesh-Ha[1], Steven Brueck[1]; [1]*CHTM (Center for High Tech Materials), Univ. of New Mexico, USA.* A CMOS-compatible, visible, plenoptic (angle, polarization and wavelength) detector, based on a grating-coupled waveguide structure, is demonstrated with an angular resolution of < 1° and a corresponding wavelength resolution of < 5 nm.

Meeting Room 212 A/C

CLEO: Applications & Technology

ATh1J • Biomedical Imaging and Sensing II—Continued

ATh1J.4 • 08:45
Characterization of optical resolution photoacoustic microscopy in comparison to confocal microscop, Paweena U-Thainual[1], Do-Hyun Kim[1]; [1]*Food and Drug Administration, USA.* Lateral resolution and depth discrimination in turbid samples was measured with optical resolution photoacoustic microscopy (ORPAM) and compared to confocal microscopy (CM). ORPAM signal strength and CM resolution were relatively less affected by scattering.

ATh1J.5 • 09:00
Degenerate Volume Holographic Imaging Techniques and Instruments for Subsurface Tissue Visualization, Raymond K. Kostuk[1], Isela D. Howlett[1], Michael Gordon[1], John Brownlee[1], Erich de Leon[1], Gabriel Orsinger[1], Jennifer Watson[1], Marek Romanowski[1], Kenneth Hatch[1], Yuan Luo[2], George Barbastathis[3], Jennifer Barton[1]; [1]*Univ. of Arizona, USA;* [2]*National Taiwan Univ., Taiwan;* [3]*MIT, USA.* Degenerate Bragg matching with a volume hologram can lead to reduction in image contrast. Incorporating very high selectivity holograms, high numerical aperture objectives, and image processing can provide image information comparable with histology stained images.

ATh1J.6 • 09:15
High-throughput Imaging of Self-luminous Objects through a Single Optical Fiber, Roman Barankov[1], Jerome Mertz[1]; [1]*Boston Univ., USA.* We demonstrate a strategy of imaging through a fiber in which the spatial information is encoded into distinct spectrum codes spanning the bandwidth of the object spectrum, enabling high-throughput 2D imaging insensitive to fiber bending.

Meeting Room 212 B/D

ATh1K • Spectroscopy and Metrology—Continued

ATh1K.3 • 08:45
Advanced wideband cavity enhanced spectroscopy, Toby K. Boyson[1], Charles C. Harb[1]; [1]*School of Engineering and Information Technology, UNSW Australia, Australia.* We present new results from a variant of cavity enhanced spectroscopy that allows large spectral bandwidths to be analysed in real time, and demonstrate new methods to apply the technique to real-time monitoring of species with broad absorbances.

ATh1K.4 • 09:00
Broadband dual-comb coherent anti-Stokes Raman spectroscopy at high signal-to-noise ratio, Ming Yan[2,1], Simon Holzner[2,1], Theodor Hänsch[2,1], Nathalie Picqué[2,1]; [1]*Max Planck Inst. of Quantum Optics, USA;* [2]*Physics Dept., Ludwig-Maximilians-Universitä t München, Germany.* Coherent anti-Stokes Raman spectroscopy is achieved on microsecond time scale with two frequency combs and a heterodyne detection with a local oscillator. The vibrational transitions reach a signal-to-noise ratio of 1600 with linear concentration dependence.

ATh1K.5 • 09:15
Depolarization Sensitive Optical Inspection of Semiconductor Integrated Circuits, Abdulkadir yurt[1], Michael Grogan[1], Selim Unlu[1], Bennett Goldberg[1]; [1]*Boston Univ., USA.* We demonstrate dark-field, through-silicon imaging of semiconductor integrated circuits by exploiting depolarization-sensitive, high aperture angle reflectivity.

Marriott Salon I & II

CLEO: Science & Innovations

STh1L • Mode-Locked Fiber Lasers—Continued

STh1L.3 • 08:45
Fast Wavelength-Tunable Picosecond Pulses from Mode-Locked Er Fiber Laser using an Intracavity Filter with Repetition Rate Compensator, Yasuyuki Ozeki[1], Daigo Tashiro[1]; [1]*The Univ. of Tokyo, Japan.* We present a polarization-maintaining, SESAM-mode-locked fiber laser with a wavelength-tuning speed of <5 ms and a duration of ~10 ps. Within the tunability of >30 nm, the variation in the repetition rate was <300 Hz.

STh1L.4 • 09:00
Passively Mode-locked Holmium-doped Fiber Oscillators Optimized for Ho:YLF Amplifier Seeding, Peng Li[1], Axel Ruehl[1], Colleen Bransley[1,2], Ingmar Hartl[1]; [1]*Deutsches Elektronen Synchrotron, Germany;* [2]*Physics Dept., Univ. of Dayton, USA.* We present soliton operation of holmium-doped fiber oscillators with independently tunable central wavelengths from 2040nm to 2070nm and spectral widths from 5nm to 10nm, which can be matched to the requirements of Ho:YLF amplifiers.

STh1L.5 • 09:15
Reducing Nonlinear Limitations of Ytterbium Mode-Locked Fibre Lasers with Hollow-Core Negative Curvature Fibre, Clarissa Harvey[1], Fei Yu[1], Jonathan C. Knight[1], William Wadsworth[1], Paulo Almeida[2]; [1]*Univ. of Bath, UK;* [2]*Fianium ltd., UK.* Ultralow nonlinearity hollow-core negative curvature fibre is used in a mode-locked Ytterbium fibre laser to prevent the onset of pulse breakup at low repetition-rates. Identical pulse peak-power limit at 37MHz and 11MHz is experimentally demonstrated.

CLEO: Science & Innovations

STh1M • Beam Shaping for Optimized Laser-matter Interaction—Continued

STh1M.3 • 08:45
Generating Optical Tractor Beams of Improved Stability with Metasurfaces, Carl Pfeiffer[1], Cheng Zhang[1], L. Jay Guo[1], Anthony Grbic[1]; [1]*Univ. of Michigan, USA.* A tractor beam is a propagation invariant beam that pulls objects towards a light source. Here, an efficient tractor beam with improved stability is generated by illuminating a dielectric metasurface with a Gaussian beam.

STh1M.4 • 09:00
Laser Micromachining with Femtosecond Higher-order Bessel Beams, Weibo Cheng[1], Pavel G. Polynkin[1]; [1]*College of Optical Sciences, Univ. of Arizona, USA.* We use femtosecond higher-order Bessel beams for micromachining of borosilicate glass plates. The self-focusing of the beams inside the glass results in the production of beaded ring structures on the back surfaces of the plates.

STh1M.5 • 09:15
Light Localization in Axisymmetric Nano-Structured Plasmonic Gratings, Alexander Lozano[1,2], Moein shayegannia[1], Arthur Montazeri[1], Yuan Fang[3], Kaveh Moussakhani[1], Nazir Kherani[1,4]; [1]*Dept. of Electrical and Computer Engineering, Univ. of Toronto, Canada;* [2]*Dept. of Physics, Univ. of Toronto, Canada;* [3]*Dept. of Physics, Univ. of California, Berkeley, USA;* [4]*Dept. of Materials Science and Engineering, Univ. of Toronto, Canada.* We present a novel technique for spectral decomposition of light in a sub-wavelength plasmonic bull's eye grating structure. Controlling plasmon coupling through the variation of groove width enables spatial control over light localization in the grating.

STh1N • Frequency Conversion of Combs—Continued

STh1N.4 • 08:45
Measured Carrier Envelope Offset and Linewidth of Degenerate Optical Parametric Oscillator, Kevin F. Lee[1], C. Mohr[1], Jie Jiang[1], Peter G. Schunemann[2], M. E. Fermann[1]; [1]*IMRA America, Inc., USA;* [2]*BAE Systems, USA.* We measure the carrier envelope offset frequency of a degenerate optical parametric oscillator. We verify that it has half the value of the pump frequency comb, and sub-Hertz level relative linewidth.

STh1N.5 • 09:00
Frequency Comb Spanning 2.5-7.5 μm from a Subharmonic GaAs OPO and its Coherence Properties, Viktor O. Smolski[1], Sergey D. Gorelov[2], Jian Zhao[1], Jia Xu[1], Peter G. Schunemann[3], Konstantin L. Vodopyanov[1]; [1]*Univ. of Central Florida, CREOL, USA;* [2]*Univ. of Nizhny Novgorod, Russia;* [3]*BAE Systems, USA.* We demonstrate a record-wide mid-IR comb using Tm-fiber-laser-pumped near-degenerate GaAs OPO. By varying intracavity dispersion, we observe a transition from a single-comb to a two-comb state, where two combs are offset by a constant value.

STh1N.6 • 09:15
1-GHz Harmonically Pumped Femtosecond Optical Parametric Oscillator Frequency Comb, Karolis Balskus[1], Stewart Leitch[1], Zhaowei Zhang[1], Richard McCracken[1], Derryck T. Reid[1]; [1]*Heriot Watt Univ., USA.* We present the first example of a femtosecond optical parametric oscillator frequency comb by using a 333-MHz Ti:sapphire laser to achieve a stabilized comb at 1-GHz mode spacing in the 1.1-1.6-μm wavelength band.

STh1O • All Optical Signal Processing—Continued

STh1O.4 • 08:45
Experimental Demonstration of Tunable Homodyne Detection for Two Channels Simultaneously using Nonlinear Optical Signal Processing to Automatically Lock a Single "Local" Pump Laser to Two 20-Gbaud BPSK Data Signals, Ahmed Almaiman[1], Morteza Ziyadi[1], Amirhossein Mohajerin Ariaei[1], Yinwen Cao[1], Mohammad-Reza Chitgarha[1], Peicheng Liao[1], Youichi Akasaka[5], Jeng-Yuan Yang[5], Motoyoshi Sekiya[5], Joseph Touch[3], Carsten Langrock[2], Martin M. Fejer[2], Moshe Tur[4], Alan Willner[1]; [1]*Univ. of Southern California, USA;* [2]*Stanford Univ., USA;* [3]*Information Sciences Inst., USA;* [4]*Tel Aviv Univ., Israel;* [5]*Fujitsu Labs of America, USA.* We demonstrate homodyne detection for multiple channels using nonlinear optical signal processing to automatically lock a single "local" pump laser to these data channels simultaneously and perform experimental demonstration with two 20-Gbaud BPSK channels.

STh1O.5 • 09:00
Experimental Demonstration of Tunable and Automatically-Locked Homodyne Detection for Dual-Polarization 20-32-Gbaud QPSK Channels using Nonlinear Mixing and Polarization Diversity, Morteza Ziyadi[1], Amirhossein Mohajerin Ariaei[1], Ahmed Almaiman[1], Yinwen Cao[1], Mohammad-Reza Chitgarha[1], peicheng liao[1], Youichi akasaka[2], Jeng-Yuan Yang[2], Motoyoshi Sekiya[2], Joseph Touch[3], Moshe Tur[4], Carsten Langrock[5], Martin M. Fejer[5], Alan Willner[1]; [1]*Univ. of Southern California, USA;* [2]*Fujitsu Labs of America, USA;* [3]*Information Sciences Inst., USC, USA;* [4]*Tel Aviv Univ., Israel;* [5]*Stanford Univ., USA.* We experimentally demonstrate a tunable homodyne receiver on polarization multiplexed QPSK signals. PPLN waveguides inside the polarization diversity loops are used to frequency/phase lock the signals with the LO. Open eye diagrams with BER measurements are shown.

STh1O.6 • 09:15
Demonstration of Tunable and Automatic Frequency/Phase Locking for Multiple-Wavelength QPSK and 16-QAM Homodyne Receivers using a Single Nonlinear Element, Morteza Ziyadi[1], Amirhossein Mohajerin Ariaei[1], Mohammad-Reza Chitgarha[1], Yinwen Cao[1], Ahmed Almaiman[1], Youichi Akasaka[2], Jeng-Yuan Yang[2], Guodong Xie[1], Peicheng Liao[1], Motoyoshi Sekiya[2], Joseph Touch[3], Moshe Tur[4], Carsten Langrock[5], Martin M. Fejer[5], Alan Willner[1]; [1]*Univ. of Southern California, USA;* [2]*Fujitsu Labs of America, USA;* [3]*Information Sciences Inst., USC, USA;* [4]*Tel Aviv Univ., Israel;* [5]*Stanford Univ., USA.* We experimentally demonstrate a tunable homodyne receiver on multiple-wavelength QPSK and 16-QAM channels at 20/30 Gbaud. A single PPLN waveguide is used to frequency/phase lock the signals with their tones. Open eye diagrams with BER measurements are shown.

Executive Ballroom 210A	Executive Ballroom 210B	Executive Ballroom 210C	Executive Ballroom 210D

CLEO: QELS-Fundamental Science

FTh1A • Quantum Entanglement III—Continued

FTh1A.7 • 09:30
High Resolution Bi-Photon Spectral Correlation Measurements from a Silicon Nanowire in the Quantum and Classical Regimes, Iman Jizan[1], Luke G. Helt[2], Chunle Xiong[1], Matthew J. Collins[1], Duk-Yong Choi[3], Chang Joon Chae[4], Marco Liscidini[5], Michael J. Steel[2], Benjamin J. Eggleton[1], Alex Clark[1]; *[1]Centre for Ultrahigh bandwidth Devices for Optical Systems, School of Physics, The Univ. of Sydney, Australia; [2]CUDOS and MQ Photonics Research Centre, Dept. of Physics and Astronomy, Macquarie Univ., Australia; [3]Laser Physics Centre, Research School of Physics & Engineering, Australian National Univ., Australia; [4]NICTA Victoria Laboratary, Melbourne School of Engineering, The Univ. of Melbourne, Australia; [5]Dipartimento di Fisica, Universita degli Studi di Pavia, Italy.* We use classical stimulated four-wave mixing to directly characterize quantum spectral correlations generated in a silicon nanowire for two different pump durations. Signal to noise is increased and acquisition time reduced compared to coincidence detection.

FTh1A.8 • 09:45
Temporal Position Modulation of Biphoton Correlations through Pump Frequency Tuning, Ogaga D. Odele[1], Joseph M. Lukens[1], Jose A. Jaramillo-Villegas[1], Carsten Langrock[2], Martin M. Fejer[2], Daniel E. Leaird[1], Andrew M. Weiner[1]; *[1]Purdue Univ., USA; [2]Stanford Univ., USA.* We describe and demonstrate a novel approach for controlling the temporal position of the biphoton correlation by pump frequency tuning. Our method relies on precise waveguide engineering as well as the nonlocal dispersion cancellation effect.

FTh1B • Quantum Control and Precision Measurements—Continued

FTh1C • High-field FTh1C • High-field and XFEL Physics—Continued

FTh1C.6 • 09:30
Investigation of the Newly Proposed Carrier-Envelope-Phase Stable Attosecond Pulse Source, Zoltan Tibai[1], György Tóth[2], Zsuzsanna Nagy-Csiha[1], József Fülöp[2], Gábor Almási[1,2], János Hebling[1,2]; *[1]Univ. of Pécs, Hungary; [2]MTA-PTE High Field Terahertz Research Group, Hungary.* The carrier-envelope-phase and energy stability of formerly proposed accelerator-based attosecond source is investigated numerically. Carrier-envelope-phase stable pulses with tens of nJ energy and 80 as duration are predicted with 31 mrad phase stability.

FTh1C.7 • 09:45
Intense broadband THz pulse generation from relativistic laser-plasma interaction, Sudipta Mondal[1]; *[1]INRS-Énergie Matériaux Télécommunication, Canada.* We demonstrate intense broadband terahertz pulse generation from the interaction of high intensity femtosecond laser with solid density plasmas. We measure substantial enhancement of terahertz pulse energy (32 mJ/pulse) by using aligned copper nanorod targets.

FTh1D • Nonlinear Resonators and Optical Frequency Combs—Continued

FTh1D.6 • 09:30
Synchronization of multiple parametric frequency combs, Yanan H. Wen[1], Michael R. Lamont[1], Alexander L. Gaeta[1]; *[1]Cornell Univ., USA.* We theoretically demonstrate passive synchronization of solitons in systems of two- and three-microresonator-based parametric frequency combs resulting in time-locked pulses and frequency-locked comb lines.

FTh1D.7 • 09:45
A New Route for Fabricating On-Chip Chalcogenide Microcavity Resonators, Ozan Aktas[1,2], Ersin Huseyinoglu[2,3], Mehmet Bayindir[1,2]; *[1]Bilkent Univ., Turkey; [2]UNAM-National Nanotechnology Research Center, Bilkent Univ., Turkey; [3]Inst. of Materials Science and Nanotechnology, Bilkent Univ., Turkey.* We report a novel versatile method for the high yield production and on-chip integration of self-assembled globally oriented high-Q Whispering Gallery Mode (WGM) chalcogenide microresonators. The results of optical and material characterization of the microresonators are given.

09:30–12:30 Technology Transfer Program, *Exhibit Hall Theater*

10:00–15:00 Exhibits Open, *Exhibit Hall*

10:00–14:00 Coffee Break (10:00–10:30) and Unopposed Exhibit Only Time, *Exhibit Hall*

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Thursday, 14 May
12:30–14:00
Exhibit Hall

Executive Ballroom 210E | Executive Ballroom 210F | Executive Ballroom 210G | Executive Ballroom 210H

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FTh1E • Electron and Ultrafast Probing of Plasmonic Nanostructures—Continued

FTh1E.6 • 09:30
Withdrawn

FTh1E.7 • 09:45
Coherent Control in Single Plasmonic Nanostructures, Alberto Comin[1], Richard Ciesielski[1], Alexandre Bouhelier[2], Achim Hartschuh[1]; *[1]Dept. Chemie, Ludwig-Maximilians-Universitaet, Germany; [2]Laboratoire Interdisciplinaire Carnot de Bourgogne, Université de Bourgogne, France.* Coherent control in plasmonic nanostructures is a door to space-time confinement of optical excitation and femtosecond super-resolution spectroscopy. Towards this goal, here we demonstrate femtosecond pulse-shaping of single gold nanostructure and local phase compensation.

STh1F • Mode Division Multiplexing—Continued

STh1F.7 • 09:30
Detecting orbital angular momentum of light with an arc slit, Hailong Zhou[1], Jianji Dong[1], Pei Zhang[2], Yifeng Zhou[1], Xinliang Zhang[1]; *[1]Wuhan National Lab for Optoelectronics, China; [2]MOE Key Lab for Nonequilibrium Synthesis and Modulation of Condensed Matter, Dept. of Applied Physics, Xi'an Jiaotong Univ., China.* When the orbital angular momentum (OAM) beam is incident on a 90 degree arc slit, a focus will be generated and have a displacement which is nearly linear with the topological charge of the incoming OAM beam. It can detect the OAM beams with a very simple structure.

STh1F.8 • 09:45
2x2 Broadband Adiabatic 3-dB Couplers on SOI Strip Waveguides for TE and TM modes, Han Yun[1], Zeqin Lu[1], Yun Wang[1], Wei Shi[2], Lukas Chrostowski[1], Nicolas A. Jaeger[1]; *[1]Electrical and Computer Engineering, Univ. of British Columbia, Canada; [2]Electrical and Computer Engineering, Universite Laval, Canada.* We demonstrated adiabatic 3-dB couplers on silicon-on-insulator strip waveguides. We obtained average splitting ratios, from 1500 nm to 1600 nm, of 44.5%/55.5% and 50.5%/49.5% for our transverse electric and transverse magnetic couplers, respectively.

STh1G • Glass and Rare Earth Doped Materials—Continued

STh1G.7 • 09:30
Characterization of $Ge_{28}Sb_{12}Se_{60}$ Waveguides, Molly R. Krogstad[1], Sungmo Ahn[1], Wounjhang Park[1], Juliet Gopinath[1]; *[1]Univ. of Colorado, USA.* Single-mode $Ge_{28}Sb_{12}Se_{60}$ waveguides, fabricated with thermal evaporation and lift-off, were characterized at 1.03 and 1.53 μm. Measured linear propagation loss agrees with theoretical predictions, and large nonlinear absorption at 1.03 μm has optical limiting applications.

STh1G.8 • 09:45
Solution processed Chalcogenide photonic crystal, Tingyi Gu[1,2], Chao Lu[3], Tony Heinz[1], Alejandro Rodriguez[3], Craig Arnold[3]; *[1]Columbia Univ., USA; [2]Hewlett-Packard Lab, USA; [3]Princeton Univ., USA.* We demonstrate formation of amorphous chalcogenide photonic crystal light emitter by using microtrench filling method in solution processing.

STh1H • Nonlinear Optics for Advanced Measurements and Characterization—Continued

STh1H.7 • 09:30
High-Resolution Sub-Surface Microscopy of CMOS Intagrated Circuits Using Radially Polarized Light, Marius Rutkauskas[1], Carl Farrell[1], Christophe Dorrer[2], Kenneth Marshall[2], Ted Lundquist[3], Praveen Vedagarbha[3], Derryck T. Reid[1]; *[1]Heriot-Watt Univ., UK; [2]Univ. of Rochester, USA; [3]DCG Systems Inc., USA.* Comparison of high-resolution sub-surface microscopy shows that illumination with linear polarization resolves an edge with resolutions of 95 nm and 120 nm, depending on E-field orientation, while radial polarization achieves a resolution of 98 nm.

STh1H.8 • 09:45
3-D Scanning Mid-IR Imaging of Buried Structures Using Extremely Nondegenerate Two-photon Absorption in a GaN Photodiode, Himansu S. Pattanaik[1], Matthew Reichert[1], David J. Hagan[1], Eric W. Van Stryland[1]; *[1]Univ. of Central Florida, CREOL, USA.* We demonstrate a scanning 3-D IR imaging technique using extremely nondegenerate two-photon absorption in an uncooled GaN photodiode, and obtain ~2 μm depth resolution at a wavelength of ~5 μm in buried semiconductor structures.

09:30–12:30 Technology Transfer Program, *Exhibit Hall Theater*

10:00–15:00 Exhibits Open, *Exhibit Hall*

10:00–14:00 Coffee Break (10:00–10:30) and Unopposed Exhibit Only Time, *Exhibit Hall*

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Meeting Room 211 B/D

CLEO: Science & Innovations

STh1I • Photodetectors—Continued

STh1I.7 • 09:30
Enhanced Responsivity up to 2.85 A/W of Si-based $Ge_{0.9}Sn_{0.1}$ Photoconductors by Integration of Interdigitated Electrodes, Thach Pham[1], Benjamin Conley[1], Joe Margetis[2], Huong Tran[1], Seyed Amir Ghetmiri[1], Aboozar Mosleh[1], Wei Du[1], Gregory Sun[3], Richard Soref[3], John Tolle[2], Hameed Naseem[1], Baohua Li[4], Shui-Qing Yu[1]; *[1]Univ. of Arkansas, USA; [2]ASM, USA; [3]Univ. of Massachusetts Boston, USA; [4]Arktonics, USA.* The $Ge_{0.9}Sn_{0.1}$ photoconductor was fabricated with interdigitated structures on Si using a CMOS-compatible process. Temperature-dependent responsivity and specific detectivity were measured. The peak responsivity of 2.85A/W at 77K was achieved due to enhanced photoconductive gain.

STh1I.8 • 09:45
Dual-Drifting-Layer Uni-Traveling Carrier Photodiode for Wide Bandwidth and High Power Performance, li jin[1], Xiong Bing[1], Sun Changzheng[1], Yi Luo[1]; *[1]Tsinghua Univ., China.* Uni-traveling-carrier photodiodes with novel dual-drifting-layer structure is proposed to realize wide bandwidth and high saturation power performance. High-speed operation at high bias voltage is demonstrated by optimizing the electric field profile within the dual-drifting-layer structure.

Meeting Room 212 A/C

CLEO: Applications & Technology

ATh1J • Biomedical Imaging and Sensing II—Continued

ATh1J.7 • 09:30
Three-color two-photon three-axis digital scanned light-sheet microscopy (3C2P3S-DSLM), Weijian Zong[1,2], Zuosheng Liu[1], Fuzeng Niu[1], Shaowa Li[1], Jia Zhao[1], Aimin wang[1], Liangyi Chen[1]; *[1]Peking Univ., China; [2]China Dept. of Cognitive Sciences, Inst. of Basic Medical Sciences, China.* We demonstrate a new two-photon light-sheet microscopy with three-color excitation, diffraction-limited thickness and tailorable illumination area, capable of multi-color multi-scale live imaging in one setup.

Meeting Room 212 B/D

ATh1K • Spectroscopy and Metrology—Continued

ATh1K.6 • 09:30
External Cavity Semiconductor Laser Optimized for Frequency Metrology, Wei Liang[1], Vladimir S. Ilchenko[1], Danny Eliyahu[1], Elijah Dale[1], Anatoliy A. Savchenkov[1], David Seidel[1], Andrey B. Matsko[1], Lute Maleki[1]; *[1]OEwaves Inc, USA.* A frequency modulatable 795 nm semiconductor laser is created. The laser is characterized with residual amplitude modulation below -80 dB and frequency noise better than 300 $Hz/Hz^{1/2}$ at offset frequencies ranging from 100 Hz to 10 MHz.

Marriott Salon I & II

CLEO: Science & Innovations

STh1L • Mode-Locked Fiber Lasers—Continued

STh1L.6 • 09:30
Timing Jitter of Normal-Dispersion Mode-Locked Er- and Yb-Fiber Lasers, Junho Shin[1], Peng Qin[2], Kwangyun Jung[1], Youjian Song[2], Ming-lie Hu[2], Chingyue Wang[2], Jungwon Kim[1]; *[1]Korea Advanced Inst of Science & Tech, Korea; [2]Tianjin Univ, China.* We experimentally identify that narrow bandpass-filtering can significantly reduce the timing jitter in normal-dispersion fiber lasers. Both the split-step method-based jitter simulation and the modified Namiki-Haus analytic model agree well with the measured jitter spectrum.

STh1L.7 • 09:45
Generation of 10 W, 100 fs, 10 GHz pulse train using high power EDFA-MOPA system with cascaded Raman pumping, Akira Fujisaki[1,2], Masato Yoshida[1], Toshihiko Hirooka[1], Masataka Nakazawa[1]; *[1]Tohoku Univ., Japan; [2]Furukawa Electric, Japan.* We demonstrate a record high output power 10 W, 100 fs 10 GHz pulse train using an all-fiber MOPA system at 1562 nm with a high-power EDFA and 1480 nm cascaded Raman laser pumping.

09:30–12:30 Technology Transfer Program, *Exhibit Hall Theater*

10:00–15:00 Exhibits Open, *Exhibit Hall*

10:00–14:00 Coffee Break (10:00–10:30) and Unopposed Exhibit Only Time, *Exhibit Hall*

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CLEO: Science & Innovations

STh1M • Beam Shaping for Optimized Laser-matter Interaction—Continued

STh1M.6 • 09:30
Ultra-broadband Tunable Polarization Converter for Micro-fluidic-meta-surfaces, Pin Chieh Wu[2], Libin Yan[2], Qinghua Song[2], Weimiing Zhu[2], Zhang Wu[2], Din Ping Tsai[1,3], Federico Capasso[4], Ai-Qun Liu[2]; *[1]National Taiwan Univ., Taiwan; [2]Nanyang Technological Univ., Singapore; [3]Academia Sinica, Taiwan; [4]Harvard Univ., USA*. We present a widely tunable polarization converter with ultra-broad working frequency for microfluidic metasurface. By adjusting the configuration of L-shaped antenna, both cross and circular polarization conversion can be achieved under a linear-polarized illumination.

STh1M.7 • 09:45
Unraveling the Effects of Radiation Forces in Water, Nelson G. Astrath[1,2], Luis Malacarne[1], Mauro Baesso[1], Gustavo Lukasievicz[1], Stephen Bialkowski[2]; *[1]Universidade Estadual de Maringá, Brazil; [2]Utah State Univ., USA*. We measure the surface deformation at the air-water interface induced by laser excitation and match this to rigorous theory of radiation forces. The experimental results are quantitatively described by the numerical calculations of radiation forces.

STh1N • Frequency Conversion of Combs—Continued

STh1N.7 • 09:30
Mid-Infrared 333-MHz Frequency Comb Continuously Tunable from 1.95 μm to 4.0 μm, Karolis Balskus[1], Zhaowei Zhang[1], Richard A. McCracken[1], Derryck T. Reid[1]; *[1]Heriot Watt Univ., USA*. Idler pulses from a 333-MHz femtosecond optical parametric oscillator were carrier-envelope-offset stabilized using a versatile locking technique which allowed the resulting comb to be tuned continuously over a range from 1.95 μm to 4.0 μm.

STh1N.8 • 09:45
Adaptive Sampling Dual Comb Spectroscopy in Terahertz Region Using Unstabilized Dual Femtosecond Lasers, Ryuichi Ichikawa[1], Yi-Da Hsieh[1,2], Kenta Hayashi[1], Kaoru Minoshima[3,2], Hajime Inaba[4,2], Takeshi Yasui[1,2]; *[1]Tokushima Univ., Japan; [2]ERATO Intelligent Optical Synthesizer Project, JST, Japan; [3]The Univ. of Electro-Communications, Japan; [4]National Inst. of Advanced Industrial Science and Technology, Japan*. The adaptive sampling clock was extracted by dual THz-comb-referenced spectrum analyzers and used for THz dual comb spectroscopy (THz-DCS) with unstabilized dual lasers. The demonstrated results implied better spectroscopic performance than THz-DCS with stabilized lasers.

STh1O • All Optical Signal Processing—Continued

STh1O.7 • 09:30
All-Optical Ultrafast Wavelength and Mode Converter Based on Inter-Modal Nonlinear Wave Mixing in Few-Mode Fibers, Yi Weng[1], Xuan He[1], Junyi Wang[2], Zhongqi Pan[1]; *[1]Dept. of Electrical & Computer Engineering, Univ. of Louisiana at Lafayette, USA; [2]Qualcomm Technologies Inc., USA*. An ultrafast all-optical simultaneous wavelength and mode conversion scheme is purposed based on intermodal nonlinear wave mixing, with the capability of switching state of polarization and mode degeneracy orientation in few-mode fibers with high efficiency.

STh1O.8 • 09:45
Record Phase Sensitive Extinction Ratio in a Silicon Germanium Waveguide, Mohamed A. Ettabib[1], Francesca Parmigiani[1], Alexandros Kapsalis[2], Adonis Bogris[2], Mickael Brun[3], Pierre Labeye[3], Sergio Nicoletti[3], Kamal Hammani[4], Dimitris Syvridis[2], David Richardson[1], P Petropoulos[1]; *[1]Univ. of Southampton, UK; [2]Dept. of Informatics and Telecommunications, National and Kapodistrian Univ. of Athens, Greece; [3]CEA-Leti, France; [4]Laboratoire Interdisciplinaire Carnot de Bourgogne, France*. A binary step-like phase response and phase-sensitive extinction ratio in excess of 28dB under CW pump operation was demonstrated in a 20mm-long low birefringence SiGe waveguide, using a polarization-assisted phase sensitive amplifier scheme.

09:30–12:30 Technology Transfer Program, *Exhibit Hall Theater*

10:00–15:00 Exhibits Open, *Exhibit Hall*

10:00–14:00 Coffee Break (10:00–10:30) and Unopposed Exhibit Only Time, *Exhibit Hall*

11:30–13:00
JTh2A • Poster Session III

JTh2A.1
Generation of Broadband Chaos Signal by Self-injection Monolithic Integrated Mode-beating Amplified Feedback Laser, Biwei Pan[1], Dan Lu[1], Liqiang Yu[1], Limeng Zhang[1], Lingjuan Zhao[1]; [1]*Inst. of Semiconductors, Chinese Academy of Sciences, China*. A broadband chaos generation scheme using monolithic integrated mode-beating amplified feedback laser under self-injection is presented. A robust chaotic spectrum that extends over 50 GHz with a flatness of ±5 dB is experimentally achieved.

JTh2A.2
Lithographic VCSEL Reliability Under Extreme Operating Conditions, Xu Yang[1], Guowei Zhao[2], Mingxin Li[1], Dennis Deppe[1,2]; [1]*CREOL, Univ. of Central Florida, USA;* [2]*sd-Photonics, LLC, USA*. Data are presented showing lithographic VCSELs has higher reliability than oxide VCSELs in a stress test with a severe condition. The increased reliability is consistent with its lower junction temperature and reduced internal stress.

JTh2A.3
Improved Performance of Tunable Single Mode Laser Array Based on Non Uniformly Spaced Slots, Azat Abdullaev[1], Qiao Y. Lu[1], Wei H. Guo[2], Michael Wallace[1], Marta Nawrocka[1], James O. Callaghan[3], John Donegan[1]; [1]*Trinity College Dublin, USA;* [2]*School of Electrical and Electronic Engineering, Wuhan Univ., China;* [3]*Tyndall National Inst., Ireland*. We present a 12-channel wavelength-tunable single-mode laser array based on non-uniformly spaced slots. A quasi-continuous tuning range of >36 nm is obtained over 35˚C (from 10˚C-45˚C) temperature range with side mode suppression ratio >50 dB.

JTh2A.4
Arrayed Waveguide Grating Based Monolithic Multi-wavelength Mode-locked Semiconductor Laser, Songtao Liu[1], Qing Ke[1], Mengdie Sun[1], Dan Lu[1], Ruikang Zhang[1], Chen Ji[1]; [1]*Inst. of Semiconductors, CAS, China*. We report a novel monolithic multi-wavelength mode-locked semiconductor laser design based on arrayed waveguide grating (AWG) for the first time. 19.6 ps pulses at a repetition rate of 2.9 GHz are obtained.

JTh2A.5
Fiber Pump-Delivery System for Spectral Narrowing and Wavelength Stabilization of Broad-Area Lasers, Jordan P. Leidner[1], John R. Marciante[1]; [1]*The Inst. of Optics, USA*. Off-axis far-field coupling of a broad-area laser to a single-mode fiber containing a fiber Bragg grating is used for spatio-spectral filtering. This results in a ~10x narrower spectral width and potential spatial brightness improvements.

JTh2A.6
Withdrawn

JTh2A.7
High performance 2150nm InAs/InGaAs/InP quantum well lasers grown by metal-organic vapor phase epitaxy, Luo Shuai[1], Ji Haiming[1], Feng Gao[1], Xiaoguang Yang[1], Tao Yang[1]; [1]*Key Lab of Semiconductor Materials Science, Inst. of semiconductors, CAS, China*. We demonstrate high performance 2150 nm InAs/InGaAs/InP quantum well (QW) lasers grown by metalorganic vapor phase epitaxy (MOVPE).

JTh2A.8
GaSb-based Mid Infrared Photonic Crystal Surface Emitting Laser, Chien Hung Pan[1], Chien Hung Lin[2], Tien Yuan Chang[3], Tien-Chang Lu[3], Chien Ping Lee[2]; [1]*CNST, National Chiao Tung Univ., Taiwan;* [2]*Dept. of Electronics Engineering, National Chiao Tung Univ., Taiwan;* [3]*Dept. of Photonics, National Chiao Tung Univ., Taiwan*. We demonstrate an optically pumped GaSb-based mid-Infrared photonic crystal surface emitting laser (PCSEL) at 2.3μm with line width of 0.3nm. The PCSEL was operated with temperature up to 350K, showing a shift rate of 0.21 nm/K.

JTh2A.9
Modulation-Frequency Dependence of the Phase-Amplitude Coupling in Quantum Dot Lasers, Cheng Wang[1,2], Marek A. Osinski[1,3], Kevin Schires[1], Jacky Even[2], Frederic Grillot[1]; [1]*Telecom-Paristech, France;* [2]*Institut National des Sciences Appliquées, France;* [3]*The Univ. of New-Mexico, USA*. The phase-amplitude coupling of quantum dot lasers is studied by taking into account carrier dynamics and the contribution of off-resonant states to the refractive index change. Calculations reveal a strong dependence on the modulation frequency.

JTh2A.10
Volume Holographic Grating Stabilized 780 nm Ridge Waveguide Laser With an Output Power of 380 mW, Simon Rauch[1], Joachim Sacher[1]; [1]*Sacher Lasertechnik GmbH, Germany*. A ridge waveguide laser stabilized by a compact holographic grating-cavity with an output power of 380 mW, a linewidth of 18 kHz and a nearly diffraction-limited beam for saturation spectroscopy of rubidium is presented.

JTh2A.11
Broadband quantum cascade laser at wavelength λ~10 mm based on continuum-to-continuum design, Bo Meng[1], Yuan Quan Zeng[1], Etienne Rodriguez[1], Qijie Wang[1]; [1]*Nanyang Technological Univ., Singapore*. Broadband mid-infrared quantum cascade lasers (QCLs) at ~10 mm based on the continuum-to-continuum design are presented. The prototypes show broadband lasing spectra (978 cm^{-1} -1055 cm^{-1}), 580 mW peak powers and 0.5 W/A slope efficiencies.

JTh2A.12
Timing Jitter Reduction of a Passively Mode-Locked External-Cavity Semiconductor Laser Via Repetition Rate Transitions and Optical Feedback, Simon Rauch[2,1], Lukas Drzewietzki[2], Andreas Klehr[3], Joachim Sacher[1], Wolfgang Elsässer[2], Stefan Breuer[2]; [1]*Sacher Lasertechnik GmbH, Germany;* [2]*Inst. of Applied Physics, Technische Universität Darmstadt, Germany;* [3]*Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Germany*. We investigate experimentally the influence of harmonic mode-locking and optical feedback on the timing-jitter of a passively mode-locked external-cavity diode laser yielding a jitter reduction of up to a factor of 10 and we compare the results with numerical simulations.

JTh2A.13
A Modulated Segmented Contact Method for the Measurement of Internal Optical Mode Loss, Peter Rees[1], Robert Pascoe[1], Peter M. Smowton[1], Peter Blood[1]; [1]*Cardiff Univ., UK*. An order of magnitude improvement in the precision of measurements of internal optical mode losses to better than 0.1cm^{-1} is demonstrated using a modulated segmented contact method.

JTh2A.14
The Effect on Dot Gain Behaviour of Confining Layer Composition in InP/(Al)GaInP Quantum Dot Lasers , Martyn Smith[1], Stella Elliott[1], Makarimi Kasim[1], Peter M. Smowton[1], Andrey Krysa[2]; [1]*Cardiff Univ., UK;* [2]*Sheffield Univ., UK*. Reductions in non-radiative recombination and α_i with increasing Ga composition of the upper-confining-layer in InP self-assembled quantum-dot lasers reduce threshold-current-density and temperature dependence. Carrier population of 2-D layers limits further improvement at higher Ga compositions.

JTh2A.15
Exernal Cavity Quantum Cascade Laser Based on Fabry-Perot Reflector, Deivis Vaitiekus[1], Michael Hemingway[1], Andrey Krysa[1], John Cockburn[1], Dmitry G. Revin[1]; [1]*The Univ. of Sheffield, UK*. External cavity quantum cascade laser based on Fabry-Pérot etalon design is demonstrated for the first time. Fabry-Pérot reflector was adjusted to produce single mode emission across the whole gain region.

JTh2A.16
Femtosecond Laser Repairing of the effects in Glass Materials Induced by Ion Implantation, Qiang Cao[1], Jiajun Zhang[1]; [1]*Beijing Inst. of Technology, China*. Metal ion implantation in glass causes lots of defects in lattice during its fabricating process. We found that the femtosecond laser irradiation have a great efficiency to repair these defects with high spatial selectivity.

JTh2A.17
Frequency Degenerate Two Beam Coupling In Organic Media Using a Single Nanosecond Pump, Jonathan Slagle[2,1], Joseph Haus[3], Shekhar Guha[2], Daniel McLean[2,1], Douglas Krein[2,4]; [1]*Leidos, Inc., USA;* [2]*Materials and Manufacturing Directorate, Air Force Research Lab, USA;* [3]*Electro-Optics Program, Univ. of Dayton, USA;* [4]*General Dynamic Information Technology, USA*. We present degenerate two-beam coupling in organic dye solutions using a single nanosecond beam where the probe originates from a Fresnel reflection and the phase and frequency shifts are the result of transient self-phase modulation.

JTh2A.18
Stabilization of Premixed High Flow Speed Methane/air Flames Using a Nanosecond Laser Induced Plasma, Xiaohui Li[1,2], Xin Yu[1,2], Yang Yu[1,2], Rongwei Fan[1,2], Deying Chen[1,2], Rui Sun[3]; [1]*National Key Lab of Science and Technology on Tunable Laser, Harbin Inst. of Technology, China;* [2]*Inst. of Opto-electronics, Harbin Inst. of Technology, China;* [3]*Inst. of Combustion Engineering, Harbin Inst. of Technology, China*. Stabilization of premixed methane/air flames with a flow speed up to 20 m/s was realized using a 50 Hz nanosecond Nd:YAG laser induced plasma. The stability of the flames in terms of blow off limit and the temporal evolution of the flame kernel generated by the laser plasmas were investigated.

JTh2A.19
Photon-stimulated desorption surface spectroscopy by VUV emissions from a laser-produced plasma, Masanori Kaku[1], Daichi Kai[1], Masahito Katto[1], Atsushi Yokotani[1], Wataru Sasaki[2], Shoichi Kubodera[1]; [1]*Univ. of Miyazaki, Japan;* [2]*NTP inc., Japan*. We have developed photon-stimulated desorption surface spectroscopy system using broadband VUV emissions from a laser-produced plasma. Observed desorbed atoms or molecules from material surfaces depended on bond energy or molecular structure.

JTh2A.20
Optical Scattering of Airy Beam and Gaussian Beam Through Turbid Medium, Romanus Hutchins[1], Miao Zhang[1], Lixin Ma[1], Ping Yu[1]; [1]*Univ. of Missouri-Columbia, USA*. We compared optical scattering of Airy and Gaussian beams, generated simultaneously using a LCD panel, through a turbid medium. The Airy beam had a smaller speckle size due to its self-healing property.

JTh2A.21
Generalizing and extending Kubelka-Munk theory, Chris Sandoval[1], Arnold D. Kim[1]; [1]*Applied Mathematics, Univ. of California, Merced, USA*. Kubelka-Munk theory is an intuitive theory that approximates the flow of power through a plane parallel slab of a scattering medium. We derive it from the radiative transport equation, accounting for general boundary sources and non-homogeneous terms, and then generalize it to three dimensions.

11:30–13:00
JTh2A • Poster Session III

JTh2A.22
Fano Resonance Structural Color in Patterned Dielectric Surfaces, Emma Regan[1], Yichen Shen[2], Marin Soljacic[2]; [1]*Physics, Wellesley College, USA;* [2]*Physics, MIT, USA.* Fano resonance is used to generate structural color in microscopically structured dielectric materials that can be tuned through the visible spectrum.

JTh2A.23
Sm^{3+} Ions Doped Phosphate Glasses for Multiband Visible Laser Applications, Nitin Jha[1], K Linganna[2], C K Jayasankar[2], Ajoy Kar[1]; [1]*Heriot-Watt Universiy, UK;* [2]*Physics, Sri Venkateswara Univ., India.* Sm^{3+} ions doped phosphate glasses have been fabricated. Their absorption and emission properties have been studied. Significant amplification in emission with side pumping is being reported indicating its potential application for visible lasers.

JTh2A.24
GaN-based Ridge Waveguides with Very Smooth and Vertical Sidewalls by ICP Dry Etching and Chemical Etching, Wanyong Li[1], Yi Luo[1], Bing Xiong[1], Sun Changzheng[1], Wang Lai[1], Jian Wang[1], Han Yanjun[1], Jianchang Yan[2], Tongbo Wei[2], Hongxi Lu[2]; [1]*Tsinghua Univ., China;* [2]*Chinese Academy of Sciences, China.* GaN-based ridge waveguides with very smooth and vertical sidewalls are fabricated with combined inductively coupled plasma (ICP) etching and chemical etching. Reduction in scattering loss is estimated to be 2 dB/mm at 1.55 μm.

JTh2A.25
Inband-Pumped Ho:KLu$(WO_4)_2$ Microchip Laser Q-switched with a PbS-Quantum-Dot-Doped Glass, Xavier Mateos[1], Pavel Loiko[2,1], Josep Maria Serres[1], Konstantin Yumashev[2], Alexander Malyarevich[2], Alexei Onushchenko[3], Valentin Petrov[4], Uwe Griebner[4], Magdalena Aguilo[1], Francesc Diaz[1]; [1]*Universitat Rovira i Virgili, Spain;* [2]*Center for Optical Materials and Technologies, Belarusian National Technical Univ., Belarus;* [3]*Vavilov State Optical Inst., Russia;* [4]*Max Born Inst., Germany.* Maximum average output power of 84 mW, slope efficiency of 42%, and pulse duration of 55 ns are achieved at 2.06 μm with a passively Q-switched Ho:KLu$(WO_4)_2$ microchip laser inband-pumped by a Tm:KLu$(WO_4)_2$ microchip laser.

JTh2A.26
A new type of Yb^{3+} doped fiber with an octagonal-shaped core, Wang Yibo[1], Nan zhao[1], Lei Liao[1], Nengli Dai[1], Jinggang Peng[1], Haiqing Li[1], Jinyan Li[1]; [1]*Wuhan National Lab of Eletroptics, China.* A new type of Yb^{3+} doped fiber with an octagonal-shaped core is fabricated.This fiber has the potential to be applied into the laser system to optimize the beam quality.when this type of fiber core is introduced into the CCC fiber, an easier coupling of the HOM to the side cores can be observed.

JTh2A.27
Structural optimization for modulation efficiency enhancement in a top-gated graphene optical modulator, Kaori Warabi[1], Rai Kou[2,3], Hidetaka Nishi[2,3], Shinichi Tanabe[3], Yuzuki Kobayashi[1], Tsuyoshi Yamamoto[3], Koji Yamada[2,3], Hirochika Nakajima[1]; [1]*Waseda Univ., USA;* [2]*NTT Nanophotonics Center, Japan;* [3]*NTT Device Technology Labs., Japan.* We investigated a top-gated graphene optical modulator on a CMOS compatible silicon photonic platform. The structural optimization results revealed that the modulation efficiency is able to reach to 0.05 dB/μm with very low insertion loss.

JTh2A.28
Growth and Electroluminescent Property of Multi-Facet InGaN/GaN Multiple Quantum Well Light Emitting Device, Yun-Jing Li[2], Shih-Pang Chang[3], Yuh-Jen Cheng[1], Hao-Chung Kuo[3], Chun-Yen Chang[2]; [1]*Academia Sinica, Taiwan;* [2]*Dept. of Electronics Engineering and Inst. of Electronics, National Chiao Tung Univ., Taiwan;* [3]*Dept. of Photonics and Inst. of Electro-Optical Engineering, National Chiao Tung Univ., Taiwan.* We report the study of InGaN/GaN multiple quantum wells (MQWs) grown on multi-facet microrods. The multi-facet MQWs have broad emission spectrum. Electrical injection was demonstrated with emission color ranged from red to blue.

JTh2A.29
Silicate Spin-on-Glass as an Overcoat Layer for SiO_2 Ridge Waveguides, Matthew Stott[1], Thomas Wall[1], Damla Ozcelik[2], Josh Parks[2], Gopikrishnan G. Meena[2], Erik Hamilton[1], Roger Chu[1], Holger Schmidt[2], Aaron Hawkins[1]; [1]*Electrical and Computer Engineering, Brigham Young Univ., USA;* [2]*Univ. of California, Santa Cruz, USA.* Silicate spin-on-glass is used to coat PECVD SiO_2 waveguides in order to smooth out surface topology and act as a moisture barrier. The measured optical throughput improved compared to uncoated waveguides.

JTh2A.30
Fabrication and Characterization of Fiber Waveguides from Single-Crystal Er^{3+}-Doped YAG, Elizabeth F. Dreyer[1], Logan Stagg[1], Stephen Trembath-Reichert[2], Christopher Hoef[2], Craig D. Nie[3], James A. Harrington[3], Stephen C. Rand[1,2]; [1]*Electrical Engineering and Computer Science, Univ. of Michigan, USA;* [2]*Physics, Univ. of Michigan, USA;* [3]*Material Science, Rutgers Univ., USA.* Rod-in-tube preforms and laser heated pedestal growth were used successfully to fabricate graded-index Erbium doped YAG fibers suitable for low-loss waveguides in laser gain or power delivery applications.

JTh2A.31
Strain Relaxation in InGaN/GaN Multiple-Quantum Wells by Nano-Patterned Sapphire Substrates with Smaller Period, Po-Hsun Chen[4,1], Vin-Cent Su[4], Ming-Lun Lee[4], Yao-Hong You[4,1], Yen-Pu Chen[4], Zheng-Hung Hung[5], Ta-Cheng Hsu[2], Yu-Yao Lin[2], Ray-Ming Lin[3], Chieh-Hsiung Kuan[4]; [1]*Kingwave Corporation, Taiwan;* [2]*Epistar Corporation, Taiwan;* [3]*Graduate Inst. of Electronic Engineering and Green Technology Research Center, Chang Gung Univ., Taiwan;* [4]*Graduate Inst. of Electronics Engineering, Dept. of Electrical Engineering, National Taiwan Univ., Taiwan;* [5]*Graduate Inst. of Photonics and Optoelectronics, Dept. of Electrical Engineering, National Taiwan Univ., Taiwan.* The growth of InGaN-based light-emitting diodes (LEDs) on dry-etched patterned sapphire substrates (DPSSs) with nano-sized periods can relax the residual compressive strain in InGaN/GaN multiple-quantum wells (MQWs), given that the stronger the light emitted.

JTh2A.32
Extraordinary Optical Properties of Atomic-Layer Doped Transparent Conductive Oxide Superlattice, Do-Joong Lee[1], Jiyeon Kim[2], Gustavo E. Fernandes[1], Jin Ho Kim[1], Carlos Bledt[1], Ki-Bum Kim[2], Jimmy Xu[1]; [1]*Brown Univ., USA;* [2]*Seoul National Univ., Korea.* Atomic-layer doped transparent conductive oxide superlattices are prepared by ALD. Extraordinary optical properties, such as enhanced optical transparency, bandgap widening, and improved crystallinity with atomic-layers doping, that counter expectations based on conventional models, are observed.

JTh2A.33
Numerical Study of a 10 GHz Optical Flip-Flop Based on a Short Asymmetric DFB Laser, Amin Abbasi[1], Gunther Roelkens[1], Geert Morthier[1]; [1]*Dept. of Information Technology, Univ. of Ghent-IMEC, Belgium.* We report on a numerical optimization of an all-optical flip-flop based on an asymmetric DFB laser. For the optimized design the repetition rate can increase up to 10 GHz and the switching time can reduce to 5 ps.

JTh2A.34
Dispersion Engineering Employing Curved Space Mapping and Chromo-Modal Excitation, Haeri Park[1], Mohammad Asghari[1], Bahram Jalali[1]; [1]*UCLA, USA.* We report a new optical design capable of providing large group delay dispersion with tunable nonlinear dispersion profile.

JTh2A.35
Integrated Photonic Reservoir Computing based on Hierarchical Time-multiplexing Structure, Hong Zhang[1], Xue Feng[1], Boxun Li[1], Yu Wang[1], Kaiyu Cui[1], Fang Liu[1], Weibei Dou[1], Yidong Huang[1]; [1]*Tsinghua Univ., China.* An integrated photonic reservoir computing based on hierarchical time-multiplexing structure is proposed by numerical simulations.Error rates of 2.2~6.5% for chaotic time series prediction are achieved with the sample rate of 1.3~0.4Gbps and bandwidth of 40~10GHz.

JTh2A.36
Stable, Tuneable, All-optical Pulse Generation with 1 Hz Phase Noise, Amr S. Helmy[1], Fangxin Li[1]; [1]*Univ. of Toronto, Canada.* Feedback-free, RF-free, long-term stable, all optical, short pulse generation utilizing gain-induced FWM is demonstrated. The approach utilizes passive mode-locked (10 MHz) laser for injection locking to provide pulses with a phase noise of 1 Hz.

JTh2A.37
Metamaterial Electric-LC Resonators on Electro-Optic Modulator for Wireless THz-Lightwave Signal Conversion, Yusuf Nur Wijayanto[1], Atsushi Kanno[1], Tetsuya Kawanishi[1]; [1]*NICT, Japan.* Metamaterial electric-LC resonators on an electro-optic modulators are proposed for wireless THz-lightwave signal conversion. Strong electric field can be induced on the resonators by wireless THz irradiation and converted to lightwave signals through electro-optic modulation.

JTh2A.38
Robust Large-Port-Count Hybrid Switches with Relaxed Control Tolerances, Qixiang Cheng[1], Adrian Wonfor[1], Richard V. Penty[1], Ian H. White[1]; [1]*Univ. of Cambridge, UK.* The control tolerances of large-port-count optical switches with up to 128×128 ports using the MZI-SOA hybrid design are investigated. The first quantitative analysis is presented showing tolerant control requirements of the hybrid switch design.

JTh2A.39
A Multi-frequency Optoelectronic Oscillator based on a Single Phase-Modulator, Pei Zhou[1], Fangzheng Zhang[1], Shilong Pan[1]; [1]*Nanjing Univ Aeronautics & Astronautics, China.* A multi-frequency optoelectronic oscillator is proposed based on a single phase modulator. Simultaneous generation of 10 and 40 GHz signals is demonstrated and the phase noise is -100.62 dBc/Hz and -84.64 dBc/Hz@ 10kHz offset, respectively.

JTh2A.40
Pure Single-Sideband Modulation Using High Extinction-Ratio Parallel Mach-Zehnder Modulator with Third-Order Harmonics Superposition Technique, Yuya Yamaguchi[1], Atsushi Kanno[2], Tetsuya Kawanishi[2], Masayuki Izutsu[1,3], Hirochika Nakajima[1]; [1]*Waseda Univ., Japan;* [2]*National Inst. of Information and Communications Technology, Japan;* [3]*Japan Society for the Promotion of Science, San Francisco, USA.* We demonstrate high spurious suppression ratio single-sideband modulation by a high extinction-ratio parallel Mach-Zehnder modulator. An electrical third-order nonlinearity suppression technique can enhance the suppression ratio as high as 47 dB.

JTh2A.41
High-Speed Data Transmission Through Silicon Contra-Directional Grating Coupler Optical Add-Drop Multiplexers, Michael Caverley[1], Robert Boeck[1], Lukas Chrostowski[1], Nicolas A. Jaeger[1]; [1]*Univ. of British Columbia, Canada.* We demonstrate 12.5 Gbit/s data transmission through a silicon contra-directional grating coupler optical add-drop multiplexer while signals are being simultaneously added and dropped at the same wavelength.

11:30–13:00
JTh2A • Poster Session III

JTh2A.42
Suppressed XMD in Multi-carrier, RF-amplified RF Photonic Link by Cascaded MZMs, Xiaodong Liang[1], Feifei Yin[1], Yitang Dai[1], Jianqiang Li[1], Kun Xu[1]; [1]*Beijing Univ. of Posts and Telecoms, China.* We experimentally demonstrate the elimination of cross-modulation distortion (XMD) in multicarrier, intensity-modulation direct-detection (IMDD) analog photonic links by cascaded Mach-Zehnder modulators (MZMs). XMD, from both the MZMs and electrical amplifiers, is suppressed by 33 dB.

JTh2A.43
Optical Leaky Wave Antenna Experiment Demonstration and Electronic Modulation Investigation, Qiancheng Zhao[1], Yuewang Huang[1], Caner Guclu[1], Filippo Capolino[1], Ozdal Boyraz[1]; [1]*Univ. of California, Irvine, USA.* Fabrication and characterization of optical leaky wave antennas with dielectric waveguides and semiconductor perturbations is presented. Directive radiation at 1550nm is measured. Detailed study on electrical modulation capability with bandwidth exceeding 75GHz is presented.

JTh2A.44
A Time-to-frequency Converter Utilizing a Modified Time Lens, Dong Wang[1], Li Huo[1], Yanfei Xing[1], Caiyun Lou[1]; [1]*Tsinghua Univ., USA.* A time-to-frequency converter based on a modified time lens is proposed and demonstrated experimentally. Return-to-zero pulse with a duty cycle of 33 % and 67 % are both accurately mapped into the spectral domain.

JTh2A.45
Wide-spectrum-range Power-efficient Compact Thermo-optic Switch Based on Coupled Photonic Crystal Microcavities, Xingyu Zhang[1], Swapnajit Chakravarty[2], Chi-jui Chung[1], Zeyu Pan[1], Ray T. Chen[1,2]; [1]*Univ. of Texas at Austin, USA;* [2]*Omega Optics, Inc., USA.* We demonstrate a thermo-optic switch comprising a 3.78μm-long coupled photonic crystal resonators coupled to a photonic crystal waveguide. The device has 6nm optical bandwidth, 20dB optical extinction ratio, 18.2mW switching power, and 14.8μsec rise time.

JTh2A.46
Permanent Trimming of Silicon Ring Resonator Filters by Thermal Modification, Steven Spector[1], Jeffrey M. Knecht[1], Paul W. Juodawlkis[1]; [1]*Massachusetts Inst of Tech Lincoln Lab, USA.* Reported here is a method for trimming the resonant frequency of microring resonators by permanent thermal modification of a waveguide cladding. This method would use in-situ heaters, avoiding the need for highly specialized equipment.

JTh2A.47
High-speed Directly Modulated Laterally-coupled Twin Stripe Lasers for Optical Interconnects, Hiroki Taniguchi[1], Hamed Dalir[1], Fumio Koyama[1]; [1]*Tokyo Inst. of Technology, Japan.* We present the modeling of a laterally coupled twin-stripe laser for boosting the modulation bandwidth far beyond relaxation frequencies. The 3dB-modulation bandwidth is increased to be doubled thanks to optical feedback in laterally coupled cavities.

JTh2A.48
Photonically-Enabled Microwave Function Generation Via Tailored Distortion, Amit Bhatia[1], Hong-Fu Ting[1], Mark A. Foster[1]; [1]*Johns Hopkins Univ., USA.* We demonstrate a microwave function generator based on precisely engineering the distortion in a microwave photonic link. By distorting a 5-GHz sinusoid we are able to generate a 5-GHz triangle wave and square pulse train.

JTh2A.49
Fiber Nonlinearity Tolerance of Traceback Equalization for Non-Uniformly Distorted QAM Signals, Takahide Sakamoto[1], Guo-Wei Lu[1], Tetsuya Kawanishi[1]; [1]*NICT, Japan.* We investigate fiber nonlinearity tolerance of traceback equalization (TBE) for mitigating non-uniform distortion caused by unbalance of modulation electrodes in QAM transmitters. TBE outperforms conventional FIR-based adaptive equalizers in an adequately linear transmission regime.

JTh2A.50
Real-time heterodyne-based measurements of fiber laser spectral dynamics, Srikanth Sugavanam[1], Simon Fabbri[1], Thai L. Son[1], Ivan Lobach[2], Sergey I. Kablukov[2], Serge Khorev[3], Dmitry V. Churkin[1,4]; [1]*Aston Inst. of Photonic Technologies, UK;* [2]*Inst. of Automation and Electrometry, Russia;* [3]*Zecotek Photonics, Canada;* [4]*Novosibirsk State Univ., Russia.* We present a method to measure in real-time the instantaneous generation spectrum of fiber lasers over consecutive cavity round-trips.

JTh2A.51
Analytical Step-Size Selection Rule for Simulation of Signal Propagation in Vector Optical Fiber Channel, Qun Zhang[1], Liudong Xing[3], Hyekyung Min[1], M.I. Hayee[2]; [1]*Minnesota State Univ. Mankato, USA;* [2]*Univ. of Minnesota Duluth, USA;* [3]*Univ. of Massachusetts Dartmouth, USA.* An analytical step-size selection rule is proposed for the simulation of polarization multiplexed signal propagation through the single mode optical fiber. The method leads to approximately constant one step simulation error and high computational efficiency.

JTh2A.52
Novel Unipolar Sign Encoded OFDM for Next Generation PONs, Mohammed Mohammed[1], Ziad A. El-Sahn[1]; [1]*Photonics Group, Electrical Engineering Dept., Alexandria Univ., Egypt.* We propose a novel unipolar encoding technique for orthogonal frequency-division multiplexing (OFDM) that increases the bandwidth efficiency by 33% and reduces computational complexity by 50% compared to conventional intensity modulation/direct detection (IM/DD) OFDM systems.

JTh2A.53
Evaluation of Nonlinear Interference in Few-Mode Fiber Using the Gaussian Noise Model, Abdulaziz E. El-Fiqi[2], Abdallah Ismail[2], Ziad A. El-Sahn[3], Hossam M. Shalaby[2,3], Rameash K. Pokharel[1]; [1]*E-JUST Center, Kyushu Univ., Japan;* [2]*Elect. and Comm. Dept., Egypt-Japan Univ. of Science and Technology (E-JUST), Egypt;* [3]*Photonics Group, Electrical Engineering Dept., Alexandria Univ., Egypt.* The nonlinear propagation in few-mode fibers (FMFs) is modeled using a Gaussian approach, where a closed-form formula for the nonlinear interference is derived. The impacts of different nonlinearity penalties are investigated using this model.

JTh2A.54
Fiber-Optic Distribution of Arbitrary Radio-Frequency Waveforms with Stabilized Group Delay, Assaf Ben Amram[1], Yonatan Stern[1], Avi Zadok[1]; [1]*Bar-Ilan Univ., Israel.* Arbitrary RF waveforms are distributed over long fiber with stable group delay, using chromatic dispersion. Input and control waveforms modulate separate tunable lasers. Tracking of the control wave phase is used to adjust both wavelengths.

JTh2A.55
Symbol Rate Identification Using Asynchronous Delayed Sampling, Jin Shang[1,2], Sheng Cui[1,2], Changjian Ke[1,2], Zijie Xia[1,2], Songnian Fu[1,2], Deming Liu[1,2]; [1]*School of OEI, Huazhong Uni. of Sci.&Technology, China;* [2]*NGIA, China.* A symbol rate identification method is proposed for optical signals with commonly used modulation formats. Numerical simulation and experimental results show it is accurate and robust to different link impairments.

JTh2A.56
Frequency Transfer and Time Synchronization Via Urban Fiber, Nan Cheng[1], Wei Chen[1], Qin Liu[2], Dan Xu[1], Fei Yang[1], Youzhen Gui[2], Haiwen Cai[1]; [1]*Shanghai Key Lab of All Solid-State Laser and Applied Techniques, Shanghai Inst. of Optics and Fine Mechanics, Chinese Academy of Sciences, China;* [2]*Key Lab for Quantum Optics, CAS, Shanghai Inst. of Optics and Fine Mechanics, Chinese Academy of Sciences, China.* The frequency transfer and time synchronization system over 110km urban fiber link is described. The precise frequency transfer and accurate time synchronization are verified experimentally and demonstrated in the paper.

JTh2A.57
Tunable, narrow line-width silicon microring laser source for coherent optical communications, Ying Qiu[1]; [1]*WRI, China.* We demonstrate a tunable laser source based on a silicon microring. 1.1 kHz line-width, >8 mW output power and wide tuning range are achieved. 4-QAM and 16-QAM coherent transmissions using this laser are also demonstrated.

JTh2A.58
Frequency Chirp Reducing of a Colorless Laser Diode for 40-Gbit/s 256-QAM OFDM Transmission, Cheng-Ting Tsai[1], Yu-Chieh Chi[1], Gong-Ru Lin[1]; [1]*National Taiwan Univ., Taiwan.* A wavelength controlled and frequency chirp reduced colorless laser diode is directly modulated by 256-QAM-OFDM data to achieve a high spectral efficiency of 8 bit/sec/Hz at 40 Gbit/s with an optimized BER of 3.7×10^{-3}.

JTh2A.59
LDPC-Coded 16-Dimensional Modulation Based on the Nordstrom-Robinson Nonlinear Block Code, Toshiaki Koike-Akino[1], David S. Millar[1], Keisuke Kojima[1], Kieran Parsons[1], Kenya Sugihara[2], Yoshikuni Miyata[2], Tsuyoshi Yoshida[2]; [1]*Mitsubishi Electric Research Labs, USA;* [2]*Information Technology R&D Center, Mitsubishi Electric Corporation, Japan.* We propose a new high-dimensional modulation (HDM) format, based on the Nordstrom-Robinson code, which is the best-known nonlinear block code in 16 dimensions. With EXIT chart, we optimize LDPC codes for various HDM formats, and show their benefits.

JTh2A.60
Routing Algorithm to Optimize Loss and IPDR for Rearrangeably Non-Blocking Integrated Optical Switches, Minsheng Ding[1], Qixiang Cheng[1], Adrian Wonfor[1], Richard V. Penty[1], Ian H. White[1]; [1]*Dept. of Engineering, Univ. of Cambridge, UK.* A practical path-selection algorithm is proposed to optimize the worst-case path loss and IPDR for large-scale integrated switches. The modeling of an 8×8 Clos-tree switch shows an improvement of up to 2.7dB/1.9dB in loss/IPDR.

JTh2A.61
SNR Equalized Optical Direct-Detected OFDM Transmission with CAZAC Equalization, Zhenhua Feng[1], Ming Tang[1], Rui Lin[1,2], Ruoxu Wang[1], Qiong Wu[1], Liangjun Zhang[1], Liang Xu[1], Xiaolong Wang[1], Cong Zhou[1], Jiadi Wu[1], Shiwei Zhou[1], Lei Deng[1], Songnian Fu[1], Deming Liu[1], Ping Shum[3]; [1]*Huazhong Univ of Science & Technology, China;* [2]*School of Information and Communication Technology, The Royal Inst. of Technology (KTH), Sweden;* [3]*Nanyang Technological Univ., Singapore.* 50Km SSMF optical direct-detected OFDM transmission with Constant Amplitude Zero Auto Correlation Sequence (CAZAC) equalization is experimentally demonstrated with over 15dB power budget. 2.5dB enhancement in sensitivity has been achieved simultaneously with 3dB PAPR suppression.

JTh2A.62
Performance Metrics for a Free-space Communication Link Based on Multiplexing of Multiple Orbital Angular Momentum Beams with Higher Order Radial Indice, Guodong Xie[1], Long Li[1], Yan Yan[1], Yongxiong Ren[1], Zhe Zhao[1], peicheng liao[1], Nisar Ahmed[1], Zhe Wang[1], Nima Ashrafi[2,3], Solyman Ashrafi[2], moshe tur[4], alan willner[1]; [1]*U. of Southern California, USA;* [2]*NxGen Partners, USA;* [3]*Univ. of Texas at Dallas, USA;* [4]*Tel Aviv Univ., USA.* We analyze and measure the performance metrics for a free-space communication link using OAM beams with non-zero radial index *p*. The received power of OAM beams with *p*=1 is ~6 dB higher than p=0.

11:30–13:00
JTh2A • Poster Session III

JTh2A.63
Experimental Demonstration of Using Multi-Layer-Overlay Technique for Increasing Spectral Efficiency to 1.18 bits/s/Hz in a 3 Gbit/s Signal over 4-km Multimode Fiber, Guodong Xie[1], Changjing Bao[1], Yongxiong Ren[1], Yan Yan[1], ahmed almaiman[1], Long Li[1], peicheng liao[1], Zhe Zhao[1], Nisar Ahmed[1], Zhe Wang[1], yinwen cao[1], Hao Huang[1], Nima Ashrafi[2,3], Solyman Ashrafi[2], moshe tur[4], alan willner[1]; *[1]U. of Southern California, USA; [2]NxGen Partners, USA; [3]Univ. of Texas at Dallas, USA; [4]Tel Aviv Univ., Israel.* We report a transmission of 3 Gbit/s signal over a 4-km grade-index multimode fiber within a bandwidth of 2.54 GHz using multiple-layer-overlay (MLO) modulation format, achieving a spectral efficiency of 1.18 symbols/s/Hz.

JTh2A.64
Low-Cost In-Band OSNR Monitoring based on Coherent Hybrid in CO-OFDM System, liangjun zhang[1], Zhenhua Feng[1], Ruoxu Wang[1], Rui Lin[1,2], Liang Xu[1], Xiaolong Wang[1], Cong Zhou[1], Jiadi Wu[1], Shiwei Zhou[1], Lei Deng[1], Songnian Fu[1], Ming Tang[1], Deming Liu[1]; *[1]Next Generation Internet Access National, China; [2]The Royal Inst. of Technology, Sweden.* We proposed and demonstrated a cost-effective in-band optical signal to noise ratio (OSNR) monitoring technique based on coherent hybrid in 20Gb/s CO-OFDM system. Less than 0.5dB monitoring error is achieved with 400MHz balanced photodetector (PD).

JTh2A.65
Sub-Harmonic Injection-Locking of Quantum Dash Laser Through Spectral Enrichment for All-Optical Clock Recovery, Manas Srivastava[1], Prince M. Anandarajah[2], Balaji Srinivasan[1], Sean O Duill[2], Deepa Venkitesh[1], Pascal Landais[2]; *[1]Indian Inst. of Technology, Madras, India; [2]School of Electronics Engineering, Dublin City Univ., Ireland.* We perform injection-locking of a passively mode-locked Fabry-Perot quantum dash laser at 40 GHz using 10 Gbps PRBS data in NRZ-OOK format after spectral enrichment and thus demonstrate all-optical clock recovery through sub-harmonic injection-locking.

JTh2A.66
56 Gb/s WDM transmitter module based on silicon microrings using comb lasers, Heiko Füser[1], Anna Lena Giesecke[1], Andreas Prinzen[1], Stephan Suckow[2], Caroline Porschatis[1], Daniel Schall[1], Holger Lerch[1], Mohsin M. Tarar[2], Jens Bolten[1], Thorsten Wahlbrink[1], Heinrich Kurz[1]; *[1]AMO GmbH, Germany; [2]Institut für Halbleitertechnik, RWTH Aachen Univ., Germany.* We demonstrate the performance and the reliable fabrication process of a 56 Gb/s wavelength-division multiplexing transmitter module with integrated feedback structures. The device is based on microring silicon depletion modulators, optimized for O-band comb-laser operation.

JTh2A.67
Experimental Demonstration of Free-Space Optical Communications Using Orbital Angular Momentum (OAM) Array Encoding/Decoding, Shuhui Li[1], Zhidan Xu[1], Jun Liu[1], Nan Zhou[1], Yifan Zhao[1], Long Zhu[1], Fei Xia[1], Jian Wang[1]; *[1]Wuhan National Lab for Optoelectronics, China.* We present a novel free-space communication link using orbital angular momentum (OAM) array encoding/decoding.

JTh2A.68
Arrays of WSi Superconducting Nanowire Single Photon Detectors for Deep Space Optical Communications, Matthew Shaw[1], Francesco Marsili[1], Andrew Beyer[1], Jeffrey Stern[1], Giovanni Resta[1], Prasana Ravindran[2], Su Wei Chang[2], Joseph Bardin[2], Ferze Patawaran[1], Varun Verma[3], Richard P. Mirin[3], Sae Woo Nam[3], William Farr[1]; *[1]Jet Propulsion Lab, USA; [2]Electrical Engineering, Univ. of Massachusetts, USA; [3]National Inst. of Standards and Technology, USA.* We have developed 64 pixel free space coupled arrays of WSi SNSPDs as a pathfinder for the ground detector in a deep space optical communication system. Our receiver prototype was used to close a real time deep space optical communication link at 47 Mbps.

JTh2A.69
A Colorless ONU Scheme for WDM-OFDM-PON with Symmetric Bitrate and Low-cost Direct-detection Receivers, Cheng Lei[1], Minghua Chen[1], Hongwei Chen[1], Sigang Yang[1], Shizhong Xie[1]; *[1]Tsinghua Univ., China.* By suppressing one of the conjugated sidebands, the phase-modulated downstream OFDM signal can be directly detected and remodulated for upstream transmission simultaneously. Thus, colorless ONU can be realized with symmetric bitrate and low-cost direct-detection receiver.

JTh2A.70
Experimental Demonstration of Bandwidth Reduction using Nyquist Shaped PSK for Flexible udWDM, Jose A. Altabas[1], Jose A. Lazaro[2], Felix Sotelo[1], Ignacio Garces[1]; *[1]Univ. of Zaragoza, Spain; [2]Universitat Politècnica de Catalunya, Spain.* Nyquist shaped PSK for flexible udWDM is proposed. 1.25Gb/s (2.5Gb/s) Nyquist-PSK with a 1200 homodyne coherent receiver reduces the used optical bandwidth to 3.75GHz (5GHz) with receiver sensitivity of -48.5dBm at BER=10^{-3}.

JTh2A.71
Dynamic Adaptation of Bandwidth Granularity for Multipath Routing in Elastic Optical OFDM Networks, Luae' Altarawneh[1], Sareh Taebi[1]; *[1]Electrical and Computer Engineering, Southern Illinois Univ., USA.* We introduce the concept of bandwidth granularity dynamic adaptation for spectrum allocation using multipath provisioning in elastic optical OFDM networks. Results show that dynamic bandwidth adaptation significantly improves the performance in terms of throughput and blocking probability.

JTh2A.72
Study of Methane Saturated Dispersion Resonances Amplitude near 2.36 μm over the Temperature Range 77-300 K, Vladimir A. Lazarev[1], Mikhail K. Tarabrin[1], Valeriy E. Karasik[1], Alexey N. Kireev[2], Alexander S. Shelkovnikov[2], Yuri P. Podmarkov[2,4], Yuri V. Korostelin[2], Mikhail P. Frolov[2,4], Vladimir I. Kozlovsky[2], Mikhail A. Gubin[2,3]; *[1]Science and Education Center Photonics and IR-Techniques, Bauman Moscow State Technical Univ., Russia; [2]P. N. Lebedev Physical Inst. of the Russian Academy of Sciences, Russia; [3]National Research Nuclear Univ. MEPhI, Russia; [4]Moscow Inst. of Physics and Technology, Russia.* Saturated dispersion resonances of the methane E(2)-line $\nu_1+\nu_4$-band over the temperature range 77-300 K were observed with two-mode Cr^{2+}:ZnSe laser with intracavity absorption cell. The resonances amplitudes were measured and compared with calculations.

JTh2A.73
Phase Noise Measurement of Microwave Signal Sources based on Microwave Photonic Technologies, Fangzheng Zhang[1], Dengjian Zhu[1], Shilong Pan[1]; *[1]Nanjing Univ Aeronautics & Astronautics, China.* Phase noise measurement of microwave signal sources using microwave photonic technologies is demonstrated. Accurate measurement is achieved in an operation bandwidth from 5 to 40 GHz, and the sensitivity is below -130 dBc/Hz@10 kHz offset.

JTh2A.74
Proposal and Experimental Verification of Brillouin Optical Correlation Domain Reflectometry with Lock-in Detection Scheme, Yuguo Yao[1], Masato Kishi[1], Kazuo Hotate[1]; *[1]The Univ. of Tokyo, Japan.* We have newly proposed a Brillouin optical correlation domain reflectometry with lock-in detection scheme. The scheme is verified by experiments using intensity and phase modulation. The phase modulation suppresses the background noise effectively.

JTh2A.75
Composite 1-GHz Optical Parametric Oscillator Frequency Comb from 400 - 1900 nm, Richard A. McCracken[1], Karolis Balskus[1], Zhaowei Zhang[1], Derryck T. Reid[1]; *[1]Heriot-Watt Univ., UK.* We report a fully-stabilized synchronously-pumped optical parametric oscillator frequency comb at 1-GHz repetition frequency, comprising pump, signal and idler combs as well as combs at their sum-frequency and second-harmonic frequencies.

JTh2A.76
Laser Noise Improvement Through Pulse Nonlinear Propagation in a Dispersion-Increasing Fiber, Ming-Hsien Lin[1], Chen-Bin Huang[1]; *[1]National Tsing Hua Univ., Taiwan.* We demonstrate experimentally that laser amplitude and timing jitters can be improved when the laser pulse undergoes adiabatic spectral compression in a dispersion-increasing fiber.

JTh2A.77
Doppler-free spectroscopy of $2^3P\rightarrow3^3D$ and spin-forbidden $2^3P\rightarrow3^1D$ transitions at 588 nm, Pei-Ling Luo[1], Jinmeng Hu[2], Yan Feng[2], Li-Bang Wang[1], Jow-Tsong Shy[1,3]; *[1]Dept. of Physics, National Tsing Hua Univ., Taiwan; [2]Shanghai Key Lab of Solid State Laser and Application and Shanghai Inst. of Optics and Fine Mechanics,Chinese Academy of Sciences, China; [3]Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan.* We demonstrated the Doppler-free intermodulated fluorescence spectroscopy of the ^4He $2^3P\rightarrow3^{1,3}D$ transitions using a one-watt compact laser system at 588 nm. The power-dependent spectra of the $2^3P\rightarrow3^3D$ transitions were studied and the Doppler-free spectrum of the $2^3P\rightarrow3^1D$ transitions was first achieved.

JTh2A.78
Semiconductor Optical Amplifier with Holding Beam Injection for Single Path Accurate Time Transmission, Josef Vojtech[1], Jan Radil[1], Vladimir Smotlacha[1]; *[1]CESNET, Czech Republic.* We experimentally demonstrated an accurate time transfer over 200 km single fiber path using semiconductor optical amplifiers in bidirectional operation with holding beam injection. Experiments show significant reductions of spontaneous lase of the fiber path.

JTh2A.79
Ultra-Narrow Linewidth, Micro-Integrated Semiconductor External Cavity Diode Laser Module for Quantum Optical Sensors in Space, Christoph Pyrlic[1], Wojciech Lewoczko-Adamczyk[1,2], Sven Schwertfeger[1], Johannes Häger[1], Andreas Wicht[1,2], Achim Peters[1,2], Götz Erbert[1], Günther Tränkle[1]; *[1]Ferdinand Braun Inst., Germany; [2]Humboldt Universität zu Berlin, Germany.* We present an external-cavity-diode-laser for quantum sensor applications based on distributed feedback diode laser with resonant feedback from an external cavity. The intrinsic linewidth is 31 Hz. Design, micro-integration concept and experimental results are shown.

JTh2A.80
Frequency-Control Characteristics of an Erbium-Based Mode-Locked Fiber Laser with an Optically Pumped Ytterbium Fiber, Hajime Inaba[1], Sho Okubo[1], Malte Schramm[1], Kenta Gunji[1], Feng-Lei Hong[1], Kazumoto Hosaka[1], Atsushi Onae[1]; *[1]National Metrology Inst. of Japan (NMIJ), Japan.* Frequency-control characteristics of a mode-locked erbium-fiber laser with an intracavity optically pumped ytterbium-fiber were investigated. The fixed frequency of the comb when the pump power to the ytterbium-fiber is changed varies with the power.

JTh2A.81
Photonic Generation of Linearly-Chirped Microwave Waveform With Tunable Center Frequency and Time-Bandwidth Product, Hao Zhang[1], Weiwen Zou[1], Jianping Chen[1]; *[1]State Key Lab of Advanced Optical Communication Systems and Networks, Dept. of Electronic Engineering, Shanghai Jiao Tong Univ., China.* A novel approach is presented to generate linearly-chirped microwave waveforms with tunable center frequency and expandable time-bandwidth product (TBWP). Different types of waveforms are demonstrated and the maximum measured TBWP is up to ~166.4.

11:30–13:00
JTh2A • Poster Session III

JTh2A.82
Investigation of Trace Gas Sensor Based on QEPAS Method Using Different QTFs, Yufei Ma[1], Guang Yu[1], Jingbo Zhang[1], Xin Yu[1], Hao Luo[1], Deying Chen[1], Rui Sun[1], Frank K. Tittel[2]; [1]*Harbin Inst. of Technology, China;* [2]*Dept. of Electrical and Computer Engineering, Rice Univ., USA.* A trace gas sensor platform based on quartz-enhanced photoacoustic spectroscopy using quartz tuning forks (QTFs) with resonant frequency of 38 kHz and 40 kHz were experimentally investigated and theoretically analyzed for the first time.

JTh2A.83
Optical Heterodyne Micro-Vibration Measurement Based on All-Fiber Acousto-Optic Frequency Shifter, Ligang Huang[1], Weihua Peng[1], Wending Zhang[2], Feng Gao[1], Fang Bo[1], Guoquan Zhang[1], Jingjun Xu[1]; [1]*TEDA Applied Physics Inst. and School of Physics, Nankai Univ., China;* [2]*Northwestern Polytechnical Univ., China.* We provide an optical heterodyne detection configuration based on an all-fiber acousto-optic structure, which acts as both frequency shifter and coupler simultaneously, with a resolution of 0.01 nm from 10 kHz to 90 kHz.

JTh2A.84
Dual-parameters sensing based on multimode microfiber with Fresnel reflection, Qizhen Sun[1,2], Haipeng Luo[1], Zhilin Xu[1], Deming Liu[1], Lin Zhang[2], Xiaohui Sun[1]; [1]*Huazhong Univ of Science and Technology, China;* [2]*Aston Inst. of Photonic Technologies, Aston Univ., UK.* A compact and low cost fiber sensor based on microfiber with Fresnel reflection is proposed and demonstrated for simultaneous measurement of refractive index (RI) and temperature with high sensitivities.

JTh2A.85
Analysis of signal amplitude in Chirped Laser Dispersion Spectroscopy, Jacek Wodecki[1], Michal P. Nikodem[1]; [1]*Wroclaw Research Centre EIT+, Poland.* Signals measured with Chirped Laser Dispersion Spectroscopy setup implemented with intensity modulator are analyzed experimentally. Potential strategies for signal retrieval and amplitude enhancement possibilities are described.

JTh2A.86
Cylindrical multipass reflection cells for optical trace gas sensing, Markus Mangold[1,2], Lukas Emmenegger[1], Béla Tuzson[1], Herbert Looser[3]; [1]*Empa, USA;* [2]*IRsweep, Switzerland;* [3]*FHNW, Switzerland.* Single-piece cylindrical multipass cells effectively fold a long optical path in a small detection volume. We present a systematic survey of various cell configurations and the respective mirror shapes for enhanced path-to-volume ratios.

JTh2A.87
Doppler-Based Flow Rate Sensing in Microfluidic Channels, Avraham Bakal[1], Liron Stern[1], Mor Tzur[1], Maya Veinguer[1], Noa Mazurski[1], Nadav Cohen[2], Uriel Levy[1]; [1]*The Hebrew Univ. of Jerusalem, Israel;* [2]*Tel Aviv Univ., Israel.* We design, fabricate and experimentally demonstrate a novel generic method to detect flow rates velocity in microfluidic devices. The method is appealing for variety of applications where a simple and accurate speed measurement is needed.

JTh2A.88
Stand-off Detection of Liquid Thin Films using Active Mid-Infrared Hyperspectral Imaging, Luke Maidment[1,2], Zhaowei Zhang[1], Christopher R. Howle[2], Stephen T. Lee[3], Allan Christie[3], Derryck T. Reid[1]; [1]*Scottish Universities Physics Alliance (SUPA), Inst. of Photonics and Quantum Sciences, School of Engineering and Physical Sciences, Heriot-Watt Univ., UK;* [2]*Defence Science and Technology Lab, UK;* [3]*Thales Optronics, UK.* The idler output of an ultrafast optical parametric oscillator is used with a mid-infrared camera to distinguish between water and deuterium oxide, demonstrating the potential for standoff detection of a wide range of liquids.

JTh2A.89
Filaments for Raman Spectroscopy, Chengyong Feng[1], James Hendrie[1], Jean-Claude Diels[1], Ladan Arissian[1]; [1]*CHTM, Univ. of New Mexico, USA.* Impulsive rotational/vibrational Raman scattering of molecules excited by IR filaments and thereafter probed by a narrow line-width UV beam is proposed. We show results of rotational Raman scattering of air molecules for preliminary demonstration.

JTh2A.90
Experimental and Numerical Analysis of Commercial and Homemade Tuning Forks for QEPAS, Guillaume Aoust[1], Raphaël Levy[1], Myriam Raybaut[1], Béatrice Bourgeteau[1], Jean-Baptiste Dherbecourt[1], Jean-Michel Melkonian[1], Antoine Godard[1], Michel Lefebvre[1]; [1]*ONERA, the french aerospace lab, France.* Characteristics of two commercial quartz tuning forks and a homemade tuning fork are compared for standard QEPAS experiments. An analytical model is also derived to compare theory and experiment with a reasonable agreement.

JTh2A.91
Electronics-assisted ultra-narrow optical filtering and its application in low phase noise lasing, Yitang Dai[1], Ziping Zhang[1], Feifei Yin[1], Yue Zhou[1], Jianqiang Li[1], Kun Xu[1]; [1]*Beijing Univ of Posts & Telecom, China.* A MHz-level optical filtering is achieved by frequency conversion pair between optical and radio carriers as well as electronic filtering. Narrow linewidth lasing is then obtained with 20-kHz 20-dB linewidth and 65-dB side-mode suppression ratio.

JTh2A.92
A New Method of Longitudinal Mode Selection in Q-switched Lasers, Efim A. Khazanov[1,2], Andrey Shaykin[1], Konstantin Burdonov[1]; [1]*Inst. of Applied Physics of the Russian Academy of Science, Russia;* [2]*National Univ. of Science and Technology "MISiS", Russia.* The effect of post-pulse (the second giant pulse at the neighboring longitudinal mode) generation in a Q-switched laser was revealed in experiment. Based on this effect, a new method of longitudinal mode selection was implemented.

JTh2A.93
Laser Eigenvalue, Coherence Time, Q-factor, and Linewidth, Markus Pollnau[1], Marc Eichhorn[2]; [1]*Dept. of Materials and Nano Physics, KTH-Royal Inst. of Technology, Sweden;* [2]*French-German Research Inst. of Saint-Louis ISL, France.* We generalize the theory of continuous-wave lasers by considering spontaneous emission in the photon rate equation. We relate the laser coherence time, *Q*-factor, and linewidth to the passive-resonator parameters, thereby unifying resonator and laser theory.

JTh2A.94
Nonlinear Polarization Switching and Preservation Effects in 55 μm Core Polygonal-CCC Fibers, I-Ning Hu[1], Cheng Zhu[1], Michael Haines[1], Timothy McComb[2], Geoff Fanning[2], Roger Farrow[2], Almantas Galvanauskas[1]; [1]*Univ. of Michigan, USA;* [2]*nLight, USA.* Study of nonlinear, intensity-dependent polarization evolution in 55μm core polygonal-CCC fibers reveals that both nonlinear polarization switching as well as robust and intensity-independent polarization maintenance can be achieved depending on input signal polarization.

JTh2A.95
Novel Design of Simple and Compact Tunable Fiber Laser, Yasushi Fujimoto[1], Osamu Ishii[2], Masaaki Yamazaki[3]; [1]*Osaka Univ., Japan;* [2]*Production Engineering Section, Optical Glass Production Dept., Sumita Optical Glass, Inc.,, Japan;* [3]*Glass Research Division, R&D Dept., Sumita Optical Glass, Inc.,, Japan.* We propose and demonstrate a novel design of simple and compact tunable fiber laser skillfully using chromatic aberration of a lens relay and a slit-like effect of optical fiber core.

JTh2A.96
Spatially-resolved Pulse-front-tilt and Pulse-width Distributions of Q-switched Pulses from an Unstable Nd:YAG Resonator, Chengyong Feng[1], Xiaozhen Xu[1], Jean-Claude Diels[1]; [1]*CHTM, Univ. of New Mexico, USA.* Pulse-front-tilt and negligible pulse-width spread across the laser beam are reported, both experimentally and numerically, for pulses from a Q-switched unstable resonator with a variable-reflectivity-mirror under different operation conditions.

JTh2A.97
Single Frequency 310ps, 1.67J Laser Pulses Generation with Nonfocusing-pumped Stimulated Brillouin Scattering, Xuehua Zhu[1], Zhiwei Lu[1], Yulei Wang[1], Hengkang Zhang[1]; [1]*Harbin Inst. of Technology, China.* We obtained single frequency laser pulses with enery of 1.67-J and duration of 310-ps based on the nonfocusing-pumped stimulated Brillouin scattering. A high-power Nd:glass laser system delivers 3-ns super-Gaussian-shaped pulses is used as the light-source.

JTh2A.98
Widely-tunable high-power narrow-linewidth thulium-doped all-fiber superfluorescent source, Jiang Liu[1], Hongxing Shi[1], Chen Liu[1], Pu Wang[1]; [1]*Beijing Univ. of Technology, China.* Power scaling of narrow-linewidth thulium-doped fiber superfluorescent source with wavelength tunable from 1940~2010nm is reported. The all-fiber superfluorescent source yielded 364W of output power at central wavelength of 1980nm with 3dB spectral bandwidth of 1.9nm.

JTh2A.99
UV Laser Beam Stabilization System for the European XFEL Electron Injector Laser Beamline, Florian Kaiser[1], Sebastian Köhler[1], Falko Peters[1], Lutz Winkelmann[1], Ingmar Hartl[1]; [1]*DESY, Germany.* We present a beam drift stabilization system for the 22 m UV-laser beam delivery to the electron gun of the European XFEL. The camera-based system is robust to dynamic variations in power, beam size and shape.

JTh2A.100
Spectroscopic characterization of Pr^{3+}:ZnSe crystals fabricated via post growth thermal diffusion, Alan Martinez[1], Ozarfar Gafarov[1], Dmitry Martyshkin[1], Vladimir V. Fedorov[1], Sergey B. Mirov[1]; [1]*Univ. of Alabama at Birmingham, USA.* We demonstrate post-growth thermal diffusion rates of praseodymium ions into ZnSe. Near and middle infrared luminescence spectra and kinetics of Pr:ZnSe crystals were studied at RT.

JTh2A.101
Withdrawn

JTh2A.102
Power Scaling of Femtosecond Ti:sapphire Laser Double-Side-Pumped by High-Power Green InGaN Diode Lasers, Ryota Sawada[1], Hiroki Tanaka[1], Ryosuke Kariyama[1], Kenichi Hirosawa[1], Fumihiko Kannari[1]; [1]*Dept. of Electronics and Electrical Engineering, Keio Univ., Japan.* We demonstrate a mode-locked Ti:sapphire laser pumped by high-power green InGaN diode lasers from both sides of the crystal and achieved a highest laser power of 50 mW.

JTh2A.103
Developed objective system for measuring the visibility of the display with metal mesh as a capacitive touch sensor, Kim T. Young[1,2]; [1]*SAMSUNG, Korea;* [2]*Center of Information Storage Devices, Yonsei Univ., Korea.* In this paper, we introduce a new method to measure the visibility of a metal- mesh ITO-replacement touch panels. The reason why we have developed this system is to clear up the ambiguity of the visibility estimation or readability property of the metal mesh electrodes in touch sensors.

JTh2A.104
Fabrication of Gratings with Low Spacing Error by the Dual-Beam Exposure System with Spherical Lenses, Shiwei Wang[1], Lijiang Zeng[1]; [1]*Tsinghua Univ., USA.* We propose a feedback method of adjusting the dual-beam exposure system with spherical collimation lenses based on deducing the spacing error from diffraction wavefront. The grating of 0.03 λ in 70×70 mm^2 can be achieved.

12:30–14:00 Pizza Lunch with Exhibitors, *Exhibit Hall*

13:00–14:30 Market Focus: U.S. Export Control - Review of Government Rules and Open Discussion of Possible Changes, *Exhibit Hall Theater*

NOTES

Executive Ballroom 210A	Executive Ballroom 210B	Executive Ballroom 210C	Executive Ballroom 210D

CLEO: Applications & Technology

CLEO: QELS-Fundamental Science

14:00–16:00
ATh3A • Symposium on Science and Technology of Laser Three Dimensional Printing I
Presider: Timo Mappes; Carl Zeiss AG, Germany

ATh3A.1 • 14:00 Invited
Dynamic Optics for Three-Dimensional Laser Material Processing, Martin J. Booth[1]; [1]*Univ. of Oxford, UK.* Dynamic optical elements, including spatial light modulators and deformable mirrors, improve the capabilities of laser fabrication systems. Advantages include aberration correction, parallelization and spatial control over the temporal intensity profile of ultrashort pulses.

ATh3A.2 • 14:30 Invited
Laser Written 3D Lightwave Circuits and Applications, Simon Gross[1], Nicolas Riesen[2], John Love[3], Michael J. Withford[1]; [1]*Macquarie Univ., Australia;* [2]*The Univ. of Adelaide, Australia;* [3]*The Australian National Univ., Australia.* Three dimensional lightwave circuits, fabricated using femtosecond laser direct-write techniques, are enabling new applications in quantum optics, astronomy and telecommunications. We review those and highlight our recent work on 3D compact, passive mode selective couplers.

14:00–16:00
FTh3B • NV – Centers for Metrology and Photonics
Presider: Dirk Englund; MIT, USA

FTh3B.1 • 14:00
Deterministic High-yield Creation of Nitrogen Vacancy Centers in Diamond Photonic Crystal Cavities and Photonic Elements, Tim Schroder[1], Luozhou Li[1], Edward Chen[1], Michael Walsh[1], Matthew E. Trusheim[1], Igal Bayn[1], Jiabao Zheng[1], Sara Mouradian[1], Hassaram Bakhru[2], Ophir Gaathon[1], Dirk R. Englund[1]; [1]*MIT, USA;* [2]*Univ. at Albany, USA.* We demonstrate the high-yield creation of nitrogen-vacancy centers in the mode-maxima of a variety of functional photonic elements with less than 30nm precision. We create 1.1 NVs per photonic-crystal-cavity and show strong Purcell enhancement.

FTh3B.2 • 14:15
Direct laser writing aligned with nanodiamonds containing NV-centers as single-photon emitters, Qiang Shi[1], Joachim Fischer[1], Patrik Rath[1], Bernd Sontheimer[2], Andreas Schell[2], Wolfram Pernice[1], Oliver Benson[2], Andreas Naber[1], Martin Wegener[1]; [1]*Karlsruhe Inst. of Technology, Germany;* [2]*Humboldt-Universität zu Berlin, Germany.* We present and apply an instrument allowing for localizing NV-centers in nano- diamonds in a photoresist, measuring the $g^2(\tau)$ correlation function without exposing the photoresist, and performing three-dimensional direct laser writing aligned with the single- photon emitters.

FTh3B.3 • 14:30
Efficient collection from a nitrogen-vacancy qubit in a circular grating, Luozhou Li[1], Edward Chen[1], Jiabao Zheng[2], Sara Mouradian[1], Florian Dolde[1], Tim Schroder[1], Sinan Karaveli[1], Matthew Markham[3], Daniel Twitchen[3], Dirk R. Englund[1]; [1]*MIT, USA;* [2]*Columbia Univ., USA;* [3]*Element Six, USA.* We demonstrate a circular 'bullseye' diamond grating enabling efficient collection of single photons from a single nitrogen-vacancy center with a spin coherence time of 1.7 ms. Back-focal-plane studies indicate efficient redistribution into low-NA modes.

14:00–16:00
FTh3C • Attosecond Spectroscopy
Presider: Martin Schultze; Max Planck Institut fuer Quantenoptik, USA

FTh3C.1 • 14:00 Tutorial
Attosecond Ionization Dynamics and Time Delays, Ursula Keller[1]; [1]*ETH Zurich, Switzerland.* Although time is not an quantum-mechanical operator, novel attosecond techniques can measure very fundamental time delays. Using the tunneling time as an example, this tutorial should give a better insight on current issues and hot topics.

Ursula Keller has been a tenured professor of physics at ETH Zurich since 1993 and currently serves as director of the NCCR MUST program in ultrafast science. She received a Masters at ETH 1984, a Ph.D. at Stanford Univ. 1989, and was a Member of Technical Staff at Bell Labs from 1989 to 1993.

14:00–16:00
FTh3D • Synthetic Lattices & Topological Phenomena
Presider: Alexander Szameit; Friedrich-Schiller-Universität Jena, Germany

FTh3D.1 • 14:00
Anderson Localization in Synthetic Photonic Lattices, Ilya Vatnik[1,2], Alexey M. Tikan[2], Dmitry V. Churkin[3,2], Andrey A. Sukhorukov[4]; [1]*Inst. of Automation and Electrometry SB RAS, Russia;* [2]*Novosibirsk State Univ., Russia;* [3]*Aston Inst. of Photonic Technologies, UK;* [4]*The Australian National Univ., Australia.* We experimentally demonstrate Anderson localization for optical pulses in time domain, using a photonic mesh lattice implemented with coupled optical fiber loops. We also discuss interplay of photonic band-gaps and disorder in such lattices.

FTh3D.2 • 14:15
Experimental realization of a topological Anderson insulator, Simon Stützer[1], Mikael Rechtsman[2], Paraj Titum[3], Yonatan Plotnik[2], Yaakov Lumer[2], Julia M. Zeuner[1], Stefan Nolte[1], Gil Refael[3], Netanel Lindner[2], Mordechai Segev[2], Alexander Szameit[1]; [1]*Inst. of Applied Physics, Friedrich-Schiller-Universität, Germany;* [2]*Dept. of Physics, Israel Inst. of Technology, Israel;* [3]*Dept. of Physics, Inst. of Quantum Information and Matter, USA.* We experimentally demonstrate that disorder can induce a topologically non-trivial phase. We implement this „Topological Anderson Insulator" in arrays of evanescently coupled waveguides and demonstrate its unique features.

FTh3D.3 • 14:30
Topological Insulators in *PT*-Symmetric Lattices, Gal Harari[1], Yonatan Plotnik[1], Miguel A. Bandres[1], Yaakov Lumer[1], Mikael Rechtsman[1], Mordechai Segev[1]; [1]*Physics Dept., Technion Israel Inst. of Technology, Israel.* We present the first *PT*-symmetric topological insulator system: topologically-protected transport of edge states in *PT*-symmetric photonic honeycomb lattices.

Executive Ballroom 210E	Executive Ballroom 210F	Executive Ballroom 210G	Executive Ballroom 210H
CLEO: QELS-Fundamental Science	CLEO: Science & Innovations		

14:00–16:00
FTh3E • Light Harvesting and Electroplasmonics
Presider: Dirk Englund; MIT, USA

FTh3E.1 •14:00 Invited
Ultrafast Coherent Charge Transfer in Solar Cells and Artificial Light Harvesting Systems: Toward Movies of Electronic Motion, Christoph Lienau[1]; [1]*Inst. of Physics, Carl von Ossietzky Univ. Oldenburg, Germany.* We have recently established a new approach, combining high-time resolution optical spectroscopy and time-dependent density functional theory to probe the most elementary processes of light-to-current conversion in nanostructures. I will present an overview and discuss most recent findings.

FTh3E.2 • 14:30
Atomically-thin van der Waals Heterostructure Solar Cells, Thomas Mueller[1], Marco Furchi[1], Armin Zechmeister[1], Simone Schuler[1], Andreas Pospischil[1]; [1]*Vienna Univ. of Technology, Austria.* We present atomically-thin photovoltaic solar cells based on van der Waals heterostructures of transition metal dichalcogenides and other two-dimensional semiconductors.

14:00–16:00
STh3F • Microwave Photonic Devices
Presider: Mark Foster; Johns Hopkins Univ., USA

STh3F.1 • 14:00
Linearized Intensity-Modulation Link by a Direct-Detection Intermodulation-Compensation Receiver, Dan Tu[1], Feifei Yin[1], Xiaodong Liang[1], Yitang Dai[1], Jianqiang Li[1], Kun Xu[1]; [1]*Beijing Univ. of Posts and Telecommunications, China.* By the bias-voltage-dependent responsivity, a direct-detection photo detector is proposed to eliminate the third-order intermodulation for the intensity-modulation analog photonic link. Spurious-free dynamic range of 123.4 dB within 1-Hz bandwidth is achieved with 18.1-dB improvement.

STh3F.2 • 14:15
Frequency Band Selectable Microwave Photonic Multiband Bandpass Filter based on Lyot filter, Jia Ge[1], Mable P. Fok[1]; [1]*Univ. of Georgia, USA.* We present a microwave photonic multiband bandpass filter with four selectable operating states, which can either work as an all-block, single-pass or multi-pass bandpass filter with up to 46 dB sidelobe suppression.

STh3F.3 • 14:30 Invited
Silicon-photonics-based Signal Processing for Microwave Photonic Frontends, Minghua Chen[1], Hongchen Yu[1], Jingjing Wang[1], Hongwei Chen[1], Sigang Yang[1], Shizhong Xie[1]; [1]*Tsinghua Univ., China.* Integrated signal processors offer potential high resolution, tunability and programmable microwave photonic signal processing. The high performance integrated FIR/IIR signal processers have been presented, accompanying an application for the full-band microwave photonic frontends.

14:00–16:00
STh3G • Fabrication Techniques I
Presider: Amy Foster; Johns Hopkins Univ., USA

STh3G.1 • 14:00 Tutorial
Heterogeneous 2D and 3D Photonic Integration for Future Chip-Scale Microsystems, S. J. Ben Yoo[1]; [1]*Univ. of California Davis, USA.* This tutorial reviews state-of-the-art heterogeneous 2D/3D photonic integration technologies involving various novel fabrication techniques leading to realization of chip-scale microsystems with photonic-electronic-integrated-circuits. Future prospects and challenges in computing and networking applications will also be discussed.

S. J. Ben Yoo is a Professor of Electrical Engineering at University of California at Davis (UC Davis). His research at UC Davis includes photonic integration for future computing, communication, imaging, and navigation systems. Prior to joining UC Davis in 1999, he was a Senior Research Scientist at Bellcore, leading technical efforts in integrated photonics, optical networking, and systems integration. He received BS'84, MS'86, PhD'91 from Stanford University. Prof. Yoo is Fellow of IEEE, OSA, NIAC and a recipient of the DARPA Award for Sustained Excellence (1997), the Bellcore CEO Award (1998), the Mid-Career Research Faculty Award (2004), and the Senior Research Faculty Award (2011).

14:00–16:00
STh3H • Materials and Devices for Nonlinear Frequency Upconversion
Presider: Antoine Godard; ONERA - French Aerospace Lab, France

STh3H.1 • 14:00 Invited
Nonlinear Optical Processes and DUV Generation in Random Domain Structures of SBO, Aleksandr S. Aleksandrovsky[1,2]; [1]*L.V.Kirensky Insitute of Physics, Russia;* [2]*Photonics and Laser Technologies Deoartment, Siberian Federal Univ., Russia.* Random domain structures in strontium tetraborate enhance nonlinear optical conversion for variety of processes within transparency window (121 nm). Properties of material, frequency doubling, autocorrelation measurements and conversion of supercontinuum to UV are described.

STh3H.2 • 14:30
Generation of Coherent Vacuum UV Radiation in Randomly Quasi-Phase-Matched Strontium Tetraborate, Peter Trabs[1], Frank Noack[1], Aleksandr S. Aleksandrovsky[2,3], Alexandre Zaitsev[2,3], Valentin Petrov[1]; [1]*Max Born Inst., Germany;* [2]*L. V. Kirensky Inst. of Physics, Russia;* [3]*Siberian Federal Univ., Russia.* Tunable coherent radiation is generated in the VUV down to 121 nm using random quasi-phase-matching in strontium tetraborate, the shortest wavelength ever produced with a second-order nonlinear optical process in a solid-state material.

Meeting Room 211 B/D

CLEO: Science & Innovations

14:00–16:00
STh3I • Optomechanics I
Presider: Philip Russell; Max-Planck-Inst Physik des Lichts, Germany

STh3I.1 • 14:00
Diamond Electro-optomechanical Devices with Resonance Frequencies above 100 MHz, Patrik Rath[1], Sandeep Ummethala[1], Silvia Diewald[2], Georgia Lewes-Malandrakis[3], Dietmar Brink[3], Nicola Heidrich[3], Christoph Nebel[3], Wolfram Pernice[1]; *[1]Inst. of Nanotechnology, Karlsruhe Inst. of Technology, Germany; [2]Center for Functional Nanostructures, Karlsruhe Inst. of Technology, Germany; [3]Fraunhofer Inst. for Applied Solid State Physics, Germany.* We realize diamond electro-optomechanical resonators operated at frequencies above 100 MHz. The nanomechanical motion is read-out via on-chip diamond photonic circuits showing Q-factors above 1300.

STh3I.2 • 14:15
GaAs nanobeam piezo-optomechanical crystals, Krishna C. Balram[1,2], Marcelo I. Davanco[1], Ju Young Lim[3], Jin Dong Song[3], Kartik Srinivasan[1]; *[1]Center for Nanoscale Science and Technology, National Inst. of Standards and Technology, USA; [2]Maryland Nanocenter, Univ. of Maryland, USA; [3]Center for Opto-Electronic Convergence Systems, Korea Inst. of Science and Technology, Korea.* We demonstrate GaAs optomechanical crystals with large coupling rates (g0/2π≈1.1MHz) through the photoelastic effect. We show a significant orientation (≈ 30%) dependence of g0, observe 2.5 GHz regenerative oscillations, and explore excitation via piezoelectrically-driven surface-acoustic-waves.

STh3I.3 • 14:30
Diamond Nanobeam Waveguide Optomechanics, Behzad Khanaliloo[1,2], Harishankar Jayakumar[1], David Lake[1], Paul E. Barclay[1,2]; *[1]Univ. of Calgary, Canada; [2]National Inst. for Nanotechnology, Canada.* Single crystal diamond (SCD) waveguide nanomechanical resonators with mechanical quality factors exceeding 7×10^5 in cryogenic conditions are demonstrated. Mechanical self--oscillations are observed with amplitudes of 200 nm.

Meeting Room 212 A/C

CLEO: Applications & Technology

14:00–16:00
ATh3J • Clinical Technologies and Systems I
Presider: Jin Kang; Johns Hopkins Univ., USA

ATh3J.1 • 14:00 Invited
Finding Bugs in your Ear: Clinical Imaging of Middle-Ear Infections and Biofilms using OCT, Stephen A. Boppart[1]; *[1]Univ of Illinois at Urbana-Champaign, USA.* Handheld OCT scanners have been developed for screening and characterizing middle-ear infections that are highly prevalent in the pediatric population. OCT enables non-invasive identification of bacterial biofilms that will impact clinical treatment of this disease.

ATh3J.2 • 14:30 Invited
Integrative Advances for OCT-Guided Ophthalmic Surgery and Intraoperative OCT, Yuankai K. Tao[1], Mohamed El-Haddad[1], Sunil Srivastava[1], Daniel Feiler[1], Amanda Noonan[2], Andrew Rollins[2], Justis Ehlers[1]; *[1]Cole Eye Inst. Cleveland Clinic, USA; [2]Biomedical Engineering, Case Western Reserve Univ., USA.* Microscope-integrated intraoperative OCT (iOCT) allows live cross-sectional imaging concurrent with ophthalmic surgery and dynamic visualization of tissue-instrument interactions. We present a microscope-integrated iOCT system with heads-up display (HUD) and novel semi-transparent ophthalmic surgical instruments.

Meeting Room 212 B/D

CLEO: Science & Innovations

14:00–16:00
STh3K • Novel Microscopy Techniques and OCT
Presider: Chulmin Joo; Yonsei Univ., Korea

STh3K.1 • 14:00 Invited
Brillouin Microscopy For Tissue And Cell Biomechanics, Giuliano Scarcelli[2,1]; *[1]Harvard Medical School, USA; [2]Bioengineering, Univ. of Maryland, USA.* We have developed an all-optical approach to measure material mechanical properties using Brillouin light scattering. Brillouin imaging uses the elastic modulus as contrast mechanism. We demonstrate its application *in vivo* for tissue and cellular biomechanics.

STh3K.2 • 14:30
Enhanced Detection of Longitudinal Field of a Radially Polarized Beam in Confocal Laser Microscopy, Yuichi Kozawa[1], Shunichi Sato[1]; *[1]Inst. of Multidisciplinary Research for Advanced Materials, Tohoku Univ., Japan.* The wave scattered by the longitudinal component of a tightly focused radially polarized beam is clearly detected in a confocal system, which may lead to the enhancement of the spatial resolution in confocal microscopy.

Marriott Salon I & II

14:00–16:00
STh3L • Ultrafast Fiber Lasers
Presider: Peter Fendel; Thorlabs Inc., USA

STh3L.1 • 14:00
All-fiber bidirectional optical parametric oscillator for precision rotation sensing, Roopa Gowda[1], Nam Nguyen[1], Jean-Claude diels[2], Robert Norwood[1], Nasser Peyghambarian[1], Khanh Q. Kieu[1]; *[1]Univ. of Arizona, USA; [2]Physics, Univ. of New Mexico, USA.* We demonstrate the first all-fiber bidirectional OPO which generates two highly coherent frequency combs in opposite directions. The OPO may find important applications in precision measurements including rotation sensing with ultra-large sensing area and sensitivity.

STh3L.2 • 14:15
Pulse-to-pulse spectral evolution of breathing bound solitons in a mode-locked fiber laser, Srikanth Sugavanam[1], Chengbo Mou[1,2], Junsong Peng[1], Dmitry V. Churkin[1,2]; *[1]Aston Inst. of Photonic Technologies, UK; [2]Novosibirsk State Univ., Russia.* We make first direct observation of breathing bound solitons in mode-locked laser. We measure pulse-to-pulse spectrum evolution and reveal internal interactions between bound solitons in real-time.

STh3L.3 • 14:30
Dissipative soliton thulium fiber laser with pulse energy above 10 nJ, Yuxing Tang[1], Frank W. Wise[1]; *[1]Cornell Univ., USA.* Dissipative-soliton operation of a Tm fiber laser yields 11 nJ pulses, which is several times the energy of prior femtosecond Tm fiber lasers. The pulses can be dechirped to 200 fs duration.

Marriott Salon III | Marriott Salon IV | Marriott Salon V & VI

CLEO: Science & Innovations

14:00–16:00
STh3M • Fundamental Light-material Interaction I
Presider: Emmanuel Haro-Poniatowski; UAM-Iztapalapa, Mexico

STh3M.1 • 14:00
Rapid and highly-sensitive detection using Fano resonances in ultrathin plasmonic nanogratings, Beibei Zeng[1]; [1]*Lehigh Univ., USA*. We developed a nanoplasmonic sensor employing extraordinary optical properties of 30nm-thick ultrathin Ag nanogratings. An order-of-magnitude improvement in the temporal and spatial resolutions was achieved relative to state-of-the-art nanoplasmonic sensors, for comparable detection resolutions.

STh3M.2 • 14:15
Far-field Scattering Measurement of a Single Gold Nanorod Using Total-Internal-Reflection Illumination, Donghyeong Kim[1], Kwang-Yong Jeong[2], Ho-Seok Ee[1], Hong-Gyu Park[2], Min-Kyo Seo[1]; [1]*Physics, Korea Advanced Inst. of Science and Technology(KAIST), Korea;* [2]*Physics, Korea Univ., Korea*. We demonstrate a novel method for measuring far-field scattering of a single nanostructure with a high signal-to-background ratio using total-internal-reflection illumination. Direct far-field scanning overcomes the numerical aperture limit of the typical back-focal plane imaging.

STh3M.3 • 14:30
Fabrication of high-Q lithium niobate microresonators using femtosecond laser micromachining for second harmonic generation, Jintian Lin[1], Yingxin Xu[2], Zhiwei Fang[1], Min Wang[1], Jiangxin Song[1], Nengwen Wang[1], Lingling Qiao[1], Wei Fang[2], Ya Cheng[1]; [1]*Shanghai Inst of Optics and Fine Mech, USA;* [2]*Dept. of Optical Engineering, Zhejiang Univ., State Key Lab of Modern Optical Instrumentation, China*. We report on fabrication of high-Q (i.e., a quarter million) lithium niobate whispering-gallery-mode microresonators using femtosecond laser micromachining. Second harmonic generation with a normalized conversion efficiency of 1.35×10^{-5}/mW has been experimentally demonstrated.

14:00–16:00
STh3N • Time and Frequency Transfer
Presider: Jungwon Kim; KAIST, USA

STh3N.1 • 14:00
Ultra-low Jitter Timing Transfer over a Multi-km Fiber Network with 10^{-21} Relative Stability, Kemal Shafak[1], Ming Xin[1], Michael Y. Peng[2], Franz X. Kaertner[1,2]; [1]*Center for Free-Electron Laser Science, Deutsches Elektronen-Synchrotron, Germany;* [2]*Dept. of Electrical Engineering and Computer Science and Research Lab of Electronics, MIT, USA*. Long-term stable timing transfer over a multi-km fiber network is reported. Output of two independently timing-stabilized fiber links shows only 0.73 femtoseconds RMS total jitter over 35 hours corresponding to 10^{-21} relative link stability.

STh3N.2 • 14:15
Simultaneous Time and Frequency Transfer over a 158-km-Long Fiber Network Using a Mode-Locked Laser, Maurice Lessing[1,2], Helen S. Margolis[1], C. Tom A. Brown[2], Giuseppe Marra[1]; [1]*National Physical Lab, UK;* [2]*School of Physics and Astronomy, Univ. of St Andrews, UK*. We present a technique for simultaneous optical and microwave frequency transfer as well as time transfer using a mode-locked laser. We demonstrate a time deviation of 300 fs at 10 s averaging time on an installed 158 km fiber link.

STh3N.3 • 14:30
Ultrastable Frequency Dissemination Based on Feed-forward Digital Phase Compensation Technology, Xing Chen[1], Jian Zhang[1], Jinlong Lu[1], Yifan Cui[1], Xing Lu[1], Zhiqiang Lv[1], Xusheng Tian[2], Cheng Ci[2], Bo Liu[2], Hong Wu[2], Tingsong Tang[3], Kebin Shi[1], Zhigang Zhang[1]; [1]*Peking Univ., China;* [2]*Nankai Univ., China;* [3]*Beijing Satellite Navigation Center, China*. We demonstrate a feed-forward digital compensation scheme in an optical frequency comb based microwave frequency dissemination system over 120-km telecommunication fiber link. The dissemination fractional frequency instability (Λ-counter) was measured at 5.28×10^{-16}/s.

14:00–16:00
STh3O • Remote and Standoff Optical Detection
Presider: Michael Wojcik; Space Dynamics Lab, USA

STh3O.1 • 14:00
Monostatic All-Fiber Rangefinder System, Jeffrey Leach[1], Stephen R. Chinn[2], Lew Goldberg[1]; [1]*NVESD, USA;* [2]*Fulcrum Company, USA*. An all-fiber monostatic laser rangefinder, using a double cladding fiber to transmit and receive light through a single lens is described. Ranging to >50 m with 12 uJ, 8 ns, 1540 nm pulses is shown. The all-fiber system is compact and needs no precise receiver/transmitter beam alignment.

STh3O.2 • 14:15
Continuous-Wave Laser Range Finder Based on Incoherent Compression of Periodic Sequences, Nadav Arbel[1], Lior Hirschbrand[1], Shai Weiss[1], Nadav Levanon[2], Avi Zadok[1]; [1]*Bar-Ilan Univ., Israel;* [2]*Tel Aviv Univ., Israel*. Continuous and incoherent laser range finder is presented, based on repeating transmission of Legendre amplitude codes and post detection compression. The cyclic correlation sidelobes of the sequences are identically zero. The concept is demonstrated experimentally.

STh3O.3 • 14:30
Experimental Demonstration of Differential Synthetic Aperture Ladar, Zeb W. Barber[1], Jason R. Dahl[1]; [1]*Montana State Univ. - Spectrum Lab, USA*. Differential SAL measures phase slopes to reduce the inherent sensitivity to piston phase errors during the data collection process. The first experimental demonstrations of the technique and comparisons to image based phase compensation are presented.

Executive Ballroom 210A	Executive Ballroom 210B	Executive Ballroom 210C	Executive Ballroom 210D
CLEO: Applications & Technology	CLEO: QELS-Fundamental Science		

ATh3A • Symposium on Science and Technology of Laser Three Dimensional Printing I—Continued

ATh3A.3 • 15:00 Invited

3D Printing Sets New Standards in Microfabrication, Martin Hermatschweiler[1]; *[1]Nanoscribe GmbH, Germany.* Two-photon polymerization has emerged as highest precision additive manufacturing standard for micro- to mesoscale fabrication and superior maskless lithography technique. Design freedom, resolution and processing speed drive diverse scientific as well as industrial applications.

FTh3B • NV – Centers for Metrology and Photonics—Continued

FTh3B.4 • 14:45

Strain coupling of diamond nitrogen vacancy centers to nanomechanical resonators, Srujan Meesala[1], Young-Ik Sohn[1], Haig A. Atikian[1], Michael J. Burek[1], Samuel Kim[1], Jennifer Choy[1], Marko Loncar[1]; *[1]Harvard Univ., USA.* We fabricate high quality factor diamond cantilevers containing nitrogen vacancy (NV) centers. Strain-mediated coupling of the NV spin to the displacement of a mechanical mode is observed in optically detected electron spin resonance measurements.

FTh3B.5 • 15:00

Atom-Photon Coupling from Nitrogen-vacancy Centers Embedded in Tellurite Microspheres, Yinlan Ruan[5], Brant C. Gibson[1], Des W. Lau[1], Andrew Greentree[1], Hong Ji[5], Heike Ebendorff-Heidepriem[5], Brett C. Johnson[2], Takeshi Ohshima[3], Tanya Monro[4,5]; *[1]School of Applied Science, RMIT Univ., Australia; [2]School of Physics, Univ. of Melbourne, Australia; [3]Semiconductor Analysis & Radiation Effects Group, Japan Atomic Energy Agency, Japan; [4]Univ. of South Australia, Australia; [5]School of Chemistry&Physics, Univ. of Adelaide, Australia.* A technique was developed for creating tellurite microspheres with embedded nanodiamonds. The whispering gallery mode modulated fluorescence of the nitrogen vacancy centers in the nanodiamonds was observed with resonance Q over 10,000.

FTh3B.6 • 15:15

Electrochemical potential control of charge state and fluorescence of nitrogen vacancy centers in nanodiamonds, Sinan Karaveli[1,2], Ophir Gaathon[1,3], Abraham Wolcott[1,4], Reyu Sakakibara[1], Darcy Peterka[5], Jonathan S. Owen[4], Rafael Yuste[5], Dirk R. Englund[1]; *[1]Dept. of Electrical Engineering and Computer Science, MIT, USA; [2]Dept. of Electrical Engineering, Columbia Univ., USA; [3]Diamond Nanotechnologies, Inc., USA; [4]Dept. of Chemistry, Columbia Univ., USA; [5]Dept. of Biological Sciences, Columbia Univ., USA.* We use spectro-electrochemical microscopy to demonstrate that the equilibrium charge state and fluorescence of nitrogen vacancy centers in nanodiamonds can be dynamically controlled by externally applied potentials.

FTh3C • Attosecond Spectroscopy—Continued

FTh3C.2 • 15:00

Fano Resonances in the Time Domain, Andreas Kaldun[1], Christian Ott[1], Alexander Blättermann[1], Thomas Ding[1], Andreas Fischer[1], Philipp Raith[1], Kristina Meyer[1], Martin Laux[1], Jörg Evers[1], Christoph H. Keitel[1], Thomas Pfeifer[1], Chris H. Greene[2]; *[1]Max-Planck-Institut für Kernphysik, Germany; [2]Dept. of Physics, Purdue Univ., USA.* The Fano phase formalism enables measurement and control of phase and amplitude of an emitting dipole. Here, we use this formalism to measure and understand the dynamics of bound states in strong laser fields.

FTh3C.3 • 15:15

Quantum Beats in Attosecond Transient Absorption of Krypton Autoionizing States, Yan Cheng[1], Michael Chini[1], Xiao-Min Tong[2], Andrew Chew[1], Julius Biedermann[1,3], Yi Wu[1], Eric Cunningham[1], Zenghu Chang[1]; *[1]Univ. of Central Florida, USA; [2]Univ. of Tsukuba, Japan; [3]Friedrich-Schiller Universität, Germany.* Quantum beats with periods of 5-10 fs are observed in various near-threshold autoionizing states of krypton atoms in an attosecond transient absorption experiment, such measurement allows reconstruction of the valence state wave packets.

FTh3D • Synthetic Lattices & Topological Phenomena—Continued

FTh3D.4 • 14:45

Topological Transport in Photonic Quasicrystals, Miguel A. Bandres[1], Mikael Rechtsman[1], Mordechai Segev[1]; *[1]Physics, Technion, Israel.* We show that it is possible to have topological transport in photonic quasicrytals, and therefore this lattices have one-way extended edgestates that are topologically protected against backscattering as they pass through defects or around corners.

FTh3D.5 • 15:00

Supersymmetric Laser Arrays, Ramy El-Ganainy[1], Mercedeh Khajavikhan[2], Demetrios N. Christodoulides[2], Li Ge[3]; *[1]Physics, Michigan Technological Univ., USA; [2]CREOL, College of Optics and Photonics, Univ. of Central Florida, USA; [3]Dept. of Engineering Science and Physics, College of Staten Island, CUNY, USA.* We present a new strategy for regulating light emission dynamics in high power laser arrays. Our approach is based on engineering the properties of non-Hermitian supersymmetric optical arrays and offers several advantages over previous investigations.

FTh3D.6 • 15:15

Asymmetric conical diffraction and generation of non-integer phase singularities in photonic graphene, Daohong Song[1], Sheng Liu[2,3], Vassilis Paltoglou[4], Daniel Gallardo[3], Liqin Tang[1], Jingjun Xu[1], Nikolaos K. Efremidis[4], Zhigang Chen[3,1]; *[1]Nankai Univ., China; [2]Northwestern Polytechnical Univ., China; [3]San Francisco State Univ., USA; [4]Univ. of Crete, Greece.* We demonstrate asymmetric conical diffraction accompanied by pseudospin-mediated non-integer phase singularities when two sublattices of photonic graphene are equally excited near the Dirac points. Experimental and numerical results agree with analysis of the Dirac equation.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FTh3E • Light Harvesting and Electroplasmonics—Continued

FTh3E.3 • 14:45
Plasmonic Internal Photoemission Detectors with Responsivities above 0.12 A/W, Sascha Muehlbrandt[1], A. Melikyan[1], K. Köhnle[1], T. Harter, A. Muslija[1], P. Vincze[1], S. Wolf[1], P. Jakobs[1], W. Freude[1], C. Koos[1], M. Kohl[1], Y. Fedoryshyn[2], J. Leuthold[2]; [1]*Karlsruhe Inst. of Technology, Germany;* [2]*ETH- Zurich, Switzerland*. We demonstrate first plasmonic photodetectors based on internal photoemission featuring responsivities exceeding 0.12 A/W at 1550 nm. The devices consist of ultra-compact plasmonic waveguides with electrode spacing below 100 nm receiving on-off-keying signals at 40 Gbit s-1.

FTh3E.4 • 15:00
Hot Electron Schottky Detection Based on Internal Photoemission in Silicon Structures, Boris Desiatov, Noa Mazurski, Joseph Shapir, Jacob Khurgin[2], Uriel Levy[1]; [1]*Hebrew Univ. of Jerusalem, Israel;* [2]*Electrical and Computer Engineering, , Johns Hopkins Univ., USA*. We demonstrate the design, fabrication and characterization of plasmonic enhanced silicon photo-detector for infrared light. Theoretical model, experimental results and comparison between different geometric configurations will be presented and discussed.

FTh3E.5 • 15:15
Hot-Electron Plasmonics: Quantum Transport Limitations, Ahmet A. Yanik[1], Imran Hossain[1], [1]*Univ. of California, Santa Cruz, USA*. Hot-electron plasmonics has created much excitement for solar-energy harvesting. However, experimental quantum efficiencies are too low for practical applications. Here, we develop a bottom-up quantum-transport model and introduce design parameters to achieve high efficiency solar-cells.

STh3F • Microwave Photonic Devices—Continued

STh3F.4 • 15:00
Tunable Microwave Photonic Phase Shifter Using On-Chip Stimulated Brillouin Scattering, Mattia Pagani[1], David Marpaung[1], Duk-Yong Choi[2], Stephen Madden[2], Barry Luther-Davies[2], Benjamin J. Eggleton[1]; [1]*School of Physics, Univ. of Sydney, Australia;* [2]*Australian National Univ., Australia*. We present the first microwave photonic phase shifter using on-chip stimulated Brillouin scattering. We show that shorter integrated platforms can potentially achieve lower insertion loss than fiber implementations, due to their higher pump depletion threshold.

STh3F.5 • 15:15
Photonic Generation of High-Power Pulsed Microwave Signals with Peak Powers up to 14.2 Watt, Xiaojun Xie[1], Kejia Li[1], Qinglong Li[1], Andreas Beling[1], Joe C. Campbell[1]; [1]*Dept. of Electrical and Computer Engineering, Univeristy of Virginia, USA*. We demonstrate photonic generation of pulsed 1 GHz and 10 GHz microwave signals with peak power levels as high as 41.5 dBm (14.2 W) and 40 dBm (10 W), respectively, using a modified uni-traveling carrier (MUTC) photodiode.

STh3G • Fabrication Techniques I—Continued

STh3G.2 • 15:00
Fabrication of Gray-Scale Semiconductor Structures with Dynamic Digital Projection Photochemical Etching, Kaiyuan Wang[1], Chris Edwards[1], Shailendra N. Srivastava[1], Lynford L. Goddard[1]; [1]*Univ. of Illinois at Urbana-Champaign, USA*. Digital projection photochemical etching is a novel single-step process for fabricating customized gray-scale semiconductor structures. Several features including a variable height pyramid array are fabricated, demonstrating the resolution, range, accuracy, and dynamics of the technique.

STh3G.3 • 15:15
Ultra-High Q Silicon Resonators in Planarized LOCOS, Alex Naiman[1], Boris Desiatov[1], Liron Stern[1], Noa Mazurski[1], Joseph Shapir[1], Uriel Levy[1]; [1]*The Hebrew Univ. of Jerusalem, Israel*. We describe a modified local oxidation of silicon process as a platform for the fabrication of waveguides and ultra-high Quality factor (5.3 million) silicon resonators, with nearly fully planar interface for multilayer silicon integration

STh3H • Materials and Devices for Nonlinear Frequency Upconversion—Continued

STh3H.3 • 14:45
Frequency Conversion in Periodically Oriented Gallium Nitride, Steven R. Bowman[1], Christopher G. Brown[2], Jennifer Hite[1], Francis J. Kub[1], Charles Eddy[1], Igor Vurgaftman[1], Jerry R. Meyer[1], Jacob H. Leach[3], Kevin Udwary[3]; [1]*US Naval Research Lab, USA;* [2]*Univ. Research Foundation, USA;* [3]*Kyma Technologies, USA*. Broadband transparency, high thermal conductivity, and strong nonlinearity make gallium nitride a promising material for high power frequency conversion. We have fabricated and tested periodically oriented gallium nitride (PO-GaN) devices for quasi-phase matched (QPM) frequency conversion.

STh3H.4 • 15:00
Violet second harmonic generation in adhered slab waveguide based on periodically poled lithium tantalate, Hwanhong Lim[1], Sunao Kurimura[1], Kazufumi Fujii[1], Masayuki Okano[2], Shigeki Takeuchi[2,3]; [1]*National Inst. for Materials Science, Japan;* [2]*Kyoto Univ., Japan;* [3]*Hokkaido Univ., Japan*. We demonstrated CW SHG at 400 nm in a first-order QPM adhered slab waveguide with a periodically-poled Mg-doped stoichiometric lithium tantalate core. The measured SHG normalized conversion efficiency was 34.7%/W for a 20 mm length.

STh3H.5 • 15:15
PP-LBGO device with 2nd-order QPM structure for 266nm generation, Junji Hirohashi[1], Tetsuo Taniuchi[2], Koichi Imai[1], Yasunori Furukawa[1]; [1]*Oxide Corporation, Japan;* [2]*FRIS, Tohoku Univ., Japan*. Second harmonic 266nm generation was demonstrated by periodically-poled LaBGeO5 (PP-LBGO) with 2nd-order QPM structure. More than 15mW of 266nm was obtained from nano-second-pulsed 532nm laser. Circular beam at 266nm without walk-off was obtained.

Meeting Room 211 B/D

CLEO: Science & Innovations

STh3I • Optomechanics I—Continued

STh3I.4 • 14:45
Enhanced Coupling in Si_3N_4 Slot-Mode Optomechanical Crystals via Stress Tuning, Karen Grutter[1], Marcelo I. Davanco[1], Kartik Srinivasan[1]; [1]*NIST, USA*. We demonstrate Si_3N_4 slot-mode optomechanical crystals with optical Qs up to 1.65 x 10^5 and mechanical frequencies around 3.4 GHz. Tensile stress tunes gap widths down to 24 nm, enhancing coupling and enabling radiation-pressure-driven self-oscillation.

STh3I.5 • 15:00
Subharmonics radio-frequency division in chip-scale optomechanical oscillators, Jiagui Wu[1,2], Yongjun Huang[1,3], Mingbin Yu[4], Dim-Lee Kwong[4], Chee Wei Wong[1]; [1]*Dept. Of Electrical Engineering, Univ. of California, Los Angeles,, Mesoscopic Optics and Quantum Electronic, USA;* [2]*Southwest Univ., School of Physics, China;* [3]*School of Communication and Information Engineering, Univ. of Electronic Science and Technology of China, Centre for RFIC and System Technology, China;* [4]*The Inst. of Microelectronics,, Singapore*. Subharmonics radio-frequency division and generation are experimentally demonstrated in nano-optomechanical cavity. The dual-coupled intracavity nonlinear optomechanical and Drude plasma oscillators demonstrate new dynamics regimes, with free-running high amplitude low-phase-noise clocking.

STh3I.6 • 15:15
Synchronization and Phase Noise Reduction in Arrays of Optomechanical Oscillators, Mian Zhang[1], Michal Lipson[1]; [1]*Cornell Univ., USA*. We demonstrate the reduction of phase noise 10 dB below the thermomechanical noise limit of individual oscillators in arrays up to seven synchronized self-sustaining optomechanical oscillators.

Meeting Room 212 A/C

CLEO: Applications & Technology

ATh3J • Clinical Technologies and Systems I—Continued

ATh3J.3 • 15:00
Deuterated Cholesterol Uptake Revealed With Stimulated Raman Microscopy, Alba Alfonso Garcia[1], Simon Pfisterer[2], Howard Riezman[3], Elina Ikonen[2], Eric O. Potma[1]; [1]*Univ. of California Irvine, USA;* [2]*Inst. of Biomedicine, Univ. of Helsinki, Finland;* [3]*Dept. of Biochemistry, Université de Genèva, Switzerland.* Cholesterol is involved in multiple vital processes, thus in multiple diseases. Synergies between coherent Raman microscopy and deuterated compounds provide the ultimate tool towards live visualization of cholesterol pathways.

ATh3J.4 • 15:15
Dynamic vocal fold imaging by integrating optical coherence tomography with laryngeal high-speed video endoscopy, Gopi Maguluri[1], Ernest Chang[1], Nicusor Iftimia[1]; [1]*Physical Sciences Inc., USA*. We demonstrate three-dimensional vocal fold imaging during phonation by integrating optical coherence tomography with high-speed videoendoscopy. Results from ex vivo larynx experiments yield reconstructed vocal fold surface contours for ten phases of periodic motion.

Meeting Room 212 B/D

CLEO: Science & Innovations

STh3K • Novel Microscopy Techniques and OCT—Continued

STh3K.3 • 14:45
Towards Automated Detection of Basal Cell Carcinoma from Polarization Sensitive Optical Coherence Tomography Images of Human Skin, Tahereh Marvdashti[1], Lian Duan[1], Katherine Ransohoff[1], Sumaira Aasi[1], Jean Tang[1], Audrey Ellerbee[1]; [1]*Stanford Univ., USA*. We report on the initial results of the first automated classifier to distinguish basal cell carcinomas and healthy skin using polarization sensitive optical coherence tomography (PS-OCT) with a sensitivity and specificity of 84.2% and 85.8%

STh3K.4 • 15:00
Phase-inverted sidelobe-annihilated optical coherence tomography to break through the temporal diffraction limit, Chi Zhang[2,1], Kenneth K. Y. Wong[1]; [1]*Univ. of Hong Kong, Hong Kong;* [2]*Wuhan National Lab for Optoelectronics, Huazhong Univ. of Science and Technology, China.* Understand the tomography system as a temporal microscopy by space-time duality, a simple adjustment was performed on a conventional swept-source optical coherence tomography (SS-OCT), and achieved sharper resolution (~4 μm) for the single layer measurement.

STh3K.5 • 15:15
Ultrafast spectral-domain optical coherence tomography realized by parametric spectro-temporal analyzer, Chi Zhang[2,1], Xiaoming Wei[1], Yiqing Xu[1], Jianbing Xu[1], Luoqin Yu[1], Bowen Li[1], Sisi Tan[1], Andy K. S. Lau[1], Xie Wang[1], Xing Xu[1], Kevin K. Tsia[1], Kenneth K. Y. Wong[1]; [1]*Univ. of Hong Kong, Hong Kong;* [2]*Wuhan National Lab for Optoelectronics, Huazhong Univ. of Science and Technology, China*. Performance of the spectral-domain optical coherence tomography is limited by its A-scan rate, namely the frame rate of spectrometer. In this paper, 60-MHz A-scan rate is achieved by adopting a recently demonstrated parametric spectro-temporal analyzer.

Marriott Salon I & II

CLEO: Science & Innovations

STh3L • Ultrafast Fiber Lasers—Continued

STh3L.4 • 14:45
Observing the spectral dynamics of a mode-locked laser with ultrafast parametric spectro-temporal analyzer, Xiaoming Wei[1], Chi Zhang[1], Bowen Li[1], Kenneth K. Y. Wong[1]; [1]*Wuhan National Lab for Optoelectronics & School of Optical and Electronic Information, Huazhong Univ. of Science and Technology, China*. We experimentally observe the spectral dynamics of a passively mode-locked fiber laser by using a parametric spectro-temporal analyzer (PASTA) with a frame rate up to 100 MHz, and different non-repeating transient dynamics has been observed.

STh3L.5 • 15:00 Tutorial
Nonlinearity Engineering of Ultrafast Lasers and Laser-Material Interactions, F Omer Ilday[1,2]; [1]*Dept. of Electrical and Electronics Engineering, Bilkent Univ., Turkey;* [2]*Dept. of Physics, Bilkent Univ., Turkey.* From novel mode-locking regimes to laser-induced self-assembly of nanostructures, it is not only possible, but highly rewarding to exploit the underlying nonlinear dynamics of photonic systems towards achieving superior technical functionality. These different dissipative systems manifest similar phenomena, such as nonlinear gain, feedback, and modulation instability.

F. Ömer Ilday received his PhD from Cornell Univ. in 2003 and served as a postdoc at MIT until 2006. In 2006, he joined Bilkent Univ.. He has co-authored >200 journal and conference publications and has given >100 invited talks. In 2014, he was awarded an ERC Consolidator Grant.

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CLEO: Science & Innovations

STh3M • Fundamental Light-material Interaction I—Continued

STh3M.4 • 14:45
Cavity-Enhanced Mid-IR Optical Frequency Comb Spectroscopy: Enhanced Time and Spectral Resolution, Oliver H. Heckl[1], Ben Spaun[1], Peter B. Changala[1], Bryce Bjork[1], Dave Patterson[2], John M. Doyle[2], Jun Ye[1]; *[1]JILA, CU Boulder, USA; [2]Dept. of Physics, Havard Univ., USA.* CE-DFCS has been applied to buffer gas cooled acetylene achieving a Doppler-limited spectral resolution of 90 MHz. Additionally TRFCS allows for the detection of *trans*-DOCO in photolysis reaction kinetics with a molecular sensitivity of 10^{10} cm^{-3}

STh3M.5 • 15:00
3D Laser Ablation of Biocompatible Silk Fibroin Hydrogels for Biomedical Applications, Matthew Applegate[1], Benjamin P. Partlow[1], Jeannine Coburn[1], Jodie Moreau[1], Benedetto Marelli[1], David Kaplan[1], Fiorenzo Omenetto[1,2]; *[1]Biomedical Engineering, Tufts Univ., USA; [2]Physics, Tufts Univ., USA.* Voids were created inside biocompatible, optically transparent silk fibroin hydrogels via multi-photon ablation in arbitrary 3D patterns at a maximum depth of nearly 1 cm without exogenous photoinitiators.

STh3M.6 • 15:15
Super-resolution Optical Nanolithography: Beyond the far-field diffraction limit, Apratim Majumder[1], Farhana Masid[1], Benjamin Pollock[2], Trisha Andrew[2], Rajesh Menon[1]; *[1]Univ. of Utah, USA; [2]Univ. of Wisconsin-Madison, USA.* We report on overcoming the far-field diffraction limit using an approach that we call Absorbance Modulation Optical Lithography (AMOL).

STh3N • Time and Frequency Transfer—Continued

STh3N.4 • 14:45
Phase Stabilized Radio Frequency Signal Transmission via Optical Fiber Link, Anxu Zhang[1], Feifei Yin[1], Yitang Dai[1], Jianqiang Li[1], Kun Xu[1]; *[1]Beijing Univ. of Posts and Telecommunications, China.* A phase-stabilized RF transmission scheme is demonstrated with suppressed noise. A 2.48GHz signal has been transferred through a 60km optical fiber link, with stability of 8.1×10^{-14} at 1s and 1.1×10^{-16} at 2000s averaging time, respectively.

STh3N.5 • 15:00 Tutorial
Frequency and Timing Distribution using Optical Methods, Nathan R. Newbury[1]; *[1]NIST, USA.* With the ever-increasing performance of optical clocks, it is important to develop parallel methods for optically-based frequency/timing distribution. I will review frequency combs, established methods for distribution over fiber-optics, and recent demonstrations over free-space links.

Nathan Newbury leads a group in NIST's Quantum Electronics and Photonic Division that focuses on the development and application of fiber-based frequency combs. He has received the Bronze medal, Silver medal, and Fleming award from the Department of Commerce. He is a fellow of The Optical Society.

STh3O • Remote and Standoff Optical Detection—Continued

STh3O.4 • 14:45
Rapid Swept-Wavelength External Cavity Quantum Cascade Laser for Open Path Sensing, Brian Brumfield[1], Mark C. Phillips[1]; *[1]Pacific Northwest National Lab, USA.* A rapidly tunable external cavity quantum cascade laser system is used for open path sensing. The system permits acquisition of transient absorption spectra over a 125 cm^{-1} tuning range in less than 0.01 s.

STh3O.5 • 15:00
Low Power Integrated Path Differential Absorption Lidar Detection of CO_2, CH_4 and H_2O over a 5.5 km Path using a Waveform Driven EO Sideband Spectrometer, David F. Plusquellic[1], Gerd Wagner[1], Stephen Maxwell[1], Kevin Douglass[1], David Long[1], Joseph T. Hodges[1], Adam J. Fleisher[1]; *[1]NIST, USA.* A rapid-scan remote-sensing spectrometer based on an arbitrary waveform driven electro-optic phase modulator for spectral scans over 37 GHz and a telescope/photon counting system for detection was used to measure long term ambient level concentrations of greenhouse gases from natural targets.

STh3O.6 • 15:15
Progress toward a high-resolution single-photon camera based on superconducting single photon detector arrays and compressive sensing, Thomas Gerrits[1], Shane Allman[1], Daniel Lum[2], Varun Verma[1], John Howell[2], Richard P. Mirin[1], Sae Woo Nam[1]; *[1]NIST, USA; [2]Dept. of Physics and Astronomy, Univ. of Rochester, USA.* We present our results on utilizing an SNSPD array and compressive imaging techniques to perform single photon imaging and present our progress toward a high-resolution single-photon camera for the mid-IR.

Executive Ballroom 210A	Executive Ballroom 210B	Executive Ballroom 210C	Executive Ballroom 210D
CLEO: Applications & Technology	CLEO: QELS-Fundamental Science		

ATh3A • Symposium on Science and Technology of Laser Three Dimensional Printing I—Continued

ATh3A.4 • 15:30
Achromatic polarization rotator imprinted in glass by ultrafast laser nanostructuring, Rudy Desmarchelier[1], Matthieu Lancry[1], Mindaugas Gecevivius[2], Martynas Beresna[2], Peter Kazansky[2], Bertrand Poumellec[1]; *[1]Universite de Paris Sud, France; [2]ORC, UK.* We demonstrate an achromatic polarization rotator imprinted by femtosecond laser nanostructuring in silica glass. The broadband 600-1500nm operation is achieved by replicating the structure of twisted nematic liquid crystal.

ATh3A.5 • 15:45
Characterization of melt-flow dynamics in selective laser melting (SLM) processes, Manyalibo J. Matthews[1], Sasha Rubenchik[1], Gabe Guss[1], Nielsen Norman[1]; *[1]Lawrence Livermore National Lab, USA.* High speed microscopic imaging and thermography of stainless steel microsphere assemblies exposed to high power laser light is analyzed to understand the melt-flow dynamics associated with selective laser melting processes.

FTh3B • NV – Centers for Metrology and Photonics—Continued

FTh3B.7 • 15:30 Invited
Nanoscale Magnetic Imaging using Quantum Defects in Diamond, Ronald Walsworth[1]; *[1]Physics, Harvard Univ., USA.* I describe recent progress in nanoscale magnetic imaging using Nitrogen-Vacancy (NV) quantum defects in diamond, which provide an unparalleled combination of magnetic field sensitivity and spatial resolution in a room-temperature solid, with wide-ranging applications.

FTh3C • Attosecond Spectroscopy—Continued

FTh3C.4 • 15:30
Excitation Energy Dependent Attosecond Photoemission Timing in Tungsten, Michael Jobst[1,3], Stefan Neppl[2], Johann Riemensberger[1,3], Marcus Ossiander[1,3], Martin Schäffer[1,3], Elisabeth Bothschafter[4], Michael Gerl[1,3], Andreas Kim[3,1], Johannes Barth[3], Ferenc Krausz[1,5], Peter Feulner[3], Reinhard Kienberger[3,1]; *[1]Max Planck Inst. for Quantum Optics, Germany; [2]Ultrafast X-Ray Science Lab, Lawrence Berkeley National Lab, USA; [3]Technical Univ. Munich, Germany; [4]Paul Scherrer Institut, Switzerland; [5]Ludwig Maximilians Univ., Germany.* A multitude of physical effects have been proposed to determine the photoemission delay between core and valence electrons in tungsten. We present selected streaking experiments that clarify its origins.

FTh3C.5 • 15:45
Attosecond Transient Absorption Explores Coupling Mechanisms of Autoionizing States, Birgitta Bernhardt[1,2], Xuan Li[1], Annelise Beck[1,2], Erika R. Warrick[1,2], Daniel J. Haxton[1], C W. McCurdy[1,3], Daniel M. Neumark[1,2], Stephen R. Leone[1,2]; *[1]Lawrence Berkeley National Lab, USA; [2]Dept. of Chemistry, UC Berkeley, USA; [3]Dept. of Chemistry, UC Davis, USA.* High spectral resolution attosecond transient absorption spectroscopy in xenon is used to validate quantum dynamical multi-level simulations of the on and off resonant absorption behavior of highly excited states and their strong-field induced coupling mechanisms.

FTh3D • Synthetic Lattices & Topological Phenomena—Continued

FTh3D.7 • 15:30
Generalized three-dimensional Dirac points and Z_2 gapless surface states in a topological photonic crystal, Ling Lu[1], Chen Fang[1], Timothy H. Hsieh[1], Liang Fu[1], Steven Johnson[1], John D. Joannopoulos[1], Marin Soljacic[1]; *[1]MIT, USA.* We discover robust three-dimensional generalized Dirac points - linear four-fold point degeneracies - in a non-symmorphic photonic crystal readily realizable at near-infrared wavelengths. The surface states exhibit gapless line-nodes characterized by a Z_2 topological invariant.

FTh3D.8 • 15:45
Supersymmetry and transformation optics on the line, Mohammad-Ali Miri[1], Matthias Heinrich[2,1], Demetrios N. Christodoulides[1]; *[1]Univ. of Central Florida, USA; [2]Inst. of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Univ., Germany.* We investigate scattering properties of supersymmetric partner structures. We show that SUSY transformations can be used as a new type of transformation optics to address inverse scattering problems in one-dimensional optical settings.

16:00–16:30 Coffee Break, *Concourse Level*

Executive Ballroom 210E	Executive Ballroom 210F	Executive Ballroom 210G	Executive Ballroom 210H
CLEO: QELS-Fundamental Science	CLEO: Science & Innovations		

FTh3E • Light Harvesting and Electroplasmonics—Continued

FTh3E.6 • 15:30
Integrated On-Chip Silicon Plasmonic Four Quadrant Detector in the Near Infrared, Meir Y. Grajower[1], Noa Mazurski[1], Boris Desiatov[1], Uriel Levy[1]; *[1]Hebrew Univ. of Jerusalem, Israel.* We demonstrate an integrated four quadrant detector in silicon for infrared light, based on integration of plasmonic splitting, focusing an plasmonic enhanced internal photoemission detection on a single silicon plasmonic chip.

FTh3E.7 • 15:45
Controlling Plasmon Drag with Illumination and Surface Geometry, Natalia Noginova, V. Rono, A. Jackson[2], M. Durach[3]; *[1]Norfolk State Univ., USA; [2]Purdue Univ., USA; [3]Georgia Southern Univ., USA.* We study electric signals associated with surface plasmon propagation in rough and smooth silver films. The polarity of the signal can be controlled with light illumination conditions and system geometry.

STh3F • Microwave Photonic Devices—Continued

STh3F.6 • 15:30
Impact of the Coulomb Interaction on the Franz-Keldysh Effect in a High-Current Photodetector, Yue Hu[1], Curtis R. Menyuk[1], Meredith Hutchinson[2], Vincent J. Urick[2], Keith J. Williams[2]; *[1]Univ. of Maryland Baltimore County, USA; [2]Naval Research Lab, USA.* The Franz-Keldysh effect causes semiconductor absorption to oscillate as a function of wavelength. We include this effect in calculating the nonlinear response of a high-current photodectector and obtain excellent agreement with experiments.

STh3F.7 • 15:45
Improved Carrier-to-Sideband Ratio for Free Space Millimeter Wave-Coupled Electro-Optic Polymer High Speed Phase Modulators, Dong Hun Park[1,2], Vincent R. Pagán[1,2], Thomas E. Murphy[2], Jingdong Luo[3], Alex K. Jen[3], Warren N. Herman[1]; *[1]Lab for Physical Sciences, USA; [2]Electrical and Computer Engineering, Univ. of Maryland, USA; [3]Materials Science and Engineering, Univ. of Washington, USA.* The carrier-to-sideband ratio was improved more than 20 dB by using a SiO_2 protection layer in antenna-coupled electro-optic phase modulators operating at 37 GHz based on an in-plane polymeric waveguide using the nonlinear polymer. We also demonstrate detection of 3-GHz modulation of the RF carrier.

STh3G • Fabrication Techniques I—Continued

STh3G.4 • 15:30
Improvement of Silicon Dioxide Ridge Waveguides Using Low Temperature Thermal Annealing, Josh Parks[1], Hong Cai[1], Thomas Wall[2], Matthew Stott[2], Roger Chu[2], Erik Hamilton[2], Aaron Hawkins[2], Holger Schmidt[1]; *[1]Univ. of California Santa Cruz, USA; [2]Brigham Young Univ., USA.* Penetration of liquids into SiO_2 ridge waveguides during standard processing steps is shown to cause poor mode confinement and increased loss. Thermal annealing repeatedly restores a core with uniform index and low-loss mode confinement.

STh3G.5 • 15:45
Photonic Damascence Process for high-Q SiN Microresonator Fabrication for Nonlinear Photonics, Martin Pfeiffer[1], Arne Kordts[1], Victor Brasch[1], Caroline Lecaplain[1], John D. Jost[1], Michael Geiselmann[1], Tobias Kippenberg[1]; *[1]Ecole Polytechnique Federale de Lausanne, Switzerland.* Integrated microresonators based on SiN waveguides are an attractive platform for nonlinear optics. Here we present a new photonic Damascene fabrication process that solves common problems in SiN waveguide fabrication and demonstrate frequency comb formation.

STh3H • Materials and Devices for Nonlinear Frequency Upconversion—Continued

STh3H.6 • 15:30
Tunable Second Harmonic Generation of a Continuous-wave Carbon Dioxide Laser Using 3 mm Thick Orientation Patterned GaAs Crystals in Fan-out and Single-grating-period Configurations, Shekhar Guha[1], Jacob Barnes[3], Leonel P. Gonzalez[1], Peter G. Schunemann[2]; *[1]US Air Force Research Lab, USA; [2]BAE Corporation, USA; [3]UES, Inc., USA.* We report room temperature frequency doubling of a continuous-wave carbon dioxide laser tuned from 9.26 to 10.65 micrometers using large-aperture OPGaAs crystals (>3 mm thick by >7.5 mm wide) in fan-out and single grating configurations.

STh3H.7 • 15:45
Third harmonic generation in ultrathin epsilon-near-zero media, Ting S. Willie Luk[4,6], Domenico de Ceglia[2], Gordon Keeler[4], Rohit P. Prasankumar[1,3], Maria A. Vincenti[2], Sheng Liu[4,6], Michael Scalora[5], Michael B. Sinclair[4], Salvatore Campione[4,6]; *[1]Los Alamos National Lab, USA; [2]National Research Council-AMRDEC, USA; [3]Center for Integrated Nanotechnologies-Los Alamos National Labs, USA; [4]Sandia National Labs, USA; [5]Charles M. Bowden Research Lab AMRDEC, USA; [6]Center for Integrated Nanotechnologies - Sandia National Labs, USA.* We demonstrate efficient third harmonic generation from a 21.6nm indium tin oxide film on glass substrate for a pump fundamental wavelength of 1350nm using the field enhancement properties of optical modes supported by epsilon-near-zero media.

16:00–16:30 Coffee Break, *Concourse Level*

Meeting Room 211 B/D	Meeting Room 212 A/C	Meeting Room 212 B/D	Marriott Salon I & II
CLEO: Science & Innovations	CLEO: Applications & Technology	CLEO: Science & Innovations	

STh3I • Optomechanics I—Continued

STh3I.7 • 15:30
Frequency instability and phase noise characterization of an integrated chip-scale optomechanical oscillator, Yongjun Huang[1,3], Jiagui Wu[1,2], Xingsheng Luan[2], Shu-Wei Huang[1,2], Mingbin Yu[4], Guo-Qiang Lo[4], Dim-Lee Kwong[4], Guangjun Wen[3], Chee Wei Wong[1,2]; *[1]Electrical Engineering Dept., Univ. of California at Los Angeles, USA; [2]Mechanical Dept., Columbia Univ., USA; [3]Univ of Electronic Sci & Tech of China, China; [4]The Inst. of Microelectronics, Singapore.* We characterize the frequency instability and single-sideband phase noise of chip-scale optomechanically-driven oscillators, with integrated Ge photoreceivers. At 400-μW, an open-loop frequency instability at 10^{-8} is observed, with -125 dBc/Hz phase noise at 10-kHz offset.

STh3I.8 • 15:45
Multi-stable Synchronization of Delay-Coupled Optomechanical Oscillators, Shreyas Y. Shah[1], Mian Zhang[1], Michal Lipson[1,2]; *[1]School of Electrical and Computer Engineering, Cornell Univ., USA; [2]Kavli Inst. at Cornell, Cornell Univ., USA.* We demonstrate synchronisation between two independent optomechanical oscillators coupled through an optical delay of 138.76ns. By varying the coupling strengths, we observe multiple stable synchronised states with different frequencies, enabling applications in reconfigurable RF networks.

ATh3J • Clinical Technologies and Systems I—Continued

ATh3J.5 • 15:30
Imaging Patient Derived Breast Cancer Xenografts in an Orthotopic Mammary Window Chamber Model, Hui M. Leung[1,2], Rachel Schafer[1,4], Arthur F. Gmitro[1,3]; *[1]Univ. of Arizona (OSC), USA; [2]College of Optical Sciences, USA; [3]Dept. of Medical Imaging, Univ. of Arizona, USA; [4]Dept. of Biomedical Engineering, Univ. of Arizona, USA.* We demonstrate for the first time optical and magnetic resonance imaging of breast cancer patient derived xenografts in an orthotopic mammary window chamber model. *In vivo* imaging of oxygen saturation, apparent diffusion coefficient and blood perfusion were performed.

ATh3J.6 • 15:45
Highly Selective VOC Breath Analysis Using a 3.3 μm Broadly-Tunable VECSEL, Jana Jágerská[1], Herbert Looser[2], Béla Tuzson[1], Ferdinand Felder[3], Luc Tappy[4], Lukas Emmenegger[1]; *[1]EMPA, Switzerland; [2]FHNW, Switzerland; [3]Camlin Technologies AG, Switzerland; [4]Université de Lausanne, Switzerland.* Mid-infrared VECSEL tunable over 50 cm^{-1} is employed to measure trace gas concentrations of acetone in human breath. A detection limit of 25 ppb is demonstrated without any sample preparation.

STh3K • Novel Microscopy Techniques and OCT—Continued

STh3K.6 • 15:30
Photothermal detection of single nanoparticle by using single element interferometer, Yuki Nagata[1], Yasuhiro Mizutani[1], Tetsuo Iwata[1], Yukitoshi Otani[2]; *[1]The Univ. of Tokushima, Japan; [2]Utsunomiya Univ., Japan.* A photothermal imaging microscope for single metal nanoparticles using single element interferometer has been developed. In this report, 20-nm gold nanoparticles in scattering environment was detected selectively with SNR ~20.

STh3K.7 • 15:45
Dynamic Label-free Imaging of Live-cell Adhesion Using Photonic Crystal Enhanced Microscopy (PCEM), Yue Zhuo[1,2], Ji S. Choi[3,4], Hojeong Yu[5,2], Brendan A. Harley[3,4], Brian T. Cunningham[1,2]; *[1]Dept. of Bioengineering, Univ. of Illinois at Urbana-Champaign, USA; [2]Micro and Nanotechnology Lab, Univ. of Illinois at Urbana-Champaign, USA; [3]Dept. of Chemical and Biomolecular Engineering, Univ. of Illinois at Urbana-Champaign, USA; [4]Inst. for Genomic Biology, Univ. of Illinois at Urbana-Champaign, USA; [5]Dept. of Electrical and Computer Engineering, Univ. of Illinois at Urbana-Champaign, USA.* We demonstrate label-free imaging of cell attachment upon a photonic-crystal biosensor surface. Newly-implemented image-analysis software is used to dynamically visualize individual live-cell movement and demonstrate the spatiotemporal-distribution of cellular material during adhesion and motion.

STh3L • Ultrafast Fiber Lasers—Continued

16:00–16:30 Coffee Break, *Concourse Level*

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CLEO: Science & Innovations

STh3M • Fundamental Light-material Interaction I—Continued

STh3M.7 • 15:30
The optical absorption in zincblende and wurtzite GaP nanowire polytypes, Mahtab Aghaeipour[1], Nicklas Anttu[1], Gustav Nylund[1], Lars Samuelson[1], Sebastian Lehmann[1], Mats-Erik Pistol[1]; [1]*Solid State Physics, Lund Univ., Sweden.* Diameter-dependent absorption resonances in semiconductor nanowires are promising for tunable detectors. Here, we show that the optical resonances for both wurtzite and zincblende GaP nanowires can be tuned down to $\lambda \approx 330$ nm by decreasing the diameter of the nanowires to 35 nm.

STh3M.8 • 15:45
Strong exciton-photon coupling in monolayer heterostructures in tunable microcavities, Stefan Schwarz[1], Scott Dufferwiel[1], Freddie Withers[2], Aurelien Trichet[3], Feng Li[1], Caspar Clark[4], Konstantin Novoselov[2], Jason M. Smith[3], Maurice S. Skolnick[1], Dimitrii N. Krizhanovskii[1], Alexander Tartakovskii[1]; [1]*Univ. of Sheffield, UK;* [2]*Univ. of Manchester, UK;* [3]*Univ. of Oxford, UK;* [4]*Helia Photonics, UK.* Strong light-matter interaction in two-dimensional molybdenum diselenide (MoSe2) is observed using a tunable optical microcavity. Polariton states with a Rabi splitting of 20 and 29 meV are observed for a monolayer MoSe2 and a 'double-well' MoSe2/hBN/MoSe2, respectively.

STh3N • Time and Frequency Transfer—Continued

STh3O • Remote and Standoff Optical Detection—Continued

STh3O.7 • 15:30
Computational Optical Density-Density Correlation Sensing, Milad Akhlaghi Bouzan[1], Aristide Dogariu[1]; [1]*CREOL, Univ. of Central Florida, USA.* Numerical and experimental results demonstrate a stochastic sensing technique based on enhancing intensity fluctuations. Statistical moments of reflectivity can be recovered, which characterize scattering from static and dynamic targets placed in random environments.

STh3O.8 • 15:45
Standoff Detection of Buried Landmines Using Genetically Engineered Fluorescent Bacterial Sensors, Yossi Kabessa[1], Ori Eyal[1], Ofer Bar-On[1], Sharon Yagur-Kroll[1], Shimshon Belkin[1], Aharon J. Agranat[1]; [1]*HUJI, Israel.* A Standoff detection scheme for buried landmines and concealed explosive charges based on genetically engineered bacterial biosensors is presented. Concentrations of 4 mg/L of 2,4-DNT on soil were detected from a distance of 50 meters.

16:00–16:30 Coffee Break, *Concourse Level*

Executive Ballroom 210A

CLEO: Applications & Technology

16:30–18:00
ATh4A • Symposium on Science and Technology of Laser Three Dimensional Printing II
Presider: Yves Bellouard; Ecole Polytechnique Federale de Lausanne, Switzerland

ATh4A.1 • 16:30 Invited

Strategies for Nanofabrication based on Optothermal Manipulation of Plasmonic Nanoparticles, Theobald Lohmüller[1]; [1]*Physics, LMU Munich, Germany.* Optothermal manipulation of individual gold nanoparticles renders it possible to control polymerization reactions and thermal curing of polymers at the nanoscale. This can be used to synthesize polymer nanoparticles and -wires with sub-diffraction limited resolution.

ATh4A.2 • 17:00 Invited

Multiphoton Processing Technologies for Applications in Biology and Tissue Engineering, Jan Torgersen[1], Aleksandr Ovsianikov[2], Robert Liska[3], Juergen Stampfl[2]; [1]*Nanoscale Prototyping Lab, Stanford Univ., USA;* [2]*Inst. of Materials Science and Technology, Vienna Univ. of Technology, Austria;* [3]*Inst. of Applied Synthetic Chemistry, Vienna Univ. of Technology, Austria.* Versatile microfabrication technologies are presented utilizing photochemistry induced by multiphoton absorption of ultra-short laser pulses. Processing novel biophotopolymers, we show how customized cell microenvironments can be fabricated mimicking the complexity of the natural extra-cellular matrix.

Executive Ballroom 210B

Executive Ballroom 210C

Executive Ballroom 210D

CLEO: QELS-Fundamental Science

16:30–18:30
FTh4B • Quantum Memories
Presider: Irina Novikova; College of William & Mary, USA

FTh4B.1 • 16:30

Bad Cavities for Good Memories: Storing Broadband Photons with Low Noise, Joshua Nunn[1], Tessa F. Champion[1], Joseph Munns[1,2], Cheng Qiu[1,3], Dylan Saunders[1], Ian A. Walmsley[1]; [1]*Univ. of Oxford, UK;* [2]*Physics, Imperial College, UK;* [3]*Physics, East China Normal Univ., China.* Quantum memories are vital for synchronising photonic operations. Broadband, room-temperature storage in Raman memories is hampered by four-wave mixing noise. Here we show how to eliminate the noise with a low-finesse cavity.

FTh4B.2 • 16:45

Complete Control of Frequency-Time Correlation of Narrow-Band Biphotons from Cold Atoms, Young-Wook Cho[1,2], Kwang-Kyoon Park[1], Jong-Chan Lee[1], Yoon-Ho Kim[1]; [1]*Pohang Univ. of Science and Technology (POSTECH), Korea;* [2]*Quantum Science, Centre for Quantum Computation and Communication Technology, Australia.* The nonclassical photon pair is naturally endowed with a specific form of frequency-time quantum correlations. Here, we report complete control of time quantum correlations of narrowband biphotons generated in a cold atomic ensemble.

FTh4B.3 • 17:00

Optical Nanofibers as Light-Matter Interfaces for Quantum Networks, Baptiste Gouraud[1], Dominik Maxein[1], Adrien Nicolas[1], Olivier Morin[1,2], Julien Laurat[1]; [1]*Laboratoire Kastler Brossel, UPMC-Sorbonne Universités, CNRS, ENS-PSL Research Univ., Collège de France, France;* [2]*Max-Planck-Institut für Quantenoptik, Germany.* We report the single-photon-level storage of light tightly guided in an optical nanofiber. Our setup is based on electromagnetically induced transparency for atoms interacting with the evanescent field surrounding the nanofiber.

16:30–18:30
FTh4C • Attosecond Dynamics and Strong-field Interactions
Presider: François Légaré; INRS-Energie Mat & Tele Site Varennes, Canada

FTh4C.1 • 16:30

Attosecond Spectroscopy of Band-gap Dynamics, Martin Schultze[1], Krupa Ramasesha[2], Annkatrin Sommer[1], Das Pemmaraju[3], Shunsuke Sato[4], Desiré Whitmore[2], Andrey Gandman[2], James S. Prell[2], Lauren J. Borja[2], David Prendergast[3], Daniel M. Neumark[2], Stephen R. Leone[2], Ferenc Krausz[1], Elisabeth Bothschafter[1], Kazuhiro Yabana[4]; [1]*Max Planck Institut fuer Quantenoptik, Germany;* [2]*Chemistry, UC Berkeley, USA;* [3]*The Molecular Foundry, USA;* [4]*Graduate School of Pure and Applied Sciences, Univ. of Tsukuba, Japan.* Attosecond solid state spectroscopy tracks electronic excitation mechanisms in solids. Here the technique is used to show that few-cycle laser pulses can create a transient metallization in dielectrics or permanent population transfer in semiconductors both with sub-femtosecond response time.

FTh4C.2 • 16:45

Using Attosecond Transient Absorption to Study Non-Adiabatic Molecular Dynamics, Chen-Ting Liao[1], Xuan Li[2], Daniel J. Haxton[2], C W. McCurdy[3,2], Arvinder Sandhu[4,1]; [1]*College of Optical Sciences, Univ. of Arizona, USA;* [2]*Chemical Sciences Division, Lawrence Berkeley National Lab, USA;* [3]*Dept. of Chemistry, Univ. of California, USA;* [4]*Dept. of Physics, Univ. of Arizona, USA.* We investigate superexcited Oxygen using attosecond transient absorption. Spectral lineshape evolution is used to resolve the autoionization dynamics and strong-field control is explored. We find that the symmetry of electronic states plays an important role.

FTh4C.3 • 17:00

Photoionization Time Delay Dynamics in Noble Gase, Sebastian Heuser[1], Mazyar Sabbar[1], Robert Boge[1], Matteo Lucchini[1], Lukas Gallmann[2], Claudio Cirelli[1], Ursula Keller[1]; [1]*Physics Dept., ETH Zurich, Switzerland;* [2]*Inst. of Applied Physics, Univ. of Bern, Switzerland.* For the first time, we implemented both RABBITT and attosecond energy streaking using an AttoCOLTRIMS apparatus and exploit its advantages to determine energy- and angle-resolved single-photon ionization time delays for different noble gases.

16:30–18:30
FTh4D • Quantum and Fundamental Phenomena
Presider: Zhigang Chen; San Francisco State Univ., USA

FTh4D.1 • 16:30 Tutorial

Probing and Controlling Quantum Matter in Crystals of Light, Immanuel Bloch[1,2]; [1]*Max-Planck-Institut fur Quantenoptik, Germany;* [2]*Fakultät für Physik, Ludwig Maximilians Univ., Germany.* The tutorial will focus on the remarkable opportunities offered by ultracold quantum gases trapped in optical lattices to address fundamental physics questions ranging from condensed matter physics over statistical physics to high energy physics with table-top experiment.

Immanuel Bloch is scientific director at the Max-Planck-Inst. of Quantum Optics, Garching and professor for experimental physics at the Ludwig-Maximilians Univ. in Munich. Bloch received several international prizes for his work, among them the Senior Prize for Fundamental Aspects of Quantum Electronics and Optics and the Körber European Science Prize.

Executive Ballroom 210E

CLEO: QELS-Fundamental Science

16:30–18:30
FTh4E • Nanophotonics for Thermal Transfer and Waveguiding

Presider: Dordaneh Etezadi; EPFL, Switzerland

FTh4E.1 • 16:30 Invited

Near-Field Radiative Heat Transfer between Integrated Nanostructures using Silicon Carbide, Raphael St-Gelais[1], Linxiao Zhu[2], Biswajeet Guha[1], Shanhui Fan[2], Michal Lipson[1]; [1]*Cornell Univ., USA;* [2]*Stanford Univ., USA.* We present the first experimental demonstration near-field radiative heat transfer using silicon carbide. We achieve a 110× near-field enhancement, relative to the far-field limit, of the radiative heat transfer between integrated nanostructures.

FTh4E.2 • 17:00

The analog of superradiant emission in quantum emitters leads to the well-known superradiant, Ming Zhou[1], Soongyu Yi[1], Ting S. Willie Luk[2], Qiaoqiang Gan[3], Zongfu Yu[1]; [1]*Electrical and Computer Engineering, Univ. of Wisconsin at Madison, USA;* [2]*Sandia National Labs, USA;* [3]*Electrical and Computer Engineering, State Univ. of New York at Buffalo, USA.* The superradiant spontaneous emission is caused by the collective interaction of quantum emitters. Such collective interaction also exists in nanoscale resonant thermal emitters, resulting in the analog of superradiance in thermal emission.

Executive Ballroom 210F

CLEO: Science & Innovations

16:30–18:30
STh4F • Photonic, Microwave Signal Processing

Presider: Takahide Sakamoto; NICT, Japan

STh4F.1 • 16:30

DPSK Demodulation Using Coherent Perfect Absorption, Richard R. Grote[2,1], Jacob M. Rothenberg[2], Jeffrey B. Driscoll[2], Richard M. Osgood[2]; [1]*Univ. of Pennsylvania ESE Dept., USA;* [2]*Microelectronics Sciences Labs, Columbia Univ., USA.* We propose a scheme for on-chip DPSK demodulation with balanced detection by using coherent perfect absorption (CPA) in a microring resonator. Device operation is demonstrated with finite-difference time-domain simulations.

STh4F.2 • 16:45

Continuous 119.2-GSample/s Photonic Compressed Sensing of Sparse Microwave Signals, Jasper Stroud[1], Bryan Bosworth[1], Dung Tran[1], Timothy McKenna[2], Thomas Clark[2], Trac Tran[1], Sang Chin[1], Mark A. Foster[1]; [1]*Johns Hopkins Univ., USA;* [2]*Johns Hopkins Applied Physics Lab, USA.* We demonstrate 119.2-GSample/s compressive microwave frequency detection using spectrally-encoded ultrafast laser pulses. We sense sparse tones over > 35-GHz instantaneous bandwidth with 2-MHz accuracy using < 300 consecutive compressive measurements acquired at a 400-MHz rate.

STh4F.3 • 17:00

Experimental Demonstration of Arbitrary Waveform Generation Using Anamorphic Stretch Transform, Gao hongbiao[1,2], Mohammad Asghari[2], Bahram Jalali[2]; [1]*Tsinghua Univ., China;* [2]*Univ. of California, Los Angeles, USA.* We experimentally demonstrate, for the first time, that using anamorphic stretch transform, the time-bandwidth product of photonic-assisted time-stretch arbitrary waveform generation can be greatly increased above the fundamental limit set by the spectral encoding.

Executive Ballroom 210G

16:30–18:30
STh4G • Fabrication Techniques II

Presider: Zhaowei Liu; Univ. of California, San Diego, USA

STh4G.1 • 16:30

Metamaterials Assembled by Light, Sui Yang[1,2], Xingjie Ni[1], Xiaobo Yin[1], Boubacar Kante[1], Yuan Wang[1], Xiang Zhang[1,2]; [1]*NSF Nano-scale Science and Engineering Center (NSEC), Univ. of California Berkeley, USA;* [2]*Materials Sciences Division, Lawrence Berkeley National Lab, USA.* Metamaterials are designed to achieve unprecedented light-matter interactions. Here we demonstrate a novel viable and scalable assembly route to optical metamaterials with structures dictated by their own light-matter interactions.

STh4G.2 • 16:45

Self-assembled Micro-reflectors for Signal Enhancement in Fluorescence Microscopy, Zoltán Göröcs[1], Euan McLeod[1], Shiv Acharya[1], Aydogan Ozcan[1,2]; [1]*Electrical Engineering, UCLA, USA;* [2]*Bioengineering, UCLA, USA.* Three-fold enhancement of fluorescent light collection in low numerical aperture optical systems is demonstrated using self-assembled micro-reflectors around individual micro-particles.

STh4G.3 • 17:00

Electrospun dye-doped fiber networks: Lasing emission from randomly distributed cavities, Sarah Kraemmer[1], Christoph Vannahme[2], Cameron L. Smith[2], Tobias Grossmann[1], Michael Jenne[1], Stefan Schierle[1], Lars Jørgensen[3], Minh Tran[1], Anders Kristensen[2], Ioannis Chronakis[3], Heinz Kalt[1]; [1]*Inst. of Applied Physics, Karlsruhe Inst. of Technology, Germany;* [2]*Dept. of Micro- and Nanotechnology, Technical Univ. of Denmark, Denmark;* [3]*DTU Food, Technical Univ. of Denmark, Denmark.* Dye-doped polymer fiber networks fabricated with electrospinning exhibit comb-like laser emission. We identify randomly distributed ring resonators being responsible for lasing emission by making use of spatially resolved spectroscopy. Numerical simulations confirm this result quantitatively.

Executive Ballroom 210H

16:30–18:30
STh4H • Novel Applications and Phenomena of Nonlinear Optics

Presider: Valentin Petrov; Max Born Institute, Germany

STh4H.1 • 16:30

Highly Efficient Backward Stimulated Polariton Scattering in Periodically Poled KTiOPO4, Hoon Jang[1], Andrius Zukauskas[1], Carlota Canalias[1], Valdas Pasiskevicius[1]; [1]*Royal Inst. of Technology (KTH), Sweden.* X(2)-nonlinearity enhanced by crystal lattice contribution in the THz-region is behind backward stimulated polariton scattering with efficiencies exceeding 50% in PPKTP where forward scattering process is suppressed. 10-times compression of counter-propagating signal is observed.

STh4H.2 • 16:45

Laser Induced Damage Thresholds of KTiOPO4 and Rb:KTiOPO4 at 1 μm and 2 μm, Riaan Stuart Coetzee[1], Nicky Thilmann[1], Andrius Zukauskas[1], Carlota Canalias[1], Valdas Pasiskevicius[1];[1]*Royal Inst. of Technology (KTH), Sweden.* Optimum design of high-energy parametric down-conversion schemes mandate investigation of nanosecond laser-induced damage threshold in KTiOPO4 and Rb:KTiOPO4 at 1.064 μm and 2 μm. A surface damage threshold of 10 J/cm2 at 2 μm was determined for both materials.

STh4H.3 • 17:00

Enhanced Spontaneous Raman Signal Collected Evanescently by Silicon Nitride Slot Waveguides, Ashim Dhakal[1], Frederic Peyskens[1], Ananth Subramanian[1], Nicolas Le Thomas[1], Roel Baets[1]; [1]*INTEC, Univ. of Ghent, Belgium.* We investigate the effect of waveguide geometry on the conversion efficiency of Raman signals collected by integrated photonic waveguides. Compared to strip-type photonic wires, we report a six-fold increase in conversion efficiency for silicon-nitride slot-waveguides.

Meeting Room 211 B/D

CLEO: Science & Innovations

16:30–18:30
STh4I • Optomechanics II
Presider: Peter Rakich; Yale Univ., USA

STh4I.1 • 16:30
Chip-based Silica Microspheres for Cavity Optomechanics, Xue-Feng Jiang[1], Mark Kuzyk[1], Thein Oo[1], Hailin Wang[1]; [1]*Univ. of Oregon, USA.* We realized on-chip silica microspheres, featuring excellent thermal coupling to the silicon-wafer. These chip-based microspheres can overcome the problem of thermal bistability and are especially suitable for optomechanical studies in vacuum or at low temperature.

STh4I.2 • 16:45
An Optomechanical Induced Short Pulse Raman Laser, Wenyan Yu[1], Wei Jiang[2], Qiang Lin[2,3], Tao Lu[1]; [1]*Univ. of Victoria, Canada;* [2]*Inst. of Optics, Univ. of Rochester, USA;* [3]*Electrical and Computer Engineering, Univ. of Rochester, USA.* We observed pulsations of Raman lasing on an optomechanically oscillating silica microsphere. The harmonic tones from the oscillation regeneratively produce 223.5-ns-width Raman laser pulses above a pump threshold of 186 μW.

STh4I.3 • 17:00
Strong Mechanical Nonlinearity of Optomechanically Driven Suspended Photonic Crystal Membrane, Pui-Chuen Hui[1,2], Alejandro Rodriguez[3], David Woolf[4], Eiji Iwase[5], Mughees Khan[6], Federico Capasso[1], Marko Loncar[1]; [1]*School of Engineering and Applied Sciences, Harvard Univ., USA;* [2]*Wellman Center for Photomedicine, Massachusetts General Hospital, USA;* [3]*Dept. of Electrical Engineering, Princeton Univ., USA;* [4]*Physical Sciences Inc, USA;* [5]*Dept. of Applied Mechanics and Aerospace Engineering, Waseda Univ., Japan;* [6]*Wyss Inst. for Biologically Inspired Engineering, Harvard Univ., USA.* We demonstrated the nonlinear mechanics of an optomechnaically driven silicon membrane suspended 100nm over a nearby substrate. The estimated optical force-induced Duffing nonlinearity is $10^{28}Hz^2/m^2$, significantly larger than that afforded by the nonlinear Casimir potential.

Meeting Room 212 A/C

CLEO: Applications & Technology

16:30–18:30
ATh4J • Clinical Technologies and Systems II
Presider: Yuankai Tao; Cole Eye Inst. Cleveland Clinic, USA

ATh4J.1 • 16:30 Invited
Blood Coagulation Sensing at the Point of Care, Seemantini K. Nadkarni[1,2]; [1]*Harvard Medical School, USA;* [2]*Wellman Center for Photomedicine, Massachusetts General Hospital, USA.* We describe a new approach that measures a patient's coagulation status at the bedside from laser speckle fluctuations. This technology addresses the critical unmet need to manage patients at risk of life-threatening hemorrhage.

ATh4J.2 • 17:00 Invited
Multi-spectral Imaging for Determining End-point of Photo-thermal Damage on Tissue, Do-Hyun Kim[1]; [1]*Food and Drug Administration, USA.* Multi-spectral imaging (MSI) and its analysis methods were investigated to determine end-point of photothermal damage of tissue. MSI revealed denatured porcine tissue after irradiation of laser with irradiance lower than photothermal damage threshold.

Meeting Room 212 B/D

CLEO: Science & Innovations

16:30–18:30
STh4K • Super-resolution Imaging
Presider: Dmitry Dylov; GE Global Research, USA

STh4K.1 • 16:30 Tutorial
Accelerating Localisation Microscopy, Susan Cox[1]; [1]*King's College London, UK.* Fluorescence localisation microscopy is a powerful tool for imaging cell structures at a lengthscale of tens of nm, but its utility for live cell imaging is limited, as it takes a long time to acquire the data needed for a super-resolution image. However, the data acquisition time can be cut by more than two orders of magnitude by using advanced algorithms which can analyse dense data. Different algorithms offer tradeoffs between acquisition and processing time, and quality of the fitted data.

Susan Cox leads a research group at King's College London developing new high speed super-resolution microscopy techniques, and applying them to imaging cytoskeletal dynamics. Following a PhD at Cambridge and postdoctoral fellowships at Los Alamos and King's, she was awarded a Royal Society Univ. Research Fellowship in 2011.

Marriott Salon I & II

16:30–18:30
STh4L • Fiber Lasers
Presider: Ming-lie Hu; Tianjin Univ., China

STh4L.1 • 16:30
Cladding-pumped Yb-doped Fiber Laser with Vortex Output Beam, Din Lin[1], W.A. Clarkson[1]; [1]*Univ. of Southampton, UK.* A simple technique for selectively generating a donut-shaped LP11 mode with vortex phase front in a cladding-pumped ytterbium-doped fiber laser is reported. The laser yielded 36W of output with a slope efficiency of 74%.

STh4L.2 • 16:45
All-fiber passively Q-switched fiber laser based on the multimode interference effect, Quan Sheng[1], Xiushan Zhu[2], Wei Shi[1,3], Jianquan Yao[1,3], Robert Norwood[2], Nasser Peyghambarian[2]; [1]*College of Precision Instrument and Optoelectronics Engineering, Tianjin Univ., China;* [2]*College of Optical Sciences, Univ. of Arizona, USA;* [3]*Tianjin Inst. of Modern Laser & Optics Technology, China.* An all-fiber passively Q-switched Er-Yb co-doped fiber laser (EYDFL) using a single mode-multimode-single mode (SMS) fiber structure based on the multimode interference (MMI) effect was proposed and experimentally demonstrated for the first time.

STh4L.3 • 17:00
Enhancement of OCT Imaging Depth by Pulse-modulated Dispersion-tuned Swept Fiber Laser, Yuya Takubo[1], Shinji Yamashita[1]; [1]*Meguro-ku, Japan.* The linewidth of dispersion-tuned fiber laser was improved by pulse modulation. The laser was applied to swept-source optical coherence tomography system and images with deeper imaging range were obtained.

Marriott Salon III	Marriott Salon IV	Marriott Salon V & VI

CLEO: Science & Innovations

16:30–18:30
STh4M • Fundamental Light-material Interaction II
Presider: Tsing-Hua Her; Univ of North Carolina at Charlotte, USA

STh4M.1 • 16:30
First-principles calculations for ultrafast laser-induced damage in dielectrics, Shunsuke Sato[1], Kazuhiro Yabana[1], Yasushi Shinohara[2], Tomohito Otobe[5], Kyung-Min Lee[3], George F. Bertsch[4]; [1]*Univ. of Tsukuba, Japan;* [2]*Max Planck Inst., Germany;* [3]*Inst. for Basic Science, Korea;* [4]*Univ. of Washington, USA;* [5]*Japan Atomic energy Agency, Japan.* Irradiation of intense and ultrashort laser pulses on dielectric surface is calculated using a first-principles theory. It is found that calculated energy distribution transferred from light to matter explains measured laser damage threshold.

STh4M.2 • 16:45
Doping-controlled Coherent Electron-Phonon Coupling in Vanadium Dioxide, Kannatassen Appavoo[2,1]; [1]*Vanderbilt Univ., USA;* [2]*Center for Functional Nanomaterials, Brookhaven National Lab, USA.* Broadband femtosecond transient spectroscopy and density functional calculations reveal that substitutional tungsten doping of a phase-change thin-film of vanadium dioxide modifies the coherent phonon response compared to the undoped film due to altered electronic and structural dynamics.

STh4M.3 • 17:00
Unusual Conductivity Increase Related to UV-light Assisted Domain Inversion in Mg-doped Lithium Niobate Crystals, Xiaojie Wang[1], Fang Bo[1], Shaolin Chen[1], Jing Chen[1], Yongfa Kong[1], Jingjun Xu[1], Guoquan Zhang[1]; [1]*Nankai Univ., China.* We observed an unusual conductivity increase during and after the ultraviolet-light assisted domain inversion in Mg-doped lithium niobate crystals, which may be related to the dislocation of Nb ions during the domain inversion process.

16:30–18:30
STh4N • Micro and GHz Combs
Presider: Franklyn Quinlan; NIST, USA

STh4N.1 • 16:30 Invited
Photonic Chip Based Optical Frequency Comb Using Soliton Induced Cherenkov Radiation, Victor Brasch[1], Michael Geiselmann[1], Tobias Herr[3], Grigoriy Lihachev[2], Martin Pfeiffer[1], Michael Gorodetsky[2], tobias kippenberg[1]; [1]*EPFL, Switzerland;* [2]*Moscow State Univ., Russia;* [3]*CSEM, Switzerland.* We show for the first time a fully coherent frequency comb generated in a SiN photonic chip which spans 2/3 of an octave using solitons and soliton induced Cherenkov radiation. Additionally we stabilize the spectrum.

STh4N.2 • 17:00
Parametric soliton formation in narrow-band laser-gain driven microresonators, Yanan H. Wen[1], Michael Lamont[1], Alexander L. Gaeta[1]; [1]*Cornell Univ., USA.* We investigate comb formation in laser-gain driven microresonators for various gain bandwidths and show that broadband cavity solitons exist for gain as narrow as one cavity mode, in close correspondence to parametric frequency combs.

16:30–18:30
STh4O • Optical Sensing Techniques for Combustion and Energy Research
Presider: Gerard Wysocki; Princeton Univ., USA

STh4O.1 • 16:30 Tutorial
Advances in Tunable Diode Laser Absorption Spectroscopy (TDLAS) for Measurements of Gas Properties in Combustion Systems, Ronald K. Hanson[1]; [1]*Stanford Univ., USA.* Laser absorption is ideal for monitoring reactive systems with applications ranging from fundamental studies of combustion chemistry to control of power plant emissions. Sensor design, new schemes for sensitivity in harsh environments, and successful applications are reviewed.

Ronald Hanson, the Woodard Professor of mechanical engineering at Stanford Univ., has advised over 95 PhD students in the fields of laser diagnostics and laser-based sensors, shock wave physics and combustion chemistry. He is a Fellow of AIAA, ASME and The Optical Society, a member of NAE, and a gold medal award winner of the Combustion Inst.

Executive Ballroom 210A

Executive Ballroom 210B

Executive Ballroom 210C

Executive Ballroom 210D

CLEO: Applications & Technology

CLEO: QELS-Fundamental Science

ATh4A • Symposium on Science and Technology of Laser Three Dimensional Printing II—Continued

ATh4A.3 • 17:30 Invited

Hybrid Subtractive and Additive Micromanufacturing using Femtosecond Laser for Fabrication of True 3D Biochips, Koji Sugioka[1], Dong Wu[1], Jian Xu[1], Felix Sima[1], Katsumi Midorikawa[1]; [1]*RIKEN Center for Advanced Photonics, Japan*. We propose conjugation of subtractive and additive 3D manufacturing using femtosecond laser for fabrication of functional biochips. Specifically, femtosecond laser 3D glass micromachining followed by two-photon polymerization are performed to realize true 3D biochips.

FTh4B • Quantum Memories—Continued

FTh4B.4 • 17:15

THz-bandwidth molecular memories for light, Philip J. Bustard[1], Jennifer Erskine[1], Duncan England[1], Rune Lausten[1], Benjamin Sussman[1]; [1]*National Research Council Canada, Canada*. We use the vibrational levels of hydrogen molecules as a memory for light to store 100-fs pulses. We also demonstrate non-classical correlations in an emissive quantum memory using rotational levels of hydrogen molecules.

FTh4B.5 • 17:30

Storage and retrieval of ultrafast single photons using a room-temperature diamond quantum memory, Kent Fisher[1], Duncan England[2], Jean-Philippe Maclean[1], Phillip Bustard[2], Rune Lausten[2], Kevin J. Resch[1], Benjamin Sussman[2]; [1]*Univ. of Waterloo, Canada;* [2]*National Research Council of Canada, Canada*. We experimentally demonstrated the storage and retrieval of THz-bandwidth single photons in a room-temperature diamond quantum memory. We have shown that the non-classical nature of retrieved light is preserved by the memory process.

FTh4B.6 • 17:45

Scalable Integration of Solid State Quantum Memories into a Photonic Network, Sara L. Mouradian[1], Tim Schroder[1], Carl B. Poitras[2], Luozhou Li[1], Jordan Goldstein[1], Edward Chen[1], Jiabao Zheng[3], Igal Bayn[3], Jacob Mower[1], Nicholas C. Harris[1], Andrew Dane[1], Karl K. Berggren[1], Michal Lipson[2], Dirk R. Englund[1]; [1]*MIT, USA;* [2]*EECS, Cornell Univ., USA;* [3]*Columbia Univ., USA*. Single nitrogen vacancy centers in nanostructured diamond form high quality nodes integrated into low-loss photonic circuitry, enabling on-chip detection and signal manipulation. Pre-selection provides near-unity yield. Long coherence times are demonstrated in integrated nodes.

FTh4C • Attosecond Dynamics and Strong-field Interactions—Continued

FTh4C.4 • 17:15

Structure Tomography of Argon Trimer with Laser-Driven Coulomb Explosion Imaging, Chengyin Wu[1], Xiguo Xie[1], Qihuang Gong[1]; [1]*Peking Univ., China*. The structure distribution of argon trimer was experimentally reconstructed with laser-driven Coulomb explosion imaging technique and compared with our finite-temperature ab initio calculations.

FTh4C.5 • 17:30

Explosion Dynamics of Methane Clusters Irradiated by 38 nm XUV Laser Pulses, Ahmed M. Helal[2,1], Sandra Bruce[2,1], Hernan J. Quevedo[2,1], Aaron C. Bernstein[2,1], John Keto[2,1], Todd Ditmire[2,1]; [1]*Univ. of Texas at Austin, USA;* [2]*Center for High Energy Density Science, USA*. Explosions of methane clusters using 38 nm XUV laser pulses were studied. Ion fragmentation dynamics depends upon cluster size. Coulomb explosion of protons followed by recombination of methane fragments has been observed.

FTh4C.6 • 17:45

Direct Observation of Rescattering from Strong Field Ionization by Two-Color Circularly Polarized Laser Fields, Christopher A. Mancuso[1,2], Daniel Hickstein[1,2], Patrik Grychtol[1,2], Ronny Knut[1,2], Ofer Kfir[3], Xiao-Min Tong[4], Franklin Dollar[1,2], Dmitriy Zusin[1,2], Maithreyi Gopalakrishnan[1,2], Christian Gentry[1,2], Emrah Turgut[1,2], Jennifer Ellis[1,2], Ming-Chang Chen[5], Avner Fleischer[3,6], Oren Cohen[3], Henry C. Kapteyn[1,2], Margaret M. Murnane[1,2]; [1]*Univ. of Colorado at Boulder, USA;* [2]*JILA, USA;* [3]*Physics, Solid State Inst., Israel;* [4]*Division of Material Science, Univ. of Tsukuba, Japan;* [5]*Inst. for Photonics Technologies, National Tsing Hua Univ., Taiwan;* [6]*Physics and Optical Engineering, Ort Braude College, Israel*. The photoelectron distribution from strong field ionization by a two-color counter-rotating circularly polarized laser field uniquely exhibits distinct low-energy features. These can be attributed to electron-ion Coulomb rescattering, providing a new window into this process.

FTh4D • Quantum and Fundamental Phenomena—Continued

FTh4D.2 • 17:30

Bloch Oscillations of Einstein-Podolsky-Rosen States, Maxime Lebugle[1], Markus Gräfe[1], René Heilmann[1], Armando Perez-Leija[1], Stefan Nolte[1], Alexander Szameit[1]; [1]*Inst. of Applied Physics, Abbe School of Photonics, Friedrich-Schiller Universität Jena, Germany.* We report on the first experimental observation of Bloch Oscillations of nonlocal quantum states. Our integrated photonic circuit could serve as a platform for quantum simulation of the dynamics of bosonic, anyonic and fermionic particles.

FTh4D.3 • 17:45

Optically tunable entangled photon state generation in a nonlinear directional coupler, Frank Setzpfandt[1,2], Alexander S. Solntsev[1], James Titchener[1], Che W. Wu[1], Chunle Xiong[3], Thomas Pertsch[2], Roland Schiek[4], Dragomir N. Neshev[1], Andrey A. Sukhorukov[1]; [1]*Centre for Ultrahigh Bandwidth Devices for Optical Systems (CUDOS) and Nonlinear Physics Centre, Research School of Physics and Engineering, Australian National Univ., Australia;* [2]*Inst. of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Germany;* [3]*CUDOS, the Inst. of Photonics and Optical Science (IPOS), School of Physics, Univ. of Sydney, Australia;* [4]*Univ. of Applied Sciences Regensburg, Germany.* We propose and experimentally demonstrate an all-optically tunable biphoton quantum light source using a nonlinear directional coupler. The source can generate high-fidelity N00N states, completely split states, and states with variable degrees of entanglement.

Executive Ballroom 210E

Executive Ballroom 210F

Executive Ballroom 210G

Executive Ballroom 210H

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FTh4E • Nanophotonics for Thermal Transfer and Waveguiding—Continued

FTh4E.3 • 17:15
Near complete violation of detailed balance in thermal radiation, Linxiao Zhu[1], Shanhui Fan[1]; *[1]Stanford Univ., USA.* We introduce general principles for maximally violating detailed balance in thermal radiation. We validate these principles by direct calculations, based on fluctuational electrodynamics, on thermal emitters constructed from magneto-optical photonic crystals.

FTh4E.4 • 17:30
Controlling Guided Waves In Telecom Waveguides Using One Dimensional Phased Antenna Arrays, Zhaoyi Li[1], Myoung Hwan Kim[1], Nanfang Yu[1]; *[1]Columbia Univ., USA.* We theoretically demonstrate a few novel small-footprint and broadband integrated photonic devices based on optical waveguides patterned with phased antenna arrays. These devices include waveguide mode converters, polarization rotators, perfect absorbers, and optical power diodes.

FTh4E.5 • 17:45
Epsilon-near zero wave diffraction in the optical domain, Daniel Ploss[1], Arian Kriesch[1,2], Jakob Naeger[1], Ulf Peschel[1]; *[1]Inst. of Opt., Information and Photonics (IOIP), Cluster of Excellence Engineering of Adv. Opt. Mat. (EAM) and Graduate School in Adv. Opt. Technology (SAOT) and MPL, Friedrich Alexander Univ. Erlangen-Nuremberg, Germany; [2]Applied Physics and Material Sciences, California Inst. of Technology, USA.* We experimentally demonstrate wave propagation in 2D nanophotonic epsilon-near-zero (ENZ) waveguides. We show an ENZ double-slit experiment, investigate ENZ diffraction and observe the disappearance of wavelength-scale obstacles close to the cut-off of the waveguide mode.

STh4F • Photonic, Microwave Signal Processing—Continued

STh4F.4 • 17:15
Novel Photonic Radio-frequency Arbitrary Waveform Generation based on Photonic Digital-to-Analog Conversion with Pulse Carving, Jinxin Liao[1], Boyu Chen[1], Shangyuan Li[1], Xiao Yang[1], Xiaoping Zheng[1], Hanyi Zhang[1], Bingkun Zhou[1]; *[1]Tsinghua Univ., China.* We firstly propose a photonic radio-frequency arbitrary waveform generator based on photonic digital-to-analog conversion with pulse carving, and demonstrate 10GS/s 4-bit resolution arbitrary waveform generations with 15GHz and 30GHz up-converting.

STh4F.5 • 17:30
All-Optical Optomechanical Modulation Enabling Real-Time Signal Tracking, Jianguo Huang[1,2], Bin Dong[2], Hong Cai[3], Jiuhui Wu[1], Tianning Chen[1], Yuandong Gu[3], Ai-Qun Liu[2]; *[1]Xian Jiaotong Univ., China; [2]Nanyang Technological Unversity, Singapore; [3]Inst. of Microelectronics, A*STAR, Singapore.* We present a novel all-optical light tracker by taking advantage of the nonlinear optomechanical signal amplification and modulation, which can transfer the information carried by a signal light to tracking light without electro-optical converting.

STh4F.6 • 17:45
Towards Highly Linear Intensity Modulator for High Resolution Photonic ADCs Using a Three-Section Mode-Locked Laser, Edris Sarailou[1], Peter J. Delfyett[1]; *[1]College of Optics and Photonics, CREOL, Univ. of Central Florida, USA.* A novel highly linear intensity modulator is proposed using an injection-locked three-section mode-locked laser. Modulating the passive section of the mode-locked laser reduces V_π to 1.1 mV and should greatly increase SFDR.

STh4G • Fabrication Techniques II—Continued

STh4G.4 • 17:15
Withdrawn

STh4G.5 • 17:30
Light-induced Material Displacement in Polymer Films: A New Tool for Optical Materials Structuring, Emanuele Orabona[1], Pasqualino Maddalena[1], Antonio Ambrosio[1,2]; *[1]CNR-SPIN, Italy; [2]School of Engineering and Applied Sciences, Harvard Univ., USA.* Isomerization cycles of light-activated molecular switches in a polymeric matrix can result into the polymer surface structuring with nanometric resolution. This still debated phenomenon allows designing and realizing complex architectures in plasmonic and photonic devices.

STh4G.6 • 17:45
Etch-Free Patterning of PEDOT:PSS for Optoelectronics, Steven A. Rutledge[1], Amr S. Helmy[1]; *[1]Univ. of Toronto, Canada.* A process was developed to enable polymer-based optoelectronics without need for any etch steps. The process root causes were established using optical spectroscopy. It was then used to fabricate OLED arrays and touch sensor matrices.

STh4H • Novel Applications and Phenomena of Nonlinear Optics—Continued

STh4H.4 • 17:15
Inhibiting Stimulated Brillouin Scattering in a Highly Nonlinear Waveguide, Moritz Merklein[1], Irina Kabakova[1], Thomas Buettner[1], Duk-Yong Choi[2], Stephen Madden[2], Barry Luther-Davies[2], Benjamin J. Eggleton[1]; *[1]CUDOS/IPOS, Univ. of Sydney, Australia; [2]CUDOS, Laser Physics Centre, Australian National Univ., Australia.* We demonstrate the inhibition of stimulated Brillouin scattering using a Bragg grating in a highly nonlinear chalcogenide rib waveguide on a chip.

STh4H.5 • 17:30
Broadband Fourier-transform Stimulated Raman Scattering, Julien Rehault[1], Francesco Crisafi[1], Vikas Kumar[1], Marco Marangoni[1], Giulio Cerullo[1], Dario Polli[1]; *[1]Politecnico di Milano, Italy.* We demonstrate a new approach to broadband stimulated Raman scattering based on time-domain-Fourier-transform detection of the stimulated Raman gain. Our method blends the sensitivity of single-channel lock-in detection with the spectral resolution of Fourier-transform spectroscopy.

STh4H.6 • 17:45
Handedness Control of Mid-infrared (9-12μm) Vortex Laser, Michael-Tomoki Horikawa[1], Azusa Ogawa[1], Kenji Furuki[1], Katsuhiko Miyamoto[1], Takashige Omatsu[1,2]; *[1]Chiba Univ., Japan; [2]JST, CREST, Japan.* Handedness control of the mid-infrared vortex output from a ZnGeP2 difference frequency generator pumped by a 1-μm vortex pumped KTiOPO4 optical parametric oscillator was demonstrated over a frequency range of 9-12 μm.

Meeting Room 211 B/D

CLEO: Science & Innovations

STh4I • Optomechanics II—Continued

STh4I.4 • 17:15
Unifying Brillouin scattering and cavity optomechanics in silicon photonic wires, Raphaël Van Laer[1], Bart Kuyken[1], Roel Baets[1], Dries Van Thourhout[1]; [1]*Ghent Univ. - imec, Belgium*. We prove a connection between the Brillouin gain and the zero-point optomechanical coupling rate. Moreover, we report on observations of Brillouin scattering in silicon photonic nanowires-showing efficient coupling between near-infrared light and gigahertz sound.

STh4I.5 • 17:30 Invited
Optomechanical Nonlinearities in Microstructured Optical Fibers, Philip S. Russell[1], Anna Butsch[1], Johannes Koehler[1], Roman E. Noskov[1], Meng Pang[1]; [1]*Max-Planck-Inst Physik des Lichts, Germany*. Light-driven mechanical motion or vibration in microstructured glass fibers can result in very large Raman-like optomechanical nonlinearities that may be used, e.g., to mode-lock fibre ring lasers at a high harmonic of their round-trip frequency.

Meeting Room 212 A/C

CLEO: Applications & Technology

ATh4J • Clinical Technologies and Systems II—Continued

ATh4J.3 • 17:30
Design and Implementation of a Volume Holographic Imaging Endoscope, Isela D. Howlett[1], Michael Gordon[1], Gabriel Orsinger[1], John Brownlee[1], Marek Romanowski[1], Jennifer Barton[1], Raymond K. Kostuk[1]; [1]*Univ. of Arizona, USA*. The design and packaging of a volume holographic imaging endoscope suitable for clinical studies is presented. The system is capable of simultaneous image projection from multiple tissue depths. Preliminary results show resolution to 4 µm.

ATh4J.4 • 17:45
***In vivo* longitudinal cellular imaging of small intestine by side-view confocal endomicroscopy,** Jinhyo Ahn[1], Kibaek Choe[1], Taejun Wang[2], Yoonha Hwang[1], Ki Hean Kim[2], Pilhan Kim[1]; [1]*Korea Advanced Inst of Science & Tech, USA;* [2]*Pohang Univ. of Science and Technology, Korea*. *In vivo* Longitudinal repetitive observation of microvasculature and fluorescent cells in a small intestinal tract of single mouse in minimally invasive manner was demonstrated by using GRIN lens based side-view confocal endomicroscopy.

Meeting Room 212 B/D

CLEO: Science & Innovations

STh4K • Super-resolution Imaging—Continued

STh4K.2 • 17:30
An Azimuthal Polarizer Assures Localization Accuracy in Single-Molecule Super-Resolution Fluorescence Microscopy, Matthew D. Lew[1,2], W. E. Moerner[1]; [1]*Dept. of Chemistry, Stanford Univ., USA;* [2]*Dept. of Electrical Engineering, Stanford Univ., USA*. Imaging only azimuthally-polarized light from single fluorescent molecules avoids emission from the *z* component of their transition dipole moments, resulting in accurate measurement of location regardless of emitter orientation and degree of objective lens misfocus.

STh4K.3 • 17:45
Maximally Informative Point Spread Functions for 3D Super-Resolution Imaging, Yoav Shechtman[1], Steffen J. Sahl[1,2], Adam S. Backer[1], W. E. Moerner[1]; [1]*Stanford Univ., USA;* [2]*Max Planck Inst. for Biophysical Chemistry, Germany*. We generate optimal point spread functions (PSFs) for 3D super-resolution imaging, and demonstrate their application in biological conditions. These PSFs exhibit significantly improved precision and depth of field over the current state of the art.

Marriott Salon I & II

CLEO: Science & Innovations

STh4L • Fiber Lasers—Continued

STh4L.4 • 17:15
Pulse Coherence in Self-sweeping Fiber Laser, Ivan A. Lobach[1], Sergey I. Kablukov[1], Evgeniy V. Podivilov[1,2], Andrei A. Fotiadi[3,4], Sergey A. Babin[1,2]; [1]*Inst. of Automation and Electrometry, Russia;* [2]*Novosibirsk State Univ., Novosibirsk, Russia;* [3]*Faculté Polytechnique de Mons, Service d'Electromagnétisme et de Télécommunications, Belgium;* [4]*Ulyanovsk State Univ., Russia*. Investigation of a self-sweeping fiber laser with regular dynamics shows that the phases of modes generated with different pulses are not random. A superposition of 18 consequent laser pulses inside an external ring fiber cavity highlights their coherent combining into a train of nanosecond pulses.

STh4L.5 • 17:30
Rogue Waves in a Normal-Dispersion Fiber Laser, Zhanwei Liu[1], Shumin Zhang[2], Frank W. Wise[1]; [1]*Cornell Univ., USA;* [2]*Hebei Normal Univ., China*. The first observations of rogue-wave formation in a normal-dispersion fiber laser are reported. With an interference filter in the cavity, non-Gaussian distributions with pulses as large as 6 times the significant wave height are observed.

STh4L.6 • 17:45
High Peak Power Single-Frequency Efficient Erbium-Ytterbium Doped LMA Fiber, William Renard[1], Thierry Robin[2], Benoît Cadier[2], Julien Le Gouët[1], Laurent Lombard[1], Anne Durécu[1], Pierre Bourdon[1], Guillaume Canat[1]; [1]*DOTA, ONERA, France;* [2]*iXfiber, France*. We report on single-frequency all-fiber amplifiers based on Er-Yb doped P2O5-Al2O3-SiO2 fibers. Peak power up to 1120 W at 1545 nm for 108 ns pulse duration has been obtained with 18 % slope-efficiency. Continuous-wave operation generated up to 14 W.

Marriott Salon III	Marriott Salon IV	Marriott Salon V & VI

CLEO: Science & Innovations

STh4M • Fundamental Light-material Interaction II—Continued

STh4M.4 • 17:15
Non-thermal ablation and deposition of graphite induced by ultrashort pulsed laser radiation, Christian Kalupka[1]; [1]*RWTH Aachen, Germany.* We study the non-thermal ablation threshold of graphite in dependence on the applied ultrashort pulse duration. Our results indicate lattice motions to play a relevant role in the non-thermal ablation process.

STh4M.5 • 17:30
Single photon sources using diamond colour centres in novel open access microcaviities, Philip Dolan[1], Sam Johnson[1], Aurelien Trichet[1], Lucas Flatten[1], Laiyi Weng[1], Jason M. Smith[1]; [1]*Univ. of Oxford, UK.* Finite difference time domain results support the design of microcavities which can be produced with unparalleled fidelity to the modelled surface with a focused ion beam. Coupling of NV centres at low temperature is also shown.

STh4M.6 • 17:45
Electrical Valley Excitation by Spin Injection in Monolayer TMDC, Yu Ye[1], Xiaobo Yin[1,2], Hailong Wang[3], Ziliang Ye[1], Hanyu Zhu[1], Yuan Wang[1], Jianhua Zhao[3], Xiang Zhang[1,4]; [1]*UC Berkeley, USA;* [2]*Univ. of Colorado Boulder, USA;* [3]*Chinese Academy of Sciences, Inst. of Semiconductors, China;* [4]*Lawrence Berkeley National Lboratory, Materials Sciences Division, USA.* We show experimentally the new valley indices of carriers can be electrically generated by spin injection, unifying the spintronics and emerging valleytronics.

STh4N • Micro and GHz Combs—Continued

STh4N.3 • 17:15
Spectral broadening of Kerr Frequency Combs Generated from a Normal Dispersion Silicon Nitride Microresonator, Yang Liu[1], Andrew J. Metcalf[1], Yi Xuan[1], Xiaoxiao Xue[1], Pei-Hsun Wang[1], Minghao Qi[1], Andrew M. Weiner[1]; [1]*Purdue Univ., USA.* We demonstrate a scheme to broaden the bandwidth of the Kerr frequency comb generated through mode interaction in a normal dispersion SiN microresonator. The broadened comb has a bandwidth of over 5 THz and can be compressed to the bandwidth limited time profile via dispersive fiber propagation.

STh4N.4 • 17:30
Microwave to Optical Link Using an Optical Microresonator, John D. Jost[1], Tobias Herr[1,2], Caroline Lecaplain[1], Erwan Lucas[1], Victor Brasch[1], Martin Pfeiffer[1], tobias kippenberg[1]; [1]*EPFL, Switzerland;* [2]*CSEM, Switzerland.* Microresonator based optical frequency combs have the potential to greatly extend optical frequency measurements. Here we demonstrate the first self-referenced microresonator based optical comb suitable for optical frequency metrology applications.

STh4N.5 • 17:45
Self-referencing a 10 GHz Electro-optic Comb, Daniel C. Cole[1], Katja Beha[1], Frederick N. Baynes[1], Pascal Del'Haye[1], Antoine Rolland[1], Tara M. Fortier[1], Franklyn Quinlan[1], Scott Diddams[1], Scott B. Papp[1]; [1]*NIST Boulder, USA.* An octave-spanning frequency comb is generated using electro-optic modulation of a 1550 nm laser and nonlinear broadening. With this comb we demonstrate offset frequency detection, precise metrology, and ultrastable synthesis of 10 GHz microwaves.

STh4O • Optical Sensing Techniques for Combustion and Energy Research—Continued

STh4O.2 • 17:30
Cavity-Enhanced Optical Frequency Comb Spectroscopy of High-Temperature Water in a Flame, Amir Khodabakhsh[1], Zhechao Qu[2], Chadi Abd Alrahman[1], Alexandra C. Johansson[1], Lucile Rutkowski[1], Florian M. Schmidt[2], Aleksandra Foltynowicz-Matyba[1]; [1]*Dept. of Physics, Umeå Univ., Sweden;* [2]*Thermochemical Energy Conversion Lab, Dept. of Applied Physics and Electronics, Umeå Univ., Sweden.* We demonstrate detection of broadband high-temperature water spectra in a laminar, premixed methane/air flat flame using high-resolution near-infrared cavity-enhanced optical frequency comb spectroscopy incorporating a fast-scanning Fourier transform spectrometer.

STh4O.3 • 17:45
Fiber Optical Chemical Sensors Rated for 800°C Operation, Aidong Yan[1], Rongzhang Chen[1], Zsolt L. Poole[1], Paul R. Ohodnicki[3], Tino Elsmann[2], Tobias Habisreuther[2], Manfred Rothhardt[2], Hartmut Bartelt[2], Kevin P. Chen[1]; [1]*Univ. of Pittsburgh, USA;* [2]*Leibniz Inst. of Photonic Technology, Germany;* [3]*National Energy Technology Lab, USA.* A high-temperature fiber optical hydrogen sensor is demonstrated. The sensor is based on single-crystal sapphire fiber coated with nanostructured Pd-doped TiO_2 thin film. The sensitivity of the sensor was evaluated for hydrogen concentrations varying from 0.02 % to 3% at temperature up to 800°C.

Executive Ballroom 210A	Executive Ballroom 210B	Executive Ballroom 210C	Executive Ballroom 210D
CLEO: Applications & Technology	CLEO: QELS-Fundamental Science		

FTh4B • Quantum Memories—Continued

FTh4B.7 • 18:00
Towards Detection of Single Rare-Earth-Ions in a Nanophotonic Resonator, Tian Zhong[1], Jonathan Kindem[1], Evan Miyazono[1], Andrei Faraon[1]; *[1]California Inst. of Technology, USA.* We report a scheme for detecting single rare-earth-ions coupled to an Yttrium Orthosilicate (YSO) nanophotonic resonator, which could enable precise optical addressing of individual ions as single qubits for quantum information applications.

FTh4B.8 • 18:15
Coupling an erbium spin ensemble to a 3D superconducting cavity at zero magnetic field, Yu-Hui Chen[1], Xavier Fernandez-Gonzalvo[1], Jevon Longdell[1]; *[1]Univ. of Otago, New Zealand.* We report zero-magnetic-field electron-paramagnetic-resonance experiments of an $^{167}Er:Y_2SiO^5$ crystal coupled to a tunable 3D superconducting cavity of a 10^5 Q-factor.

FTh4C • Attosecond Dynamics and Strong-field Interactions—Continued

FTh4C.7 • 18:00
Sub-Ångström Scale Imaging of Aligned Acetylene, Benjamin Wolter[1], Michael G. Pullen[1], Anh-Thu Le[2], Matthias Baudisch[1], Michele Sclafani[1], Hugo Pires[1], Michael Hemmer[1], Arne Senftleben[3], Claus Dieter Schröter[4], Joachim Ullrich[4,5], Robert Moshammer[4], Chii-Dong Lin[2], Jens Biegert[1,6]; *[1]ICFO -The Inst. of Photonic Sciences, Spain; [2]J. R. Macdonald Lab, Physics Dept., Kansas State Univ., USA; [3]Inst. of Physics, Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), Univ. of Kassel, Germany; [4]Max-Planck-Institut für Kernphysik, Germany; [5]Physikalisch-Technische Bundesanstalt (PTB), Germany; [6]ICREA - Institucio Catalana de Recerca i Estudis Avancats, Spain.* We present the simultaneous measurement of the C-C and C-H bond lengths of aligned acetylene. Our approach combines an ultrafast 160 kHz mid-IR source with 3D electron-ion coincidence detection towards imaging of molecular dynamics.

FTh4C.8 • 18:15
Observation of High-Lying Rydberg States Survived from Strong Field Interaction, Seyedreza Larimian[1], Sonia Erattupuzha[1], Raffael Maurer[1], Christoph Lemell[2], Stefan Nagele[2], Shuhei Yoshida[2], Joachim Burgdörfer[2], Andrius Baltuska[1], Markus Kitzler[1], Xinhua Xie[1]; *[1]Photonics Inst., Vienna Univ. of Technology, Austria; [2]Inst. for Theoretical Physics, Vienna Univ. of Technology, Austria.* We observed high-lying (n>238) Rydberg states which survived from strong field interaction of atoms and molecules with electron and ion coincidence detection. The high-lying Rydberg states are measured through field ionization with weak DC fields.

FTh4D • Quantum and Fundamental Phenomena—Continued

FTh4D.4 • 18:00
Nondegenerate Two-Photon Gain in GaAs, Matthew Reichert[1], David J. Hagan[1], Eric W. Van Stryland[1]; *[1]Univ. of Central Florida, CREOL, USA.* We present data indicating two-photon gain using extremely nondegenerate (END) photons in optically excited GaAs. These results are consistent with our demonstration of END two-photon absorption enhancement and points a possible way to two-photon lasing.

FTh4D.5 • 18:15
Optical Bistability in Electrically Driven Polariton Condensates, Matthias Amthor[1], Timothy C. H. Liew[2], Christian Metzger[1], Sebastian Brodbeck[1], Lukas Worschech[1], Martin Kamp[1], Ivan A. Shelykh[2], Alexey V. Kavokin[3,4], Christian Schneider[1], Sven Höfling[1]; *[1]Technische Physik, Univ. of Wuerzburg, Germany; [2]Division of Physics and Applied Physics, Nanyang Technological Univ., Singapore; [3]Spin Optics Lab, St-Petersburg State Univ., Russia; [4]Physics and Astronomy School, Univ. of Southampton, UK.* We observe a bistability in an electrically driven polariton condensate, which is manifested by a memory dependent threshold characteristic. The bistability is explained by a dependence of the electron-hole tunneling lifetime on the carrier density.

18:30–20:00 Dinner Break *(on your own)*

20:00–22:00 Postdeadline Paper Sessions
Locations announced in the postdeadline paper digest.

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Executive Ballroom 210E | Executive Ballroom 210F | Executive Ballroom 210G | Executive Ballroom 210H

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FTh4E • Nanophotonics for Thermal Transfer and Waveguiding—Continued

FTh4E.6 • 18:00
Coupling Control Based on Adiabatic Elimination in Densely Integrated Nano-Photonics, Michael Mrejen[1], Haim Suchowski[1], Taiki Hatakeyama[1], Chihhui Wu[1], Liang Feng[1], Kevin O'Brien[1], Yuan Wang[1], Xiang Zhang[1]; *[1]Univ. of California Berkeley, USA.* We experimentally demonstrate a novel approach based on adiabatic elimination scheme to control the coupling between densely packed waveguides. At the nano-scale, cancellation of the coupling between the waveguides can be achieved.

FTh4E.7 • 18:15
Plasmonic Waveguide Array: Simulating Topological Photonic States and Massless Dirac Fermion, Q.Q. Cheng[1,2], Tao Li[1,2]; *[1]College of Engineering and Applied Sciences, Nanjing Univ., China; [2]National Lab of Solid State Microstructures, Nanjing Univ., China.* In the binary plasmonic waveguide array (PWA), we experimentally demonstrated a topologically protected optical mode with immunity against structural disorders, and theoretically proposed an optical analogue of massless Dirac Fermion by alternating positive and negative couplings.

STh4F • Photonic, Microwave Signal Processing—Continued

STh4F.7 • 18:00
On-Chip Instantaneous Microwave Frequency Measurement System based on a Waveguide Bragg Grating on Silicon, Maurizio Burla[1], Xu Wang[2], Ming Li[3], Lukas Chrostowski[2], José Azaña[1]; *[1]Institut National de la Recherche Scientifique, Canada; [2]Univ. of British Columbia, Canada; [3]Inst. of Semiconductors, Chinese Academy of Sciences, China.* We experimentally demonstrate an instantaneous frequency measurement system based on a 65 μm-long integrated Bragg grating filter. An amplitude comparison function based on its transmission and reflection responses allows identification of unknown RF frequencies above 30 GHz.

STh4F.8 • 18:15
Large frequency range photonic-assisted software-defined radio transceiver, Jingjing Wang[1], Hongchen Yu[1], Minghua Chen[1], Hongwei Chen[1], Sigang Yang[1], Shizhong Xie[1]; *[1]Tsinghua Univ., China.* We present a novel software-defined radio transceiver, which takes advantages of RF photonic techniques to realize the state-of-the-art performance in the aspect of the frequency range to cover from C band to Ka band.

STh4G • Fabrication Techniques II—Continued

STh4G.7 • 18:00
Microfluidic Reconfigurable Metasurface: A Demonstration of Tunable Focusing from Near Field to Far Field, Weimiing Zhu[1]; *[1]Nanyang Technological Univ., USA.* We present a reconfigurable transmission metasurface based on microfluidic system. As a proof of concept, the focal length of the metasurface is tuned from near-field region (1 λ) to far-field region (18 λ).

STh4G.8 • 18:15
On-Demand Fabrication of Micro-Wired Rods and Nano-Coupling Control for 3D Polymeric Optical System, Hiroaki Yoshioka[1], Noboru Hirakawa[1], Mitsuhiro Nakano[1], Yuji Oki[1]; *[1]Dept. of Electronics, Kyushu Univ., Japan.* Fully polymeric 3D microcavity system was proposed and demonstrated in which integrates whisper-gallery-mode microrod lasers and output coupling waveguide. As on-site additive-manufacturing technique, microdispensing wired 7.3 μmϕ polymer-microrods. Their repositioning accuracy <100 nm was attained.

STh4H • Novel Applications and Phenomena of Nonlinear Optics—Continued

STh4H.7 • 18:00
Electrically Controllable Saturable Absorption in Hybrid Graphene-Silicon Waveguides, Koen Alexander[1, 2], Yingtao Hu[1, 2], Marianna Pantouvaki[3], Steven Brems[3], Inge Asselberghs[3], Simon-Pierre Gorza[4], Cedric Huyghebaert[3], Joris Van Campenhout[3], Bart Kuyken[1, 2], Dries Van Thourhout[1, 2]; *[1]Photonics Research Group, Depart. of Information Technology, Ghent Univ.-IMEC, Belgium; [2]Center for Nano- and Biophotonics (NB-Photonics), Ghent Univ., Belgium; [3]IMEC, Belgium; [4]Service OPERA-photonique, Université libre de Bruxelles (U.L.B.), Belgium.* Electrical tunability of saturable absorption is demonstrated in a graphene/SOI hybrid waveguide. The saturation modulation depth is tunable between 0 and 2.2 dB (~0-40% decrease of absorption at saturation), with saturation powers between ~1.25-2.5 W.

STh4H.8 • 18:15
Ultra-low power passive mode-locking using an integrated nonlinear microring resonator, Christian Reimer[1], Michael Kues[1], Benjamin Wetzel[1], Piotr Roztocki[1], Brent E. Little[2], Sai T. Chu[3], David Moss[1, 4], Roberto Morandotti[1]; *[1]INRS-EMT, Canada; [2]Xi'an Inst. of Optics and Precision Mechanics of CAS, China; [3]Depart. of Physics and Material Science, City Univ. of Hong Kong ,China; [4]School of Electrical and Computer Engineering, RMIT Univ.,Australia.* Using high nonlinear enhancement in a CMOS compatible microring resonator incorporated in a SOA based nonlinear loop-mirror laser architecture, we observe passive mode-locking at extremely-low power levels generating 570ps pulses at a 14.8MHz repetition rate.

18:30–20:00 Dinner Break *(on your own)*

20:00–22:00 Postdeadline Paper Sessions
Locations announced in the postdeadline paper digest.

Meeting Room 211 B/D	Meeting Room 212 A/C	Meeting Room 212 B/D	Marriott Salon I & II
CLEO: Science & Innovations	CLEO: Applications & Technology	CLEO: Science & Innovations	

STh4I • Optomechanics II—Continued

STh4I.6 • 18:00
Microwave Frequency Traveling Surface Acoustic Wave Induced Transparency, Huan Li[1], Semere A. Tadesse[1,2], Qiyu Liu[1], Mo Li[1]; *[1]Dept. of Electrical and Computer Engineering, Univ. of Minnesota, USA; [2]School of Physics and Astronomy, Univ. of Minnesota, USA.* Inter-digital transducers and photonic crystal cavities are integrated on a piezoelectric aluminum nitride film sputtered on an oxidized silicon wafer, which leads to the first demonstration of microwave frequency traveling surface acoustic wave induced transparency.

STh4I.7 • 18:15
Surface Acoustic Wave Modulation of Optical Cavities on a Suspended Membrane, Semere Tadesse[1], Huan Li[1], Qiyu Liu[1], Mo Li[1]; *[1]Univ. of Minnesota, USA.* Optical race-track resonators and one-dimensional photonic crystal cavities are integrated with surface acoustic wave devices on a suspended piezoelectric aluminum nitride film to realize strong, ultrafast sound-light interaction.

ATh4J • Clinical Technologies and Systems II—Continued

ATh4J.5 • 18:00
***In Vivo* Real-time Observation of ICG Pharmacokinetics by NIR Laser-scanning Confocal Microscopy,** Yoonha Hwang[1], Hwanjun Yoon[1], Kibaek Choe[1], Ji Ho Park[1], Pilhan Kim[1]; *[1]Korea Advanced Inst of Science & TechnologyTechnology, Korea.* By utilizing custom-design video-rate near-infrared laser-scanning confocal microscope, we imaged the pharmacokinetic dynamics of intravenously injected ICG at the skin and liver of mouse in sub-cellular scale *in vivo*.

ATh4J.6 • 18:15
Field-Portable Smartphone Microscopy Platform for Wide-field Imaging and Sizing of Single DNA molecules, Qingshan Wei[1], Wei Luo[1], Samuel Chiang[1], Tara Kappel[1], Crystal Mejia[1], Derek Tseng[1], Raymond Yan Lok Chan[1], Eddie Yan[1], Hangfei Qi[1], Faizan Shabbir[1], Haydar Ozkan[1], Steve Feng[1], Aydogan Ozcan[1]; *[1]Univ. of California Los Angeles, USA.* We demonstrate a field-portable smartphone-based fluorescence microscopy platform for imaging and sizing of single DNA molecules across ~2 mm2 field-of-view with <1 kbp length accuracy.

STh4K • Super-resolution Imaging—Continued

STh4K.4 • 18:00
Adaptive optics for single molecule switching nanoscopy, Martin J. Booth[1]; *[1]Univ. of Oxford, UK.* Specimen-induced aberrations frequently affect image quality in high-resolution microscopes. Aberration effects can be even more problematic in super-resolution methods. We show adaptive aberration correction in STORM microscopy of deep cell and tissue specimens.

STh4K.5 • 18:15
Single-Shot Sparsity-based Sub-wavelength Fluorescence Imaging of Biological Structures Using Dictionary Learning, Maor Mutzafi[1], Yoav Shechtman[2,1], Yonina C. Eldar[1], Mordechai Segev[1]; *[1]Technion Israel Inst. of Technology, Israel; [2]Chemistry, Stanford Univ., USA.* We present a novel technique to algorithmically enhance the resolution in optical microscopy. To do that, we exploit the characteristic features of biological images to construct a dictionary which enables sparsity-based reconstruction of sub-wavelength features.

STh4L • Fiber Lasers—Continued

STh4L.7 • 18:00
2.6 mJ Energy and 81 GW Peak Power Femtosecond Laser-Pulse Delivery and Spectral Broadening in Inhibited Coupling Kagome Fiber, Benoît Debord[1], Frédéric Gérôme[1], Pierre-Mary Paul[2], Anton Husakou[3], Fetah Benabid[1]; *[1]Xlim Research Inst., Université de Limoges, France; [2]Amplitudes Technologies, France; [3]Max Born Inst., Germany.* We report on 800nm laser-pulse delivery record by using inhibited coupling Kagome fiber. Strong spectral broadening and projected pulse compression down to ~10fs were achieved with input 2.6mJ energy and 81GW peak power.

STh4L.8 • 18:15
High-power, high-efficiency random fiber lasing with a low reflectivity mirror, Zinan Wang[1], Han Wu[1], Mengqiu Fan[1], Li Zhang[1], Weili Zhang[1], Yunjiang Rao[1]; *[1]Univ. Electronic Sci. & Tech. of China, China.* We theoretically investigate the role of point reflector's reflectivity in the performance of forward-pumped high power random fiber lasing, and demonstrate that the maximum 1st-oder random lasing output power can even increase when the reflectivity decreases from 0.9 to 0.01.

18:30–20:00 Dinner Break *(on your own)*

20:00–22:00 Postdeadline Paper Sessions
Locations announced in the postdeadline paper digest.

NOTES

Marriott Salon III	Marriott Salon IV	Marriott Salon V & VI

CLEO: Science & Innovations

STh4M • Fundamental Light-material Interaction II—Continued

STh4M.7 • 18:00
Multi-shots ablation of polymethylmethacrylate by two-color femtosecond synthesized waveform, Chih-Hsuan Lin[1], Chan-Shan Yang[2], Alexey Zaytsev[2], Ci-Ling Pan[2,1]; *[1]Inst. of Photonics Technologies, National Tsing Hua Univ., Taiwan; [2]Dept. of Physics, National Tsing Hua Univ., Taiwan.* We observed clear modulation in ablated area and threshold as a function of relative phase between the ω and 2ω beams and the increase of incubation coefficient up to 0.83 compared to single color case.

STh4M.8 • 18:15
Control of Absorption in Femtosecond Laser-Dielectric Interaction with the Polarization of a Seeding Pulse, Mark Green[1], Tsing-Hua Her[1], Chih-Hsuan Lin[2], Ci-Ling Pan[2]; *[1]Univ. of North Carolina at Charlott, USA; [2]National Tsing Hua Univ., Taiwan.* We investigate femtosecond pulse transmission through BK7 in the presence of its second harmonic as a seeding pulse. Enhanced absorption is observed when the pulses are co-polarized. Such phenomenon can be used to control absorption.

STh4N • Micro and GHz Combs—Continued

STh4N.6 • 18:00
Low-Phase-Noise Millimeter-Wave Signal Generator assisted with Frequency Comb based on Electro-Optics-Modulators, Atsushi Ishizawa[1], Tadashi Nishikawa[2], Takahiro Goto[2], Kenichi Hitachi[1], Tetsuomi sogawa[1], HIdeki Gotoh[1]; *[1]NTT Basic Research Labs, Japan; [2]Tokyo Denki Univ., Japan.* By employing 25-GHz-mode-spacing electro-optics-modulator-based optical frequency comb at telecommunications wavelengths, we have successfully demonstrated that phase noise in a commercially available signal generator at 25 GHz can be dramatically reduced to less than ever before.

STh4N.7 • 18:15
Low Phase-noise Tunable Optoelectronic Comb Generator, Andrew J. Metcalf[1], Franklyn Quinlan[2], Tara M. Fortier[2], Scott Diddams[2], Andrew M. Weiner[1]; *[1]Purdue Univ., USA; [2]Time and Frequency Division, National Inst. of Standards and Technology, USA.* We investigate the phase-noise properties of a tunable single-pass optoelectronic frequency comb generator. Residual phase noise at 1 Hz offset from a 10 GHz carrier is as low as -100 dBc/Hz.

STh4O • Optical Sensing Techniques for Combustion and Energy Research—Continued

STh4O.4 • 18:00
Monitoring of Hydraulic Fracturing Using DFB Fiber Laser Acoustic Sensors, Rongzhang Chen[1], Aidong Yan[1], Mohamed Zaghloul[1], Guanyi Lu[4], Andrew P. Bunger[4,3], Gary A. Miller[2], Geoffrey Cranch[2], Kevin P. Chen[1]; *[1]Dept. of Electrical and Computer Engineering, Univ. of Pittsburgh, USA; [2]Naval Research Lab, USA; [3]Dept. of Chemical and Petroleum Engineering, Univ. of Pittsburgh, USA; [4]Dept. of Civil and Environmental Engineering, Univ. of Pittsburgh, USA.* This paper studies acoustic emission from hydraulic fracturing using DFB fiber laser sensors interrogated by a 3×3 coupler. This study shows that fiber lasers are useful tools to monitor fracturing processes for oil gas extraction.

STh4O.5 • 18:15
Demonstration of a Differential Absorption Lidar for Emissions Measurement of a Coal-Fired Power Plant, Michael Wojcik[1], Blake Crowther[2], Robert Lemon[1], Prasad Valupadas[3], Long Fu[3], Bonnie Leung[3], Zheng Yang[3], Quamrul Huda[3], Allan Chambers[4]; *[1]Space Dynamics Lab, USA; [2]Synopsys, Inc., USA; [3]AEMERA, Canada; [4]AITF, Canada.* A mobile Differential Absorption Lidar (DIAL) system for measurement of aerosols, CO_2 and $CH_4$is presented. The DIAL system can operate in day/night conditions. A system overview and representative field trial results are presented.

18:30–20:00 Dinner Break *(on your own)*

20:00–22:00 Postdeadline Paper Sessions
Locations announced in the postdeadline paper digest.

NOTES

Executive Ballroom 210A

Executive Ballroom 210B

Executive Ballroom 210C

Executive Ballroom 210D

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

08:00–10:00
FF1A • Quantum Key Distribution
Presider: Ping Lam; Australian National Univ., Australia

FF1A.1 • 08:00 Invited

Device-Independent Quantum Key Distribution, Antonio Acin[1,2]; [1]*ICFO -The Inst. of Photonic Sciences, Spain;* [2]*ICREA-Institucio Catalana de Recerca i Estudis Avançats, Spain.* Device-independent quantum key distribution protocols allow distributing a secret key whose security does not rely on any assumption on the inner working of the devices in the implementation. We discuss recent progress on the problem.

FF1A.2 • 08:30

Practical High-Dimensional Quantum Key Distribution with Decoy States, Darius Bunandar[1], Zheshen Zhang[1], Jeffrey Shapiro[1], Dirk R. Englund[1]; [1]*MIT, USA.* We propose a high-dimensional quantum key distribution protocol secure against photon-number splitting attack by employing only one or two decoy states. Decoy states dramatically increase the protocol's secure distance.

08:00–09:30
FF1B • Quantum Optics with Quantum Dots
Presider: Sergey Polyakov; NIST, USA

FF1B.1 • 08:00

Highly indistinguishable photons from a QD-microcavity with a large Purcell-factor, Sebastian Unsleber[1], Dara McCutcheon[2], Michael Dambach[1], Matthias Lermer[1], Niels Gregersen[2], Sven Höfling[1,3], Jesper Mork[2], Christian Schneider[1], Martin Kamp[1]; [1]*Technische Physik, Univ. of Wuerzburg, Germany;* [2]*Dept. of Photonics Engineering, Technical Univ. of Denmark, Denmark;* [3]*Univ. of St Andrews, SUPA, School of Physics and Astronomy, UK.* We demonstrate the emission of highly indistinguishable photons from a quasi-resonantly pumped coupled quantum dot-microcavity system operating in the weak coupling regime. Furthermore we model the degree of indistinguishability with our novel microscopic theory.

FF1B.2 • 08:15

Screening Nuclear Field Fluctuations in Quantum Dots for Indistinguishable Photon Generation, Ralph Malein[1], Ted Santana[1], Joanna Zajac[1], Pierre Petroff[2], Brian Gerardot[1]; [1]*Inst. of Photonics and Quantum Sciences, Heriot-Watt Univ., UK;* [2]*Materials Dept., Univ. of California, USA.* We probe the effect of nuclear spin interaction with a resident electron spin in a quantum dot using resonance fluorescence spectroscopy and two-photon interference experiments. Screening of the nuclear field fluctuations is demonstrated to successfully generate indistinguishable single photons.

FF1B.3 • 08:30

Phonon-Assisted Population Inversion of a Single Quantum Dot, Alistair Brash[1], John H. Quilter[1], Feng Liu[1], Martin Glässl[2], Andreas Barth[2], Vollrath M. Axt[2], Andrew Ramsay[3], Maurice S. Skolnick[1], A. Mark Fox[1]; [1]*Univ. of Sheffield, UK;* [2]*Institut für Theoretische Physik III, Universität Bayreuth, Germany;* [3]*Hitachi Cambridge Lab, Univ. of Cambridge, UK.* We demonstrate a new method to produce a population inversion in an InGaAs quantum dot by quasi-resonant, incoherent excitation within the LA phonon sideband. A maximum exciton population of 0.67 is measured; applications include single photon sources and single QD lasers.

08:00–10:00
FF1C • Nanophotonics and Photonic Crystals
Presider: To be Determined

FF1C.1 • 08:00 Tutorial

Nanophotonics in material-systems of Large Sizes, Marin Soljačić[1]; [1]*MIT, USA.* Recent nano-fabrication developments enabled implementation of many nanophotonic techniques to macroscopic scales, which is crucial for many applications of interest (e.g. energy conversion, displays, lighting). Some exciting new opportunities in this area will be presented.

Marin Soljacic is a Professor of Physics at MIT. He is the recipient of the Adolph Lomb medal from The Optical Society (2005), the TR35 award of the Technology Review magazine (2006), MacArthur fellowship "genius" grant (2008), and Blavatnik National Award (2014).

08:00–10:00
SF1D • Nonlinear Optics Frequency Conversion with Integrated Optical Devices
Presider: Michal Lipson; Cornell Univ., USA

SF1D.1 • 08:00 Invited

AlGaAs Guided-Wave Optical Parametric Oscillator: Results and Perspectives, Giuseppe Leo[1], Sara Ducci[1], Ivan Favero[1], Cécile Ozanam[1], Xavier Lafosse[2]; [1]*Universite Paris-Diderot Paris VII, France;* [2]*Laboratoire de Photonique et Nanostructures, CNRS, France.* We demonstrate the first near-infrared optical parametric oscillator in a semiconductor waveguide. With an AlGaAs/AlOx heterostructure placed in a 2 μm-centered doubly-resonant monolithic cavity, we reach the threshold at 210 mW in the CW regime.

SF1D.2 • 08:30

Exact Solutions and Scaling Laws for Kerr Frequency Combs, William H. Renninger[1], Peter T. Rakich[1]; [1]*Yale Univ., USA.* An exact, closed-form solution is analyzed for Kerr frequency combs. The model reproduces the behavior of both soliton and wavetrain regimes. Simple scaling laws validate the results and predict new regimes of performance.

Thank you for attending CLEO:2015.

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CLEO: Applications & Technology

CLEO: Science & Innovations

08:00–10:00
AF1E • A&T Topical Review on High Performance Optics I
Presider: Vladimir Pervak; Ludwig-Maximillians-Universität Munchen, Germany

AF1E.1 • 08:00 Invited
Multilayer Optics for Ultrafast Applications, Michael K. Trubetskov[1,2]; [1]*Lab for Attosecond Physics, Max Planck Inst. of Quantum Optics, Germany;* [2]*Research Computing Center, Moscow State Univ., Russia.* Design and production of multilayer optical coatings is considered as multi-stage integral problem. The combination of state-of-the-art design methods and modern deposition techniques advances coating performance to theoretical limits.

AF1E.2 • 08:30 Invited
Dispersive Mirror Compressors for Few-Cycle Laser Pulses, Fabian Lücking[1], Tuan Le[1], Catalin Neacsu[1], Gabriel Tempea[1]; [1]*Femtolasers Produktions GmbH, Austria.* The implementation of multilayer optics for the compression and delivery of few-cycle femtosecond pulses will be discussed in the case of several cutting-edge applications.

08:00–10:00
SF1F • Solid State Lasers
Presider: Shawn Redmond; Massachusetts Inst of Tech Lincoln Lab, USA

SF1F.1 • 08:00
Mid-IR and Near-IR Photoluminescence of Fe^{2+} and Cr^{2+} Ions in ZnSe Excited via Ionization Transitions, Jeremy Peppers[1], Vladimir V. Fedorov[1], Sergey B. Mirov[1]; [1]*Univ. of Alabama at Birmingham, USA.* Spectroscopic characterization of Iron and Chromium doped ZnSe under visible excitation into the charge transfer bands of Transition Metal ions is reported. Energy transfer rates to the upper laser level are sufficient for population inversion.

SF1F.2 • 08:15
High Average Power (35 W) Pulsed Fe:ZnSe laser tunable over 3.8-4.2 μm, Dmitry V. Martyshkin[1], Vladimir V. Fedorov[1], Mike Mirov[1], Igor Moskalev[1], Sergey Vasilyev[1], Sergey B. Mirov[1]; [1]*IPG Photonics Mid-IR Lasers, USA.* We report to the best of our knowledge the highest output average power of 35W (0.35J per pulse) of Fe:ZnSe laser operating at 100 Hz repetition rate in nonselective cavity, and 23 W (0.23J per pulse) in dispersive cavity. The lasing wavelength was tuned over 3.88-4.17 μm at 77K.

SF1F.3 • 08:30
High Energy and Low Noise Ho:YLF Regenerative Amplifiers: A Noise and Stability Analysis, Peter Kroetz[1,2], Axel Ruehl[3], krishna murari[2,3], Huseyin Cankaya[2,3], Anne-Laure Calendron[2,3], Franz Kaertner[2,3], Ingmar Hartl[3], R.J. Dwayne Miller[1,2]; [1]*The Atomically Resolved Dynamics Division, Max-Planck Inst. for the Structure and Dynamics of Matter (MPSD), Germany;* [2]*Center for Free-Electron Laser Science, Germany;* [3]*Deutsches Elektronen-Synchrotron (DESY), Germany.* The dynamics and stability of Ho:YLF regenerative amplifiers is studied experimentally and numerically, whereas operating conditions are analyzed with respect to energy fluctuations. We propose a low-noise laser design operating at a second stability point.

08:00–10:00
SF1G • Novel Devices
Presider: Real Vallee; Universite Laval, China

SF1G.1 • 08:00 Invited
All-carbon photodetectors, Frank Wang[1], Yuanda Liu[1], X Wang[2], E Flahaut[3,4], Y Li[1], x wang[5], X. R. Wang[1], Y Xu[1], Y Shi[1], R Zhang[1]; [1]*School of Electronic Science and Engineering, Nanjing Univ., China;* [2]*Dept. of Electrical Engineering, Yale Univ., USA;* [3]*UPS, INP; Institut Carnot Cirimat, Université de Toulouse, France;* [4]*CNRS; Institut Carnot Cirimat, France;* [5]*School of Chemistry and Chemical Engineering, Nanjing Univ., China.* We demonstrate a graphene/nanotube hybrid phototransistor, in which photogating provided by the nanotube layer leads to a dramatically enhanced photoresponsivity (>100A/W) in the visible range, corresponding to ~10^4 enhancement with respect to a graphene-only device.

SF1G.2 • 08:30
Highly Efficient Hybrid Quantum Dot Light Emitting Diodes with Prolonged Lifetime, Shun-Chieh Hsu[1], Yin-Han Chen[2], Zong-Yi Tu[3], Hau-Vei Han[3], Shih-Li Lin[2], Teng-Ming Chen[4], Hao-Chung Kuo[3], Chien-Chung Lin[1]; [1]*Inst. of Photonic System, Natl Chiao Tung Univ, Taiwan;* [2]*Inst. of Lighting and Energy Photonics, College of Photonics, National Chiao-Tung Univ., Taiwan;* [3]*Inst. of Electro-Optical Engineering, National Chiao-Tung Univ., Taiwan;* [4]*Dept. of Applied Chemistry, National Chiao-Tung Univ., Taiwan.* A highly efficient LED is demonstrated by incorporating the colloidal quantum dots and sodium chloride. Further lifetest shows great stability up to 104 hours under 194 mW/cm^2 of UV pump power.

Meeting Room 211 B/D	Meeting Room 212 A/C	Meeting Room 212 B/D
CLEO: Science & Innovations		CLEO: Applications & Technology

08:00–10:00
SF1H • Microcavities
Presider: To be Determined

SF1H.1 • 08:00
Visible Photoluminescence in Cubic (3C) Silicon Carbide Coupled to High Quality Microdisk Resonators, Marina Radulaski[1], Thomas M. Babinec[1], Kai Muller[1], Konstantinos G. Lagoudakis[1], Jingyuan L. Zhang[1], Sonia M. Buckley[1], Kassem Alassaad[2], Gabriel Ferro[2], Jelena Vuckovic[1]; [1]*Stanford Univ., USA;* [2]*Universite de Lyon, France.* We present the design, fabrication and characterization of cubic (3C) silicon carbide microdisk resonators with high quality factor modes at visible and near infrared wavelengths which couple to the intrinsic luminescence in silicon carbide.

SF1H.2 • 08:15
Silicon Cabide Nanobeam Cavities with High Q/V, Jonathan Yiho Lee[1], Xiyuan Lu[1], Qiang Lin[1]; [1]*Univ. of Rochester, USA.* We demonstrate photonic-crystal nanobeam cavities in amorphous SiC. The fundamental mode exhibits intrinsic-Q of 7.69×10^4 with mode volume of $\sim0.60(\lambda/n)^3$. This is, to the best of our knowledge, the highest Q/V value in SiC cavities.

SF1H.3 • 08:30
Monolithic Single Crystal Diamond High-Q Optical Microcavities, Matthew Mitchell[1,2], Behzad Khanaliloo[1,2], Aaron Hryciw[2,3], Paul E. Barclay[1,2]; [1]*Inst. for Quantum Science & Technology, Canada;* [2]*NRC-National Inst. for Nanotechnology, Canada;* [3]*nanoFAB, Univ. of Alberta, Canada.* Monolithic whispering gallery mode (WGM) optical microcavities are fabricated from bulk single crystal diamond (SCD) via a scalable process. Optical quality factors of $Q_i \sim 1.15 \times 10^5$ at 1.5 μm are demonstrated.

08:00–10:00
SF1I • Lasers for Optical Communications
Presider: To be Determined

SF1I.1 • 08:00
Tunable Parity-Time-Symmetric Microring Lasers, Hossein Hodaei[1], William Hayenga[1], Mohammad-Ali Miri[1], Absar Ulhassan[1], Demetrios N. Christodoulides[1], Mercedeh Khajavikhan[1]; [1]*Univ. of Central Florida, CREOL, USA.* Wavelength tuning in a single mode parity-time (PT) symmetric semiconductor microring laser is demonstrated. Stable continuous tuning over a spectral range of 4 nm has been obtained at telecom wavelengths by adjusting the ambient temperature.

SF1I.2 • 08:15
Widely-tunable narrow-linewidth lasers with monolithically integrated external cavity, Tin Komljenovic[1], Sudharsanan Srinivasan[1], Michael Davenport[1], Erik Norberg[2], Greg Fish[2], John Bowers[1]; [1]*UCSB, USA;* [2]*Aurrion Inc, USA.* We demonstrate preliminary results from a monolithically integrated tunable laser with narrow-linewidth. We show tuning in excess of 54 nm in the O-band as well as significant reduction in linewidth due to the external cavity. The measured linewidth, limited by measurement setup, is around 150 kHz.

SF1I.3 • 08:30
Continuously Tunable Laser Based on Multiple-Section DFB Laser Technology for 1.25 Gbps WDM-PON Applications, Dion McIntosh-Dorsey[1], Rajesh Bikky[1], Huanlin Zhang[1], K. Alex Anselm[1], Justin Lii[1], Hsiu-Che Wang[1], Hao-Hsiang Liao[1], I Lung Ho[1], Hang Xie[1], Lingjun Bo[1], Patrick Lorenzo[1], Yi Wang[1], Jun Zheng[1]; [1]*Applied Optoelectronics Inc, USA.* A low-cost continuously tunable laser based on multiple in-line DFB sections and thermal tuning is demonstrated. It is capable of 16 channel tuning and 1.25 Gbps operation. Transceiver performance will also be shown.

08:00–10:00
AF1J • Measurement of Process Parameters
Presider: Robert Hickernell; NIST, USA

AF1J.1 • 08:00 Invited
Diode Laser Spectroscopy based Monitoring of Pharmaceutical Freeze Drying: Linking Measurements to Critical Process Parameters, William J. Kessler[1]; [1]*Physical Sciences Inc., USA.* Freeze drying is used to produce dry solid from a solution to improve product stabilization. We have applied absorption spectroscopy to monitor water sublimation rates and determine product temperature during drying, a critical process parameter.

AF1J.2 • 08:30
Real-time Full Characterization of Colloidal Dynamics, Jose R. Guzman-Sepulveda[1], Aristide Dogariu[1]; [1]*CREOL, College of Optics and Photonics, Univ. of Central Florida, USA.* We present an optical technique capable of measuring simultaneously hydrodynamic size and mass density of colloidal suspensions. The technique is fiber optic-based, non-invasive, and permits continuous online measurements over a broad range of colloidal parameters.

CLEO: Science & Innovations

08:00–09:15
SF1K • Flexgrid Networking
Presider: David Geisler; MIT Lincoln Lab, USA

SF1K.1 • 08:00 Invited
High Speed and Flexible Optical Transport Network, Tiejun J. Xia[1], Glenn A. Wellbrock[1]; [1]*Verizon Communications Inc, USA.* Optical network operators have been focused on increasing channel speeds and fiber capacities to meet high data traffic demand growth in past decades. Network efficiency improvement with flexible optics will be network operators' next focus.

SF1K.2 • 08:30 Invited
Experimental Demonstration of 3D Elastic Optical Networking in Space, Time and Frequency, Chuan Qin[1], Binbin Guan[1], Ryan P. Scott[1], Roberto Proietti[1], Nicolas K. Fontaine[2], S.J.B. Yoo[1]; [1]*Univ. of California Davis, USA;* [2]*Bell Labs, USA.* We demonstrate elasticity in time, frequency and space domains for an optical link at 960-Gb/s with 6.4-b/s/Hz spectral efficiency. Modulation format and number of spatial modes are selected based on Shannon's Law and crosstalk-dependent impairments.

08:00–10:00
SF1L • Frequency Standards and Timing
Presider: Kristan Corwin; Kansas State Univ., USA

SF1L.1 • 08:00 Invited
Frequency comparisons of Sr, Yb, and Hg based optical lattice clocks and their applications, Hidetoshi Katori[1,2]; [1]*Univ. of Tokyo, Japan;* [2]*Quantum Metrology Lab, RIKEN, Japan.* We report recent progress of optical lattice clocks with strontium, ytterbium and mercury atoms with an emphasis on their synchronous frequency comparison inside a Lab and inter-Labs connected by a phase-stabilized fiber link.

SF1L.2 • 08:30
Broadband Phase Noise Limit in the Direct Detection of Ultralow Jitter Optical Pulses, Franklyn Quinlan[1], Wenlu Sun[2], Tara M. Fortier[1], Jean-Daniel Deschenes[1], Yang Fu[2], Joe C. Campbell[2], Scott Diddams[1]; [1]*NIST, USA;* [2]*Dept. of Electrical and Computer Engineering, Univ. of Virginia, USA.* The lowest measured phase noise floors of photonically generated microwave signals are orders-of-magnitude above the quantum limit. We show this discrepancy is likely due to photocarrier scattering in high speed, high linearity photodetectors.

08:00–10:00
SF1M • Symposium on OPA/OPCPA – Next Generation of Ultra-Short Pulse Laser Technology I
Presider: Albert Stolow; National Research Council Canada, Canada

SF1M.1 • 08:00 Invited
High Energy and Power Optical Waveform Synthesizers, Franz X. Kaertner[2,1]; [1]*MIT, USA;* [2]*Center for Free-Electron Laser Science, Deutsches Elektronen Synchrotron, Germany.* We report on recent progress in high-energy optical waveform synthesis with optical parametric amplifiers pumped by high-energy Ti:Sapphire and Yb-based lasers delivering more than 2-octave spanning sub-cycle waveforms with multi-mJ energy.

SF1M.2 • 08:30 Invited
Third-generation femtosecond technology, Hanieh Fattahi[1], Nicholas E. Karpowicz[1], Thomas Metzger[2], zsuzsanna Major[1], Ferenc Krausz[1]; [1]*Max-Planck-Institut fur Quantenoptik, Germany;* [2]*TRUMPF Scientific Lasers, Germany.* The design of a 3-channel OPCPA system, generating ultrashort pulses with terawatt peak and sub-kilowatt average powers is presented. Coherent synthesis of the channels is predicted to produce intense, sub-cycle transients, presenting a route toward keV attosecond pulses.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FF1A • Quantum Key Distribution—Continued

FF1A.3 • 08:45
Multi-Photon Quantum Key Distribution Based on Double-Lock Encryption, Kam Wai C. Chan[1], Mayssaa El Rifai[1], Pramode Verma[1], Subhash Kak[2], Yuhua Chen[3]; [1]*School of Electrical and Computer Engineering, Univ. of Oklahoma-Tulsa, USA;* [2]*School of Electrical and Computer Engineering, Oklahoma State Univ., USA;* [3]*Dept. of Electrical and Computer Engineering, Univ. of Houston, USA*. We present a quantum key distribution protocol based on the double-lock cryptography. It exploits the asymmetry in the detection strategies between the legitimate users and the eavesdropper. With coherent states, the mean photon number can be as larger as 10.

FF1A.4 • 09:00
Quantum Teleportation over 100 km of Fiber using MoSi Superconducting Nanowire Single-Photon Detectors, Hiroki Takesue[1], Shellee D. Dyer[2], Martin J. Stevens[2], Varun Verma[2], Richard P. Mirin[2], Sae Woo Nam[2]; [1]*NTT Basic Research Labs, Japan;* [2]*National Inst. of Standards and Technology, USA*. Using high-efficiency superconducting nanowire single-photon detectors based on MoSi, we successfully achieved quantum teleportation of weak coherent states over 100 km of fiber with an average fidelity of 82.9% for six distinct input states.

FF1A.5 • 09:15
Polarization Insensitive 100 MHz Clock Subcarrier Quantum Key Distribution over a 45 dB Loss Optical Fiber Channel, Artur V. Gleim[1], Vladimir Egorov[1], Yuri V. Nazarov[1], Semen V. Smirnov[1], Vladimir V. Chistyakov[1], Oleg I. Bannik[1], Andrey A. Anisimov[1], Sergei M. Kynev[1], Robert J. Collins[2], Sergei A. Kozlov[1], Gerald S. Buller[2]; [1]*Dept. of Photonics and Optical Information Technology, ITMO Univ., Russia;* [2]*Inst. of Photonics and Quantum Sciences, Heriot-Watt Univ., UK*. We experimentally demonstrate quantum key distribution at 28 bit/s rate in a telecommunications fiber channel with 45 dB loss using a subcarrier wave approach. This approach offers polarization independency, high bitrates and wide multiplexing capabilities.

FF1B • Quantum Optics with Quantum Dots—Continued

FF1B.4 • 08:45
Coherent Writing of the Dark Exciton State Using One Picosecond Long Optical Pulse, Ido Schwartz[1], Dan Cogan[1], Emma R. Schmidgall[1], Liron Gantz[1], Yaroslav Don[1], David Gershoni[1]; [1]*Physics, Technion, Israel*. We demonstrate a one to one correspondence between the polarization of a picosecond optical pulse and the coherent spin state of the long lived dark exciton that it deterministically photogenerates in a single quantum dot .

FF1B.5 • 09:00
Single Emitter Vacuum Rabi Splitting Measured Through Direct Free Space Spontaneous Emission, Yasutomo Ota[1], Ryuichi Ohta[2], Naoto Kumagai[1], Satoshi Iwamoto[1,2], Yasuhiko Arakawa[1,2]; [1]*Nanoquine, Univ. of Tokyo, Japan;* [2]*IIS, The Univ. of Tokyo, Japan.* We measured the vacuum Rabi splitting of a single quantum emitter through direct free space spontaneous emission. This lays the groundwork for accessing diverse cavity quantum electrodynamics phenomena manifesting themselves only in the spontaneous emission.

FF1B.6 • 09:15
Two-Photon Spectrum of the Light Scattered by a Quantum Dot, Manoj Peiris[1], Ben Petrak[1], kumarasiri konthasinghe[1], Ying yu[2], Zhichuan Niu[2], Andreas muller[1]; [1]*Univ. of South Florida, USA;* [2]*Chinese Academy of Sciences, China*. We report the measurement of the two-photon spectrum of the light scattered by a single InAs quantum dot interacting with a strong near-resonant monochromatic laser.

FF1C • Nanophotonics and Photonic Crystals—Continued

FF1C.2 • 09:00
Circularly Polarized Light Emission of Quantum Dots at the Band Edge of Three-Dimensional Chiral Photonic Crystals, Shun Takahashi[1], Takeyoshi Tajiri[1], Yasutomo Ota[1], Jun Tatebayashi[1], Satoshi Iwamoto[1], Yasuhiko Arakawa[1]; [1]*Univ. of Tokyo, Japan*. We demonstrate highly circularly polarized emission from quantum dots in semiconductor chiral photonic crystals. The emission is influenced by the difference in density of states between the orthogonal circular polarizations at the polarization band edge.

FF1C.3 • 09:15
Enhanced Transverse Photo-Induced Voltage by Slow Light, Nicholas Proscia[1,2], Ilona Ketzschmar[2], Ronald Koder[2], Vinod M. Menon[2], Luat T. Vuong[1]; [1]*Queens College-CUNY, USA;* [2]*Physics, City College of New York-CUNY, USA*. We demonstrate the presence of spin-polarized transverse voltage in a metal-dielectric two-dimensional photonic crystal in the visible regime and determine that the presence of slow light at the photonic band edge leads to voltage enhancement.

SF1D • Nonlinear Optics Frequency Conversion with Integrated Optical Devices—Continued

SF1D.3 • 08:45
Generation of Mid-IR Radiation by Four-Wave Mixing in Metal Coated Waveguides, Tobias Flöry[1], Pavel Malevich[1], Audrius Pugzlys[1], Aleksander Voronin[2], Aleksei Zheltikov[2,3], Andrius Baltuska[1]; [1]*Photonics Inst., TU Vienna, Austria;* [2]*Physics Dept., International Laser Center, M.V. Lomonosov Moscow State Univ., Russia;* [3]*Dept. of Physics and Astronomy, Texas A&M Univ., USA*. 2.7-μm microjoule femtosecond pulses are generated in a metal coated hollow fiber thru four-wave-mixing parametric amplification. Numerical simulations predict generation of few-cycle optical pulses with the central wavelength extending beyond 10 μm.

SF1D.4 • 09:00
Signal Gain from Four-Wave Mixing in Anomalous AlGaAs nanowaveguides, Pisek Kultavewuti[1], Vincenzo Pusino[2], Marc Sorel[2], J. Stewart Aitchison[1]; [1]*Dept. of Electrical and Computer Engineering, Univ. of Toronto, Canada;* [2]*School of Engineering, Univ. of Glasgow, UK*. We experimentally demonstrate efficient four-wave mixing with a net signal gain of 4.1 dB and a conversion efficiency of 5.3 dB in low-loss AlGaAs nanowaveguides in an anomalous dispersion regime.

SF1D.5 • 09:15
Low-Noise Silicon Mid-Infrared Frequency Comb, Austin G. Griffith[1], Yoshitomo Okawachi[1], Jaime Cardenas[1], Alexander L. Gaeta[1], Michal Lipson[1]; [1]*Cornell Univ., USA*. We demonstrate low-noise mid-infrared frequency comb generation using a silicon microresonator. Using an integrated PIN-diode detector, we show a transition to a low RF-amplitude-noise state consistent with demonstrations of phase-locking in other microresonator platforms.

CLEO: Applications & Technology

CLEO: Science & Innovations

AF1E • A&T Topical Review - High Performance Optics I—Continued

SF1F • Solid State Lasers—Continued

SF1G • Novel Devices—Continued

SF1F.4 • 08:45
Design and Development of a High-Power LED-Pumped Ce:Nd:YAG Laser, Brenden Villars[1], E. S. Hill[1], Charles G. Durfee[1]; [1]*Colorado School of Mines, USA*. Our quasi-continuous wave Ce:Nd:YAG solid-state laser was directly pumped by LED arrays, yielding a maximum of 8mJ/pulse. Comparison of pumping at 460nm and 810nm allows analysis of the performance and potential of this laser system.

SF1G.3 • 08:45
Inhibited Coupling Kagome Fibers with Ultra-large Hollow-core Size for High Energy Ultrafast Laser Applications, Benoît Debord[1], Abhilash Amsanpally[1], Meshaal Alharbi[1], Luca Vincetti[2], Jean-Marc Blondy[1], Frédéric Gérôme[1,3], Fetah Benabid[1,3]; [1]*GPPMM group, Xlim Research Inst., UMR CNRS 7252, Univ. of Limoges, France, France;* [2]*Dept. of Engineering "Enzo Ferrari", Univ. of Modena and Reggio Emilia, I-41125 Modena Italy, Italy;* [3]*GLOphotonics S.A.S, France*. We report on enlarged hollow-core diameter inhibited coupling Kagome fibers with record loss of 100 dB/km and ppm power overlap with silica surround, suitable for high energy ultrafast laser handling.

AF1E.3 • 09:00
Ultra-broadband Spectral Beam Combiner, Eric Stanton[1], Martijn J. Heck[1], Jock Bovington[1], Alexander Spott[1], John Bowers[1]; [1]*Univ. of California Santa Barbara, USA*. A novel ultra-broadband spectral beam combiner is designed and demonstrated spanning greater than four octaves from ultraviolet to mid-wave infrared bands with low M squared output.

SF1F.5 • 09:00
Compact, Passively Q-Switched 523-nm Laser, Bhabana Pati[1], Eric D. Park[1], Ken Stebbins[1]; [1]*Q-Peak, Inc., USA*. We have developed a compact, passively Q-switched, intra-cavity frequency doubled Nd:YLF laser that produces 1-mJ of energy in a 10-ns pulse at a 1-20 Hz repetition rate.

SF1G.4 • 09:00
Electro-optic effect in silicon nitride, Steven Miller[1], Yoon Ho Daniel Lee[1], Jaime Cardenas[1], Alexander L. Gaeta[2,3], Michal Lipson[1,3]; [1]*School of Electrical and Computer Engineering, Cornell Univ., USA;* [2]*School of Applied and Engineering Physics, Cornell Univ., USA;* [3]*Kavli Inst. at Cornell for Nanoscale Science, Cornell Univ., USA*. We present the first demonstration of the electro-optic effect in Si_3N_4 by using a multi-slot waveguide structure. We measure the maximum EO coefficient of 8.31±5.6fm/V, and demonstrate EO modulation at 1GHz.

AF1E.4 • 09:15
Mobility Enhancement of Graphene Nanoribbon by ALD HfO_2 and Its Optoelectronic Properties, Xuechao Yu[1], Qi Jie Wang[1,2]; [1]*OPTIMUS, Photonics Centre of Excellence, School of Electrical and Electronic Engineering, Nanyang Tech Univ, Singapore;* [2]*Centre for Disruptive Photonic Technologies, Nanyang Technological Univ., Singapore*. We demonstrated that depositing HfO_2 film on graphene nanoribbons greatly enhance the mobility through weakening the Coulombic interactions. As a result, the graphene nanoribbon photodetectors with HfO_2 layer exhibits high responsivity of ~2A/W at room temperature.

SF1F.6 • 09:15
Microchip Tm:KYW Laser with 2.5 W of Output Power, Maxim S. Gaponenko[1], Nikolai Kuleshov[2], Thomas Sudmeyer[1]; [1]*Université de Neuchâtel, Switzerland;* [2]*BNTU, Belarus*. Diode-pumped 1.9-um Tm:KYW microchip laser with 1.6 W TEM_{00} cw output power operates with 72% slope eff. to absorbed pump power. Output power of 2.5 W is achieved with generation of a "doughnut" mode. *Q*-switched operation with pulse duration of 2.2 ns at 1.5 MHz repetition rate is demonstrated.

SF1G.5 • 09:15
Suppression of Optical Damage in Electro-Optical Modulator Using Potassium Lithium Tantalate Niobate, Yossi Kabessa[1], Aharon J. Agranat[1]; [1]*HUJI, Israel*. Suppression of optical damage in a KLTN based electrooptical modulator operated with 30 W/cm^2 light beam at λ=445 nm is demonstrated. The modulator is driven by bipolar voltage which prevents the induced space-charge from accumulating.

Meeting Room 211 B/D

Meeting Room 212 A/C

Meeting Room 212 B/D

CLEO: Science & Innovations

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SF1H • Microcavities—Continued

SF1H.4 • 08:45
Optical Microresonators as Single-Molecule Spectrometers, Kevin H. Heylman[1], Kassandra Knapper[1], Erik H. Horak[1], Randall H. Goldsmith[1]; [1]*Univ. of Wisconsin Madison, USA.* A new approach is described for sensing and spectroscopy of single non-luminescent nano-objects which combines the spatial and spectral selectivity of laser microscopy with the tremendous sensitivity of ultrahigh-quality factor optical microresonators.

SF1H.5 • 09:00
Photocurrent-induced Peak-dragging in a Nanobeam Photonic Crystal Cavity, Majid Sodagar[1], Mehdi Miri[1], Ali Eftekhar[1], Ali Adibi[1]; [1]*Georgia Inst. of Technology, USA.* We demonstrate here the peak-dragging phenomenon in a nanobeam photonic crystal cavity with low optical power thresholds. In our device, Joule-heating mechanism enhances the absorption-induced heat by collecting the generated photocarries in a reverse-biased pn-junction.

SF1H.6 • 09:15
Free-Space Read-Out of WGM Lasers Using Circular Micromirrors, Tobias Wienhold[1], Sarah Kraemmer[3], Andreas Bacher[1], Heinz Kalt[3], Christian Koos[1,4], Sebastian Koeber[1,4], Timo Mappes[1,2]; [1]*Inst. of Microstructure Technology (IMT), Karlsruhe Inst. of Technology (KIT), Germany;* [2]*Corporate Research and Technology, Carl Zeiss AG, Germany;* [3]*Inst. of Applied Physics (APH), Karlsruhe Inst. of Technology (KIT), Germany;* [4]*Inst. of Photonics and Quantum Electronics (IPQ), Karlsruhe Inst. of Technology (KIT), Germany.* We report on efficient free-space read-out of whispering-gallery mode microlasers using circular micromirrors. A ten-fold improvement in detection efficiency can be achieved by directing emission from all azimuthal angles of the cavity to the detector.

SF1I • Lasers for Optical Communications—Continued

SF1I.4 • 08:45
All-Optical Carrier Recovery Using a Single Injection Locked Semiconductor Laser Stabilized by an Incoherent Optical-Feedback, Aaron Albores-Mejia[1], Toshimitsu Kaneko[2], Eiichi Banno[2], Katsumi Uesaka[2], Hajime Shoji[2], Haruhiho Kuwatsuka[1]; [1]*National Inst. of AIST, USA;* [2]*Sumitomo Electric Industries, Ltd, Japan.* Novel all-optical-hardware-efficient carrier recovery unit for carrier-suppressed BPSK signals is demonstrated. For the first time, carrier recovery with an optically stabilised injection-locked semiconductor laser enabled successful homodyne detection of 32-Gbit/s carrier-suppressed BPSK signals.

SF1I.5 • 09:00
Double Half-Wave-Coupled Rectangular Ring-FP Semiconductor Laser with 19-nm Quasi-Continuous Tuning Range, Mengtian Sun[1], Lin Wu[1], Xiaohai Xiong[1], Xiaolu Liao[1], Jian-Jun He[1]; [1]*Dept. of Optical Engineering, Zhejiang Univ., China.* We present our latest experimental results of the double half-wave-coupled rectangular ring-FP laser in a XMD TOSA package. A 19-nm quasi-continuous tuning range with over 30dB side mode suppression ratio is obtained.

SF1I.6 • 09:15
Effect of microcavity size to the RIN and 40 Gb/s data transmission performance of high speed VCSELs, Fei Tan[1], Mong-Kai Wu[1], Curtis Wang[1], Michael Liu[1], Milton Feng[1], Nick Holonyak[1]; [1]*Dept. of Electrical and Computer Engineering, Univ. of Illinois at Urbana-Champaign, USA.* We demonstrated that larger aperture VCSELs have better performance in 40Gb/s error free data transmission, and smaller aperture VCSELs have lower laser RIN. Medium aperture VCSELs may excel in high fidelity and high speed applications.

AF1J • Measurement of Process Parameters—Continued

AF1J.3 • 08:45
Indentation hardness and scratch tests for thin layers manufactured by sol-gel process, Hervé Piombini[1], Christel Ambard[1], François Compoint[1], Karine Valle[1], Philippe Belleville[1], Clément Sanchez[2]; [1]*CEA Le Ripault, France;* [2]*Collège de France, France.* We introduce our first tests to characterize the mechanical properties of elastic layer manufactured by sol-gel process obtained with an indenter designed from a microscope. They are performed with a microscope and a diamond tip

AF1J.4 • 09:00
Fiber-optic SERS detection enabled by light-induced gold nano-particle aggregation, Haitao Liu[1], Jiansheng Liu[1], Luoyang Chen[1], Hongwen Zhou[1], Zheng Zheng[1,2]; [1]*School of Electronic and Information Engineering, Beihang Univ., China;* [2]*Collaborative Innovation Center of Geospatial Technology, China.* We demonstrated a SERS detection scheme where fiber-optic light-induced aggregation of gold nano-particles enhances the Raman signal by 30-fold over the non-aggregation case, even by exciting and collecting light through low-cost, standard silica fibers.

AF1J.5 • 09:15
Picometer-Scale Surface Roughness Measurements Inside Hollow Glass Fibres, Xavier Buet[1,2], Coralie Brun[1,3], Bruno Bresson[1], Matteo Ciccotti[1], Marco Petrovitch[4], Francesco Poletti[4], david Richardson[4], Damien Vandembroucq[1], Gilles Tessier[1]; [1]*ESPCI, USA;* [2]*Neurophotonics Lab, France;* [3]*Institut langevin, France;* [4]*orc, UK.* A differential optical profilometry technique with picometre-range sensitivity is adapted to the non invasive measurement of the roughness inside hollow glass fibres by use of immersion objectives and index-matching liquid.

CLEO: Science & Innovations

SF1K • Flexgrid Networking—Continued

SF1K.3 • 09:00
Wavelength Conflict Resolution by Spectral Overlap of Two Nyquist-WDM Signals, Lingchen Huang[1], Shuang Gao[2], Chun-Kit Chan[2]; [1]*Center for Optical and Electromagnetic Research, Zhejiang Univ., China;* [2]*Dept. of Information Engineering, The Chinese Univ. of Hong Kong, China.* Two Nyquist-WDM signals are spectrally overlapped to resolve the possible wavelength conflict in network routing. Recovery of individual signals is realized by digital signal processing techniques and has been experimentally demonstrated and characterized.

SF1L • Frequency Standards and Timing—Continued

SF1L.3 • 08:45
Electro-optical frequency division and stable microwave synthesis, Xu Yi[1], Jiang Li[1], Hansuek Lee[1], Scott Diddams[1,2], Kerry Vahala[1]; [1]*California Inst. of Technology, USA;* [2]*National Inst. of Standard and Technology, USA.* Optical frequency division and stable microwave generation is demonstrated using an electro-optical-based frequency comb created through phase modulation of two stable optical signals. The technique is simple, tunable and scalable to higher division ratios.

SF1L.4 • 09:00
Attosecond-Resolution Timing Jitter Spectrum Measurement of Free-Running Mode-Locked Lasers Over 10 Decades of Fourier Frequency, Kwangyun Jung[1], Jungwon Kim[1]; [1]*Korea Advanced Inst of Science & Tech, Korea.* We show timing jitter spectrum measurement of free-running mode-locked lasers from 1-mHz to 40-MHz Fourier frequency. The demonstrated method can resolve different noise mechanisms that cause specific jitter characteristics from <100-ns to >1000-s time scales.

SF1L.5 • 09:15
Attosecond Timing Jitter Characterization of Mode-locked Lasers Using Optical Heterodyne Techniques, Dong Hou[1], Chien-Chung Lee[1], Zhengyin Yang[1], Kevin Silverman[2], Ari Feldman[2], Todd Harvey[2], Richard P. Mirin[2], Thomas R. Schibli[1]; [1]*Univ. of Colorado Boulder, USA;* [2]*National Inst. of Standards and Technology, USA.* We demonstrate timing jitter characterization of mode-locked lasers with attosecond-resolution using optical heterodyne techniques. The measured integrated jitter for a free-running mode-locked Er:Yb:glass laser was found below 20 as from 10 kHz to 5 MHz.

SF1M • Symposium - OPA/OPCPA - Next Generation of Ultra-Short Pulse Laser Technology I—Continued

SF1M.3 • 09:00
Sub-Two-Cycle Millijoule Optical Pulses at 1600 nm from a BiB_3O_6 Optical Parametric Chirped-Pulse Amplifier, Nobuhisa Ishii[1], Keisuke Kaneshima[1], Teruto Kanai[1], Shuntaro Watanabe[2], Jiro Itatani[1]; [1]*Inst. for Solid State Physics, Japan;* [2]*Tokyo Univ. of Science, Japan.* We report on the generation of 10.1-fs, 1.5-mJ pulses at 1 kHz from a BiB_3O_6 OPCPA with passive CEP stabilization. This light source is promising for the generation of high-flux isolated soft x-ray pulses.

SF1M.4 • 09:15
High-Energy Infrared Femtosecond Pulses by Dual-Chirped Optical Parametric Amplification, Yuxi FU[1], Eiji J. Takahashi[1], Katsumi Midorikawa[1]; [1]*Attosecond Science Research Team, RIKEN Center for Advanced Photonics, RIKEN, Japan.* A total output energy exceeding 30 mJ has been achieved in the infrared region by dual-chirped optical parametric amplifier for generating soft x-ray harmonic pulses. Obtained spectrum supports a pulse duration shorter than 40 fs.

CLEO: QELS-Fundamental Science

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FF1A • Quantum Key Distribution—Continued

FF1A.6 • 09:30
Integrated Photonic Devices for Quantum Key Distribution, Philip Sibson[1], Mark Godfrey[1], Chris Erven[1], Shigehito Miki[2], Taro Yamashita[2], Mikio Fujiwara[2], Masahide Sasaki[2], Hirotaka Terai[2], Michael G. Tanner[3], Chandra M. Natarajan[3], Robert H. Hadfield[3], Jeremy O'Brien[1], Mark G. Thompson[1]; *[1]Univ. of Bristol, UK; [2]National Inst. of Information and Communications Technology, Japan; [3]Univ. of Glasgow, UK*. We demonstrate a fully integrated photonic transmitter for time-bin based multi-protocol quantum key distribution. This GHz rate Indium Phosphide device prepares states for Coherent One Way (COW), Differential Phase Shift (DPS), and BB84 protocols.

FF1A.7 • 09:45
Quantum hacking of continuous-variable quantum key distribution systems: real-time Trojan-horse attacks, Birgit Stiller[1,2], Imran Khan[1,2], Nitin Jain[1,2], Paul Jouguet[3], Sebastien Kunz-Jacques[3], Eleni Diamanti[4], Christoph Marquardt[1,2], Gerd Leuchs[1,2]; *[1]Max-Planck-Institut for the Science of Light, Germany; [2]Inst. for Optics, Information and Photonics, Germany; [3]SeQureNet, France; [4]LTCI, CNRS - Telecom ParisTech, France*. We experimentally demonstrate successful Trojan-horse attacks on Lab and commercial continuous-variable quantum key distribution systems with binary and Gaussian modulation. Furthermore, we analyze appropriate countermeasures regarding their spectral performance.

FF1B • Quantum Optics with Quantum Dots—Continued

FF1B.7 • 09:30
Withdrawn

FF1B.8 • 09:45
Withdrawn

FF1C • Nanophotonics and Photonic Crystals—Continued

FF1C.4 • 09:30
Region Specific Enhancement of Quantum Dot Emission Using Interleaved Two-dimensional Photonic Crystals, Gloria G. See[1], Lu Xu[1], Matt Naughton[1], Tiantian Tang[1], Yolanda Bonita[1], Jake Joo[2], Peter Trefonas[2], Kishori Deshpande[3], Paul Kenis[1], Ralph G. Nuzzo[1], Brian T. Cunningham[1]; *[1]Univ of Illinois at Urbana-Champaign, USA; [2]Dow Electronic Materials Company, USA; [3]The Dow Chemical Company, USA*. A photonic crystal (PC) incorporating two interleaved regions, each with distinct periods in orthogonal directions, enables simultaneous resonant coupling of ultraviolet excitation photons to quantum dots and visible emission for up to 5.8X enhancement of photon extraction for multiple types of QDs.

FF1C.5 • 09:45
GaN L3 Photonic Crystal Cavities With an Average Quality Factor in Excess of 16000 in the Near Infrared, Noelia Vico Triviño[1], Momchil Minkov[1], Giulia Urbinati[2], Matteo Galli[2], Jean-François Carlin[1], Raphael Butte[1], Vincenzo Savona[1], Nicolas Grandjean[1]; *[1]Ecole Polytechnique Federale de Lausanne, Switzerland; [2]Universita di Pavia, Italy.* GaN L3 photonic crystal cavities were fabricated based on a genetic algorithm optimization. Optical characterization of several replicas led to an average unloaded quality factor of 16900, which is well accounted for by first-principles simulations.

SF1D • Nonlinear Optics Frequency Conversion with Integrated Optical Devices—Continued

SF1D.6 • 09:30
Mode-Locked and Repetition-Rate-Tunable Comb Generation Using Dual Coupled Microrings, Xiaoxiao Xue[1], Yi Xuan[1,2], Pei-Hsun Wang[1], Yang Liu[1], Daniel E. Leaird[1], Minghao Qi[1,2], Andrew M. Weiner[1,2]; *[1]School of Electrical and Computer Engineering, Purdue Univ., USA; [2]Birck Nanotechnology Center, Purdue Univ., USA*. A method incorporating controllable mode interaction is proposed for Kerr frequency comb generation in normal-dispersion microresonators. Repetition-rate-tunable combs and broadband mode-locking transitions are demonstrated by using dual silicon nitride microrings.

SF1D.7 • 09:45
Parametric Frequency Conversion in Silicon Carbide Waveguides, Jaime Cardenas[1], Steven Miller[1], Yoshitomo Okawachi[1], Sven Ramelow[1], Austin G. Griffith[1], Alessandro Farsi[1], Alexander L. Gaeta[1,2], Michal Lipson[1,2]; *[1]Cornell Univ., USA; [2]Kavli Inst. at Cornell for Nanoscale Science, USA*. We show the first demonstration of frequency conversion via four wave mixing in a silicon carbide channel waveguide with a conversion efficiency as high as -19.5 dB over a 180 nm wavelength range.

10:00–10:30 Coffee Break, *Concourse Level*

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AF1E • A&T Topical Review on High Performance Optics I—Continued

AF1E.5 • 09:30
Selective Lasing and Nonlinear Relaxation of Confined Exciton-Polaritons, Gabriele Grosso[1,2], Stéphane Trebaol[1,3], Michiel Wouters[4], François Morier-Genoud[1], Marcia Portella Oberli[1], Benoît Deveaud[1]; *[1]ICMP, Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland; [2]EECS, MIT, USA; [3]UMR Foton, Université de Rennes, France; [4]TQC, Univ. of Antwerp, Belgium.* We detail an innovative laser device based on a new relaxation mechanism for confined exciton-polaritons which preserves nonlinearity. We demonstrate the selective activation of polariton lasers at different wavelengths allowing to perform all-optical logic operations with fully coherent output.

AF1E.6 • 09:45
All-Optical Tunable Multilevel Amplitude Regeneration Based on Coherent Polarization Mixing, Zahra Bakhtiari[1], Alexander Sawchuk[1]; *[1]USC, USA*. We propose an all-optical phase-preserving scheme for multilevel amplitude regeneration based on coherent polarization mixing for optical star-8QAM/star-16QAM signals with a power ratio of 1:5. A regeneration factor of 5.3 for star 8-QAM is achieved.

SF1F • Solid State Lasers—Continued

SF1F.7 • 09:30
Synchronously Pumped Mid-IR Hollow Core Fiber Gas Laser, Muhammad Rosdi Abu Hassan[1], Fei Yu[1], Zefeng Wang[1,2], Walter Belardi[1], William Wadsworth[1], Jonathan Knight[1]; *[1]Dept. of Physics, Centre for Photonics and Photonic Materials, Univ. of Bath, UK; [2]College of Optoelectronic Science and Engineering, National Univ. of Defense Technology, China.* We report a synchronously pumped 3.16 μm acetylene fiber laser based entirely on low-loss silica hollow-core fiber. Our system oscillates at 2.568 MHz repetition rate, when pumped with a modulated amplified 1.53 μm diode laser.

SF1F.8 • 09:45
Single-frequency crystalline Raman amplifier at 1178 nm, Zhaojun Liu[1], Zhenhua Cong[1], Sasa Zhang[1], Shaojie Men[1], Yang Liu[1], Jinbao Xia[1], Wenyong Cheng[1], Yongfu Li[1], Chaoyang Tu[2], Xingyu Zhang[1]; *[1]Shandong Univ., China; [2]Fujian Inst. of Research on the Structure of Matter, Chinese Academy of Sciences, China.* Single-frequency crystalline Raman amplifier at 1178 nm was demonstrated. After three stages of amplifications, the output pulse energy was 26.7 mJ and the pulse width was 2.9 ns. The linewidth was less than 500 MHz.

SF1G • Novel Devices—Continued

SF1G.6 • 09:30
Graphene-Based Saturable Absorber for Passive Q-switching of Tm:KLu(WO_4)$_2$ Microchip Laser, Xavier Mateos[1], Josep Maria Serres[1], Pavel Loiko[2,1], Konstantin Yumashev[2], Valentin Petrov[3], Uwe Griebner[3], Magdalena Aguilo[1], Francesc Diaz[1]; *[1]Universitat Rovira i Virgili, Spain; [2]Center for Optical Materials and Technologies, Belarusian National Technical Univ., Belarus; [3]Max Born Inst., Germany.* A diode-pumped Q-switched Tm:KLu(WO_4)$_2$ microchip laser generated a maximum average output power of 310 mW with $M^2 < 1.2$ at 1947 nm. The shortest pulse duration was 285 ns at a pulse repetition rate of 190 kHz.

SF1G.7 • 09:45
A ZnO/InN/GaN Heterojunction Photodetector with Extended Infrared Response, Lung-Hsing Hsu[1], Shun-Chieh Hsu[2], Hsin-Ying Lee[3], Yu-Lin Tsai[4], Da-Wei Lin[4], Hao-Chung Kuo[4], Yi-Chia Hwang[2], Yin-Han Chen[2], Jr-Hau He[5], Yuh-Jen Cheng[6], Shih-Yen Lin[6], Chien-Chung Lin[2]; *[1]Inst. of Lighting and Energy Photonics, National Chiao Tung Univ., Taiwan; [2]Inst. of Photonic System, National Chiao Tung Univ., Taiwan; [3]Dept. of Photonics, National Cheng Kung Univ., Taiwan; [4]Inst. of Electro-Optical Engineering, National Chiao Tung Univ., Taiwan; [5]Inst. of Photonics and Optoelectronics, National Taiwan Univ., Taiwan; [6]Research Center for Applied Sciences, Academia Sinica, Taiwan*. An extended infrared photoresponse is observed in a ZnO/InN/GaN heterojunction diode with InN grown by MOCVD. The external quantum efficiency is measured between 1200 and 1800 nm and can be as high as 3.55%.

10:00–10:30 Coffee Break, *Concourse Level*

Meeting Room 211 B/D	Meeting Room 212 A/C	Meeting Room 212 B/D
CLEO: Science & Innovations		CLEO: Applications & Technology

SF1H • Microcavities—Continued

SF1H.7 • 09:30
Yb^{3+}-doped Silica WGM Milled Microrod laser, Shahab Bakhtiari Gorajoobi[1], Ganapathy Senthil Murugan[1], Michalis Zervas[1]; [1]*Optoelectronics Research Centre, Univ. of Southampton, UK.* A fast and versatile fabrication method for high Q milled microrod resonators, directly on rare-earth doped fibers, is demonstrated using a pulsed CO_2 laser. Evanescently pumped WGM microlaser with ~9μW output power has been achieved.

SF1H.8 • 09:45
Demonstration of the first monolithically integrated self-rolled-up tube based vertical photonic coupler, Xin Yu[1], Ehsan Arbabi[1,2], Xiuling Li[1], Lynford L. Goddard[1], Xiaogang Chen[1]; [1]*Univ of Illinois at Urbana-Champaign, USA;* [2]*California Inst. of Technology, USA.* We demonstrated the first monolithically integrated self-rolled-up SiN_x tube based vertical photonic coupler on top of a planar ridge waveguide. The coupling efficiency between the elements is >10 times higher than similar non-integrated device.

SF1I • Lasers for Optical Communications—Continued

SF1I.7 • 09:30
Millimeter-wave Modulation of 850 nm VCSELs for Radio over Fiber Applications, Hamed Dalir[1], Fumio Koyama[1]; [1]*Electronics and Applied Physics, Tokyo Inst. of Technology, Japan.* A slow-light modulator-integrated with 850nm-VCSEL is presented, exhibiting small signal response of over 55dB enhancement at frequencies beyond 35GHz. Also, the direct modulation bandwidth is expanded beyond 20GHz thanks to optical-feedback in the integrated device.

SF1I.8 • 09:45
Microwave Signal Generation Using a 1550 nm VCSEL Subject to Dual-Beam Orthogonal Optical Injection, Pablo Pérez[1,2], Ana Quirce[3], Angel Valle[1], Luis Pesquera[1], Antonio Consoli[4], Ignacio Esquivias[5]; [1]*Instituto de Física de Cantabria (CSIC-UC), Spain;* [2]*Departamento de Física Moderna, Universidad de Cantabria, Spain;* [3]*Faculty of Engineering Sciences, Brussels Photonics Team, Vrije Universiteit Brussel, Belgium;* [4]*Instituto de Ciencia de Materiales de Madrid, CSIC, Spain;* [5]*Departamento de Tecnología Fotónica, Universidad Politécnica de Madrid, Spain.* We experimentally and theoretically investigate microwave signal generation using a 1550nm VCSEL subject to two-frequency orthogonal optical injection. It is found that microwave linewidth is given by the sum of the linewitdhs of the two master lasers.

AF1J • Measurement of Process Parameters—Continued

AF1J.6 • 09:30 Invited
Metrology for Quantum Communications, Christopher Chunnilall[1]; [1]*NPL, UK.* Industrial technologies based on single photons are emerging. We report on work to develop traceable metrology for the quantum optical devices used in quantum key distribution (QKD), one of the most commercially-advanced quantum technologies.

10:00–10:30 Coffee Break, *Concourse Level*

NOTES

CLEO: Science & Innovations

SF1L • Frequency Standards and Timing—Continued

SF1L.6 • 09:30
Fiber-based portable optical frequency standard for telecommunication, Marco Triches[1,2], Anders Brusch[1], Jan Hald[1], Jesper Lægsgaard[2], Ole Bang[2]; [1]*DFM A/S - Danish Fundamental Metrology Inst., Denmark;* [2]*Dept. of Photonics Engineering, Technical Universitiy of Denmark, Denmark.* Gas-filled hollow-core fiber-based *portable* optical frequency standard is developed for laser stabilization to the $^{13}C_2H_2$ transition at 1.5 μm using saturated absorption. The system, assembled in an *easy-to-use configuration*, has an Allan deviation $<8x10^{-11}$ ($1<\tau<1000$ s) with 60 kHz locking accuracy.

SF1L.7 • 09:45
Compact and robust laser system for precision atom interferometry based on a frequency doubled telecom fiber bench, Fabien Theron[1], Nassim Zahzam[1], Yannick Bidel[1], Malo Cadoret[1], Alexandre Bresson[1]; [1]*ONERA, France.* We present a compact and robust narrow linewidth laser system for onboard Rubidium atom interferometry using only one laser source based on a frequency doubled telecom fiber bench.

SF1M • Symposium on OPA/OPCPA – Next Generation of Ultra-Short Pulse Laser Technology I—Continued

SF1M.5 • 09:30
Improved Characteristics of High Repetition Rate Non-Collinear Optical Parametric Amplifiers for Electron-Ion Coincidence Spectroscopy, Federico J. Furch[1], Alexandria Anderson[1], Sascha Birkner[1], Yicheng Wang[1], Achut Giree[1,2], Claus Peter Schulz[1], Marc Vrakking[1]; [1]*Max Born Inst., Germany;* [2]*Amplitude Technologies, France.* A non-collinear optical parametric amplifier (NOPA) for applications in attosecond science is presented. The amplifier delivers carrier-envelope phase (CEP) stable few-cycle pulses at an average power of 5 W at 400 and 800 kHz.

SF1M.6 • 09:45
High-Power 300-kHz OPCPA System Generating CEP-Stable Few-Cycle Pulses, Marcel Schultze[1], Stephan Prinz[1,2], Matthias Haefner[1], Catherine Y. Teisset[1], Robert Bessing[1], Knut Michel[1], Thomas Metzger[1]; [1]*TRUMPF Scientific Lasers, Germany;* [2]*Dept. of Physics, Technische Universität München, Germany.* An OPCPA system with 15 W of average power at 300 kHz repetition rate generating CEP-stable few-cycle pulses is presented. The system exhibits pulse durations below 6 fs, a peak power of 4.5 GW and an excellent long-term performance over hours of operation with power fluctuations of less than 1.5%.

10:00–10:30 Coffee Break, *Concourse Level*

NOTES

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

10:30–12:30
FF2A • Single Photon Detectors
Presider: Jevon Longdell; Univ. of Otago, New Zealand

FF2A.1 • 10:30
Low-jitter single-photon detector arrays integrated with silicon and aluminum nitride photonic chips, Faraz Najafi[1], Jacob Mower[1], Nicholas C. Harris[1], Francesco Bellei[1], Andrew Dane[1], Catherine Lee[1], Xiaolong Hu[1], Sara Mouradian[1], Tim Schroder[1], Prashanta Kharel[2], Francesco Marsili[3], Solomon Assefa[4], Karl K. Berggren[1], Dirk R. Englund[1]; *[1]MIT, USA; [2]Columbia Univ., USA; [3]Jet Propulsion Lab, USA; [4]IBM TJ Watson Research Center, USA.* We present progress on a scalable scheme for integration of single-photon detectors with silicon and aluminum nitride photonic circuits. We assemble arrays of low-jitter waveguide-integrated single-photon detectors and show up to 24% system detection efficiency.

FF2A.2 • 10:45
Probing Number-Correlated States of up to 50 Photons, Georg Harder[1], Tim J. Bartley[2,1], Adriana Lita[2], Sae Woo Nam[2], Thomas Gerrits[2], Christine Silberhorn[1]; *[1]Applied Physics, Univ. of Paderborn, Germany; [2]National Inst. for Standard and Technology, USA.* Using spontaneous parametric down-conversion in ppKTP waveguides, we probe photon-number correlated states of up to 50 photons with a Klyshko efficiency of >60%, in a single mode characterised by an unheralded marginal $g^{(2)}(0)=1.87\pm0.05$.

FF2A.3 • 11:00
Saturated Photon Detection Efficiency in NbN Superconducting Photon Detectors, Ryan Murphy[1], Matthew Grein[1], Theodore Gudmundsen[1], Adam McCaughan[2], Faraz Najafi[2], Karl K. Berggren[2], Francesco Marsili[3], Eric Dauler[1]; *[1]MIT Lincoln Lab, USA; [2]Research Lab of Electronics, MIT, USA; [3]Jet Propulsion Lab, USA.* In this work, we demonstrate saturated photon detection efficiency with narrow NbN nanowires and SNAPs to boost the signal-to-noise ratio, and we demonstrate a stabilizing choke inductance that is part of the optically-active area.

10:30–12:30
FF2B • Quantum Nonlinear Optics
Presider: Michal Bajcsy; Univ. of Waterloo, Canada

FF2B.1 • 10:30 Invited
Giant Polarization Rotation Induced by a Single Spin: a Cavity-Based Spin-Photon Interface, Justin Demory[1], Christophe Arnold[1], Vivien Loo[1], Aristide Lemaître[1], Isabelle Sagnes[1], Mikhaïl Glazov[3], Olivier Krebs[1], Paul Voisin[1], Pascale Senellart[1], Loic Lanco[1,2]; *[1]LPN-CNRS, France; [2]Université Paris Diderot Paris 7, France; [3]Ioffe Physical-Technical Inst., Russia.* We report the amplification by three orders of magnitude of the spin-photon interaction, using a single hole spin in a quantum dot-pillar cavity system: a macroscopic and spin-dependant polarization rotation is induced on incident photons by a single spin, initialized either in the up or down state.

FF2B.2 • 11:00
Macroscopic Kerr Rotation from a Bright Negatively Charged Quantum Dot in a Low-Q Micropillar Cavity, Petros Androvitsaneas[1], Andrew Young[1], Christian Schneider[2], Sven Höfling[2,3], Martin Kamp[2], Edmund Harbord[1], John Rarity[1], Ruth Oulton[1]; *[1]Univ. of Bristol, UK; [2]Universitat Wurzburg, Germany; [3]Univ. of St. Andrews, UK.* We report the measurement of macroscopic phase shifts of several degrees for reflected incident light resonant with a bright negatively charged quantum dot (QD) in a micropillar structure of Q-factor less than 200.

10:30–12:30
FF2C • Near-field Imaging, Spectroscopy and Optomechanics
Presider: To be Determined

FF2C.1 • 10:30
High-Contrast Nanoparticle Sensing using a Hyperbolic Metamaterial, Wenqi Zhu[1], Ting Xu[1], Amit Agrawal[1], Henri J. Lezec[1]; *[1]NIST, USA, USA.* Using planar hyperbolic metamaterials composed of alternating layers of metal (Ag) and dielectric (SiO_2), we demonstrate a transmission device for nanoparticle sensing that exhibits extremely high optical contrast.

FF2C.2 • 10:45
Gap Mode Formation in Metallic, Nanofocusing SNOM Tapers for High Spatial Resolution Broadband Spectroscopy, Martin Esmann[1], Simon Becker[1], Kyung Wan Yoo[1,2], Heiko Kollmann[1], Petra Gross[1,3], Ralf Vogelgesang[1], Nam Kyoo Park[2], Christoph Lienau[1]; *[1]Carl V. Ossietzky Universität, Germany; [2]Seoul National Univ.,, Korea; [3]Universität Osnabrück, Germany.* Nanofocusing of surface plasmon polaritons enables broadband elastic scattering spectroscopy on individual nanoantennas without any signal demodulation. Clear experimental signatures of tip-sample gap mode formation hint at a potential increase in lateral resolution to single nanometers.

FF2C.3 • 11:00
Holographic 3D Superlocalization of Brownian Scattering Particles for Stochastic Optical Mapping, ariadna martinez-marrades[1], Jean-François Rupprecht[3], Michel Gross[4], Gilles Tessier[2,1]; *[1]Institut Langevin, ESPCI, CNRS UMR 7587, France; [2]Neurophotonics lab, Université Paris Descartes, France; [3]Laboratoire de Physique Théorique de la Matière Condensée, UPMC, UMR CNRS 7600, France; [4]Laboratoire Charles Coulomb, UMR CNRS 5221, Université Montpellier 2, France.* We present a wide field microscopy technique for the 3D mapping of optical intensity using Brownian gold nanoparticles as local probes. Localization by off-axis holography allows stochastic subwavelength optical characterization in water-based systems.

10:30–12:30
SF2D • Supercontinuum Generation: Fundamentals Issues and New Technologies
Presider: Jaime Cardenas; Cornell Univ., USA

SF2D.1 • 10:30
Coherent Supercontinuum from a Silicon Nitride Waveguide, Adrea R. Johnson[1], Aline Sophie Mayer[2], Alexander Klenner[2], Kevin Luke[3], Erin S. Stranford[1], Michael Lamont[1,3], Yoshitomo Okawachi[1], Frank W. Wise[1], Michal Lipson[3,4], Ursula Keller[2], Alexander L. Gaeta[1,4]; *[1]School of Applied and Engineering Physics, Cornell Univ., USA; [2]Dept. of Physics, Inst. of Quantum Electronics, ETH Zurich, Switzerland; [3]School of Electrical and Computer Engineering, Cornell Univ., USA; [4]Kavli Inst. at Cornell for Nanoscale Science, Cornell Univ., USA.* We show experimentally and theoretically that the coherence of a two-octave-spanning supercontinuum generated in a silicon nitride waveguide via 1-μm-pumping with ~100-fs pulses is fully coherent over most of its bandwidth.

SF2D.2 • 10:45
Blue-enhanced supercontinuum generation pumped by a giant-chirped SESAM mode-locked fiber laser, Shoufei Gao[1], Ruoyu Sun[1], Dongchen Jin[1], Pu Wang[1]; *[1]Inst. of Laser Engineering, Beijing Univ. of Technology, China.* We report a blue-enhanced supercontinuum generation pumped by a giant-chirped SESAM mode-locked ytterbium-doped fiber laser. An extremely wide optical spectrum spanning from 380 nm to 2400 nm with total power of 3 W is obtained.

SF2D.3 • 11:00
Silicon-on-Sapphire Nanowire for Mid-IR Supercontinuum Generation, Neetesh Singh[1], Darren Hudson[1], Yi Yu[2], Christian Grillet[3], Andrew Read[4], Petar Atanackovic[4], Steven Duval[4], Stephen Madden[2], David Moss[5], Barry Luther-Davies[2], Benjamin J. Eggleton[1]; *[1]Univ. of Sydney, Australia; [2]Australian National Univ., Australia; [3]Univ. of Lyon, France; [4]Silanna Semiconductor, Australia; [5]RMIT, Australia.* We demonstrate an octave spanning, 1.9-6.2 μm supercontinuum generation in a low loss silicon on sapphire (SOS) nanowire. This establishes SOS as a promising new platform for integrated nonlinear photonics in the mid-IR.

CLEO: Applications & Technology

10:30–12:30
AF2E • A&T Topical Review on High Performance Optics II
Presider: Michael Trubetskov; Max Planck Inst. of Quantum Optics, Germany

AF2E.1 • 10:30 Invited
Laser-Induced Ionization and Damage of High-Performance Optics by Ultrashort Pulses, Vitaly Gruzdev[1]; [1]*Univ. of Missouri-Columbia, USA.* Damage of high-performance optics by ultrashort laser pulses is attributed to the laser-induced ionization and electron excitation. New theoretical models and current state of knowledge in the field are overviewed and critically analyzed based on the recent developments and results.

AF2E.2 • 11:00 Invited
Laser-induced damage of nodular defects in dielectric multilayer coatings, Zhanshan Wang[1], Xinbin Cheng[1], Jinlong Zhang[1], Tao Ding[1], Hongfei Jiao[1], Bin Ma[1]; [1]*Tongji Univ., China.* This paper reviews our recent studies on the laser-induced damage of nodules in dielectric multilayer coatings, where the influence of the electric-field enhancement and the mechanical stability on the thermo-mechanical damage of nodules is discussed.

CLEO: Science & Innovations

10:30–12:15
SF2F • Novel Approaches
Presider: Efim Khazanov; Inst. of Applied Physics, Russia

SF2F.1 • 10:30
Novel Diode Pumped Sulfur Oxide Laser: DPSOL, William F. Krupke[1]; [1]*WFK Lasers, USA.* The concept of a diode pumped molecular gas laser is introduced, with energy storing sulfur monoxide (SO) as the active molecule. Key spectroscopic and kinetic characteristics are presented, along with a kW laser point design.

SF2F.2 • 10:45
Diode Pumped Sodium Molecular Laser, Walter Luhs[1], B. Wellegehausen[2]; [1]*Photonic Engineering Office, Germany;* [2]*Institut für Quantenoptik, Universität Hannover, Germany.* First continuous laser oscillation around 554 nm on $B^1\Pi_u \rightarrow X^1\Sigma^+_g$ transitions of Na_2 has been obtained, optically pumped with a common cw blue emitting InGaN diode laser at 461 nm. Spectroscopic investigations and laser experiments are reported.

SF2F.3 • 11:00
Doubly-Resonant Fabry-Perot Cavity for Power Enhancement of Burst-Mode Picosecond Ultraviolet Pulses, Abdurahim Rakhman[1,2]; [1]*Oak Ridge National Lab, USA;* [2]*Dept. of Physics and Astronomy, Univ. of Tennessee, USA.* We report on a first experimental demonstration of locking a doubly-resonant Fabry-Perot cavity to burst-mode 402.5MHz/50ps ultraviolet (UV) pulses with a MW level peak power by using a temperature controlled dispersion compensation method at the Spallation Neutron Source.

10:30–12:00
SF2G • III/V Photonics
Presider: To be Determined

SF2G.1 • 10:30
Realization of A SOI-Like III-V Platform Based On the Integration of GaAs With Silicon, Rajat Sharma[1], Hung-Hsi Lin[1], Matthew W. Puckett[1], Yeshaiahu Fainman[1]; [1]*Univ. of California, San Diego, USA.* We demonstrate the integration of gallium arsenide with silicon to create a SOI-like platform capable of exploiting the optical properties of III-V materials. We fabricate nanoscale waveguides and design Bragg gratings on this new platform.

SF2G.2 • 10:45
Recovery Time Control in a Nanophotonic Nonlinear Gate Using Atomic Layer Deposition, Gregory Moille[1], Sylvain Combrié[1], Gaëlle Lehoucq[1], Laurence Morgenroth[2], François Neuilly[2], Didier Decoster[2], Alfredo De Rossi[1]; [1]*Thales Research & Technolgy, France;* [2]*Institut d'Electronique de Microelectronique et de Nanotechnologie, France.* Atomic Layer Deposition is used to control the surface recombination of carriers in GaAs photonic crystal cavities. All-optical wavelength conversion at a GHz repetition rate is demonstrated with recovery time below 10 ps.

SF2G.3 • 11:00
1.5μm High Density Quantum Dots Waveguide Photodetector with Avalanche Effect, Toshimasa Umezawa[1], Kouichi Akahane[1], Naokatsu Yamamoto[1], Atsushi Kanno[1], Tetsuya Kawanishi[1]; [1]*National Inst of Information & Comm Tech, Japan.* We have fabricated a waveguide photodetector using a 1.55-um high-density InAs quantum dot absorption layer. A high responsivity (0.4 A/W) without using fiber coupling designs, and a large avalanche multiplication factor of over 10 could be successfully achieved.

Meeting Room 211 B/D

Meeting Room 212 A/C

Meeting Room 212 B/D

CLEO: Science & Innovations

CLEO: Applications & Technology

10:30–12:30
SF2H • Photonic Crystals
Presider: Paul Barclay; Univ. of Calgary, Canada

SF2H.1 • 10:30
Over-1mm-long Wideband on-Chip Slow-light Waveguides Realized by 1,000 Coupled L3 Nanocavities, Eiichi Kuramochi[1], Nobuyuki Matsuda[1], Kengo Nozaki[1], Hiroki Takesue[1], Masaya Notomi[1]; [1]*NTT Corporation, Japan.* Enhanced coupling in slanted L3 nanocavity array expanded bandwidth to 4 THz at telecom wavelength. High-Q tuned L3 nanocavity realized 1,000 coupled cavities with acceptable propagation loss and delay-bandwidth product over 100.

SF2H.2 • 10:45
Systematic tuning of ultrahigh-Q no-missing-hole (H0) nanocavity, Eiichi Kuramochi[1], Hadrien Duprez[1], Hideaki Taniyama[1], Hisashi Sumikura[1], Kengo Nozaki[1], Akihiko Shinya[1], Masaya Notomi[1]; [1]*NTT Corporation, Japan.* Systematic multi-hole tuning of H0 nanocavity with theoretical Q of ~10^7 is reported that outperforms L3 and other a-few-missing-hole nanocavities over a wide slab-thickness range. Experimental Q of ~10^6 is achieved.

SF2H.3 • 11:00
Bending Behavior of Flexible Crystalline Silicon Nanomembrane Photonic Crystal Microcavities, Xiaochuan Xu[2,1], Harish subbaraman[2], Swapnajit Chakravarty[2], Ray T. Chen[1,2]; [1]*Univ. of Texas at Austin, USA;* [2]*Omega Optics, Inc., USA.* We demonstrated a flexible crystalline silicon nanomembrane photonic crystal microcavity with a quality factor of 22,000 and experimentally studied its bending behavior.

10:30–12:30
SF2I • Laser Surface Nanostructuring
Presider: Emmanuel Haro-Poniatowski; UAM-Iztapalapa, Mexico

SF2I.1 • 10:30 Tutorial
Nano-Ablation by Femtosecond Laser-Matter Interactions, Shuji Sakabe[1,2], Masaki Hashida[1,2]; [1]*Inst. for Chemical Research, Kyoto Univ., Japan;* [2]*Graduate School of Science, Kyoto Univ., Japan.* Distinguishing ablation characteristic, nanometer phenomena such as surface morphology and ion emission, resulting from femtosecond laser-matter interactions for metals, and some their applications are reviewed, comparing with conventional nanosecond laser-matter interactions and ablation.

Shuji Sakabe acquired a mater's degree in 1980 and a doctoral degree of engineering in 1984 from Osaka Univ. He was an Assistant Professor at the Institute of Laser Engineering, Osaka Univ. during the 1980's and also served as Associate Professor, Faculty of Engineering from 1998 to 2002. Between his terms at Osaka Univ. he was a researcher at the Max-Planck Institute for Quantum Optics. Associate Professor, Currently he is a full Professor at the Institute for Chemical Research at Kyoto University.

He has been studying laser plasma physics, laser nuclear fusion, and laser isotope separation (1977-2002), and contributed to the construction of laser facility GEKKO XII (1983-84). Currently he is involved in the research for the physics of intense laser matter interaction and its applications. He serves on the board of directors for Laser Society of Japan.

10:30–12:30
AF2J • Chemical and Gas Sensing
Presider: Ekaterina Golovchenko; TE Connectivity, USA

AF2J.1 • 10:30
Silicon on Sapphire Chip Based Photonic Crystal Waveguides for Detection of Chemical Warfare Simulants And Volatile Organic Compound, Yi Zou[1], Parker Wray[1], Swapnajit Chakravarty[2], Ray T. Chen[1,2]; [1]*Univ. of Texas at Austin, USA;* [2]*Omega Optics Inc., USA.* We experimentally demonstrate the first holey and slotted photonic crystal waveguides in silicon-on-sapphire at mid-infrared wavelength of 3.43μm. Chemical warfare simulant triethylphosphate was detected in gas phase at 10ppm concentration via optical absorbance signature.

AF2J.2 • 10:45
Highly Sensitive Chemical Gas Sensor Based on Graphene Deposited D-shaped-fiber, Yu Wu[1], Baicheng Yao[1], Xuli Cao[1], Zegao Wang[1,2], Yunjiang Rao[1], Yuanfu Chen[1], Kin S. Chiang[1,3]; [1]*UESTC, China;* [2]*Aarhus Univ., Denmark;* [3]*City Univeristy of Hong Kong, Hong Kong.* A graphene coated D-shaped fiber chemical-gas sensor demonstrated, with maximum sensitivity ~0.04ppm and ~0.1ppm for NH_3 and H_2O gas detections, respectively. This work may pave a way to explore graphene based lab-on-fiber devices.

AF2J.3 • 11:00
Mid-infrared detection of atmospheric CH_4, N_2O and H_2O based on a single continuous wave quantum cascade laser, Yingchun Cao[1], Nancy P. Sanchez[1], Robert Griffin[1], Frank K. Tittel[1]; [1]*Rice Univ., USA.* A continuous wave, distributed feedback quantum cascade laser based absorption system was developed and demonstrated for simultaneous atmospheric CH_4, N_2O and H_2O detection, with minimum detection limits below 2% of their typical atmospheric concentrations.

CLEO: Science & Innovations

10:30–11:45
SF2K • Short Reach & PON Communication
Presider: Neda Cvijetic; NEC Labs America, USA

SF2K.1 • 10:30
100Gb/s WDM-SSB-DD-OFDM using a Gain Switched Monolithically Integrated Passive Feedback Comb Source, Prince M. Anandarajah[1], Tong Shao[1], Rui Zhou[1], Deseada Gutierrez Pascual[1,2], Liam P. Barry[1]; *[1]Dublin City Univ., Ireland; [2]Pilot Photonics, Ireland.* We demonstrate a 100Gb/s short reach system using a multi-carrier transmitter based on a gain switched monolithically integrated laser. 25km SSMF transmission of a 5x20Gb/s WDM-SSB-DD-OFDM channels with a SE of 1.6b/s/Hz is reported.

SF2K.2 • 10:45
Up to 16 Gb/s CAP16 Modulation over 100 km IM/DD Dispersion Uncompensated Transmission using Dual-EML, Mohamed Essghair Chaibi[1], Christophe Kazmierski[2], Didier Erasme[1]; *[1]Institut MINES-TELECOM, TELECOM ParisTech, France; [2]III-V Lab-Common Lab of "Alcatel-Lucent Bell Labs France","Thales Research and Technology" and "CEA Leti", France.* Transmissions at 16 Gb/s of 16-QAM CAP signals over 100 km IM/DD dispersive channel are reported. They are performed in an optical SSB context generated with an integrated Dual-EML.

SF2K.3 • 11:00
Design of 100G PDM-QPSK Unrepeatered Transmission Systems with EDFA Only Amplification, Xuan He[1,2], Bo Zhang[2], Dan Pudvay[2], Rob Lofland[2], Massimiliano Salsi[2], Qiang Wang[2], Jason O'neil[2], Yang Yue[2], Jon Anderson[2], Zhongqi Pan[1]; *[1]Univ. of Louisiana at Lafayette, USA; [2]Juniper Networks, USA.* We investigate three EDFA only amplification architectures for 100G unrepeatered transmission. With > 4 dBQ margin, pre-amplifier only, booster only and both booster and pre-amplifier amplifications can achieve 130, 150 and 220 km reach respectively.

10:30–12:30
SF2L • Ranging and Metrology
Presider: Mark Notcutt; Stable Laser Systems, USA

SF2L.1 • 10:30
Fiber-based optical frequency comb interferometer with nm-stability and meters-wide scanning range, Yoshiaki Nakajima[2,1], Kaoru Minoshima[2,1]; *[1]JST, ERATO, Japan; [2]The Univ. of Electro-Communications, Japan.* A 167-m fiber-based optical frequency comb interferometer was stabilized to nm-level with extremely wide scanning of 2.8 m by frequency scanning. Fiber noise cancellation with direct use of a frequency comb was also demonstrated.

SF2L.2 • 10:45
Attosecond-Resolution Time-of-Flight Stabilization of Optical Pulse Train in 76-m Indoor Atmospheric Link, Jinho Kang[1], Junho Shin[1], Chur Kim[1], Kwangyun Jung[1], Jungwon Kim[1]; *[1]Korea Advanced Inst of Science & Tech, Korea.* We demonstrate sub-100-attosecond-resolution time-of-flight stabilization method for optical pulse trains in atmospheric links. The rms excess fluctuation in timing for 76.2-m-long indoor free-space transfer is suppressed from >230 fs to 2.6 fs over 130-hour.

SF2L.3 • 11:00
Dual-comb absolute ranging using balanced optical cross-correlator as time-of-flight detector, Haosen Shi[1], Youjian Song[1], Fei Liang[1], Liming Xu[1], Ming-lie Hu[1], Chingyue Wang[1]; *[1]Tianjin Univ., China.* We demonstrate dual-comb absolute ranging using balanced optical cross correlator as high resolution pulse time-of-flight detector. Actual test performed at ~3 meters target distance proves a 200 nm ranging precision at 50 ms acquisition time.

10:30–12:30
SF2M • Symposium on OPA/OPCPA – Next Generation of Ultra-Short Pulse Laser Technology II
Presider: Dong Eon Kim; Max Planck Center for Attosecond Science, Germany

SF2M.1 • 10:30 Invited
Tunable Few-optical-Cycle Pulses by Group-velocity-matched OPAs, Giulio Cerullo[1], Cristian Manzoni[1], Daniele Brida[2]; *[1]Politecnico di Milano, Italy; [2]Univ. of Konstanz, Germany.* We review our work on the development of ultra-broadband OPAs. By group-velocity matching between signal and idler waves, we generate pulses with duration of few optical cycles and tunability from the visible to the infrared.

SF2M.2 • 11:00 Invited
Few-Cycle and Phase Stable OPCPA Systems with High Repetition Rate, Uwe Morgner[1,2], Jan Ahrens[1,3], Tino Lang[1,2], Marcel Schultze[4], Thomas Binhammer[3], Oliver Prochnow[3], Anne Harth[5], Piotr Rudawski[5], Cord L. Arnold[5], Anne L'Huilier[5]; *[1]Inst. of Quantum Optics, Leibniz Universität Hannover, Germany; [2]QUEST, Leibniz Universität Hannover, Germany; [3]VENTEON Laser Technologies GmbH, Germany; [4]TRUMPF Scientific Lasers GmbH & Co. KG, Germany; [5]Dept. of Physics, Lund Univ., Sweden.* We present different approaches for high repetition rate, few-cycle pulse generation with µJ-level energy from compact OPCPA systems. The sources are based on octave spanning Ti:Sa oscillators with all-optical synchronization to state-of-the-art Ytterbium based amplifiers.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FF2A • Single Photon Detectors—Continued

FF2A.4 • 11:15
Polarization-Insensitive Superconducting Nanowire Single-Photon Detectors, Shellee D. Dyer[1], Hiroki Takesue[2], Varun Verma[1], Robert Horansky[1], Richard P. Mirin[1], Sae Woo Nam[1]; *[1]NIST, USA; [2]NTT Basic Research Labs, NTT, Japan.* We report MoSi superconducting nanowire single-photon detectors (SNPDs) with low polarization sensitivity over a 120 nm wavelength range, covering the standard fiber telecom wavelengths. Our models indicate that this low polarization sensitivity is consistent with the design geometry.

FF2A.5 • 11:30
Superconducting Nanowire Detectors Based on MgB_2, Francesco Marsili[1], Daniel P. Cunnane[1], Ryan Briggs[1], Matthew D. Shaw[1], Boris S. Karasik[1], Matthaeus Wolak[2], Narendra Acharya[2], Xiaoxing Xi[2]; *[1]Jet Propulsion Lab, USA; [2]Temple Univ., USA.* We fabricated and characterized the optical response of MgB_2 nanowires with critical temperature T_c = 33 K. The devices showed optical response at 4 K and subnanosecond relaxation time. The detectors responded to the simultaneous absorption of three photons, but not to single photons.

FF2A.6 • 11:45
A Robust Optical Coupler for Alignment of Superconducting Nanowire Detector Array, R. H. Shepard[1], Andrew Guzman[1], Matthew Grein[1], Eric Dauler[1], Danna Rosenberg[1], Theodore Gudmundsen[1], Ryan Murphy[1]; *[1]Massachusetts Inst of Tech Lincoln Lab, USA.* We present an athermalized design and performance analysis of a robust imaging system used to couple light from an input fiber to a superconducting nanowire single photon detector.

FF2B • Quantum Nonlinear Optics—Continued

FF2B.3 • 11:15
Optical Pumping of Individual Spins in Self-Assembled and Site-Controlled Quantum Dots, Konstantinos Lagoudakis[1], Peter L. McMahon[1], Kevin Fischer[1], Kai Muller[1], Tomas Sarmiento[1], Shruti Puri[1], Dan Dalacu[2], Philip Poole[2], Michael Reimer[3], Val Zwiller[3], Yoshihisa Yamamoto[4], Jelena Vuckovic[1]; *[1]Stanford Univ., USA; [2]National Research Council of Canada, Canada; [3]T U Delft, Netherlands; [4]National Inst. of Informatics, Japan.* We investigate optical spin pumping of self-assembled p-type δ-doped InAs quantum dots as well as site-controlled InP nanowire quantum dots and find that they are both promising for scalable quantum information processing platforms.

FF2B.4 • 11:30
Nonlinear Optics with Single Molecules, Benjamin Gmeiner[1,2], Andreas Maser[1,2], Tobias Utikal[1,2], Stephan Götzinger[1,2], Vahid Sandoghdar[1,2]; *[1]Max Planck Inst., Germany; [2]Friedrich Alexander Univ., Germany.* We report on four-wave mixing in a single organic molecule placed at the tight focus of two near resonant laser beams. By directly monitoring the intensity of a weak probe beam after the interaction with the molecule, we observe a rich set of resonance profiles in excellent agreement with theory.

FF2B.5 • 11:45
Xenon-based Nonlinear Fabry-Perot Interferometer for Quantum Information Applications, Garrett Hickman[1], Todd B. Pittman[1], James D. Franson[1]; *[1]Univ. of Maryland, Baltimore County, USA.* We describe a nonlinear Fabry-Perot interferometer useful for optical quantum information applications. We observe self-phase modulation and other nonlinear effects with ultra-low input powers using metastable xenon in a high-finesse cavity.

FF2C • Near-field Imaging, Spectroscopy and Optomechanics—Continued

FF2C.4 • 11:15
FRET-based Scanning Probe Microscopy with a Donor Dye Coated AFM Tip, Basanth Kalanoor[1]; *[1]Bar Ilan Univ., Israel.* A FRET-based method of near-field fluorescence lifetime imaging is developed. Lumogen dye attached to the apex of an AFM tip acts as a nanometeric light source for exciting the sample via non-radiative energy transfer.

FF2C.5 • 11:30
Optical Trapping of a Colloidal Quantum Dot, I-Chun Huang[1], Russel Jensen[2], Ou Chen[2], Jennifer Choy[1], Thomas Bischof[2], Moungi Bawendi[2], Marko Loncar[1]; *[1]Harvard Univ., USA; [2]MIT, USA.* Bowtie apertures fabricated by lift-off were used to optically trap a 30-nm silica coated quantum dot (scQD) with 1.56-MW/cm^2 intensity at 1064-nm wavelength. The trapped scQD emitted fluorescence by two photon excitation from the trapping laser.

FF2C.6 • 11:45
Nonreciprocal Optical Interaction of Dissimilar Particles, Sergey Sukhov[1], Alexander Shalin[2], David Haefner[1], Aristide Dogariu[1]; *[1]Univ. of Central Florida, CREOL, USA; [2]National Research Univ. of Information Technologies, Mechanics and Optics, Russia.* We show that optical interaction of dissimilar particles results in apparent violation of *actio et reactio* principle. Interaction asymmetry in an optically-bound dimer can lead to unexpected movement transversal to the direction of light propagation.

SF2D • Supercontinuum Generation: Fundamentals Issues and New Technologies—Continued

SF2D.4 • 11:15
Relative Timing Jitter of Raman Soliotns and its Effect on Nonlinear Wavelength Conversion, Gengji Zhou[1,2], Ming Xin[1], Franz Kaernter[1,2], Guoqing Chang[1,3]; *[1]CFEL,DESY, Germany; [2]Univ. of Hamburg, Germany; [3]MIT, USA.* We demonstrate that shorter fiber length and the excitation pulse with shorter duration and higher energy can reduce a Raman soliton's relative timing jitter and leads to reduced noise in nonlinear wavelength conversion.

SF2D.5 • 11:30
Enhanced Supercontinuum Generation by Polarization Control of Filamentation in Molecular Gases, Shermineh Rostami[1], Michael Chini[2], Khan Lim[2], Magali Durand[2], Matthieu Baudelet[2], Martin Richardson[2], Jean-Claude Diels[1], Ladan Arissian[1]; *[1]Univ. of New Mexico, USA; [2]Univ. of Central Florida, USA.* Supercontinuum generation by filamentation in molecular gases is optimized by studying the ellipticity of the pulse polarization during the interaction with the species of the gas medium via strong field ionization and molecular alignment effects.

SF2D.6 • 11:45
Visible-to-near-Infrared Octave Spanning Supercontinuum Generation in a Partially Underetched Silicon Nitride Waveguide, Haolan Zhao[1,2], Bart Kuyken[1,2], Francois Leo[1,2], Stephane Clemmen[1,2], Edouard Brainis[2,3], Gunther Roelkens[1,2], Roel Baets[1,2]; *[1]Photonics Research Group, Dept. of Information Technology, Ghent Univ.-imec, Belgium; [2]Center for Nano- and Biophotonics (NB-Photonics), Ghent Univ., Belgium; [3]Physics and Chemistry Nanostructures Group, Dept. of Electronics and Information Systems, Ghent Univ., Belgium.* The generation of an octave spanning supercontinuum covering most of the visible spectrum is demonstrated for the first time in a silicon nitride waveguide. This result is achieved by dispersion engineering through partially underetching a waveguide.

CLEO: Applications & Technology

CLEO: Science & Innovations

AF2E • A&T Topical Review on High Performance Optics II—Continued

SF2F • Novel Approaches—Continued

SF2F.4 • 11:15
Double Pass Gain in Helium-Xenon Discharges in Hollow Optical Fibres at 3.5µm, Adrian Love[1], Sam Bateman[1], Walter Belardi[1], Colin Webb[2], William Wadsworth[1]; [1]*Univ. of Bath, UK;* [2]*Dept. of Physics, Univ. of Oxford, UK.* Gain is observed in a double pass of a Helium-Xenon gas DC discharge in a 90cm long flexible hollow core fibre. Output at 3.5µm increases with discharge current up to the maximum of 0.55mA.

SF2G • III/V Photonics—Continued

SF2G.4 • 11:15
Monolithically Integrated Multi-Color (Blue and Green) Light-Emitting Diode Chips, Chu-Hsiang Teng[1], Lei Zhang[1], Yu-Lin Tsai[2], Chien-Chung Lin[2], Hao-Chung Kuo[2], Hui Deng[1], Pei-Cheng Ku[1]; [1]*Univ. of Michigan, USA;* [2]*National Chiao Tung Univ., Taiwan.* An LED chip with monolithically integrated, individually addressable multi-color pixels was demonstrated with a color tuning range from blue to green on a single epitaxial wafer.

AF2E.3 • 11:30
Generating Structural Colors from Dielectric Surface Resonances, Yichen Shen[1], Veronika Rinnerbauer[1], Marin Soljacic[1], John D. Joannopoulos[1], imbert wang[1]; [1]*MIT, USA.* We propose a new structural color generation mechanism that produces colors by the Fano resonance effect. We experimentally realize the proposed idea by fabricating the samples that show resonance-induced colors with weak angular dependence.

SF2F.5 • 11:30
The Physical Origin of Kramers-Kronig Self-Phasing in Coherent Laser Beam Combination, James R. Leger[1], Hung-Sheng Chiang[1], John Hanson[1]; [1]*Univ. of Minnesota Twin Cities, USA.* The Kramers-Kronig self-phasing observed in coherently coupled fiber laser arrays is experimentally shown to originate from a change in the supermode intensity distribution. The conditions that lead to accurate self-phasing are modeled and experimentally confirmed.

SF2G.5 • 11:30
GaInAs/InP MQW light-emitting diode fabricated on wafer bonded InP/Quartz substrate, Keiichi Matsumoto[1], Makoto Takasu[1], Yoshinori Kanaya[1], Junya Kishikawa[1], Kazuhiko Shimomura[1]; [1]*Sophia Univ., Japan.* GaInAs/InP multi quantum wells light-emitting diode, emitting at 1.3-um, was fabricated by metal organic vapor phase epitaxi on wafer bonded InP/Quartz substrate. The device has been operated under continuous wave operation at room temperature.

AF2E.4 • 11:45
Laser Damage of Interference Coatings at = 1.6 µm with an Optical Parametric Chirped Pulse Amplifier, Drew Schiltz[1], Dinesh Patel[1], Cory Baumgarten[1], Brendan Reagan[1], Jorge J. Rocca[1], Carmen S. Menoni[1]; [1]*Electrical and Computer Engineering, Colorado State Univ., USA.* Laser damage of interference coatings is investigated with 1.6 µm wavelength, 2 picosecond pulses from an optical parametric chirped pulse amplification system. 7 J/cm^2 damage thresholds are achieved and deviation from conventional damage models is reported.

SF2F.6 • 11:45
Phase Locking of Many Lasers by Combined Talbot Cavity and Fourier Filtering, Chene Tradonsky[1], Vishwa Pal[1], Ronen Chriki[1], Asher A. Friesem[1], Nir Davidson[1]; [1]*Weizmann Inst. of Science, Israel.* Efficient in-phase coupling of hundreds of lasers by means of combined Talbot cavity and intra-cavity spatial Fourier filtering is developed. Simulated and experimental results for square, triangular and honeycomb laser arrays are presented.

SF2G.6 • 11:45
Phosphor-free Monolithic High-Efficiency White Light-Emitting-Diodes on Ternary InGaN Substrates, Yu Kee Ooi[1], Jing Zhang[1]; [1]*Dept. of Electrical and Microelectronics Engineering, Rochester Inst. of Technology, USA.* Phosphor-free monolithic high-efficiency tunable white LEDs are realized on ternary InGaN substrates. This proof-of-concept study demonstrates that high quantum efficiency and stable white color emission are achieved by using ternary substrates and correctly-engineered device structures.

Meeting Room 211 B/D | Meeting Room 212 A/C | Meeting Room 212 B/D

CLEO: Science & Innovations

CLEO: Applications & Technology

SF2H • Photonic Crystals—Continued

SF2H.4 • 11:15
Femtojoule Optical Switching in Hydrogenated Amorphous Silicon Photonic Crystal Nanocavities, Jason Pelc[1], Ranojoy Bose[1], Charles Santori[1], Tho Tran[1], Raymond Beausoleil[1]; [1]*Hewlett Packard Labs, USA*. We demonstrated 1.5-μm-band optical switching using the Kerr effect in hydrogenated amorphous silicon (a-Si:H) photonic crystal nanocavities. Switching with pulse energies down to 18 fJ using a degenerate pump-probe technique was observed in cavities with *Q*-factors up to 30,000.

SF2H.5 • 11:30
Experimental demonstration of non-reciprocal transmission in a nonlinear photonic-crystal Fano structure, Yi Yu[1], Yaohui Chen[1], Hao Hu[1], Weiqi Xue[1], Kresten Yvind[1], Jesper Mork[1]; [1]*Danmarks Tekniske Universitet, Denmark*. We demonstrate a photonic-crystal structure with >30 dB difference between forward and backward transmission levels. The non-reciprocity relies on the combination of ultrafast carrier nonlinearities and spatial symmetry breaking in a Fano structure employing a single nanocavity.

SF2H.6 • 11:45
Low-loss Mode Converter for Silicon-Polymer Hybrid Slot Photonic Crystal Waveguide, Xingyu Zhang[1], Harish subbaraman[2], Zeyu Pan[1], Chi-jui Chung[1], Amir Hosseini[2], Ray T. Chen[1,2]; [1]*Univ. of Texas at Austin, USA;* [2]*Omega Optics, Inc., USA*. We demonstrate an efficient adiabatic mode converter for coupling light into a silicon slot photonic crystal waveguide with slot width as large as 320nm. The loss of the mode converter is measured to be 0.08dB.

SF2I • Laser Surface Nanostructuring—Continued

SF2I.2 • 11:30
Deep and Near Sub wavelength Ripples on Natural MoS_2 Induced by Femtosecond Laser with Threshold Dependence, Yusong Pan[1], Yumei Li[1], Jianghong Yao[1], Qiang Wu[1], Jingjun Xu[1]; [1]*Nankai Univ., China*. We generate deep and near sub-wavelength ripples on MoS_2 by femtosecond laser irradiation with incident fluence dependence and pulse number insensitivity. Raman analysis demonstrates that no amorphous or oxidative exhibition remains after laser processing.

SF2I.3 • 11:45
Laser fluence dependence of periodic structures on metals produced by femtosecond double pulse laser, Masaki Hashida[1], Laura Gemini[2], Takaya NIshii[1], Yasuhiro Miyasaka[1], Hitoshi Sakagami[3], Shunsuke Inoue[1], Jiri Limpouch[2], Tomas Mocek[4], Shuji Sakabe[1]; [1]*Kyoto Univ., Japan;* [2]*FNSPE, Czech Technical Univ., Czech Republic;* [3]*National Inst. for Fusion Scienc, Japan;* [4]*Inst. of Physics, HiLASE Project, Czech Republic*. The formation mechanism of LIPSS has been investigated for titanium irradiated by double pulse. We found that variation of the surface plasma density characterized by first pulse led to a variation of the grating interspaces.

AF2J • Chemical and Gas Sensing—Continued

AF2J.4 • 11:15 Tutorial
Miniature and Handheld Spectroscopic Instruments for Chemical Sensing and Security Applications: Enabled by Photonics, Richard A. Crocombe[1]; [1]*Thermo Fisher Scientific Inc, USA*. Consumer electronics gave us powerful mobile platforms, compact batteries, displays, user interfaces, while telecomm photonics has revolutionized miniature optics, sources and detectors. Handheld spectrometers are now routinely used for chemical sensing and security applications.

Richard Crocombe graduated from Oxford Univ. and Southampton Univ. in the UK in chemistry and spectroscopy. He has spent his career developing anlaytical instruments, in the last dozen years focussing on portable and handheld instrumentation. Crocombe is co-chair of SPIE's 'Next-Generation Spectroscopic Technologies' conference.

CLEO: Science & Innovations

SF2K • Short Reach & PON Communication—Continued

SF2K.4 • 11:15
Software-Defined Intra-PON Optical Flow Transmission via a Quasi-Passive Reconfigurable (QPAR) Node, Shuang Yin[1], Thomas Shun Rong Shen[1], Yingying Bi[1], Jing Jin[1], Leonid Kazovsky[1]; [1]*Stanford Univ., USA.* This paper demonstrates Intra-PON optical Flow transmission via a QPAR node. Simulations show 2 to 20x traffic waiting time reduction comparing to no or fixed Intra-PON designs. Experiments show error-free Intra- and Inter-traffic with/without QPAR reconfiguration.

SF2K.5 • 11:30
8-User PAM-ECDMA PON with 25.6 Gb/s Aggregate Data Rate, Xuhan Guo[1], Xin Li[1], Adrian Wonfor[1], Lei Zhou[2], Liming Fang[2], Richard V. Penty[1], Ian H. White[1]; [1]*Univ. of Cambridge, UK;* [2]*Huawei Technologies, China.* We report a PAM-ECDMA PON system with 2.5-fold performance improvement over the prior NRZ-ECDMA system. Error-free transmission of two channels in an 8-user 25.6 Gb/s aggregate-data-rate PON is achieved in a proof-of-principle demonstration.

SF2L • Ranging and Metrology—Continued

SF2L.4 • 11:15
Dual-comb Reciprocal Temporal Scanning for Absolute Distance Measurement, Hongyuan Zhang[1], Xuejian Wu[1], Haoyun Wei[1], Yan Li[1]; [1]*Tsinghua Univ., China.* Pulse trains from dual combs with different repetition rates are coupled and directed onto a target for simultaneous absolute distance measurement. Non-ambiguity range extension is immune to drift and accuracy is about 100 nm.

SF2L.5 • 11:30
Stabilization of Squeezed Vacuum States Using Weak Pump Depletion, Timo Denker[1], Dirk Schütte[1], Maximilian H. Wimmer[1], Trevor Wheatley[3], Elanor H. Huntington[2], Michele Heurs[1]; [1]*Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), and Institut für Gravitationsphysik, Leibniz Universität Hannover, Germany;* [2]*College of Engineering and Computer Science, Australian National Univ., Australia;* [3]*School of Engineering and Information Technology, Univ. of New South Wales, Australia.* We present a new phase-locking technique based on weak pump depletion. It allows for the first experimental realization of a pump-phase lock of an optical parametric oscillator by reading out the pre-existing phase information in the pump field. No degradation of the detected squeezed states occurs.

SF2L.6 • 11:45
Factor of 18 Enhancement in the Sensitivity-Bandwidth Product of the aLIGO Gravitational Wave Detector Using a White Light Cavity, Minchuan Zhou[1], Zifan Zhou[1], Selim M. Shahriar[1]; [1]*Northwestern Univ., USA.* We show that the sensitivity-bandwidth product of the aLIGO gravitational wave detector can be enhanced by a factor of 18, while remaining below the standard quantum limit, by employing a white light cavity configuration.

SF2M • Symposium on OPA/OPCPA – Next Generation of Ultra-Short Pulse Laser Technology II—Continued

SF2M.3 • 11:30
Broadband 2D-QPM Frequency Domain OPA, Christopher R. Phillips[1], Benedikt Mayer[1], Lukas Gallmann[1,2], Ursula Keller[1]; [1]*ETH Zurich, Switzerland;* [2]*Univ. of Bern, Switzerland.* We demonstrate broadband mid-IR frequency-domain OPA (FOPA) in the Fourier-plane of a 4f pulse shaper via two-dimensional (2D) quasi-phasematching (QPM) device adapted to the pump intensity profile and spatial chirp of the mid-infrared beam.

SF2M.4 • 11:45
500 kHz OPCPA-Based UV-XUV Light Source For Time-Resolved Photoemission Spectroscopy, Michele Puppin[1], Yunpei Deng[1], Chris Nicholson[1], Claude Monney[1,3], Marcel Krenz[1], Oliver Prochnow[2], Jan Ahrens[2,4], Thomas Binhammer[2], Uwe Morgner[4], Martin Wolf[1], Ralph Ernstorfer[1]; [1]*Fritz-Haber Institut, Germany;* [2]*VENTEON Laser Technologies, Germany;* [3]*Dept. of Physics, Zurich Univ.,, Switzerland;* [4]*Inst. of Quantum Optics, Leibniz Universität Hannover, Germany.* A 15 W, sub-20 fs OPCPA based on an Yb laser is used to demonstrate 6.3 eV fourth harmonic-based UV photoelectron spectroscopy with sub-60 fs time resolution and XUV high harmonic generation at 500 kHz.

CLEO: QELS-Fundamental Science

CLEO: Science & Innovations

FF2A • Single Photon Detectors—Continued

FF2A.7 • 12:00
Using Double Compressive Sensing in Simultaneous Imaging of Spatial Entanglement, Samuel H. Knarr[1,2], Gregory Howland[3], James Schneeloch[1,2], Daniel Lum[1,2], John Howell[1,2]; [1]*Univ. of Rochester, USA;* [2]*Center for Coherence and Quantum Optics, Univ. of Rochester, USA;* [3]*Air Force Research Lab, USA*. We use compressive sensing in the image and Fourier planes of a spontaneous parametric down conversion source to simultaneously gather the joint position and momentum distributions. We witness entanglement by violating a continuous variable steering inequality.

FF2A.8 • 12:15
Classical Imaging with Undetected Photons, Jeffrey H. Shapiro[1], Dheera Venkatraman[1], Franco N. Wong[1]; [1]*MIT, USA*. We describe a classical-state system capable of mimicking the essential features of Barreto Lemos *et al.*'s quantum imaging with undetected photons [Nature, **512**, 409-412 (2014)], but with a much higher signal-to-noise ratio.

FF2B • Quantum Nonlinear Optics—Continued

FF2B.6 • 12:00
Experimental Generation of Quadruple Quantum Correlated Beams from Cascaded Four-Wave Mxing Processes in Hot Rubidium Vapors, Jietai Jing[1]; [1]*East China Normal Univ., China*. We report on our recent experimental results of generating quadruple quantum correlated beams by using cascaded four-wave mixing processes in hot rubidium vapor. The intensity-difference squeezing of the four beams is about 8.0 dB.

FF2B.7 • 12:15
Continuous Generation of Rubidium Vapor in a Hollow Core Photonic Band-Gap Fiber, Prathamesh Donvalkar[1], Sven Ramelow[1], Stephane Clemmen[1], Alexander L. Gaeta[1]; [1]*Cornell Univ., USA*. We demonstrate high optical depths of > 50 lasting over 100 minutes in a Rubidium filled PBGF using an off-resonant CW laser beam, which enables straightforward measurement of cross-phase modulation at the single photon level.

FF2C • Near-field Imaging, Spectroscopy and Optomechanics—Continued

FF2C.7 • 12:00
Optical manipulation of Janus nanoparticles, Ognjen Ilic[1], Ido Kaminer[1], Yoav Lahini[1], Hrvoje Buljan[2], Marin Soljacic[1]; [1]*MIT, USA;* [2]*Dept. of Physics, Univ. of Zagreb, Croatia*. We explore optical forces and torques acting on Janus nanoparticles in a plane electromagnetic wave. We find rotationally stable points and propose a scheme for all-optical manipulation of orientation and position of Janus nanoparticles.

FF2C.8 • 12:15
Simultaneous Transport of Multiple Nanoparticles Across a Patterned Plasmonic Substrate, Jason Ryan[1], Yuxin Zheng[1], Paul Hansen[1], Tiffany Huang[1], Lambertus Hesselink[1]; [1]*Stanford Univ., USA*. We demonstrate the controlled transport of simultaneous nano-scale particles across a patterned gold film. Nanopillars patterned onto the gold surface load particles onto nearby plasmonic conveyor belts formed from C-shaped engravings.

SF2D • Supercontinuum Generation: Fundamentals Issues and New Technologies—Continued

SF2D.7 • 12:00 Invited
Mid-Infrared Supercontinuum Generation Spanning More Than 11 μm in a Chalcogenide Step-Index Fiber, Christian R. Petersen[1], Uffe Møller[1], Irnis Kubat[1], Binbin Zhou[1], Sune Dupont[2], Jacob Ramsay[2], Trevor Benson[3], Slawomir Sujecki[3], Nabil Abdel-Moneim[3], Zhuoqi Tang[3], David Furniss[3], Angela Seddon[3], Ole Bang[1,4]; [1]*DTU Fotonik, Dept. of Photonics Engineering, Danmarks Tekniske Universitet, Denmark;* [2]*Dept. of Chemistry, Aarhus Univ., Denmark;* [3]*George Green Inst. for Electromagnetics Research, Univ. of Nottingham, UK;* [4]*NKT Photonics A/S, Denmark*. Supercontinuum generation covering an ultra-broad spectrum from 1.5-11.7μm and 1.4-13.3μm is experimentally demonstrated by pumping an 85mm chalcogenide step-index fiber with 100fs pulses at a wavelength of 4.5μm and 6.3μm, respectively.

NOTES

CLEO: Applications & Technology

AF2E • A&T Topical Review on High Performance Optics II—Continued

AF2E.5 • 12:00
Withdrawn

AF2E.6 • 12:15
Full-range Gate-controlled Terahertz Phase Modulation with Graphene Metasurfaces, Ziqi Miao[1], Qiong Wu[1], Xin Li[1], Qiong He[1], Kun Ding[1], Zhenghua An[1], Yuanbo Zhang[1], Lei Zhou[1]; [1]*Fudan Univ., China.* Combining metasurfaces with gate controlled graphene, we experimentally demonstrate ±180° phase modulation can be realized at certain frequencies in THz domain, and describe a practical scheme to achieve *full-range* active phase modulation with such graphene metasurfaces.

CLEO: Science & Innovations

SF2F • Novel Approaches—Continued

SF2F.7 • 12:00
Transverse mode competition in index-antiguided planar waveguide lasers with large mode area, Yuanye Liu[1], Tsing-Hua Her[1], Casperson Lee[1]; [1]*Univ. of North Carolina Charlotte, USA.* We study transverse mode competition in index-antiguided planar lasers theoretically and experimentally. Robust fundamental mode operating 10 times above lasing threshold is predicted and confirmed experimentally.

NOTES

Meeting Room 211 B/D	Meeting Room 212 A/C	Meeting Room 212 B/D
CLEO: Science & Innovations		CLEO: Applications & Technology

SF2H • Photonic Crystals—Continued

SF2H.7 • 12:00
Flat-top Drop Filter based on a Single Topology Optimized Photonic Crystal Cavity, Lars H. Frandsen[1], Yuriy Elesin[2], Xiaowei Guan[1], Ole Sigmund[3], Kresten Yvind[1]; [1]*DTU Fotonik, Dep. Photonics Engineering, Denmark;* [2]*Haldor Topsoe, Denmark;* [3]*Dept. of Mechanics Engineering, DTU Mekanik, Denmark.* A flat-top drop filter has been realized in silicon-on-insulator material by applying 3D topology optimization to a *single* L3 photonic crystal cavity. Measurements reveal that the pass-band of the drop channel is flat within 0.44 dB over a wavelength range of 9.7 nm with an insertion loss <0.85 dB.

SF2H.8 • 12:15
Photonic Surfaces for Designable Nonlinear Power Shaping, Roshni Biswas[1], Michelle Povinelli[1]; [1]*Univ. of Southern California, USA.* We introduce a mechanism for nonlinear optical power transmission using partially absorptive resonances in photonic crystal slabs. We experimentally demonstrate increasing, decreasing, and nonmonotonic transmission as a function of optical power.

SF2I • Laser Surface Nanostructuring—Continued

SF2I.4 • 12:00
Polarization Sensitive Printing by Ultrafast Laser Nanostructuring in Amorphous Silicon, Rokas Drevinskas[1], Martynas Beresna[1], Mindaugas Gecevičius[1], mark khenkin[2], andrey G. kazanskii[2], oleg I. konkov[3], Peter Kazansky[1]; [1]*Univ. of Southampton, UK;* [2]*Physics Dept., M.V. Lomonosov Moscow State Univ., Russia;* [3]*Russian Academy of Sciences, A.F. Ioffe Physicotechnical Inst., Russia.* We demonstrate femto- and picosecond laser assisted nanostructuring of hydrogenated amorphous silicon (a-Si:H). The laser-induced periodic sub-wavelength structures exhibit the dichroism and giant form birefringence giving extra dimensions to the polarization sensitive image recording.

SF2I.5 • 12:15
Influence of Self-scattering on the Fabrication of Surface Nanostructures in Zinc Phosphate Glass Using Fs-laser Pulses, Jasper Clarijs[2], Javier Hernandez Rueda[1], Marcel Scholten[2], Hao Zhang[2], Denise M. Krol[1,2], Dries van Oosten[2]; [1]*Univ. of California Davis, USA;* [2]*Utrecht Univ., Netherlands.* Zinc-phosphate glass surface ablation was investigated using tightly focused fs-laser pulses. Evidences of self-scattering effects due to the interaction between the laser light and a transient plasma generated during surface ablation have been investigated.

AF2J • Chemical and Gas Sensing—Continued

AF2J.5 • 12:15
An Interband Cascade Laser based Sulfur Dioxide Sensor for Emission Monitoring Applications, Peter Geiser[1], Ove Bjorøy[1], Peter Kaspersen[1], Lars Nähle[2], Julian Scheuermann[2], Michael von Edlinger[2], Johannes Koeth[2]; [1]*Norsk Elektro Optikk A/S, Norway;* [2]*nanoplus Nanosystems and Technologies GmbH, Germany.* A mid-infrared sensor for sulfur dioxide in emission monitoring applications using a monomode DFB ICL at 4 µm and second harmonic detection has been developed. The detection limit of the sensor is below 3 ppm·m.

NOTES

CLEO: Science & Innovations

SF2L • Ranging and Metrology—Continued

SF2L.7 • 12:00
Nested Fabry-Perot in mode-locked lasers to monitor minute changes of index, James Hendrie[1], Ladan Arissian[1], Koji Masuda[1], Adam Hecht[1], Jean-Claude Diels[1]; [1]*Univ. of New Mexico, USA*. An uncoated glass etalon inserted in a mode-locked laser results generating two nested frequency combs. The ratio of their frequencies, insensitive to external parameters, is an accurate measure of the optical path in the etalon.

SF2L.8 • 12:15
Ultrahigh Resolution Frequency-to-Time Mapping Based on Frequency Shifting Recirculating Lasers, Hugues Guillet de Chatellus[1], José Azaña[2]; [1]*LIPhy, France;* [2]*EMT-INRS, Canada*. We demonstrate a novel implementation of frequency-to-time mapping based on a frequency shifting recirculating laser, achieving a 10 kHz-frequency resolution and a time-bandwidth product greater than 1000.

SF2M • Symposium on OPA/OPCPA – Next Generation of Ultra-Short Pulse Laser Technology II—Continued

SF2M.5 • 12:00
Multi-mJ, kHz, intense picosecond deep-ultraviolet source, Chun-Lin L. Chang[1], Peter R. Krogen[1], Houkun Liang[1], Gregory J. Stein[1], Jeffrey Moses[1], Chien-Jen Lai[1], Jonathas P. Siqueira[1], Luis E. Zapata[1], Franz X. Kaertner[1,2], Kyung-Han Hong[1]; [1]*Dept. of Electrical Engineering and Computer Science and Research Lab of Electronics, MIT, USA;* [2]*Dept. of Physics, Univ. of Hamburg, Center for Free-Electron Laser Science, DESY, Germany.* We demonstrate a 2.74 mJ, 1 kHz, ~4.2 ps DUV laser at ~257.7 nm with M^2~2.54 from a frequency-quadrupled hybrid Yb-doped chirped-pulse amplifier. An infrared-to-DUV conversion efficiency of ~10% is achieved.

SF2M.6 • 12:15
Deviation From [Pump=Signal + Idler] Photon Energy Conservation in an Ultrafast Optical Parametric Amplifier, Oleksandr Isaienko[1], Victor Klimov[1]; [1]*Los Alamos National Lab, USA*. We report on considerable photon energy losses of [signal+idler] pair (~60 meV) in $KTiOPO_4$ optical parametric amplifier pumped by <40-fs 800-nm pulses and explains it by optical rectification enhanced by coupling to large third-order nonlinearity.

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