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March 20-21
2018
San Jose, CA

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400G CWDM8 Data Center Optics



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CWDM8 MSA Project Chair

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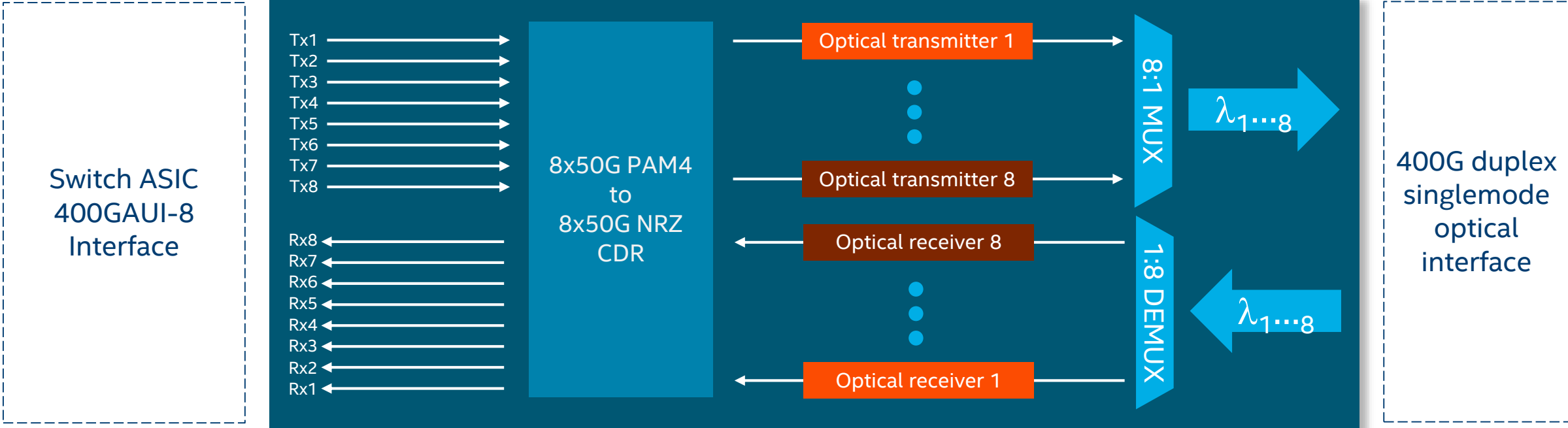
400G CWDM8 MSA

- Multiple optics, component, and system companies have formed an MSA group to define 2 km and 10 km reach 400G optical interface specifications
 - Common MSA specs ensure interoperability between multiple vendors
- Goal is to help accelerate development and adoption of 400G duplex-fiber optics to enable deployment of the next generation of 12.8T OCP switches and routers



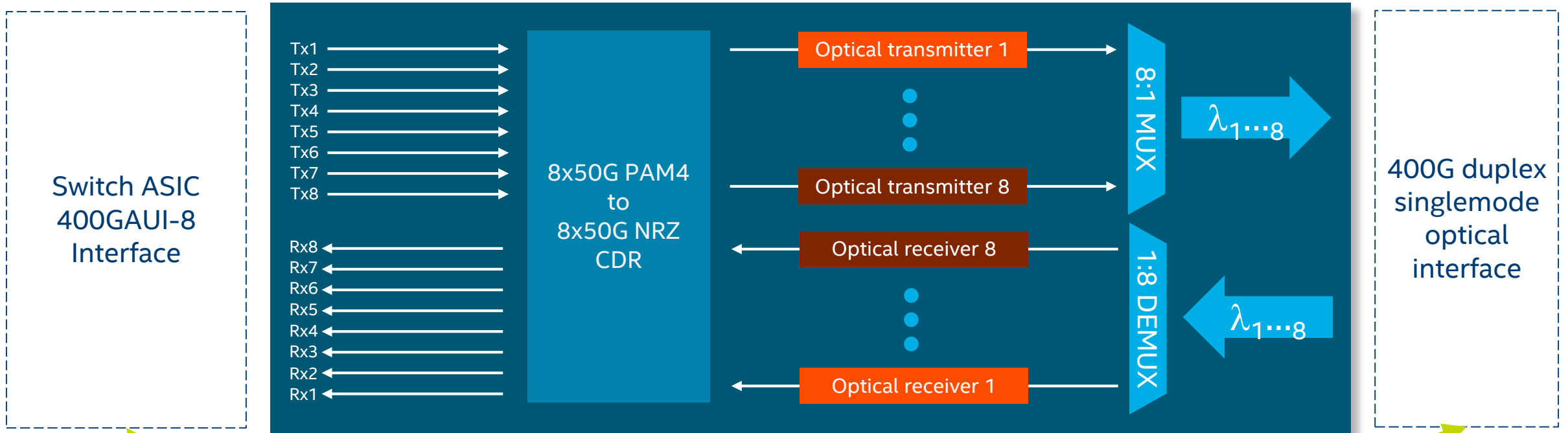
400G CWDM8 Optical PMD Block Diagram

QSFP-DD/OSFP/OBO module



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QSFP-DD/OSFP/OBO module



Electrical interface defined by IEEE

Module form factor and management interface defined by module MSA

Optical interface defined by CWDM8 MSA Group

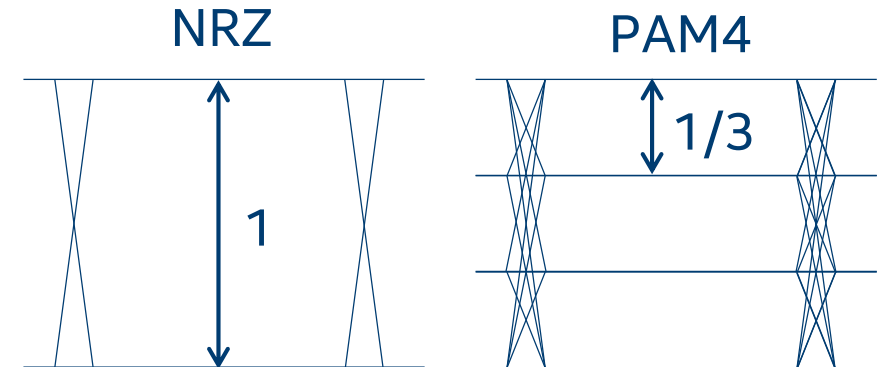
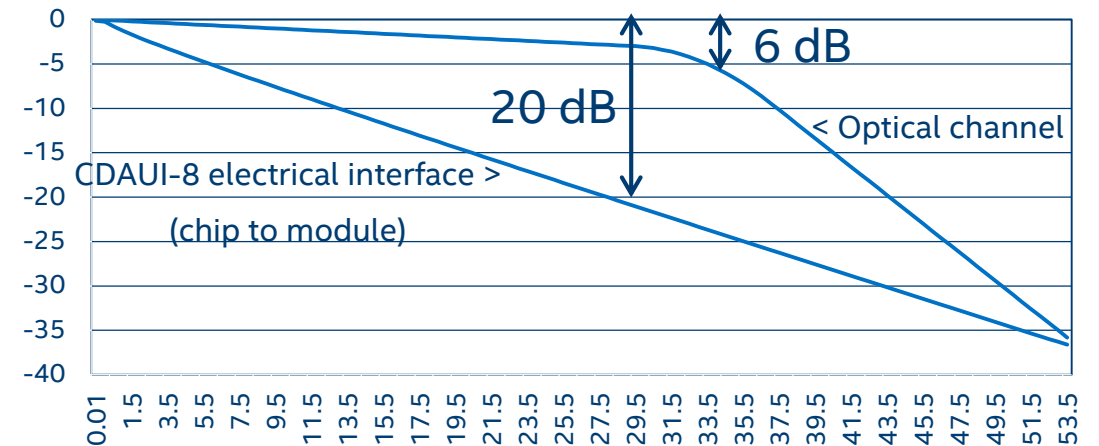
400G CWDM8 Benefits

- IEEE compliant 8 x 50G PAM4 electrical interface for compatibility with 12.8T switches and routers
- 8 λ x 50G NRZ CWDM optical interface for fully uncooled operation and best link performance on duplex singlemode fiber
- Proven technology, already demonstrated
- High link margin = high yield, low cost, maximum scalability, fastest time to volume
- Will comfortably fit in QSFP-DD and OSFP power envelope
- Transmission demonstrated at both 2 km and 10 km
 - Industry's only datacenter-targeted 10 km optical interface
- Technical approach lays groundwork for future 800G interfaces

PAM4 vs. NRZ

- **PAM4** is well-suited to channels with low bandwidth and high SNR
 - E.g. electrical DAC & backplane links
 - CDAUI-8: 20dB loss at 28G
 - Significant SNR penalty from multi-level signaling (4.8 dBo or higher)
- **NRZ** is well-suited to channels with higher bandwidth and lower SNR
 - Example optical channel: 3dBo loss at > 30G

Optical and electrical channel losses



400G Duplex Optical Interface Comparison: Optical Penalties and Losses

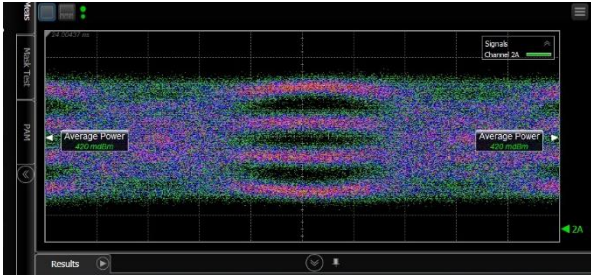
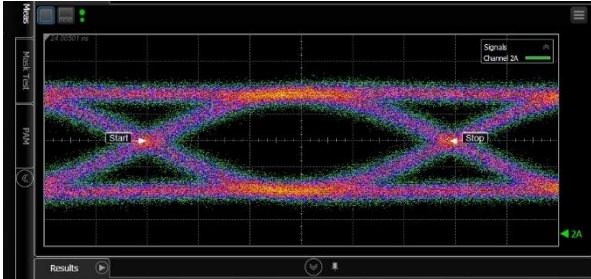
Link Penalty	8x50G PAM4 WDM (FR8)	8x50G NRZ CWDM (CWDM8)	4x100G PAM4 CWDM (FR4)
Higher BW modulator		1.5 dB	1.5 dB
Mux loss	2 dB	2 dB	2 dB
TDP/TDECQ	3.1 dB	2.8 dB	3.4 dB
PAM4 modulation	4.8 dB		4.8 dB
Channel loss (+MPI)	4.4 dB	4 dB	4.4 dB
Demux loss	3 dB	3 dB	3 dB
Rx noise BW penalty		1.5 dB	1.5 dB
PAM4 implementation ¹	1.5 dB		1.5 dB
Total penalties	18.8 dB	14.8 dB	22.1 dB

¹Estimated additional penalties for PAM4 (linearity/compression penalty, decreased timing margin, increased sensitivity to crosstalk/noise/ISI)

– cf. Xilinx DesignCon 2017 paper (>11dB penalty for 50G [25Gbd] PAM4 not including jitter and other sensitivity to impairments)

Also see Finisar 2014-15 link budget analysis presentations in IEEE

50G NRZ (CWDM8) Tx eye (test bed optics)

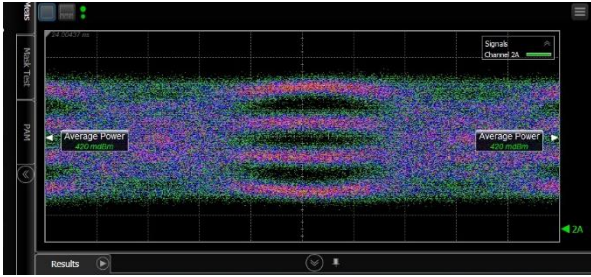
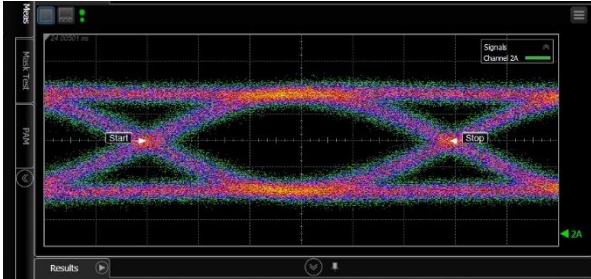


100G PAM4 (FR4) Tx eye (test bed optics)

400G Duplex Optical Interface Comparison: Optical Penalties and Losses

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50G NRZ (CWDM8) Tx eye (test bed optics)



100G PAM4 (FR4) Tx eye (test bed optics)

Good link margin / lower link penalties = high yield, low cost, maximum scalability, fastest time to volume

Optical Interface Transitions

High-volume singlemode optics

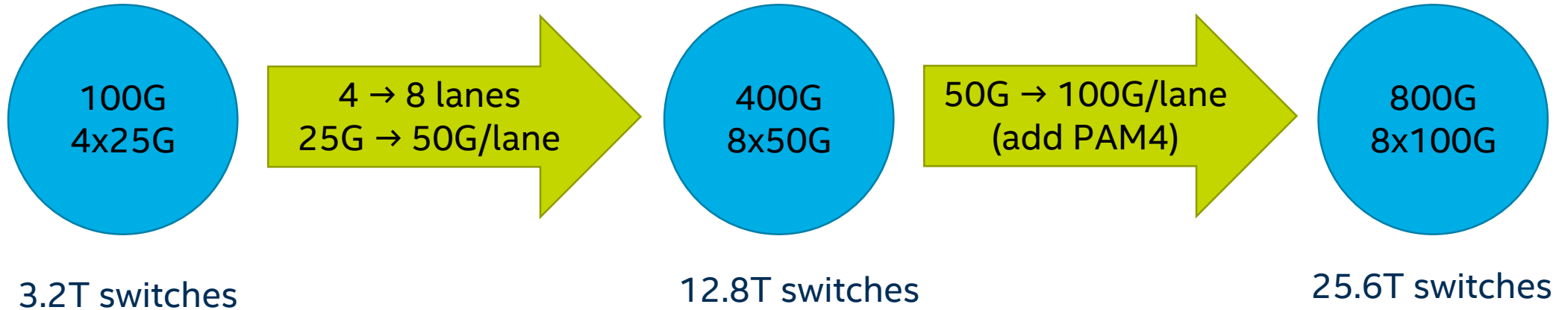
	1G	10G	40G	100G	400G duplex singlemode specs		
					CWDM8	FR4	FR8
Baud rate	1G	10G	10G	25G	50G	50G	25G
Link budget (Tx output – Rx sensitivity)	8 dB	7.4 dB	7.5 dB	6 dB	5 dB	>11 dB*	9.6 dB
New modulation format?	No	No	No	No	No	Yes	Yes
Time to volume	3 yrs.	6 yrs.	4 yrs.	6 yrs.	TBD	TBD	TBD

Tx/Rx numbers from IEEE or MSA interface specs

- Past lane speed transitions have all maintained or relaxed the effective channel budget, and have still proven very challenging and time-consuming to deploy and ramp (latest example: 100G)
 - CWDM8 keeps with this proven optical link introduction approach
 - Alternate approaches nearly triple the effective optical channel budget while simultaneously introducing a new data rate and new modulation format



Beyond 400G



- CWDM8 technology approach for 400G lays groundwork for future 2x400G or 800G interfaces for 25.6T switches
 - Allows time for maturity of 100G/lane PAM4 and optical component improvements

Products and Technology from the CWDM8 Ecosystem

Credo Raptor 400Z CDR Family for CWDM8 MSA

Raptor 400Z Family Members:

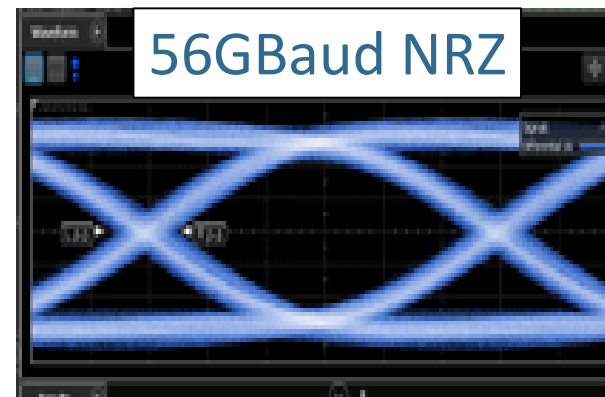
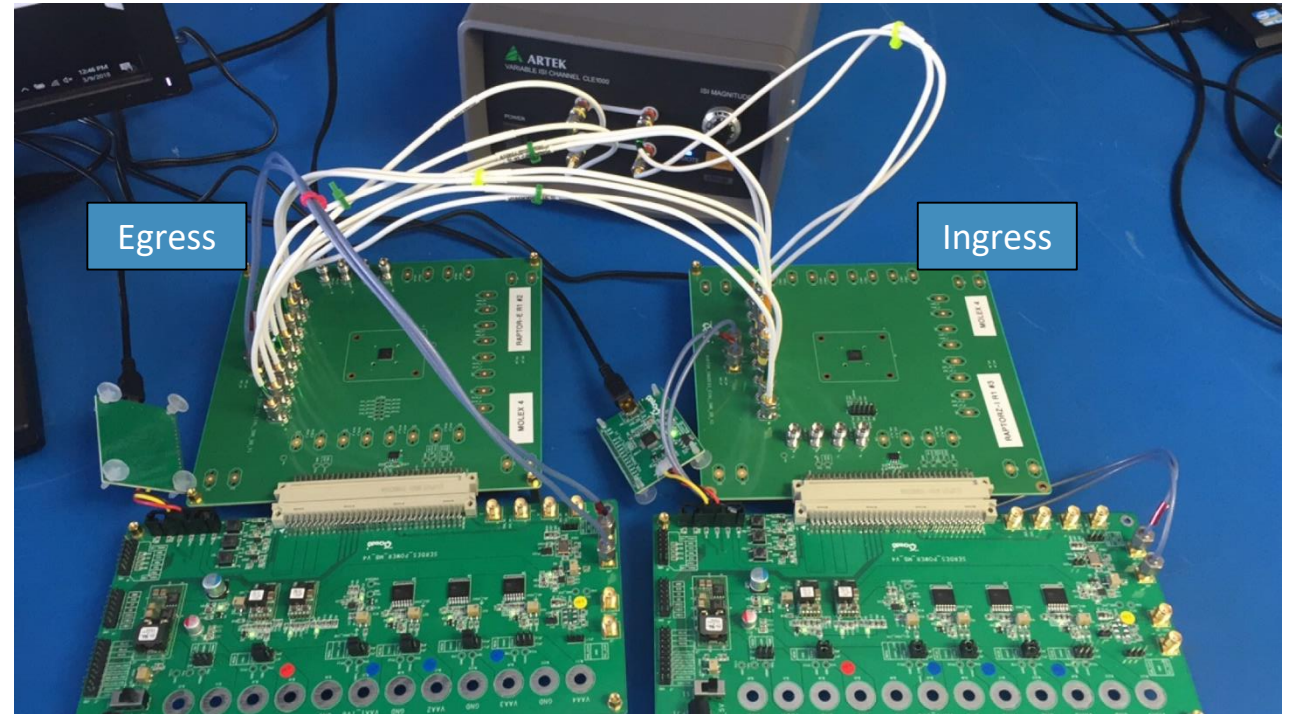
- Egress device (Tx)
 - 8x56Gbps PAM4 to 8x56Gbps NRZ
- Ingress device (Rx)
 - 8x56Gbps NRZ to 8x56Gbps PAM4

Standards Support:

- IEEE 400G-AUI-8
- OIF CEI-56G-VSR-PAM4
- OIF CEI-56G-VSR/MR-NRZ

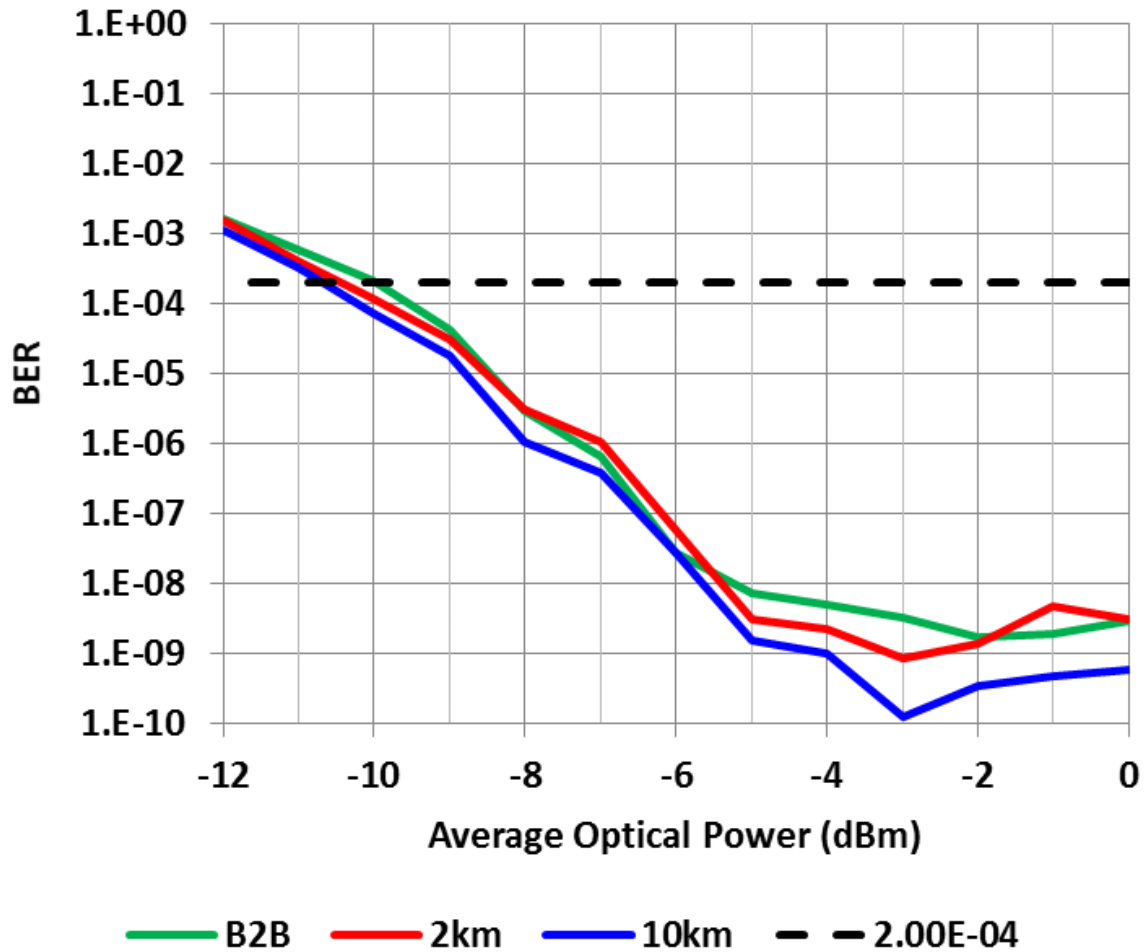
Availability:

- Evaluation boards: Now
- Samples: Now
- Production: 2H2018



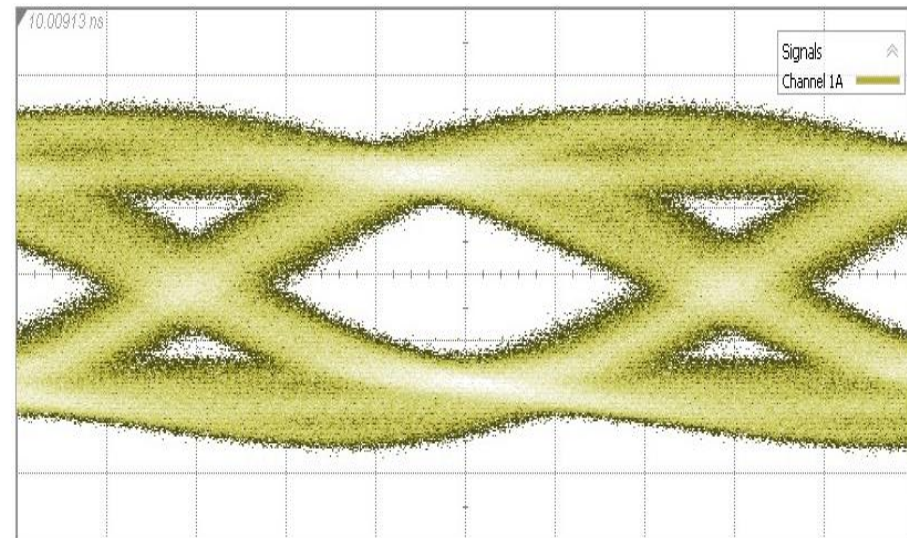
AOI 1310 nm DML for CWDM8

BER Results for AOI 1310nm DML



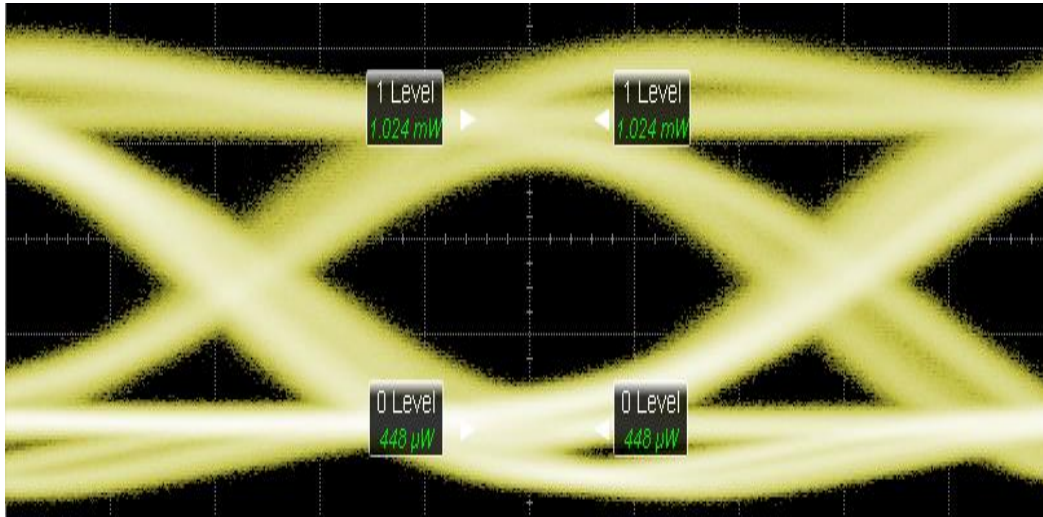
- Initial test data shows 53 Gbps NRZ DML is capable of 10 km transmission at 1310 nm wavelength
- Expected DML technology can work with CWDM8 application at 500 m reach

53Gbps NRZ eye at 25C, I_{op} = 55mA, ER = 4.5dB

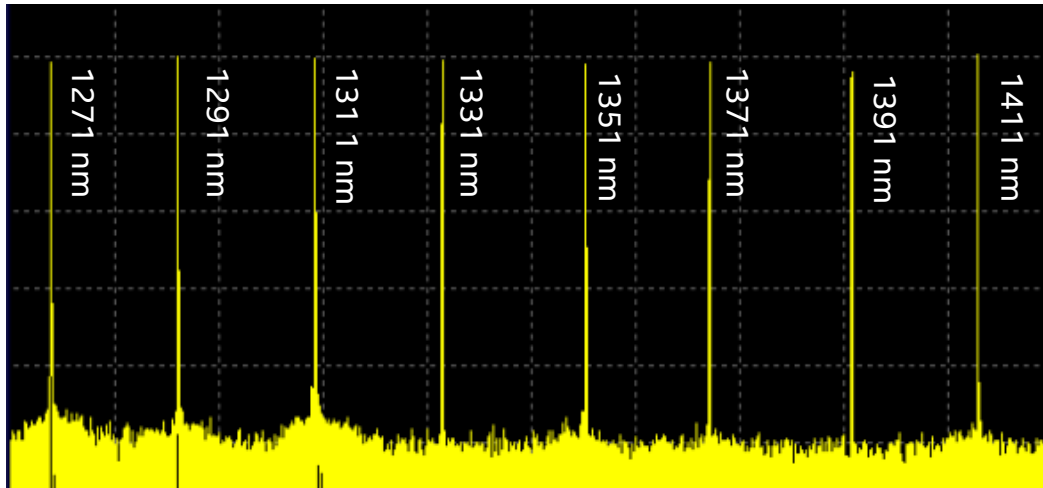
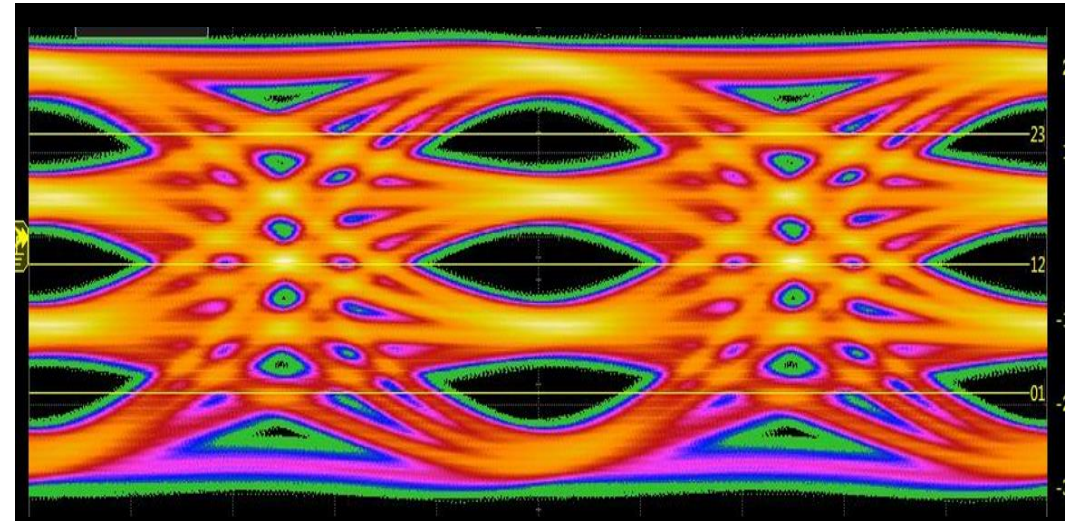


Intel 400G CWDM8 QSFP-DD Optical Module

400G Transmitter: Optical Output



400G Receiver: Host Side Electrical Output



Join Us

- The CWDM8 400G 2 km and 10 km optical interface specifications are available publicly at cwdm8-msa.org
- The CWDM8 MSA Group is taking on new member companies
- Interested in joining, or have any questions? Contact me at scott.schube@intel.com



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