SLT Sensor- und Lasertechnik GmbH

Power and Energy Measurement for Lasers

Sensor- und Lasertechnik

- Pyroelectric Detectors
- Thermopile Detectors
- Powermeter
- OEM-Detectors
- THz-Detectors

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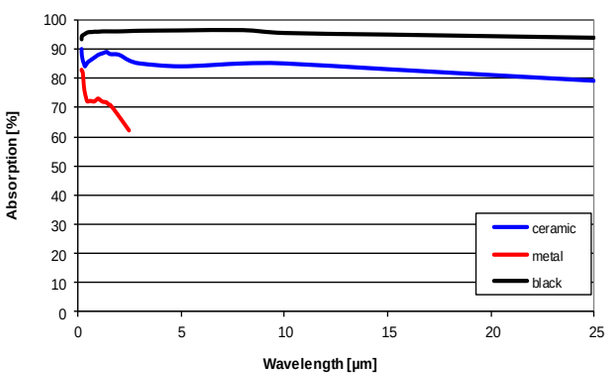
Coatings

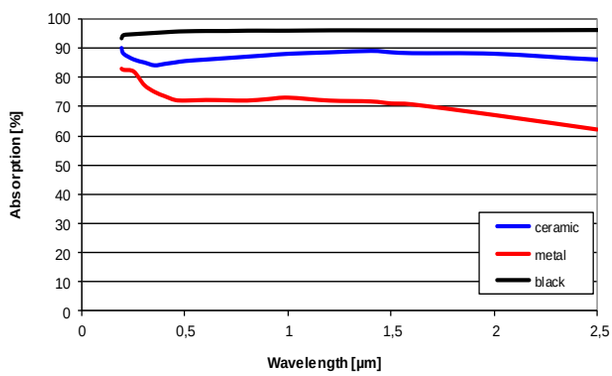
The absorber coating of the detector has to withstand the intense laser power. Its stability determines the lifetime of the detector. Nearly all absorbers are a compromise between wavelength independent absorption and stability.

We use three different coatings:

- Organic black coating with a high and nearly wavelength independent absorption of 97±1 % between 190 nm and 25 µm
- Ceramic based high power absorber, especially for all high peak power lasers (YAG, Excimer, CO_2)
- Metallic absorber with high thermal conductivity for high rep rates

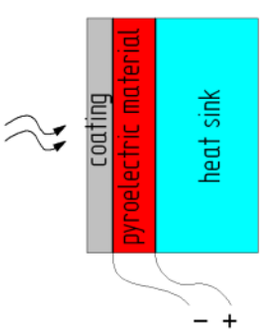
For wavelengths larger than 100 µm, the absorption decreases for all known absorbers , caused by an increasing transparency. This can only be compensated for by a larger thickness of the absorber leading to disadvantages for power and energy sensors.





Pyroelectric Detectors

Pyroelectric detectors belong to the class of thermal detectors. Such detectors work independent of wavelength. They consist of an absorber in good thermal contact to the pyroelectric element. Pyroelectric detectors do not need cooling and have the same sensitivity for all wavelengths as long as the absorption process is perfect.



The third element in the setup of a pyroelectric detector is the heat sink. It has good thermal contact to the pyroelectric sensor and is responsible for heat transfer to the surroundings.

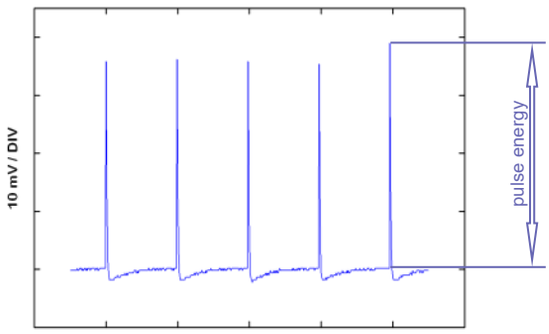
Pyroelectric sensors are only able to detect modulated or pulsed radiation.

Every pyroelectric sensor generates a charge proportional to the temperature change (the laser pulse energy). Dependent on the detection circuit, the charge is detected as a voltage peak, or the deviation of the

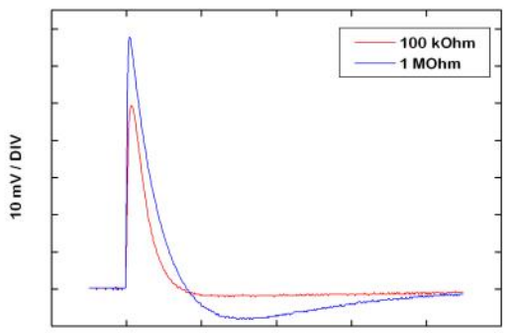
charge (a current) is detected proportional to the pulse power. For a correct measurement, the pulse duration must be smaller than the thermal time constant so no heat loss occurs during the measurement.

A good pyroelectric material shows linearity between energy and charge for at least 5 orders of magnitude.

Most of the detectors are coaxially arranged and very insensitive against electromagnetic disturbances. A benefit of such detector heads is that they can be directly connected to an oscilloscope and energies from µJ to J can be detected without an amplifier or readout unit.



typical output of an pyroelectric detector



output on dependence of load resistor

For a measurement of high rep. pulse lasers smaller thermal and electric time constants are desired. Dependent on the construction of the detectors, some types are able to detect pulse energies up to 100 kHz.

Three parameters limit the use of a pyroelectric detector:

- Too high peak power destroys or partially evaporates the absorber
- Too high average power and
- Too high pulse energy is dangerous for the sensor material

The limits depend on the wavelength of the radiation and the pulse duration. High threshold coatings are available for most sensor types.

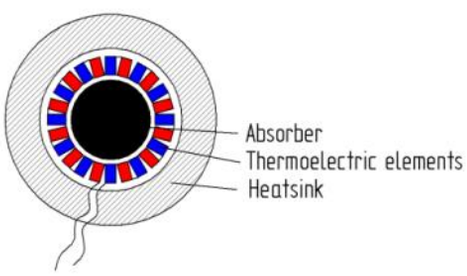
For all detectors the sensitivity (V/J) is specified for a load of 1 MΩ (oscilloscope) and for 100 kΩ for enabling higher rep. rates. For both loads the sensitivity is determined at 355 nm by a comparison with a master detector calibrated at PTB Braunschweig.

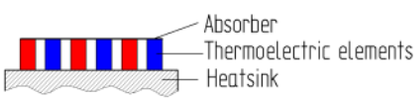
Thermopile Detectors

Such detectors are used for the determination of the average power of cw or repeatedly pulsed lasers. All types of thermopile detectors use the temperature gradient along the heat flow for the determination of the input power. As shown in the next figures the heat flow can proceed in axial or in radial directions. Independent of the setup, it needs a certain time to reach stationary state. Radial heat flux sensors have a shorter time constant and are able to handle higher power, whereas axial heat flow sensors can have higher sensitivities.

In most cases the time constant is larger than 1 second. This rise time can be reduced using adequate electronics, which is an advantage for the user, but for an evaluation of the fluctuation of pulsed lasers a pyroelectric detector is the better choice.

Similar to Joule meters the power meters can have different absorber sheets optimized for a broadband behaviour and lower power densities or for high peak powers and reduced wavelength independence.

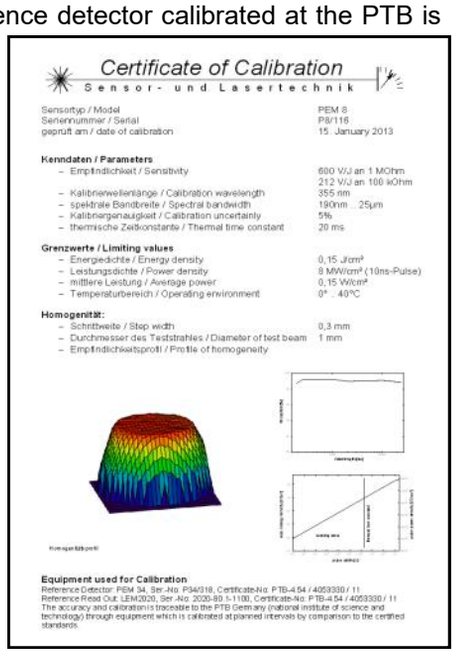




The axial design above has a much higher sensitivity than the radial design, shown on the left side. The radial types are optimal for high power applications.

Calibration

The calibration of our detectors is traceable to the PTB Braunschweig and Berlin (the National Metrological Institute). For calibration or recalibration of all detectors a reference detector calibrated at the PTB is used. During calibration procedure the output signal of the customer sample is compared with the output signal of the reference detector. To eliminate inaccuracies due to laser fluctuations, a beam splitter and a monitor detector is used.


Certificate of Calibration

Sensor- und Lasertechnik

Sensortyp / Model	PEM 8
Seriennummer / Serial	P8/116
geprüft am / date of calibration	15. January 2013

Kenndaten / Parameters

– Empfindlichkeit / Sensitivity	600 V/J an 1 MOhm 212 V/J an 100 kOhm
– Kalibrierwellenlänge / Calibration wavelength	355 nm
– spektrale Bandbreite / Spectral bandwidth	190nm ... 25µm
– Kalibriergenauigkeit / Calibration uncertainty	5%
– thermische Zeitkonstante / Thermal time constant	20 ms

Grenzwerte / Limiting values

– Energiedichte / Energy density	0,15 J/cm²
– Leistungsdichte / Power density	8 MW/cm² (10ns-Pulse)
– mittlere Leistung / Average power	0,15 W/cm²
– Temperaturbereich / Operating environment	0° ... 40°C

Homogenität:

– Schrittweite / Step width	0,3 mm
– Durchmesser des Teststrahles / Diameter of test beam	1 mm
– Empfindlichkeitsprofil / Profile of homogeneity	

Equipment used for Calibration

Reference Detector: PEM 34, Ser.-No: P34/318, Certificate-No: PTB-4.54 / 4053330 / 11
Reference Read Out: LEM2020, Ser.-No: 2020-89.1-1100, Certificate-No: PTB-4.54 / 4053330 / 11
The accuracy and calibration is traceable to the PTB Germany (national institute of science and technology) through equipment which is calibrated at planned intervals by comparison to the certified standards.

Normally the third harmonic of a YAG laser (355 nm) is used for the calibration of pyroelectric detectors and a diode laser (880 nm) is used for all thermopile detectors. For special requirements and for detectors having a strong wavelength dependent sensitivity, it is useful to calibrate at customer wavelengths. The following lasers and wavelengths are available.

Power and Energy Meter PEM 710

A large 7” capacitive touch panel and clearly arranged menus make this device very comfortable and easy to handle.

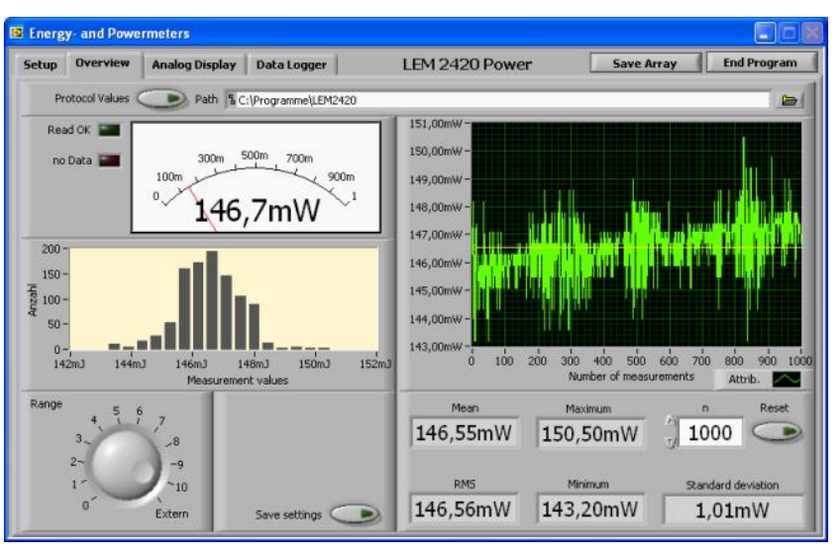
Very low noise amplifiers and for every signal path optimised AD converters, allow to use a wide range of sensor heads. After connecting a detector, the display read all relevant parameters from detector-EEPROM and setting up the device automatically. Manually setup possibilities for wave-length and correction are possible.

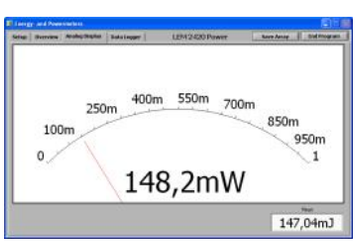
The large graphic display offers space for a variety of display and analysis choices. The digital display can be used for determining the energy, frequency and average power. The analogue part with its bar graph display is useful for e.g. laser adjustments. Laser stability can be monitored using the data logger and statistics window. Also a data logging window and a statistic window with histogram in selectable

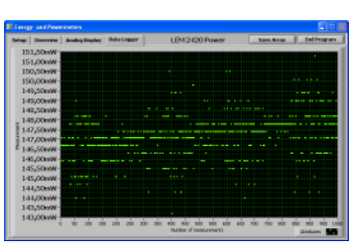
The PEM 710 is equipped with USB interfaces. These ports allow remote control and transferring of all data to a PC or USB memory stick. An analogue output give a lot of possibility fo integration the display into own measurement arrangements.

Displays

- For pyroelectric energy sensor heads and thermopile power sensor heads
- Digital display, analogue display, graphic data logger, statistics and histogram
- HiRes 7” Graphic display with background illumination
- Wide dynamic range
- Input of correction factors e.g. for mirrors or beam splitters
- Wavelength correction
- Adjustable trigger level
- Analogue output
- Capacitive touch panel
- USB 2.0 interface for remote operation
- compatible to all heads of PEM, HP, LP and BB series
- In energy mode rep rates 1000 pps
- Data storage on USB memory stick
- Compatible with E-connector with integrated EEPROM with all detector parameters
- Dimension 220 mm x 190 mm x 57 mm







A Labview based software for displaying all via USB transferred data is also available. An overview window shows a small analog instrument, Histogram, data logger and also some statistical results. Additionally it is possible to save the showed data into a file.

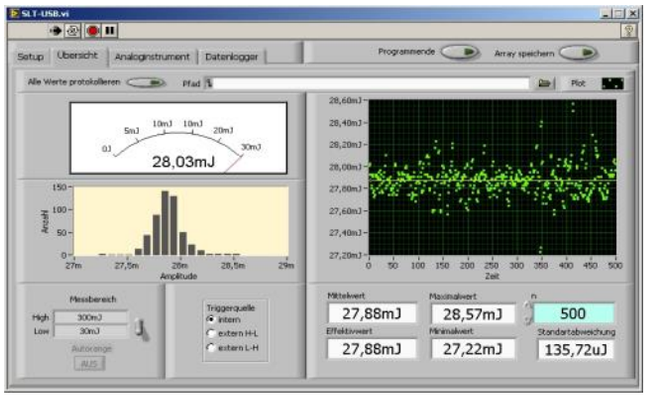
For adjustment work it is possible to switch to the analog instrument or the data logger.

Some basic Labview VIs for own projects are available. Because of the simple data structure and the simulated COM-port it is very easy to implement the device in other programming languages or other operating systems.

Pyrobox and Powerbox

Use this interfaces to connect your pyroelectric or thermopile detector directly to your PC.
It's simple to program and drivers for the most operating systems are available.

- USB 2.0 connection
- Power supply from USB
- Labview based software for different applications available (Analogue and digital display, data logger, statistics)
- Data transfer as ASCII code



Powerbox:

- For all thermopile detectors
- Compatible with E-connector
- Four ranges
- On request with RS232 output
- For BNC-Input choose Powerbox –OEM
- Dimensions 110 mm x 62 mm x 30 mm

Pyrobox:

- For all PEM detectors
- Two ranges
- Max. rep. rate 100 pps
- Additional external trigger input
- Dimensions 90 mm x 62 mm x 30 mm

LM100-3

This read out unit is designed to measure the output power of different lasers in combination with a thermopile detector. The maximum power is limited by the used power head. By using this read out unit it is possible to reduce the time constant of the whole measurement system to 1 second. Normally, the time constant of a power head is in the region of 15 to 25 seconds.

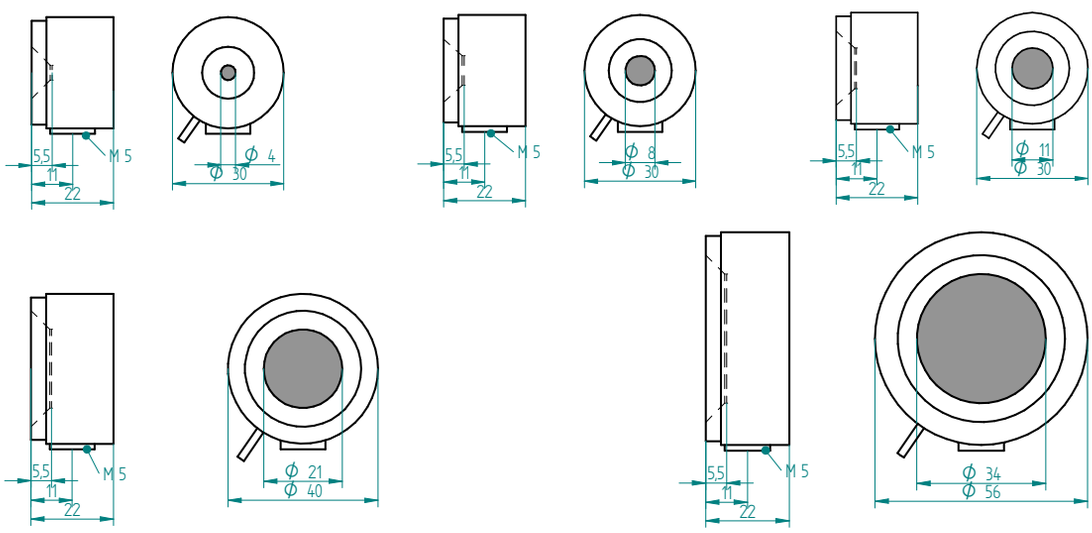
The LM100 is equipped with a rechargeable battery and charging unit. It is possible to operate the LM100 either from the power supply or rechargeable built-in batteries so that it remains versatile and can be adapted to most applications. The batteries are automatically charged when the instrument is plugged into the power supply. The batteries can also be charged when the LM100 is turned off. The charging circuit prevents the batteries from being overcharged. The state of the batteries and the charging circuit is displayed by two LEDs.

- large analogue display
- 8 ranges : 1 mW .. 3 W
- power supply and battery operation
- integrated charging unit
- time between charges: 300 hrs.
- time constant 1 sec.
- solid metal case
- outer dimensions: 160x180x70 mm³
- analogue output

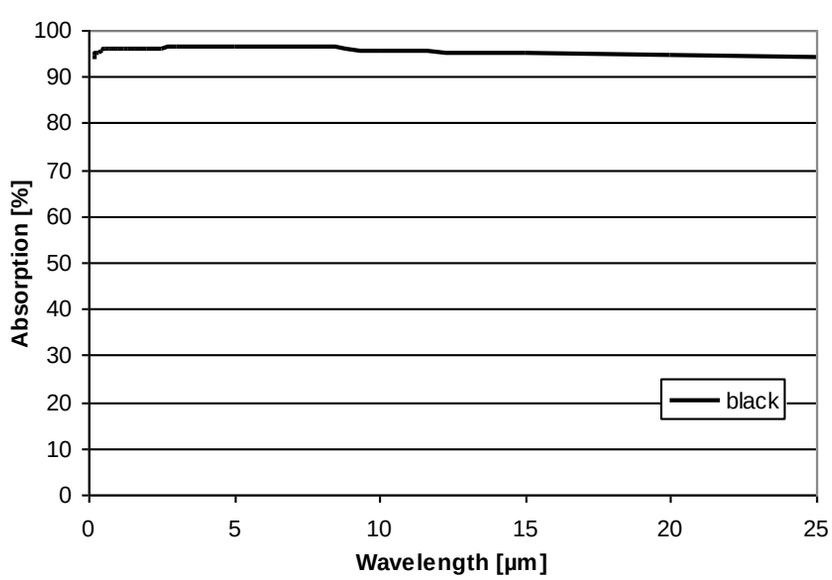
Series PEM Standard

The detectors are coated with a black absorption layer which possesses an almost constant absorption in the wavelength range from 185 nm to 25 µm. Particularly beneficial is the comparatively high sensitivity of the detectors which without an additional amplifier and due to the insensitivity to interferences permits laser pulse measurements in the µJ range.

The maximum pulse repetition rate depends on the internal capacitance of the detector as well as the load resistor. All detectors can be directly connected using the BNC connector to the 1 MOhm-Input of an oscilloscope. A small load resistor can be used to obtain the highest pulse repetition rate. Repetition rates of up to 100 Hz are then possible. Load resistors of 100 KOhm are part of the deliverable assortment. The corresponding sensitivity of the sensors is also specified.



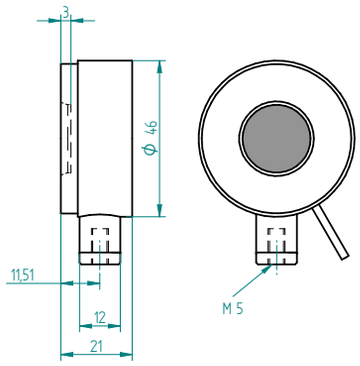
Type	PEM 4	PEM 8	PEM 11	PEM 21	PEM 34
active diameter	4 mm	8 mm	11 mm	21 mm	34 mm
working range with oscilloscope	1 µJ .. 10 mJ	2 µJ .. 30 mJ	3 µJ .. 70 mJ	5 µJ .. 200 mJ	15 µJ .. 500 mJ
sensitivity in V/J	500..1000 at 1 MΩ 130..250 at 100 kΩ	200..500 at 1 MΩ 50..200 at 100 kΩ	100..400 at 1 MΩ 50..150 at 100 kΩ	50..150 at 1 MΩ 30..80 at 100 kΩ	20.. 70 at 1 MΩ 10..40 at 100 kΩ
Repetition rates with oscilloscope	80 Hz at 1 MΩ 120 Hz at 100 kΩ	40 Hz at 1 MΩ 100 Hz at 100 kΩ	40 Hz at 1 MΩ 80 Hz at 100 kΩ	25 Hz at 1 MΩ 50 Hz at 100 kΩ	25 Hz at 1 MΩ 80 Hz at 100 kΩ
working range with PEM 710	0.1 µJ .. 10 mJ	0.2 µJ .. 30 mJ	0.3 µJ .. 70 mJ	0.5 µJ .. 200 mJ	1.5 µJ .. 500 mJ
Repetition rates with PEM 710	500 Hz	250 Hz	250 Hz	100 Hz	75 Hz
max. pulse duration	2 ms				
spectral range	0,19 .. >25 µm				
power density	8 MW/cm²				
energy density	80 mJ/cm² (10 ns - pulse); 160 mJ/cm² (20 ns - pulse)				
average power	0,15 W/cm²				
accuracy	2 %				
dimension (diameter · length)	30 mm x 22 mm	30 mm x 22 mm	30 mm x 22 mm	40 mm x 22 mm	56 mm x 22 mm
connector	BNC cable length 1.5m, E-connector with EEPROM				

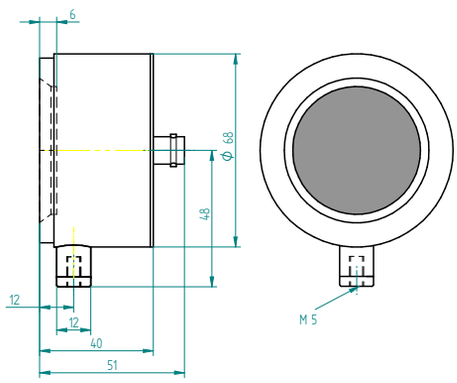


Series PEM HP

In opposition to our detectors of series PEM Standard this detectors are made for higher average power densities and a higher average power. As absorption coating we use our proven black coating with an very high and flat absorption over a wide wavelength range for these detectors.

	PEM 45 HP	PEM 20 HP
Diameter of active area	45 mm	20 mm
sensitivity	8 .. 15 V/J at 1 MOhm 4 .. 8 V/J at 100 kOhm	30 .. 50 V/J at 1 MOhm 8 .. 20 V/J at 100 kOhm
Max. repetition rate	25 Hz at 1 MOhm 100 Hz at 100 kOhm	50 Hz at 1 MOhm 150 Hz at 100 kOhm
Max. average power	5 W	3 W
Max. average power density	0.5 W/cm²	0.5 W/cm²
Detection threshold	100 µJ	50 µJ
Accuracy	±3 %	±3 %
Connector	BNC, E-connector with EEPROM	
Dimensions (Ø x Length)	70 mm x 47 mm	46 mm x 21 mm

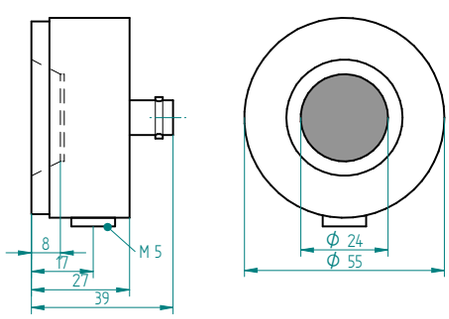


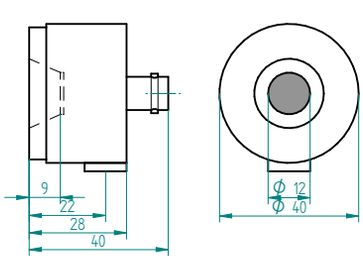


Series PEM HiRep

These sensors have a thin metallic or black absorption layer leading to a faster heat transfer to the sensor element. Repetition rates up to more than 2000 pps. are possible. The spectral behaviour is flat in the VIS and NIR but for longer wavelengths the absorption properties have to be taken into account. Main application is the use at one wavelength. The metallic coating of the two UV types is more stable in the ultraviolet region than the organic black coating.

	PEM 12 HiRep	PEM 24 HiRep	PEM 12 HiRep UV	PEM 24 HiRep UV
active diameter	12 mm	24 mm	12 mm	24 mm
sensitivity	20..30 V/J	20..30 V/J	35..45 V/J	35 .. 45 V/J
max. repetition rates	750 Hz	750 Hz	2,5 kHz	1,2 kHz
max. average power	2 W	5 W	2 W	5 W
max. energy density (10 ns pulse)	80 mJ/cm²	80 mJ/cm²	50 mJ/cm²	50 mJ/cm²
max. peak power density	8 MW/cm²	8 MW/cm²	5 MW/cm²	5 MW/cm²
working range	30 µJ - 100 mJ	30 µJ - 350 mJ	30 µJ - 60 mJ	30 µJ - 250 mJ
accuracy	±3%	±3%	±3%	±3%
dimension (diameter x length)	40 mm x 40 mm	55 mm x 39 mm	40 mm x 40 mm	55 mm x 39 mm





Series PEM K

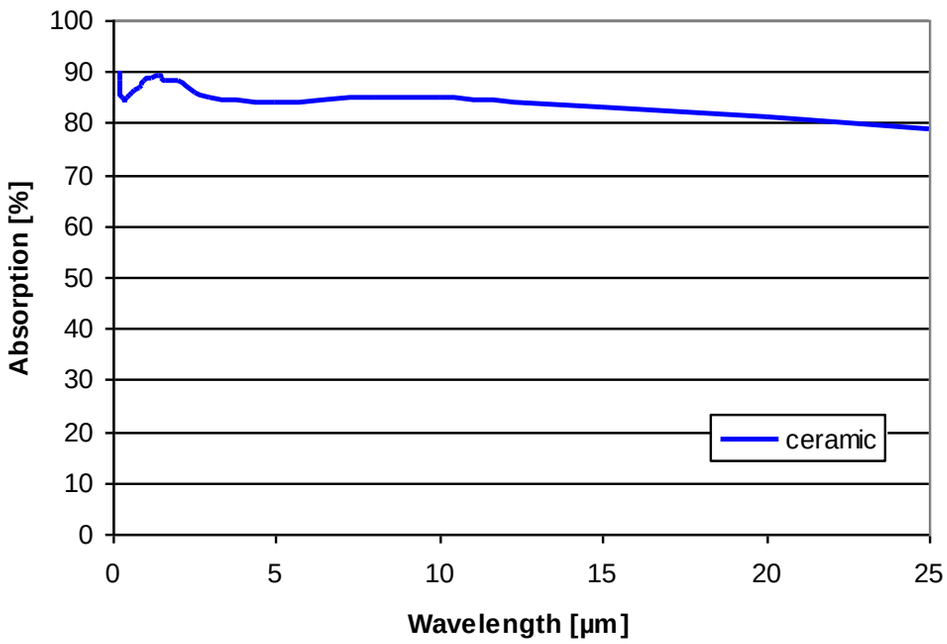
Main applications for this detector are pulse lasers with high power density (Excimer-, CO_2-TEA-, Nd-YAG-Laser). With this device we offer a sensor that can be used in a wide range of applications due to a high damage threshold, a short time constant, relatively high sensitivity and high aperture.

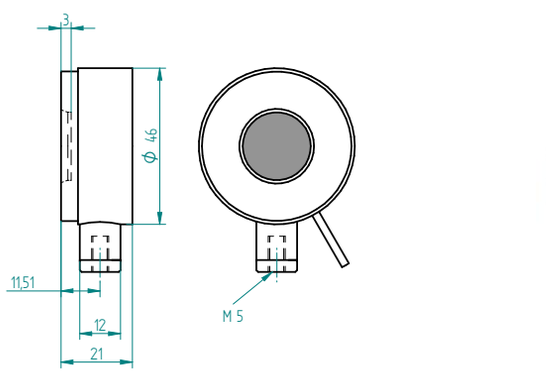
In opposite to other coatings these coating is very resistant. So it is possible to clean the surface with most solvents or disinfectants. This fact and the high damage threshold for Excimer lasers make these types ideal for medical applications.

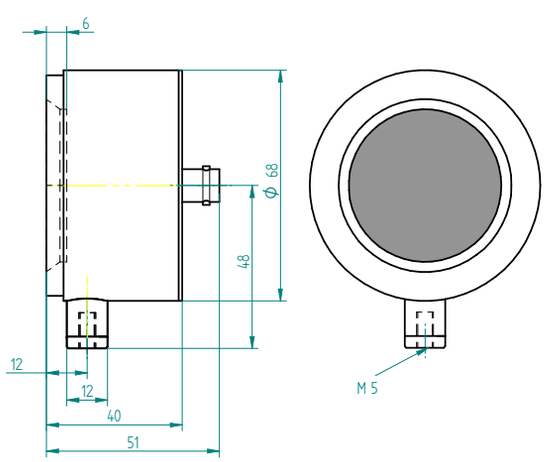
	PEM 45 K	PEM 20 K
Diameter of active area	45 mm	20 mm
sensitivity	1.5 .. 3.5 V/J at 1 MOhm 0.5 .. 1.5 V/J at 100 kOhm	10 .. 15 V/J at 1 MOhm
Max. repetition rate	30 Hz at 1 MOhm	30 Hz at 1 MOhm
Max. average power	5 W	3 W
Max. average power density	0.5 W/cm²	0.5 W/cm²
Detection threshold	1 mJ	500 µJ
Accuracy	±3 %	±3 %
Connector	BNC, E-connector with EEPROM	
Dimensions (Ø x Length)	68 mm x 51 mm	46 mm x 21 mm

permissible power- and energy densities at selected wavelengths:

	Peak power density	Energy density
Excimer, 308 nm, τ = 20 ns	50 MW /cm²	1 J/cm²
Nd:YAG, THG, 355 nm, τ = 7 ns	65 MW /cm²	450 mJ/cm²
Nd:YAG, SHG, 532 nm, τ = 8 ns	70 MW /cm²	560 mJ/cm²
Nd:YAG, 1064 nm, τ = 8 ns	120 MW /cm²	970 mJ/cm²
CO_2-TEA, 10,6 µm, τ = 0,5 µs	10 MW /cm²	5 J/cm²

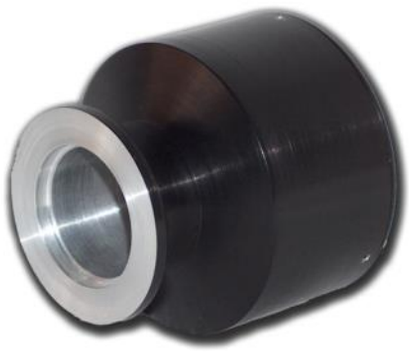

Absorption [%]
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
Wavelength [µm]
ceramic

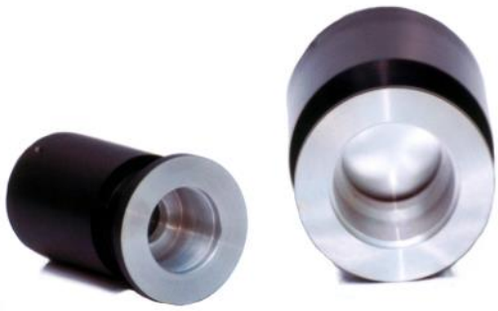

3
ϕ 46
11,51
12
21
M 5


6
ϕ 68
48
12
12
40
51
M 5

Series PEM VUV

Special design with vacuum flange for 157nm and all other wavelengths where stirring gas or encapsulated beam guiding are used. The detectors are leak tested.





	PEM 10 VUV	PEM 20 VUV	PEM 24 VUV	PEM 30 K VUV
Aperture	10 mm	20 mm	24 mm	30 mm
Sensitivity	30 .. 50 V/J at 1 MΩ	15 .. 25 V/J at 1 MΩ	200 V/J at 1 MΩ	1.5 .. 2.5V/J at 1 MΩ
Repetition Rate	50 Hz at 1 MΩ	150 Hz at 1 MΩ	300 Hz at 1 MΩ	50 Hz at 1 MΩ
max. average power	5 W	5 W	5 W	30 W
accuracy	±5 %	±5 %	±5 %	±5 %
max. energy density (t=10ns)	50 mJ/cm²	50 mJ/cm²	100 mJ/cm²	300 mJ/cm²
Max. peak power density	5 MW/cm²	5 MW/cm²	5 MW/cm²	30 MW/cm²
Detection threshold	100 µJ	200 µJ	5 µJ	1 mJ
Window	MgF_2	MgF_2	none	none
Connector	SMA	SMA	BNC	BNC
Vacuum connector	KF 16 ND	KF 25 ND	KF 25 ND	KF 40 ND
Dimension (incl. connectors)	Ø30 mm, length 54 mm	Ø 42 mm, length 72 mm	Ø55 mm, length 65 mm	Ø100 mm, length 96 mm
Read out unit	PEM 710 or Scope			

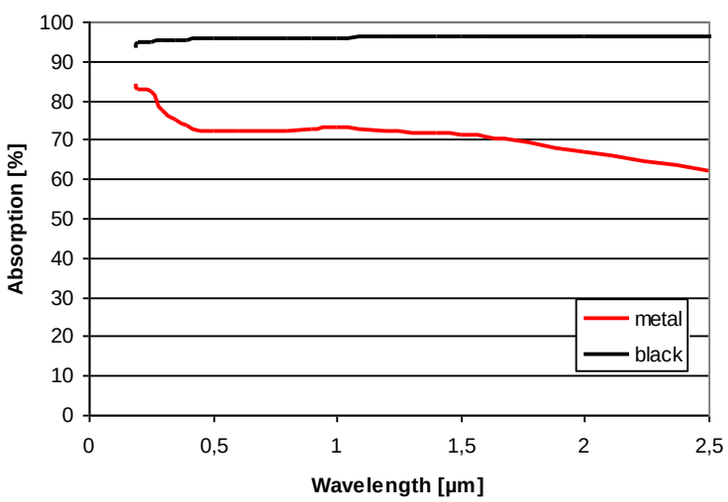
Series PEM E

The PEM12E is a 12 mm diam. Sensor, combined with a low noise preamplifier. So it is possible to measure smallest laser energies. To use the whole dynamic range of the built in sensor element, the detector is equipped with a switch for changing the amplification. We offer this detector with two different coatings. For use at different wavelengths we recommend our reliable broadband black coating, whereas for high repetition rates and the UV range we recommend the metallic coating. Higher sensitivities and repetition rates are possible on request

Sensor types:

PEM 12E MC – metallic coating

PEM 12 E BC – black coating



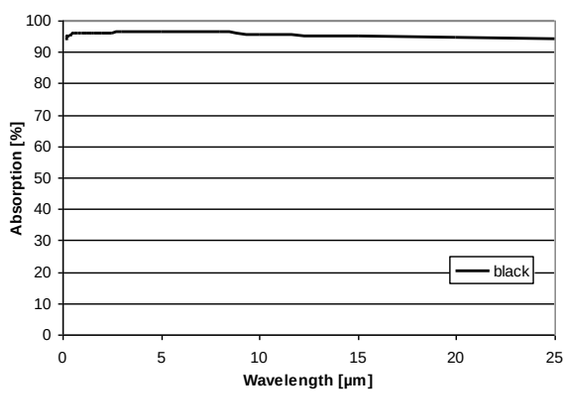
Sensitivity (switchable)	about 1000 V/J / about 10000 V/J
Working range	5 µJ .. 15 mJ
	500 nJ .. 1,5 mJ
Repetitions rate	1 kHz (black coating)
	5 kHz (metal coating)
Max. average. power	500 mW
Max. energy density [τ=10ns)	50 mJ/cm²
Active diameter	12 mm
Read out	Scope
Outer dimensions	25mm x 25mm x 60mm

Series PEM USB

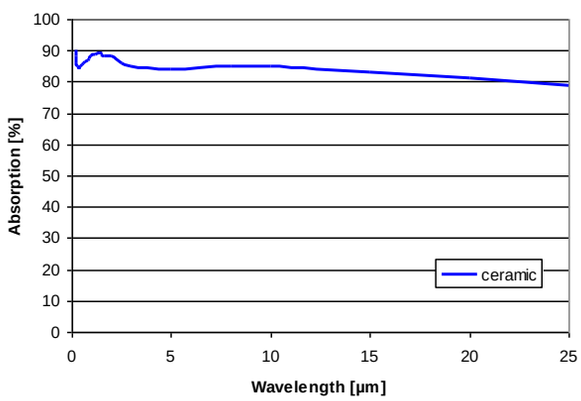
This pyroelectric detectors PEM45KUSB respectively PEM45USB are a combination of a robust pyroelectric sensor with a read out electronic with USB-port. It can be connected to an oscilloscope using the BNC-connector or to a PC using the USB port. In USB mode the BNC connector is an external trigger input.
The output signal is transferred to a connected PC via USB. The device is powered from the USB-port. To display the measured values an user friendly software is available.

The PEM 20 USB is the result of the combination of a very sensitive and low noise sensor with a high quality preamplifier for lowest laser energies. In comparison to other products in this class of sensitivity our detector features a large aperture and a windowless design.
A comfortable user interface allows a comfortable operation with a lot of display and analysis possibilities. For initial operation no driver installation is necessary. For own applications a DLL and a Labview library is available.

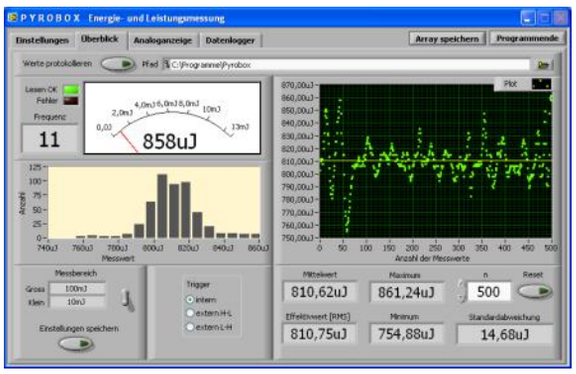
	PEM 20 USB	PEM 45 USB	PEM 45 K USB
active diameter	20 mm	45 mm	45 mm
sensitivity with oscilloscope	—	8 .. 15 V/J	1,5 .. 3,5 V/J
working range with USB	250 nJ - 2.5 mJ	100µJ – 200 mJ	1 mJ – 1 J
repetition rate	80 Hz	30 Hz	30 Hz
max. average power		5 W	5 W
max. energy density	80 mJ7cm²	80 mJ/cm²	1 J/cm²
max. pulse density	8 MW/cm²	8 MW/cm²	120 MW/cm²
accuracy	±3 %	±3 %	±3 %
connector	USB	BNC, USB	BNC, USB
dimension	70 x 42 x 18 mm³	diameter 68 mm, length 53 mm	

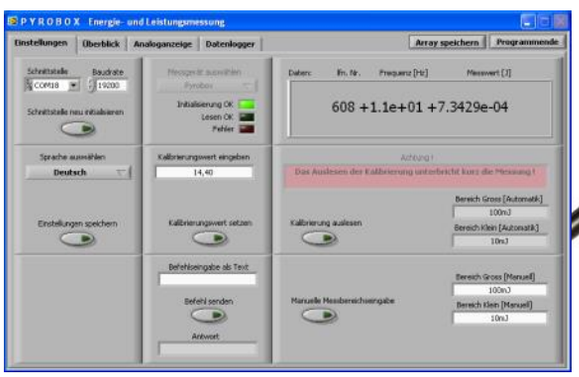


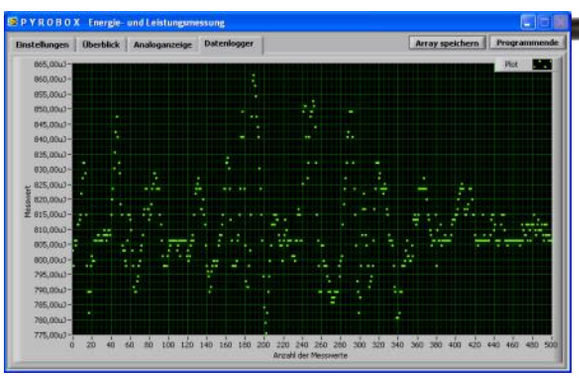
Absorption PEM 45 USB, PEM 20 USB

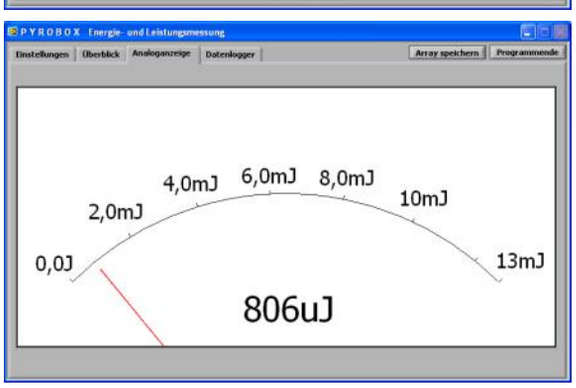


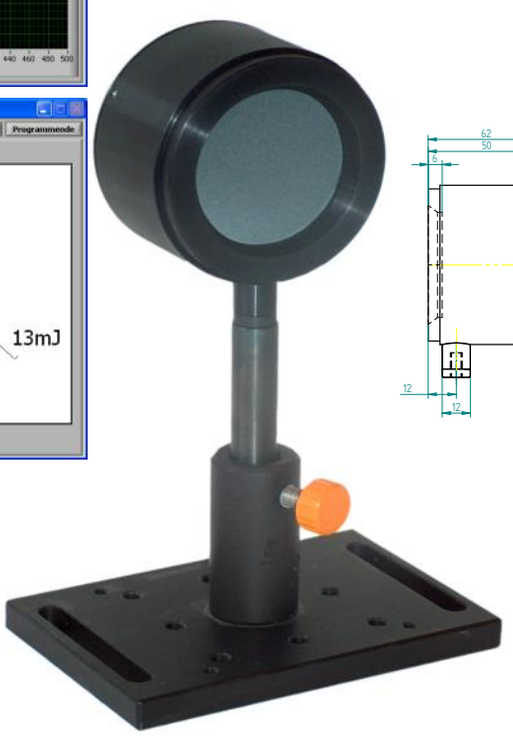
Absorption PEM 45 K USB


PYROBOX Energie- und Leistungsmessung
Einstellungen
Überblick
Analoganzeige
Datenlogger
Array speichern
Programmende
858uJ
Mittelwert
810,62uJ
Maximum
861,24uJ
Effektivwert [RMS]
810,75uJ
Minimum
754,88uJ
Standardabweichung
14,68uJ


PYROBOX Energie- und Leistungsmessung
608 +1.1e+01 +7.3429e-04


PYROBOX Energie- und Leistungsmessung
Datenlogger


PYROBOX Energie- und Leistungsmessung
Analoganzeige
0,0J
2,0mJ
4,0mJ
6,0mJ
8,0mJ
10mJ
13mJ
806uJ



62
50
6
Ø 58
12
12
Ø 8
M 5

Power Detectors

Thermopile Detectors

The listed power heads are based on thermoelectric principles, which means that the heat generated from the incident radiation is transformed directly into a voltage.

The heads of BB – series have a black, broadband absorbing coating, whereas the HP – series is equipped with a ceramic layer allowing higher energy and power densities.

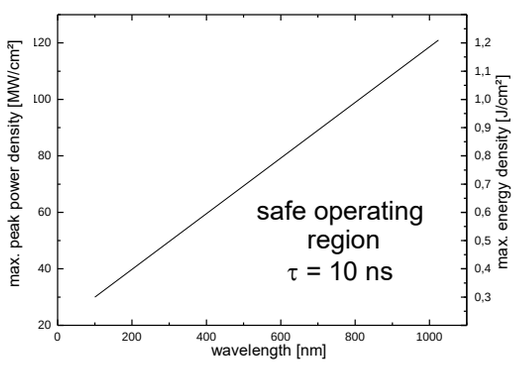
The head HP 25 S is specially made for service application. The compact dimensions enable easier transport. Due to the smaller heat sink, high powers are only possible for a short time.

The heads need several seconds to reach a thermal equilibrium. To avoid this delay time, we recommend the use of one of our read out units, such as LM 100 or PEM710. These devices determine the voltage and their increase and evaluate the laser power from this data. The time constant of the whole system is reduced to 1 second.

The main characteristic of the LP sensor is the very high sensitivity. This enables the sensor to measure small laser power with high precision and resolution over the high dynamic range of 6 orders of magnitude. For stabilisation of the sensor one can use a thermal isolation of the sensor housing. Additionally, the housing has a removable tube to protect the surface against stray light and air moving. Additionally, you can replace the tube by special adapters for using optical fibres.

	BB 10*	LP 20	BB 25 S	HP 25 S	HP 25 / 50
active diameter	10 mm	20 mm	25 mm	25 mm	25 mm
Power range	100 µW - 3 W	10 µW - 3 W	1 mW - 10 W	1 mW - 10 W	1 mW - 50 W
max. power density	40 W/cm²	2.5 W/cm²	40 W/cm²	40 W/cm²	40 W/cm²
sensitivity	250 mV/W	5 V/W	70 mV/W .. 150 mV/W		
Cooling	convection				
connector	E-connector with EEPROM				

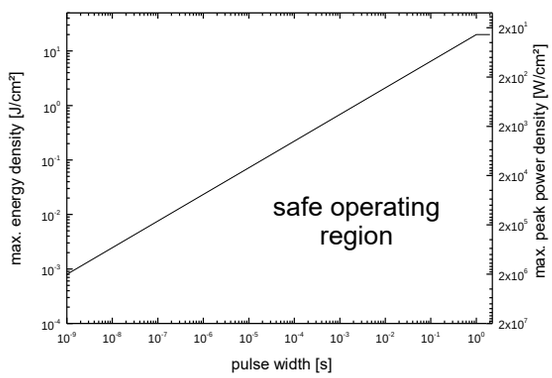
permissible power and energy densities vs. wavelength for sensors of HP-series

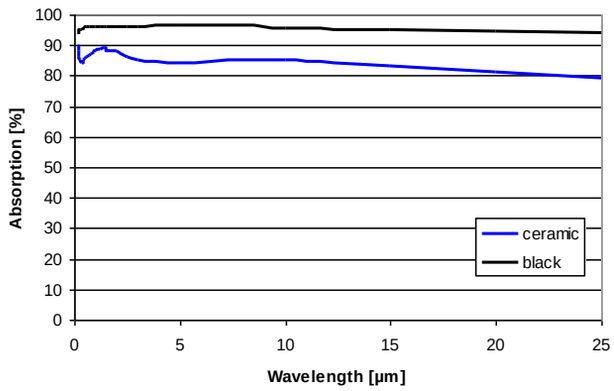


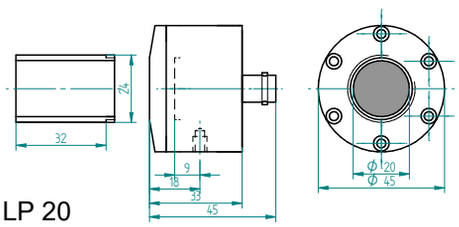
for pulses with width τ[ns] apply:

$$E_{max}[J/cm^2] = 10^{-2} \cdot (5 + 0{,}03 \cdot \lambda[nm]) \cdot \sqrt{\tau[ns]}$$

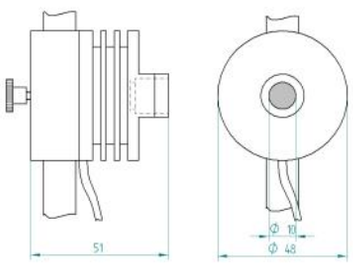
permissible power and energy densities vs. pulse width for sensors of BB-series



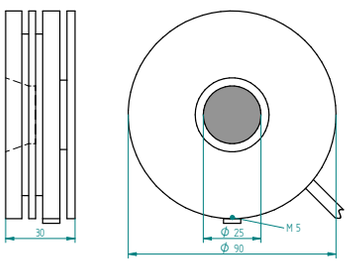




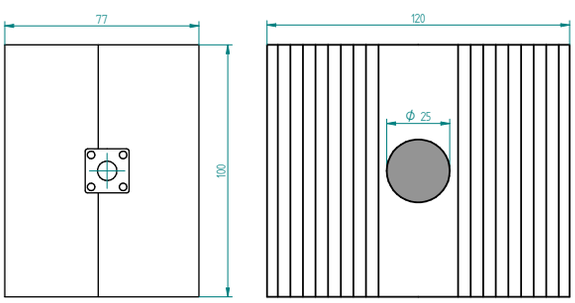
LP 20



BB 10



BB 25 S



HP 25/50

THz-Detectors

Basics

These types of pyroelectric detectors are optimized for application in THz region. The detectors are small, have a large active area and a short response time.
The basic principle of pyroelectric detection is that the radiation pulse coming from a pulsed laser or a chopped cw-laser is absorbed in an absorber sheet. From there the heat energy is transferred to the pyroelectric sensor material by heat conduction. For all types of THz detectors a broadband metallic absorber is used. For realizing broadband absorption a partial absorption of nearly 50 % is realized, whereas 25% are reflected and the 25% transmitted radiation is absorbed in a dump. A temperature change of the sensor material leads to a generation of a free charge at two opposite surfaces of the sensor. The thermal time constant (τ_{therm}) describes the relaxation of the sensor temperature to the ambient temperature.

There are two possibilities to detect this signal:

- Using a **voltage detection** with a high load resistor R fulfils the condition:

$$RC \gg t_{imp}$$

R - input resistance of the amplifier
C - capacity of the sensor element
t_{imp} - pulse duration

Furthermore the condition:

$$t_{imp} \ll t_{therm}$$

t_{imp} - pulse duration
t_{therm} - thermal time constant

must be fulfilled. In this case the output signal is proportional to the **energy of the pulse**. This is a typical principle for joule meters. Sensitivity is given in V/J.

- If the RC constant is smaller than the pulse duration, the **current** is measured. The output current is proportional to the **pulse power**. The condition:

$$t_{imp} \ll t_{therm}$$

must be fulfilled, too.

The THz detection system consists of a detector and a current preamplifier. It is optimized for application in connection with cw- lasers and a chopper.

The response of a pyroelectric detector can be very fast, but for a reduction of noise the bandwidth of the preamplifier is limited. A further reduction of noise is possible by using detectors with smaller active area. The actual bandwidth depends on the frequency limit and is given in the preamplifier datasheet. Two possibilities for a Signal/Noise improvement for continuously repeated signals are often used:
-Averaging
-Lock in amplification.

THz - Detector as Joulemeters

For many application the pyroelectric sensors can be used directly in combination with an oscilloscope (R_i= 1 MΩ). For these conditions the parameters (min. detectable energy and the max. rep. rate) are limited. In combination with a preamplifier these parameters can be extended. Some typical parameters for detectors without preamplifier are summarized in the following list:

	Sensitivity /V/J	Min. detect. energy /µJ	Max. rep. rate
THz 10	>500	0.5	30
THz 20	>200	1	25
THz 30	>20	2	20

Preamplifiers:

In dependence on sensor diameter and rep.- rate sensitivities up to 10^6 V/J can be realized. Max. rep. rates as high as 1000 pps and min. detectable energies in the order of 50 nJ are possible. Please ask for more information.

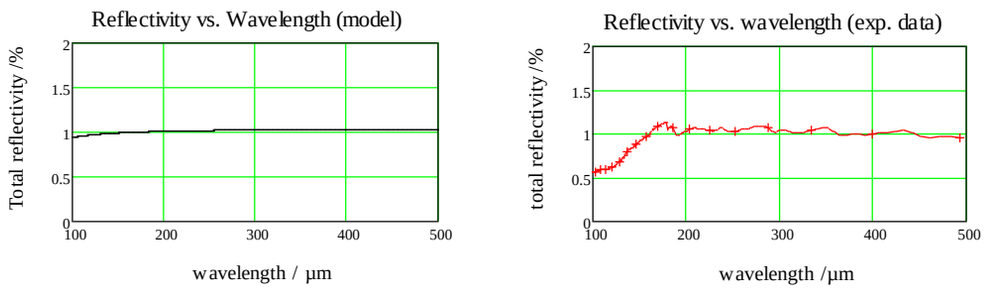
Calibration

All detectors are calibrated from PTB Germany at a wavelength of 2.4 THz in combination with a preamplifier. Other conditions on request.

The calibration of the detector is done without any window. Under these conditions any movement of air must be avoided. We deliver the detector with a protection cap having a THz transparent insert. This cap can be used for avoiding any type of disturbance from moving air or fans. You have to check if this cap can be used for your wavelength and have in mind that the calibration is done without this cap. Furthermore it is advisable to tilt the detector a little bit against the optical axes for avoiding reflexions back to the source.

Trap detector

Such a detector is characterized by a very flat spectral behaviour in the THz region. It can be calibrated at PTB in Berlin and it should be used as a calibrated normal for your lab. The 3-D arrangement of 3 sensors causes a polarization independent detection using 5 interactions of the incoming radiation with sensors. Consequently the total absorption is near to 100 % for a single absorption of >60%. The expected reflection loss is $0.4^5 < 1$ %. Normally such a detector is combined with a current preamplifier for a measurement of the power of the chopped laser.



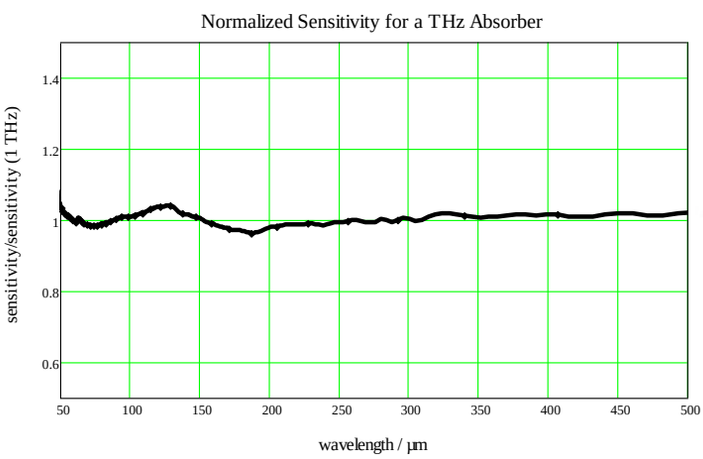
Total reflectivity (loss) for a 3 element trap, left modelled and right calculated from measured data for one detector.

Diam. of active area	20 mm
Max. power density	15 mW/cm²
Max. power	50 mW
Thermal time constant	>50 ms
Rise time*	<2 ms
Min. Detect. Power **	17 Hz: 15 µW; $f_{chopper\ max.}$: 10Hz 40 Hz: 25 µW; $f_{chopper\ max.}$: 25 Hz 70Hz: 100 µW; $f_{chopper\ max.}$: 50 Hz
Typ. Current sensitivity	0.5... 1 µA /W
Chopper frequencies*	8... 50 Hz

* only detector
**depends on parameters of the amplifier and detector

Single element detectors

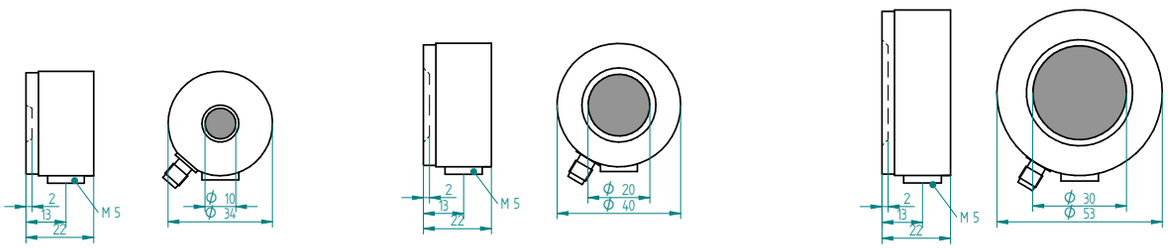
	THz 10	THz 20	THz 30
Diam. of active area [mm]	10	20	30
thermal time constant [ms]	50	50	50
Max. power density [mW/cm²]	15	15	15
Typical current sensitivity [µA/W]	0.5 ...1	0.5 ...1	0.5 ...1
Rise time * [µs]	100	700	2000
Max. chopper rate* [Hz]	>500	200	80
*Amplifiers for high rep. rate application on request			



This figure shows the sensitivity of the pyroelectric detectors normalized with the sensitivity at 1 THz. Between 200 and 500 µm the sensitivity changes within 2 %.

Detection limits for different preamplifiers in µW

Diam. of active area/mm	Preamplifier f_{gu} =17 Hz	Preamplifier f_{gu} =70 Hz	Preamplifier f_{gu} =200 Hz	Preamplifier f_{gu} =4 kHz
10	8	20	25	100
20	10	25	35	130
30	20	35	140	180



Band-Pass Filter

Product description

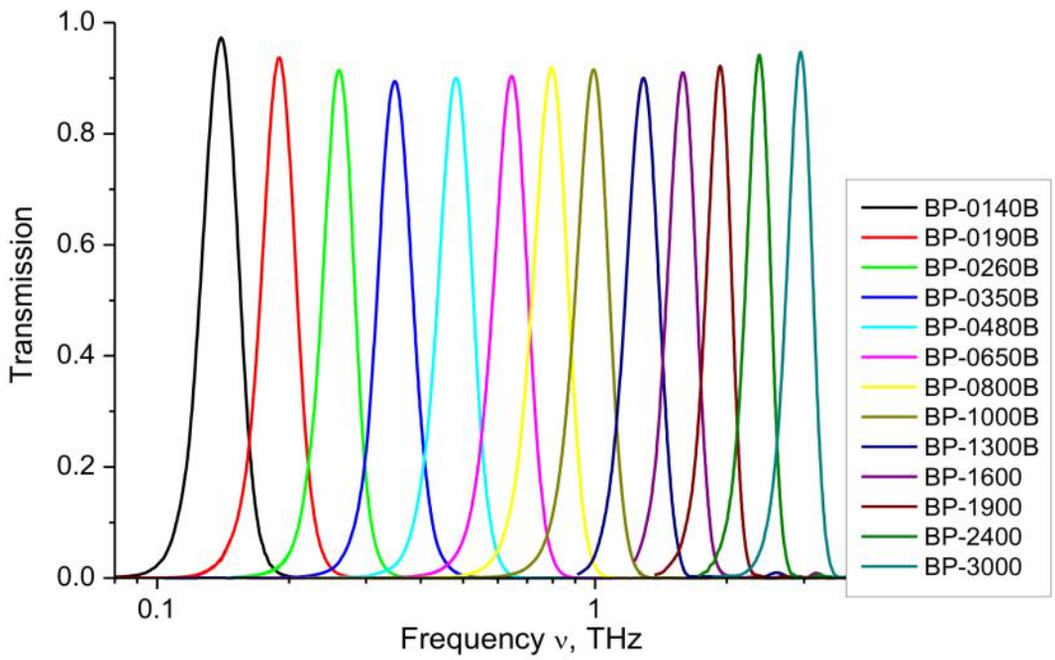
Quasi-optical band-pass filters are intended for selecting specified frequencies in the range of mm - and submm-waves. The filters can be used in a variety of applications including laboratory and space research.

The filters are implemented on basis of specially designed multilayer frequency selective microstructures, which resonantly transmit the radiation within a specified frequency band and reflect the out-of-band radiation. We offer a wide choice of high performance band-pass filters with central frequencies up to several THz. The filters exhibit high peak transmission and low out-of-band spectral leakage. To maximize the out-of-band blocking, two filters in series can be easily employed without significant losses in a peak transmittance.

Additionally, the filters can be designed according to the customer's specification. The filter characteristics can be optionally customized. Our filter technology is versatile and can be optimized for a wide range of experimental demands including operation in cryogenic environment.

Key features:

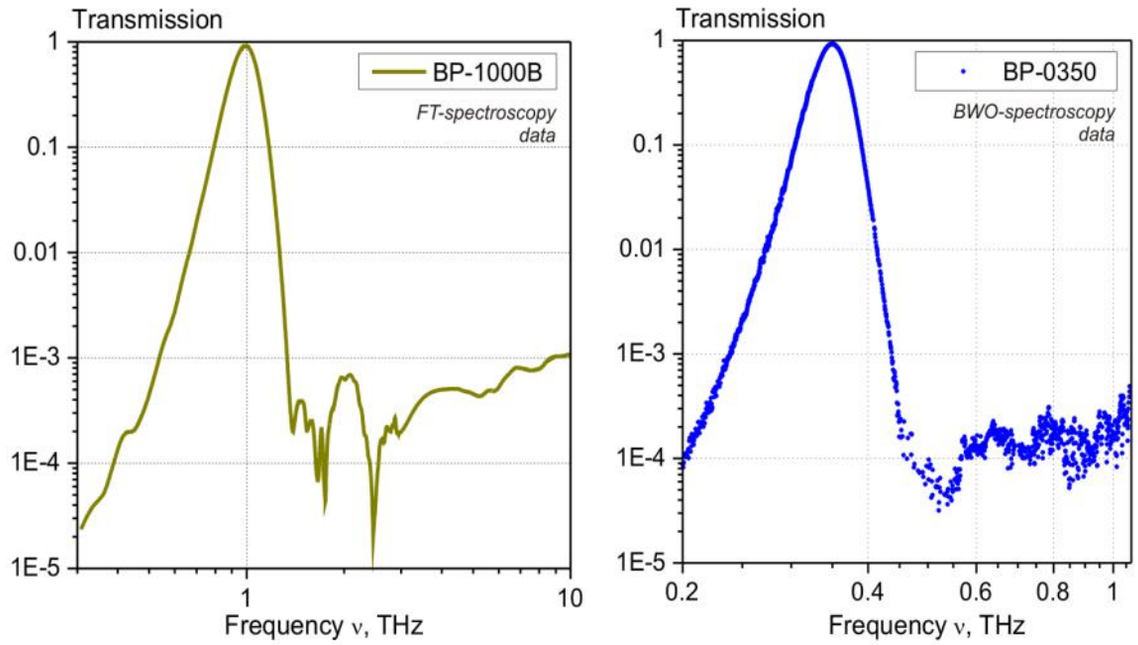
Central frequency of transmission maximum:	ν_{max} 0.07 ÷ 3 THz
Relative bandwidth:	15 ÷ 20 %
Peak transmission:	84 ÷ 97 %
Out-of-band blocking:	23 ÷ 40 dB
Standard clear aperture:	ø50 mm
Polarization insensitivity	
Compatibility with operation in vacuum	



Examples of experimentally measured transmission spectra for some standard filters (BWO+FT-spectroscopy data)

Filter model	Center frequency ν_{Max} [THz] *	Peak transmission T_{max} **	Relative bandwidth $\Delta\nu/\nu_{max}$ ***	Out-of-band spectral leaage ****
BP-0075	0.075	0.95	0.15	$\leq 10^{-4}$
BP-0094	0.094	0.95	0.15	$\leq 10^{-4}$
BP-0100	0.100	0.95	0.15	$\leq 10^{-4}$
BP-0140	0.140	0.94	0.15	$\leq 10^{-4}$
BP-0140B	0.140	0.94	0.20	$\leq 2 \cdot 10^{-4}$
BP-0150B	0.150	0.94	0.20	$\leq 2 \cdot 10^{-4}$
BP-0190B	0.190	0.94	0.20	$\leq 2 \cdot 10^{-4}$
BP-0220	0.220	0.94	0.15	$\leq 2 \cdot 10^{-4}$
BP-0220B	0.220	0.94	0.20	$\leq 2 \cdot 10^{-4}$
BP-0260B	0.260	0.93	0.20	$\leq 3 \cdot 10^{-4}$
BP-0300B	0.300	0.92	0.20	$\leq 3 \cdot 10^{-4}$
BP-0350	0.350	0.91	0.15	$\leq 4 \cdot 10^{-4}$
BP-0350B	0.350	0.92	0.20	$\leq 4 \cdot 10^{-4}$
BP-0480B	0.480	0.92	0.20	$\leq 5 \cdot 10^{-4}$
BP-0500B	0.500	0.92	0.20	$\leq 5 \cdot 10^{-4}$
BP-0600B	0.600	0.92	0.20	$\leq 5 \cdot 10^{-4}$
BP-0650	0.650	0.90	0.15	$\leq 5 \cdot 10^{-4}$
BP-0650B	0.650	0.92	0.20	$\leq 5 \cdot 10^{-4}$
BP-0800	0.800	0.90	0.15	$\leq 6 \cdot 10^{-4}$
BP-0800B	0.800	0.92	0.20	$\leq 6 \cdot 10^{-4}$
BP-1000	1.000	0.90	0.15	$\leq 8 \cdot 10^{-4}$
BP-1000B	1.000	0.91	0.20	$\leq 1 \cdot 10^{-3}$
BP-1300	1.300	0.89	0.15	$\leq 1 \cdot 10^{-3}$
BP-1300B	1.300	0.91	0.20	$\leq 3 \cdot 10^{-3}$
BP-1600	1.600	0.89	0.15	$\leq 1 \cdot 10^{-3}$
BP-1600B	1.600	0.91	0.20	$\leq 3 \cdot 10^{-3}$
BP-1900	1.900	0.88	0.15	$\leq 3 \cdot 10^{-3}$
BP-2400	2.400	0.88	0.15	$\leq 4 \cdot 10^{-3}$
BP-3000	3.000	0.88	0.15	$\leq 5 \cdot 10^{-3}$

* tolerance ±1%; ** tolerance ±2%; ****evaluation at frequencies 1.5 - 10 $\cdot \nu_{max}$;
**** tolerance ±1%, the bandwidth is evaluated at the level of 0.5 $\cdot$ T_{max} (FWHM)



Examples of transmission spectra for some standard filters showing their out-of-band blocking

In standard filters, their operating apertures are protected by thin THz-transparent polymeric films.

The annular aluminum shell is supplied with a blackcolored protective coating.

Customization capabilities:

Optional supplementary holder
Optional diameter: 10÷75 mm
Optional ν_{max} and $\Delta\nu/\nu_{max}$ values
Out-of-band blocking enhancement
Several passbands
Polarization discrimination
Cryogenic operation

A supplementary holder is available for mounting filters on a quasi-optical bench.

Having two nests, the holder allows placing two filters one by one to achieve the higher out-of-band blocking.

Generally, the holder can be customized upon a customer's request.

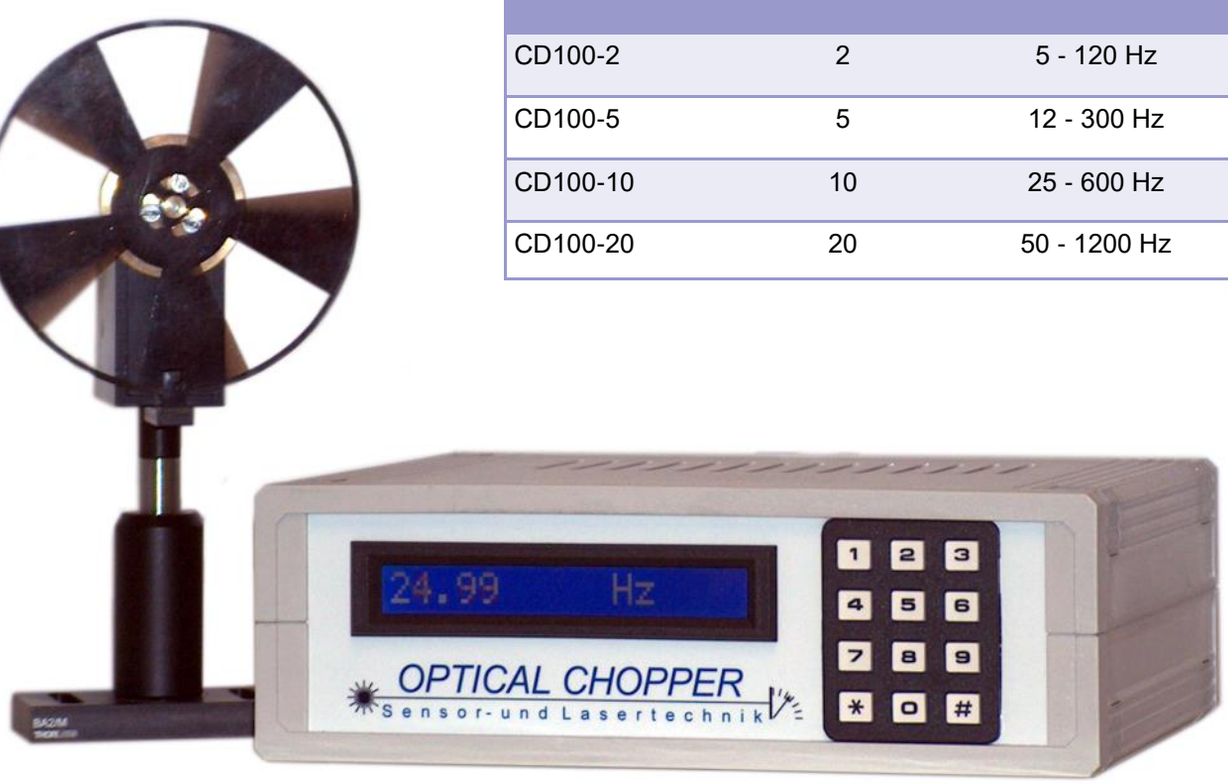
Optical Chopper

Product description

This chopper is needful to modulate continuous radiation to measure the power in combination with a pyro-electric detector and especially for THz detectors. We use a microprocessor controlled PID controller to offer an easy handling and stable frequency. The frequency can set with a keypad. To repeat measurements at different choppers rates is very easy. Additionally it is possible to control and read out the frequency via USB port.

In standard configuration replaceable chopper discs have a diameter of 100mm. For alternatively operation, for instance in combination with a LockIn amplifier a sync out signal is generated.
One chopper disc with two slots, the most useful for our THz detectors, is included.

Chopper disc	No. of slots	Chopper frequency
CD100-2	2	5 - 120 Hz
CD100-5	5	12 - 300 Hz
CD100-10	10	25 - 600 Hz
CD100-20	20	50 - 1200 Hz



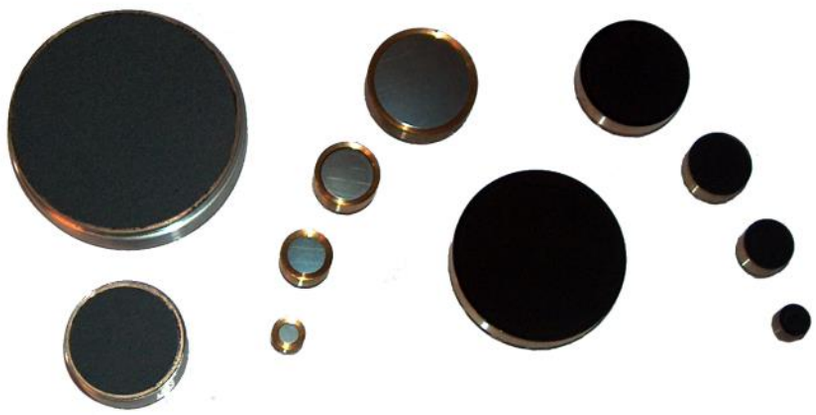
Parameters	
Diameter of chopping discs	100 mm
Frequency drift and jitter	< 1%
Sync Out compatibility	TTL/CMOS
Supply	85 VAC - 240 VAC; 50 - 60 Hz

OEM PES

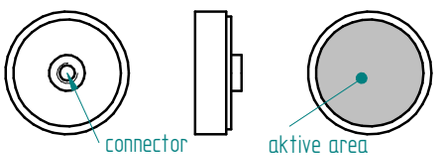
The main application for this type of sensor is energy monitoring of high repetition rate lasers. The co-axially built sensors have a high sensitivity and can be applied in a wide spectral range.
Detector diameters between 4 mm and 45 mm are available. The maximum repetition rate depends on the sensor diameter and the load resistor; values up to 3000 pps. are possible. For these sensors 3 absorber coatings are available:

- organic black, flat spectral behaviour
- Metallic coating for high repetition rates
- Ceramic coating for highest peak powers

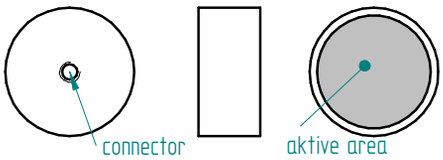
The sensors can easily be combined with own electronics. Additionally we offer our OEM-Pyrobox with RS232 or USB-output.



	PES	PES HR	PES K
Max. energy density:	150 mJ/cm²	100 mJ/cm²	up to 1 J/cm²
Max. power density:	150 mW/cm²	150 mW/cm²	500 mW/cm²
Max. peak power density: (10 ns—pulse)	8 MW/cm²	8 MW/cm²	70 MW/cm²
Temperature range:	0 .. 40°C	0 .. 40°C	0 .. 70°C
Spectral range		190 nm .. 25 µm	
Max. pulse duration		2 ms	
Accuracy		±3%	

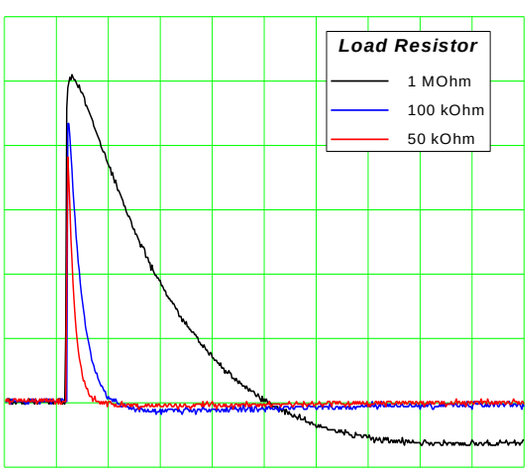


Type PES and PES HR

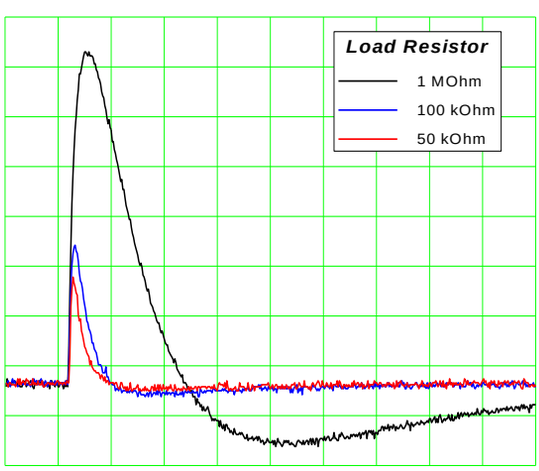


Type PES K and HP

	Aperture	Sensitivity	Rep Rate	Dimension (Dia x lengh Conector)
PES 4	4 mm	500..1000 V/J at 1 MΩ 130..250 V/J at 100 kΩ	80 Hz at 1 MΩ 120 Hz at 100 kΩ	7 x 9,5 mm² M 3
PES 8	8 mm	200..500 V/J at 1 MΩ 50..200 V/J at 100 kΩ	40 Hz at 1 MΩ 100 Hz at 100 kΩ	11 x 9,5 mm² M 3
PES 11	11 mm	100..400 V/J at 1 MΩ 50..150 V/J at 100 kΩ	40 Hz at 1 MΩ 80 Hz at 100 kΩ	14 x 9,5 mm² M 3
PES 21	21 mm	50..150 V/J at 1 MΩ 30..80 V/J at 100 kΩ	25 Hz at 1 MΩ 50 Hz at 100 kΩ	24 x 9,5 mm² M 4
PES 34	34 mm	40.. 70 V/J at 1 MΩ 10..40 V/J at 100 kΩ	25 Hz at 1 MΩ 80 Hz at 100 kΩ	37 x 10 mm² M 4
PES 20 HP	20 mm	30.. 50 V/J at 1 MΩ 8..20 V/J at 100 kΩ	50 Hz at 1 MΩ 150 Hz at 100 kΩ	25 x 12 mm² M 3
PES 45 HP	45 mm	8.. 15 V/J at 1 MΩ 4..8 V/J at 100 kΩ	25 Hz at 1 MΩ 100 Hz at 100 kΩ	50 x 13 mm² M 4
HR 4	4 mm	1000..1500 V/J at 1 MΩ 900..1200 V/J at 100 kΩ 900..1100 V/J at 50 kΩ	250 Hz at 1 MΩ 2,5 kHz at 100 kΩ 3,3 kHz at 50 kΩ	7 x 9,5 mm² M 3
HR 8	8 mm	700..900 V/J at 1 MΩ 400..500 V/J at 100 kΩ 300..400 V/J at 50 kΩ	150 Hz at 1 MΩ 2 kHz at 100 kΩ 2,5 kHz at 50 kΩ	11 x 9,5 mm² M 3
HR 11	11 mm	400..600 V/J at 1 MΩ 400..500 V/J at 100 kΩ 300..400 V/J at 50 kΩ	250 Hz at 1 MΩ 1,5 kHz at 100 kΩ 2 kHz at 50 kΩ	14 x 9,5 mm² M 3
HR 21	21 mm	150..250 V/J at 1 MΩ 100..250 V/J at 100 kΩ 100..200 V/J at 50 kΩ	50 Hz at 1 MΩ 200 Hz at 100 kΩ 1,4 kHz at 50 kΩ	24 x 9,5 mm² M 4
PES 20 k	20 mm	7..15 V/J at 1 MΩ 1..8 V/J at 100 kΩ	50 Hz at 1 MΩ 50 Hz at 100 kΩ	25 x 12 mm² M 3
PES 45K	45 mm	1.5..4.5 V/J at 1 MΩ 0.4..1.5 V/J at 100 kΩ	20 Hz at 1 MΩ 50 Hz at 100 kΩ	50 x 13 mm² M 4



HR 11, 500 µs/div; 5 mV/div; 100 µJ



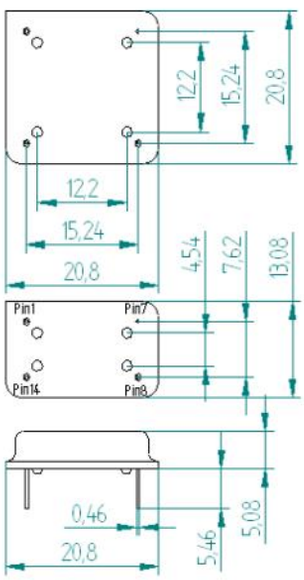
PEM 11, 1 ms/div; 5 mV/div; 100 µJ

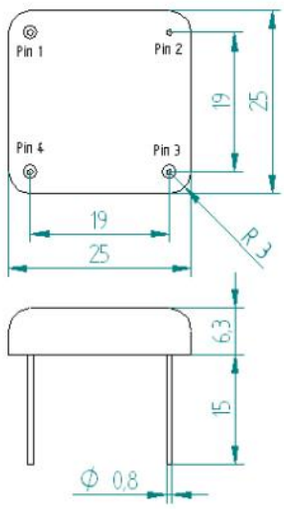
Samples of the output signal of different sensors

OEM PEO

These sensors are characterised by a high sensitivity and a high repetition rate. Because of the windowless design and the used metallic absorption coating an usage also in the UV-range is possible. The sensors PEO 8A and PEO 12A have a built-in preamplifier which improves the insensitivity to interferences and avoids problems when using longer signal cables. If needed, for example when using the sensor at different wavelengths, we will also supply these sensors with our reliable, broadband black coating. The modular construction set EMK100 can be combined with PEO sensors.

	Aperture	Sensitivity [V/J]	Rep Rate [Hz]
PEO 8	Ø 8 mm	400..500 V/J at 1 MOhm 200..300 V/J at 100 kOhm	1 kHz at 1 MOhm 10 kHz at 100 kOhm
PEO 8 A	Ø 8 mm	10000 .. 25000 V/J (by order)	10 kHz
PEO 8 B	Ø 8 mm	300..400 V/J at 1 MOhm 200..300 V/J at 100 kOhm	750 Hz at 1 MOhm 1 kHz at 100 kOhm
PEO 12	Ø 12 mm	300..400 V/J at 1 MOhm 200..300 V/J at 100 kOhm	700 Hz at 1 MOhm 6 kHz at 100 kOhm
PE12 A	Ø 12 mm	4000 .. 6000 V/J (by order)	3 kHz
PEO 12 B	Ø 12 mm	20..40 V/J at 1 MOhm 10..20 V/J at 100 kOhm	500 Hz at 1 MOhm 750 HHz at 100 kOhm
PEO 20	Ø 20 mm	100..160 V/J at 1 MOhm 70..120 V/J at 100 kOhm	250 Hz at 1 MOhm 2 kHz at 100 kOhm
PEO 88	8 x 8 mm²	2..3 V/J at 50 Ohm	250 kHz at 50 Ohm





	PEO8A / PEO12A	PEO8 / PEO12
Pin 1	+Vcc	NC
Pin 7	Ground	Ground
Pin 8	-Vcc	NC
Pin 14	Out	Out

	PEO 20
Pin 1	NC
Pin 2	Ground
Pin 8	NC
Pin 14	Out

max. energy density	50 mJ/cm²
max. average power	0,5 W
Calibration uncertainly	±3 %
Temperature environment	10°C .. 50°C
Temperature coefficient	+0,1%/K
Power Supply (only PEO8A and PEO 12A)	±5V .. ±15V

Highspeed sensor PEO 88

These sensors are designed for highest repetition rates. Applied with a metallic coating these sensors allow repetition rates up to 250 kHz, according to the load resistor. One highlight is the relatively large aperture for such high repetition rates.

active area	8mm x 8mm
max. energy density	50 mJ/cm²
max. average power	0,5 W
Calibration uncertainly	±3 %
Temperature environment	10°C .. 50°C
Temperature coefficient	+0,1%/K

OEM EMK

EMK 100 is a sensor and electronic system for an internal energy measurement.

It consists of a basis board including a switchable amplifier and a peak detector. The basis board output is a trigger signal and an analogue signal corresponding to the laser energy. Additionally, we offer different modules with customer specified output ports. The connectors of these modules are standardised and the boards are place under the basis board.

The connectors or pads for different sensors, especially for the PEO series, are at the upper side of the basis board

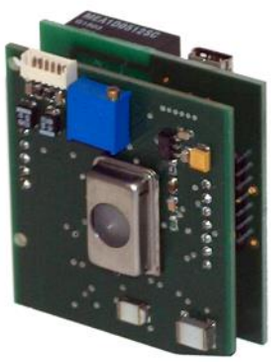
It is also possible to place sensor and electronics separate of each other. In this case we recommend to use the amplified sensors (PEO8A, PEO12A). For such an application the basis board has an own port for the power supply for the sensor.

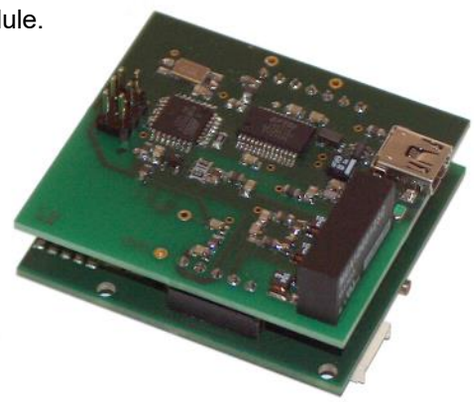
Dimension (housing)	55 mm x 52 mm x 16 mm
Mounting	Customer specified
Rep. rate	5 kHz (10 kHz on request)
Power supply	±12V .. ±15V, 4-pol. Molex, pitch 1.27 mm
Output	6-pol. Molex, pitch 1.27
Environment	0°C .. 50°C

Microcontrollermodule MCM

The MCM module connects an USB port (Mini-USB connector) to the EMK 100. This electronic module is self powered via the USB port and also supplies the EMK100 module. It also takes over the control of the preamplifier. For the communication between a PC and the MCM a simple ASCII protocol is used. The maximum pulse repetition rate is about 1 kHz. The outer dimensions are the same like for the EMK 100 module.
The following pictures shows the MCM combined with a EMK 100 module.

Outer dimension:
45mm x 50mm x 20mm (MCM only)
45mm x 50mm x 27mm (MCM +EMK100)



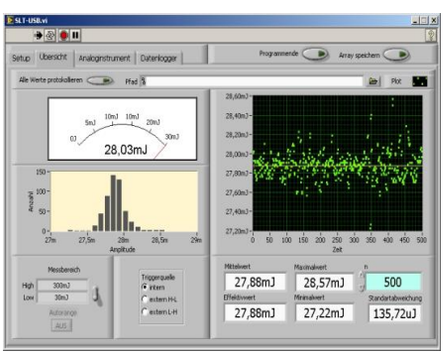


OEM Pyrobox

In this device a Pyrobox and a sensor is combined. The layout is optimized for the sensors PES20 and PES20K and all other sensors of series PES. Two different versions are available; with USB or RS232.

The USB-port simulates a serial port. So it is easy to use the same software for both types. Because of the simple ASCII-protocol it is easy to implement the Pyrobox in your designs. A software frontend written in Labview and drivers for it are available.

- For all PES-sensors
- Two different sensitivities
- USB 2.0 or RS232 connection
- Max. rep. rate 100 pps.
- Additional external trigger input possible
- Data transfer as ASCII code
- Power supply from USB or external supply with RS232
- Software for different applications available (Analogue and digital display, data logger, statistics)
- Dimensions 80 mm x 50 mm x 20 mm



OEM Powermeter

These family of high sensitive thermopile sensors and electronics are ideally for online power monitoring.

The sensor elements are available in different sizes for different power ranges. The housings have a lot of holes for mounting and combination with additional optical components like beam splitters, diffuser discs or optical fibre adaptors, please ask for a solution.

Additionally a preamplifier module with analogue output is available to read the power directly into own applications. For digital interface the OEM Powerbox are available.

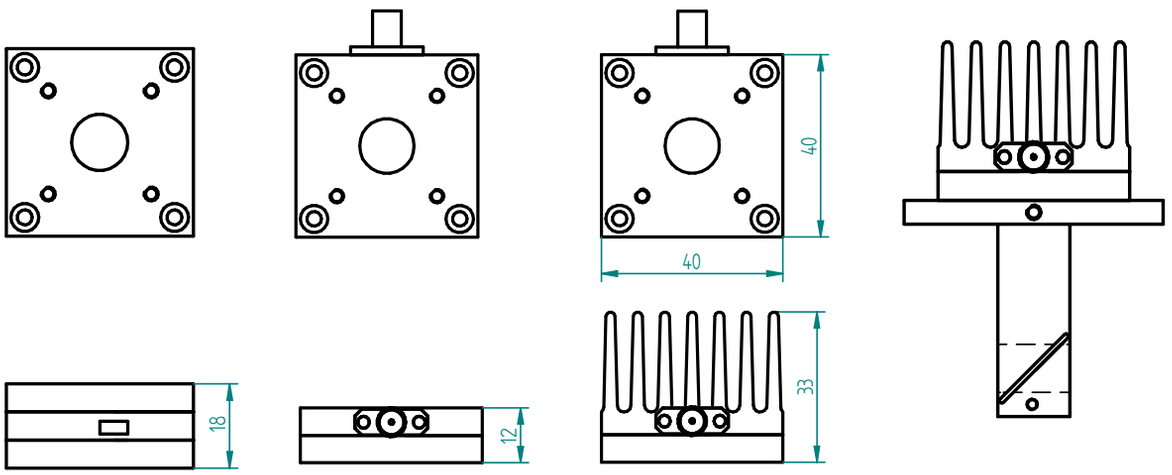
PM404010

	PM404010-3	PM404010-5	PM404010-3-A	PM404010-5-A
active diameter	10 mm	10 mm	10 mm	10 mm
Power range	0.5 mW - 3 W	0.5 mW - 5 W	0.5 mW - 3 W	0.5 mW - 5 W
max. power density	40 W/cm²	40 W/cm²	40 W/cm²	40 W/cm²
sensitivity	250 mV/W .. 450 mV/W		1 V/W	
Cooling	convection			
connector	SMA	SMA	Molex Microblade	

PM404010-5

PM404010-5-A

PM404010-3

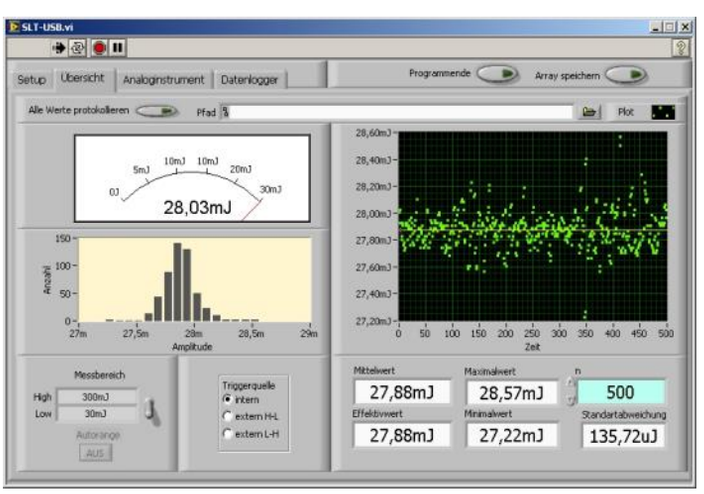


PM404010-3-A | PM404010-3 | PM404010-5 | PM404010-5 with additional beam splitter

OEM Powerbox

This „Powerbox“ processes the signals of all thermopile power detectors. The output signal will be transferred to a connected PC via USB. The device is powered from the USB-port. The Powerbox communicates with the computer using ASCII code and is very easy to integrate into your own existing software program or systems.

- USB 2.0 connection
- Power supply from USB
- Labview based software for different applications available (Analogue and digital display, data logger, statistics)
- Data transfer as ASCII code
- For all thermopile detectors
- Four ranges
- On request with RS232 output
- Dimensions 100 mm x 41 mm x 24 mm



Voltage Preamplifiers VST

With these amplifiers measuring of lowest energies (some 10 nJ with PEM 4) is possible. Due to the amplification and reduction of the capacity load the sensitivity of the detector will be considerably increased. The bandwidth of the amplifiers is specially adapted to this application.

Due to the modular assembly the whole dynamic range will be greatly increased. Additionally, losses of sensitivity by using a smaller load resistor (to increase the possible repetition rate) can be compensated.

Because of this facts for all PEM detectors in combination with one preamplifier we get a very low detection threshold (S/N>1) :

Detector	Detection threshold
PEM 8	30 nJ
PEM 11	50 nJ
PEM 21	100 nJ
PEM 34	200 nJ

Specifications:

Connectors:	BNC
Amplification:	10, 100, 1000 or 10000
Bandwith:	5 kHz
Input Impedance:	1 MΩ
Power supply:	5 V, Micro-USB

Current Preamplifiers CPA

The current preamplifier is necessary to realize a power measurement of the incoming radiation. The amplifier consists of an IC as transimpedance amplifier at the input side and two further voltage amplifier stages. There are some additional components for a noise reduction and offset regulation. In praxis the maximum amplification is limited by the cut off-frequency. Highest amplification can only be realized for small frequency intervals. For THz detectors in combination with a chopper often the upper frequency is limited to values less than 50 Hz. For such amplifiers conversion factors between 10^{7} V/W and 10^{10} V/W can be realized.

The sensitivity of the combination detector and preamplifier is determined by multiplication of the current sensitivity of the detector and the amplification of the current amplifier (e.g. detector 10^{-6} A/W and CPA 10^{9} V/A leads to a total sensitivity : 10^{-6}A/W*10^{9} V/A=1000 V/W). The amplification can be set by a switch.

The CPA needs an operating voltage ±15 V from an included separate power supply.

Specifications:

Connectors:	BNC
Amplification:	10^{7}, 10^{8} , 10^{9} , 10^{10} V/A
Bandwidth:	50 Hz - 250 Hz, switchable
Power supply:	5 V, Micro-USB

The amplification can be set by a 4-step switch: e.g. 10^{7}... 10^{10} V/A ; the bandwidth is fixed* to e.g. 50Hz or 250 Hz. The detection limit depends on the amplification, the bandwidth and detector diameter. Amplification and bandwidth can be adapt on your requests.

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