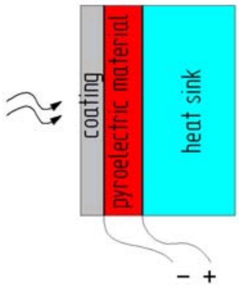
Sensor- und Lasertechnik

Power and Energy Measurement for Lasers

Sensor- und Lasertechnik

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

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.

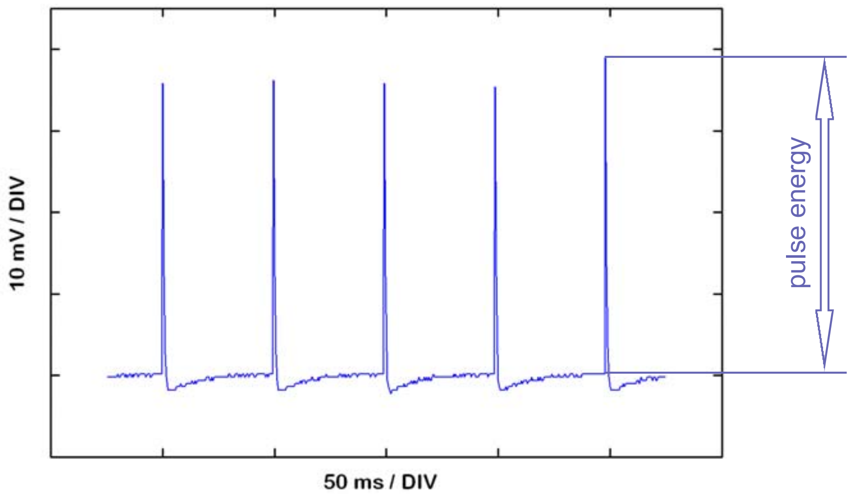
The third element in the setup of a pyroelectric detector is the heat sink. It has good thermal contact to the pyroelectric sensor and is responsible for heat transfer to the surroundings.

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

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.

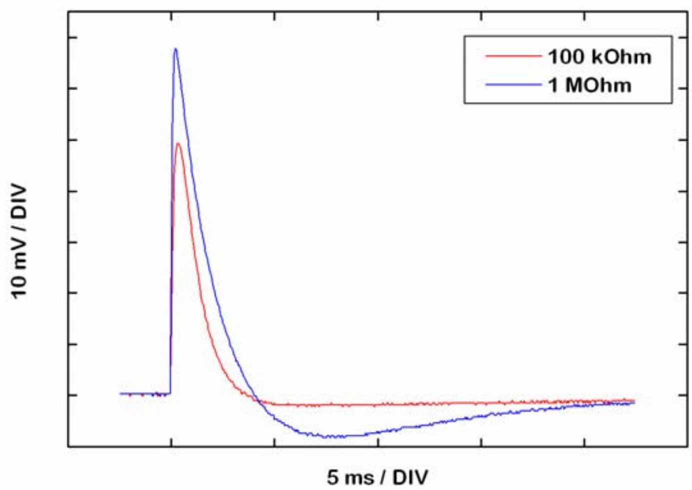
Pyroelectric detectors for THz radiation are often used in combination with a chopper and power detection (current measurement) is used. Transimpedance amplifiers facilitate a conversion from current to voltage so the output voltage is proportional to the (pulse) power. For such detectors a larger thermal time constant is desired, enabling chopper frequencies as small as 10 Hz. Such sensors do not reach the sensitivity of Golay cells but can work up to rep. rates of more than 100 Hz.

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.



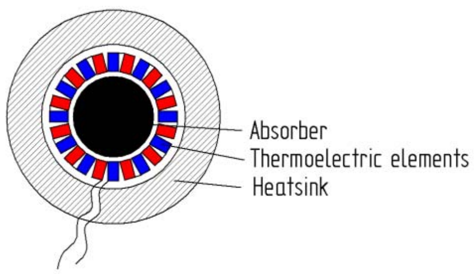
output on dependence of load resistor

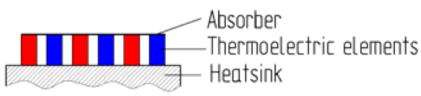
Thermopile Detectors

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.



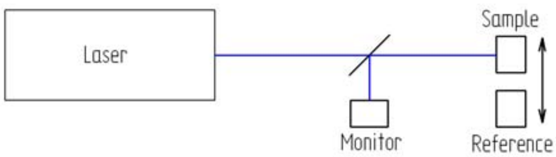


The axial design above has a much higher sensitivity than the radial design, shown on the left side. The radial types are optimal for high power applications.

Furthermore , one can distinguish between thin surface absorbers and relatively thick volume absorbers, showing different behaviour concerning threshold power density and rise time.

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.



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.

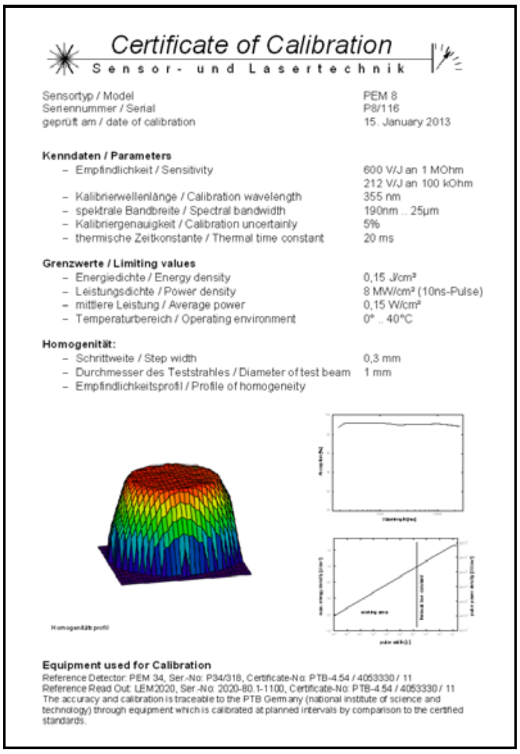
For special requirements and for detectors having a strong wavelength dependent sensitivity, it is useful to calibrate at customer wavelengths. The following lasers and wavelengths are available.

Pulsed Lasers:

- Nd:YAG: 1064nm, 532mn, 355nm
- Excimer: 308nm
- High Power Laser Diode: 880nm
- Dye Laser: vis

cw-Lasers:

- High Power Laser Diode: 880nm
- Nd:YAG: 1064nm



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 uncertainly	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	

Homogenitätsprofil

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: 2020-80.1-1100, 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.

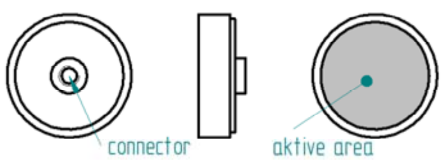
OEM PES

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:

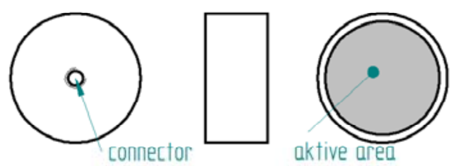
- organic black, flat spectral behaviour
- Metallic coating for high repetition rates
- Ceramic coating for highest peak powers

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%	

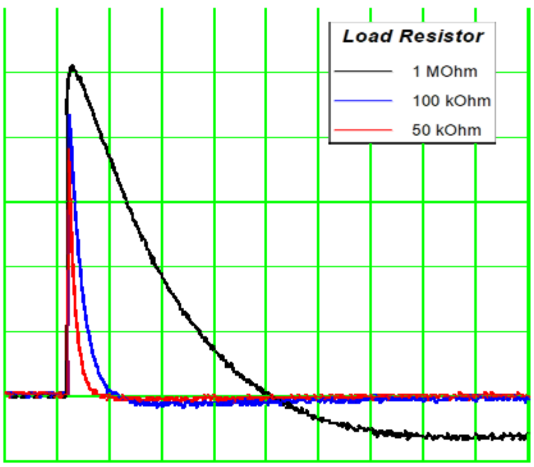


Type PES and PES HR

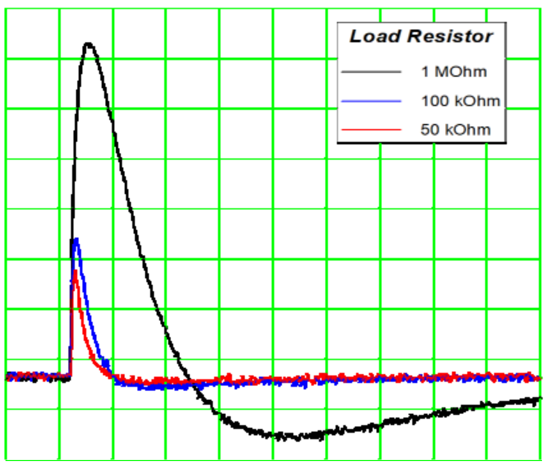


Type PES K and HP

	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 45 K	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



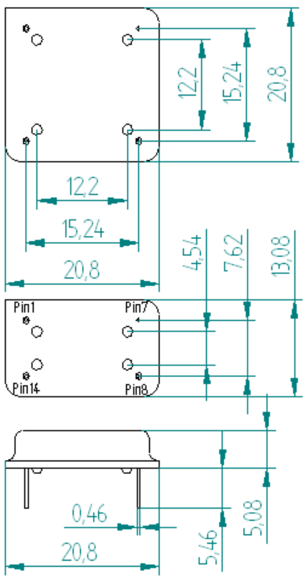
PEM 11, 1 ms/div; 5 mV/div; 100 µJ

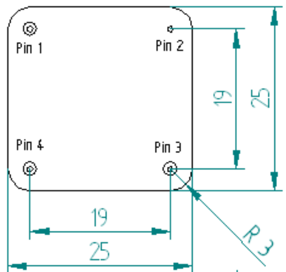
Samples of the output signal of different sensors

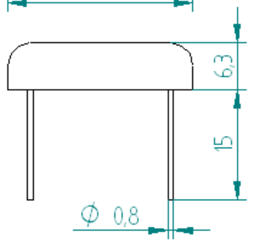
OEM PEO

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, broad-band 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

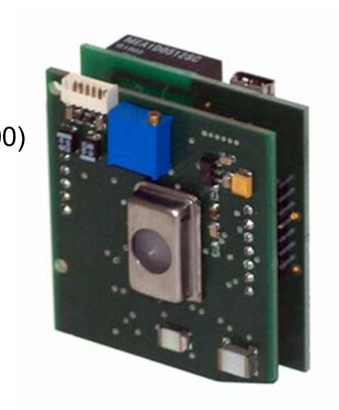
The MCM module connects an USB port (Mini-USB connector) to the EMK 100. This electronic module is self powered via the USB port and also supplies the EMK100 module. It also takes over the control of the preamplifier. For the communication between a PC and the MCM a simple ASCII protocol is used. The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

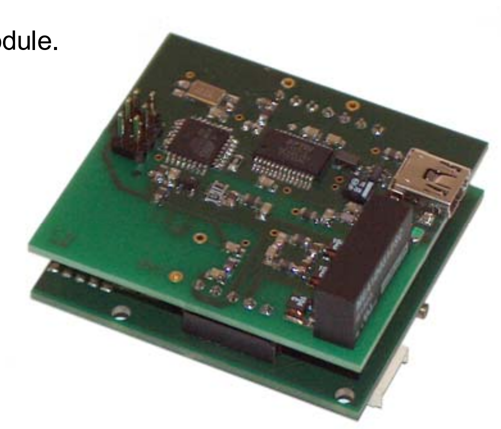
The following pictures shows the MCM combined with a EMK 100 module.

Outer dimension:

45mm x 50mm x 20mm (MCM only)

45mm x 50mm x 27mm (MCM +EMK100)



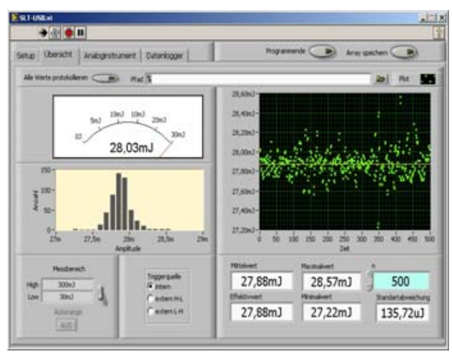


OEM Pyrobox

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.

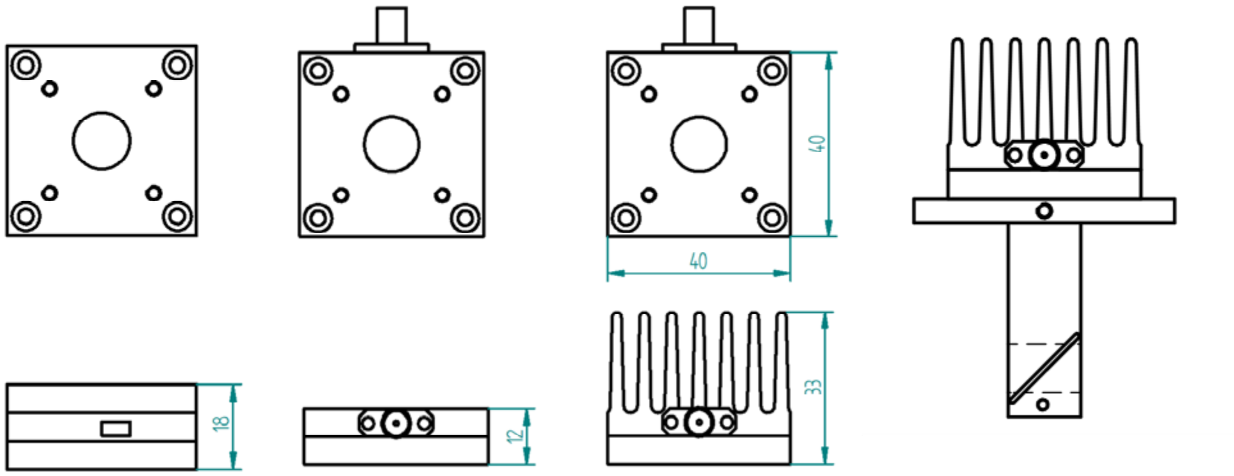
PM404010

	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

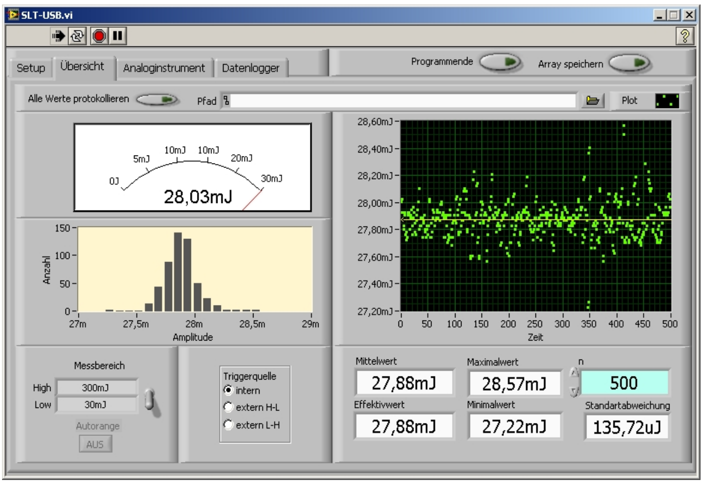


PM404010-3-A PM404010-3 PM404010-5 PM404010-5 with additional beam splitter

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



Basics
Calibration
Displays
Energy Detectors
Power Detectors
THZ Detectors
OEM
Amplifiers

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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