Sensor- und Lasertechnik

Power and Energy Measurement for Lasers

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

. **THz-Detectors**

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. Always the thermal time constant (τ_{therm}) describing the relaxation of the sensor temperature to the ambient temperature must be larger than the pulse duration.

There are two possibilities to detect this signal:

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

  $RC >> t_{imp}$

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

  Furthermore the condition:

  $t_{imp} << t_{therm}$

  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:

  $t_{imp} << t_{therm}$

  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.

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.

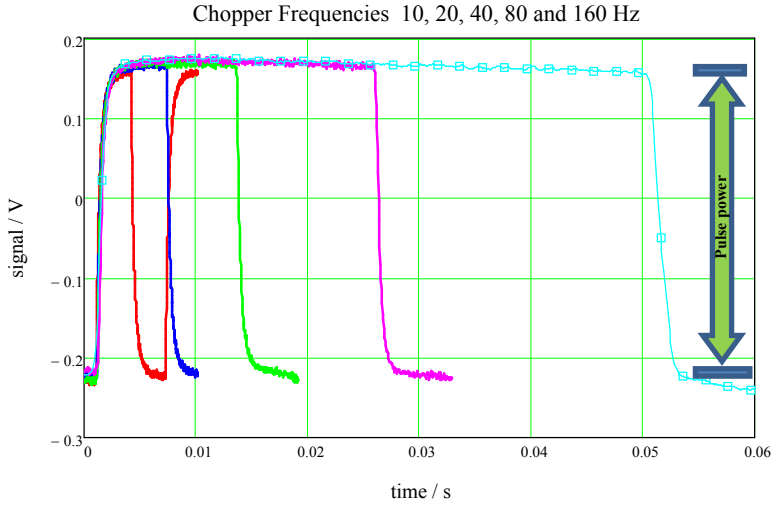
The sensitivity of the combination detector and preamplifier is determined by multiplication of the current sensitivity of the detector and the amplification of the current amplifier (e.g. detector 10^{-6} A/W and CPA 10^{9} V/A leads to a total sensitivity : 10^{-6}A/W·10^{9} V/A=1000 V/W). The amplification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

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

Specifications:

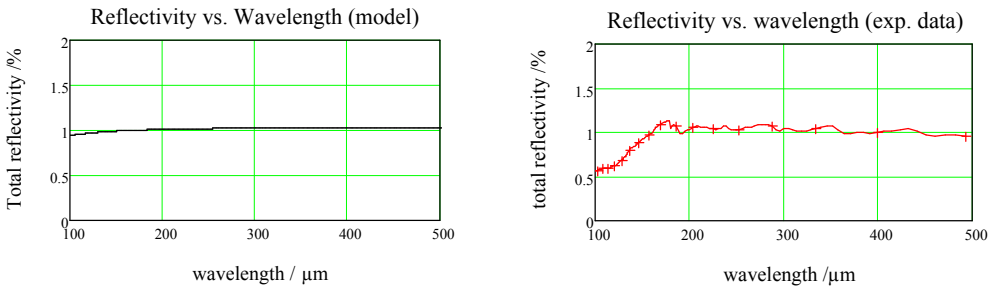
Power supply:	±15 V
Input connector:	SMA or BNC
Output connector:	BNC
Power connector:	Lemo

The amplification can be set by a 4-step switch: e.g. 10^{7}... 10^{10} V/A ; the bandwidth is switchable in two steps, 20Hz and 200 Hz. The detection limit depends on the amplification, the bandwidth and detector diameter. Please ask if you need other parameters



Trap detector

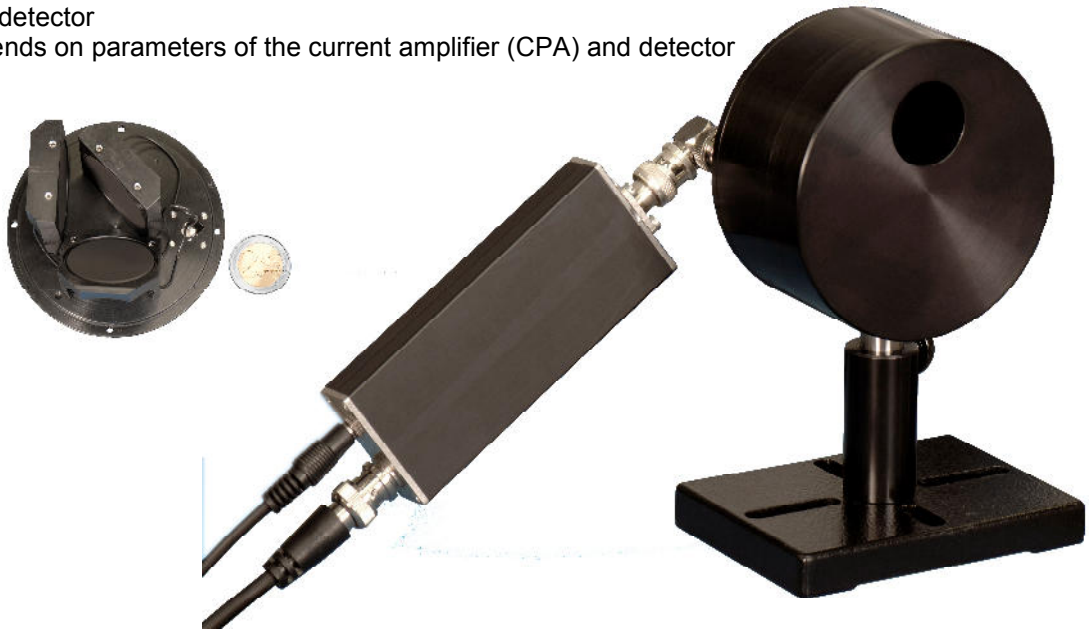
Such a detector is characterized by a very flat spectral behaviour in the THz region. It can be calibrated at PTB in Berlin and it should be used as a calibrated normal for your lab. The 3-D arrangement of 3 sensors causes a polarization independent detection using 5 interactions of the incoming radiation 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. Energy detection is possible too.



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	>500 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

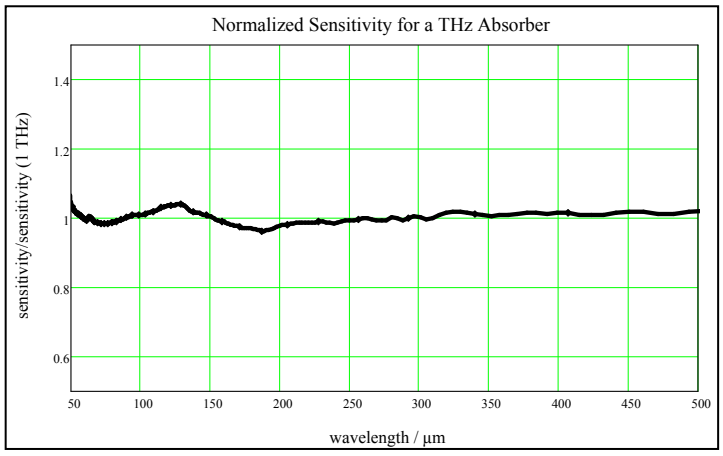
* only detector
**depends on parameters of the current amplifier (CPA) and detector



Single element detectors for power measuring

In combination with current preamplifier CPA

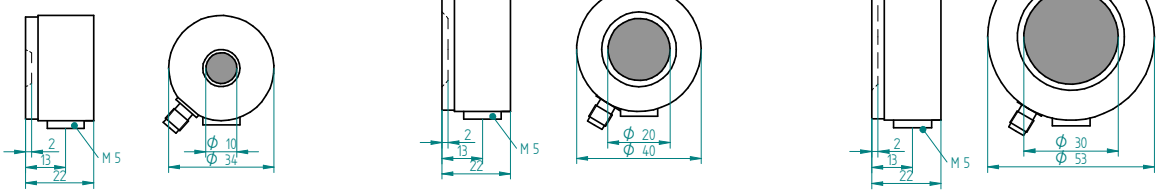
	THz 10	THz 20	THz 30
Diam. of active area [mm]	10	20	30
thermal time constant [ms]	50	50	50
Max. power density [mW/cm²]	15	15	15
Typical current sensitivity [µA/W]	0.5 ...1	0.5 ...1	0.5 ...1
Rise time * [µs]	100	700	2000
Max. chopper rate* [Hz]	>500	200	80
*Amplifiers for high rep. rate application on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



Terahertz-Powermeter

This device is a microcontroller based read out unit for THz detectors. Normally it is used when measuring the power of a cw source with THz detector and an optical chopper. It enables power detection, background subtraction, some statistical functions, data logging and connection to PC.

- Large 7” Graphic display with touch screen
- USB and network connection for remote control
- USB ports for external peripheral devices and data storage
- Integrated chopper controller
- Oscilloscope mode for observing the detector signal
- Analogue output
- Stable metal case

Calibration

All detectors are calibrated from PTB Germany at 1.40 THz in combination with a preamplifier CPA. 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.

Band-Pass Filter

Product description

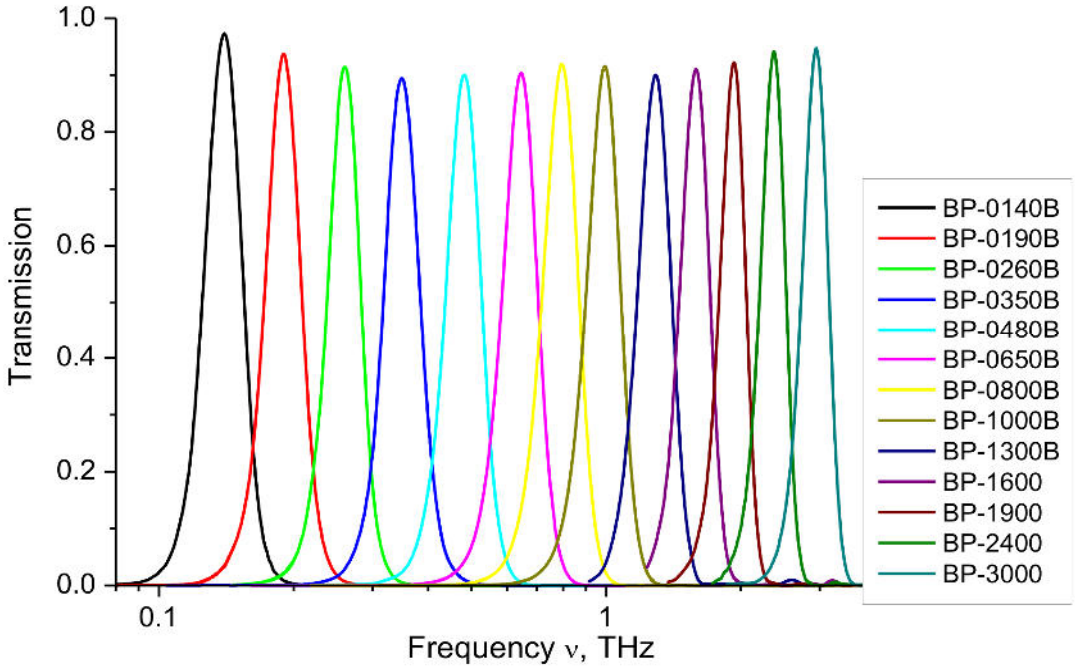
Quasi-optical band-pass filters are intended for selecting specified frequencies in the range of mm- and submm-waves. The filters can be used in a variety of applications including laboratory and space research.

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.

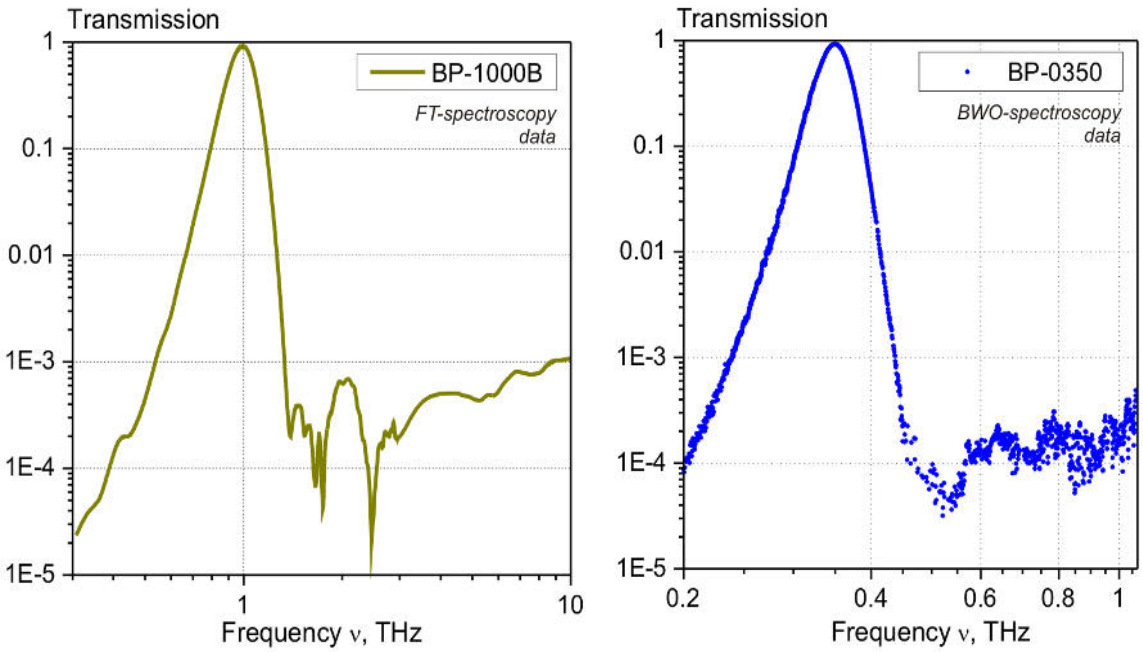
Key features:

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)

Band-Pass Filter



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 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.

Filter model	Center frequency $\nu_{Max\ [THz]}$ *	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)

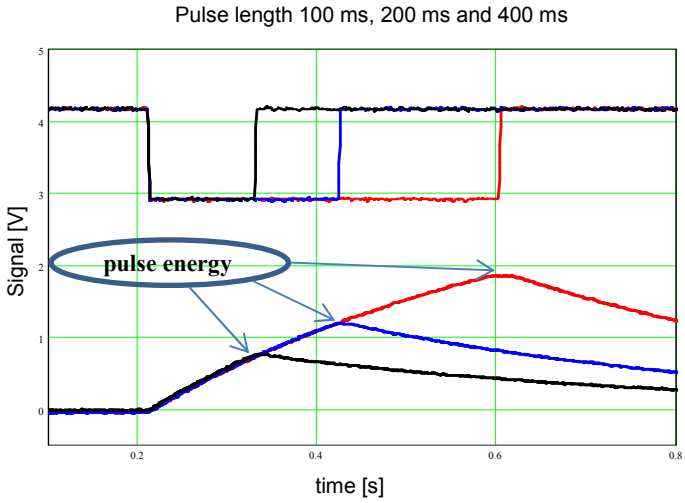
THz - Detector as Joulemeters

in combination with voltage preamplifier VST

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

Voltage Preamplifiers VST

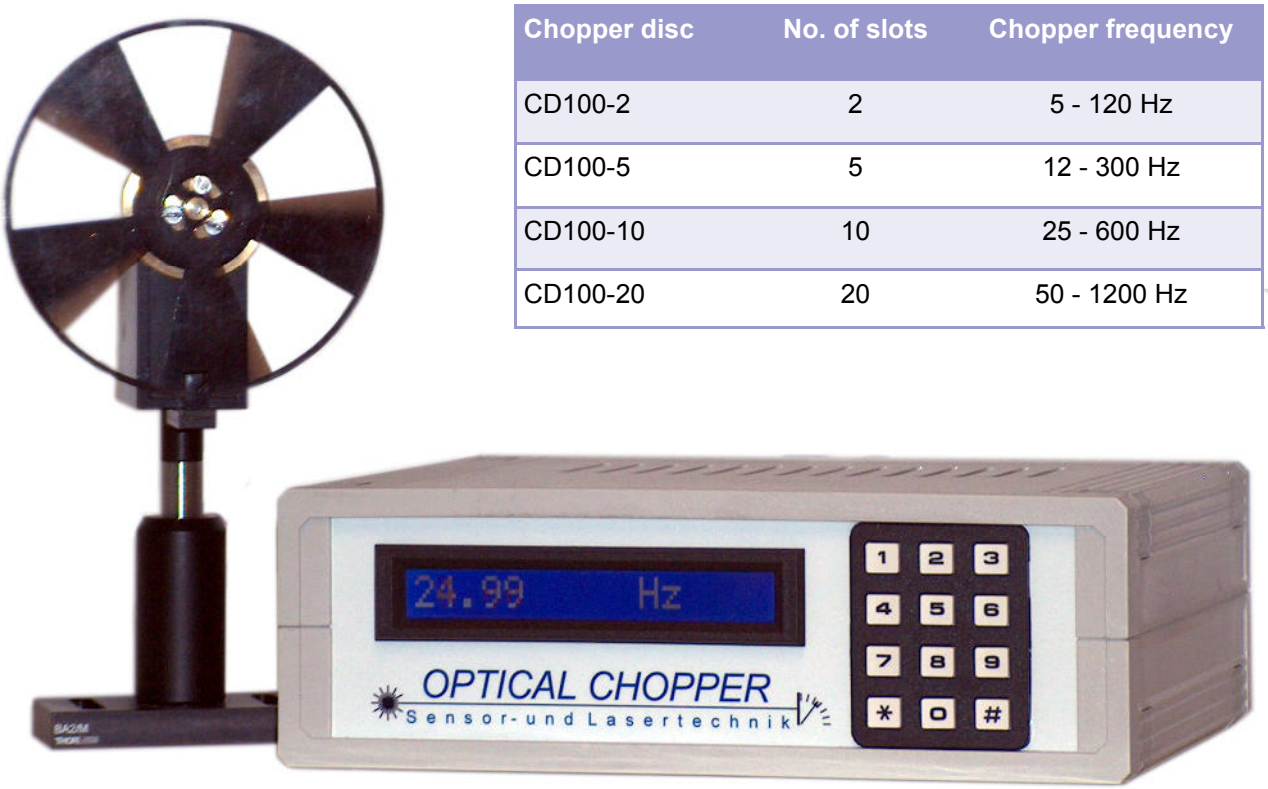
Connectors:	BNC
Amplification:	10, 100, 1000 and 10000
Bandwidth:	5 kHz
Input Impedance:	1 MΩ
Power supply:	±15 V

Optical Chopper

Product description

This chopper is needful to modulate continuous radiation to measure the power in combination with a pyroelectric 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 chopper 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

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