Instruction manual and data sheet PCA-44-06-10-800-x

Photoconductive THz antenna for laser excitation wavelengths λ ~ 500 nm … 850 nm

PCA – Photoconductive Antenna

http://www.batop.de/

PCA-44-06-10-800-0 - unmounted antenna chip 2 mm x 2 mm with 4 bond contact pads

PCA-44-06-10-800-h - mounted antenna on hyperhemispherical silicon substrate lens

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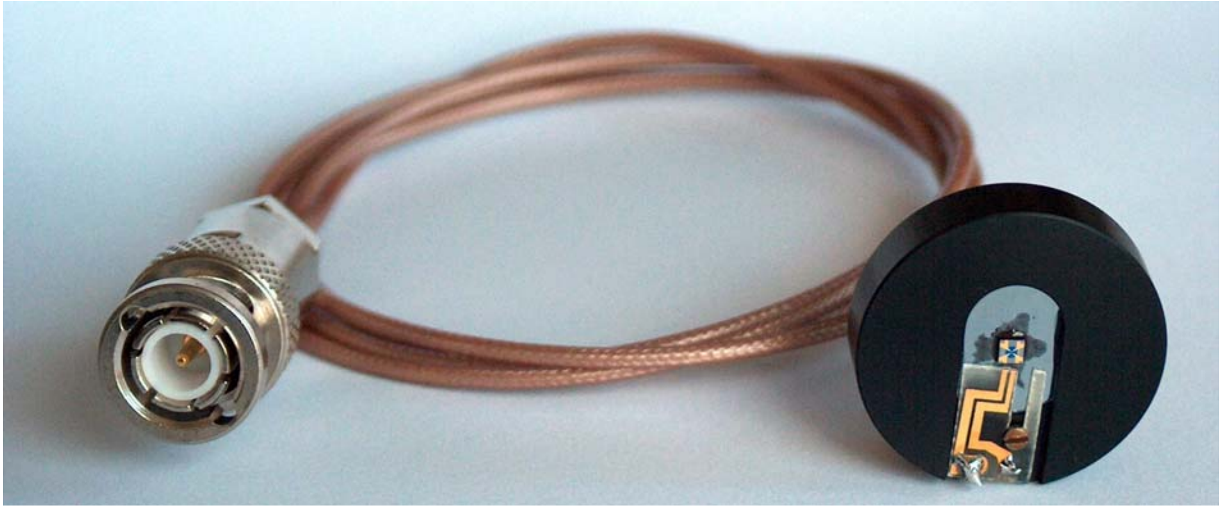


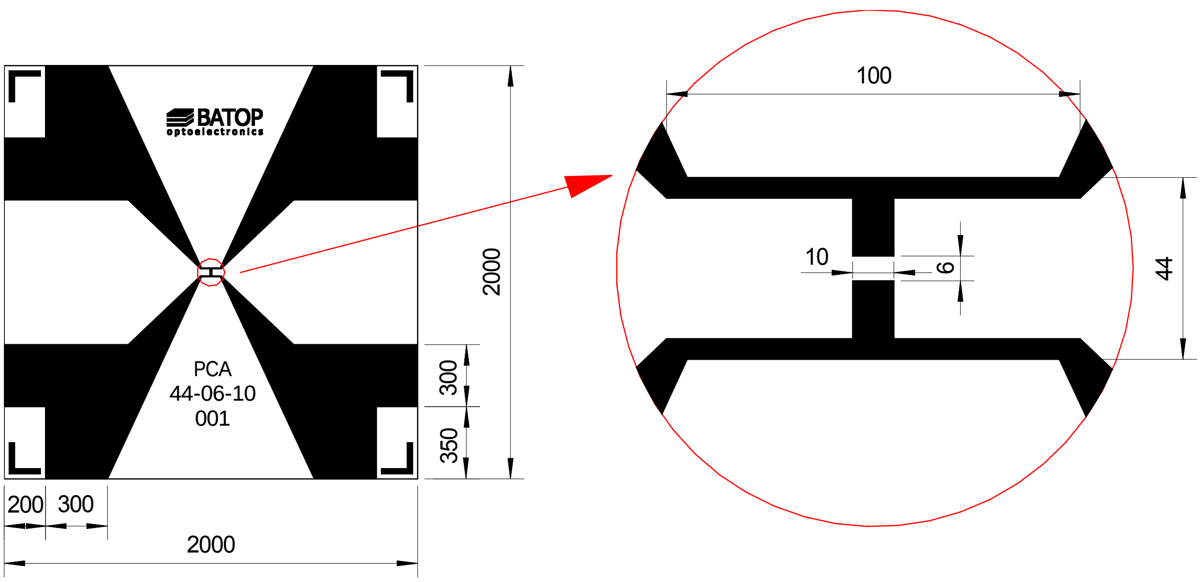
1. PCA applications

The PCA can be used as terahertz (THz) emitter or detector in pulsed laser gated broadband THz measurement systems for time-domain spectroscopy and as photomixing emitter or detector in tunable cw THz measurement systems in the frequency region from 0.1 to 3 THz.

Main PCA data

- Laser excitation wavelength $\lambda \sim$ 800 nm
- Antenna resonance frequency 1 THz

2. Antenna design



all dimensions in micrometers

Photo PCA 44-06-10 (survey)

Photo PCA 44-06-100

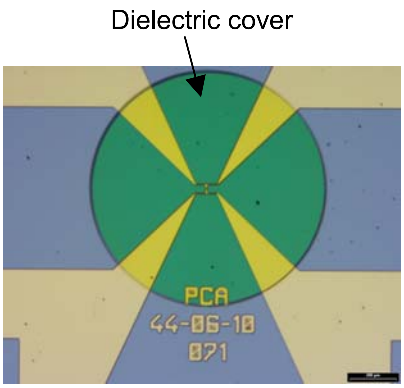
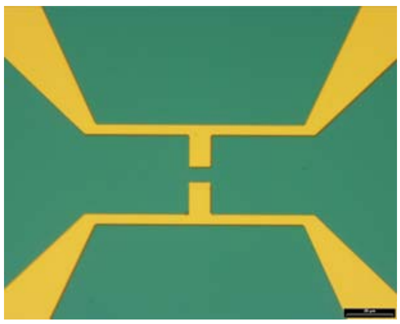


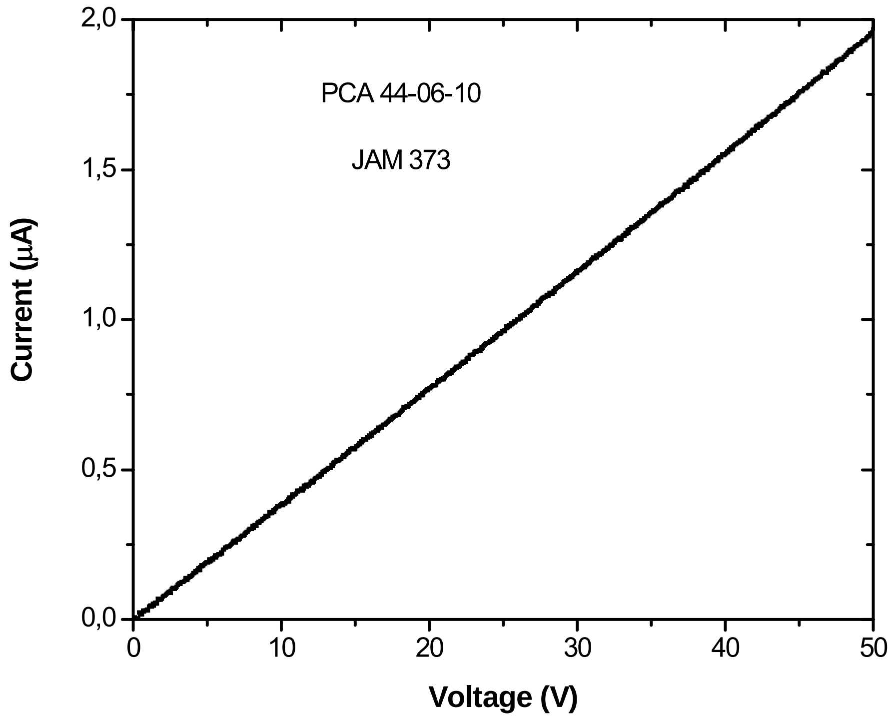
Photo PCA 44-06-10 (detail)



3. Antenna parameters

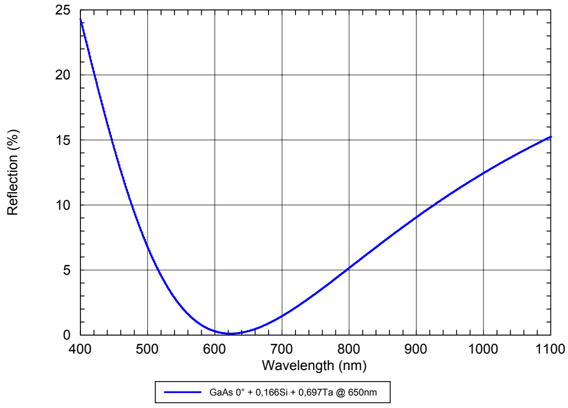
Electrical parameters	minimum ratings	standard	maximum ratings
Dark resistance	20 MΩ	25 MΩ	30 MΩ
Dark current @ 10 V	300 nA	400 nA	500 nA
Voltage		20 V	30V

Dark current voltage characteristic at T = 300 K

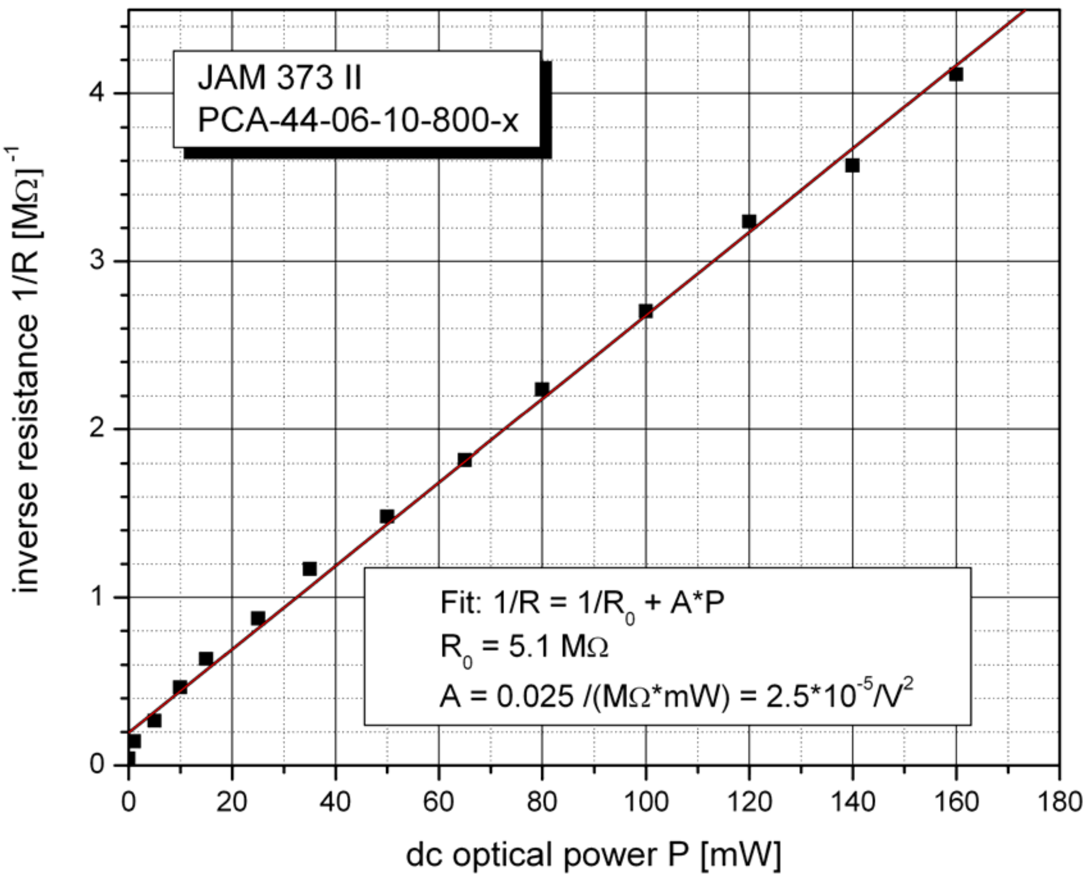


Optical excitation parameters	minimum ratings	standard	maximum ratings
Excitation laser wavelength	500 nm	800 nm	850 nm
Optical reflectance @ 1040 nm	7 % @ 500 nm	5 % @ 800 nm	7 % @ 850 nm
Optical mean power		30 mW	80 mW
Optical mean power density		100 kW/cm^2	200 kW/cm^2
Carrier recovery time		400 fs	

Spectral reflectance



Illumination dependent resistance R



BATOP GmbH
Wildenbruchstraße 15
D-07745 Jena
Germany

Tel: +49 3641 634009 - 0
Fax: +49 3641 634009 - 20
E-mail: info@batop.de

Deutsche Bank Jena
Bank Code: 82070024
Account No: 3922655
IBAN: DE49 8207 0024 0392 2655 00

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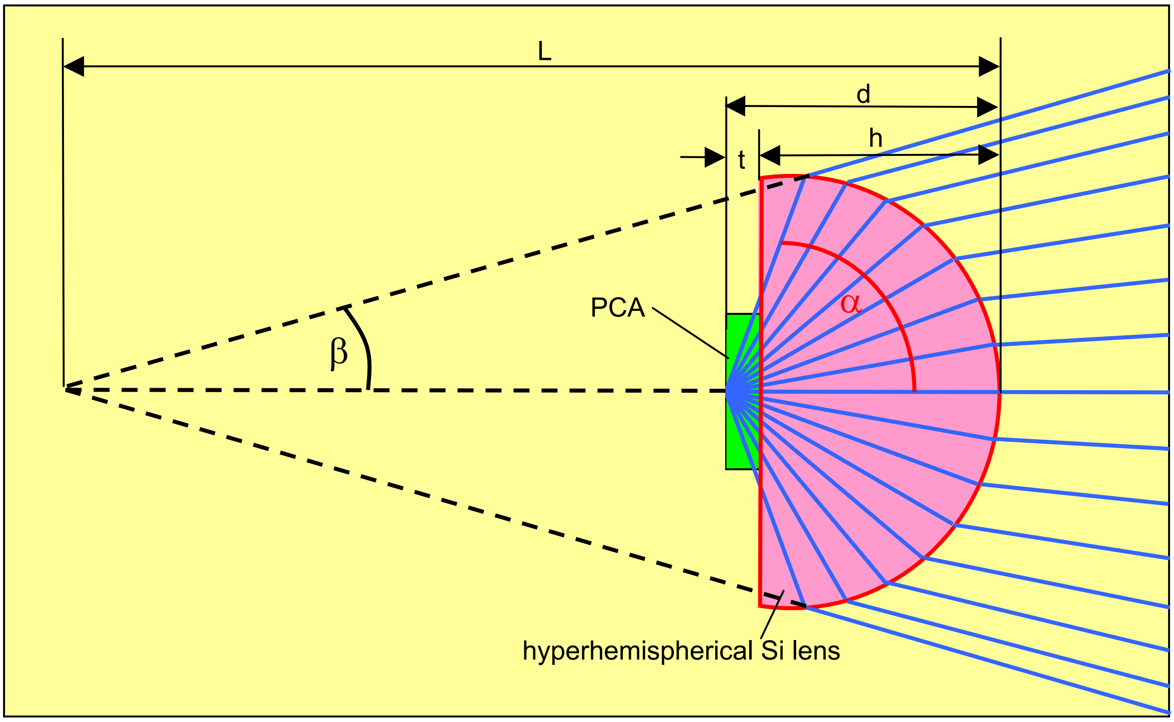
4. Mounted PCA on hyperhemispherical silicon substrate lens

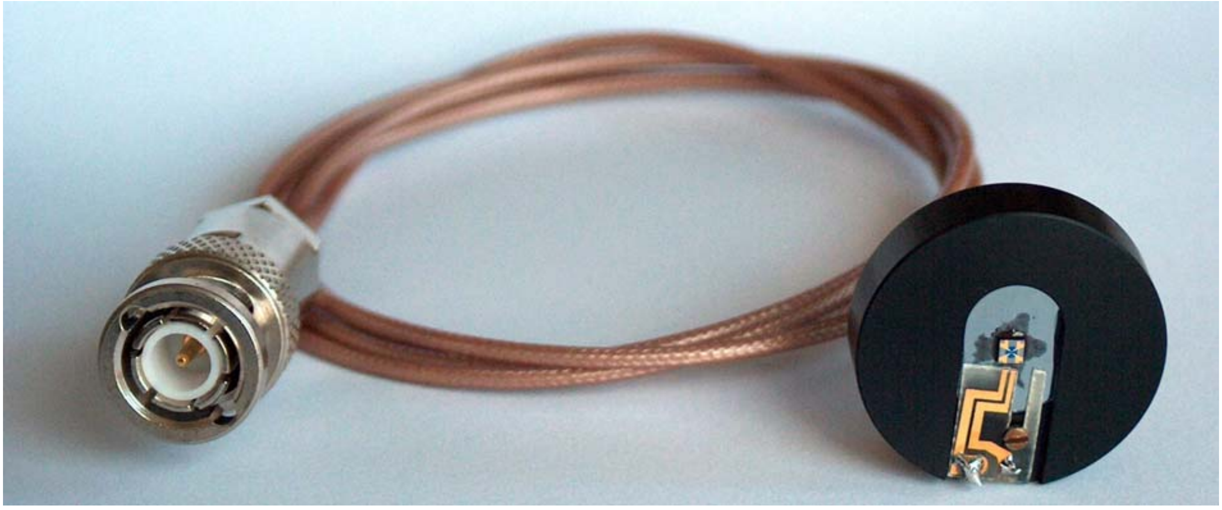
Photoconductive antenna	substrate	semi-insulating GaAs
	chip area	2 mm x 2mm
	thickness t	650 µm
Hyperhemispherical lens	material	undoped HRFZ-silicon,
	specific resistance ρ	>10 kΩcm
	refractive index n	3.4
	diameter	12 mm
	height h	7.1 mm
	distance d	7.7 mm
Terahertz beam	collection angle α	57°
	divergence angle ß	15°
	virtual focus length L	26.4 mm



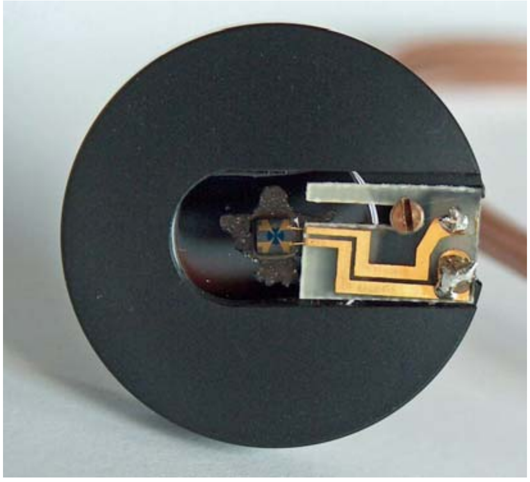
Aluminum mount	25.4 mm diameter, 6 mm thick
Coaxial cable	type RG178 B/U, impedance 50Ω, capacitance 96pF/m, 1 m long
Connector type	BNC

- The PCA chip is optically adjusted and glued on the hyperhemispherical silicon lens with a thermal conducting glue.
- The silicon lens is fixed on the aluminum mount with a thermal conducting glue.
- The two antenna contacts are wire bonded on a printed circuit board, which provides the connection to a 1m long coaxial cable with BNC or SMA connector
- A central hole in the aluminum mount allows the Terahertz radiation to escape from the hyperhemispherical silicon lens

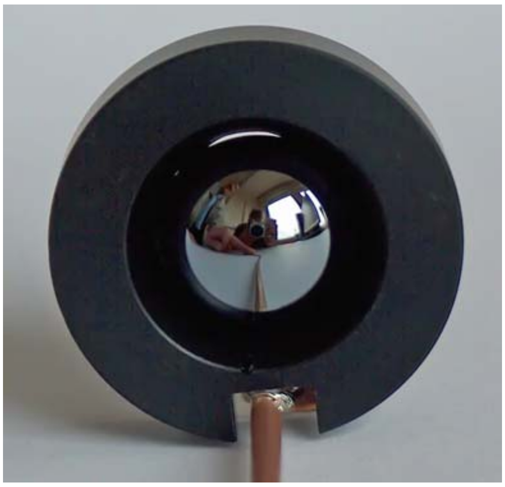
PCA with hyperhemispherical silicon lens, coaxial cable RG 178 and BNC connector



Front view on mounted PCA (laser side)

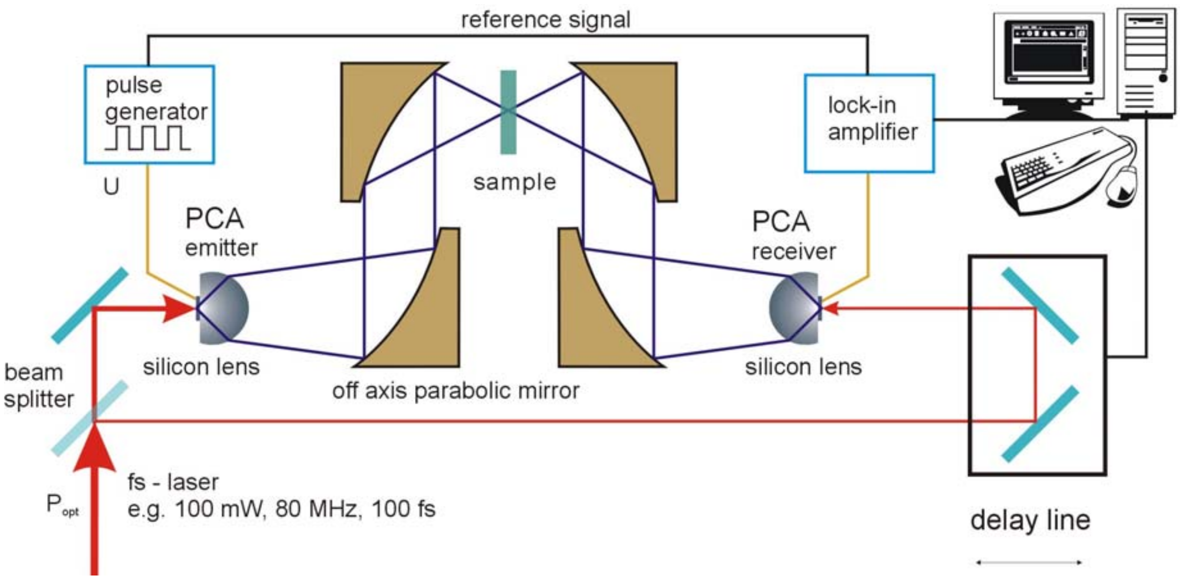


Back view on mounted PCA (THz side)

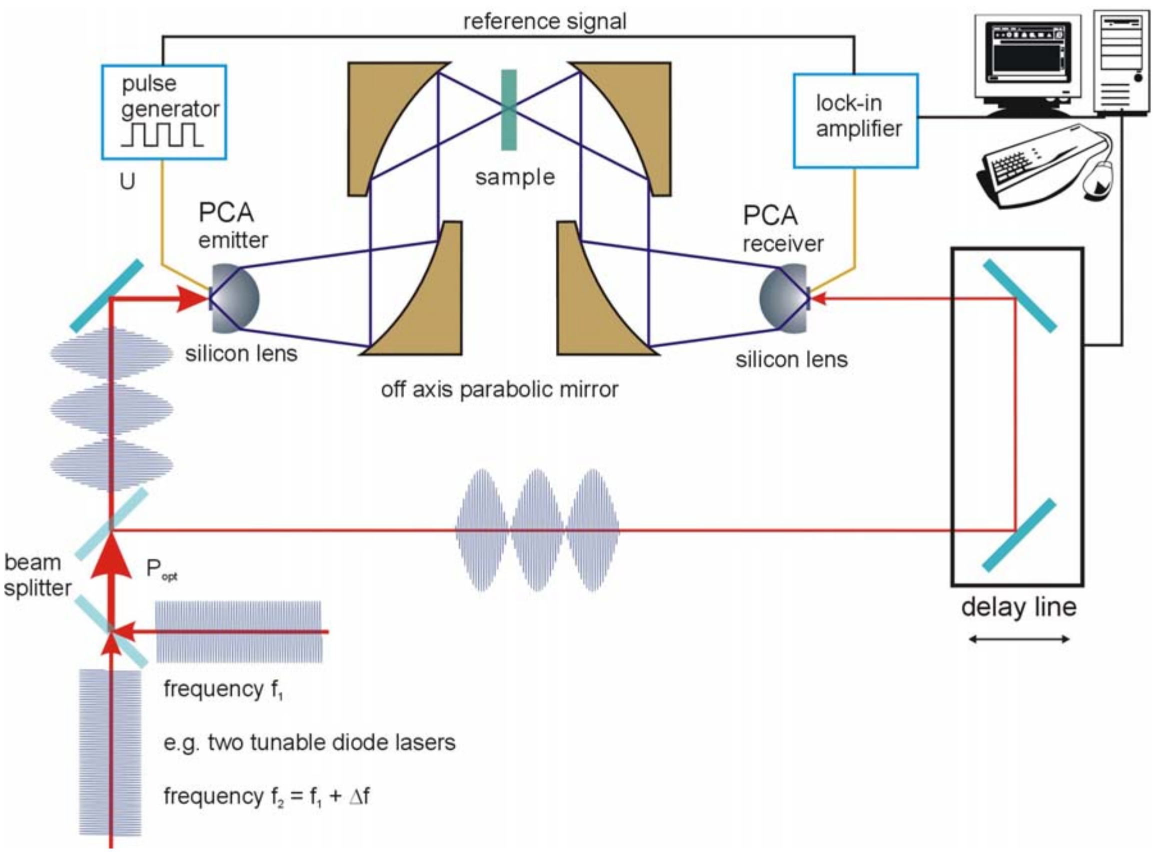


5. Instructions for use of the PCA-44-06-10-800-h

The antenna can be used as terahertz emitter or detector in pulsed laser gated broadband THz measurement systems for time-domain spectroscopy and as photomixing emitter or detector in tunable cw THz measurement systems in the frequency region from 0.1 to 3 THz (see schematics below).



Schematic of a time-domain spectroscopy setup



Photomixing setup

Emitter:

The pulsed laser beam (in case of time domain spectroscopy) or the mixed cw laser beam (in case of cw THz emitter) has to be focussed onto the antenna gap using an appropriate lens or objective with a beam diameter of about 6 µm to bridge the antenna gap with photo-excited carriers within the semiconductor. At the same time a voltage U of ~ 20 V (maximum 30 V peak voltage) has to be supplied on the gap by connecting the BNC connector cable to a voltage source. The recommended optical mean laser power P_{opt} is 30 mW (maximum 80 mW).

Receiver:

The pulsed laser beam (in case of time domain spectroscopy) or the mixed cw laser beam (in case of cw THz emitter) has to be focussed onto the antenna gap using an appropriate lens or objective with a beam diameter of about 6 µm to bridge the antenna gap with photo-excited carriers within the semiconductor. The phase of the laser beam with respect to the beam on the emitter site has to be adjusted by using of an optical delay line in such a way, that the measured value of the THz field on the antenna meets a maximum of the optical beam. By changing the phase difference between the emitter and receiver antenna the time-dependent shape of the THz field can be measured.

The cable with the BNC connector must be connected with a sensitive electronic current amplifier.

Attention: Please be sure, that the focusing lens or the lens mounting parts does not touch the antenna chip or the tiny gold contact wires between the antenna chip and the PCB. See figure “front view on mounted PCA (laser side)” above.

Lock-in detection

Because of the very small detector signal a lock-in detection scheme is recommended. The following two possibilities for lock-in detection can be used:

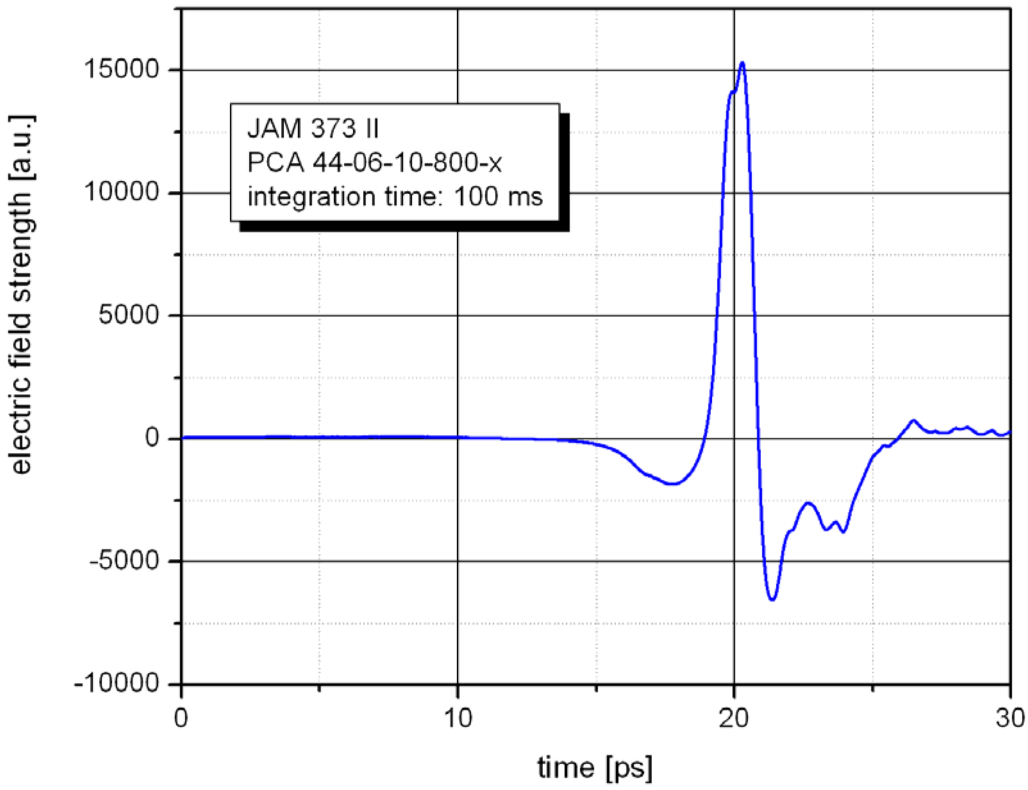
- An optical chopper can be used in front of the emitter antenna to chop the optical beam with a frequency ~ 1 kHz. The result is a chopped emitted THz signal, which meets the detector antenna. The output of the detector antenna is than a chopped current, which can be amplified using an ac amplifier and rectified using a standard lock-in system. The disadvantage of this system is the loss of 50 % of the optical excitation power on the emitter antenna.
- A square wave voltage generator with an output voltage U of maximum +/- 30 V and a frequency of some kHz can be used as supply for the emitter antenna. The result is an emitted alternating THz signal, which meets the detector antenna. The output of the detector antenna is than an alternating current, which can be amplified using an ac amplifier and rectified using a standard lock-in system. This setup is shown in the figures above.

Direct voltage detection

If the THz signal is large enough, a direct dc voltage detection scheme can be used. In this case the emitter antenna has to be supplied by a dc voltage U of up to 30 V. The detector antenna rectifies the THz signal like in a lock-in system using the delay line for adjusting the optical reference signal. The maximum antenna output voltage is in the region of ~ 10 mV and the current ~ 1 nA. In this case a low drift dc current amplifier is needed to increase the signal level for registration.

6. Time-domain measurements

THz detector signal at 10 mW optical pulse



THz pulse, measured by B. Pradarutti, Fraunhofer-Institut Angewandte Optik und Feinmechanik, Jena, Germany

BATOP GmbH
Wildenbruchstraße 15
D-07745 Jena
Germany
Tel: +49 3641 634009 - 0
Fax: +49 3641 634009 - 20
E-mail: info@batop.de
Deutsche Bank Jena
Bank Code: 82070024
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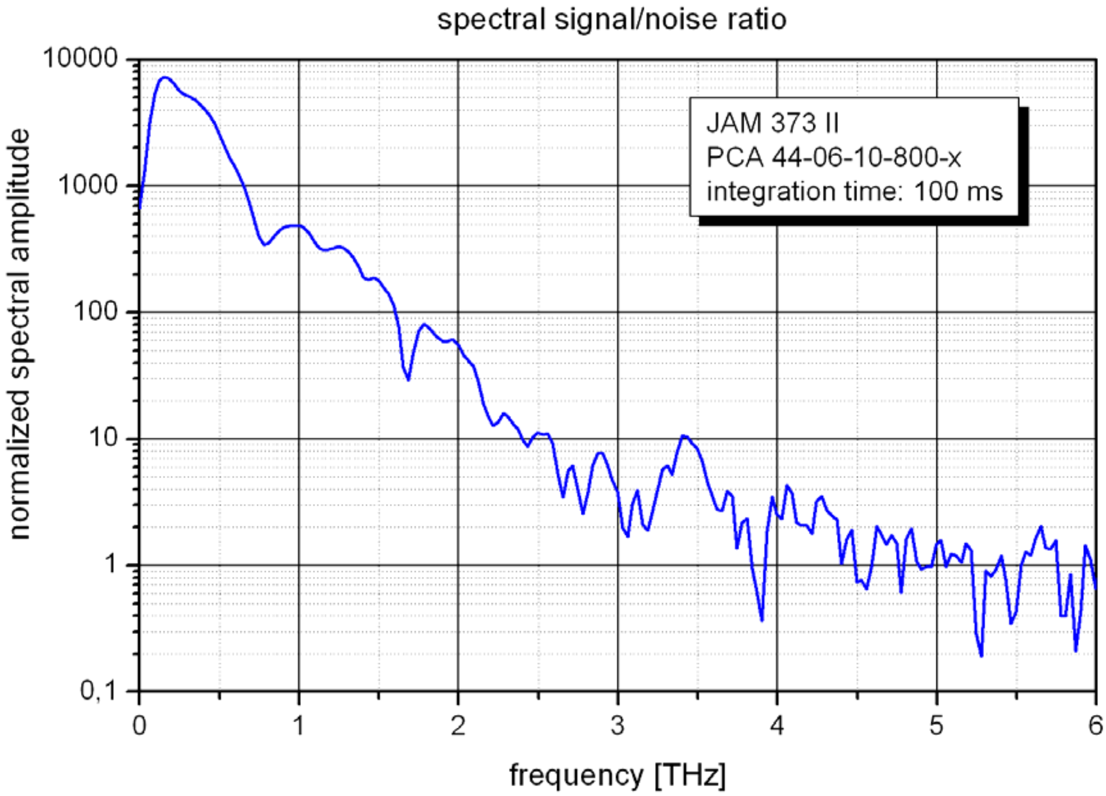


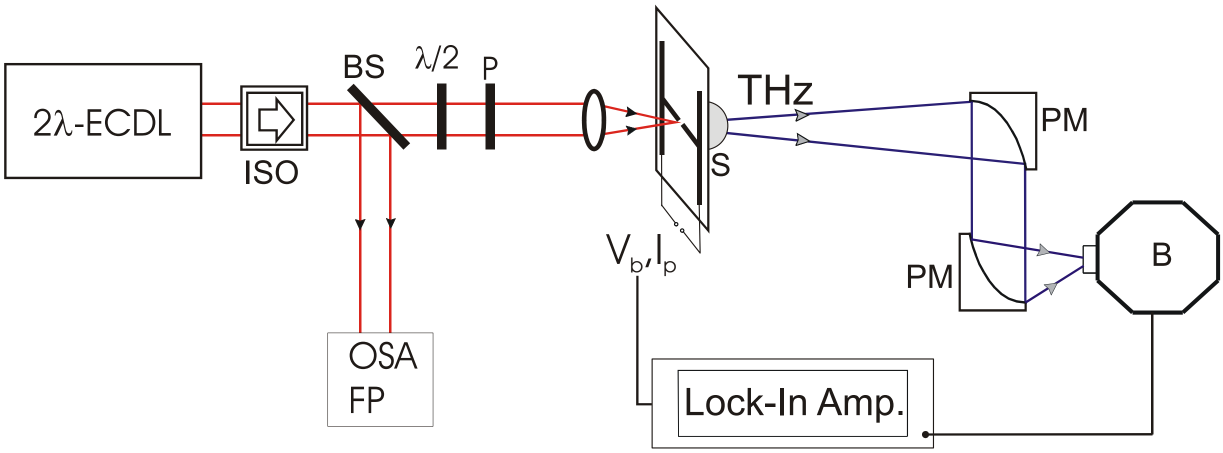
7. *Photomixing measurements*

The THz photomixing measurements have been done at the Institute of Applied Physics, Technische Universität Darmstadt by Dominik Blömer in the group of Prof. Wolfgang Elsäßer.

Photomixing setup

The setup for the measurement of the emitted THz power is shown in the figure below. The dipole antenna was optically excited by a semiconductor laser based dual-wavelength external cavity source (2λ-ECDL) with a laser chip from Dr. Andreas Klehr und Dr. Goetz Erbert from Ferdinand-Braun-Institut fuer Hochfrequenztechnik (FBH) Berlin. The laser power can be adjusted using a λ/2-plate together with a polarizer (P). An optical spectrum analyzer (OSA) and a Fabry-Perot-Interferometer (FPI) have been used for the characterization of the laser radiation. The laser beam with a mean wavelength of ~ 830 nm was focussed via a microscope objective (10x, NA 0.16) on the gap of the photoconductive antenna. The emitted THz power was directed with two off-axis parabolic mirrors (PM) onto a liquid helium cooled Si-bolometer (B).

The bolometer does not give a calibrated signal, but the THz signal level is very low in the region of some 100 pW.



THz photomixing setup at the Darmstadt University of Technology

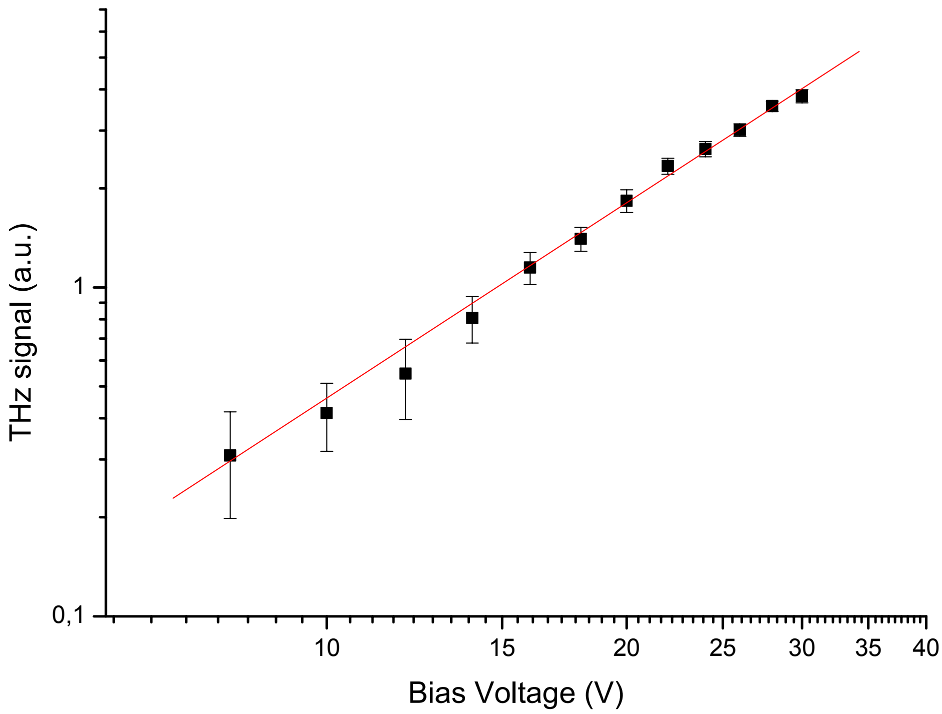
Bias voltage

The dependency of the emitted THz power P_{THz} on the antenna bias voltage V is shown in the next figure. From the slope of the measured points a quadratic dependency of the THz power on the bias voltage can be deduced according the formula

$$P_{THz} \sim V^2$$

This dependency can be expected, because it means a proportionality between the electric field strength in the antenna gap with the emitted THz field strength E_{THz}, which is correlated with the THz power P_{THz} according to

$$P_{THz} \sim E_{THz}^{\ 2}$$



THz power as a function of the antenna bias voltage

BATOP GmbH
Wildenbruchstraße 15
D-07745 Jena
Germany

Tel: +49 3641 634009 - 0
Fax: +49 3641 634009 - 20
E-mail: info@batop.de

Deutsche Bank Jena
Bank Code: 82070024
Account No: 3922655
IBAN: DE49 8207 0024 0392 2655 00

VAT Reg. No: DE 813698804
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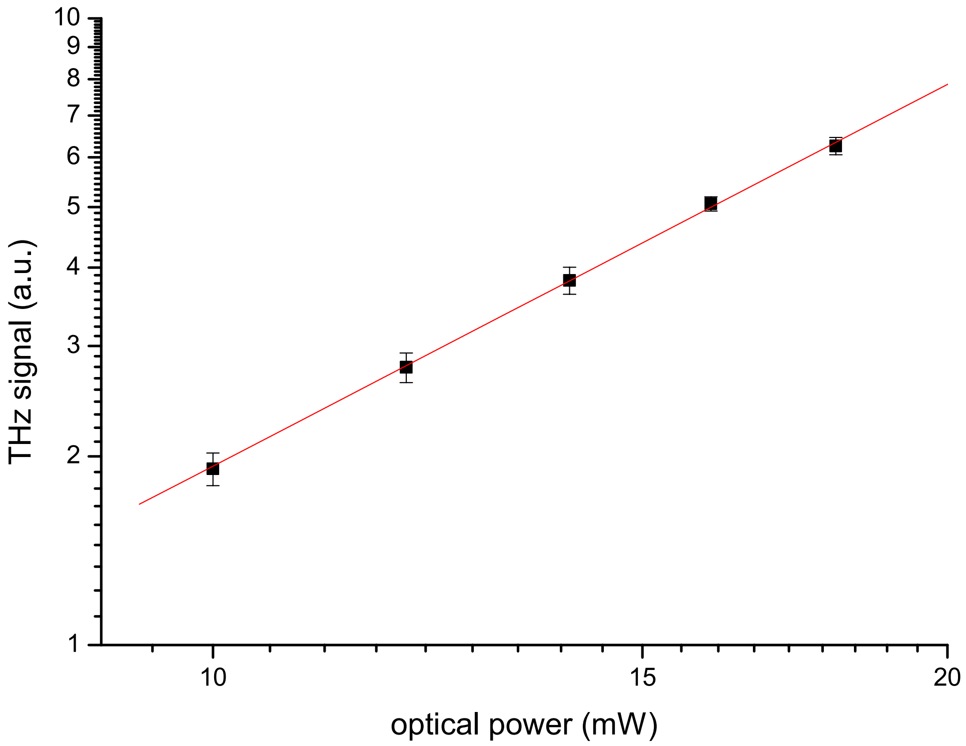
Optical excitation power

In the figure below the measured dependency of the emitted THz power P_{THz} on the optical excitation power P_{opt} is shown. The data points show a quadratic dependency according to the relation

$$P_{THz} \sim P_{opt}^2$$

This dependency can also be expected because of the following relations between the optical power P_{opt}, the excited free carrier density in the antenna gap ρ, the current density j, the emitted THz field strength E_{THz} and the THz power P_{THz}

$$P_{opt} \sim \rho \sim j \sim E_{THz} \sim P_{THz}^{1/2}$$

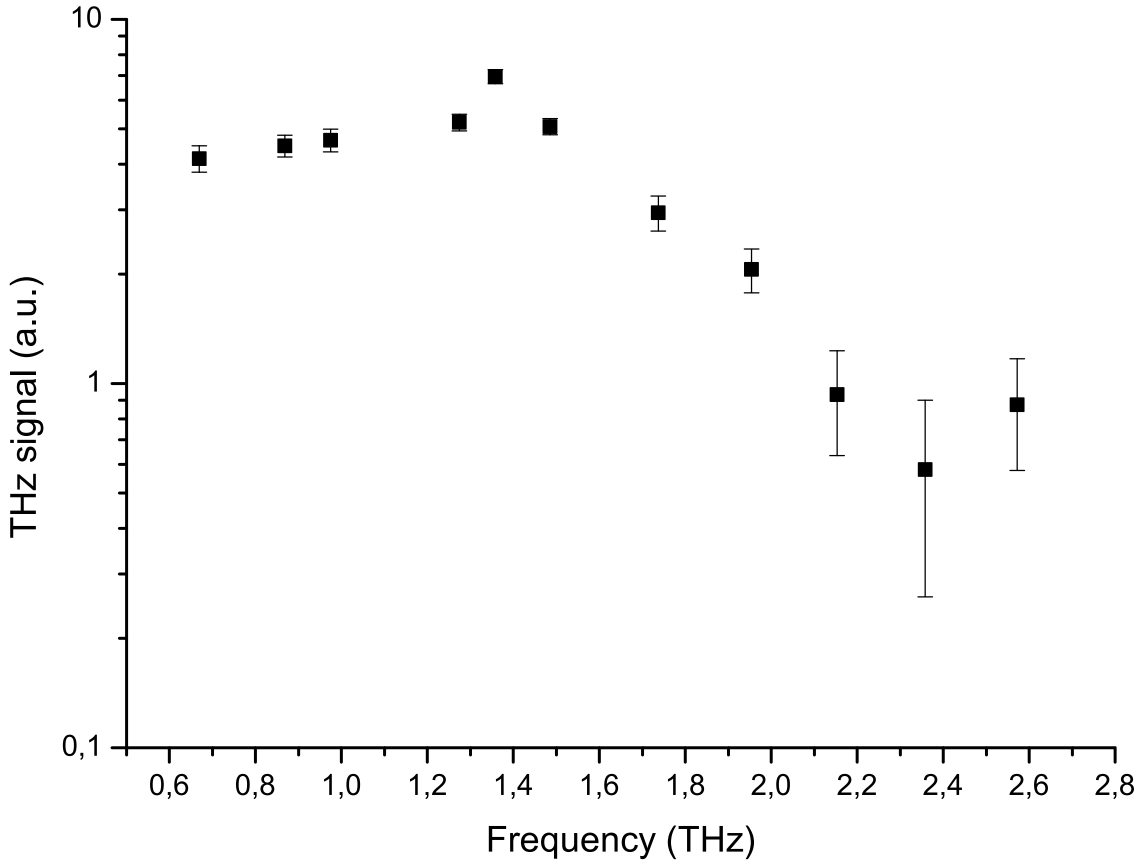


THz power as a function of the optical excitation power

Difference frequency

The measured influence of the difference frequency f on the emitted THz power P_{THz} is shown below. A resonance peak at f = 1.4 THz can be seen. The expected resonance frequency f_{res} of a dipole antenna with a length l = λ/2 = 44 µm in a semiconductor environment with the refractive index n ~ 3.4 can be estimated using the following relation:

$$f_{res} = \frac{c}{n \cdot \lambda} = \frac{c}{2 \cdot n \cdot l} =$$



THz power as a function of the difference frequency

8. Order information

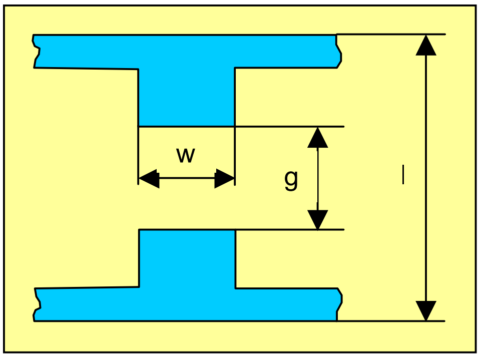
PCA-44-06-10-800-**x** Photoconductive antenna

length l = 44 µm

gap g = 6 µm

width w = 10 µm

laser wavelength λ = 800 nm
(500 nm … 850 nm)



x denotes the type of mounting as follows:

- **x** = 0 unmounted chip 2 mm x 2 mm with bond contact pads 300 µm x 650 µm
- **x** = h mounted on an Al disc with 25.4 mm ∅ and **h**yperhemispherical silicon substrate lens, 1m coaxial cable with SMA connector