

Instruction manual and data sheet PCA-44-06-10-1030-x

Photoconductive THz antenna for laser excitation wavelengths $\lambda \sim 990 \text{ nm} \dots 1060 \text{ nm}$

PCA – Photoconductive Antenna

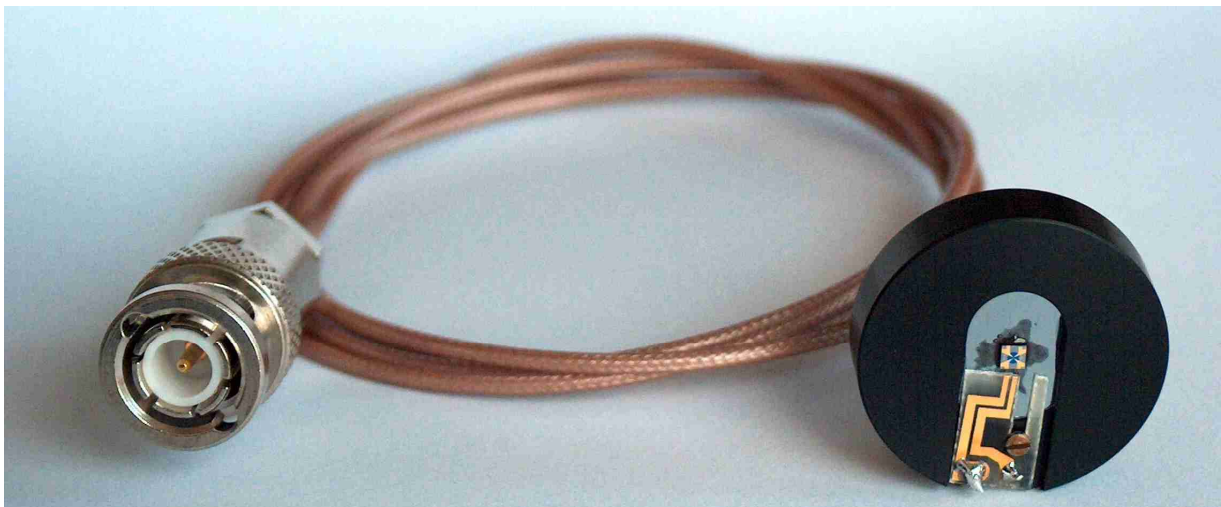
PCA-44-06-10-1030-0 - unmounted antenna chip 2 mm x 2 mm with 4 bond contact pads

PCA-44-06-10-1030-h - mounted antenna on hyperhemispherical silicon substrate lens

PCA-44-06-10-1030-a - mounted antenna on aspheric silicon substrate lens

Table of contents:

1. PCA applications	2
2. Antenna design.....	2
3. Antenna parameters	3
4. Mounted PCA on hyperhemispherical silicon substrate lens: PCA-44-06-10-1030-h	4
5. Mounted PCA on aspheric silicon substrate lens: PCA-44-06-10-1030-a	8
6. Instructions for use of the PCA-44-06-10-1030-x	11
7. Time-domain measurements with PCA-44-06-10-1030-h.....	12
8. PCA-44-06-10-1030-h as detector and PCA-40-05-1060-h as emitter.....	15
9. Order information	16

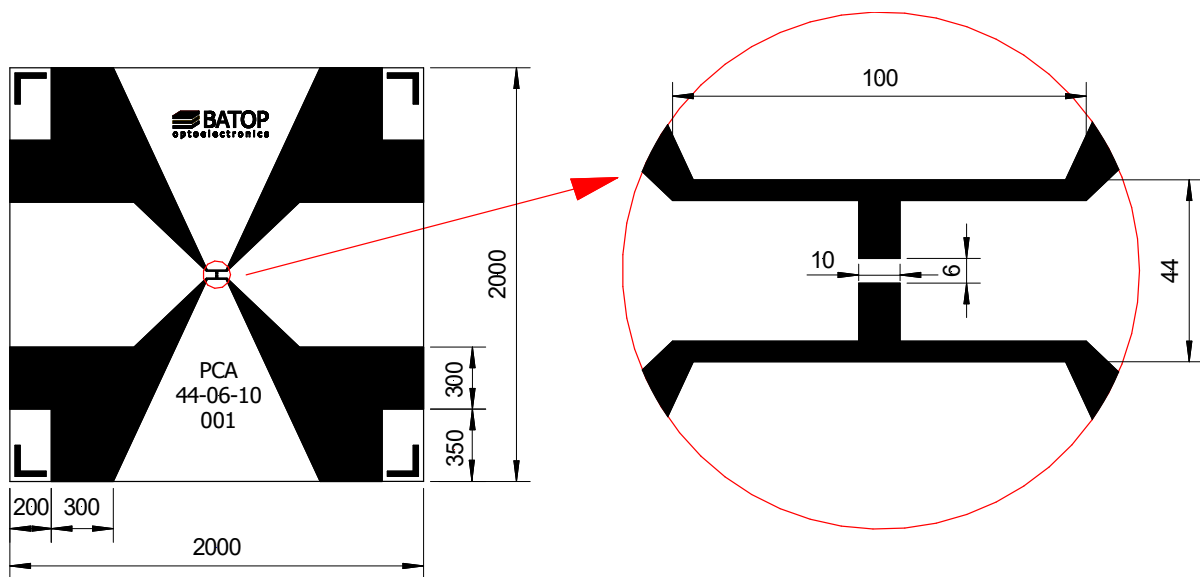


1. PCA applications

The PCA can be used as terahertz (THz) emitter or detector in pulsed laser gated 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 1.5 THz. The antenna delivers a large signal at frequencies below 500 GHz.

- Main PCA data**
- Laser excitation wavelength $\lambda \sim 1030 \text{ nm}$
 - Bandwidth $\sim 1 \text{ THz}$

2. Antenna design



all dimensions in micrometers

Photo PCA 44-06-10 (survey)



Photo PCA 44-06-10

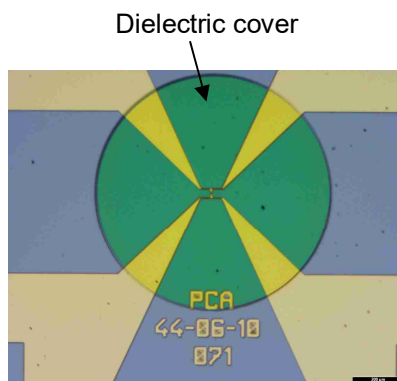
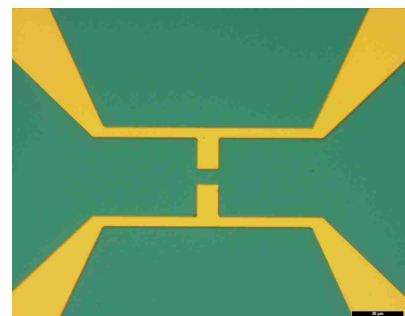


Photo PCA 44-06-10 (detail)

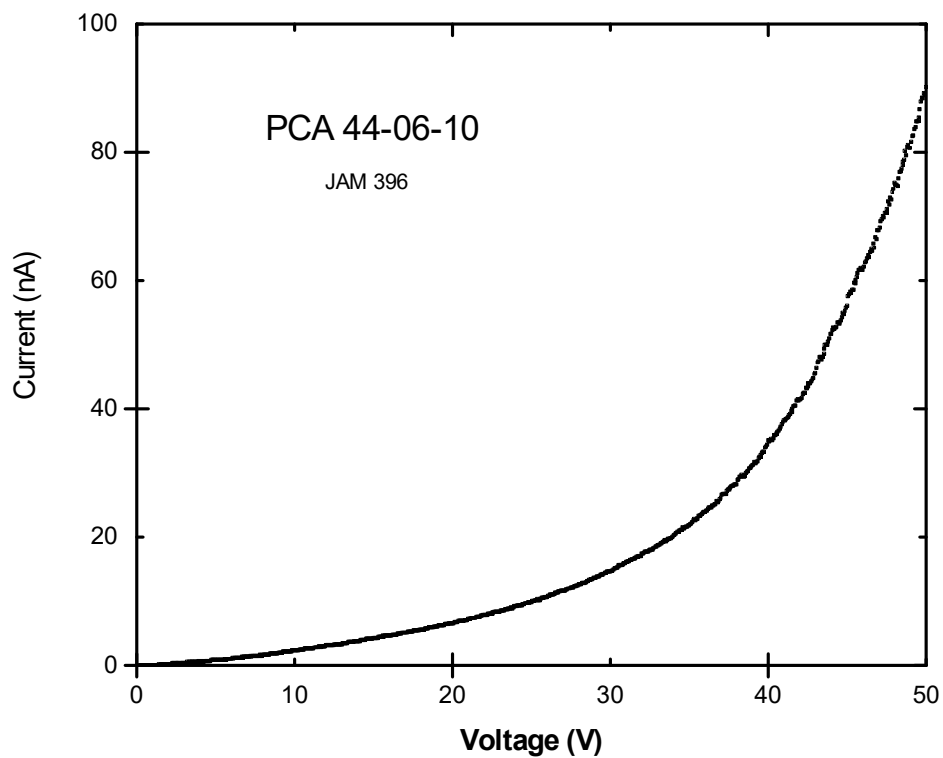


3. Antenna parameters

Electrical parameters

Parameter	minimum ratings	standard	maximum ratings
Dark resistance	5 G Ω	10 G Ω	15 G Ω
Dark current @ 10 V	500 pA	2 nA	5 nA
Voltage		20 V	30V

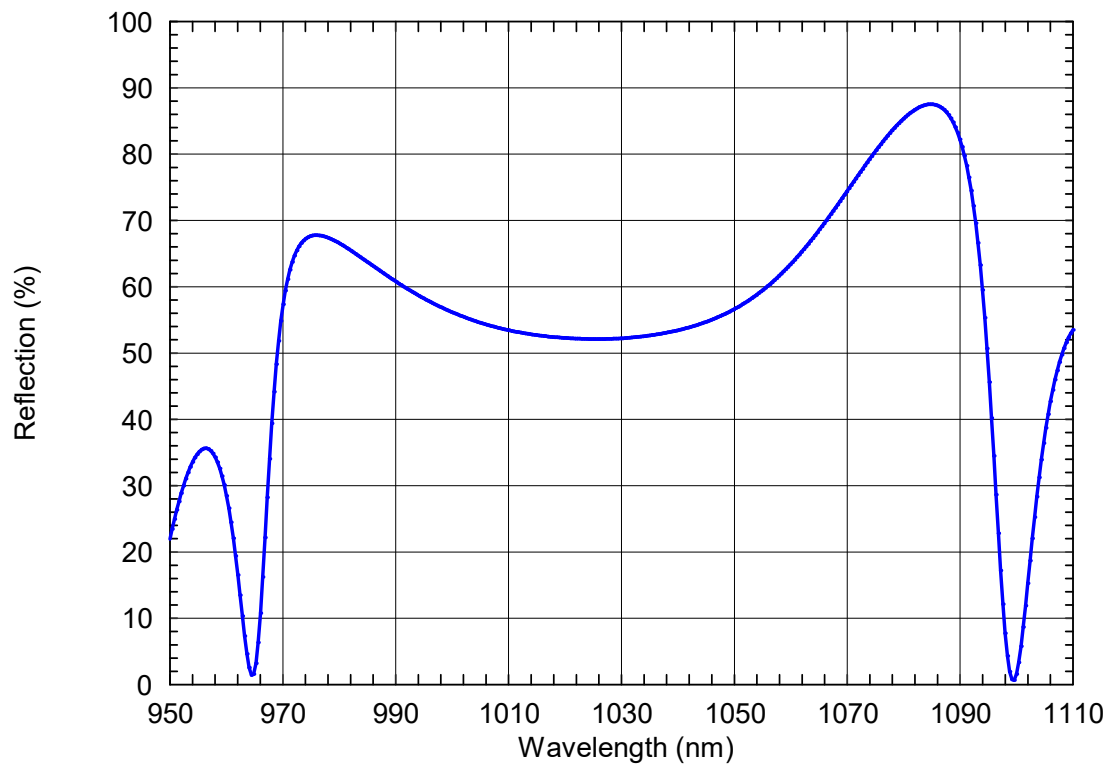
Dark current voltage characteristic at T = 300 K



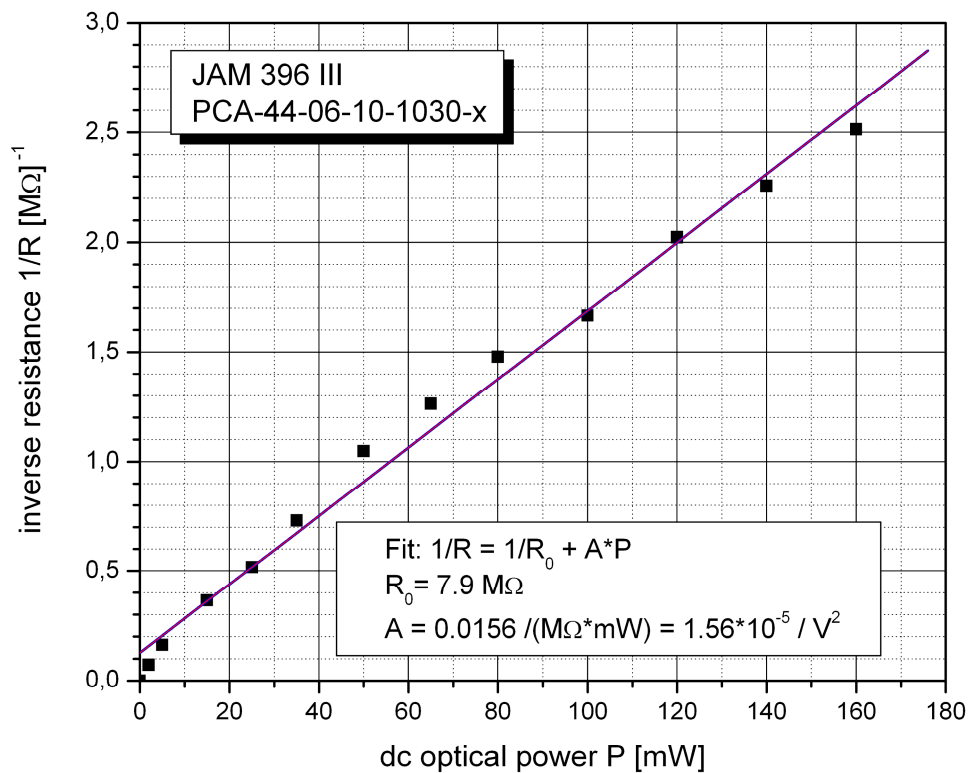
Optical excitation parameters

Parameter	minimum ratings	standard	maximum ratings
Excitation laser wavelength	990 nm	1030 nm	1060 nm
Optical reflectance @ 1040 nm	60 % @ 990 nm	52 % @ 1030 nm	65 % @ 1060 nm
Optical mean power		30 mW	80 mW
Carrier recovery time		400 fs	

Spectral reflectance



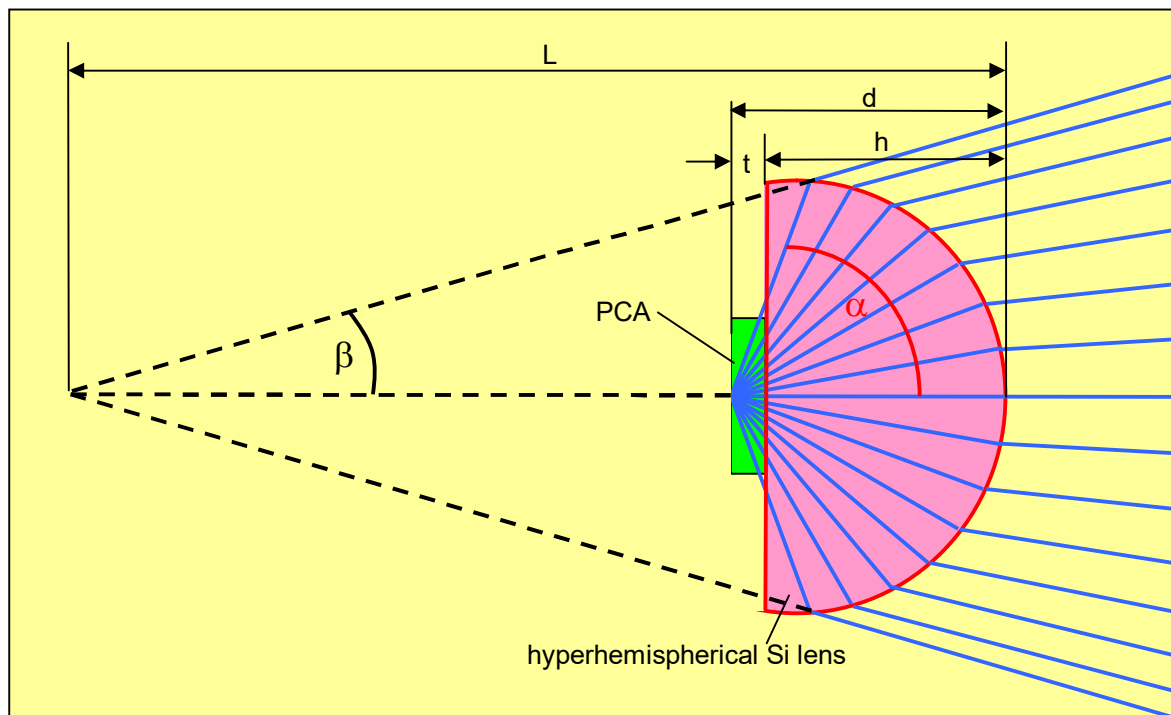
Illumination dependent resistance R



4. Mounted PCA on hyperhemispherical silicon substrate lens: PCA-44-06-10-1030-h

Photoconductive antenna substrate semi-insulating GaAs

	chip area	2 mm x 2 mm
	thickness t	600 μm
Hyperhemispherical lens	material	undoped HRFZ-silicon,
	specific resistance ρ	>10 $\text{k}\Omega\text{cm}$
	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 β	15°
	virtual focus length L	26.4 mm



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

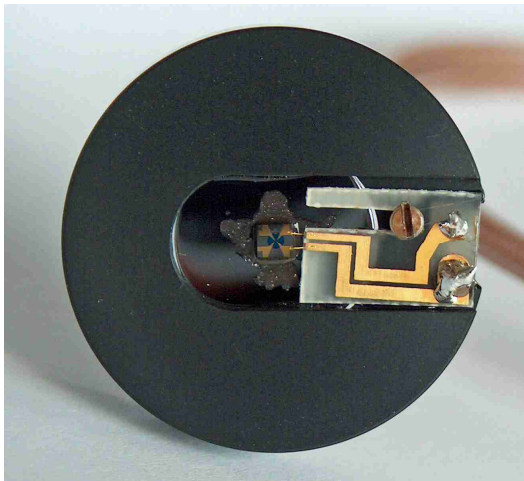
- The PCA chip is optically adjusted and glued on the hyperhemispherical silicon lens. The alignment of the PCA chip centre is done with respect to the optical axis of the silicon lens.
- The silicon lens is glued on the aluminium mount.

- 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 aluminium mount allows the Terahertz radiation to escape from the hyperhemispherical silicon lens

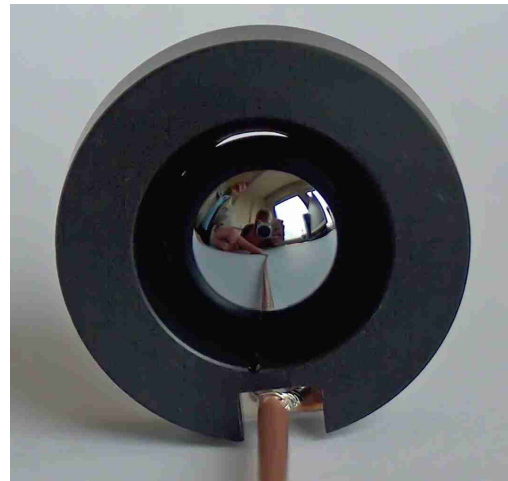
PCA with hyperhemispherical silicon lens, coaxial cable RG 178 and BNC connector



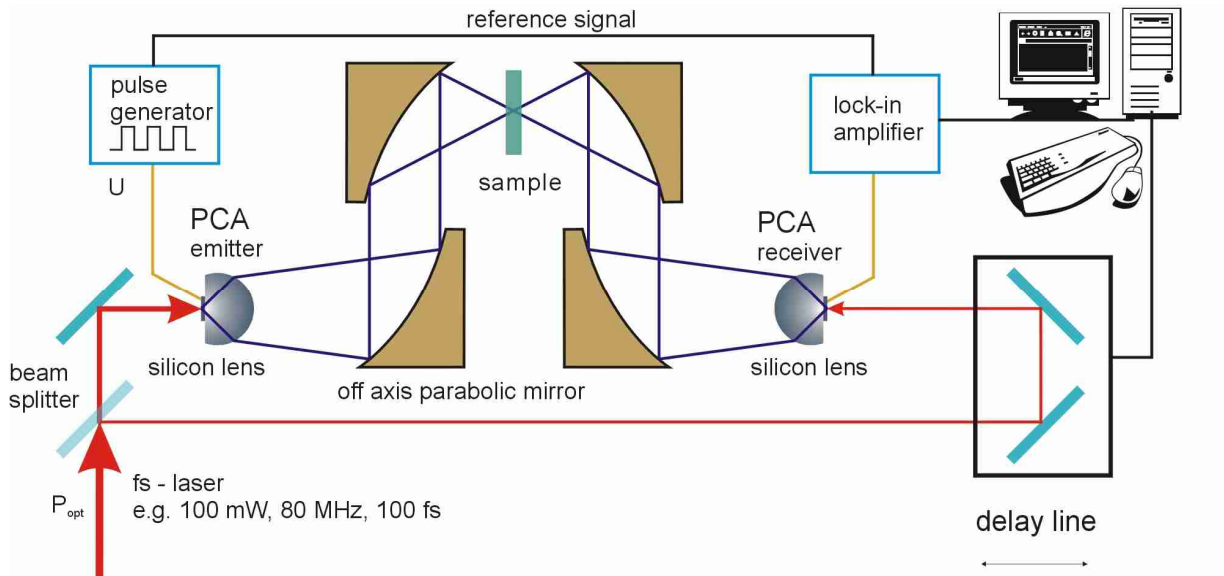
Front view on mounted PCA (laser side)



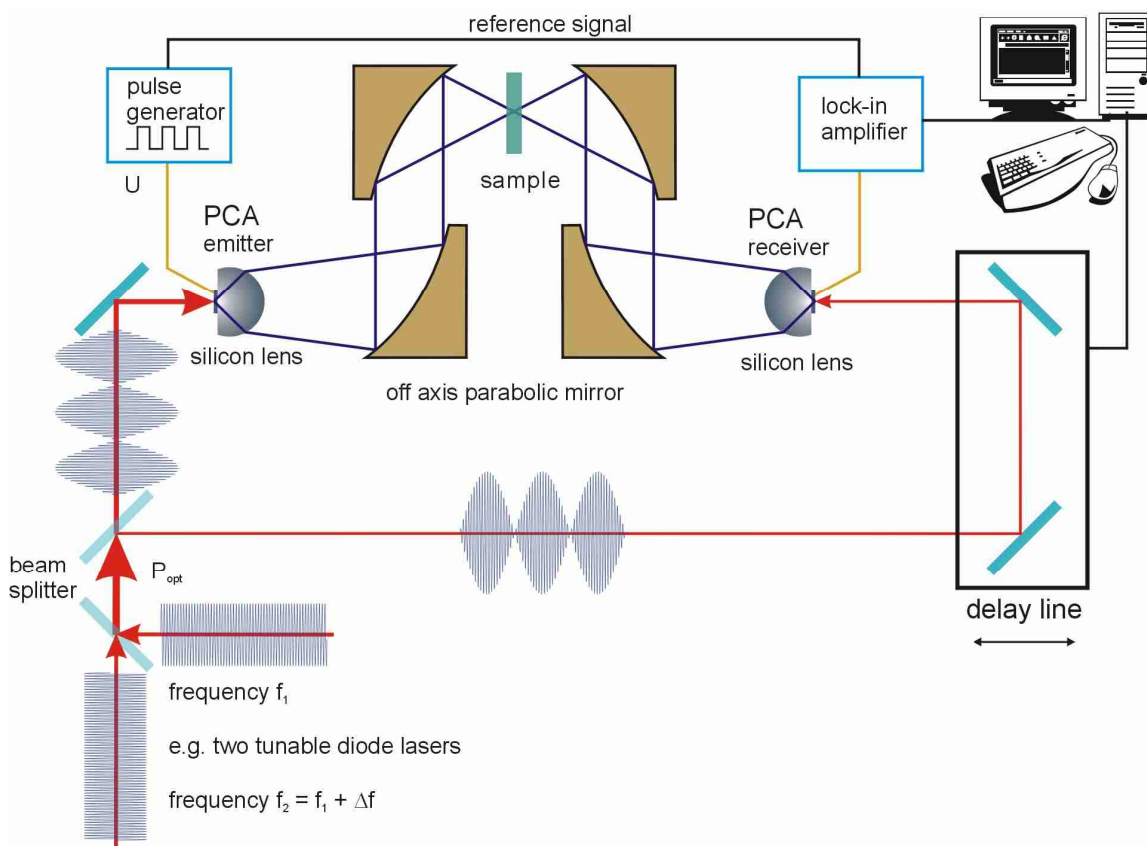
Back view on mounted PCA (THz side)



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).



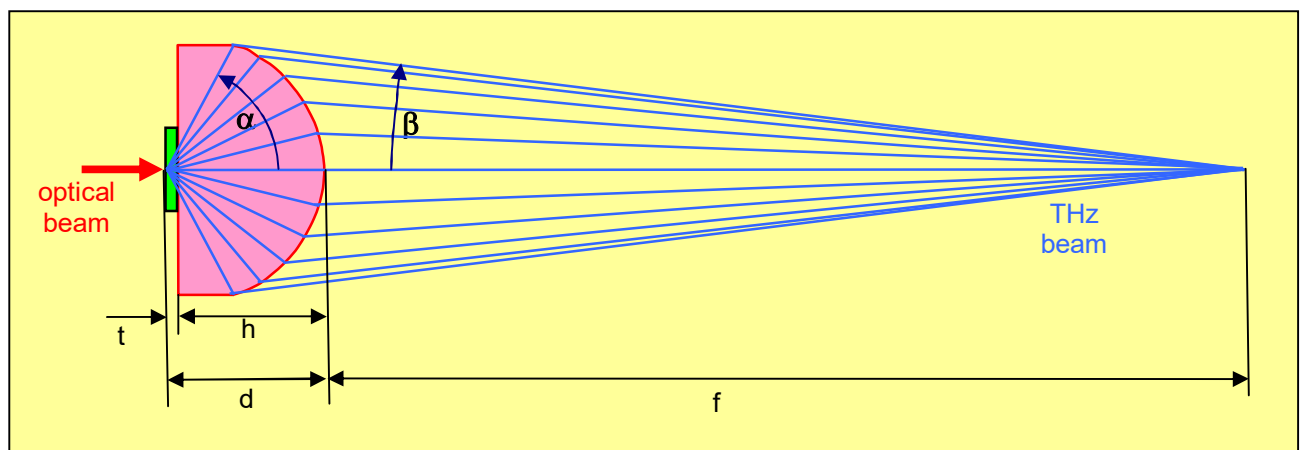
Schematic of a time-domain spectroscopy setup



Photomixing setup

5. Mounted PCA on aspheric silicon substrate lens: PCA-44-06-10-1030-a

Photoconductive antenna	substrate	semi-insulating GaAs
	chip area	2 mm x 2mm
	thickness t	600 μm
Aspheric lens	material	undoped HRFZ-silicon
	specific resistance ρ	>10 k Ωcm
	refractive index n	3.4
	diameter	12 mm
	height h	8 mm
	distance d	8.6 mm
	rough AR surface	
Terahertz beam	focal length f	50 mm
	collection angle α	57.6°
	convergence angle β	6.8°
Airy disc diameter	at 300 GHz	5 mm
	at 1 THz	1.5 mm
	at 3 THz	0.5 mm

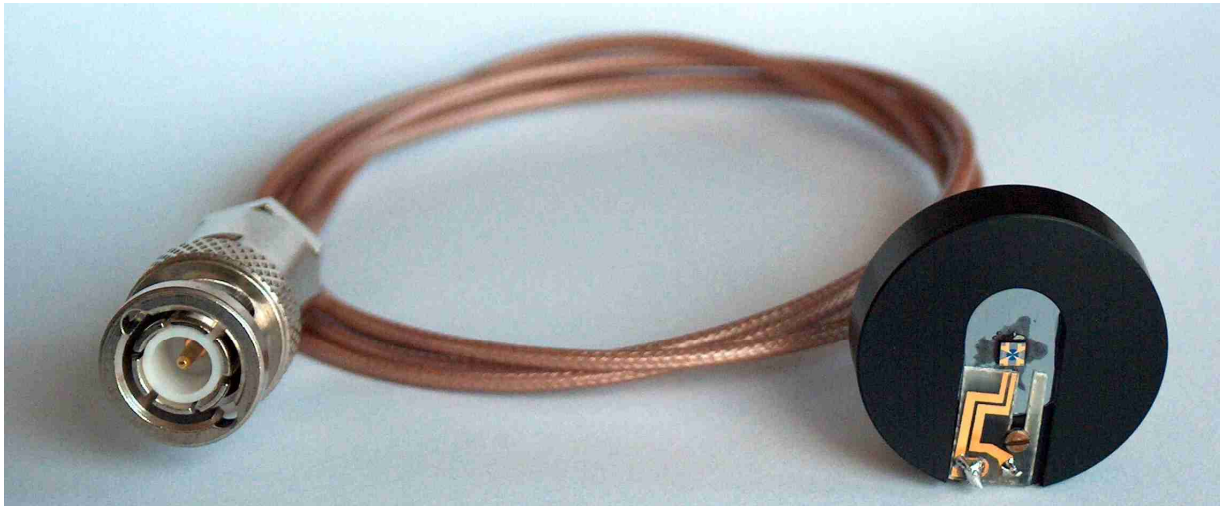


Aluminium mount	25.4 mm diameter, 6 mm thick
Coaxial cable	type RG178 B/U, impedance 50 Ω , capacitance 96pF/m, 1 m long
Connector type	BNC or SMA

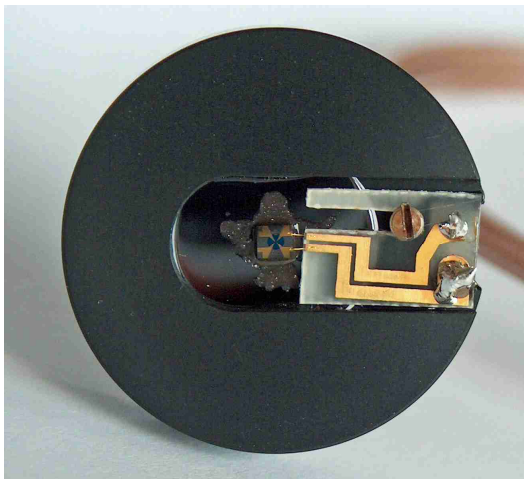
- The PCA chip is optically adjusted and glued on the aspheric silicon lens. The alignment of the PCA chip centre is done with respect to the optical axis of the silicon lens.
- The silicon lens is glued on the aluminium mount.

- 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 aspheric silicon lens as a collimated beam with a focus 50 mm away and an Airy disc diameter dependent on the THz frequency.

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



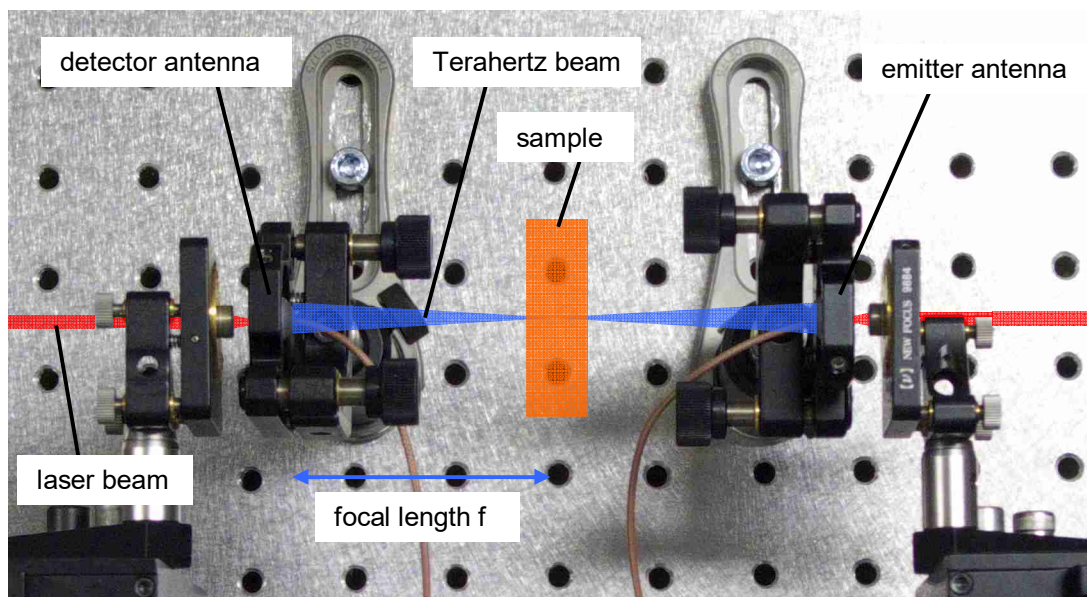
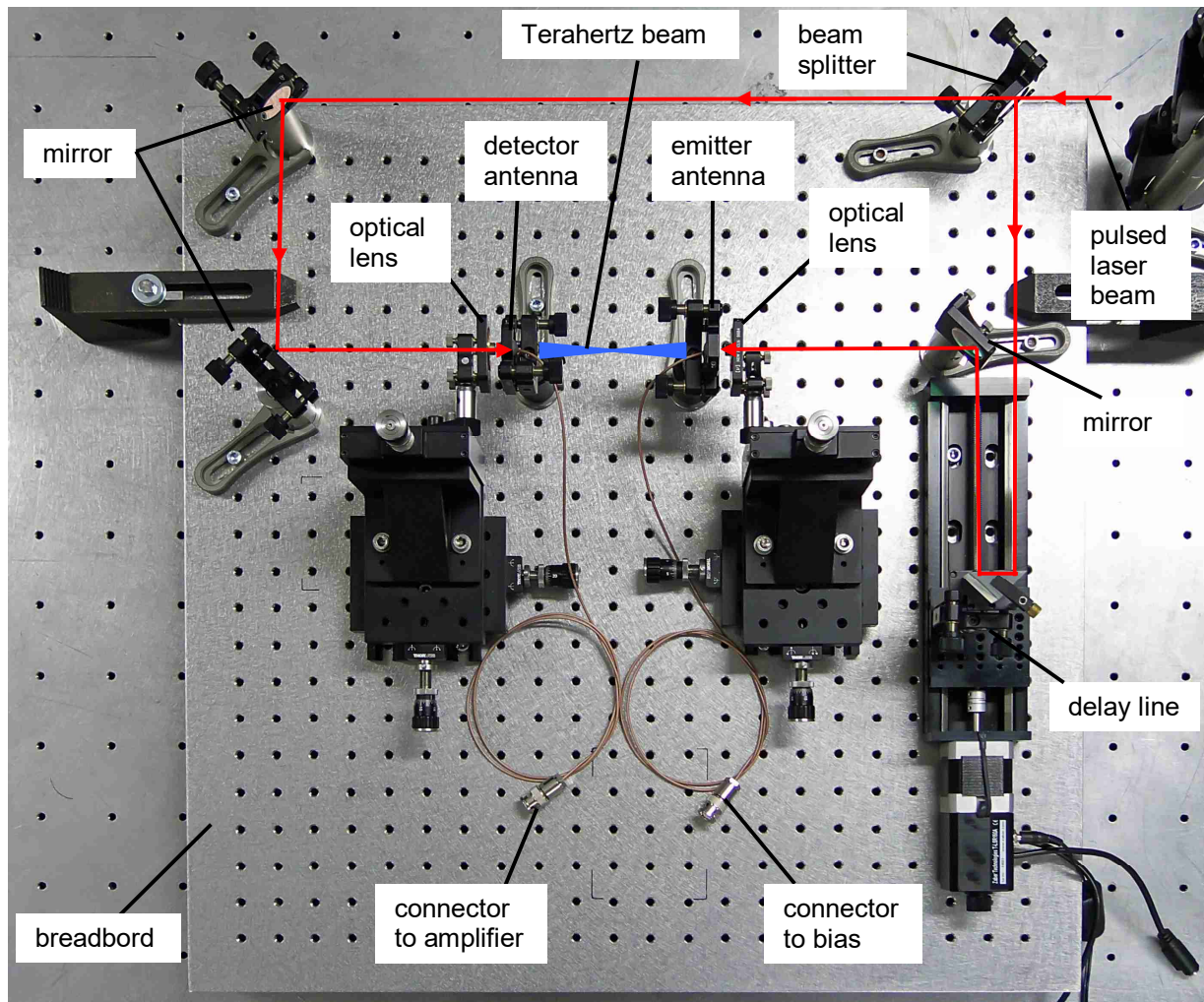
Front view on mounted PCA (laser side)



Back view on mounted PCA (THz side)



Terahertz time-domain spectrometer with two photoconductive antennas on aspheric lenses



Extended view of the Terahertz light path with sample

Bias voltage of the emitter antenna:

- dc voltage: In this case the dc output voltage of the detector antenna (typical in the region of 1 .. 100 mV) can be measured using a dc voltage amplifier.

- ac voltage: As a result of the emitter square wave bias voltage between $-V$.. $+V$ the detector antenna delivers an ac voltage, which can be phase sensitive measured using a lock-in detector

6. Instructions for use of the PCA-44-06-10-1030-x

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 $6\text{ }\mu\text{m}$ to bridge the antenna gap with photo-excited carriers within the semiconductor. At the same time a voltage U of $\sim 20\text{ V}$ (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 $6\text{ }\mu\text{m}$ 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 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 $\sim 1\text{ kHz}$. 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 $\pm 30\text{ V}$ 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

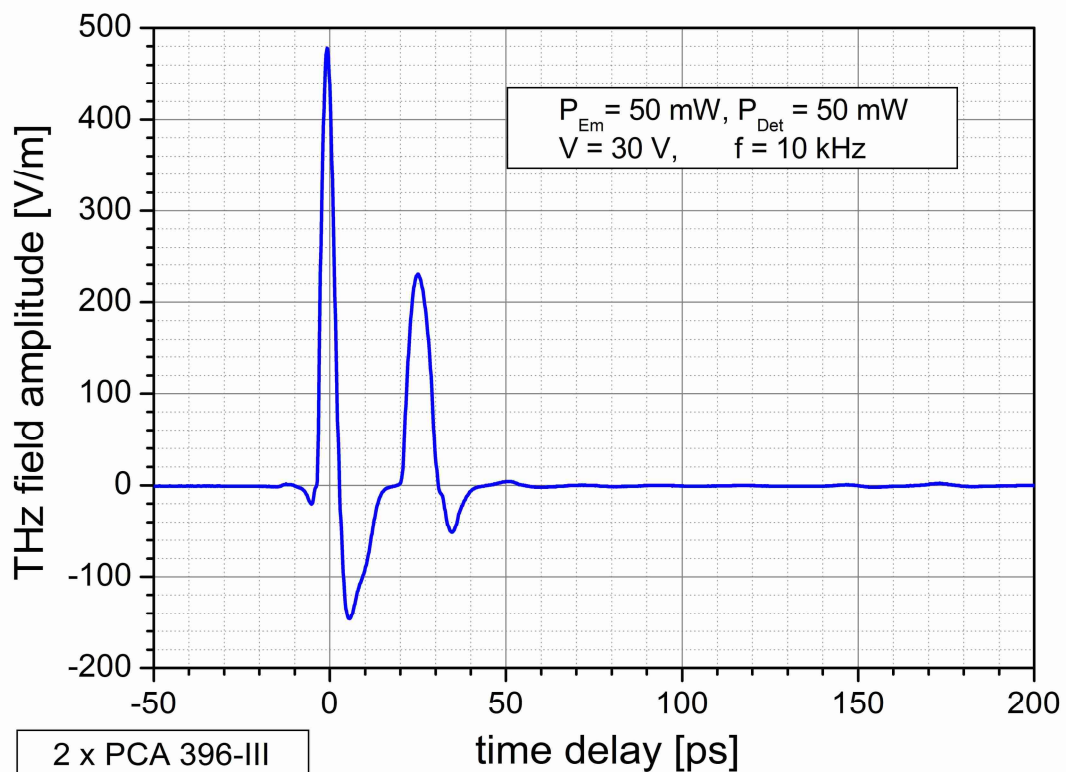
is than an alternating current, which can be amplified using an ac amplifier and rectified using a standard lock-in system. This setup is shown in the figures above.

Direct voltage detection

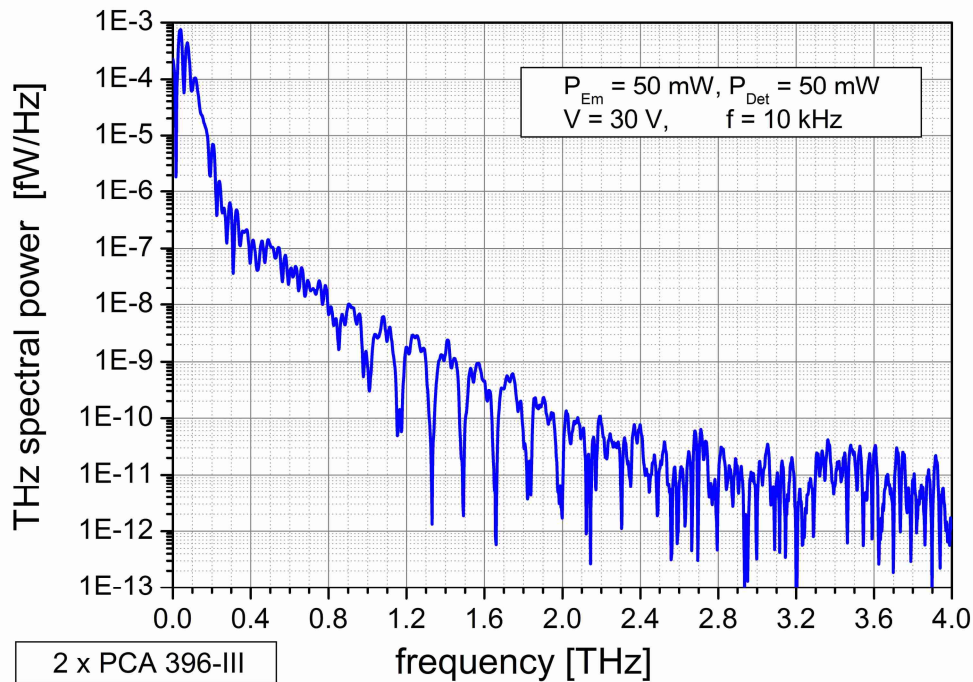
If the THz signal is large enough, a direct dc voltage detection scheme can be used. In this case the emitter antenna has to be supplied by a dc voltage U of up to 30 V. The detector antenna rectifies the THz signal like in a lock-in system using the delay line for adjusting the optical reference signal. 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.

7. Time-domain measurements with PCA-44-06-10-1030-h

The PCA-44-06-10-1030-h has been used as emitter and as detector in a time-domain setup using a pulsed laser source at 1060 nm wavelength and a pulse width of 220 fs. A square wave voltage generator supplied a bias ac voltage with a frequency of 10 kHz to the emitter antenna. The detector signal has been measured using a standard lock-in. The detector field amplitude was calculated by the following formula: $E_d = V_d/I$ with V_d – detector voltage, $I = 44 \mu\text{m}$ antenna length.

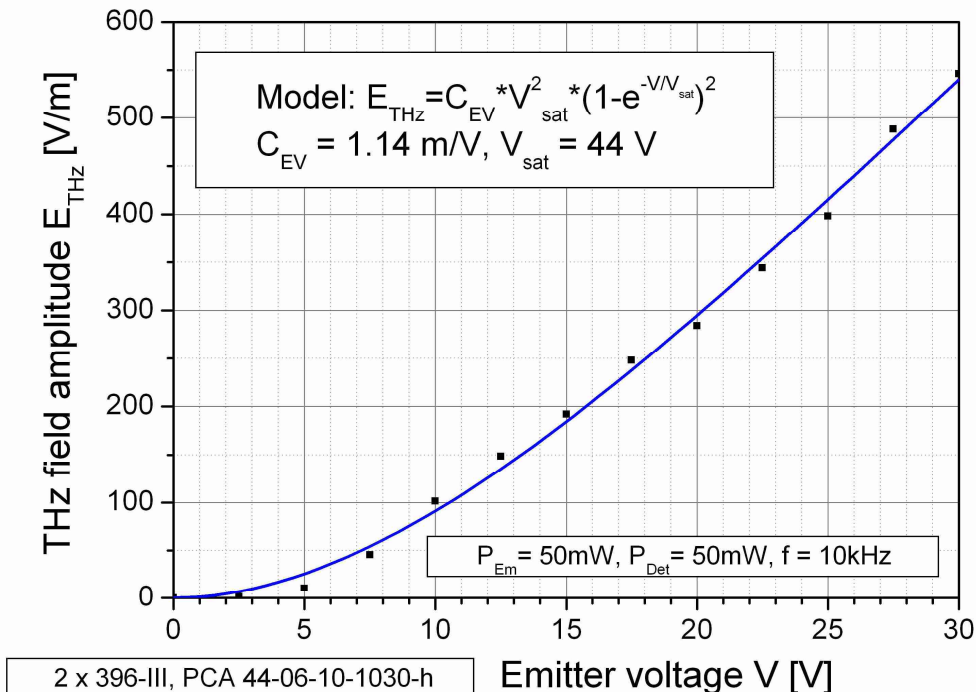


Time domain measurement with PCA-44-06-10-1030-h on the emitter and detector side. Modulation frequency 10 KHz, emitter voltage 30 V, mean optical laser power 50 mW on emitter and on detector, laser wavelength 1060 nm, pulse width 220 fs.



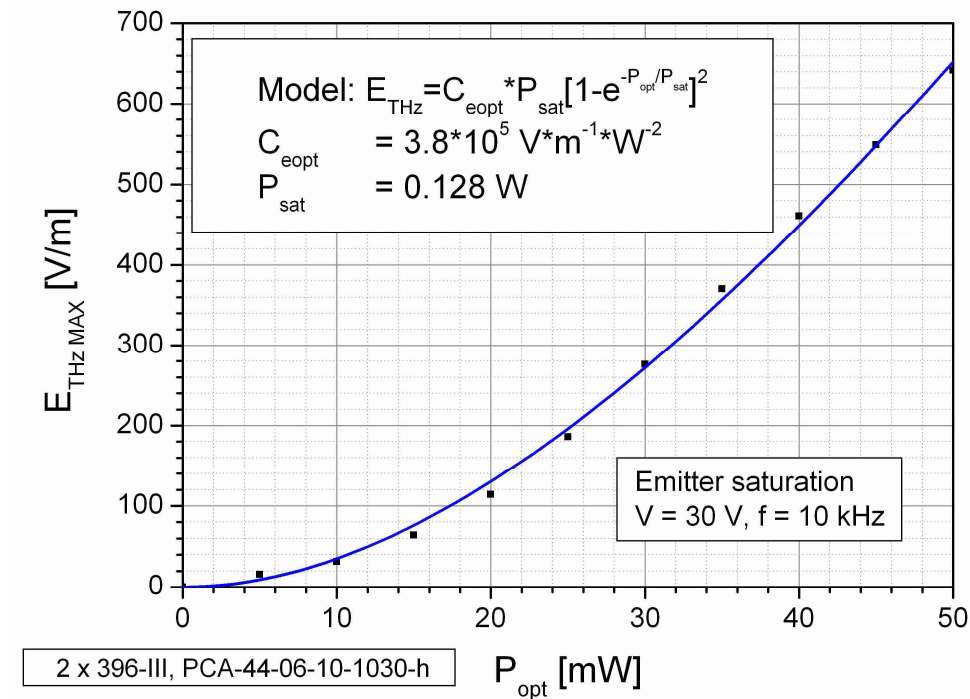
Time domain measurement with PCA-44-06-10-1030-h on the emitter and detector side. Modulation frequency 10 KHz, emitter voltage 30 V, mean optical laser power 50 mW on emitter and on detector, laser wavelength 1060 nm, pulse width 220 fs.

Influence of the emitter voltage V on the detector signal E_{THz}



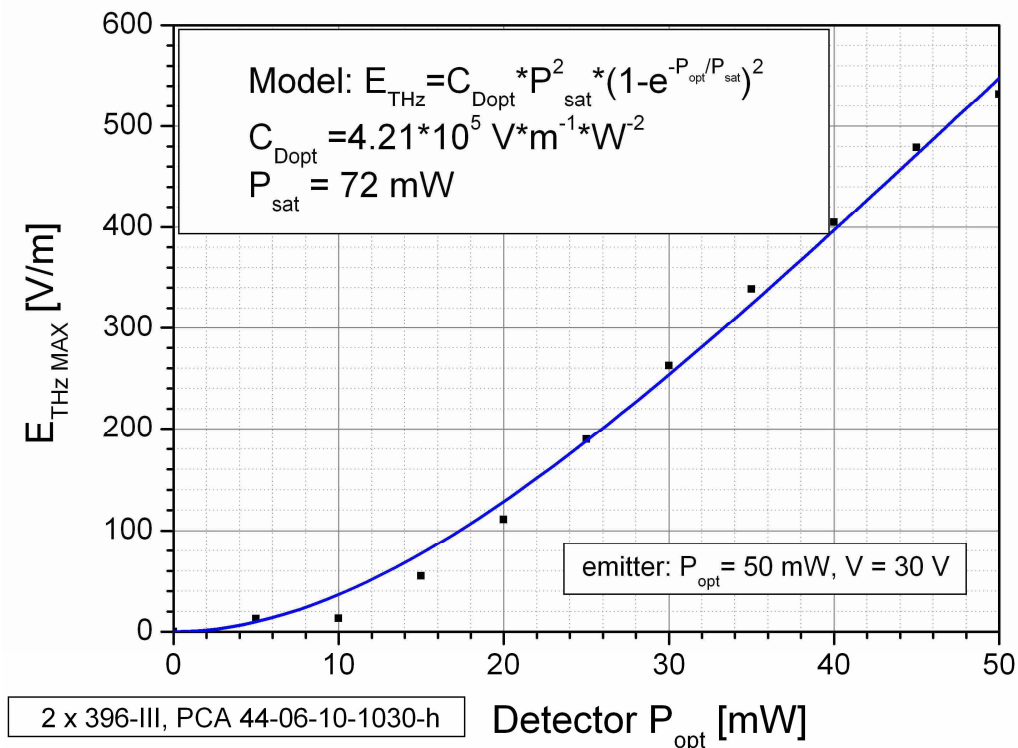
Time domain measurement with PCA-44-06-10-1030-h on the emitter and detector side. Modulation frequency 10 kHz, mean optical laser power 50 mW on emitter and on detector, laser wavelength 1060 nm, pulse width 220 fs. Saturation voltage on the emitter antenna $V_{sat} = 44 \text{ V}$.

Influence of the optical power P_{opt} on the emitter antenna on the detector signal E_{THz}



Time domain measurement with PCA-44-06-10-1030-h on the emitter and detector side. Modulation frequency 10 kHz, emitter voltage 30 V, mean optical laser power 50 mW on detector, laser wavelength 1060 nm, pulse width 220 fs. Saturation optical power on the emitter antenna $P_{\text{sat}} = 128 \text{ mW}$.

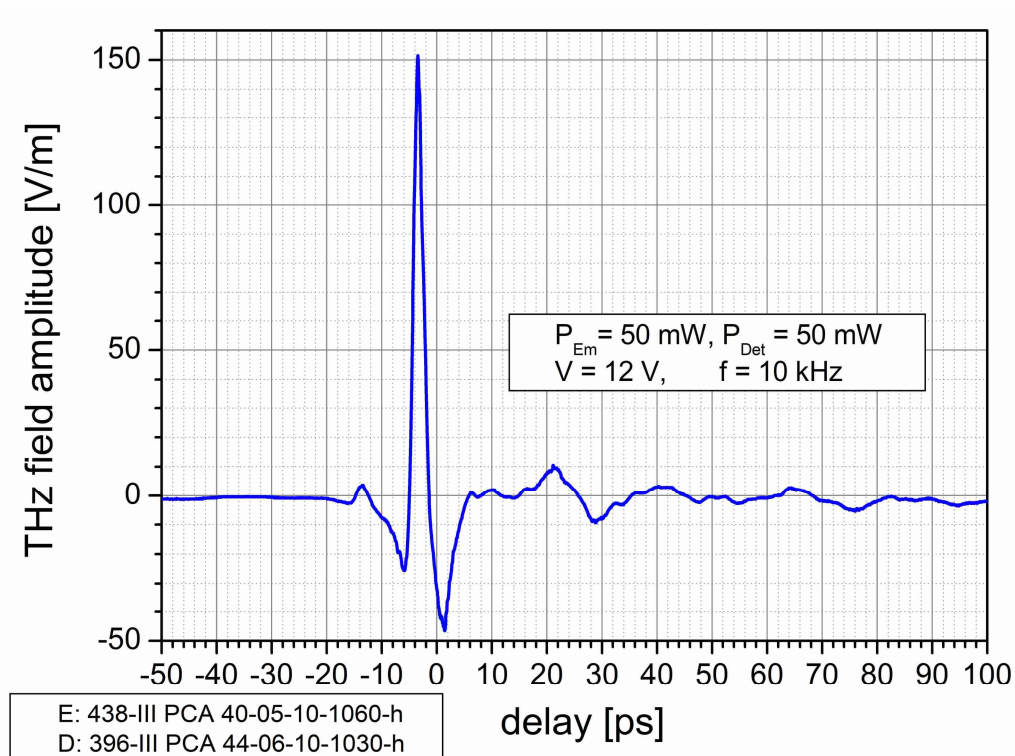
Influence of the optical power on the detector antenna on the detector signal



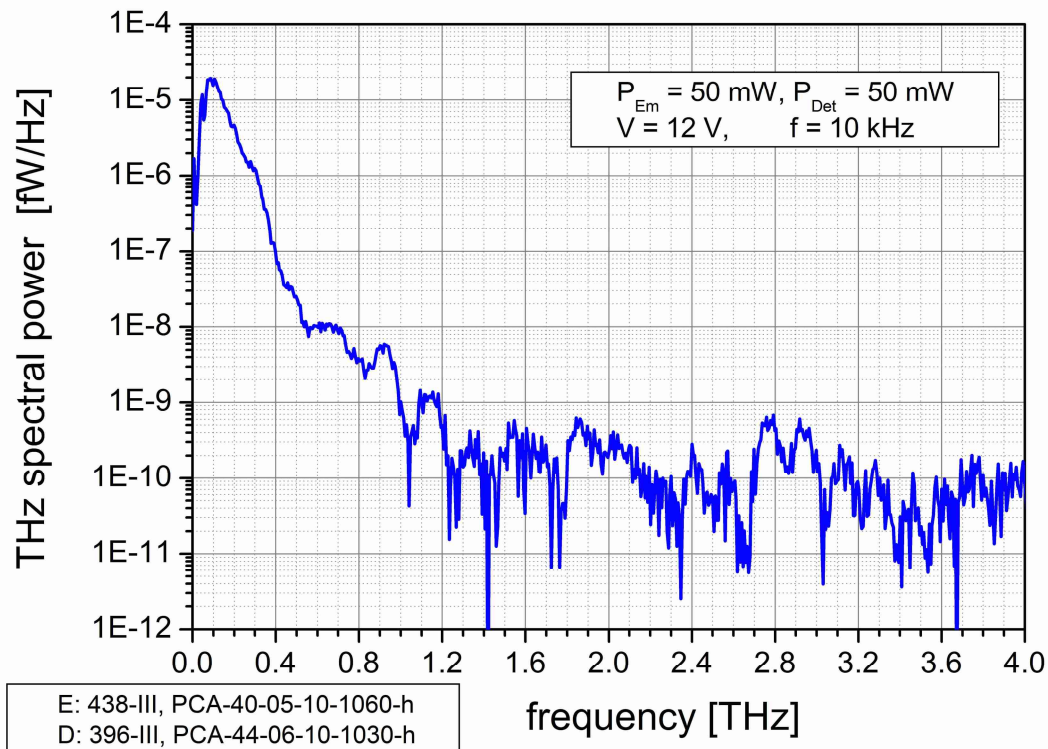
Time domain measurement with PCA-44-06-10-1030-h on the emitter and detector side. Modulation frequency 10 kHz, emitter voltage 30 V, mean optical laser power 50 mW on emitter, laser wavelength 1060 nm, pulse width 220 fs. Saturation optical power on the detector antenna $P_{\text{sat}} = 72 \text{ mW}$.

8. PCA-44-06-10-1030-h as detector and PCA-40-05-1060-h as emitter

The PCA-40-05-10-1060-h has been used as broadband emitter and as the PCA-44-06-10-1030-h as detector in a time-domain setup using a pulsed laser source at 1060 nm wavelength and a pulse width of 220 fs. A square wave voltage generator supplied a 12 V bias ac voltage with a frequency of 10 kHz to the emitter antenna. The detector signal has been measured using a standard lock-in. The detector field amplitude was calculated by the following formula: $E_d = V_d/l$ with V_d – detector voltage, $l = 44 \mu\text{m}$ antenna length.



Time domain measurement with PCA-44-06-10-1030-h on the detector side. The emitter was a PCA-40-05-10-1060-h. Modulation frequency 10 KHz, emitter voltage 12 V, mean optical laser power 50 mW on emitter and on detector, laser wavelength 1060 nm, pulse width 220 fs.



Time domain measurement with PCA-44-06-10-1030-h on the detector side. The emitter was a PCA-40-05-10-1060-h. Modulation frequency 10 KHz, emitter voltage 12 V, mean optical laser power 50 mW on emitter and on detector, laser wavelength 1060 nm, pulse width 220 fs.

9. Order information

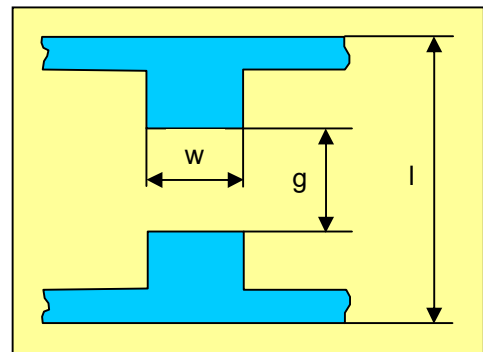
PCA-44-06-10-1030-**x** Photoconductive antenna

length $l = 44 \mu\text{m}$

gap $g = 6 \mu\text{m}$

width $w = 10 \mu\text{m}$

laser wavelength $\lambda = 1030 \text{ nm}$
(990 nm ... 1060 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 \varnothing and **h**yperhemispherical silicon substrate lens, 1m coaxial cable with BNC or SMA connector
- x** = a mounted on an Al disc with 25.4 mm \varnothing and **a**spheric silicon substrate lens, 1m coaxial cable with BNC or SMA connector