# Instruction manual and data sheet PCA-44-16-16-1030-x

Photoconductive THz antenna for laser excitation wavelengths λ ~ 990 nm … 1060 nm

PCA – Photoconductive Antenna

PCA-44-16-16-1030-0 - unmounted antenna chip 2 mm x 2 mm with 4 bond contact pads

PCA-44-16-16-1030-h - mounted antenna on hyperhemispherical silicon substrate lens

PCA-44-16-16-1030-a - mounted antenna on aspheric silicon substrate lens

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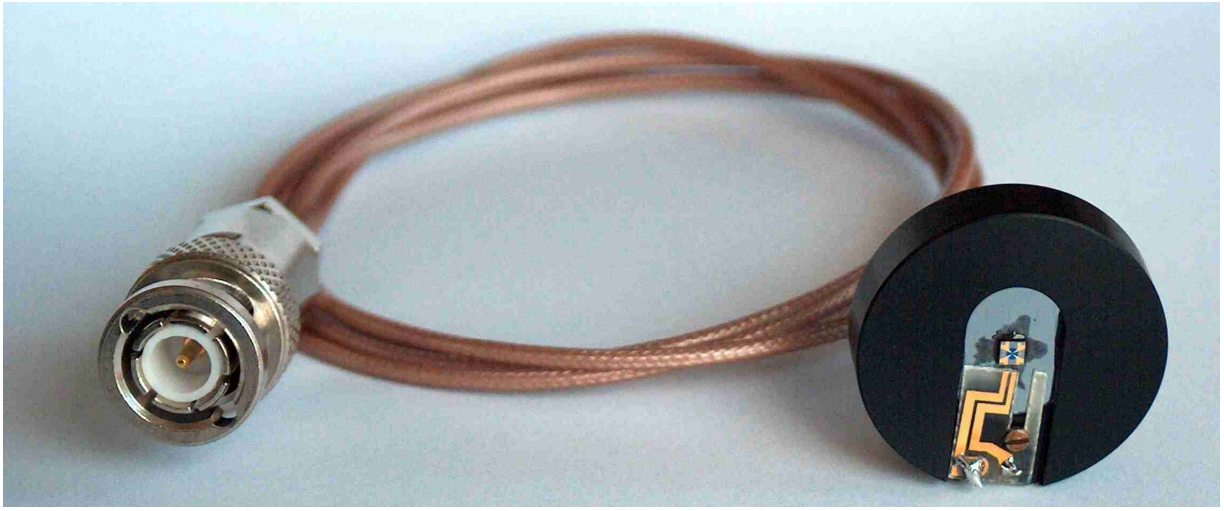


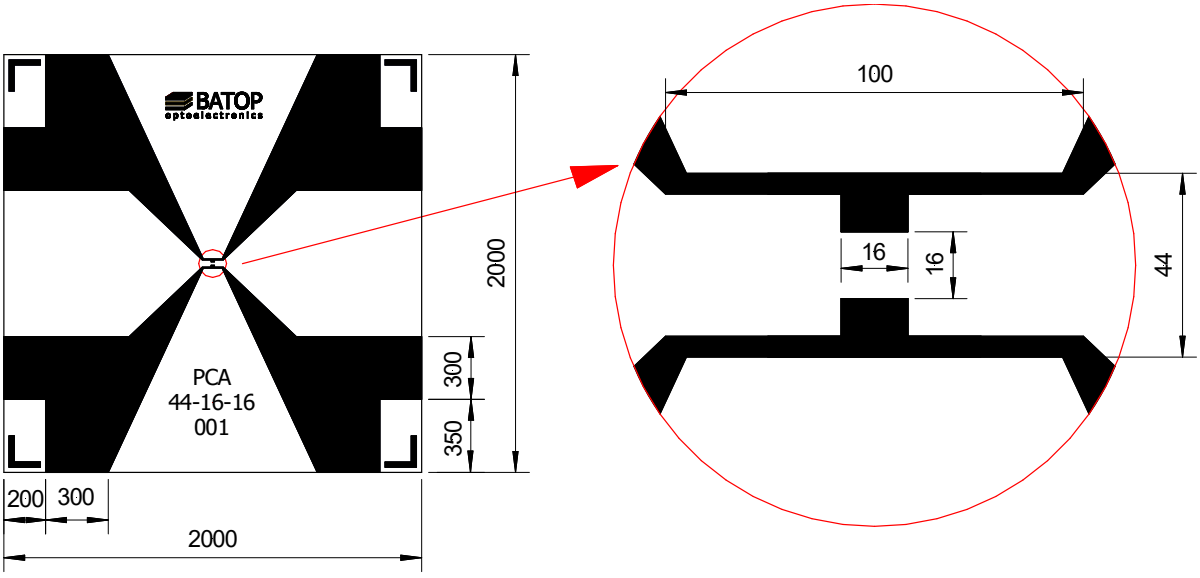
## 1. PCA applications

The PCA can be used as terahertz (THz) emitter or detector in pulsed laser gated 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 nm
- Bandwidth ~ 1 THz

## 2. Antenna design




all dimensions in micrometers

***Photo PCA 44-16-16 (survey)***

***Photo PCA 44-16-16***

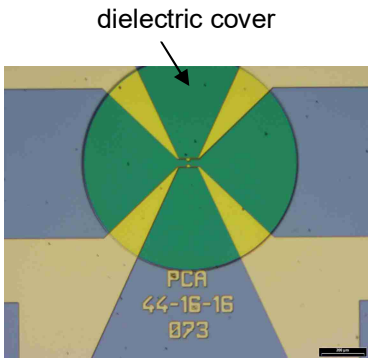
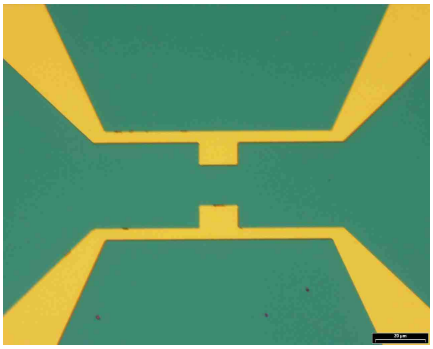



***Photo PCA 44-16-16 (detail)***

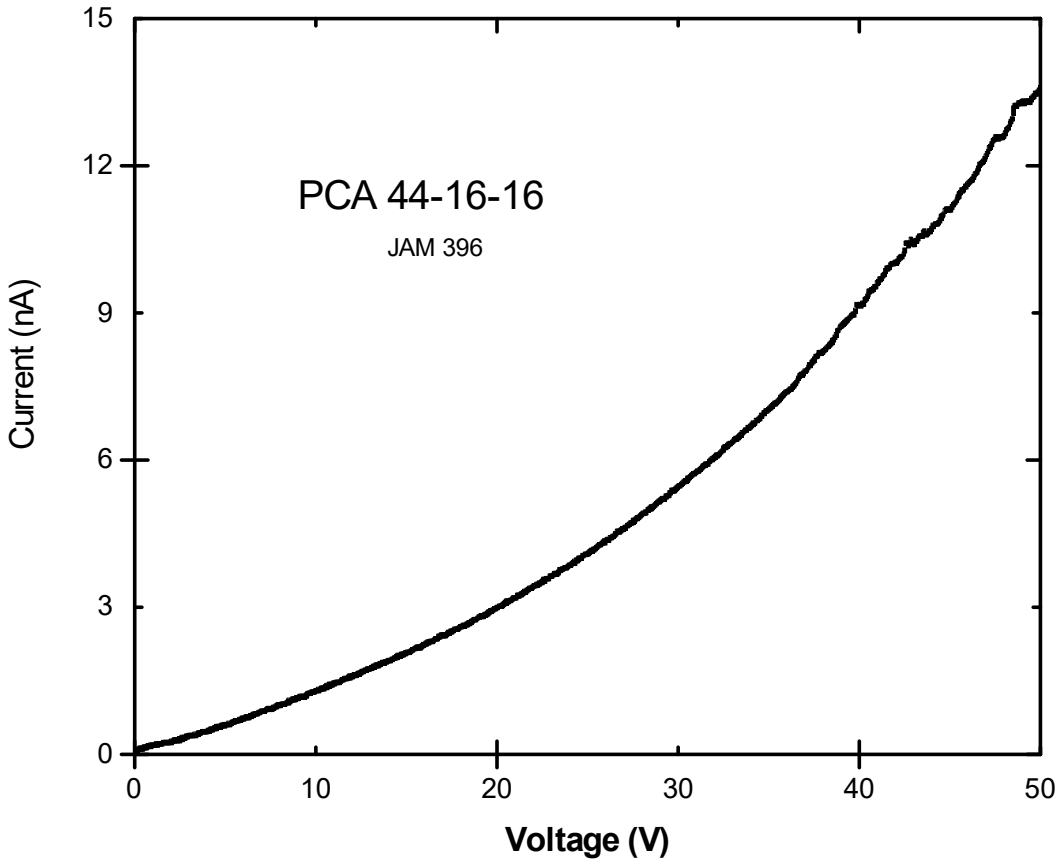


## 3. Antenna parameters

**Electrical parameters**

| Parameter | minimum ratings | standard | maximum ratings |
|---|---|---|---|
| Dark resistance | 5 GΩ | 10 GΩ | 15 GΩ |
| Dark current @ 10 V | 500 pA | 2 nA | 5 nA |
| Voltage | | 40 V | 50 V |

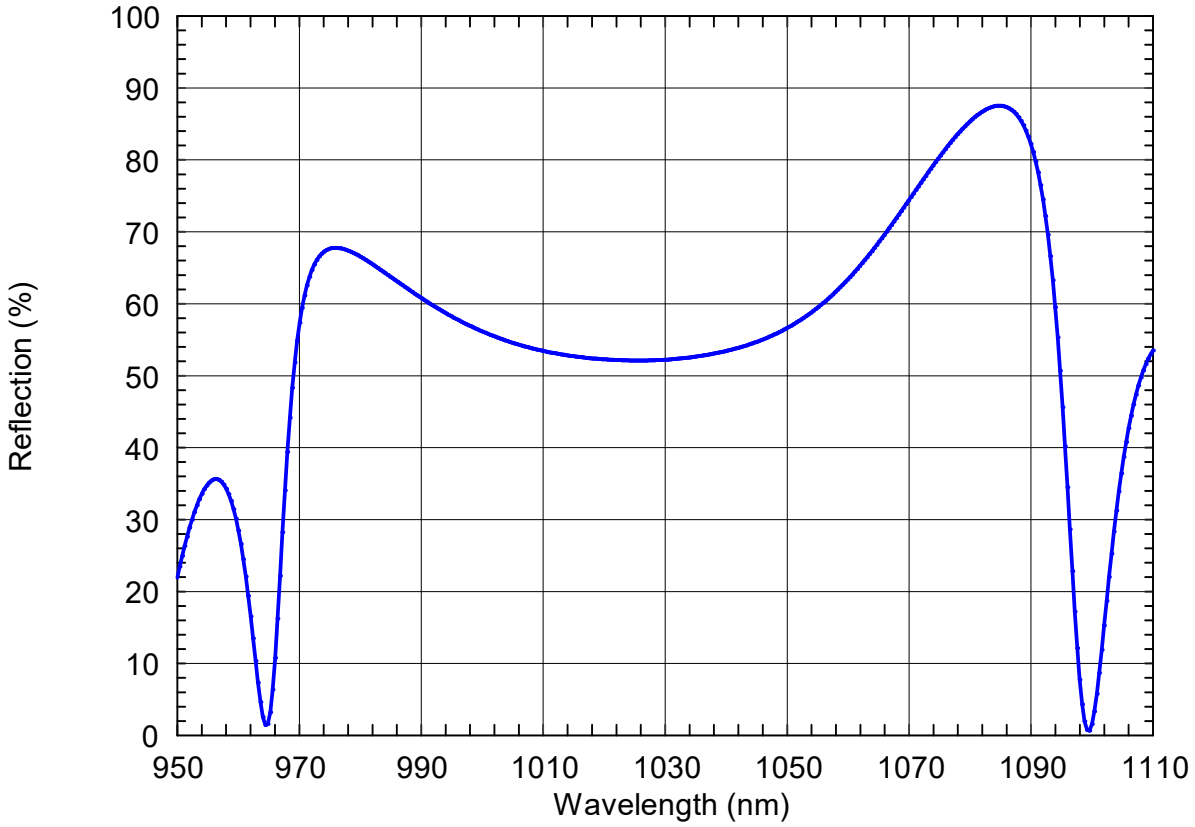
**Dark current voltage characteristic at T = 300 K**



**Optical excitation parameters**

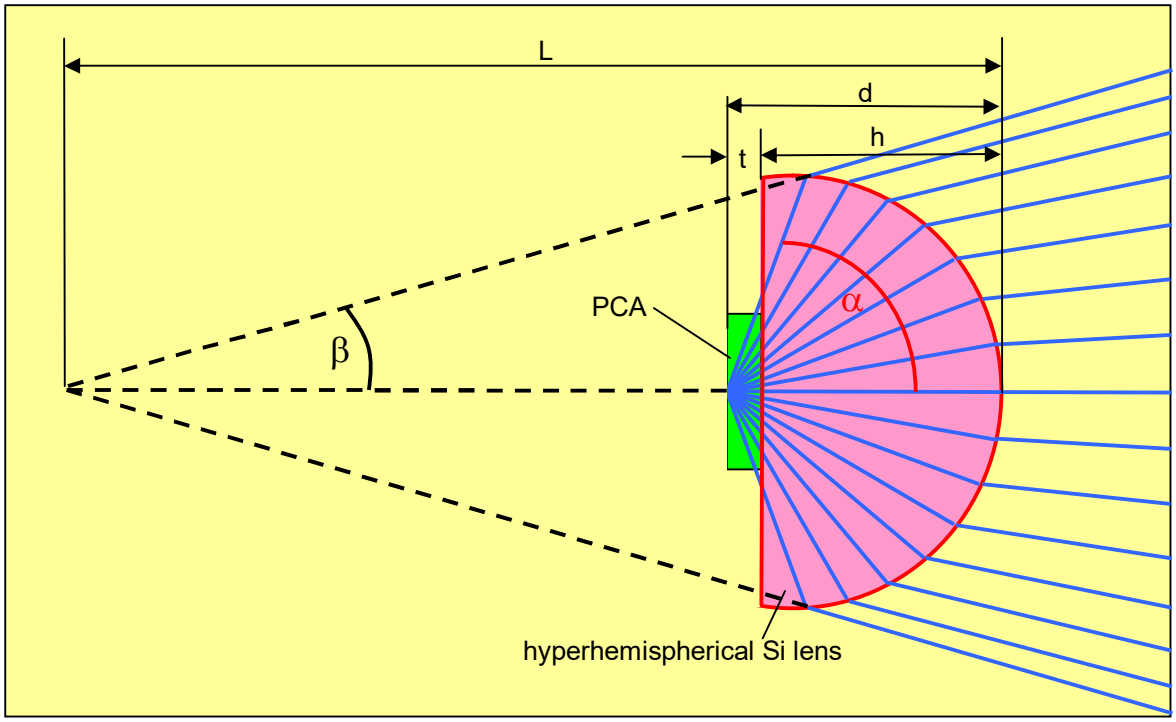
| Parameter | minimum ratings | standard | maximum ratings |
|---|---|---|---|
| Excitation laser wavelength | 990 nm | 1030 nm | 1060 nm |
| Optical reflectance | 60 % @ 990 nm | 52 % @ 1030 nm | 65 % @ 1060 nm |
| Optical mean power | | 40 mW | 80 mW |
| Carrier recovery time | | 300 fs | |

**Spectral reflectance**



### *4. Mounted PCA on hyperhemispherical silicon substrate lens: PCA-44-16-16-1030-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 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 |

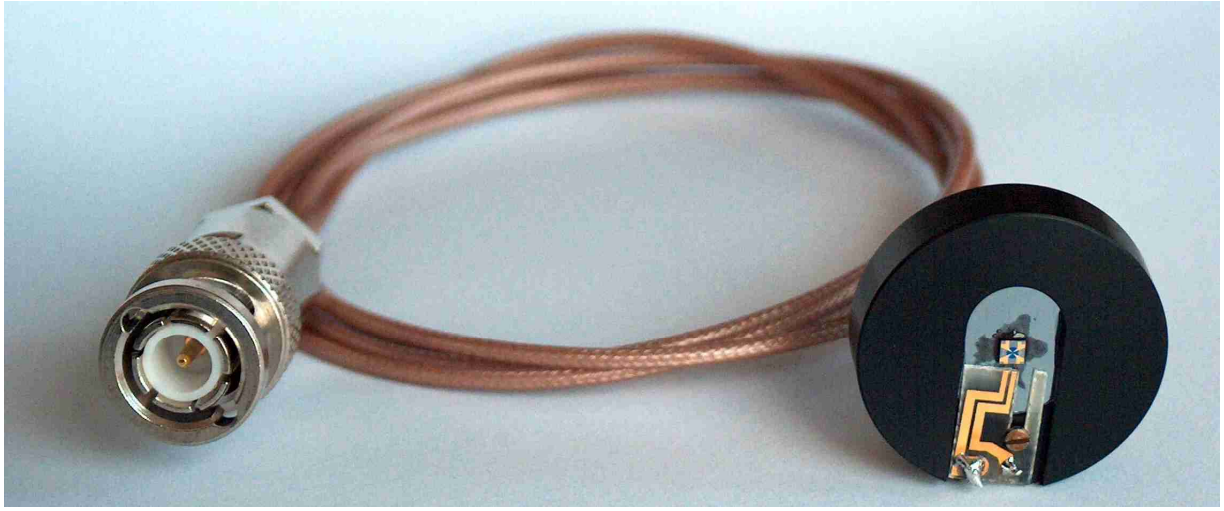



| | |
|---|---|
| **Aluminuim mount** | 25.4 mm diameter, 6 mm thick |
| **Coaxial cable** | type RG178 B/U, impedance 50Ω, capacitance 96pF/m, 1 m long |
| **Connector type** | BNC or SMA |

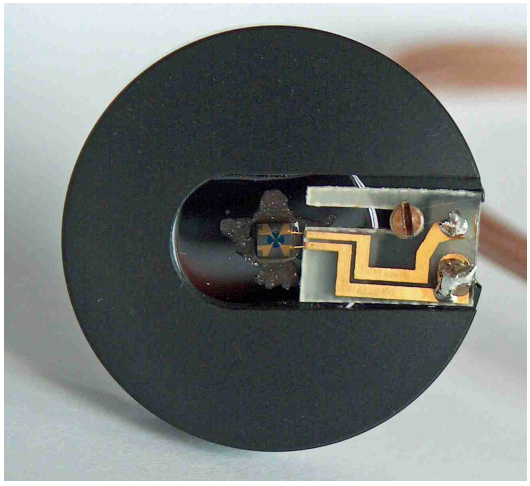
- The PCA chip is optically adjusted and glued on the hyperhemispherical silicon lens. The alignment of the PCA chip centre is done with respect to the optical axis of the silicon lens.

- 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

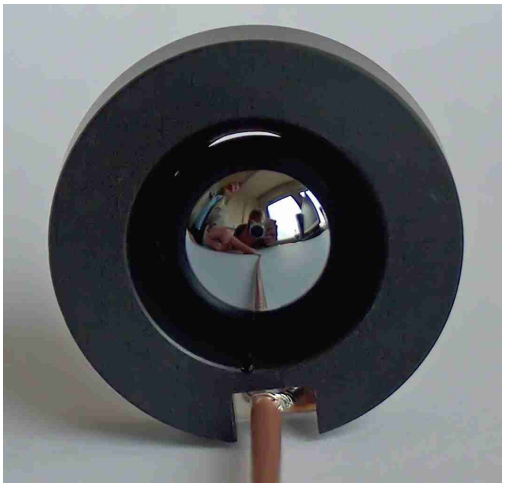
PCA with hyperhemispherical silicon lens, coaxial cable RG 178 and BNC connector



Front view on mounted PCA (laser side)

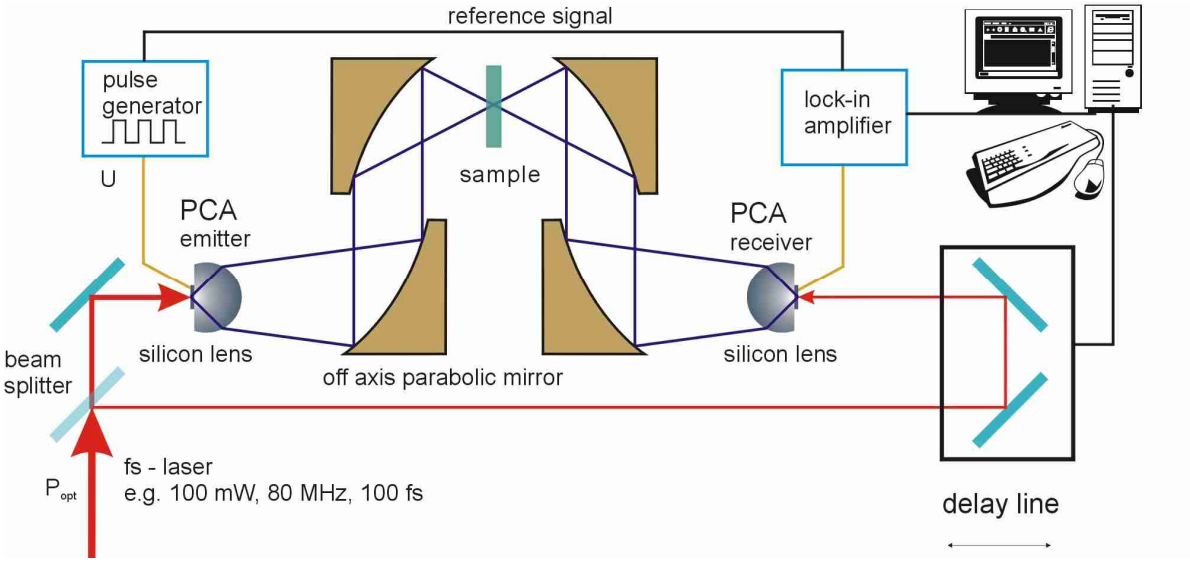


Back view on mounted PCA (THz side)

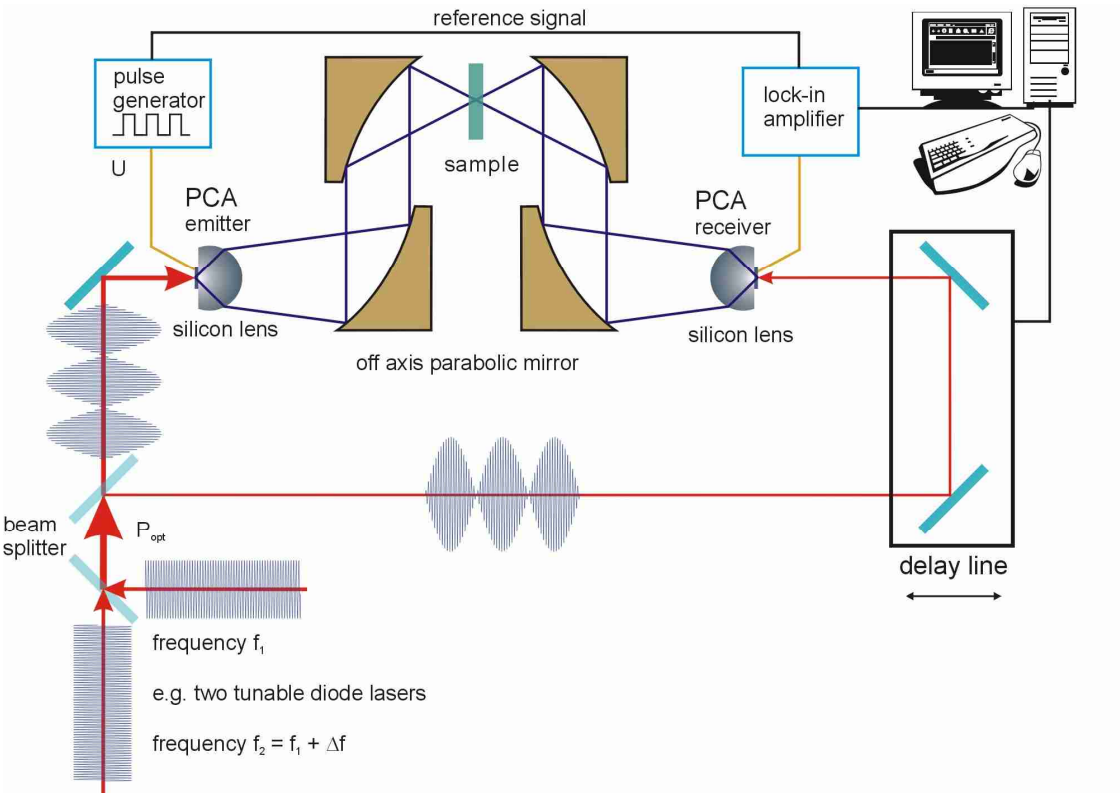


The antenna can be used as terahertz emitter or detector in pulsed laser gated broadband THz measurement systems for time-domain spectroscopy and as photomixing emitter or detector in tunable cw THz measurement systems in the frequency region from 0.1 to 3 THz (see schematics below).

***Schematic of a time-domain spectroscopy setup***

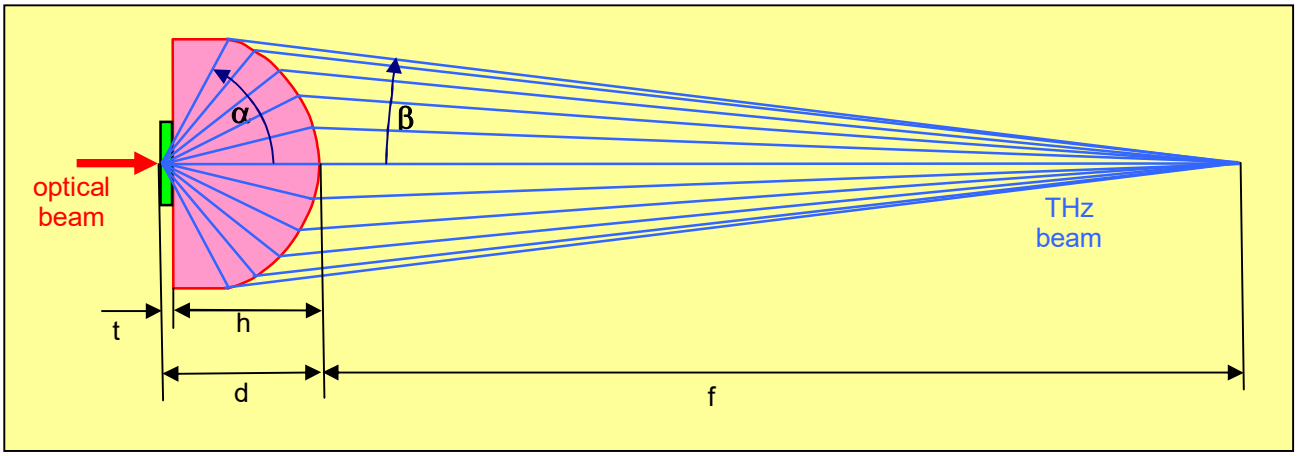



***Photomixing setup***



## 5. Mounted PCA onaspheric silicon substrate lens: PCA-44-16-16-1030-a

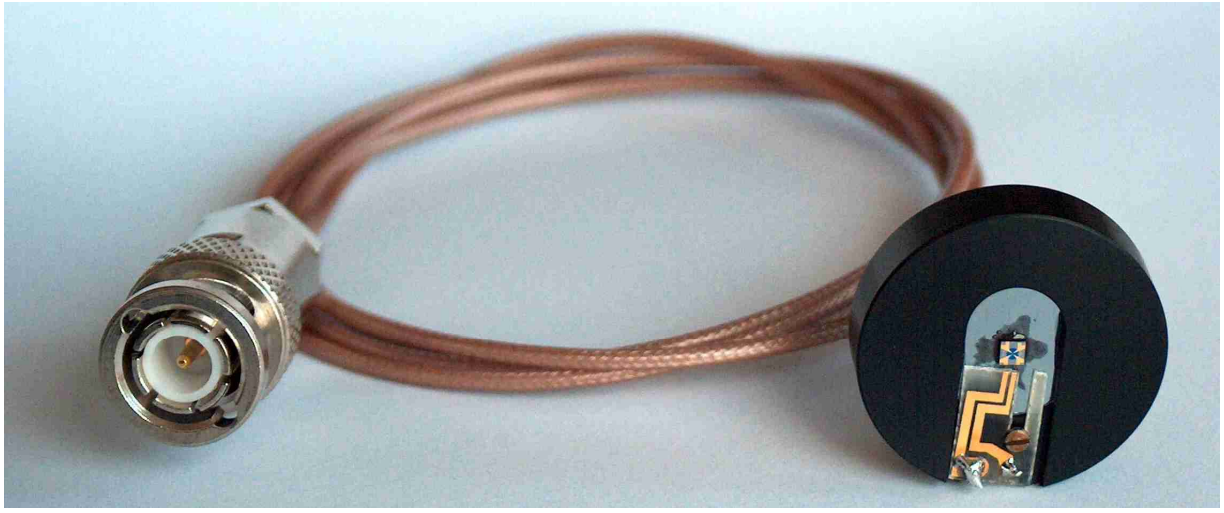
| | | |
|---|---|---|
| **Photoconductive antenna** | substrate | semi-insulating GaAs |
| | chip area | 2 mm x 2 mm |
| | thickness t | 600 µm |
| **Aspheric lens** | material | undoped HRFZ-silicon |
| | specific resistance ρ | >10 kΩcm |
| | refractive index n | 3.4 |
| | diameter | 12 mm |
| | height 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 ß | 6.8° |
| **Airy disc diameter** | at 300 GHz | 5 mm |
| | at 1 THz | 1.5 mm |
| | at 3 THz | 0.5 mm |



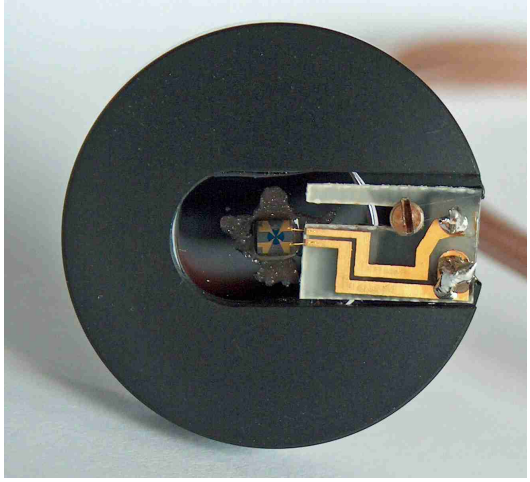

| | |
|---|---|
| **Aluminium mount** | 25.4 mm diameter, 6 mm thick |
| **Coaxial cable** | type RG178 B/U, impedance 50Ω, capacitance 96pF/m, 1 m long |
| **Connector type** | BNC or SMA |

- 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 aluminium 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

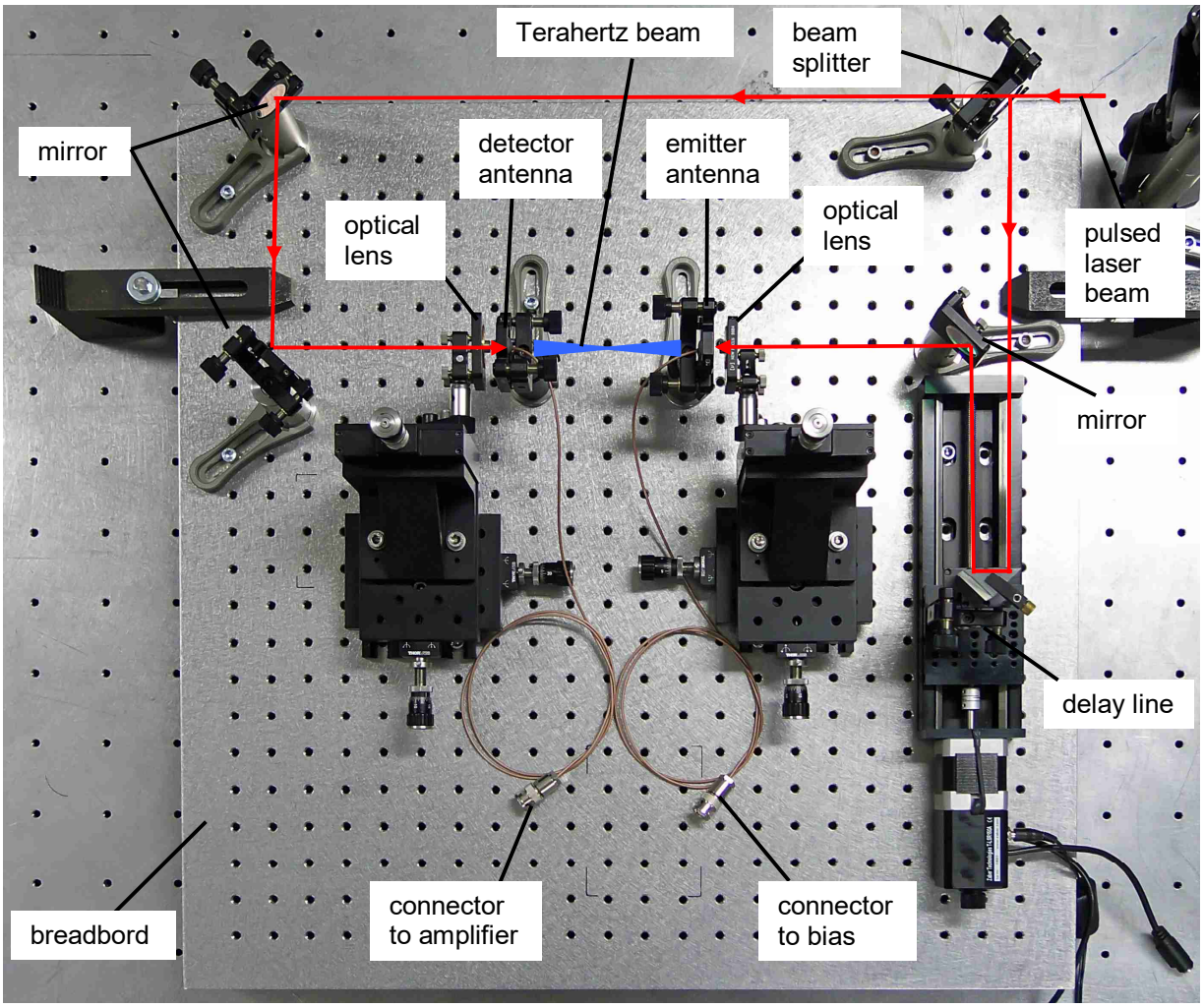


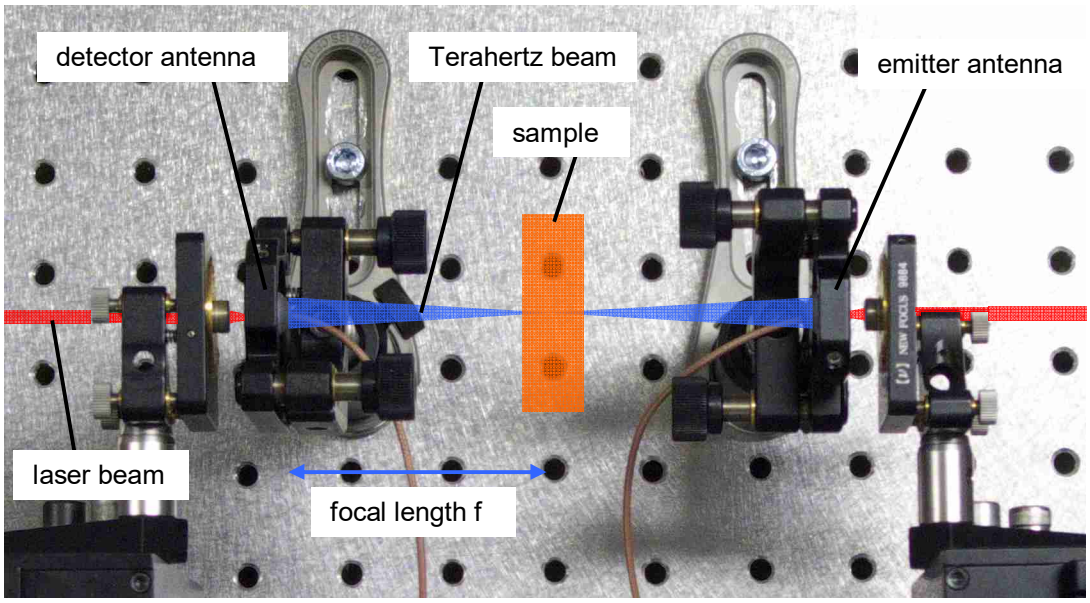
Front view on mounted PCA (laser side)



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-44-16-16-1030-x*

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 within the antenna gap using an appropriate lens or objective with a beam diameter of about 16 µm to bridge the antenna gap with photo-excited carriers within the semiconductor. At the same time a voltage U of ~ 40 V (maximum 50 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 40 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 16 µm to bridge the antenna gap with photo-excited carriers within the semiconductor. But because of the large gap this antenna is not the best solution for the detector side. 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 ~ 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 +/- 80 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

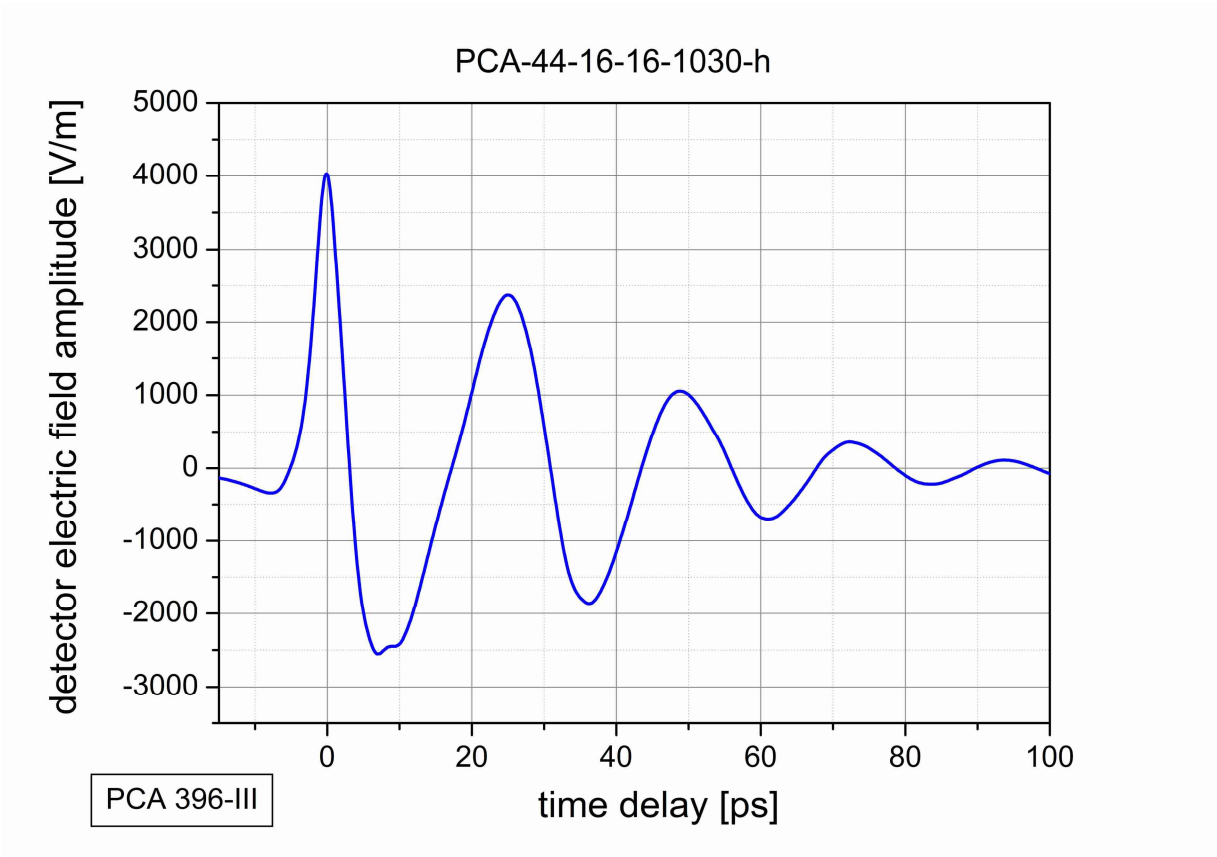
is than an alternating current, which can be amplified using an ac amplifier and rectified using a standard lock-in system. This setup is shown in the figures above.

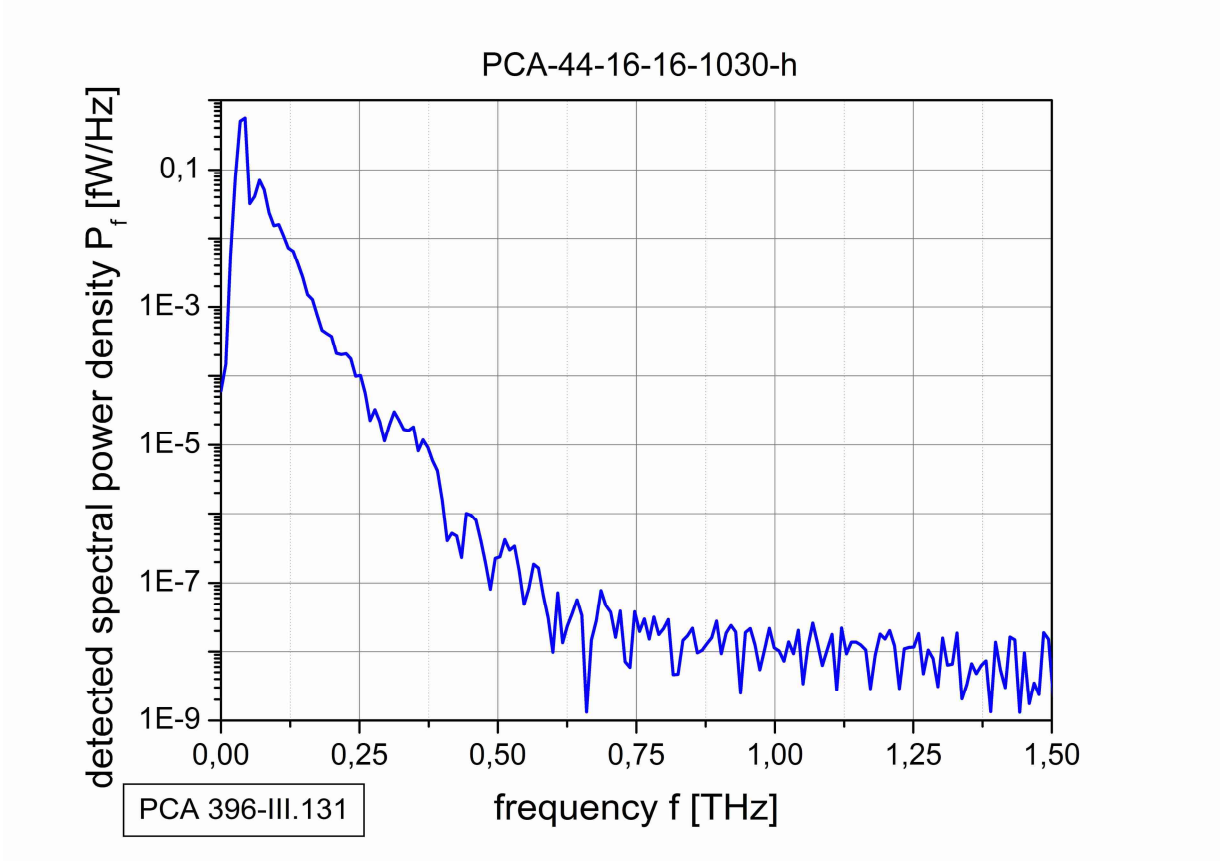
**Direct voltage detection**

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 80 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.

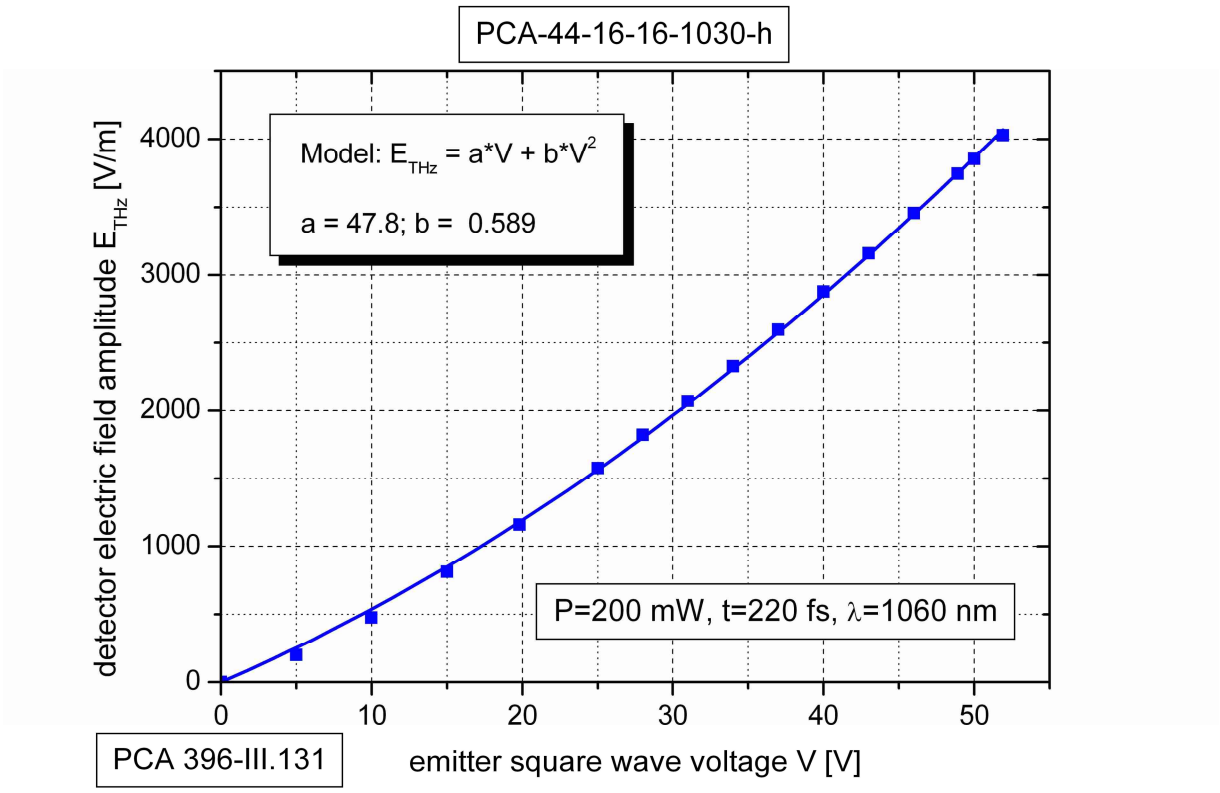
## *7. Time-domain measurements*

The PCA-44-16-16-1030-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 1.5 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 µm antenna length. The spectral power density results from $P_f = V_d^2 * n/(2*\eta)$ with n ~ 3.4 refractive index of GaAs and $\eta$ ~ 377 $\Omega$ vacuum impedance.

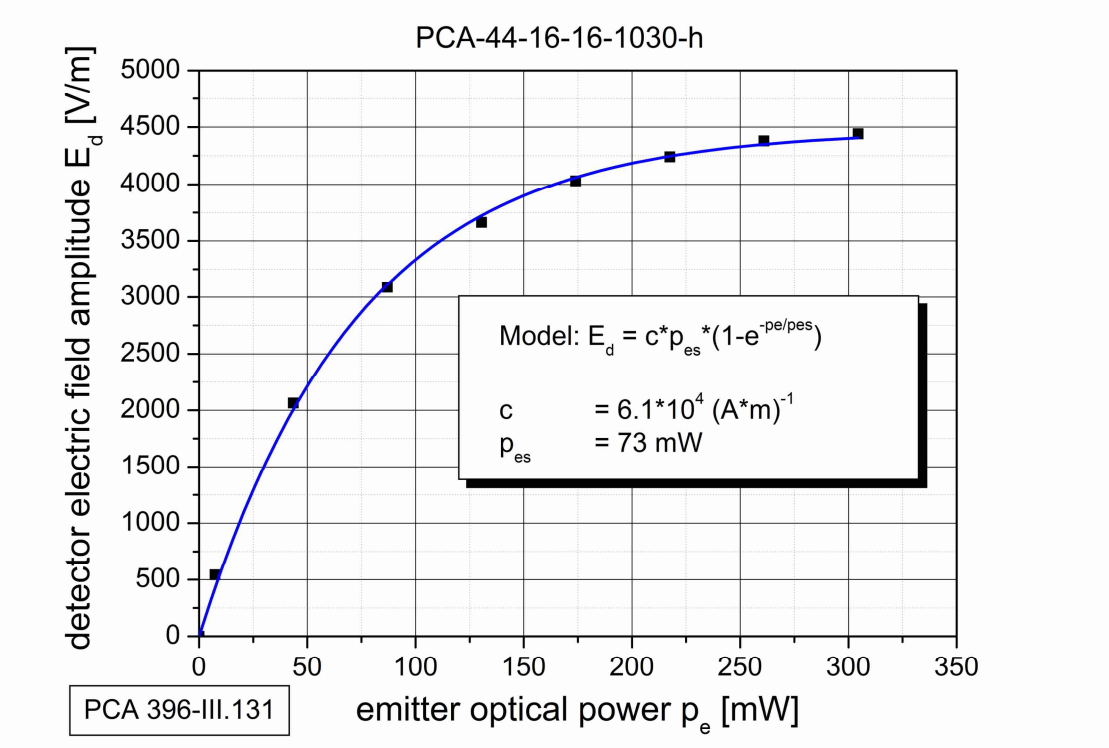





***Influence of the emitter voltage on the detector signal***

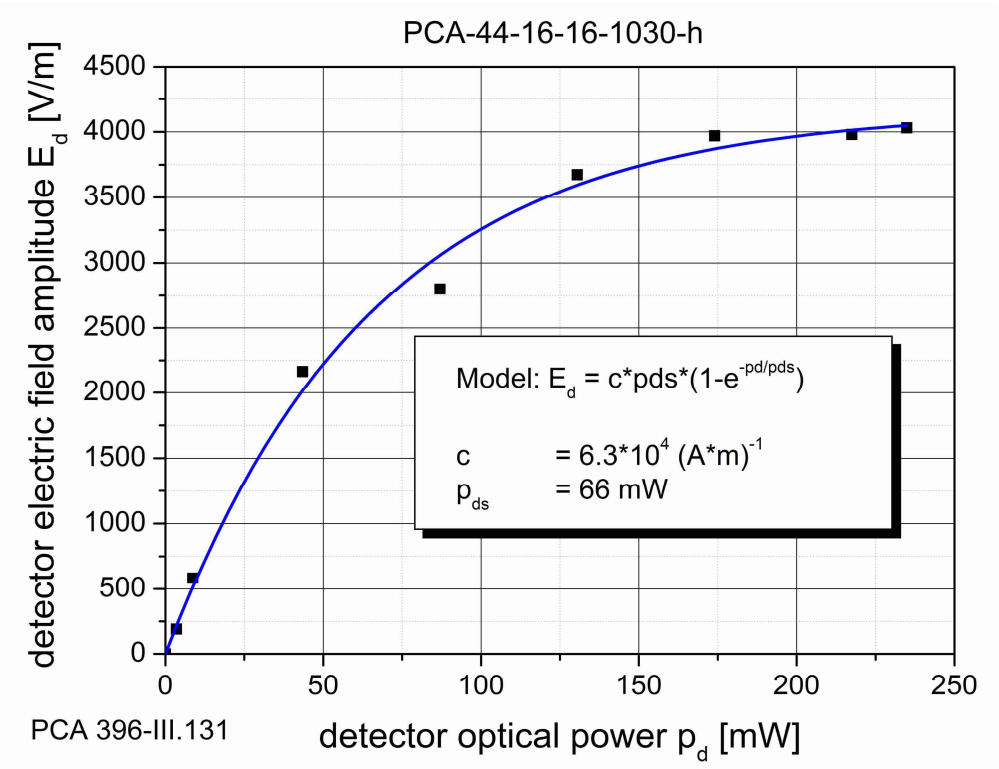


***Influence of the optical power on the emitter antenna on the detector signal***



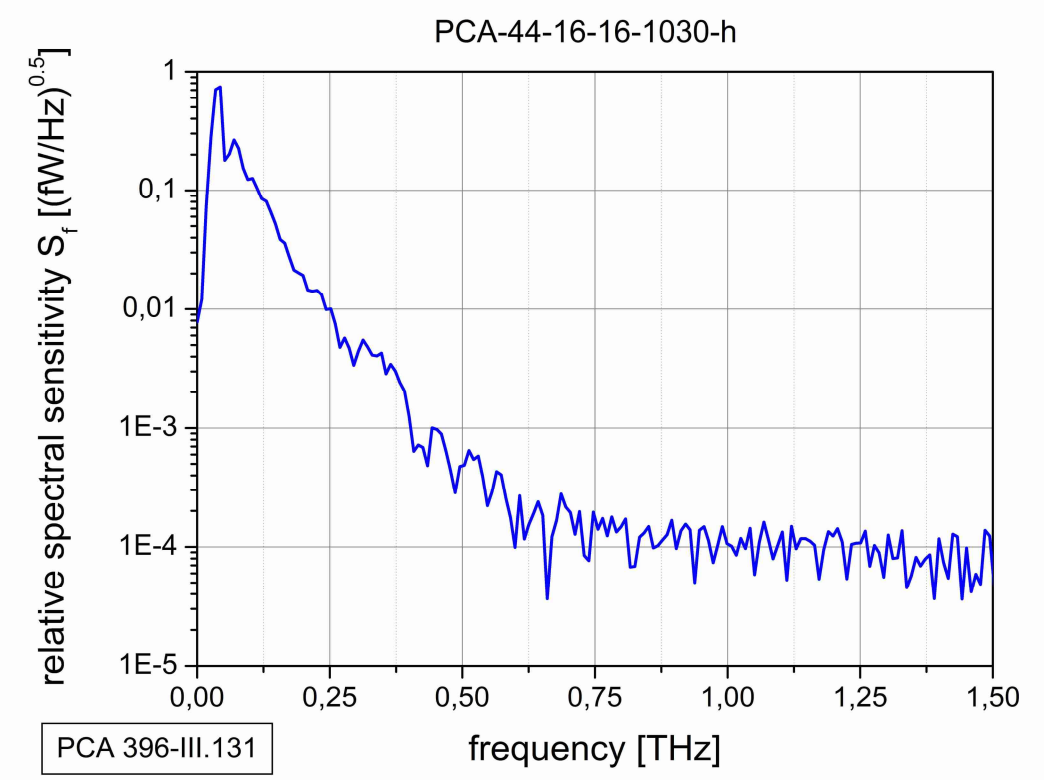

Saturation optical power on the emitter antenna $p_{es}$ = 73 mW

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




Saturation optical power on the detector antenna $p_{ds}$ = 66 mW

***Relative spectral sensitivity $S_f$ of one antenna according to $P_f = S_f^2$***




## *8. Order information*

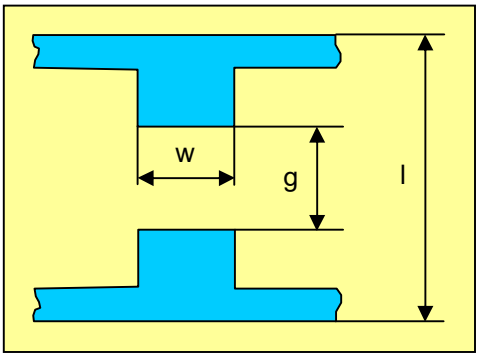
PCA-44-16-16-1030-**x** Photoconductive antenna

length l = 44 µm

gap g = 16 µm

width w = 16 µm

laser wavelength λ = 1030 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 ∅ 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 ∅ and **a**spheric silicon substrate lens, 1m coaxial cable with BNC or SMA connector |