THz Radiometry Traceable to SI and Suitable Detectors

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***Abstract*—PTB, the metrology institute of Germany, operates the worldwide first and still unique THz detector calibration facility traceable to International System of Units. A research and development project in cooperation with a manufacturer of pyroelectric detectors is dedicated to develop suitable THz detectors.**

I. Introduction and Background

THE terahertz spectrum is the last spectral range of optical radiation where radiometry is not well established. Up to now, the PTB in Germany is the only national metrology institute which offers the calibration of THz detectors as part of its radiometric services. In order to determine the spectral responsivity with respect to radiant power traceable to the International System of Units SI in the THz spectral range, PTB operates a dedicated detector calibration facility [1]. Its design is based on a pilot experiment of measuring the power of a quantum cascade laser at 2.52 THz and the first calibration of a THz detector against a cryogenic substitution radiometer of PTB [2].

Now the laser source for detector-based radiometry is a far-infrared molecular gas laser. It is running at 2.52 THz but can also be operated at a variety of discrete molecular lines in many different gases at frequencies between 1 THz and 5 THz. Pumped by a frequency stabilized CO_2 laser, this continuous wave laser delivers monochromatic THz radiation power in the mW range.

Fig. 1. The molecular gas laser with its gas handling infrastructure is the core instrument of the THz detector calibration facility. The focal beam profile at each laser line is measured by a pyroelectric THz camera.

II. Expansion of THz Calibration

A commercially available but modified thermopile detector with a volume absorber is used as reference detector to expand the detector calibration service to the wider frequency range spanning from 1 THz to 5 THz. This reference detector was calibrated against the standard detector at 2.52 THz. It can be used also at other lines of the THz laser because the physics of its measurement principle is understood and characterized, i.e. the absorption of the absorber and the wavelength depending reflection of its polished surface was measured. In order to achieve reliable results, different spectroscopic techniques were used such as time domain spectroscopy and Fourier transform spectroscopy by a classical FT-IR spectrometer. The results were verified by measurements at the discrete THz laser lines. Then the real power at a given frequency is the sum of the measured power and the known, well characterized losses. This is true if standing waves by interference of the reflected radiation with the impinging laser radiation do not occur. Therefore the detector has to be tilted off normal incidence. These precautionary measures are necessary to get a reproducible and reliable power reading of the reference detector.

III. Development of Pyroelectric THz Detectors

The limitations of the reference detector and of all other commercial THz detectors which have been calibrated so far were analysed and lead to an invention of a new design of a windowless thermal THz detector which overcomes these limitations [3]. Its meanwhile patented setup as radiation trap has the following advantages for the long wavelength of THz radiation:

- It uses more than one sensor element to detect the reflected radiation of a single detector.
- Multiple sensor elements - one after the other - minimize the final reflected part.
- A pair of sensor elements are arranged to compensate for the polarization depending reflection and absorption of radiation of a single sensor element at 45° angle of incidence.
- A compact arrangement of the sensor elements minimizes the diffraction losses.

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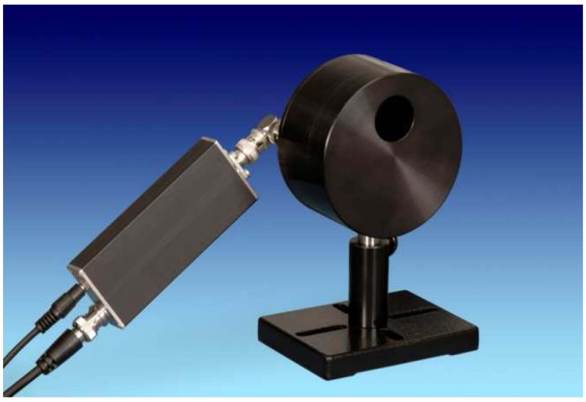

Fig. 2. Prototype of the patented radiation trap design of a new THz detector with pyroelectric sensor elements. A comparison with the 50 Ω BNC connector to the preamplifier yields the size of the detector.

Based on the patent, a new kind of pyroelectric THz detector is developed within a cooperation project. Thin pyroelectric sensor elements facilitate a fast detection and a high sensitivity. Three senor elements yield five absorption processes in series which minimize unwanted back reflection of THz radiation. A prototype has been produced by Sensor- und Lasertechnik (SLT), a German manufacturer of pyroelectric detectors. A novel special black paint with carbon nanotubes yields a high absorption at optical frequencies above 1 THz. The promising spectral properties have been characterized by Fourier transform spectroscopy and at the THz lines of the molecular gas laser.

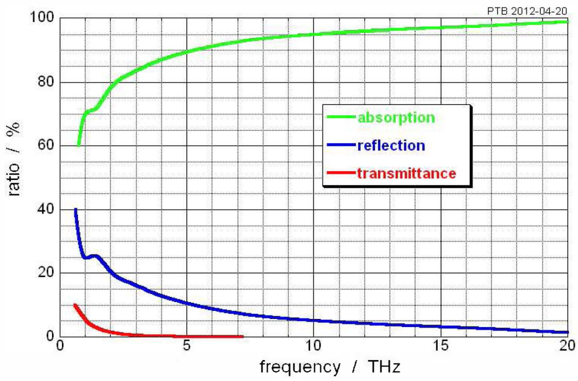

Fig. 4. Optical properties of the novel black paint with carbon nanotubes measured by means of a FT-IR spectrometer.

IV. Conclusion

As part of its radiometric services PTB operates a unique THz detector calibration facility dedicated to determine the spectral power responsivity. The core instrument is a molecular gas laser which covers the broad frequency spectrum from 1 THz to 5 THz. The outcome of a cooperation project with SLT Company is a new kind of pyroelectric THz detector which can be easily calibrated because its patented design as THz radiation trap is polarization insensitive and minimizes unwanted back reflection of THz radiation.

Acknowledgment

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