Towards Traceable Radiometry in the Terahertz Region

R. Müller[a], H.-W. Hübers[b], P. Meindl[a], H. Richter[b], A. Steiger[a] and L. Werner[a]
[a]Physikalisch-Technische Bundesanstalt (PTB), Abbestr. 2-12, 10587 Berlin, Germany
[b] German Aerospace Center (DLR), Rutherfordstr. 2, 12489 Berlin, Germany

***Abstract*— PTB and DLR join their expertise and experience in optical radiometry and in THz techniques to perform what is to our knowledge the first traceable measurement of radiant power of a THz quantum cascade laser (QCL) and the first absolute calibration of a THz-radiation detector against a cryogenic radiometer. This paves the way for comparable, accurate and reliable power measurements strongly missing throughout the THz community.**

I. Introduction And Background

THE measurement of radiant power is the crucial part of many applications. Calibration of suitable detectors is done by comparison of their response to the absolute measurement of radiant power by a highly accurate radiometer. Confidence in the accuracy and reliability of absolute measurements is achieved by the concept of traceability. Traceability briefly means that the result of a measurement can be related to stated references, i.e. national or international measurement standards, through an unbroken chain of comparisons all having specified uncertainties [1]. Such a traceable calibration of a THz detector has not been reported up to now.

PTB - the German National Metrology Institute - will meet this challenging task by two approaches:

Our approach utilizes the primary detector standard widely used in optical radiometry: a so-called cryogenic radiometer which is an electrical substitution radiometer operated at low temperature. The basic principle is the substitution of the optical heating of a highly absorbing cavity by electrical heating. It allows for the measurement of optical radiant power with uncertainties well below 0.01% in the visible and near infrared spectral range.

Another approach at PTB is based on the primary source standard traditionally used in optical radiometry and thermometry: a calculable black body cavity radiator [2].

II. Experimental Setup And Results

It is known from traditional spectral ranges of detector calibration that the lowest uncertainty is achieved by cryogenic radiometers combined with stable monochromatic lasers as radiation sources. Therefore a THz quantum cascade laser (QCL) is used for the first calibration of a THz radiation detector against a cryogenic radiometer. The QCL, operating at 2.5 THz, has been thoroughly characterised with respect to output power stability, beam profile, emission linewidth, and frequency stability [3]. The power of the QCL is measured by a cryogenic radiometer which is part of a UV to NIR calibration facility of PTB [4]. The cryogenic radiometer has been adapted to the THz region using a wedged Tsurupica entrance window which is transparent in the THz and visible range with similar refractive indices. As the wavelength of the QCL is by a factor of more than 60 longer than the wavelengths of radiation used so far the work had to concentrate on:

- characterization of the optical properties of the cavity absorber of the cryogenic radiometer in the THz region,
- minimization of diffraction losses in the optical setup,
- determination of remaining diffraction effects.

A suitable optical setup was identified to focus the QCL radiation through the input apertures for thermal radiation shielding of the cryogenic radiometer into its cavity absorber. Clipping is negligible because the size of the focus measured with a pyroelectric THz camera with 124 x 124 pixels with 100 µm spacing (Spiricon: Pyrocam III) is 3.2 mm for its full width at 5% of its central maximum compared to the 5.8 mm aperture in front of the absorbing cavity. The influence of remaining diffraction losses is minimized by equal optical paths to the absorbing cavity of the cryogenic radiometer and the detector under test.

The proof of principle and first results in calibrating THz detectors including the uncertainty budget will be presented.

References

[1] www.bipm.org/en/convention/wmd/2004/traceability.html
[2] B. Gutschwager, C. Monte, J. Hollandt, H. Delsim-Hashemi, O. Grimm, “Determination of the Spectral Responsivity of THz Detectors with Blackbody Radiation”, accepted in Proc. Infrared Sensors and Systems, 2008.
[3] H.-W. Hübers, S. G. Pavlov, A. D. Semenov, R. Köhler, L. Mahler, A. Tredicucci, H. E. Beere, D. A. Ritchie, E. H. Linfield, “Terahertz quantum cascade laser as local oscillator in a heterodyne receiver”, in *Opt. Express* vol. 13, 2005, pp. 5890-5896.
[4] P. Meindl, A.E. Klinkmüller, L. Werner, U. Johannsen, K. Grützmacher, “New UV spectral responsivity scale of the PTB based on a cryogenic radiometer and an argon plasma arc radiation source”, *Metrologia*, vol. 43, pp. S72-S77, 2006.

978-1-4244-2120-6/08/$25.00 ©IEEE.