Absolute Calibration of the Spectral Responsivity of Thermal Detectors at a High-Temperature Blackbody at the PTB

Tobias Pohl[1], Peter Meindl[1], Lutz Werner[1], Uwe Johannsen[1], Christian Monte[1], Richard Dieter Taubert[1], and Jörg Hollandt[1]

[1]*Phyiskalisch-Technische Bundesanstalt (PTB), Berlin, Germany*
Corresponding e-mail address: lutz.werner@ptb.de

The Physikalisch-Technische Bundesanstalt (PTB) is setting up an additional measurement approach for the absolute calibration of the spectral responsivity in the near- and mid-infrared by using a high-temperature blackbody operating at about 1200 K with a precision aperture. The blackbody radiation is described by Planck's law and is spectrally selected by accurately characterized optical bandpass filters. Thus, the detector under calibration is irradiated by a calculable spectral irradiance within the bandpass of the applied transmission filters. First results for the spectral responsivity of thermopile detectors agree within the uncertainty with previous calibrations at PTB´s national primary detector standards.

INTRODUCTION

Currently, the calibration of detectors in view of their spectral responsivity in the spectral range of the near-infrared (NIR) and mid-infrared (MIR) is of increasing interest and market importance, e.g. for remote sensing [1] or radiation thermometry [2].

These applications need traceability to the International System of Units (SI). Therefore, the Physikalisch-Technische Bundesanstalt (PTB) operates cryogenic electrical substitution radiometers as primary detector standards to measure radiant power and to calibrate detectors in view of their spectral responsivity [3]. Furthermore, different types of transfer detectors which have been calibrated absolutely against the primary detector standards are used for the dissemination of the spectral responsivity.

In the NIR and MIR, these transfer detectors are partially thermal detectors, whose measurement principle is based on the heating effect of an absorber. Therefore, the detector responsivity is spectrally more or less constant as long as the absorptance of the incident radiant power is independent of the wavelength [4]. This enables a sufficiently accurate interpolation of the spectral responsivity between widely separated calibration wavelengths.

Currently, the PTB realizes an additional approach for detector calibrations in view of the spectral responsivity traceable to the SI by using a high-temperature blackbody operating at about 1200 K with a precision aperture as a standard of spectral irradiance.

DETECTOR CALIBRATION AT A HIGH-TEMPERATURE BLACKBODY

The calibration facility is a cavity radiator named Large-Area Blackbody (LABB) assembled of two concentrically stacked heat pipes and a temperature stabilized precision aperture with a radius of 10 mm. The LABB is temperature controlled with calibrated standard platin resistance thermometers. With an emissivity of 0.9999 it is an almost ideal realization of a blackbody radiator [5] whose spectral radiance is described by Planck's law.

The blackbody radiation is spectrally selected by optical bandpass filters with characterized transmissions. By this means, the detector is irradiated by a calculable spectral irradiance within the bandpass of the applied transmission filters. The radiant power reaching the detector absorber can be calculated, considering the input aperture of the detector.

Fig. 1 shows the LABB measurement setup for the calibration of thermopile transfer detectors called TS-76 (Leibnitz-Institut für Photonische Technologien e.V.). This type of detector is a well characterized and calibrated MIR transfer standard at

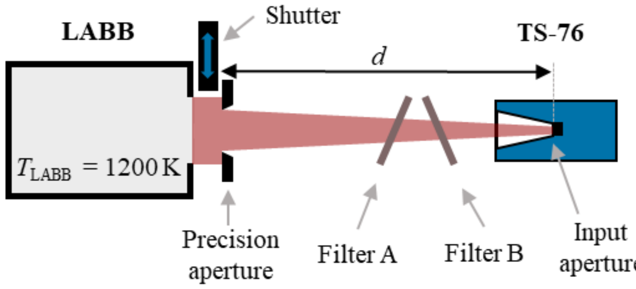

Figure 1. Calibration setup for the thermopile detector TS-76 at the high-temperature blackbody LABB with two transmission filters.

the PTB with an aperture radius of 2.9 mm. The distance *d* between the apertures of the LABB and the detector was varied between 350 mm and 650 mm.

FILTER TRANSMISSION MEASUREMENT

To calibrate detectors in terms of their spectral responsivity with blackbody radiation, well characterized optical transmission filters are needed: A bandpass filter ("Filter A", see Fig. 1) is combined with an additional wider bandpass filter or an edge filter ("Filter B"). In fact, the combination of two filters reduces the maximum bandpass transmission slightly but realizes significantly better blocking of the out-of-bandpass radiation.

As a first step, three pairs of filters were chosen and characterized in view of their bandpass and blocking transmission at a Fourier Transform Spectrometer (FTS). Fig. 2 shows the calculated transmittance of a filter pair for calibrations at 1.55 µm. Similar pairs were characterized for calibrations at 2.7 µm and 3.9 µm.

Typically, power levels of about 30 µW at the detector were realized considering the filter transmission and measurement geometry. The two filters are slightly tilted to avoid interreflections between them.

FIRST MEASUREMENT RESULTS

First results for the spectral responsivity of the thermopile transfer detectors TS-76 at the LABB agree with their calibrations at the cryogenic electrical substitution radiometer within the uncertainty considering corrections due to absorption in air. Main uncertainty contributions are given by the filter transmission measurement resulting in a combined measurement uncertainty in the range of several percent. A detailed uncertainty budget will be given.

This measurement approach is SI traceable and independent from the calibration with the cryogenic electrical substitution radiometer.

Furthermore, the calibration at the LABB offers calibrations at wavelengths, where no laser radiation sources at the cryogenic electrical substitution radiometer exist. This is especially of interest for the spectral range above 10.6 µm.

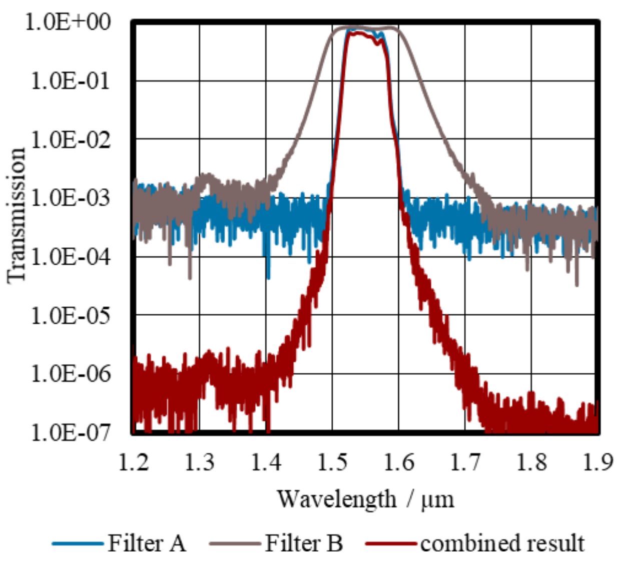

Figure 2. With FTS measured filter transmittances of two filters with bandpass at 1.55 µm (blue and brown) and the calculated resulting transmission of both filters combined (red) with better blocking.

OUTLOOK

Currently, more optical filters are characterized to conduct calibrations at the LABB at further wavelengths. Furthermore, this measurement approach will be used for calibrations of other detectors, such as pyroelectric detectors serving as MIR transfer detectors at the PTB.

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