DOI 10.5162/SMSI2020/C1.3

Absolute Calibration of the Spectral Responsivity of Detectors in the MIR at the PTB

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Summary:
The Physikalisch-Technische Bundesanstalt (PTB) expanded its capabilities of absolute calibration of the spectral responsivity in the mid-infrared (MIR) by equipping a cryogenic electrical substitution radiometer facility with MIR laser radiation sources to enable absolute measurement of radiant power traceable to the International System of Units (SI). Furthermore, the PTB is installing a new MIR detector comparator facility to disseminate the spectral responsivity from the absolutely calibrated transfer standards to other detectors.

Keywords: detector calibration, spectral responsivity, mid-infrared, SI traceable, uncertainty

Introduction

The PTB operates cryogenic electrical substitutions radiometers as national primary detector standards to measure radiant power and to calibrate detectors in view of their spectral responsivity. The spectral responsivity $s(\lambda)$ is the ratio between the output signal of the detector and the received radiant power Φ.

Furthermore, the PTB uses different types of transfer detectors, which have been calibrated absolutely against the primary detector standards, for the dissemination of the spectral responsivity.

Currently, the calibration of detectors in the spectral range of the near-infrared (NIR) and mid-infrared (MIR) is of increasing importance, e.g. for remote sensing [1] or radiation thermometry. These applications need, in general, traceability to the International System of Units (SI). Therefore, the PTB is expanding its capabilities of realization and dissemination of the spectral responsivity into the MIR by

- equipping a cryogenic electrical substitution radiometer facility with MIR lasers as radiation sources,
- establishing different types of detectors as MIR transfer standards and
- installing a new MIR detector comparator facility for routine customer calibrations.

Cryogenic electrical substitution radiometer

The measurement principle of cryogenic electrical substitution radiometers is based on the substitution of absorbed radiant power with electric heating power, which can be measured SI traceable with low uncertainty [2]. Hence, cryogenic electrical substitution radiometers are national primary standards for the measurement of radiant power.

By implementing a CO_2-laser (10.6 µm) and a quantum cascade laser (QCL, 3.96 µm and 9.45 µm) at one of PTB´s cryogenic electrical substitution radiometer facilities, absolute detector calibrations of the spectral responsivity in the MIR were enabled. Calibrations are usually performed at power levels between 1 µW and 1 mW.

Calibration of MIR transfer standards

The cryogenic electrical substitution radiometer facility with MIR lasers was used to calibrate the following types of windowless detectors in view of their spectral responsivity:

- thermopile detectors TS-76 (Leibnitz-Institut für Photonische Technologien e.V. Jena)
- pyroelectric detectors (InfraTec)

The properties of these detectors have been improved by an optimized and thermally stabilized detector housing design [3].

The measurement principle of these thermal detectors is based on the heating effect of an absorber. Therefore, the detector responsivity should be spectrally more or less constant assuming that the absorptance of the incident radiant power is independent of the wavelength.

Fig. 1 and 2 show results of spectral responsivity calibrations of a thermopile and a pyroelectric detector, respectively. In fact, only slight dependencies of the spectral responsivity on the wavelength have been found. Therefore, a linear approach seems to be sufficient for the interpolation of the spectral responsivity $s(\lambda)$ between the results at the laser wavelengths.

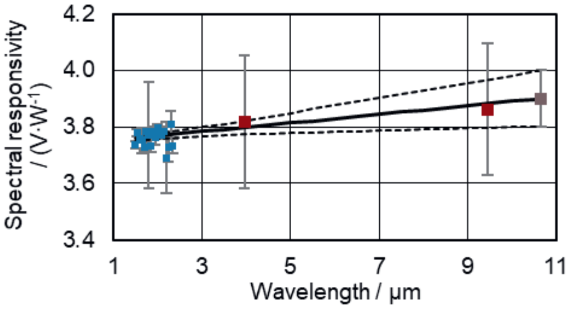

Fig. 1. Spectral responsivity s(λ) of a TS-76, measured with a supercontinuum laser (blue), a QCL (red) and a CO2-laser (brown), including the standard measurement uncertainty.

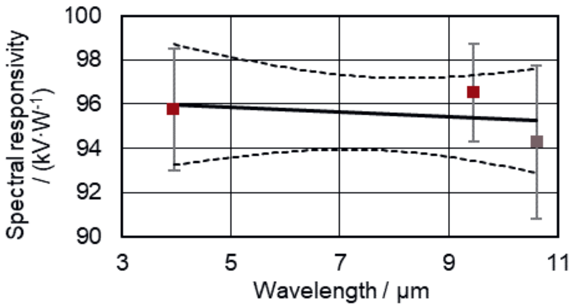

Fig. 2. Spectral responsivity s(λ) of a pyroelectric detector at a chopper-frequency of 10 Hz, measured with a QCL (red) and a CO2-laser (brown), including the standard measurement uncertainty.

The standard measurement uncertainties of the spectral responsivity determined with MIR lasers against the cryogenic electrical substitution radiometer range between 1.3% and 3.6%. The main uncertainty contributions for the calibration at 9.45 µm are given in Tab. 1. Based on these calibrations, the TS-76 and pyroelectric detector were established as MIR transfer standards for the measurement of radiant power.

Tab. 1: Main contributions to the standard measurement uncertainty for the calibration of a pyroelectric detector at 9.45 µm

Noise of detector, source, radiometer	0.85%
Measurement of ZnSe window transmittances at the radiometer	0.30%
Stray radiation	2.1%
Relative standard uncertainty	2.3%

MIR detector comparator facility

The PTB is installing a new measurement facility for detector calibrations in the MIR to disseminate the spectral responsivity from the primary detector standard by using the established transfer standards.

This facility uses laser radiation sources to calibrate various detectors at specific wavelengths and a thermal, broad-band radiation source in combination with a monochromator setup to calibrate detectors at any wavelength by using the interpolated spectral responsivity $s(\lambda)$ of the transfer standards.

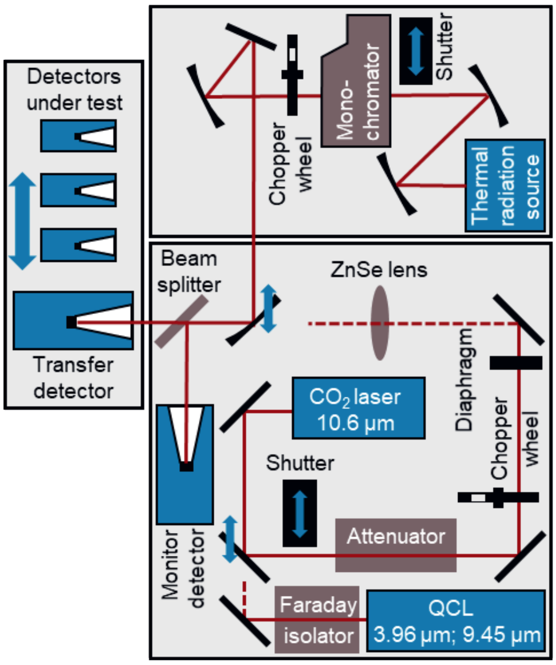

Fig. 3. MIR detector comparator facility

Outlook

Currently, the PTB is developing an additional, independent approach for MIR spectral responsivity calibrations of detectors 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 optical filters with accurately characterized bandpass transmissions.

By this means the detector under calibration is irradiated by a calculable spectral irradiance within the bandpass of the applied transmission filters. First results on the thermopile transfer detectors agree with their calibrations at the cryogenic electrical substitution radiometer.

References

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