Realization and Dissemination of the Spectral Responsivity of Thermal Detectors in the Mid-Infrared Spectral Range at the PTB

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The Physikalisch-Technische Bundesanstalt (PTB) has set up a portable collection of mid-infrared (MIR) laser radiation sources for the application at different measurement facilities. Primarily, these lasers can be used at a cryogenic electrical substitution radiometer facility to enable absolute calibrations of the spectral responsivity of MIR detectors traceable to the International System of Units (SI). Besides, it is intended to use the MIR lasers also at a detector comparator facility to disseminate the spectral responsivity from the absolutely calibrated transfer standards to other detectors. As a first step, the expanded cryogenic electrical substitution radiometer facility has been used to calibrate thermopile and pyroelectric detectors for the use as transfer detector standards.

INTRODUCTION

Currently, the calibration of detectors in the spectral range of the near-infrared (NIR) and mid-infrared is of increasing importance, e.g. for remote sensing [1] or radiation thermometry [2]. In general, these applications need traceability to the International System of Units. Therefore, the PTB is expanding its capabilities of realization and dissemination of the spectral responsivity from the NIR into the MIR.

At the PTB, the measurement of radiant power for the calibration of detectors in view of their spectral responsivity is performed with cryogenic electrical substitutions radiometers as national primary detector standards [3]. One of these cryogenic electrical substitution radiometer facilities has been extended with different MIR lasers as radiation sources. Additionally, these MIR lasers can also be used at another MIR detector comparator facility which is set up mainly for the calibration of customer detectors. A number of different thermal detectors have been characterized and calibrated at the extended cryogenic electrical substitution radiometer facility for the use as MIR transfer standards.

CALIBRATION OF MIR TRANSFER STANDARDS WITH CRYOGENIC ELECTRICAL SUBSTITUTION RADIOMETER

Cryogenic electrical substitution radiometers are usually used as 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 (Fig. 1). The calibrations are usually performed at power levels between 1 µW and 1 mW. The laser radiant power can be adjusted by using an attenuator.

The lasers are used to irradiate a diaphragm of 2.4 mm diameter. This diaphragm is then imaged onto the plane of the detector aperture. Additional baffles are used to reduce stray radiation to a minimum which otherwise causes errors if the apertures of the compared detectors are diverging. The MIR beam profile including the amount of stray radiation in the plane of the detector aperture is characterized by scanning the profile using a detector which has a known aperture size. An additional monitor detector can be applied if necessary.

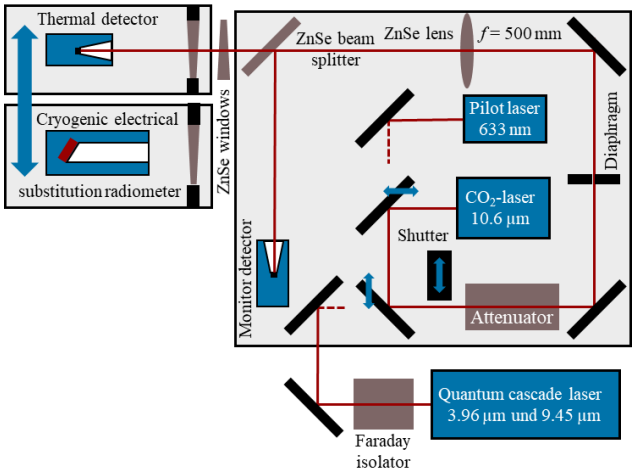

Figure 1. MIR detector calibration facility with cryogenic electrical substitution radiometer and MIR lasers.

The facility was used to calibrate the spectral responsivity of windowless thermopile detectors (TS-76 from the Leibnitz-Institut für Photonische Technologien e.V.) and windowless pyroelectric detectors (InfraTec GmbH). The properties of these types of detectors have been improved by an optimized and thermally stabilized detector housing design [4].

The measurement principle of these thermal detectors is based on the heating effect of an absorber area. 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. 2 shows results of spectral responsivity calibrations of a thermopile detector TS-76. In fact, a slight dependency of the spectral responsivity on the wavelength has been found. A linear approximation seems to be sufficient for an interpolation of the spectral responsivity $s(\lambda)$ between the results at the laser wavelengths. However, this result underlines the importance of measuring the spectral responsivity at different wavelengths.

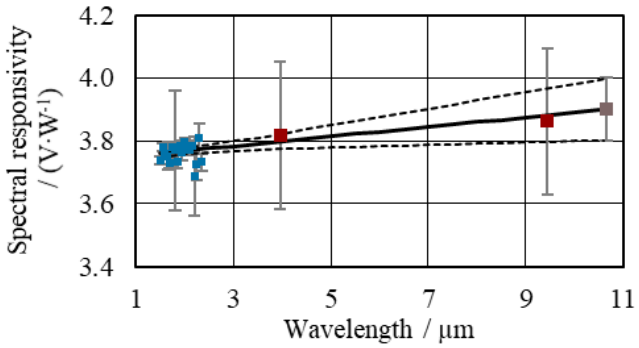

Figure 2. Spectral responsivity $s(\lambda)$ of a thermopile detector TS-76, measured with a supercontinuum laser (blue), a QCL (red) and a CO_2-laser (brown), including the standard measurement uncertainty.

The relative 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 of the spectral responsivity is caused by the correction due to stray radiation and the noise of detector, cryogenic radiometer and radiation source. A further uncertainty contribution is caused by the measurement of the ZnSe window transmittances. Based on these calibrations, the TS-76 thermopile detectors and pyroelectric detectors were established as MIR transfer standards for the measurement of radiant power.

OUTLOOK: MIR DETECTOR COMPARATOR FACILITY

The PTB is building a new detector comparator facility for calibrations in the MIR to disseminate the spectral responsivity from the transfer detector standards to other customer detectors (Fig. 3). This facility also uses the portable MIR lasers as radiation sources and furthermore a thermal, broad-band radiation source in combination with a monochromator setup to calibrate detectors at any desired wavelength by using the interpolated spectral responsivity $s(\lambda)$ of the transfer standards.

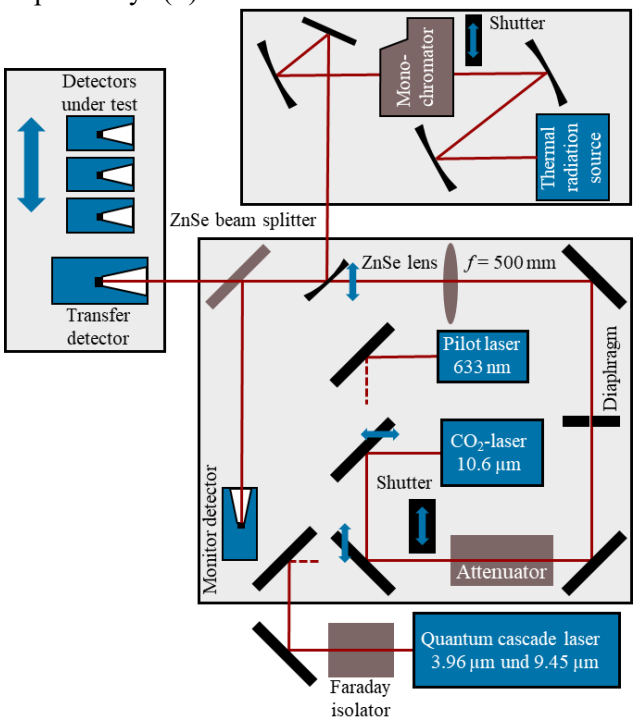

Figure 3. MIR detector comparator facility with MIR lasers and monochromator.

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