Improved NIR spectral responsivity scale of the PTB and implications for radiation thermometry

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Abstract. The NIR spectral responsivity scale has been improved using a monochromator-based cryogenic radiometer. A relative standard uncertainty of 0.1 % has been attained for the spectral responsivity between 950 nm and 1650 nm. In the limited wavelength range from 1520 nm to 1620 nm an even lower uncertainty has been demonstrated using a tuneable diode laser source. Implications to the measurement of thermodynamic temperatures with absolutely calibrated NIR filter radiometers are discussed.

Introduction

The NIR spectral responsivity scale of the PTB has been improved to meet the demanding applications of filter radiometers in radiation thermometry.

Hitherto the spectral responsivity scale between 950 nm and 1650 nm was realized by calibrating InGaAs photodiodes at four laser lines at the PTB laser-based radiation thermometry cryogenic radiometer and interpolating the spectral responsivity with thermal detectors [1]. However, the interpolation with conventional thermal detectors is very time-consuming and of limited accuracy. An interpolation of the spectral responsivity between widely separated laser-based calibrations as for Si trap detectors is not possible because of the lack of an accurate model of the responsivity for the commonly used detectors in this wavelength range. Therefore, calibrations against a cryogenic radiometer at arbitrary wavelengths have been chosen to reach a higher accuracy.

Apparatus

A calibration facility based on a cryogenic radiometer and presently optimized for UV calibrations [2] has been used for measurements in the NIR between 950 nm and 1650 nm. A halogen lamp has been chosen as light source. The facility further consists of a prism-grating double monochromator, a mirror imaging system, a cryogenic radiometer of type CryoRad II manufactured by Cambridge Research & Instrumentation, and a positioning system. A power of 1 µW to 2 µW is available with a bandwidth of 8.3 nm. The facility also allows to direct light through a fiber into the final imaging stage. A fiber coupled tunable laser has been attached to the system.

Measurements and Discussion

The detectors are calibrated by measuring their electrical signal when inserted into the beam from the monochromator at the same position where the radiant power of the beam is determined by the cryogenic radiometer. A monitor detector is used to correct for power variations between the radiometer and the detector measurement. Any polarisation dependencies are corrected by measuring at three different angles of detector rotation. The detectors are calibrated at controlled temperature.

InGaAs photodiodes are used as secondary standards for the spectral responsivity. They have been calibrated from 950 nm to 1650 nm with a relative standard uncertainty of 0.1 %. The uncertainty of this calibration is dominated by the cryogenic radiometer drift of typically 20 nW/10 min. The second largest contribution is the uncertainty of the window transmittance correction, which is measured before and after each calibration.

A comparison of these calibrations with calibrations at the laser-based radiation thermometry cryogenic radiometer at three laser wavelengths shows good agreement.

In addition, a calibration of an InGaAs photodiode between 1520 nm and 1620 nm has been performed with a tunable diode laser source. The much higher power and the narrow bandwidth allow to reduce the uncertainty to well below 0.1 %. Thus, the uncertainty of radiometric temperature measurements can also be reduced utilizing filter radiometers calibrated against InGaAs photodiodes as secondary standards. An uncertainty of 0.1 % for radiometric measurements with filter radiometers in the spectral range around 1550 nm allows to determine thermodynamic temperatures below the temperature of the Zinc fixed point (693 K) with an uncertainty of 50 mK. This is in the order of the uncertainty of the International Temperature Scale of 1990 (ITS-90).

Conclusion

The new facility allows to improve the accuracy of the NIR spectral responsivity scale at PTB to 0.1 % between 950 nm and 1650 nm. The even higher accuracy in the limited wavelength range around 1550 nm opens a perspective to extend filter radiometer measurements of thermodynamic temperatures to below the Zinc fixed point (693 K) with uncertainties comparable to those of the ITS-90.

References

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