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Short Communication

Comparison of optical-power meters between the NIST and the PTB*

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Abstract. We describe the results of a comparison of optical-power meters undertaken by the National Institute of Standards and Technology (NIST, USA) and the Physikalisch-Technische Bundesanstalt (PTB, Germany) at nominal wavelengths of 1300 nm and 1550 nm. Both laboratories used thermal detectors as reference standards, which were compared using a germanium trap detector as a transfer standard. Measurement results showed differences of less than 1 part in 10^3, well within the combined uncertainty for both laboratories.

1. Introduction

Because of an increasing need for lower uncertainties in optical-power measurements in the telecommunications industry, both the NIST and the PTB have developed measurement systems that provide absolute power calibrations of optical-power meters at several telecommunications wavelengths. The goal of this work was to compare the NIST and PTB laboratory standards at nominal wavelengths of 1300 nm and 1550 nm. Both national laboratories use cryogenic radiometers as primary standards whose uncertainties are less than a few parts in 10^4. The NIST and PTB laboratory standards (thermal detectors) were compared using a germanium (Ge) trap transfer standard made by the NIST. Collimated laser beams were used in the measurements. The transfer standard was first calibrated at the NIST, then carried to Germany and calibrated at the PTB. On its return to the United States, the transfer standard was again calibrated at the NIST. Both laboratories used the same laser sources to calibrate the transfer standard at wavelengths of 1302 nm and 1546 nm.

2. Transfer standard

For the comparison of the PTB and NIST laboratory standards, a transfer standard designed and built by the NIST was used. The transfer standard [1] is an optical-trap detector consisting of two Ge photodiodes and a spherical mirror. The photodiodes and mirror are contained in a thermally stable package. The trap detector has two, 13 mm diameter, Ge photodiodes and a 25 mm diameter, $f/1$ concave mirror made from aluminium coated with magnesium fluoride. Each photodiode is oriented relative to the entrance aperture such that the principal ray of incoming radiation strikes each diode once at a 45° angle of incidence and then reflects from the concave mirror back on to the photodiodes in reverse order.

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3. NIST measurement system

The NIST measurement system consists of laser sources (mounted on platforms) at wavelengths of 1302 nm and 1546 nm, a lens assembly to provide a collimated beam, and a positioning stage for comparing the NIST laboratory and transfer standards. Each laser-source platform contains a laser diode whose output is transmitted by fibre optics to a fibre splitter from which about 1 % of the energy travels through one fibre to a monitor detector. The remaining 99 % of the energy is transmitted through another fibre to the collimating lens.

The NIST laboratory standard [2] is an electrically calibrated pyroelectric radiometer (ECPR), which had been previously calibrated against the NIST laser-optimized cryogenic radiometer (LOCR). The ECPR is a thermal detector with an absorbing coating that causes the detector to be spectrally insensitive over the wavelength region 1300 nm to 1550 nm.

4. PTB measurement system

The PTB measurement system consists of laser sources (supplied by the NIST for these measurements) at

Table 1. Results of NIST/PTB comparison.

Source wavelength/nm	100 × Relative difference	100 × NIST rel. combined standard uncertainty	100 × PTB rel. combined standard uncertainty
1302	0.03	0.15	0.23
1546	0.09	0.20	0.23

wavelengths of 1302 nm and 1546 nm, imaging optics, shutter, spatial filter, and a positioning stage for comparing the PTB laboratory and transfer standards. The laser source irradiates a 2.5 mm aperture. Using a lens, the aperture is imaged (1:1) at the detector surface. A beam splitter and a monitor detector are used to monitor the power during the calibrations. The PTB laboratory and transfer standards are placed together on a computer-controlled translation stage.

The PTB laboratory standard is a thermopile-based detector that has been calibrated against a silicon trap detector at 633 nm. The silicon trap detector was previously calibrated against the PTB cryogenic radiometer at 633 nm.

5. Results of the comparison

The NIST and PTB laboratory standards were compared using a germanium trap transfer standard. The measurements were performed using collimated laser beams at wavelengths of 1302 nm and 1546 nm. At the NIST, nine measurement runs were taken at a wavelength of 1302 nm (relative standard deviation 1.4×10^{-3}) and eight at 1546 nm (relative standard deviation 1.5×10^{-3}). The power used in the comparisons was approximately 100 μW. At the PTB, seventeen measurement runs were taken at a wavelength of 1302 nm (relative standard deviation 5×10^{-4}) and five at 1546 nm (relative standard deviation 10×10^{-4}). Table 1 gives the results of the comparison. The uncertainty for the NIST optical-power measurements was evaluated in accordance with [3] and that of the PTB measurements in accordance with [4]. At 1302 nm the difference between the NIST and PTB results was 3 parts in 10^4, and at 1546 nm the difference was 9 parts in 10^4. The NIST combined standard uncertainty was 1.5 parts in 10^3 at 1302 nm and 2.0 parts in 10^3 at 1546 nm, while that of the PTB was 2.3 parts in 10^3 for both wavelengths. The interlaboratory differences observed are less than the stated combined standard uncertainties for both laboratories.

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