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Power Metrology

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NIST optical fiber power measurements: intramural and international comparisons *

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Abstract
We discuss the results of intramural comparisons of NIST laser power meter and optical fiber power meter (OFPM) measurements, and the results of OFPM comparisons between NIST and three national measurement institutes (NMIs). We also describe transfer standards, measurement systems, and the associated uncertainties that we used in these comparisons. The comparisons show a reasonably good agreement between the participating laboratories, with relative differences that are within the combined standard uncertainties.

1. Introduction

In our previous work we compared the results of intramural responsivity calibrations of several transfer standards in four different NIST calibration laboratories [1] that meet requirements of ISO 17025 [2]. In addition, we have previously reported international comparisons with several NMIs [3-5] for 1302 and 1546 nm wavelength laser beams transmitted free field [3,5] and by optical fiber cable [3-5]. In this paper we present new measurement responsivity results at 1550 nm that were obtained with a germanium (Ge) trap-based detector as a transfer standard, and summarize previous fiber-based power measurements.

For OFPM calibrations, the NIST primary standard at NIST is the cryogenic radiometer, [6] having expanded measurement uncertainty of absolute optical power of 2 parts in 10^4. NIST reference standards are calibrated against the primary standard by the use of collimated (free field) beams, but are typically used with divergent beams characteristic of laser light exiting an optical fiber.

2. Transfer standards

The transfer standards for our own intramural comparisons of optical power as well as international comparison may be broadly described as "trap detectors" [7]. In the present case, our trap detectors, known as the "4x trap", are two photodiodes and a spherical mirror (either Ge or indium gallium arsenide (InGaAs) photodiodes). It has been shown in [8] that such a configuration provides a uniform response over a wide field of view and therefore requires no correction for beam geometry. This design increases the coupling efficiency for larger values of numerical apertures [9]. The 4x trap is depicted in Figure 1.

The trap detectors were calibrated at the participating laboratories against their reference standards at approximately 100 µW, or -10 dBm. We employed a direct substitution method for the measurements. We used Ge and InGaAs trap-based detectors in the intramural comparisons and several Ge trap-based detectors in the international comparisons. NIST's measurement system is described in detail in [10].

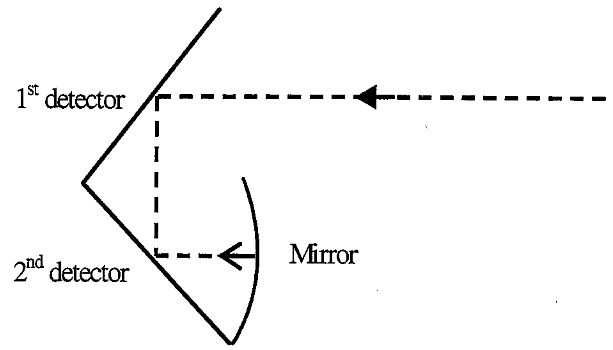

Figure 1. Schematic of a trap detector.

3. Results

We present the results of the responsivity comparisons and their associated uncertainties in Tables 1 and 2. The standard uncertainties for the optical power measurements were evaluated in accordance with the International Organization for Standardization Guide to the Expression of Uncertainty in Measurement [11].

3.1. NIST intramural comparisons

We currently have four measurement systems used to calibrate optical power meters. These systems are based on: (1) the Laser Optimized Cryogenic Radiometer (LOCR), (2) the Electrically Calibrated Pyroelectric Radiometer (ECPR, located in the OFPM laboratory) for fiber-based measurements, (3) the wedge-trap pyroelectric detector (located in the spectral responsivity laboratory) for spectral responsivity, and (4) the isoperibol calorimeter (located in the C-series calorimeter laboratory). We calibrated the 4x traps in all four laboratories. These measurement systems are described in detail in [1].

Table 1 shows the relative difference (expressed in percent) between responsivities obtained with three NIST measurement systems compared to the responsivities obtained by the LOCR. Minus sign indicates that the responsivity measured by a given laboratory is lower than that measured using LOCR. The combined standard uncertainties are provided in the last column of Table 1.

Table 1. Responsivity comparison of NIST laboratories vs. LOCR at 1550 nm

Laboratory name	Transfer standard	Difference (%)	Combined standard uncertainty (%)
OFPM	InGaAs	-0.02	0.20
	Ge	-0.04	
Spectral responsivity	InGaAs	-0.32	0.62
	Ge	0.34	
C-series calorimeter	InGaAs	-0.56	0.50
	Ge	-0.17	

3.2. International comparisons

Table 2 shows the relative difference (expressed in percent) at two laser wavelengths (1302 and 1546 nm) among three NMIs: (1) Physikalisch-Technische Bundesanstalt (PTB-Germany), (2) the National Metrology Institute of Japan/National Institute of Advanced Industrial Science and Technology (NMIJ/AIST-Japan), and (3) the Federal Office of Metrology (METAS-Switzerland) compared to the National Institute of Standards and Technology (NIST-USA). The reference standard for each laboratory was compared by means of temperature-controlled, Ge-based 4x traps. A minus sign indicates that the responsivity measured by an NMI is lower than that measured by NIST. The combined standard uncertainties are provided in the last column of Table 2.

Table 2. Responsivity comparison of PTB, NMIJ/AIST and METAS results vs. NIST

Laboratory name	Source wavelength (nm)	Difference (%)	combined standard uncertainty (%)
PTB	1302	0.02	0.15
	1546	-0.13	0.23
NMIJ/AIST	1302	-0.10	0.36
	1546	-0.30	0.40
METAS	1302	-0.26	0.39
	1546	-0.04	0.42

4. Conclusions and future work

The comparisons we have described show reasonably good agreement between the participating laboratories, with relative differences that are within the combined standard uncertainties. In the coming year we are planning OFPM comparisons with several Asian and one Latin American NMI.

Acknowledgements

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5. References

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