

# *Optical-Fiber Power Meter Comparison between NIST and LAMETRO*

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## Summary:

- We describe the results of a comparison of reference standards between the National Institute of Standards and Technology (NIST, USA) and Laboratorio de Metrología, Instituto Costarricense de Electricidad (LAMETRO-ICE, Costa Rica) for optical fiber-based power measurements at wavelengths of 1310.0 nm, 1550.2 nm, and 1625.0 nm.
- We compared the laboratories' reference standards by means of a commercial temperature-controlled optical-fiber power meter. Measurement results showed the largest difference of less than 5.8 parts in 10<sup>3</sup>, which is within the combined standard ( $k = 1$ ) uncertainty for the two laboratories' reference standards.

**Key words:** international comparison; optical fiber; optical power.

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## 1. Introduction

To demonstrate and maintain our technical competence as well as quality system compliance, national metrology institutes such as the Laboratorio de Metrología (LAMETRO, Costa Rica) and the National Institute of Standards and Technology (NIST, USA) undertake comparisons of measurement standards and protocols. Publication of such comparisons is an important part of maintaining standing with The Bureau International de Poids et Mesures (BIPM), which is served by regional metrology organizations such as the Inter-American Metrology System (SIM), of which LAMETRO and NIST are part. Construction and maintenance of optical communications infrastructure underpin the telephony and high-speed networking (*i.e.*, worldwide web) of modern life. Optical fiber-based communication relies on accurate optical-power measurements that allow network nodes to achieve optimum signal-to-noise-ratio to increase data rates and decrease cost of infrastructure for public and private users.

In our previous work [1–9], we reported the results of international comparisons of reference standards used in the calibration of optical-fiber power meters (OFPMs). Those reports described the results that were obtained by use of open laser beams [1, 4, 6] and optical-fiber patchcord cables [2–9] at nominal wavelengths of 1310 nm and 1550 nm. In this paper, the reference standard maintained by LAMETRO was

calibrated by the two laboratories at wavelengths of 1310.0 nm, 1550.2 nm, and 1625.0 nm by launching optical power from the same reference optical-fiber patchcord cable. In our earlier work, it was shown that different optical-fiber connectors or even the same type of optical-fiber connector made by different connector vendors can skew optical-fiber power measurements [10].

For OFPM measurements, the primary standard of NIST [11] is a cryogenic radiometer that has a standard uncertainty of 2 parts in  $10^4$  ( $k = 1$ ); the reference standard of LAMETRO is a commercial, temperature-controlled OFPM that has a standard uncertainty of 3.5 parts in  $10^3$  ( $k = 1$ ).

## 2. Transfer Standard

For this comparison, we used a typical commercial transfer standard. The transfer standard is an OFPM that consists of a temperature-controlled germanium (Ge) photodiode. The Ge-based OFPM was calibrated at both national laboratories against their reference standards. This transfer standard is also referred to as “device under test” (DUT).

## 3. Measurement Systems

The NIST and LAMETRO measurement systems are very similar. Both laboratories used their own extended-cavity tunable lasers, operating at wavelengths of 1310.0 nm, 1550.2 nm, and 1625.0 nm (all center wavelengths in this paper are based on refractive index in vacuum), and the same optical-fiber patchcord cable with physical contact (FC/PC) fiber connectors, and both laboratories employed a direct-substitution method for their measurements. The NIST measurement system is depicted in Fig. 1; it contains a positioning stage (see double-headed arrow on the right side of the Fig. 1) for comparing the reference and transfer (DUT) standards.

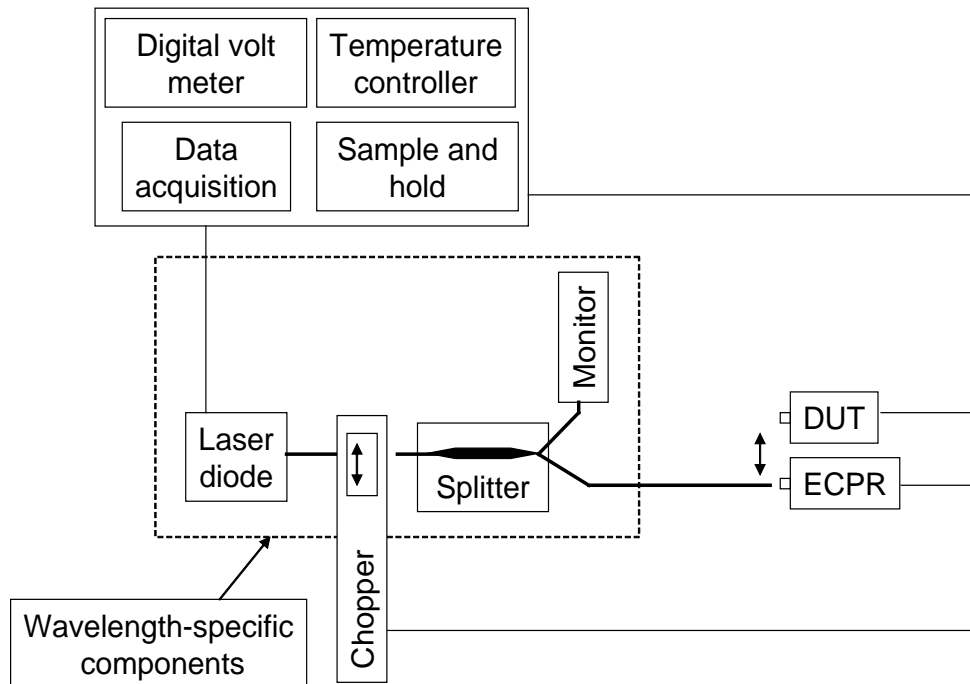


Fig 1. NIST measurement system.

The positioning stage allows the fiber patchcord to be stationary. The NIST measurement system is described in more detail in Ref. [12]. NIST's reference standard is an electrically calibrated pyroelectric radiometer (ECPR) that has been previously calibrated against a NIST primary standard. The ECPR consists of a thermal detector that utilizes a gold-black absorber. The response of the ECPR does not depend on the wavelength of the incident radiation over the wavelength region of 1300 nm to 1625 nm [13].

The LAMETRO measurement system is depicted in Fig. 2. LAMETRO's reference standard, which is based on a temperature-controlled germanium photodiode, is a commercial OFPM, which gets its traceability through METAS (Swiss National Metrology Institute).

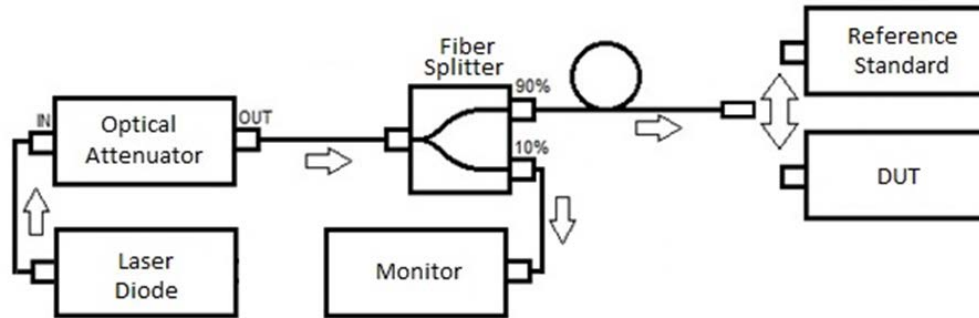


Fig 2. LAMETRO measurement system.

#### 4. Results of the Comparison

The NIST and LAMETRO reference standards were compared by means of calibration factors at an optical power of approximately 100  $\mu\text{W}$  ( $-10$  dBm). The authors followed the guidelines and procedures described in the International Electrotechnical Commission (IEC) 61315 standard [14] for OFPMs, and the standard uncertainties for the OFPM measurements were evaluated in accordance with the International Organization for Standardization (ISO) document standard [15].

Both laboratories used the same reference optical-fiber patchcord cable. At NIST, six measurement runs were taken with a relative standard deviation of  $1.6 \times 10^{-3}$  at a wavelength of 1310.0 nm and a relative standard deviation of  $9.1 \times 10^{-4}$  at a wavelength of 1550.2 nm, and 17 measurement runs were taken with a relative standard deviation of  $3.6 \times 10^{-3}$  at a wavelength of 1625.0 nm. At LAMETRO, 20 measurement runs were taken with a relative standard deviation of  $2.4 \times 10^{-3}$  at 1310.0 nm, with a relative standard deviation of  $8.5 \times 10^{-4}$  at 1550.2 nm, and with a relative standard deviation of  $2.5 \times 10^{-3}$  at 1625.0 nm, respectively. Ten measurement runs at LAMETRO were performed before NIST measurements, and then 10 measurement runs were performed after NIST measurements. The results of the comparison are given in Table 1.

At 1310.0 nm, the relative difference between the NIST and LAMETRO results was 5.8 parts in  $10^3$ ; at 1550.2 nm, the relative difference was 2.6 parts in  $10^3$  (the plus sign for both relative differences indicates that the LAMETRO reference standard read lower than that of NIST); and at 1625.0 nm, the relative difference was  $-5.1$  parts in  $10^3$  (the minus sign for the relative difference indicates that the LAMETRO reference standard read higher than that of NIST). The NIST standard uncertainty was 2.1 parts in  $10^3$  at 1310.0 nm, 2.5 parts in  $10^3$  at 1550.2 nm, and 2.5 parts in  $10^3$  at 1625.0 nm, while that of LAMETRO was 5.5 parts in  $10^3$  (at all three wavelengths).

Table 1 provides the values of relative combined standard uncertainty for NIST and LAMETRO. These values were calculated by taking a square root of the sum of the squares of each laboratory's standard uncertainty. The observed interlaboratory differences (0.58 % at 1310.0 nm, 0.26 % at 1550.2 nm, and  $-0.51$  % at 1625.0 nm) are less than the relative combined standard ( $k = 1$ ) uncertainties for the laboratories' reference standards.

**Table 1.** Results of LAMETRO and NIST comparison.

Source Wavelength (nm)	Difference (%)	LAMETRO Standard Uncertainty (%)	NIST Standard Uncertainty (%)	Combined Standard Uncertainty (%)
1310.0	0.58	0.55	0.21	0.59
1550.2	0.26	0.55	0.25	0.60
1625.0	-0.51	0.55	0.25	0.60

## 5. Conclusion

The comparison results demonstrate that the calibration factor differences at the three laser wavelengths between NIST and LAMETRO measurements are within the combined standard ( $k = 1$ ) uncertainty for the laboratories' reference standards. Therefore, this OFPM comparison shows a good agreement between NIST and LAMETRO reference standards. The purpose of this work was to verify a consistency in measurements of optical-fiber power in the area of optical telecommunications.

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