



Physikalisch-Technische Bundesanstalt
Nationales Metrologieinstitut



Bericht

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On behalf of PTB

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1. Measurement device

The measurement device LIGO TSA (device under test, "DUT") is an optical power sensor, which consists of an integrating sphere (Labsphere, serial number: S2101646) with an input aperture diameter of 25.4 mm (1 inch) and an InGaAs photodetector attached to one of its output apertures. The InGaAs photodetector was electrically connected to a PCal PD Satellite Box (serial number: 2200128) and this to a digital multimeter (Keithley 2100, serial number: 1424247). All connections and configurations of the measurement device were performed following the instructions provided by LIGO in the document LIGO-T2200130-03.

2. Type of Calibration

Determination of the responsivity s in mV/W at the optical power Φ of 100 mW and 300 mW at the wavelength λ of 1047 nm.

3. Measurement Procedure

The calibration of the optical power sensor was performed by a comparison with a standard for laser power, which is traced to PTB's primary standard for optical radiant power via a calibration chain. The responsivity s to be determined is the ratio between the signal voltage V of the sensor upon irradiation, corrected by the voltage V_0 without any irradiation, and the laser power Φ measured by the standard: $s = (V - V_0) / \Phi$.

4. Measurement Conditions

Mode of irradiation:

A circular aperture with a diameter of 4 mm was irradiated with a laser diode (CrystaLaser, Type: Nd:YFL, IRCL1047-500) at the wavelength of 1047 nm. The irradiated aperture was imaged 1:1 with an antireflecting coated lens of approx. 500 mm focal length centrically on the input aperture plane of the LIGO's integrating sphere power sensor. The integrating sphere input aperture was oriented nearly perpendicular to the incoming laser beam.

Measurement of

the output quantity:

The output signal (voltage) of the integrating sphere power sensor was measured with a digital multimeter (Keithley 2100) provided by LIGO. The measurements were performed in 10 s time periods with and without radiation, respectively. The operating parameters of the digital multimeter were configured as follows: Range: Auto, NPLC: 1, Averaging: False, Number of values averaged: 1, Autozero: True, Auto Gain: True and Digital Filter: Off.

Room temperature: $(22.1 \pm 0.5) \text{ }^\circ\text{C}$

Humidity: $(38 \pm 5) \%$

5. Calibration Results

The following table contains the wavelength, the optical power, the responsivity, the expanded uncertainty (in absolute value and in percent) and the expansion factor k . The uncertainty stated is the expanded measurement uncertainty obtained by multiplying the standard measurement uncertainty by the coverage factor $k = 2$. It has been determined in accordance with the "Guide to the Expression of Uncertainty in Measurement (GUM)". The value of the measurand then normally lies, with a probability of approximately 95 %, within the attributed coverage interval.

Wavelength (nm)	Optical power (mW)	s (mV/W)	$U(s)$ (mV/W)	$U(s)$ (%)	k
1047	100	-4362.6	9.2	0.21	2
1047	300	-4363.6	8.7	0.20	2

6. Remarks

The laser source (Crystalaser, Type: Nd:YFL, IRCL1047-500) used for calibration was provided by LIGO.

The PCal PD Satellite Box was connected to a power supply +/- 15 V of the laboratory.

Measurements of the temperature sensor (in Volt) performed during the calibration are attached to this report.

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Zur Sicherstellung der weltweiten Einheitlichkeit der Maßeinheiten arbeitet die PTB mit anderen nationalen metrologischen Instituten auf regionaler europäischer Ebene in EURAMET und auf internationaler Ebene im Rahmen der Meterkonvention zusammen. Dieses Ziel wird durch einen intensiven Austausch von Forschungsergebnissen und durch umfangreiche internationale Vergleichsmessungen erreicht.

The Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig and Berlin is the National Metrology Institute and the supreme technical authority of the Federal Republic of Germany for metrology. The PTB comes under the auspices of the Federal Ministry for Economic Affairs and Climate Action. It meets the requirements for calibration and testing laboratories as defined in DIN EN ISO/IEC 17025.

The central task of PTB is to realize, to maintain and to disseminate the legal units in compliance with the International System of Units (SI). PTB thus is at the top of the metrological hierarchy in Germany. The calibration certificates issued by PTB document a calibration traceable to national measurement standards.

PTB cooperates with other national metrology institutes - at the regional European level within EURAMET and at the international level within the framework of the Metre Convention - with the aim of ensuring the worldwide coherence of the measurement units. This aim is achieved by an intensive exchange of the results of research work and by comprehensive international comparison measurements.

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