



Report of Calibration (42110CA)

LASER POWER METER

Detector model number InGaAs photodetector, S/N S1400482, NIST ID 686110

Labsphere integrating sphere 3P-LPM-040-SL S/N 05076191

Keithley current amplifier 428, S/N 1154940

Keithley digital multimeter 2100, S/N 1148559

Submitted by

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Table 1. Calibration results

Wavelength (nm)	Nominal input power	N	Calibration factor (V/W)	Standard deviation (%)	Expanded uncertainty ($k=2$) (%)
1047	264 mW	4	-1.6935	0.13	± 0.87

Page: 1 of 4
NIST ID: 686110
Folder Number: 285143-14
Date of Calibration: 12-AUG-2014
Date of Report: 12-AUG-2014
Reference: 28-OCT-2013, 75ADV-S184489

Calibration summary

The laser power meter was compared to NIST standard calorimeters at a wavelength of 1047 nm (Diode Laser). The laser beam had a nominal diameter of 5 mm on the detector surface, and the test detector was centered and normal to the incident beam. The power impinging upon the test instrument was measured concurrently using a calibrated beamsplitter and a NIST standard calorimeter (see Figure 1). The beamsplitter ratio was calibrated for each data set using two NIST standard calorimeters.

Before the measurements began, the test instrument was allowed to reach equilibrium with the laboratory environment. Readings were recorded from the test meter via USB interface to KI Ttools software. The calibration factor was then found by dividing the test instrument reading by the calculated incident power. The ambient temperature during these measurements was 22 ± 1 °C.

A summary of the measurements is given in Table 1. If the readings of the test instrument are **divided** by the appropriate calibration factor listed in the table, then, on the average, the resulting values will agree with those of the NIST measurement system.

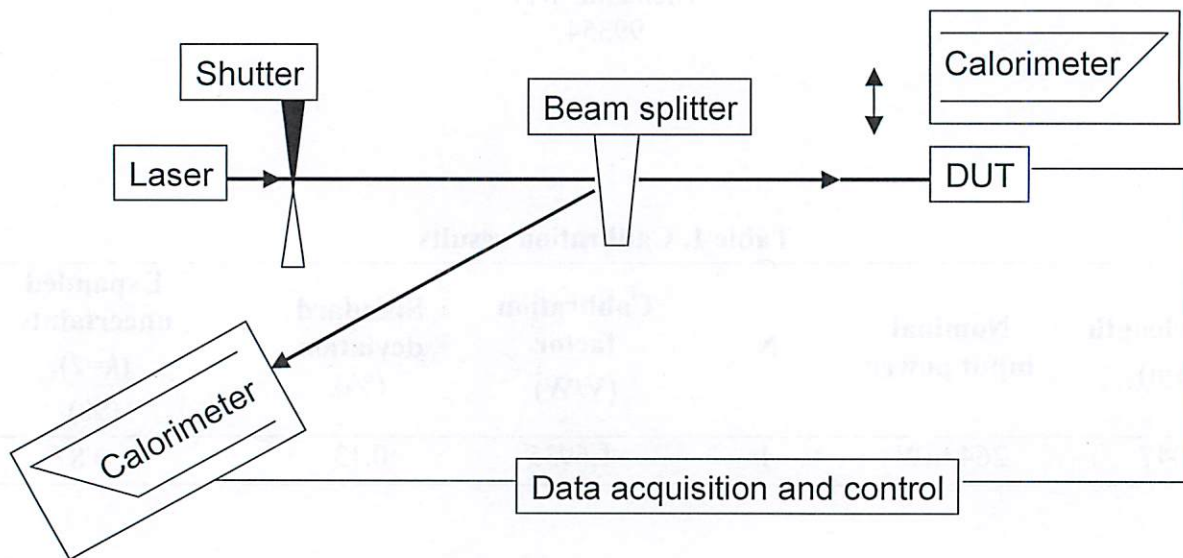


Figure 1. Measurement setup

Page:	2 of 4
NIST ID:	686110
Folder Number:	285143-14
Date of Calibration:	12-AUG-2014
Date of Report:	12-AUG-2014
Reference:	28-OCT-2013, 75ADV-S184489

Uncertainty assessment

The uncertainty estimates for the NIST laser energy measurements are assessed following guidelines given in NIST Technical Note 1297, "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results" by Barry N. Taylor and Chris E. Kuyatt, 1994 Edition. To establish the uncertainty limits, the error sources are separated into (1) Type B errors, whose magnitudes are determined by subjective judgment or other non-statistical method, and (2) Type A errors, whose magnitudes are obtained statistically from a series of measurements.

All the Type B error components are assumed to be independent and have rectangular or uniform distributions (that is, each has an equal probability of being within the region, $\pm \delta_i$, and zero probability of being outside that region). If the distribution is rectangular, the standard uncertainty, σ_s , for each Type B error component is equal to $\delta_i/3^{1/2}$ and the total "standard deviation" is approximated by $(\sum \sigma_s^2)^{1/2}$, where the summation is performed over all Type B error components.

The Type A errors are assumed to be independent and normally distributed, and consequently the

$$S_r = \sqrt{\frac{\sum x^2 - \frac{(\sum x)^2}{N}}{N-1}},$$

standard deviation, S_r , for each component is

where the x values represent the individual measurements and N is the number of x values used for a particular Type A error component. The standard deviation of the mean is $S_r/N^{1/2}$, and the total standard uncertainty of the mean is $[\sum (S_r^2/N)]^{1/2}$, where the summation is carried out for all the Type A error components.

The expanded uncertainty is determined by combining the Type A and Type B "standard uncertainties" in quadrature and multiplying this result by an expansion factor of 2. The expanded uncertainty, U , is then

$$U = 2 \sqrt{\sum \sigma_s^2 + \sum \frac{S_r^2}{N}}.$$

The values used to calculate the NIST uncertainties are listed in Table 2 for the wavelength and power level tested.

The number of decimal places used in reporting the mean value of the calibration factor listed in Table 1 was determined by expressing the total NIST uncertainty to two significant digits.

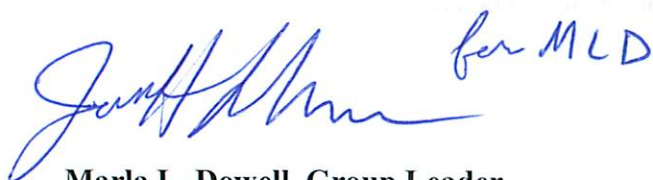
Page: 3 of 4
NIST ID: 686110
Folder Number: 285143-14
Date of Calibration: 12-AUG-2014
Date of Report: 12-AUG-2014
Reference: 28-OCT-2013, 75ADV-S184489

Table 2. NIST measurement uncertainties at 1047 nm, 300 mW

Source	Type B	Type A	
	δ_i	S_r	N
Standard calorimeter			
Inequivalence	0.15 %		
Absorptivity	0.01 %		
Electronics	0.10 %	0.10 %	30
Heater leads	0.01 %		
Window trans	0.11 %	0.02 %	6
Measurements			
Inject time	0.05 %		
Laser power drift	0.50 %		
Standard meter ratio	0.50 %	0.01 %	8
Transfer meter ratio		0.13 %	4
Relative expanded uncertainty (k=2)		0.87 %	

**For the Director,
National Institute of Standards and Technology**

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Page: 4 of 4
NIST ID: 686110
Folder Number: 285143-14
Date of Calibration: 12-AUG-2014
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