Supplementary Comparison

COOMET.PR-S7

Laser Power Responsivity

(COOMET Project 599/RU/13)

Technical Protocol

Contents

1. Introduction

1.1 The aim of this project is to perform a comparison of measurement standards of the unit of laser power at wavelengths of 532 nm, 1.064 μm and 10.6 μm This technical protocol has been prepared by and between the National Institute of Standards and Technology, USA (hereinafter referred to as NIST), and All-Russian Research Institute for Optical and Physical Measurements, Russian Federation (hereinafter referred to as VNIIOFI) and agreed by both participants.

1.2 The procedures outlined in this document cover the technical procedure to be followed during measurement of the transfer standards.

2. Organization

2.1. Participants

2.1.1 The VNIIOFI is acting as a pilot laboratory in the comparison among the participants.

2.1.2 Both participants must be able to demonstrate traceability to an independent realization of the quantity, or make clear the route of traceability to the quantity via another named laboratory.

2.1.3 By their declared intention to participate in this comparison, the laboratories accept the general instructions and the technical protocols written down in this document and commit themselves to follow the procedures strictly.

2.1.4 Once the protocol has been agreed, no change to the protocol may be made without prior agreement of all the participants.

2.2. Participants' details

NMI Name (Country)	Personnel	Contact information
NIST (USA)	Joshua Hadler	National Institute of Standards and Technology. Quantum Electronics and Photonics Division 325 Broadway, Boulder, CO 80305, USA Phone: +1 303.497.4451
VNIIOFI (Russia)	Anatoly Liberman	Federal State-Owned Unitary Enterprise "All-Russian Research Institute for Optical and Physical Measurements" Department of near-monochromatic optical radiation (F-2) 119361, Russia, Moscow, Ozernaia str., 46, Phone: +7 495 437-34-47

2.3. Form of comparison

2.3.1 The comparison will principally be carried out through detector heads for measuring laser power.

2.3.2 A description of the detector heads of both sides for use in this comparison are given in section 3 of this protocol.

2.3.3 One detector head is supplied by NIST, the other detector head is supplied by the VNIIOFI.

2.3.4 The comparison will take the form of a double sided type comparison. The VNIIOFI will calibrate the VNIIOFI-detector head and then send to NIST. NIST will calibrate and return the package to VNIIOFI. VNIIOFI will recalibrate them to check the drift during the period. NIST will calibrate the NIST-detector head and then send to VNIIOFI. VNIIOFI will calibrate and return the package to NIST. NIST will recalibrate them to check the drift during the period.

2.3.5 The participants will exchange their measurement results of power responsivity as soon as possible (no more than 2 months) after all measurements have been completed .

2.3.6 The timetable given below shows an overview on how the comparison is planned.

2.3.7 Each laboratory has two months for calibration and transportation. With its confirmation to participate, each laboratory has confirmed that it is capable of performing the measurements in the time allocated to it.

2.3.8 If for some reason, the measurement facility is not ready or customs clearance takes too much time so that it could not meet the timetable, the laboratory must contact the coordinator immediately.

2.4. Timetable (subject to change)

Activity	Start Date	End Date
Circulation of technical protocol	January 2013	February 2013
Confirmation of participation by member labs and revision of protocol	February 2013	March 2013
Submission of technical protocol to TCPR chair for approval	March 2013	June 2013
Calibration VNIIOFI PM at VNIIOFI	July 2013	August 2013
Transportation VNIIOFI PM to NIST	September 2013	October 2013
Calibration VNIIOFI and NIST PM-s at NIST	November 2013	January 2014
Transportation VNIIOFI and NIST PM-s to VNIIOFI	February 2014	April 2014
Calibration VNIIOFI and NIST PM-s at VNIIOFI	May 2014	June 2014
Transportation NIST PM to NIST	July 2014	August 2014
Calibration NIST PM at NIST	September 2014	October 2014
Draft A report preparation	November 2014	April 2015

2.5. Handling of artefacts

2.5.1 Each detector head should be examined immediately upon receipt. However, care should be taken to ensure that the detector head has sufficient time to acclimatise to the room's environment thus preventing any condensation, etc. The condition of the detector head and associated packaging should be noted and communicated to the coordinator. Please use the fax form in the appendix.

2.5.2 Each detector head should only be handled by the authorized persons and stored in such a way as to prevent damage.

2.5.3 No cleaning of any windows of the detector head should be attempted, except using dry air.

2.5.4 During operation of the detector head, if there is any unusual occurrence, e.g. change of sensitivity, etc., the coordinator should be notified immediately before proceeding.

2.5.5 Please inform the coordinator via fax or e-mail when the measurements on the detector head is completed to arrange a suitable date for dispatch.

2.5.6 After the measurements, the detector head should be repackaged in its original transit cases. Ensure that the content of the package is complete before shipment. Always use the original packaging.

2.6. Transport of artefacts

2.6.1 It is of utmost importance that the detector head be transported in a manner in which they will not be lost, damaged or handled by un-authorized persons.

2.6.2 Packaging for the detector head has been made which should be suitably robust to protect the artefacts from being deformed or damaged during transit. Care must be taken in order to prevent mould spots growing on the surface of the detector due to changes in temperature and humidity.

2.6.3 The detector head is sufficiently robust to be sent by courier. The packages should be marked as 'Fragile'. If the possibility arises to hand-carry the packages this should be done.

2.6.4 The detector head will be accompanied by a suitable customs carnet (where appropriate) or documentation identifying the items uniquely.

2.6.5 Transportation is at each participating laboratory's responsibility and cost. Each participating laboratory covers the cost for its own measurements, transportation and any customs charges as well as for any damages that may have occurred within its country.

3. Description of the artefacts

3.1. NIST Artefact

3.1.1 The NIST measurement artefact is the detector head Coherent PM10

3.1.2 The detector head is sensitive to dust and pollution. When not used they must always be stored with the cover closed.

3.1.3 The detector housing of the Coherent PM10 is equipped with a fixed cable with a 25-pin sub-D connector. The signal voltage has to be measured between Pin 1 (+) and Pin 14 (-). Connecting cables will be provided by NIST.

3.1.4 Details on the PM10 detector head are given in Appendix B.

3.2 VNIIOFI Artefact

3.2.1 The VNIIOFI measurement artefact is the detector head Ophir 10A.

3.2.2 The detector head is sensitive to dust and pollution. When not used they must always be stored with the cover closed. The detector is accompanied by a lid which fits onto the radiation-entrance opening and enables storage and reduces risk of contamination. This lid also contains an adjusting aid for central alignment and should be completely removed for measurements.

3.2.3 The detector housing of the Ophir 10A is equipped with fixed cable with a 15-pin sub-D connector. The signal voltage has to be measured between Pin 9 (+) and Pin 1 (-). Connecting cables will be provided by VNIIOFI.

3.2.4 Details on the Ophir 10A detector head are given in Appendix B.

4. Measurement instructions

4.1. Traceability

4.1.1 Temperature measurements should have an absolute accuracy capable of supporting the "±1 °C" specification of 4.2.1.

4.1.2 Electrical measurements should be independently traceable to the latest realisation of the Volt.

4.2. *Measurand*

4.2.1 The participants are to measure responsivity. The responsivity is defined as the ratio of the artefact voltage to the optical power determined by the participating laboratory (reading in mV per W). The measurements should be performed in suitable laboratory accommodation maintained at a temperature as close as possible to 21.5 ± 1 °C. The exact temperature of the laboratory during the time of the measurements must be reported.

4.2.2 Each independent measurement should consist of the optical head of the power meter being reconnected in the measurement facility. It should be noted that each independent measurement may consist of more than one set of measurements, the exact number should be that normally used by the participating laboratory to obtain the appropriate accuracy as limited by the noise characteristics of their specific measurement facility. The exact number of measurements used should be stated in the measurement report but only the mean or final declared value of the set is required to be included.

4.3. *Measurement instructions*

4.3.1 The voltage of the head has to be measured with a high precision voltage meter.

4.3.2 The participants are to measure the responsivity at wavelengths of 532 nm, 1.064 µm and 10.6 µm. The types of the sources and their central wavelength with uncertainty should be specified.

4.3.3 If the source wavelengths are detuned from the recommended values, it is the participants' responsibility to report the actual wavelengths used, corrections to be added to the measurement results for the central wavelength offsets and uncertainties associated with such corrections. The participants should make corrections based on the spectral responsivity data of the transfer power meter determined by its own means.

4.3.4 If required (see 4.3.3), the spectral responsivity of the detector heads can be measured. The exposure time should be at least minimum 30 s for the NIST Coherent PM10 and at least minimum 30 s for the VNIIOFI Ophir 10A before the voltage is read. The offset voltage should also be measured and subtracted.

4.3.5 No other measurements are to be attempted by the participants nor any modification to the detectors during the course of this comparison. The transfer detectors used in this comparison should not be used for any purpose other than described in this document nor given to any party other than the participants in the comparison.

4.3.6 Any information obtained relating to the use or any results obtained by a participant during the course of the comparison shall be sent only to the pilot laboratory who will be responsible for co-ordinating how the information should be disseminated to other participants. No communication whatsoever regarding any details of the comparison other than the general conditions described in this protocol shall occur between any of the participants or any party external to the comparison without the written consent of the pilot laboratory. The pilot laboratory will in turn seek permission of all the participants. This is to ensure that no bias from whatever accidental means can occur.

4.3.7 The participants are recommended to measure the responsivity at 1 W. If the power level differs by more than 10 %, linearity measurements have to be carried out in order to yield the sensitivity at the nominal power level, taking into account any subsequent uncertainty component.

4.3.8 The beam should be prepared according to the participant's normal practise and ideally following EN ISO 11554, with a nominal diameter of 6 mm (measured as "extent of beam", the diameter containing 99 % of the beam power).

5. Reporting of results and uncertainties

5.1 The report on the calibrations must contain a comprehensive uncertainty budget, comprising all the contributions to the total uncertainty. The uncertainty of measurements shall be estimated according to the "Evaluation of measurement data — Guide to the expression of uncertainty in measurement", Joint Committee for Guides in Metrology, September 2008.

5.2 The report on the calibrations must include a description of the participants' measurement facility or a reference to a published work of the facility. It would be useful for a schematic diagram of the facility to be included.

5.3 It is recommended that the report could be completed by computer and sent back electronically to the coordinator. **In any case, the signed report must also be sent in paper form by mail.** In case of any differences, the paper forms are considered to be the definitive version.

5.4 Following receipt of all measurement reports from the participants, the pilot laboratory will analyze the results and prepare the first draft report on the comparison. This will be sent to the participants for comments, additions and corrections. Subsequently, the procedure outlined in the BIPM Guidelines will be followed.

5.5 Reporting the results, the following uncertainty contributions should be considered:

- Uncertainty associated with the reference standard used
- Uncertainty associated with correction made for the source central wavelength offset or uncertainty associated with the source central wavelength offset (if no correction is made)
- Uncertainty associated with the correction to the reference condition:
  Ambient temperature and humidity
- Uncertainty associated with the drift during the measurement
- Voltage measurement
- Other additional parameters may be felt appropriate to include dependent on specific measurement facilities and these should be added with an appropriate explanation and/or reference. As well as the value associated with the uncertainty, participants should give an indication as to the basis of their estimate. All values should be given as standard uncertainties.

Appendix A

Inspection questionnaire of the detector head

Has the detector head transportation package been opened during transit? e.g. Customs …… Y / N

If Yes please give details.

Is there any damage to the transportation package? …… Y / N

If Yes please give details.

Are there any visible signs of damage to the detector head or housing? …… Y / N

If Yes please give details (e.g. scratches, dust, etc).

Do you believe the detector head is functioning correctly? …… Y / N

If not please indicate your concerns.

Laboratory:

Date: Signature: ……..

Appendix B: Technical details of the detector heads

Coherent PM10 type (NIST)

Wavelength Range:	0.19 – 11 µm
Max Power:	10 W
Max Intermittent Power (<5 min):	30 W
Resolution:	1 mW
Max Avg. Power Density:	26 kW/cm^2
Max Pulse Energy Density:	0.6 J/cm^2
Response Time:	2 sec
Detector Coating:	broadband
Detector Diameter:	19 mm
Probe Dimensions:	Ø 63 mm x 36 mm
Calibration Uncertainty:	±3%

Figure 1. Detector head of the COHERENT PM10 type.

OPHIR 10A type (VNIIOFI)

Wavelength Range:	0.19 – 20 µm
Max Power:	10 W
Resolution:	1 mW
Max Avg. Power Density:	28 KW/cm^2
Max Pulse Energy Density:	2 J/cm^2
Response Time:	0.8 sec
Absorber Type:	broadband
Detector Diameter:	16 mm
Calibration Uncertainty:	±3%

Figure 2. Detector head of the OPHIR 10A type.