Technical Protocol on

APMP supplementary comparison of laser power responsivity

Contents

1. Introduction

1.1 Under the Mutual Recognition Arrangement (MRA) [1] the metrological equivalence of national measurement standards will be determined by a set of key or supplementary comparisons chosen and organized by the Consultative Committees of the CIPM working closely with the Regional Metrology Organizations (RMOs).

1.2 This technical protocol has been prepared by the AIST and agreed by all the other participants.

1.3 The procedures outlined in this document cover the technical procedure to be followed during measurement of the transfer standards. The procedure follows the guidelines established by the BIPM [2].

2. Organization

2.1. Participants

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

2.1.2 All the 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.

1 MRA, Mutual Recognition Arrangement, BIPM, 1999.

2 T.J. Quinn, “Guidelines for key comparisons carried out by Consultative Committees”, Appendix F to the MRA, BIPM, Paris

2.2. Participants' details

Table 1. Participants' details

NMI Name (Country)	Personnel	Contact information
NMIJ/AIST (Japan)	Daiji Fukuda Tatsuya Zama	Laser Standards Section, Photometry and Radiometry National Metrology Institute of Japan AIST Umezono 1-1-1, Tsukuba, Ibaraki 305-8563 Japan Tel: +81 29 861-6834 Fax: +82 29 861-4259 Email: d.fukuda@aist.go.jp, zama-t@aist.go.jp
NIST (United States of America)	John Lehman Igor Vayshenker David Livigni	Sources, Detectors and Displays Group, Optoelectronics Division National Institute of Standards and Technology, MS 815.01 325 Broadway, Room 3074, Boulder, CO 80305-3328 U.S.A Tel: +01-303-497-3394 Fax: +01-303-497-3387 Email: lehman@boulder.nist.gov, igor@boulder.nist.gov, livigni@boulder.nist.gov
NIMT (Thailand)	Narat Rujirat	Laser Power Laboratory, Electrical Metrology Department National Institute of Metrology (Thailand) 3/4-5 Technopolis, Klong 5, Klongluang, Pathumthani 12120 Thailand Tel: +66 2 577 5100 Fax: +66 2 577 3658 Email: narat@nimt.or.th
NMIA (Australia)	Peter Manson	Optical Standards, National Measurement Institute Department of Innovation, Industry, Science and Research.National Measurement Institute Bradfield Road, West Lindfield NSW 2070, Australia Ph: 61-2-8467 3858 Fax: 61-2-8467 3752 Email: peter.manson@measurement.gov.au
NIM (China)	LIN Yandong Lv Liang	Division of optics National Institute of Metrology (China) No. 18 Bei San Huan Dong Lu Beijing 100013 China Tel: +86 10 64524805 Fax: +86 10 64524805, 64218651 Email: linyd@nim.ac.cn, lvliang@nim.ac.cn

2.3. Form of comparison

2.3.1 The comparison will principally be carried out through transfer detectors, that are Silicon-photo-diode based trap detectors.

2.3.2 A description of the measurement setup in this comparison is given in section 3 of this protocol.

2.3.3 The comparison will take the form of a star type comparison. The AIST will calibrate the transfer detectors and then send them to one participant. The participant will calibrate and return the package to the AIST. The AIST will recalibrate them to check the drift during the period. The process will be repeated until all the other participants finish the calibration.

2.3.4 Two different types of trap detectors are used in this comparison. One is developed by NIST, and the other is fabricated by Hamamatsu Photonics K.K in Japan. These trap detectors will be shipped to each participant by the AIST in the order of the timetable, which is given below and showing an overview on how the comparison is planned.

2.3.5 As to read-out of the output current of the transfer detectors, a current meter (or an IV converter) and a connecting BNC cable should be prepared by each participant.

2.3.6 Each participant is to send the responsivity measurement results of the trap detectors to the AIST as soon as possible after finishing the calibration.

2.3.7 Each laboratory has 6 weeks for calibration and transportation. AIST will recalibrate the transfer detectors within 2 weeks. 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 reasons, 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

Table 2. Timetable of the activity and the start/end date

Activity	Start Date	End Date
Circulation of technical protocol and invitation of participants to members	1 Aug, 2008	31 Aug, 2008
Confirmation of participation by member labs and revision of protocol	1 Sep, 2008	30 Oct, 2008
Submission of technical protocol to TCPR chair for approval	1 Nov, 2008	30 Nov, 2008
Final revision and announcement of kick-off	1 Dec, 2008	31 Dec, 2008
Calibration of NMI 1 (AIST, Japan)	1 Jan, 2009	14 Mar, 2009
Calibration of NMI 2 (NIST, United States)	1 Apr, 2009	14 May, 2009
Calibration of NMI 3 (NIMT, Thailand)	1 Jun, 2009	14 Jul, 2009
Calibration of NMI 4 (NMIA, Australia)	1 Aug, 2009	14 Sep, 2009
Calibration of NMI 5 (NIM, China)	1 Oct, 2009	14 Nov, 2009
Draft A report	1 Dec, 2009	31 Jan, 2010
Draft B report	1 Feb, 2010	31 Mar, 2010

2.5. Handling of artefact

2.5.1 The transfer detectors should be examined immediately upon receipt. However, care should be taken to ensure that the transfer detectors have sufficient time to acclimate to the room environment thus preventing any condensation, etc. The condition of the transfer detectors and associated packaging should be noted and communicated to the coordinator. Please use the fax form in the appendix.

2.5.2 The transfer detectors 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 trap detectors should be attempted. The use of dry air is also strictly prohibited, that may damage the detectors.

2.5.4 During operation of the transfer detectors, 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 transfer detectors are completed to arrange a suitable date for dispatch.

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

2.6. Transport of artefact

2.6.1 It is of utmost importance that the artefacts should 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 artefact 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 spot growing on the surface of the detector due to changes in temperature and humidity.

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

2.6.5 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 measurement apparatus

3.1. Artefact

3.1.1 The artefacts, which will be shipped to the participants, are two transfer detectors and a laser source at 405 nm wavelength. The descriptions of the trap detectors and the laser source are shown in Table 3 and Table 4, respectively.

3.1.2 Each trap detector consists of a laser entrance hole, carefully-aligned silicon photo diodes, and a BNC connector for the current output.

3.1.3 The transfer detectors are mechanically robust but sensitive to dust and pollution. When not used they must always be stored with the cover closed.

3.1.4 The measurement set-up is shown in Figure 1. A current meter or an IV converter including the connecting BNC cable, which is used to measure the output current of the transfer detector, should be prepared by each participant. These instruments should be traceable to the Ampere or Volt.

3.1.5 The trap detector housings are provided with a thread hole that may be used for attachment of the transfer detector to the participants' measurement facilities.

3.1.6 Do not exceed the input power 1 mW to the trap detectors.

Table 3: The descriptions of the trap detectors.

Index	Trap A	Trap B
manufacturer	HPK*	NIST
Type	Reflection trap (5 times)	Reflection trap (4 times)
Elements	Si PD	Si PD
Diameter of entrance hole	6 mm	7 mm

HPK* : Hamamatsu Photonics K.K.

Table 4: The descriptions of the laser source.

Manufacturer	Neoark corp.*
Type	Temperature stabilized LD
Wavelength	405 nm (typical)
Maximum power	30 mW
Beam diameter	1.5 mm

Neoark corp.* : http://www.neoark.co.jp/english/index.html

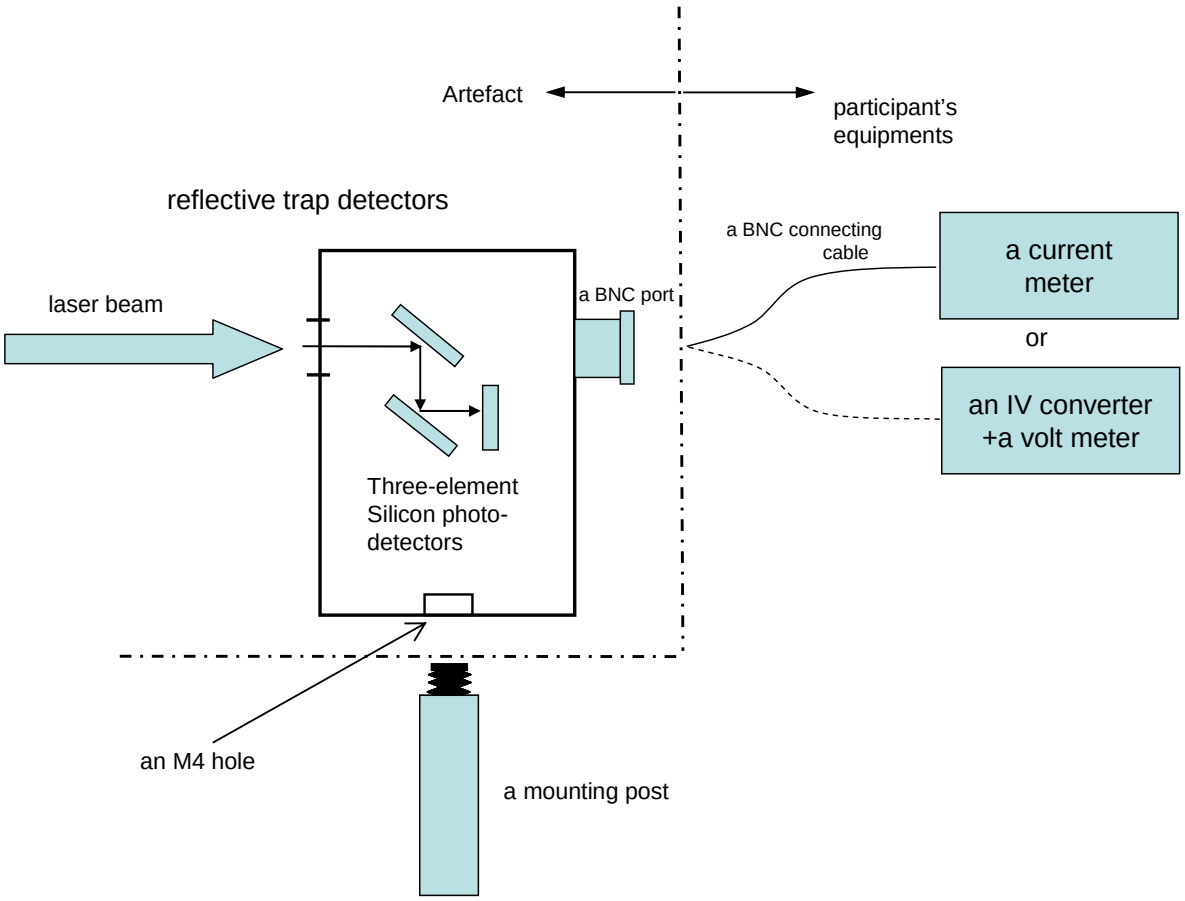

Figure 1. Schematic of the trap detector.

4. Measurement instructions

4.1. Traceability

4.1.1 Temperature measurements should be made using the International Temperature Scale of 1990 (ITS-90).

4.1.2 Electrical measurements should be independently traceable to the latest realization of the Ampere and Volt.

4.2. *Measurand*

4.2.1 The measurand is the laser power responsivity defined as the ratio of the laser power determined by the participating laboratory to the output current of the artefacts (Ampere per Watt). The measurements should be performed in suitable laboratory accommodation maintained at a temperature as close as possible to 23.0 °C. The exact temperature of the laboratory during the time of the measurements must be reported.

4.2.2 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 laser wavelengths in vacuum used in the comparison are totally five wavelengths as follows:

405.0 nm (LD) (the laser source is included in the artefacts.)

488.0 nm (Ar)

514.5 nm (Ar)

632.8 nm (He/Ne)

The calibration can be done at all or a part of the wavelengths. For the wavelength at 405 nm, the participants should use the laser source attached to the artefact. If the wavelength of the laser source of the participant is different, the expected difference for the responsivity compared to the wavelengths listed above should be taken into account, also in the uncertainty budget.

4.3.2 Participants should calibrate all or two of trap detectors.

4.3.3 The beam diameter of the laser ($1/e^2$) should be 1.2 mm to 3 mm. If the diameter is smaller than 1.2 mm, the laser power intensity should be decreased, so as to avoid non-linearity effects in the detector responsivity.

4.3.4 Typical radiant power intensity should be 400 μW. The power intensity strictly should be kept below 1 mW including the beam alignment to avoid damages.

4.3.5 The alignment procedure for the trap detector is as follows (See fig. 2).

A) Remove the whole dust cap (for Trap A) and the alignment device.

B) Align the laser beam with the trap detector perpendicular to the metal of the detector's faceplate. The use of a flat plane-parallel mirror or a flat glass on the faceplate is preferable to observe the back reflection.

C) Attach the alignment device.

D) Adjust the beam position using the alignment target (crosshairs on the alignment device). The beam position should be set to the center of the crosshairs.

E) If necessary, repeat steps B) to D) to check both the position and the orientation.

F) Remove the alignment device again before you start the measurement.

4.3.6 The polarization of the laser should be aligned in parallel to the marker on the detectors, as shown in Fig. 3.

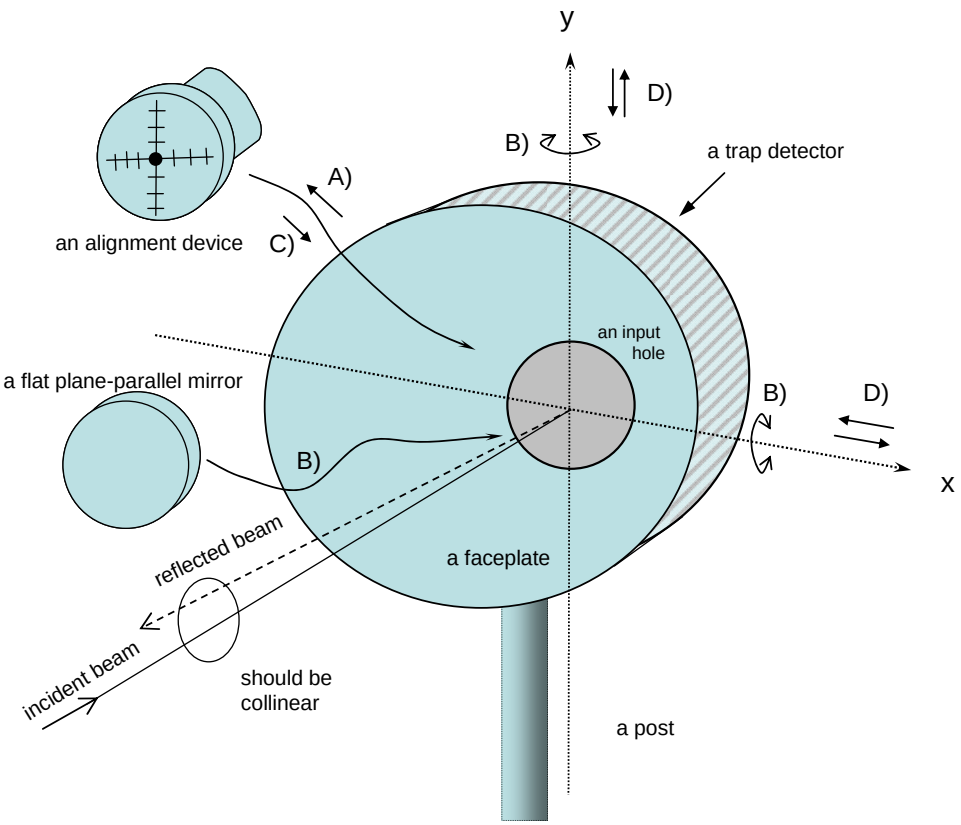

Figure 2. Alignment procedure for the trap detectors.

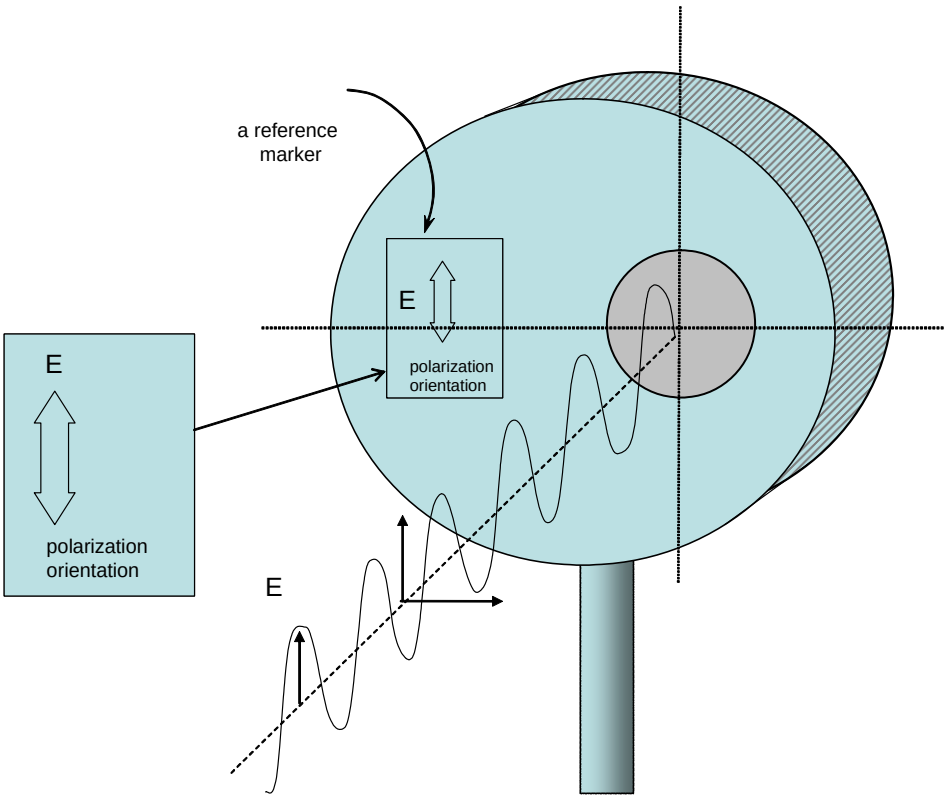

Figure 3. Orientation of the trap detector with respect to the direction of polarisation of the laser beam.

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 *ISO Guide to the Expression of Uncertainty in Measurements*.

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 recommendable 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
- Current 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

Receipt Confirmation

FAX

To: Dr. Daiji Fukuda
National Metrology Institute of Japan
National Institute of Advanced Industrial Science and Technology
Umezono 1-1-1, Tsukuba, Ibaraki 305-8563
Japan

Fax: +81-29-861-4259
E-mail: d.fukuda@aist.go.jp

From: (*participating Laboratory*)

We confirm having received the transfer detectors of the APMP Comparison of Laser power responsivity on ……(date).

□ No damage has been noticed.
□ The following damage(s) has been found:
……
……
……
……

Inspection questionnaire of the transfer detectors

Has the transfer detector 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 or housing? …… Y / N

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

Do you believe the transfer detectors are functioning correctly? …… Y / N

If not please indicate your concerns.

Laboratory:
……

Date: …… Signature: ……..

Completion Confirmation

FAX

To: Dr. Daiji Fukuda
National Metrology Institute of Japan
National Institute of Advanced Industrial Science and Technology
Umezono 1-1-1, Tsukuba, Ibaraki 305-8563
Japan

Fax: +81-29-861-4259
E-mail: d.fukuda@aist.go.jp

From: (*participating Laboratory*)

We confirm having completed the measurements of the transfer detectors for the APMP Comparison of Laser power responsivity on ……(date).

The transfer detectors were sent to AIST/NMIJ on ……..(date).

Further remarks:

……
……
……

Laboratory: ……..
Date: …… Signature: ……..