APMP.PR.K1.a.1

Bilateral Comparison between KRISS and VNIIOFI

Spectral Irradiance in Wavelength Range 250 to 2500 nm

Technical protocol

12 March, 2008

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Contents

1. Introduction

1.1. KRISS and VNIIOFI agreed in April 2007 to conduct a bilateral comparison on the spectral irradiance of tungsten halogen lamps over the spectral region from 250 nm to 2500 nm.

1.2. The aim of this comparison is to assess the equivalence of the spectral irradiance scales between the two laboratories.

1.3. This technical protocol follows as closely as possible with the technical protocol used for the CCPR Key comparison CCPR-K1.a, Spectral Irradiance 250 to 2500 nm. The procedures outlined in this protocol cover the technical procedure to be followed during measurement of the transfer standard lamps.

2. Organization

2.1. Participants

2.1.1. The technical protocol and the participants' details listed below will be submitted to the APMP-TCPR for approval.

2.1.2. Both laboratories will accept the general instructions and the technical protocol written down in this document and commit themselves to follow the procedures strictly.

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

2.2. Participants' details

Laboratory	Function	Person in Charge	Contact
Korea Research Institute of Standards and Science(KRISS), P.O. Box 102, 1 Doryong-Dong, Yuseong-Gu, Daejeon, Korea	Pilot lab	Dong-Joo Shin	Tel: +82-42-860-5209 Fax: +82-42-868-5022 Email: djshin@kriss.re.kr
All-Russian Research Institute for Optical and Physical Measurements (VNIIOFI), Ozernaya 46, 119361 Moscow, Russia	Link lab	Boris B. Khlevnoy	Tel: +7 (495) 437-29-88 Fax: +7 (495) 437-29-92 Email: khlevnoy-m4@vniiofi.ru

2.3. Form of comparison

2.3.1. The comparison will principally be carried out through the calibration of three transfer standard lamps which will be prepared by KRISS and in the following section shall be referred to as “artifacts.” These artifacts are 1000 W tungsten halogen lamps (FEL-type). The artifacts shall be operated with the constant current of 8.100 A. The voltage across lamp terminals is approximately 105 V. The full description of the artifacts is given in section 3 of this protocol.

2.3.2. The artifacts are initially calibrated by KRISS. They will then be hand-carried to VNIIOFI for calibration. After the calibration at VNIIOFI these artifacts will be hand-carried back to KRISS for a repeat calibration to monitor the drift.

2.3.3. Timetable

Activity	Start Date	End Date
◆ First calibration of artifacts at KRISS (Korea)	14 April, 2008	2 May, 2008
◆ Calibration at VNIIOFI (Russia)	2 June, 2008	15 June, 2008
◆ Second calibration at KRISS	1 July, 2008	15 July, 2008
◆ Draft comparison report produced		31 July, 2008
◆ Final comparison report submitted to APMP-TCPR		31 August, 2008

2.4. Handling of artifacts

2.4.1. The artifacts should be examined immediately upon receipt at final destination. However, care should be taken to ensure that the lamps and packaging have sufficient time to acclimatize to the room's environment thus preventing any condensation etc. The condition of the lamps and associated packaging should be noted and recorded using the form in appendix A.2.

2.4.2. The artifacts should only be handled by authorized persons and stored in such a way as to prevent damage.

2.4.3. No cleaning of any lamp envelope should be attempted.

2.4.4. If there is any unusual occurrence during operation of the lamps, e.g. change of voltage, change in output etc., it should be noted and recorded using the form in appendix A.2.

2.4.5. After the measurements, the lamps should be repackaged in their original transit cases.

2.5. Transport of artifacts

2.5.1. The lamps used for this bilateral comparison will be carried by hand between the two laboratories.

3. Description of the artifacts

3.1. The artifacts are three 1000 W tungsten halogen lamps of the FEL type. This lamp consists of a double coiled tungsten filament supported at the top and bottom of the filament and operated in a halogen filled quartz envelope.

3.2. Each lamp will be operated at the same current, 8.100 A. The lamp is operated at a nominal DC voltage of 105 V and should be operated in constant current mode.

3.3. The lamp is mounted on a holder supported by a post on a kinematical base. The lamp mounted on a holder and its alignment jig is shown schematically in Figure 3.1.

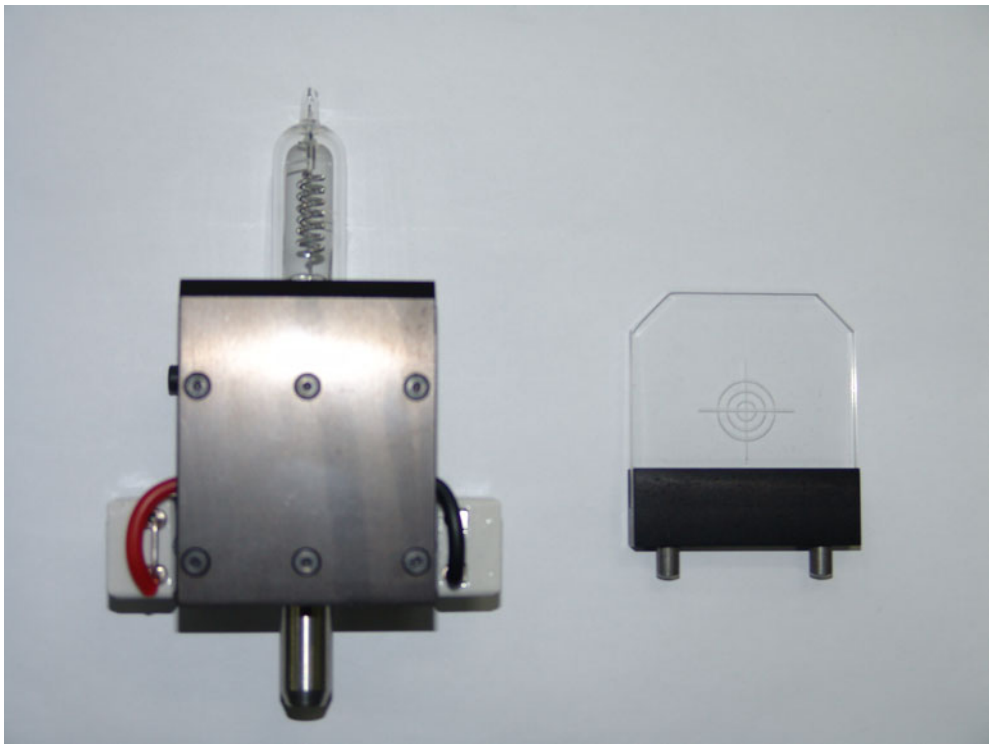

Figure 3.1. Transfer standard lamp and alignment jig.

3.4. Each lamp has its own alignment jig. The alignment jig is assembled in front of the lamp so that the grooved surface is pointing towards the detector. Distances are measured with respect to the reference plane that has been defined to be the front surface of the lamp socket.

4. Measurement instructions

4.1. Traceability

4.1.1. Length measurements should be independently traceable to the latest realization of the meter.

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

4.1.3. Electrical measurements should be independently traceable to the latest realization of the Amp and Volt.

4.2. Measurand

4.2.1. The measurand is the spectral irradiance of a lamp in a plane at the distance of 500 mm from

a reference plane defined in 3.4. The spectral irradiance should be measured for the defined operating current passing through the filament. The measurements should be performed in suitable laboratory accommodation maintained at a temperature of 20 to 25 °C. The exact temperature of the laboratory during the time of the measurements should be reported.

4.3. Measurement instructions

4.3.1. Before connecting to any electrical power supply, the standard lamps should be inspected for damage or contamination. Any damage should be documented using the form in appendix A.2.

4.3.2. The burn time of each lamp should be recorded using the form in appendix A.6.

4.3.3. Switch on the power supply and ramp the current up slowly to the given operating value over a period of about two minutes. The prescribed warm-up period of 20 minutes for the lamp should be observed before the measurement sequence is launched.

4.3.4. The operational conditions and alignment procedure for the lamp should be followed according to the details described in appendix A.5.

4.3.5. The spectral irradiance of the lamps should then be measured over the spectral region 250 to 2500 nm. Measurements should be performed at wavelengths specified in the table in appendix A.1.

4.3.6. The bandwidth used to measure the spectral irradiance should be less than 10 nm (Full Width at Half Maximum) and ideally less than 5 nm in the visible and UV spectral regions. The exact bandwidth used for each spectral point should be reported, together with the center wavelength uncertainty.

4.3.7. The spectral irradiance of each lamp should be measured independently at least 3 times. Each independent measurement should consist of the lamp being re-alignment in the measurement facility. Each independent measurement should be reported. 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 to obtain the appropriate accuracy as limited by noise characteristics of the 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.

4.3.8. At the end of the measurement sequence the burn time for each lamp to be recorded on the in

Appendix A.6.

4.3.9. When the measurements are completed, ramp the current down at the same rate as it was ramped up then turn off the power supply.

5. Measurement uncertainty

5.1. The uncertainty of measurement shall be estimated according to the *ISO Guide to the Expression of Uncertainty in Measurement*. In order to achieve optimum comparability, a list containing the principal influence parameters for calibration of spectral irradiance standard lamps is given below. An example table which should be completed by participants is included as appendix A.4. Other additional parameters may be felt appropriate to include dependent on specific measurement facilities and these should be added with an appropriate explanation and 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 for a coverage factor of k=1.

5.2. Type A

5.2.1. **Repeatability of reference standard** - reproducibility (run to run) without realignment of the participant's reference standard. This component should be largely caused by the measurement set-up related to the output from the reference standard. In effect the standard deviation of a single set of measurements made on the reference standard.

5.2.2. **Repeatability of transfer standard** - reproducibility (run to run) without realignment of the measurements of the transfer standard. This should be largely caused by the measurement set-up related to the output from the transfer standard. The standard deviation of a single set of measurements made on the transfer standard.

5.3. Type B

5.3.1. **Participants disseminated scale** - This is the total uncertainty of the participant's underpinning scale as disseminated by them. This should include the uncertainty in the primary SI realization. All uncertainties contributing to this parameter should be itemized as part of the report, or if published a copy of this publication attached. It is assumed that this will include all uncertainties associated with the measurement facility e.g. linearity, stray light, positioning of reference standard etc.

5.3.2. **Distance to the transfer standard** - This is the uncertainty in setting the distance between

the reference plane on the transfer standard and the measurement plane as specified in the comparison.

5.3.3. **Absolute value of current passed through the transfer standard** - This is the uncertainty in setting the specified current for each lamp and should include both the uncertainty in absolute value, noise and resolution available from the power supply/reading electronics.

5.3.4. **Wavelength** - This is the uncertainty in the absolute value of the wavelength used for the comparison. This should only be taken account in terms of the transfer standard, any similar error which occurs in establishing the primary scale should be separated.

6. Report of results

6.1. On completion of the measurements by the participating laboratory the provisional results of these measurements should be sent to the pilot laboratory with the standard lamps.

6.2. In completing the description of the participants' measurement facility, appendix A.3, it would be useful for a schematic diagram of the facility to be included.

6.3. To ensure the blindness of results, PTB*, as a neutral partner, collects all data (measurement reports) from both participants and then forwards them to the pilot laboratory.

6.4. Following receipt of the measurement report from the neutral partner, the pilot laboratory will analyze the results and prepare a first draft report on the comparison. This will be sent to the participant for comments, additions and corrections.

*** Contact person:**
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A.1 Measurement results

The attached measurement summary should be completed for each lamp and each completed set of measurements. A complete set being one which may include multiple measurements on the same lamp but does not include any realignment of the lamp. For each realignment setup, a separate measurement sheet should be completed.

For clarity and consistency the following list describes what should be entered under the appropriate heading in the table.

Wavelength The assigned center wavelength of the measured spectral irradiance.

Spectral Irradiance The value of the spectral irradiance of the lamp as measured by the participating laboratory

Uncertainty The total uncertainty of the measurement of spectral irradiance including both Type A and B for a coverage factor of k=1.

A.1 Measurement results

Reference Number of artifact: ……..…… Ambient temperature: …… ^{o}C

Wavelength	Spectral Irradiance	Uncertainty
nm	W m^{-2} nm^{-1}	%
250		
260		
270		
280		
290		
300		
310		
320		
330		
340		
350		
360		
380		
400		
450		
500		
550		
600		
650		
700		
800		
900		
950		

Continuation sheet

Wavelength	Spectral Irradiance	Uncertainty
nm	**W m^{-2} nm^{-1}**	**%**
1000		
1100		
1200		
1300		
1500		
1600		
1700		
2000		
2100		
2300		
2400		
2500		

Laboratory: ……

Date: …… Signature: ……..……..

A.2 Inspection of the transfer standards

1) Has the lamp transportation package been opened during transit? e.g.Customs…(Y/N) If Yes please give details.

2) Is there any damage to the transportation package? (Y/N) If Yes please give details.

3) Are there any visible signs of damage to the artifacts? (Y/N) If Yes please give details.

4) Do you believe the artifacts are functioning correctly? (Y/ N) If not please give details.

Laboratory: ……

Date: …… **Signature: ……..**

A.3 Description of the measurement facility and primary scale

This form should be used as a guide. It is anticipated that many of the questions will require more information than the space allocated, please use separate sheets of paper as appropriate.

1) Makers and type of spectroradiometer:

2) Laboratory transfer standards used:

3) Description of measuring technique (please include a diagram):

4) Establishment or traceability route of primary scale including date of last realization and breakdown of uncertainty:

5) Description of calibration laboratory conditions: (e.g. temperature, humidity etc)

Laboratory: ……

Date: …… Signature: ……..

A.4 Uncertainty of measurement

Parameter	Type A Uncertainty in Value / %	Type B Uncertainty in Value / %	Uncertainty in Spectral Irradiance / %
Repeatability of Ref.	U_{Ref}		U_{Ref}
Repeatability of Trans	U_{Trans}		U_{trans}
Scale		U_{scale}	U_{scale}
Distance		U_d	$2U_d$
Current		U_I	$\left(\frac{1}{E}\cdot\frac{dE}{dI}\right)_I \cdot U_I$
Wavelength		U_λ	$\left(\frac{1}{E}\cdot\frac{dE}{d\lambda}\right)_\lambda \cdot U_\lambda$
RMS total			$\left(\sum_i c_i^2 \cdot U_i^2\right)^{1/2}$

The above table is a suggested layout for the presentation of uncertainties for the calibration of each lamp. However, it should be noted that since the wavelength uncertainty has a dependency on wavelength this table can only present a range for that parameter. The summary table associated with the results (appendix A.1.) will of course take account of this wavelength dependent parameter.

The RMS total refers to the usual expression i.e. square root of the sum of the squares of all the individual uncertainty terms as shown.

The uncertainty associated with wavelength is dependent on the rate of change of spectral irradiance with wavelength and so will need to be calculated for each wavelength point.

Laboratory: ……

Date: …… Signature: ……..

A.5 Alignment procedure for transfer standard lamps

1. Position the lamp in front of the measurement instrument. Make sure the lamp number is facing towards the measurement instrument at approximately 500 mm, the distance used to define the spectral irradiance of the lamp.

2. The lamp should be mounted in an area providing good natural circulation of air around the lamp and with black shielding or large open side and rear spaces such as to minimize reflections of flux from the lamp to the measurement instrument.

3. Attach the current leads to the lamp holder terminals making sure to attach the positive lead to the positive terminal. Attach the lamp voltage monitoring leads.

4. Lamps are aligned perpendicular to the optical axis using the alignment jig (Figure 3.1). The grooved surface of the alignment jig must be pointing away from the lamp. The optical axis is marked with white target on the alignment jig.

5. Finally, accurately position the measurement instrument at the correct distance, i.e. 500 mm, from the reference.

A.6 Record of Lamp burn hours

Reference Number of artifact: ……..

Date dd/mm/yyyy	Switch-on Local Time	Activity (Test, Alignment, Measure)	Switch-off Local Time	Burn Hrs	Operator initials

Laboratory: ……

Date: …… Signature: ……..

A.7 Agreement on the bilateral comparison

PARTICIPATION IN THE BILATERAL COMPARISON OF SPECTRAL IRRADIANCE

Agreement on the Bilateral Comparison

This form must be returned to Dong-Joo shin at KRISS. (email: djshin@kriss.re.kr, Fax:: + 82-42-868-5022)

Participating Laboratories: KRISS (Korea Research Institute of Standards and Science) and VNIIOFI (All-Russian Research Institute for Optical and Physical Mesurements)

□ would like to participate in the above comparison and will agree to follow all the rules and conditions described in the Technical Protocol.

Contact persons:	**KRISS**	**VNIIOFI**
Name Telephone: Fax: E-mail:	Dong-Joo Shin (042)-868-5209 (042)-868-5209 djshin@kriss.re.kr	B. Khlevnoy (495) 437-29-88 (495) 437-29-92 khlevnoy-m4@vniiofi.ru
Authorizing signature	…… Seung-Nam Park Position : Director of Physical Metrology Date: 12 March, 2008	…… Victor I. Sapritsky Position: Head of Photometry and Radiometry Division Date: 12 March, 2008