Bilateral Comparison between MIKES and NIMT (Thailand) on Spectral Irradiance in Wavelength Range 290 to 900 nm

Technical Protocol

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1. Introduction

1.1. MIKES and NIMT agreed in June 2007 to conduct a bilateral comparison on the spectral irradiance of tungsten halogen lamps covering the spectral region 290 nm to 900 nm.

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

1.3. The technical protocol described in this document follows as closely as possible with the technical protocols used for the recent key comparisons CCPR-K1.a Spectral Irradiance 250 to 2500 nm (starting in summer 1999) and CCPR-K1.a.1 (bilateral between CSIRO and SPRING Singapore).

2. Organization

2.1. Participants

2.1.1. The technical protocol and the participants' details listed below will be submitted to the TC-PR of EURAMET for approval.

2.1.2. Both laboratories will accept the general instructions and the technical protocol written down in this document.

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

Address	Person in Charge	Contact
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2.3. Form of comparison

2.3.1. The comparison will principally be carried out through the calibration of a group of three transfer standard lamps which will be prepared by MIKES. These lamps are 1000W tungsten halogen lamps all of which are of the FEL type. The lamps shall be operated with the constant current of about 8.1000 A. The voltage across lamp terminals is approximately 105 V. The full description of the lamps is given in section 3 of this protocol.

2.3.2. The lamps are initially calibrated by MIKES (Finland). They will then be hand-carried to NIMT (Thailand) for calibration. After the calibration at NIMT (Thailand) these lamps will be hand-carried back to MIKES for a repeat calibration to monitor the drift.

2.3.3. Timetable

Activity	Start Date	End Date
First calibration of artifacts at MIKES (Finland)	November 1st, 2006	December 20th, 2006
Calibration at NIMT (Thailand)	October 31st, 2007	November 16th, 2007
Repeat calibration at MIKES (Finland)	February 1st, 2008	February 28th, 2008
Draft comparison report produced		April 30th, 2008
Final comparison report submitted to EURAMET		June 30th, 2008

2.4. Handling of lamps

2.4.1. The lamps should be examined immediately after being received 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 should be noted and recorded using the form in appendix A.2.

2.4.2. The lamps 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 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 lamps

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

3. Description of the transfer standard lamps

3.1. The lamps are 1000W 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 envelop. The nominal operating color temperature of this lamp is 3200K.

3.2. Each lamp will be operated at a nominated direct current that will be approx 8.1 A. The lamp is operated in constant current mode and the DC voltage of the power supply should be approximately 105 V.

3.3. The lamp, potted on a black base, is supported by a post on a kinematical base. The kinematical post is then supported at the bottom of its post by a metric 6 mm thread. The optical axis for measurement is at least 200 mm from the bottom surface of the lower post. A photograph of the lamp mounted on a post is shown in Figure 3.1.

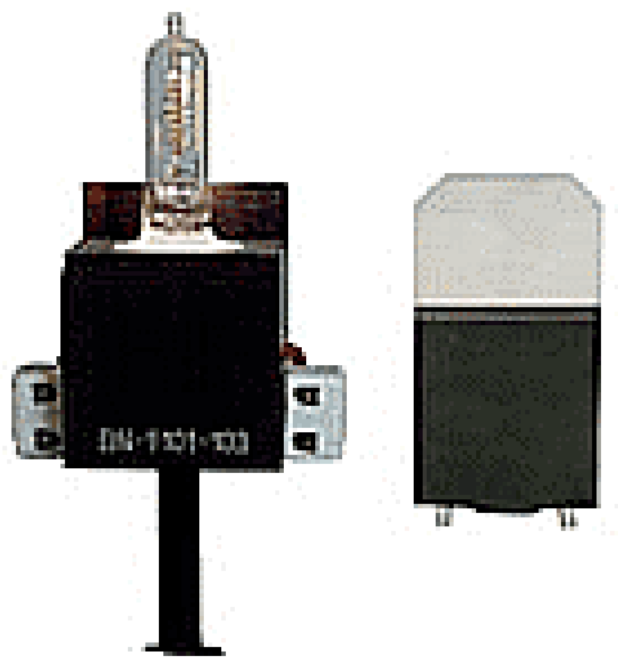

Figure 3.1: Transfer standard lamp (left) and alignment jig (right)

3.4. Each lamp has its own alignment jig (Figure 3.1). The alignment jig is inserted to the front of the lamp base when alignment is performed. It is mounted so that the grooved surface is pointing towards the detector(s). Distances are measured with respect to the reference plane that has been defined to be the front surface of the lamp base (without the alignment jig) as described in Figure 3.2.

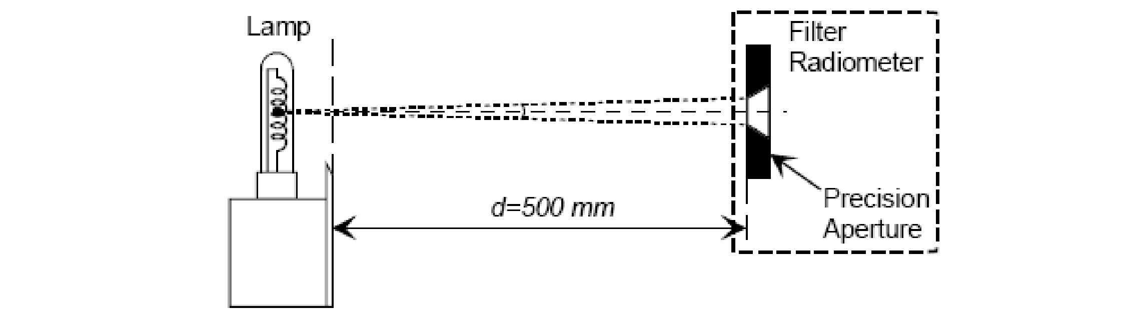

Figure 3.2: Distance setting in spectral irradiance measurements at MIKES

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

4.3. Alignment of the lamp

4.3.1. 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.

4.3.2. 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.

4.3.3. 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.

4.3.4. Lamps are aligned perpendicular to the optical axis using the alignment jig (Figure 3.1) and a laser beam. The grooved surface of the alignment jig must be pointing away from the lamp. The horizontal and vertical position of the lamp (with respect to the optical axis) is aligned so that the optical axis hits the white target mark on the alignment jig.

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

4.4. Measurement instructions

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

4.4.2. The burn time of each lamp should be recorded using the form in appendix A.5.

4.4.3. 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.

4.4.4. After setting to the specified current value of the lamp the actual voltage drop across the lamp should be recorded using the form in appendix A.5.

4.4.5. The spectral irradiance of the lamps should then be measured over the spectral region from 290 to 900 nm. Measurements should be performed at a minimum wavelength interval of 10 nm between 290 and 400 nm, and 50 nm between 400 and 900 nm for the dispersive method which shall be the case for NIMT. MIKES shall adopt the same measurement method based on filter radiometers as they did in the CCPR-K1.a comparison.

4.4.6. The bandwidth of the monochromator 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 UV and visible spectral regions. The exact bandwidth used for each spectral point should be reported, together with the centre wavelength uncertainty.

4.4.7. The spectral irradiance of each lamp should be measured independently at least 3 times. Each independent measurement should consist of the lamp being re-aligned 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 the 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 values of the set is required to be included.

4.4.8. At the end of the measurement sequence the voltage across the lamp should again be measured and recorded on the form in Appendix A.5.

4.4.9. 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 of uncertainty budget tables, which should be completed by participants, is included as Appendix A.4. All values should be given for a coverage factor of k=1.

5.2. Types of measurement uncertainties

5.2.1. Type A

5.2.1.1. **Repeatability of reference standard -** the standard deviation of a single set of measurements made on the reference standard without realignment

5.2.1.2. **Repeatability of transfer standard** - the standard deviation of a single set of measurements made on the transfer standard (prepared by MIKES) without realignment

5.2.2. Type B

5.2.2.1. **Participants disseminated scale** - This is the total uncertainty of the participants underpinning scales as disseminated by them. This should include the uncertainty in the primary SI realization, or in the case of scale originating from another laboratory, the uncertainty of the scale disseminated to it by that laboratory and this originating laboratory should be referenced. It is assumed that this will include all uncertainties associated with the measurement facility e.g. linearity, stray light, positioning of reference standards etc.

5.2.2.2. **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.

5.2.2.3. **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.

5.2.2.4. **Wavelength** - This is the uncertainty in the absolute value of the wavelength used for the comparison. This should only be taken into 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 measurement the results should be reported in the results sheet shown in the Appendix A.1.

A 1. Measurement results

The attached measurement summary should be completed for each transfer standard 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 centre wavelength of the measured spectral irradiance.*
Spectral Irradiance	*The value of spectral irradiance of the lamp as measured.*
Bandwidth	*The spectral bandwidth of the instrument used for the comparison defined as the Full Width at Half Maximum.*
Std Deviation	*The standard deviation of the number of measurements made to obtain the assigned spectral irradiance without realignment.*
Number of Runs	*The number of measurements made to obtain the specified std deviation.*
Uncertainty	*The total uncertainty of the measurement of spectral irradiance including both Type A and Type B for a coverage factor of k=1.*
Burn Hrs	*The estimated number of operational burn hours made on the lamp taken from a start time of 0hrs on receipt of the lamp.*

A1. Measurement results

Reference number of
transfer standard lamp ____________ Ambient temperature __________________

Wavelength nm	Spectral Irradiance $W\ m^{-2} nm^{-1}$	Bandwidth	Std Dev.	Number of Runs	Uncertainty %	Burn Hours
290						
300						
310						
320						
330						
340						
350						
360						
370						
380						
390						
400						
450						
500						
550						
600						
650						
700						
750						
800						
850						
900						

Laboratory: ....

Signature: .... **Date:** ....

A 2. Inspection of the transfer standard lamps

1) Has the transportation package been opened during transit? (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 lamps? (Y/N) If yes please give details.

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

Laboratory: ______________________________

Signature: ______________________ **Date:** ______________________

A 3. Description of the measurement facility and traceability

This form should be used as a guide. Please use separate sheets of paper as appropriate.

1) Makers and types of spectroradiometer:

2) Laboratory reference standards used:

3) Description of measuring set-ups (please include a diagram):

4) Establishment of traceability route of the spectral irradiance scale including date of last realization and breakdown of uncertainty:

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

Laboratory: ....

Signature: ______________ **Date:** ....

A 4. Uncertainty of measurement

Parameter	Type A Uncertainty in Value %	Type B Uncertainty in Value %	Uncertainty in Spectral Irradiance%
Repeatability of Reference	U_{Ref}		
Repeatability of Transfer Standard	U_{Trans}		
Scale		U_{Scale}	
Distance		U_d	
Current		U_I	
Wavelength		U_λ	
RMS Total			

The above table is suggested layout for the presentation of uncertainties for the calibration of each lamp. However, as uncertainties will vary with wavelength particularly since the wavelength uncertainty has a dependency on the wavelength and transfer uncertainties will vary through the spectrum this table can only present a range for that parameter. A table presenting individual uncertainties in more columns for each wavelength would be preferred. The summary table associated with the results (Appendix A.1) will of course take account of these wavelength dependent parameters.

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

The uncertainty associated with the 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: ....

Signature: .... **Date:** ....

A 5. Record of lamp burn hours

Reference number of transfer standard lamp

Date	Switch-on Local Time	Activity (Test, Measure, etc.)	Lamp Voltage (V)		Switch-off Local Time	Burn Hrs	operator Initials
			Start	End			

Laboratory: ....

Signature: .... **Date:** ....