

COOMET Key Comparison

Bilateral between VNIIOFI and PTB

COOMET.PR-K1.b.1

Spectral Irradiance 200 nm to 350 nm

Technical protocol

(Final Approved)

05 December 2014

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1. Introduction

- 1.1. The metrological equivalence of national measurement standards will be determined by a set of key comparisons chosen and organized by the Consultative Committees of the CIPM working closely with the Regional Metrology Organizations (RMOs).
- 1.2. At its meeting in March 1997, the Consultative Committee for Photometry and Radiometry, CCPR, identified several key comparisons in the field of optical radiation metrology. In particular, it decided that a key comparison of spectral irradiance in the air-UV spectral range shall be carried out. The comparison “CCPR-K1.b Spectral Irradiance 200 nm to 350 nm” was started in 2003 and completed in 2008 [1]. It was piloted by the Physikalisch-Technische Bundesanstalt (PTB), Germany.
- 1.3. All-Russian Research Institute for Optical and Physical Measurements (VNIIOFI) did not take part in the CCPR-K1.b. VNIIOFI and PTB agreed to conduct a bilateral comparison that allowed VNIIOFI to be linked to the CCPR-K1.b Key Comparison Reference Values (KCRV). This bilateral comparison will be carried out within the RMO COOMET (Euro-Asian Cooperation of National Metrological Institutions).
- 1.4. This technical protocol follows as close as possible the technical protocol used for the CCPR Key comparison CCPR-K1.b, Spectral Irradiance 200 nm to 350 nm.

2. Organization

2.1. Participants

- 2.1.1. The participants are VNIIOFI and PTB (details are presented in the table below). The VNIIOFI result is to be linked to CCPR-K1.b. PTB acts as a link laboratory. PTB participated in CCPR-K1.b and provides the link of results between this bilateral KC and CCPR-K1.b.
- 2.1.2. VNIIOFI acts as the pilot laboratory and is responsible for developing the comparison protocol, preparing transfer standards, checking stability of transfer standards, registering the comparison, preparing Draft A and subsequent work.
- 2.1.3. PTB as a link laboratory is responsible for Pre-Draft A.
- 2.1.4. The non-link laboratory (VNIIOFI) must be able to demonstrate independent traceability to the realization of the quantity, or make clear the route of traceability to the quantity via another named laboratory.
- 2.1.5. The participants accept the general instructions and the technical protocol written down in this document and commit themselves to follow the procedures strictly.
- 2.1.6. 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	Contact person	Contact
Physikalisch-Technische Bundesanstalt (PTB) 4.11 Spectroradiometry Bundesallee 100 D 38116 Braunschweig Germany	Link lab	Peter Sperfeld	Tel. +49 531 592 4144 Fax +49 531 592 69 4144 Email: Peter.Sperfeld@ptb.de
All-Russian Research Institute for Optical and Physical Measurements (VNIIOFI), Ozernaya 46, 119361 Moscow, Russia	Pilot lab Non-link lab	Boris 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 a group of transfer standard lamps (artefacts). These lamps have been shown to have reasonable and with care, robustness, to be used to transfer a spectral irradiance scale maintained in non-link laboratory (VNIIOFI) to that of the link laboratory (PTB).
- 2.3.2. A full description of the transfer standard lamps selected for use in this comparison is given in section 3 of this protocol. The minimum set of transfer standards used for this comparison should be a group of three lamps. This minimizes the risk of unknown drift and damage.
- 2.3.3. The transfer standard lamps used in this comparison will all be supplied pre-aged and mounted in a suitable holder. VNIIOFI as a pilot will implement the selection, checking, assembling and ageing of all the lamps.
- 2.3.4. The comparison will be carried out in the following sequence: VNIIOFI – PTB – VNIIOFI. The artefacts will initially be calibrated by the pilot lab (VNIIOFI). They will then be transported to the link lab (PTB) for calibration. They will then be returned to VNIIOFI to carry out a repeat calibration to monitor drift.
- 2.3.5. Following the requirements of the Guidelines for CCPR and RMO Bilateral Key Comparisons (paragraphs 5.2 – 5.4) a third party (CCPR WG-KC Secretary: Michael Stock, mstock@bipm.org) is designated for the comparison, and all the measurement results, both from the non-link laboratory (VNIIOFI) and the link laboratory (PTB) are submitted electronically to the third party upon completion of each measurement, to ensure blindness of the comparison. At completion of all measurements, the third party sends all the data received to the link laboratory (PTB), so that the link laboratory can start Pre-Draft A process. The third party sends to both participants all the raw data received after Draft A is issued.
- 2.3.6. The participants agree to perform the measurements according to the timetable below. If for some reasons, the measurement facility is not ready or customs clearance takes too much time in a country, a participant must contact the second partner to discuss further details.

2.3.7. Timetable

Activity	Date
Lamps pre-aged and characterized by VNIIOFI	September 2014
Comparison registration	December 2014
Calibration at VNIIOFI	December 2014
Lamp delivery to PTB	January 2015

Lamp calibration at PTB	February 2014
Lamp return to VNIIOFI	March 2014
Repeat lamp calibration at VNIIOFI	April 2015
Measurement reports submission to Third party	May 2015
Pre-Draft A	July 2015
Draft A	August 2015
Draft B submitted to WG-KC for approval	September 2015

2.4. Handling of artefacts

- 2.4.1. The artefacts 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 inspected and reported to the pilot.
- 2.4.2. The artefacts 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 windows, jigs or envelopes should be attempted. No parts should be removed; the housing of the lamp systems must not be opened.
- 2.4.4. The monitoring of the standard lamps during operation is needed to determine whether an occurrence is "unusual" (change of voltage, change in output etc). If so, other participant should be notified immediately and the situation should be discussed before proceeding.
- 2.4.5. Please inform other participant when the measurements are completed to arrange a suitable date for dispatch.
- 2.4.6. After the measurements, the lamps should be re-packaged in their original transit cases. Ensure that the content of the package is complete before shipment. Always use the original packaging.

2.5. Transport of artefacts

- 2.5.1. It is of utmost importance that the artefacts be transported in a manner in which they will not be lost, damaged or handled by un-authorized persons.
- 2.5.2. Packaging for the artefacts should be suitably robust to protect the artefacts from being deformed or damaged during transit.

- 2.5.3. Artefacts should as a preference be carried by hand between participating laboratories, either by personal road transport or in an aircraft cabin. However, recognising that this may result in high financial costs to some participants and recognising that the lamp systems are fragile and may be subject to change in their characteristics from transportation, it should be noted that there is as yet no conclusive evidence indicating whether lamps are less likely to change when hand carried as opposed to a careful postal service. They should under all circumstances be marked as 'Fragile'.
- 2.5.4. The artefacts should be accompanied by a suitable customs documentation identifying the items uniquely. The packaging is to be easy to open with minimum delay to allow customs inspections to take place.

3. Description of the artefact

The measurement artefact is a set of three transfer standard deuterium lamp systems. Each system consists of a deuterium lamp in special housing, associated power supply, shunt resistor and alignment jig. Each lamp has to be operated with its own specific power supply, shunt resistor and jig. Each lamp, jig and shunt resistor have unique identification numbers. Identification numbers of a jig that must be used with a lamp will be shown in a label on the lamp housing. Each power supply has a label showing lamp and shunt resistor numbers it must be used with. The identification number and labels are shown in Fig1.

- 3.1. **Lamps:** The lamp are 30 W deuterium lamps of the HAMAMATSU L6308 type. The lamps were mounted in housing by the company "SPECTR" (Russia), Fig.2. The pilot will carry out initial ageing of lamps and alignment of each lamp inside the housing. Each lamp is assigned to its own special power supply and must only be operated with this power supply and must be aligned using its correlated jig. The lamps must be allowed to warm up at least 40 min before starting spectral measurements.



Figure 1. The identification number and labels on lamp (up left), power supply (up right), shunt resistor (down left) and alignment jig (down right)



Figure 2. Deuterium Lamp in housing. Front view.

- 3.2. **Lamp housing:** Each deuterium lamp is set up in its own housing, which protects the lamps from environmental conditions. The housing together with the alignment jig defines the optical measurement axis. On the back side of the housing there is a connector for connecting to the associated power supply (Fig. 3). The screws at the bottom of the housing base can be used for alignment. The lamp can be mounted using a plate that can be fixed to the housing base by the fixing screw (Fig.2)

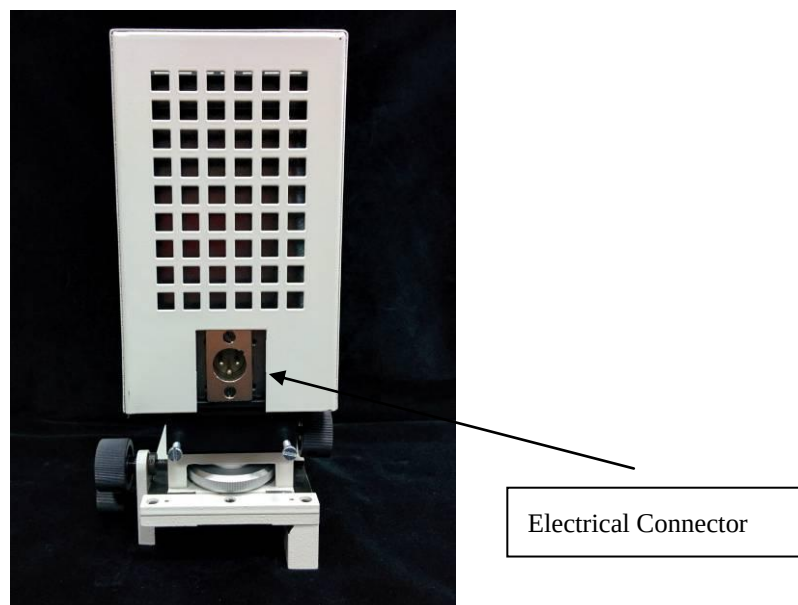


Figure 3. Deuterium Lamp in housing. Back view.

- 3.3. **Alignment jig:** Each lamp has its own alignment jig with a glass window and a “cross” target in its centre. The jig has to be connected to the internal (black) screen of the lamp housing in that way that the mark on the jig coincides the mark on the housing (Fig. 4). It is necessary to remove the jig for spectral calibrations. The front surface of the jig glass window is used as the reference plane for the distance measurement (Fig.5).



Figure 4. The Jig has to be connected to the internal (black) screen of the lamp housing in that way that the mark on the jig coincides the mark on the housing



Figure 5. The front surface of the jig glass window is used as the reference plane for the distance measurement

- 3.4. **Power supply:** The deuterium lamp power supply is specially designed for the 30 W deuterium lamps. On its front (Fig.6) it has a power switch (big green), a switch (small black) for switching on a lamp and an ignition button (red). On the back there is a connector for connecting to a lamp. Each power supply is equipped with its own resistor to measure the lamp current. The number of the resistor is labeled on the top of the power supply.

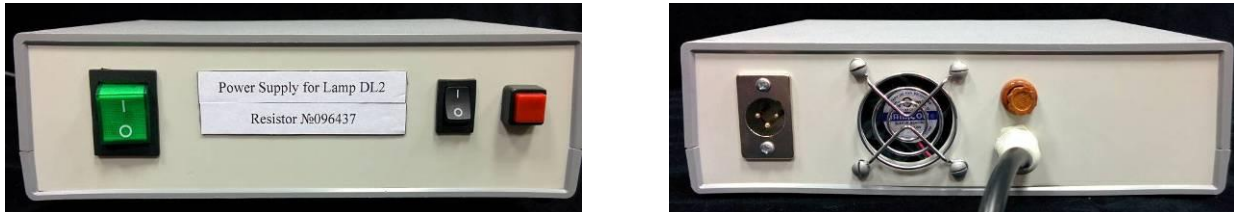


Figure 6. Power supply. Front view (left) and Rear view (right)

The resistor has cables going to a power supply and a lamp as well as wires for measuring lamp current and voltage. The cable and wires are connected to the resistor. **Please do not disconnect them!** Fig.7 shows electrical connections of the lamp, power supply and resistor. The short cable with a massive connector goes to the power supply; the long cable with similar connector goes to the lamp; the white wires are for lamp current measurement, and red and black wires are for lamp voltage measurement.



Figure 7. Electrical connections

The sequence of the switching ON a lamp:

- turn on the big green switch
- turn on the small black switch,
- wait for 20 sec. to allow lamp pre-heating.
- push the ignition button (red), hold it for 2 to 3 sec. and then release the button.

The sequence of the switching OFF a lamp:

- turn off the small black switch
- turn off the big green switch

- 3.5. **Lamp pre-alignment:** The pilot will perform pre-alignment of each lamp using the mounting inside the lamp housing in such a way that its UV-irradiance is maximum on the optical axis defined by the housing and the jig.
- 3.6. **Lamp pre-ageing:** The initial ageing of each lamp will take approximately 200 h. During that time the lamps will be switched on and off several times. The temporal irradiance drift will be monitored. This drift data might be used to correct for changes during the calibration process.

4. Measurement instructions

4.1. Traceability

- 4.1.1. Length measurements should be independently traceable to the latest realization of the metre.
- 4.1.2. Ambient 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 ampere and volt.

4.2. Measurand

- 4.2.1. The measurand is the spectral irradiance of a lamp at wavelengths from 200 nm to 350 nm with 10 nm steps in a plane at a specific distance from a reference plane defined by a jig aligned to the optical axis of the lamp system. The spectral irradiance should be measured for the defined operating conditions for each lamp, defined by the associated power supply. The measurements should be performed in suitable laboratory accommodation maintained at a temperature of 20 °C to 25 °C. The ambient temperature of the laboratory during the time of the measurements should be reported.
- 4.2.2. The spectral irradiance of each lamp should be measured independently at least 3 times. Each

independent measurement should consist of the lamp being realigned in the measurement facility and being switched off and on after a break of at least 2 h for each lamp. Each independent measurement set should be reported separately. 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. Participants are reminded that the spectral irradiance of the transfer standard lamps will change as a function of the operational burn time and so it is recommended that this is kept to a minimum.

- 4.2.3. The measurements must be taken at the defined distance of 400 mm described in Appendix A.5.7. Due to the limited uniformity of the irradiance of deuterium-lamps, measurements at other distances are unfeasible to be corrected.

4.3. Measurement instructions

- 4.3.1. Before connecting to any electrical power supply, the standard lamps should be inspected for damage or contamination of either the window of the lamp (viewed through the front aperture), its housing or its supporting mount. The housing of a lamp system must not be removed by the participants at any time. Any damage should be documented by photos and a drawing using the appropriate form in appendix A.2 and the other laboratory should be informed immediately.
- 4.3.2. The burn time of each lamp should be recorded using the form in appendix A.6.
- 4.3.3. After switching on each lamp should be warmed up for at least 40 min.
- 4.3.4. The operational conditions and alignment procedure for each lamp should be followed according to the details described in appendix A.5. The check list presented in appendix A.5 should be followed, filled out and signed for each measurement. The check list should be kept by the participants for documentation and quality assurance.
- 4.3.5. The spectral irradiance of the transfer standards should then be measured over the spectral range from 200 nm to 350 nm. Measurements should be performed at a wavelength interval of 10 nm.
- 4.3.6. The bandwidth used to measure the spectral irradiance should be equal or less than 5 nm (Full Width at Half Maximum) and ideally equal or less than 3 nm. The exact bandwidth used for each spectral point should be reported, together with the center wavelength uncertainty.
- 4.3.7. No other measurements are to be attempted by the participants nor any modification to the operating conditions during the course of this comparison. The transfer standards 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.

5. Measurement uncertainty

5.1.1. The uncertainty of measurement shall be estimated according to *the Guide to the Expression of Uncertainty in Measurement* (JCGM 100:2008). 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. The participating laboratories are encouraged to follow this breakdown as closely as possible, and adapt it to their instruments and procedures. 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. Participants are asked to make 3 independent (after full realignment) measurements of spectral irradiance on each lamp and record the results in separate versions of Appendix A1, this will allow the reproducibility for each lamp to be calculated and, therefore, this does not need to be calculated separately by the participants.

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.

5.2.3. Repeatability of transfer to reference standards ratio – This uncertainty should replace previous two uncertainties if the measurement is performed as a ratio measurement and it is impossible to evaluate the repeatability of standards separately.

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 associated with instability of the current or discrepancy between current values measured at participant laboratories. The current of each lamp is defined by the power supply. The current value can not be changed by participants, but it will be monitored. Ideally, this uncertainty component is zero if the current is stable and reproducible.

5.3.4. Wavelength - This is the uncertainty in the absolute value of the wavelength used for the comparison.

5.3.5. Lamp stability – This uncertainty will be estimated using the pilot measurements performed **before** and **after** a participant measurement. This uncertainty will be taken into account for calculating Degree of equivalence.

6. Report of results

6.1. On completion of all measurements by the non-link laboratory (VNIIOFI) the provisional results of these measurements should be sent to the third party as soon as possible and at the latest within six weeks.

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. Following the CCPR Guideline G5 "Guidelines for CCPR and RMO Bilateral Key Comparisons" the link laboratory (PTB) will carry out Pre-Draft A procedures, and the pilot laboratory (VNIIOFI) will prepare Draft A report and following reports.

7. Evaluation of Degree of Equivalence of non-link laboratory

7.1.1. The Degree of Equivalence of the non-link laboratory (VNIIOFI) will be evaluated using the results of present RMO bilateral KC and the results of CCPR-K1b following the CCPR Guideline **G5 "Guidelines for CCPR and RMO Bilateral Key Comparisons"**.

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. Therefore, for each lamp at least 3 complete measurements sheets are needed.

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

The sheet can be presented in an appropriate Excel-file following the layout of the given example.

Wavelength	The assigned center wavelength of the measured spectral irradiance in nm.
Spectral Irradiance	The value of the spectral irradiance of the lamp as measured by the participating laboratory, in $W/(m^2 \text{ nm})$
Bandwidth	The spectral bandwidth of the instrument used for the comparison defined as the Full Width at Half the Maximum, in nm
Std Dev.	The standard deviation of the number of measurements made to obtain the assigned spectral irradiance without realignment, in %
Num of Runs	The number of independent measurements made to obtain the specified standard deviation.
Uncertainty	The total standard uncertainty of the measurement of spectral irradiance separating this into Type A and B.

Additionally the following parameters should be reported:

Ambient temperature	The mean of the ambient temperature at the measurement facility during the spectral measurements measured in °C.
Lamp Current	The lamp current recorded during the spectral measurement and its standard deviation.
Lamp Voltage	The lamp voltage recorded during the spectral measurement and its standard deviation.
Burning Hours	The estimated number of operational burn hours made on the lamp taken from a start time of 0 hrs on receipt of the lamp from the pilot.

A.1 Measurement results

Lamp system number:

Measurement Number:

Laboratory:

Contact person:

Date:

Ambient temperature:

°C

Lamp Current:

± mA

Lamp Voltage:

± V

Burning Hours:

h

Wavelength nm	Spectral Irradiance $\text{W m}^{-2} \text{nm}^{-1}$	Bandwidth nm	Std Dev., %	Num of Runs	Uncertainty		
					Type A	Type B	
200							
210							
220							
230							
240							
250							
260							
270							
280							
290							
300							
310							
320							
330							
340							
350							

Remarks:

A.2 Inspection of the transfer standards

Must be filled out and sent electronically to the other laboratory immediately after receiving the lamps and operating it for the first time by the participant.

Lamp system number:

Laboratory:

Contact person:

Date:

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 artefacts? (Y/N) If Yes please give details.

4) After warm-up is the lamp voltage and current within its specified range? (Y/ N)

If not what is the voltage and the current? V, mA

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

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. The description together with the uncertainty budget should be submitted to the link laboratory latest at the time the measurement results are submitted to the third party.

1) Make and type of spectroradiometer:

2) Laboratory transfer standards used:

3) Description of measuring technique (please include a schematic 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. stray light protection, temperature, humidity etc)

A.4 Uncertainty budget

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}	$2u_{\text{d}}$
Current		u_{I}	$\left(\frac{1}{E} \cdot \frac{dE}{dI} \right)_I \cdot u_{\text{I}}$
Wavelength		u_{λ}	$\left(\frac{1}{E} \cdot \frac{dE}{d\lambda} \right)_{\lambda} \cdot u_{\lambda}$
Combined standard uncertainty ($k=1$)			$\left(\sum_i c_i^2 \cdot u_i^2 \right)^{1/2}$

* Or combined Repeatability uncertainty instead the first two if the u_{Ref} and u_{Trans} are not measured separately.

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 uncertainties of several parameters have a dependency on wavelength, this table can only represent a range for that parameter. The summary table associated with the results (appendix A.1.) will of course take account of these wavelength dependent parameters. 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.

A.5 Checklist for the alignment and operation procedure for deuterium lamps

1. Position a laser beam so that is aligned along the optical axis of the measurement system, with the laser pointing towards the lamp front.
2. This lamp is very fragile and great care should be taken in its handling. Do not open the lamp housing or move any screws of the lamp pre-alignment.
3. Attach the lamp and holder to a suitable mount which allows: vertical and horizontal translation of the lamp perpendicular to the optical axis; has two axis tilt to enable the lamp to be tilted in the plane of the optical axis and in a horizontal plane perpendicular to the optical axis; rotation in the horizontal plane about the lamp filament. The lamp should be positioned so that the distance measurement reference plane is pointing towards the measuring instrument and at approximately the correct distance from the facility measurement plane (400 mm). The alignment jig, should be attached to the lamp housing. The jig should be mounted in such a way that the mark on the jig coincides with the mark on the housing.
4. Connect the lamp to the power supply assigned to the lamp system via the shunt resistor as it's shown in Fig. 7. Connect the measurement channels to a suitable DVM.
5. Position the lamp so that it is aligned vertical and perpendicular to the measurement axis. This should be carried out by using the alignment target and the back reflection of the alignment laser from the alignment jig window. Additionally the target might produce a diffraction pattern when it is well aligned to the measurement axis (depending on the laser spot size). The pattern appears symmetrically to the back reflection. The horizontal pattern indicates exact horizontal alignment (pattern of the vertical target line) whereas the vertical pattern belongs to the vertical alignment. The vertical axis of the lamp (degree of freedom around the optical axis) can be adjusted by putting a water-level at one side of the lamp housing.
6. Adjust the horizontal and vertical position of the lamp so that the alignment laser beam passes through the centre of the target on the alignment jig.
7. Finally, accurately position the lamp the correct distance from the measurement plane. For this type of standard the distance of 400 mm should be measured to the distance reference plane at the front surface of the lamp jig window (see Figure 5).
8. Before switching on the power supply remove the lamp jig.
9. Switch on the power supply. For that: 1) turn on the big green switch; 2) turn on the small black switch; 3) push the ignition button (red), hold it for 2 to 3 sec. When the lamp is ignited, release the button.
10. After the ignition allow the lamp to stabilise for forty minutes before starting measurements. Record the lamp current and voltage at least every five minutes during the whole operating time of the lamp.
11. When the spectral measurements are complete, switch off the power supply. Connect the protection cap to the lamp housing for dust protection. Allow the lamp to cool down for several minutes.
12. Complete the checklist form A.5.b below and sign it. Keep it for documentation of your calibration processes. Use a new checklist for every measurement and follow it closely. Fill out the measurement summary which will be part of the measurement documentation sent back to the pilot laboratory.

Checklist for Lamp measurement

Lamp system number:

Measurement Number:

- ☐ Position a laser beam so that it is aligned along the optical axis of the measurement system.
- ☐ Attach the lamp and holder to a suitable mount.
- ☐ Attach the alignment jig to the lamp housing.
- ☐ Attach the current cable to the power supply assigned to the lamp system.
- ☐ Attach the measuring connector to the suitable DVM .
- ☐ Position the lamp using the back reflection of the jig target so that the lamp is aligned vertical and perpendicular to the measurement axis.
- ☐ Accurately position the lamp at the correct distance of 400 mm from the measurement plane to the distance reference plane at the front surface of the lamp jig window.
- ☐ Remove the alignment jig
- ☐ Switch on the power supply and start recording of the lamp current and voltage.
Time of lamp ignition: : Burning hours of lamp: h
- ☐ Allow the lamp to stabilise for forty minutes before starting measurements.

 Time of measurement start: : Lamp Current: mA

 Lamp Voltage: V

 Time of measurement end: : Lamp Current: mA

 Lamp Voltage: V

 Ambient temperature: °C
- ☐ Switch off the power supply.

 Time when lamp turned off: : Burning hours of lamp: h
- ☐ Connect the protection cap to the lamp housing for dust protection.
- ☐ Allow the lamp to cool down for several minutes.
- ☐ Fill out the summary for this measurement as shown below. Insert the values of the electrical and environmental parameters measured at the end of the spectral measurements.
- ☐ Carefully remove the lamp and store it in a dry and safe place.

Lamp system number:

Measurement Number

Ambient temperature: °C

Lamp Current: $\pm$ mA

Lamp Voltage: $\pm$ V

Burning Time: _____ h

A.6 Record of Lamp burn hours

Lamp system Number:

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

Laboratory:

Operator:

Date:

Signature: