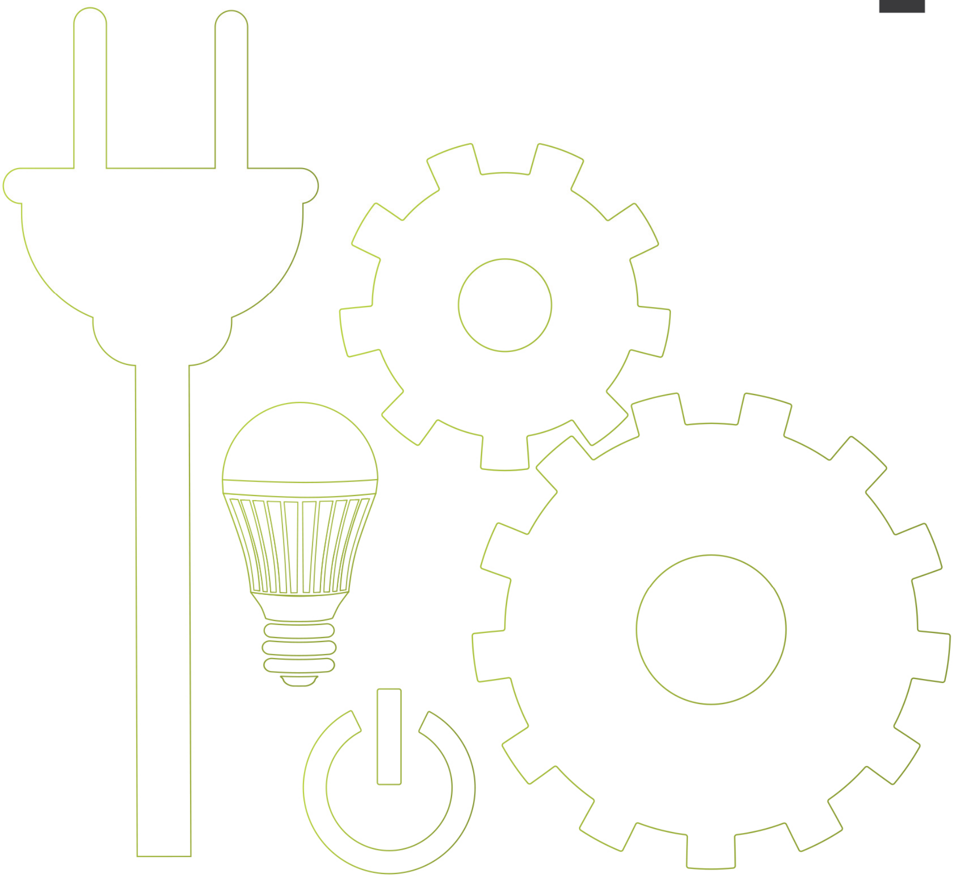

Solid State Lighting Annex: Interlaboratory Comparison 2017 (IC 2017)

Technical Protocol version 1.0

Energy Efficient End-Use Equipment (4E)
International Energy Agency

30 June 2017

IEA 4E Solid State Lighting Annex
Interlaboratory Comparison - Goniophotometers
Technical Protocol

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Acknowledgements: The authors are grateful to Dr. Wei Zhang of the National Lighting Test Centre (NLTC) in China, who contributed to preparation of this protocol and to Dr. Koichi Nara (co-author of Final Report for IC 2013) in Japan, who provided a detailed review and professional advice on the conformity of IC 2017 to ISO/IEC 17043 and related standards. The authors also thank the SSL Annex Experts and members of the Management Committee, especially Dr. Peter Bennich, Management Committee Chair of the SSL Annex, David Boughey, Management Committee Deputy Chair of the SSL Annex, Nils Borg, its Operating Agent, and Mike Scholand, Operating Agent Support.

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About the IEA 4E Solid State Lighting Annex: The SSL Annex was established in 2010 under the framework of the International Energy Agency's Energy Efficient End-use Equipment (4E) Implementing Agreement to provide advice to its member countries seeking to implement quality assurance programmes for SSL lighting. This international collaboration was established by the governments of Australia, Denmark, France, Japan, The Netherlands, the Republic of Korea, Sweden, United Kingdom and the United States of America. Further information on the 4E SSL Annex is available from: http://ssl.iea-4e.org/

About the IEA Implementing Agreement on Energy Efficient End-Use Equipment (4E) is an International Energy Agency (IEA) Implementing Agreement established in 2008 to support governments to formulate effective policies that increase production and trade in efficient electrical end-use equipment. Globally, electrical equipment is one of the largest and most rapidly expanding areas of energy consumption which poses considerable challenges in terms of economic development, environmental protection and energy security. As the international trade in appliances grows, many of the reputable multilateral organisations have highlighted the role of international cooperation and the exchange of information on energy efficiency as crucial in providing cost-effective solutions to climate change. Twelve countries have joined together to form 4E as a forum to cooperate on a mixture of technical and policy issues focused on increasing the efficiency of electrical equipment. But 4E is more than a forum for sharing information – it initiates projects designed to meet the policy needs of participants. Participants find that pooling of resources is not only an efficient use of available funds, but results in outcomes which are far more comprehensive and authoritative. The main collaborative research and development activities under 4E include:

- The Electric Motor Systems Annex (EMSA)
- The Mapping and Benchmarking Annex
- The Solid State Lighting Annex (SSL)
- The Electronic Devices and Networks Annex (EDNA)

Current members of 4E are: Australia, Austria, Canada, Denmark, France, Japan, the Republic of Korea, The Netherlands, Switzerland, Sweden, the UK and the USA. Further information on the 4E Implementing Agreement is available from: www.iea-4e.org

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Acronyms and Abbreviations

4E	Energy Efficient End-use Equipment
AB	Accreditation Body
AC	Alternating Current
ART	Artefact
CCT	Correlated Colour Temperature
cd	candela
CIE	Commission Internationale de l'Éclairage (International Commission on Illumination)
CRI	Colour Rendering Index
DC	Direct Current
DUT	Device Under Test
EN	European Norm
Hz	hertz
IC 2017	Interlaboratory Comparison 2017
ID	Identification
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IES	Illuminating Engineering Society (North America)
ISO	International Organisation for Standardisation
ITR	Individual Test Report
KILT	Korea Institute of Lighting Technology
KS	Korean Industrial Standards
LED	Light Emitting Diode
lm	lumen
LCS	Luminaire Classification System
LNE	Laboratoire national de métrologie et d'essais
PT	Proficiency Test
RMS	Root Mean Square
SDPA	Standard Deviation for Proficiency Assessment
SSL	Solid State Lighting
UK	United Kingdom
USA	United States of America
W	Watt

1 Introduction

Following the previous 2013 interlaboratory comparison (IC 2013)[1] where 110 labs from around the world were compared for measurements of solid state lighting (SSL) products, IEA 4E SSL Annex is conducting the second Interlaboratory Comparison (IC 2017) around the world for the measurement of SSL products by goniophotometers[2]. IC 2017 is organised to compare measurements of LED luminaires (including street lighting luminaires) and narrow-beam LED lamp, which were not covered in the previous IC 2013. This interlaboratory comparison will study the equivalence of measurements by different types of goniophotometers, not only the traditional far-field types but also near-field goniophotometers, and investigate the measurement variations and the capabilities of participating laboratories using goniophotometers to measure SSL products.

The IC is not only a technical study, it is designed in compliance with ISO/IEC 17043[3] to serve as a proficiency test for SSL testing accreditation programmes that recognise this comparison, as was done in IC 2013. IC 2017 will use CIE S 025[4] (Test Method for LED lamps, LED luminaires, and LED modules) as the test method. If recognised by accreditation bodies, the test report may be used as a proficiency test (PT) for CIE S 025. The technical requirements in CIE S 025 mostly encompasses those in regional/national test methods such as EN 13032-4[5] (European standard, equivalent to CIE S 025); LM-79[6] (North America); KS C 7653[7] and KS C 7651[8] (Korea), and JIS C7801[9] and JIS C8105-5[10] (Japan). The comparison of the requirements in these regional/national test methods with CIE S 025 is available in Appendix 2 of Ref. 11. Thus, if recognised by accreditation bodies, the IC's test reports may also be used as PT for these regional test methods and possibly also for the test methods in China and other countries.

Near-field goniophotometers, as well as non-standard goniophotometers that do not keep the DUT operating position constant with respect to the direction of gravity (if corrections are applied as guided in CIE S 025), can both be accepted in this interlaboratory comparison. Their results may be used for evaluation of the validation requirement for such goniophotometers in CIE S 025 or to assist in an accreditation application.

The measurement rounds of this IC will be led by two Nucleus Laboratories that have suitable facilities and recognition for this purpose and offer their commitments to serve this IC.

This document describes the technical protocol used by the participating laboratories as well as by Nucleus Laboratories.

2 Coordinator and Organising Laboratory

The coordinator of IC 2017 is:

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The coordinator is responsible for the design of IC 2017, drafting Technical Protocol, coordination of Organising Laboratory and Nucleus Laboratories, overseeing the measurement rounds, and drafting the Final Report of IC 2017.

The IC 2017 Organising Laboratory is:

Korea Institute of Lighting Technology (KILT)
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The Organising Laboratory conducts preparation and operation of the measurement rounds of IC 2017, including preparation of the artefacts (operation test, aging, and marking) and shipping of the artefacts to the Nucleus Laboratories, as well as piloting Nucleus Laboratory comparison.

3 Nucleus Laboratories

IC 2017 will be conducted as bilateral comparisons between each participating laboratory and one of the Nucleus Laboratories. To handle many participants around the world, two Nucleus Laboratories will be used. Participants will be assigned to one of these Nucleus Laboratories to work with, taking into account the region and the available capacity of the Nucleus Labs.

The contact details of the Nucleus Laboratories are given below:

Korea Institute of Lighting Technology (KILT)
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KILT is the Korean Industrial Standards (KS) certification body and has been accredited for ISO/IEC 17025 by Korea Laboratory Accreditation Scheme (KOLAS) for optical radiation measurements. KILT has been also accredited as the KS testing laboratory from Korean Agency for Technology and Standards (KATS) and high efficiency certification programme testing lab from Korea Energy Agency (KEA) for photometry, and has developed the safety and photometric performance requirement for KS as a Cooperation Organisation for Standards Development (COSD). KILT also provides testing services for Energy Star programme as an EPA-recognised lab.

LNE is the National Metrology Institute for France, maintaining photometric and radiometric units (such as lumen, candela, watt) and disseminate standards for luminous flux, luminous intensity, spectral irradiance, etc. Their calibration and measurement capabilities (CMC) for many photometric and radiometric quantities are certified and published by International Committee of Weights and Measures (CIPM)[12] under the framework of CIPM Mutual Recognition Arrangement (MRA)[13]. LNE is accredited for ISO/IEC 17025 by COFRAC (French Accreditation Body) on a wide variety of calibration services in photometry and radiometry. LNE also provides testing services for LED lighting products compliant with CIE S 025 and is accredited for ISO/IEC 17025 by COFRAC for this activity.

4 Description of the Comparison Artefacts

A set of four artefacts shown in Table 1 are used in IC 2017. One each of ART-1, ART-2, ART-3, ART-4 will be sent to each participant in two rigid shipping containers. All the artefacts are seasoned and tested for stability, and measured by a Nucleus Laboratory, before sending to participants.

These were selected as typical indoor and outdoor luminaires (and a lamp) in the current market. ART-1 is a typical MR-16 narrow beam lamp especially to compare measurements of beam angle, centre beam intensity, and partial flux. ART-2 is a typical indoor planar luminaire with broad (near-Lambertian) distribution. ART-3 is another indoor luminaire with small upward light emission especially to test capability for measurement for upward angles. ART-4 is a typical street lighting luminaire having significantly asymmetric intensity distributions in the horizontal plane. A model with fairly low power factor was chosen.

Table 1. Artefact Set for IC 2017

Designation Type	Picture (actual)	Size	Rated voltage, Power, nominal CCT	Other
ART-1: Narrow-beam lamp		MR-16 ϕ50mm x 45mm	12 V DC 7.5 W 2700K	Narrow beam angle < 20°
ART-2: Planar luminaire		615mm x 615mm x 15 mm	220 V AC, 60 Hz 40W 5700K	Broad (near Lambertian) distribution
ART-3: Batten luminaire		625mm x 56mm x 85mm diffuse cover	220 V AC, 60 Hz 20W 4000K	Broad distribution with small upward emission
ART-4: Street lighting luminaire		500mm x 251mm x 105mm 5.5 kg	220 V AC, 60 Hz 4000K 20W	Asymmetric beam emission pattern

A total of approximately 20 sets (this number is subject to change) of artefacts were prepared to be used for IC 2017 for a total of ~60 participants (this number is subject to change), and each set is assigned an ID number. There will be three sequential measurement rounds of comparison to be carried out by each Nucleus Lab, in which the same sets of artefacts will be used. In this case, the artefact ID numbers will be re-numbered (changes are tracked) in each round so that there is no possibility that participants of later rounds may gain any advantage from the disclosure of the assigned value from the results of earlier rounds.

All the artefacts for use in IC 2017 have been seasoned for 200 hours and the stability and reproducibility of several samples of each artefact type have been tested to be satisfactory by the Organising Laboratory. The reproducibility of each of these artefacts to be sent to participants will be tested by each Nucleus Laboratory.

5 Properties Measured for Comparison

The measurement quantities listed in Table 2 and Table 3 will be measured and compared in this IC test. The quantities in Table 2 are those measured in IC 2013. The reported results for quantities in Table 2 will be analysed to give the laboratory performance assessment. Therefore, the report may be readily used as objective evidence in applying for accreditation. The quantities in Table 3 are goniophotometric quantities. The results for quantities in Table 3 will be used mainly for the purposes of a technical study. While we request all participants to measure and report results of all the quantities in Table 3, if any participants have difficulty, it would be acceptable not to report one or more quantities in Table 3.

Table 2. General Quantities (for all Artefacts)

No.	Quantity	units
1	Total luminous flux	lm
2	Luminous efficacy	lm/W
3	Chromaticity coordinate (u′, v′) – spatially averaged	-
4	Correlated colour temperature (CCT) – spatially averaged	K
5	Colour rendering index (CRI) R_a – spatially averaged	-
6	Active power	W
7	RMS current	A
8	Power factor	-

Table 3. Goniophotometric Quantities – Measure Those Marked with an "X"

No.	Quantity	Artefact Identifier			
		ART-1	ART-2	ART-3	ART-4
9	Luminous intensity distribution (cd)	X	X	X	X
	C angle (horizontal)	2 planes only (0°/180°, 90/270°)**			
	Vertical angle range and interval	0-90°, 1° step	0-90°, 5° step	0-180°, 5° step	0-90°, 1° step *and* 90°-180°, 10° step
10	Partial luminous flux (lm) for cone angle 15°	X			
11	Street light partial flux (lm)				
	Forward light				X
	Back light				X
	Up-light				X
12	Beam angle (avg. of 2 planes)	X			
13	Central beam intensity	X			
14	Angular spatial colour uniformity	X		X	

** These C angle planes are only for reporting luminous intensity distributions. To measure total luminous flux and partial luminous flux, goniophotometer must be scanned with C angle intervals much smaller than 90° (see 9.2).

Only the artefacts and quantities with "X" mark need to be measured and reported.

For the details of some of these goniophotometric quantities, please refer to the following sections in CIE S 025 [ref. 4]:

- Partial luminous flux: section 3.33
- Centre beam intensity: section 6.6 (including NOTE in this section).
- Beam angle: section 3.17 and section 6.6. Report the average beam angle from the two C planes (0°/180°, 90/270°).
- Angular colour uniformity: section 7.1.4

Street light partial flux (three partial fluxes) is defined in IES TM-15-11[14]. This is illustrated in Figure 1.

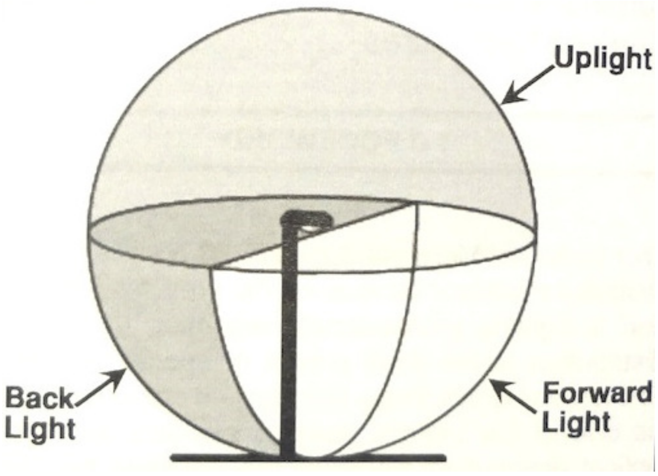

Figure 1. The three primary solid angles of the Luminaire Classification System (LCS)

For the street lighting luminaire, even if the luminaire structure may indicate that there is no upward flux, participants are asked to actually measure the luminous intensity distributions from γ=0° to 180° range and report measured data and calculated uplight flux. This is to test laboratories' capability to measure very low level light emission in uplight region when required, e.g., for TM-15 rating.

6 Assigned Values

The Interlaboratory Comparison will be conducted as a star-type comparison between a number of participants and a Nucleus Lab. The set of artefacts will be sent from the Nucleus Lab to each participant and returned to Nucleus Lab. The artefacts will be calibrated by the Nucleus Lab before and after shipping and measurement by each participant. The assigned values will be determined from the two measurements (before and after shipping) of the Nucleus Lab with the correction factors described in 6.1. The artefacts will be calibrated by the Nucleus Labs using CIE S 025 and in compliance with the accredited and/or peer reviewed procedure with the determination of the uncertainties of the measurement results.

6.1 Nucleus Laboratory Comparison

A Nucleus Laboratory comparison will be carried out to establish the equivalence between the two Nucleus Laboratories. Measurements for two sets of four artefacts for all quantities by the two Nucleus Laboratories will be compared. Due to expected measurement variations between the two Nucleus Labs for some quantities and artefacts, a decision was made to use the weighted mean of the two Nucleus Laboratories' results to establish correction factors to determine the Assigned Values for each quantity and each artefact.

First, the weighted mean $\overline{x}$ of the two measurement results x_1 and x_2 by Nucleus Labs 1 and 2, respectively, is calculated based on the uncertainties of measurements by the Nucleus Laboratories;

$$\overline{x} = x_1 \cdot \left[u^{-2}(x_1) \Big/ \left(u^{-2}(x_1) + u^{-2}(x_2) \right) \right] + x_2 \cdot \left[u^{-2}(x_2) \Big/ \left(u^{-2}(x_1) + u^{-2}(x_2) \right) \right] \quad (1)$$

where $u(x_1)$ and $u(x_2)$ are the standard uncertainties of the measurement of Nucleus Labs 1 and 2 for quantity x. The uncertainty of this weighted mean is given by

$$u(\overline{x}) = \left[1 \Big/ \left(u^{-2}(x_1) + u^{-2}(x_2) \right) \right]^{1/2} \quad (2)$$

Then, for quantities that uses relative uncertainties (e.g., luminous flux), the correction factors Nucleus Labs 1 and 2 are calculated by

$$c_1 = \frac{\overline{x}}{x_1}, \; c_2 = \frac{\overline{x}}{x_2} \quad (3)$$

For quantities that use absolute uncertainties (e.g., chromaticity coordinates *u',v'*), the correction factors Nucleus Labs 1 and 2 are calculated by

$$d_1 = \overline{x} - x_1, \; d_2 = \overline{x} - x_2 \quad (4)$$

Two sets of artefacts will be used in the Nucleus Laboratory comparison to evaluate individual variations of products within the same artefact type in these correction factors. The correction factors for each quantity and each artefact type will be obtained as an average of two artefacts.

The results of the comparison and the derived correction factors will be reported in the Nucleus Laboratory comparison report, which will be published before the start of the first measurement round.

6.2 Assigned Values for IC2017

The assigned values for the IC2017 measurement rounds will be determined for each quantity and each artefact by measurements of one of the Nucleus Labs.

For quantities that use relative uncertainties (e.g., total luminous flux), the assigned values X_{c1} and X_{c2} are calculated from measured results X_1 and X_2 by Nucleus Labs 1 and 2, respectively, for each quantity and each artefact, by

$$X_{c1} = X_1 \cdot c_1,\ \ X_{c2} = X_2 \cdot c_2 \tag{5}$$

For quantities that that use absolute uncertainties (e.g., chromaticity coordinates *u′*,*v′*), the assigned values X_{c1} and X_{c2} are calculated from measured results X_1 and X_2 by Nucleus Labs 1 and 2, respectively, for each quantity and each artefact type, by

$$X_{c1} = X_1 + d_1,\ \ X_{c2} = X_2 + d_2 \tag{6}$$

The uncertainties of the assigned values from Nucleus Lab 1 are calculated by

$$u(X_{c1}) \approx \left[u^2(\overline{x}) + u_A^2(x_1) + u_A^2(X_1) \right]^{1/2} \tag{7}$$

where $u(\overline{x})$ is from eq. (2), $u_A(x_1)$ is a Type A component of the uncertainty in x_1 (Nucleus Lab comparison result), and $u_A(X_1)$ is a Type A component of the uncertainty in X_1 (IC 2017 measurement round result). The uncertainty of the Assigned Values from Nucleus Lab 2 is calculated similarly.

This approach will force the measurements by the two Nucleus Labs to be equal in principle, and all participants’ results will be compared to a set of consistent Assigned Values.

7 Testing Period and Shipping Instructions

A. The measurement rounds for IC 2017 will start in October 2017 and will be completed by May 2018. There will be three sequential measurement rounds, to which participants will be assigned after the fee is paid, in the order of payment received, or they can request a later round if they wish. The three measurement rounds (participants’ measurement time) are scheduled:

   Round 1: October to November 2017
   Round 2: January to February 2018
   Round 3: April to May 2018

B. After the participant has been accepted to the SSL Annex 2017 IC test and paid the corresponding fee, the participant will be contacted and told which Nucleus Lab is assigned and when artefacts are ready to be shipped from the Nucleus Laboratory for testing. If the participant does not receive notification that the artefacts are ready for shipping within the expected time, the participant shall contact the technical contact person of the Nucleus Lab.

C. Upon receiving the comparison artefacts, the participant shall inform the technical contact of the Nucleus Lab immediately, at which time the participating laboratory will be informed of the deadline for testing the artefacts.

D. The participant has four weeks from the date of receipt of the artefacts to complete these measurements and report results to the technical contact person of the Nucleus Lab. Laboratories that participate with more than one goniophotometer in the same location are given one additional week per instrument, up to a maximum of two additional weeks to report results to the Nucleus Lab. If the results are not received by the deadline date, the laboratory will be disqualified.

E. After the results are received by the Nucleus Lab, the participant will receive instructions for return shipping. Upon receiving the instruction, the participant must ship the artefacts back to the Nucleus Lab promptly.
F. The artefacts are fragile and will be transported in two robust transport cases. The artefacts shall be stored in room temperature between 15 °C and 35 °C and relative humidity less than 75 %. The same transport case should be used to ship back the artefacts following the packaging instruction.

8 Initial Check

A. If anything is unclear about any of the documents, this must be reported immediately to the technical contact of the Nucleus Lab. On arrival, the artefact should be inspected for damage and tested for proper operation. If any problems are found, the participating laboratory should immediately contact the Nucleus Lab in order to receive a replacement artefact.
B. The comparison artefacts used in this IC test shall not be modified, adjusted, or used for any purpose other than that described in this document.
C. The Nucleus Lab will make an assessment of any drift in the comparison artefacts during the comparison, based on their measurements before shipment and after their return. If considerable drift is found, this will be taken into account in the evaluation of the comparison results for that participant, and the artefact will not be used any more in this Interlaboratory Comparison. Especially, if the observed drift (difference between the first and second measurements by Nucleus Lab for luminous flux, power, or chromaticity) exceeded 0.8 x SDPA (see section 13), the relevant results to the artefact will be discarded and a replacement artefact will be sent for re-measurement.

9 Measurement Instruments

The laboratory instruments shall be in compliance with CIE S 025. The goniophotometers for participation in this IC must use the CIE C,γ coordinate system[15], and the DUT operating position must be held constant with respect to the direction of gravity (except when a correction is applied, as guided in CIE S 025). The type of goniophotometer to be used is given in the IC 2017 on-line application form[1]. If the goniophotometer type does not meet the requirements of CIE S 025, the application may be rejected.

To measure all the photometric and colorimetric quantities in Tables 2 and 3, one of the following instruments or combinations of instruments may be used:

[1] IC 2017 Participant Application: http://ssl.iea-4e.org/testing-standards/laboratory-comparability/registration

(1) a gonio-spectroradiometer for all measurements
(2) a combination of a goniophotometer with a photometer head (for luminous flux and intensity distribution) and a gonio-spectroradiometer (for colour quantities),
(3) a combination of a goniophotometer with a photometer head (for luminous flux and intensity distribution) and a sphere-spectroradiometer (for colour quantities).

Measurement of colour uniformity may use a gonio-spectroradiometer or a gonio-colorimeter.

Use of a sphere-spectroradiometer (integrating sphere with a spectroradiometer) is allowed only for colour quantities in Table 2. Total luminous flux must be measured with a goniophotometer or a gonio-spectroradiometer.

Note: A sphere-spectroradiometer for colour quantities is included in this IC test because the gonio-spectroradiometer measurements are usually very time-consuming, thus it is often a common practice for laboratories for luminaire testing to use a sphere-spectroradiometer for colour measurements while using a goniophotometer with photometer head for high speed measurement of intensity distribution and total luminous flux that require measurements at many angle points. In this case the diameter of the integrating sphere must be large enough (2 metre or larger for LED luminaire artefacts).

A gonio-colorimeter (with tristimulus colorimeter head) may be used only for relative colour measurement and must not be used for absolute colour measurement (items #3, 4 and 5 in Table 2) unless it is specially designed and calibrated for measurement uncertainties at a level similar to spectroradiometers.

Near-field goniophotometers (usually equipped with a luminance camera and an illuminance head) may participate in this IC. Also, non-standard goniophotometers that change the operating position of a DUT with respect to the gravity direction, with a correction technique applied (allowed in CIE S 025), may also be accepted in this IC.

If a participant has two (or more) different goniophotometer systems at the same site, and wish to participate with both systems, the participant can do so for an additional fee and the participants can measure the same set of artefacts with the two (or more) goniophotometer systems and report two (or more) sets of results. In this case, the results of each goniophotometer system will be treated as a different laboratory (lab code) in the data analysis.

10 Measurement Procedure

10.1 General

A. The participating laboratory shall use CIE S 025 as the test method.

B. The participating laboratory may perform one measurement or repeated measurements for each artefact with their goniophotometer depending on their normal testing practice. In any case, the laboratories are asked to report one set of results (average in case of repeated measurements). Repeated measurements (typically two or three times) will provide Type A component of uncertainties for each artefact. On the other hand, measurement of each artefact can be done only once if the laboratory uses generic reproducibility uncertainties for these types of artefact for their uncertainty budget (such generic uncertainty budget is allowed in CIE S 025).

C. The Nucleus Laboratories will perform one measurement of each artefact (except when any problem is observed) for each measurement round because the reproducibility of measurements of all artefacts will be tested in advance by the Nucleus Laboratory to evaluate Type A component of uncertainty.

D. The participant's measurement instruments must meet all the requirements in CIE S 025, especially if they plan to apply for accreditation for CIE S 025 or EN 13032-4. If participant's measurement system does not comply with one or more requirements in CIE S 025, it would be accepted for this IC, but any and all of these deviations must be reported in a space provided in Results Report Form (to be published), with the corresponding phrase number(s) of CIE S 025, and this should be considered by an accreditation program if applied.

E. The participating laboratory shall not age or season the artefacts, and should keep the operating time of the artefacts to a minimum.

10.2 Goniophotometer Settings

Generally, requirements in CIE S 025 should be followed for setting the angle scanning intervals of the goniophotometer.

Angle intervals for the measurement of total luminous flux are not specified in CIE S 025. Participants may consider the requirements for partial flux measurement (section 6.3 in CIE S 025), for which measurement should be made for a minimum of eight vertical planes (C angle intervals 22.5° or smaller) at ɣ angle intervals of 5° or smaller for DUT having broad intensity distributions. The ɣ angle intervals should be smaller for narrow beam lamps. C angle intervals should be smaller for DUT having asymmetric distributions (such as street lighting luminaires).

If a gonio-spectroradiometer is used for spatially averaged colour quantities, it must measure a minimum of two vertical planes (C=0/180, C=90/270) (as specified in 7.1.4 in CIE S 025), while more planes are preferred.

Measurement of colour uniformity needs a gonio-spectroradiometer or gonio-colorimeter, and requires measurement of a minimum of two vertical planes (C=0/180° and 90/270°). See section 7.1.4 in CIE S 025.

10.3 Mounting DUT

Each artefact must be mounted in the goniophotometer as described below for each artefact.

ART-1: Base up position.
ART-2: Horizontal, light-emitting surface down.
ART-3: Major light-emitting direction down. Vertical centre of the luminaire is marked.
ART-4: Horizontal, light-emitting surface down.

For alignment of the position of luminaires, the centre points and C=0 and C=90° directions are marked on each artefact.

10.4 Environmental Conditions

Follow the tolerance interval requirements in CIE S 025 section 4.2 for ambient temperature and air movement speed. If the artefact on the goniophotometer is moved around the rotation centre of the arm, air movement speed relative to the artefact should be evaluated.

10.5 Electrical Operation

All the artefacts are operated by setting the supply voltage.

ART-1: DC 12.0 V
ART-2: AC 220 V, 60 Hz
ART-3: AC 220 V, 60 Hz
ART-4: AC 220 V, 60 Hz

Set the supply voltage within the tolerance specified in CIE S 025 (section 4.3.1). Supply voltage must be measured at (or very close to) the supply terminals of DUT (4 wire connection is required).

For ART-2, 3, 4, use an AC power supply and power meter that meet requirements in CIE S 025 (section 4.3).

For ART-1, apply the DC power with +/- polarity as marked on the base of the lamp. DC power supply must meet the requirements in section 4.3.3.3 of CIE S 025.

10.6 Stabilisation of DUT

Follow the requirements in CIE S 025 section 4.4.1, and report the stabilisation time actually required for each artefact. Pre-burning must not be used for the first measurement of the artefact (used to report the required stabilisation time). Pre-burning may be used if the same artefact is measured again, if so wished, or using different instruments (e.g., a sphere-spectroradiometer or goni-spectroradiometer for colour quantities).

11 Uncertainty Reporting by the Participants

Uncertainty statements are required in IC 2017 because they are required by CIE S 025. The uncertainty of each measured quantity shall be expressed in expanded uncertainty with a confidence interval of 95 % or a coverage factor *k*=2 (see Ref. 16).

Reporting uncertainty of all quantities in Table 2 is required especially if a laboratory plans to apply for accreditation to CIE S 025 or EN 13032-4. All participants are asked to report uncertainties of all quantities in Table 3 also, but if uncertainty budget of any quantities have not been established by the participant, it would be acceptable to leave some uncertainties blank.

Some regional/national test methods do not require uncertainty statements. If a participant seeks for accreditation for such test methods that do not require uncertainty statements, reporting uncertainty is not a requirement for proficiency tests (PT) for such accreditation programmes, though we ask all participants to report uncertainties of all measured quantities as much as possible.

12 Reporting by the Participants

Report the results using the Results Report Form (an Excel spreadsheet to be provided to the participants at the start of their measurement round). After measurements are complete, participants must submit results to the Nucleus Laboratory by the deadline (four weeks from receiving the artefacts, except for labs participating with more than one gonio - these labs are given one additional week for each additional instrument, up to a maximum of two additional weeks).

Each participant will be asked to submit brief descriptions of their goniophotometer system in the Results Report Form.

- Participants will report all measured values in at least four significant digits. The uncertainty values should be given in at most two significant digits.

- Participants shall provide a set of digital photographs that show how the comparison artefacts are mounted on the goniophotometer (paste the photos in the "Photos" tab in the Results Report Form spreadsheet).

- Except for providing ITR to an Accreditation Body (AB), participants are requested to keep their measurement results confidential, until all measurement rounds are completed (approximately May 2018).

13 Evaluation of the Performance

The assigned values are given by the Nucleus Laboratories. The criteria used to analyse and evaluate the performance are given by the E_n number (defined in ISO/IEC 17043[3]) and *z'* score (defined in ISO 13528[18]). The E_n numbers and z' scores are calculated only for the measurement quantities listed in Table 2, as there are not enough data to determine generic measurement uncertainties for the quantities in Table 3. The E_n numbers can be calculated if the uncertainty values are reported by a participating laboratory.

The *z'* score is calculated for all results, and is determined by:

$$z' = \frac{x - X}{\sqrt{\hat{\sigma} + u_X^2 + u_{\text{drift}}^2}} \qquad (8)$$

where $\hat{\sigma}$ is the SDPA value (Standard Deviation for Proficiency Assessment) which in this IC test is the generic standard uncertainty of a participant's measurement. As an estimate for such generic uncertainties, the Robust Standard Deviations of the goniophotometer results extracted from the IC 2013 results[1] will be used for the quantities in Table 2. Robust Standard Deviation is described in Algorithm A, Annex C, ISO 13528:2015[18], which provides a standard deviation calculation method that minimises the effects of extreme points (outliers). The measurement variations in IC 2017 for quantities in Table 2 are expected to be similar to those in IC 2013, though the IC 2013 data are for LED lamps.

The u_x is the standard uncertainty of the assigned value as given in equation (7). The u_{drift} is the uncertainty contribution from the expected artefact drifts (controlled to within 0.8 x SDPA, see section 8) calculated by:

$$u_{\text{drift}} = \frac{0.8 \cdot \hat{\sigma}}{2\sqrt{3}} \qquad (9)$$

The values of $\hat{\sigma}$ and u_x will be listed in the Nucleus Comparison Report, which will be published before the start of the first round of measurements.

If a value of $|E_n|$ > 1.0 is calculated, this is generally considered to be unsatisfactory. The value of 2.0 < $|z'|$ < 3.0 is considered to be questionable, and $|z'|$ ≥ 3.0 is generally considered to be unsatisfactory, but the judgment as to whether the result is acceptable will depend on the potential ABs. The E_n numbers (if available) and the z' scores of all participants will be reported in the interim and final reports in the event that they might be used by ABs.

The use of E_n numbers or z' scores or both will be up to the ABs (it also depends on which test method they refer to), but note that, if an E_n number is used, participants' reported uncertainties affect the E_n numbers and thus judgment for the competence of laboratory applying for accreditation. Currently, testing labs' uncertainties are not used in many conformity assessment programmes. z' score, on the other hand, is directly based on deviation of their results and more commonly used in conformity assessment of product testing.

14 Reporting to the Participants

14.1 Individual Test Report (ITR)

The participants will receive an Individual Test Report (ITR) within three months from the time their test results are received by the Nucleus Laboratory. The ITR will show the results measured by the participants on all the artefacts and quantities, compared with the Assigned Values determined by the Nucleus Laboratory, including associated uncertainties when available.

The ITR will also include E_n numbers and z' scores of the quantities listed in Table 2. ITRs are kept strictly confidential in IEA 4E SSL Annex. The participant shall also keep the information on the assigned values confidential until the all rounds are finished. The participants may submit the ITR as an evidence of their competence to an AB or the regulatory authority under the confidentiality of this Technical Protocol. The information of the accreditation programmes that have recognised IC 2017 will be kept updated on the IEA 4E SSL Annex website.

14.2 Final Report

After all measurement rounds are completed, a Final Report showing the results of all participants and various analyses will be published. The participants' results will be expressed using random lab codes, and only the participant will be informed which code corresponds to their laboratory. If a participant would like their name and city, country where the laboratory is located to appear in the list of participants in Final Report, it will be included.

The measurement results will be evaluated on the basis of the participants' results, the statistical calculations and the assigned values. The results of this evaluation will be specified in the final report, namely:

A. For each measurement point, for each participant:
   - The assigned values and their expanded uncertainties (*U*) per calibration point.

- SDPA per calibration point
- The results of the participant and their expanded uncertainties (*U*) per calibration point (if the uncertainties are reported).
- The E_n number and/or *z′* score of the participant per calibration point.
- A graphic representation of some typical measurement results from the laboratories, including the uncertainty limits.

B. The report can also describe the following components:
   - If necessary, a description of the measurement methods and equipment used by the participants
   - Technical derivation and Uncertainty Budget of SDPA
   - Conclusions
   - General recommendations, statistics, etc.
   - Overview of cited documents, guidelines and publications
   - A description will also be provided of the applied statistics.
   - Evaluation of the performance of CIE S 025 as experienced in this IC.

The statistical analysis of the participants' results will take place in compliance with international standard, ISO 13528[18].

If a participant wishes to appeal on the evaluation of results presented in any of the reports, they should contact the IC 2017 Coordinator and the Technical contact of the Nucleus Lab with whom they are working.

15 Confidentiality

The identity of the individual test results for each participant shall remain confidential. The files containing the results, reports and other material relating to the Interlaboratory Comparison scheme will be stored in secure folders and locked cabinets or electronically in a secured computer that are only accessible for the Regional coordinator at each Nucleus Laboratory.

The laboratories will be identified by a laboratory code comprised of four characters, such as L001...LXXX. This lab code will be unique to each participant and will only be known to the Regional coordinator.

To enable efficient dialogue around the processing and analysis of the test results, participants may choose to elect to waive the confidentiality. However, confidentiality will always be maintained in the final report and in any communication with the outside world.

Furthermore, as discussed in Section 4, the artefacts' set ID numbers will be re-numbered when they are re-used in 2nd and 3rd round so that there is no possibility that participants of later rounds may gain advantage from early disclosure.

16 Eligibility of Participation and Fee

Laboratories that have measurement equipment that is capable of conducting measurements in compliance with CIE S 025 (with small deviations allowed) are eligible to participate. However, due to the capacity limit of the two Nucleus Labs, applications may be turned down once the number of applications has reached the limit. Participants are only officially accepted and assigned to one of the Nucleus Laboratories upon receipt of the fee payment. Participants from the member countries of IEA 4E SSL Annex (*i.e.,* Australia, Denmark, France, Republic of Korea, Sweden, the United Kingdom, and the United States of America) will have a discount in the fee. The fees for participating in IC 2017 are published in Ref. 2 and are available on the SSL Annex IC 2017 Application webpage[2].

[2] Registration for IC 2017: http://ssl.iea-4e.org/testing-standards/laboratory-comparability/registration

17 References

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3. ISO/IEC 17043:2010, Conformity Assessment – General Requirements for Proficiency Testing
4. CIE S 025/E:2015, Test Method for LED lamps, LED luminaires and LED modules
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7. KS C 7653:2016 Recessed LED luminaires and fixed LED luminaires
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9. JIS C7801:2014 Measuring Methods of Lamps for General Lighting
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11. IEA 4E SSL Annex, SSL Test Methods Comparison Table; see Appendix 2 of http://ssl.iea-4e.org/files/otherfiles/0000/0110/Task_1_Application_Study_-_Final_Report.pdf
12. Calibration and Measurement Capabilities - CMCs, http://kcdb.bipm.org/appendixC/default.asp
13. International equivalence of measurements: the CIPM MRA, http://www.bipm.org/en/cipm-mra/
14. IES TM-15-2011 Luminaire Classification System for Outdoor Luminaires
15. CIE 121-1996 The Photometry and Goniophotometry of Luminaires
16. ISO/IEC Guide 98-3: 2008, Uncertainty of measurement -- Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)
17. IEA 4E SSL Annex IC 2013 Nucleus Comparison Report, link http://ssl.iea-4e.org/files/otherfiles/0000/0067/IC2013_Final_Report_final_10.09.2014a.pdf
18. ISO 13528:2015, Statistical methods for use in proficiency testing by interlaboratory comparison