Global Interlaboratory Comparison of 41 Goniophotometers Measuring Solid- State Lighting Products

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A global interlaboratory comparison (IC 2017) on measurements of solid-state lighting (SSL) products with goniophotometers was conducted under the International Energy Agency (IEA) 4E SSL Annex, participated by 36 laboratories from 19 countries with a total of 41 goniophotometers. Not only large mirror-type goniophotometers but also near-field type and source-rotating type goniophotometers were included. Three LED luminaires of different types and one narrow-beam LED lamp were used as artefacts for star-type comparisons with two reference laboratories. 16 quantities including electrical, photometric, colorimetric, and goniophotometric quantities were measured and compared. The results revealed the levels of measurement variation for SSL products across the market and a number of specific problems in participants' results.

DESIGN OF THE COMPARISON

Previously, the International Energy Agency's (IEA) Energy Efficient End-use Equipment (4E) Solid-State Lighting (SSL) Annex conducted the first interlaboratory comparison (IC 2013) for measurements of electrical, photometric, and colorimetric quantities of SSL products (LED lamps). This comparison included 55 laboratories [1,2] and provided critical data on the variability of LED lamp measurements, however measurements of luminaires by goniophotometers were not covered.

The IEA 4E SSL Annex organized another global interlaboratory comparison (IC 2017) for measurement of SSL products with goniophotometers. IC 2017 was launched in June 2017 [3] and had 36 participating laboratories from 19 countries for a total of 41 goniophotometers. IC 2017 was designed to investigate the level of agreement in measurements of various quantities for LED luminaires and beam lamps by goniophotometers. It was also designed to investigate the equivalence of non-standard goniophotometers (e.g., near-field type and source-rotating type) to traditional far-field mirror type goniophotometers.

IC 2017 used the international standard CIE S 025 [4] (and equivalent European standard EN 13032-4 [5]) as the test method. Thus, IC 2017 was able to provide information on measurement variations by laboratories that are in compliance with CIE S 025. This comparison was also designed to be in compliance with ISO/IEC 17043 [6] so that it may serve as a proficiency test for SSL testing accreditation schemes around the world.

STRUCTURE OF THE COMPARISON

IC 2017 was led by National Institute of Standards and Technology (NIST, USA) which served as Task Leader. To share the workload of comparison, two laboratories having a large mirror-type goniophotometers served as reference laboratories (called Nucleus Laboratories in IC 2017): Korea Institute of Lighting and ICT (KILT, Korea) and Laboratoire National de métrologie et d'Essais (LNE, France). To establish equivalence of measurements between these two laboratories, a Nucleus Laboratory Comparison was carried out, using two sets of the comparison artefacts and measuring all the quantities (see next section). The details and results of the comparison are available in IC 2017 Nucleus Laboratory Comparison Report [7].

IC 2017 was carried out as a star-type comparison between each participant and one of the two Nucleus Laboratories, which prepared and measured the artefacts, shipped them to participants, and measured them again upon their return. If reproducibility was poor, the measurement of a particular artefact with the participant was repeated. The measurements with participants were made in six rounds, two rounds by KILT and four rounds by LNE. These measurements, and any re-measurements, spanned a time period from November 2017 to September 2019.

TECHNICAL PROTOCOL

Table 1 shows the comparison artefacts used. ART-1 is a MR-16 type narrow-beam LED lamp with a beam angle of ≈12°; ART-2 is a 60cm x 60cm indoor planar

LED luminaire with a broad intensity distribution; ART-3 is a linear LED luminaire including small upward light emission; and ART 4 is a street light LED luminaire having asymmetric intensity distributions, with a low power factor of ≈ 0.7.

Table 1. Specifications of the comparison artefacts

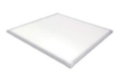
	ART-1	ART-2	ART-3	ART-4
image				
Supply	DC12 V	AC 220 V	AC 220 V	AC 220 V
Power	7.5 W	40 W	20 W	20 W
CCT	2700 K	5500 K	4000 K	4500 K

Table 2 shows the list of measurement quantities. Items 1 to 8 are general quantities used for the proficiency test as well as technical study purposes. Items 9 to 16 are goniophotometric quantities, which are used for technical study purposes. Further details are available in IC 2017 Technical Protocol [8].

Table 2. Measurement quantities used for IC 2017

No.	Quantity	Artefact
1	Total luminous flux (lm)	All
2	Luminous efficacy (lm/W)	All
3	Active power (W)	All
4	RMS current (A)	All
5	Power factor	All
6	Chromaticity coordinates *u', v'*	All
7	Correlated Color Temperature	All
8	Color Rendering Index Ra	All
9	Luminous intensity distribution	All
10	Partial luminous flux (15°)	ART-1
11	Center beam intensity	ART-1
12	Beam angle	ART-1
13	Street-side downward flux	ART-4
14	House-side downward flux	ART-4
15	Up light flux	ART-4
16	Color uniformity	ART-1,3

RESULTS

The (relative) differences between each participant and the reference value (result of the Nucleus Laboratory) were calculated for all the 16 quantities, four artefacts (one or two for goniophotometric quantities), and 41 participants, producing nearly 2000 points of comparison in total. Graphs comparing all participants were prepared for all four artefacts together or for each artefact separately, for each measurement quantity, resulting in over 54 graphs of results. In addition, z' scores and E_n numbers (see [6]) for the general quantities were calculated for proficiency test purposes. The intensity distribution curves were also plotted to compare the participant's and the reference laboratory's results.

Individual Test Reports (ITRs) reporting the results of only each participant have been issued to each participant. The IC 2017 Final Report is to be published in 2020, comparing the results of all participants anonymously.

CONCLUSIONS

This comparison provided valuable data on the agreement of SSL product measurements by goniophotometers. There were numerous problems found in the results, in some cases with very large discrepancies. While total luminous flux showed results as expected, electrical quantities (i.e., active power and RMS current) showed much larger variations than expected. The partial luminous flux quantities showed much larger variations than total luminous flux which implies problems with artefact alignment. Comparison of goniophotometer types (18 mirror-type, 13 near-field-type, 10 source-rotating type) did not show any significant differences overall, though results do vary in individual cases. Further points will be presented and discussed at the conference.

REFERENCES

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