Solid state Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

SSL Annex 2021 Fall Experts Meeting
Oct. 21, 2021 On-line

IC 2017 – Overview of Final Report, Findings and Preliminary Recommendations

Yoshi Ohno, Task Leader
JS Oh, SK Jeon
Jean Gaudemer, Jimmy Dubard

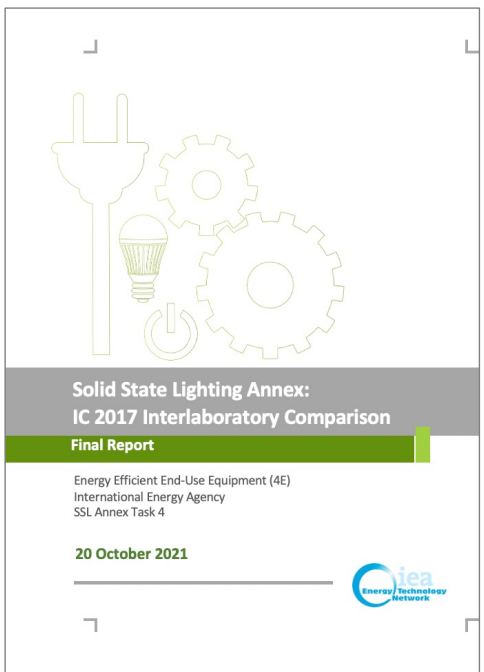
Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

Outline

1. Progress since April 2021
2. Presentation of a paper at CIE 2021 Midterm Conference
3. Structure of IC 2017 Final Report
4. Data analysis methodology
5. Results and findings
6. Luminous intensity distributions
7. Summary of Results and Recommendations
8. Future activities

Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

Progress since April 2021



April	2021 Spring Experts Meeting - First Draft of Final Report presented (comments SC, CDH, …)
June 15	**Revised Draft** distributed to all co-authors + SC, CDH + SSL Annex management
June 15	Draft submitted to **NIST Editorial Review Board** approval - Steve Coyne served as an external reviewer (Extensive comments from Steve)
July 15	Draft distributed to **all participants** for their review
Aug. 7	**CIE 2021 Midterm Conference** Proceedings paper submitted
Sep. 14	**Extensive revision** of Final Report Draft distributed to co-authors, SC, CDH, and SSL Annex Management
Sep. 17	Revised Draft distributed to **all participants,** also copy of CIE proceedings paper, informed conference presentation by YO, JG
Sep. 18	Draft distributed for **SSL Annex Experts review**
Sep. 28	YO **Presentation at CIE** 2021 Midterm conference
Sep. 28	JG Presentation at French conference
Oct	Final edit of the document (YO, MS)
Oct. 20	**Final draft** distributed to SSL Annex **MC review/approval**

Outline

1. Progress since April 2021
2. **Presentation of a paper at CIE 2021 Midterm Conference**
3. Structure of IC 2017 Final Report
4. Data analysis methodology
5. Results and findings
6. Luminous intensity distributions
7. Summary of Results and Preliminary Recommendations
8. Future activities

CIE 2021 Midterm Conference paper

IEA 4E SSL ANNEX INTERLABORATORY COMPARISON OF GONIOPHOTOMETERS MEASURING SOLID STATE LIGHTING PRODUCTS – RESULTS

Ohno, Y.[1], Gaudemer, J.[2], Dubard, J.[2], Oh, J.S.[3], Jeon, S. K.[3], Scholand, M. J.[4], Borg, N.[4], Boughey D.[5], Zissis, G.[6]

[1]National Institute of Standards and Technology, Gaithersburg, USA, [2]Laboratoire National de métrologie et d'Essais (LNE), Paris, France, [3]Korea Institute of Lighting and ICT (KILT), Bucheon, Korea, [4]International Energy Agency 4E Solid State Lighting Annex, [5]Department of Industry, Science, Energy and Resources, Canberra, Australia, [6]LAPLACE, University of Toulouse III, Toulouse, France

ohno@nist.gov

Abstract

The global interlaboratory comparison (IC 2017) on measurements of solid-state lighting (SSL) products with goniophotometers was conducted under the International Energy Agency 4E Solid State Lighting Annex with 36 participating laboratories from 19 countries with a total of 42 goniophotometric instruments including mirror-type, near-field type and source-rotating type goniophotometers. A narrow-beam LED lamp and three different types of LED luminaires, including a street lighting luminaire, were used as comparison artefacts for measurements of 16 different quantities. These included electrical, photometric, and colorimetric quantities, and

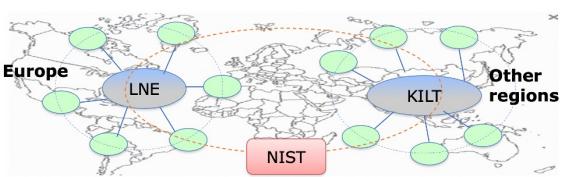
- Submitted Aug. 7
- Accepted as Oral Presentation
- Presented on Sep. 28
- Proceedings (Conference version) published
- Open access paper to be published

CIE 2021 Presentation – some slides
(Sep. 28, 2021 virtual)

Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

Interlaboratory Comparison of Goniophotometers (IC 2017)
for measurements of SSL products

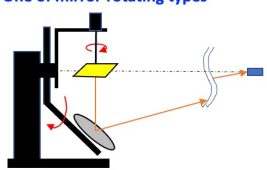
- Launched in July 2017.
- 3 types of **LED luminaires and a narrow-beam LED lamp** were used as comparison artefacts
- Had **36 labs** participating from **19 countries** with a total of **42 goniophotometers** (gonio-spectroradiometers)
- Three different types of goniophotometer (**mirror-rotating type, near-field type, source-rotating type**) were accepted
- **CIE S 025** was used as the test method
- The comparison was designed in compliance with ISO/IEC 17043 to **serve as a proficiency test** for SSL testing laboratory accreditation programs



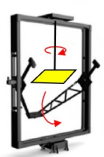
Nucleus Laboratories

LNE (Laboratoire Nationale de métrologie et d'Essais), France
KILT (Korea Institute of Lighting and ICT), Republic of Korea

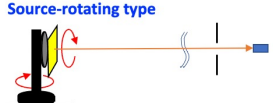
One of mirror-rotating types



Near-field type



Source-rotating type



4

CIE 2021 Presentation – some slides
(Sep. 28, 2021 virtual)

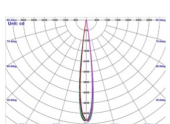
Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

IC 2017 Comparison Artefacts

ART-1: Directional lamp (MR-16)

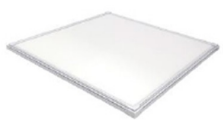
5 cm ϕ x 4.5 cm

12V DC
7.5 W
2700K



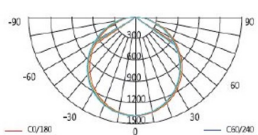
Beam angle ≈ 12°

ART-2: Planar luminaire



62 x 62 x 2 cm

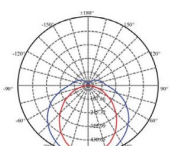
220V AC, 60 Hz
40W
5700K



ART-3: Batten luminaire

63 x 6 x 8 cm

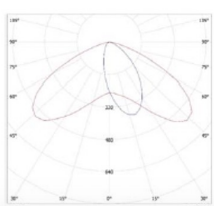
220V AC, 60 Hz
20W
4000K



ART-4: Street lighting luminaire

50 x 25 x 11 cm

220V AC, 60 Hz
30W
4000K



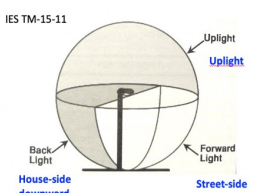
CIE 2021 Presentation – some slides
(Sep. 28, 2021 virtual)

Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

IC 2017 Measurement Quantities

General quantities						Unit
1	Total luminous flux					lm
2	Luminous efficacy					lm/W
3	Active power					W
4	Root-mean-square (RMS) current (DC current for ART-1)					A
5	Power factor					1
6	Chromaticity coordinate (u',v') - spatially averaged					1
7	Correlated colour temperature (CCT) - spatially averaged					K
8	Colour rendering index (CRI) R_a - spatially averaged					1
Goniophotometric quantity		**ART-1**	**ART-2**	**ART-3**	**ART-4**	
9	Luminous intensity distribution, value at (0,0)	X	X	X	X	cd
10	Partial luminous flux (15° cone)	X				lm
11	Centre beam intensity	X				cd
12	Beam angle	X				°
13	Street-side downward flux (Forward light*)				X	lm
14	House-side downward flux (Back light*)				X	lm
15	Upward flux (Uplight*)				X	lm
16	Angular spatial colour uniformity $\Delta_{u'v'}$	X		X		1

* These quantities (for street lighting luminaire) are defined in IES TM-15.



16

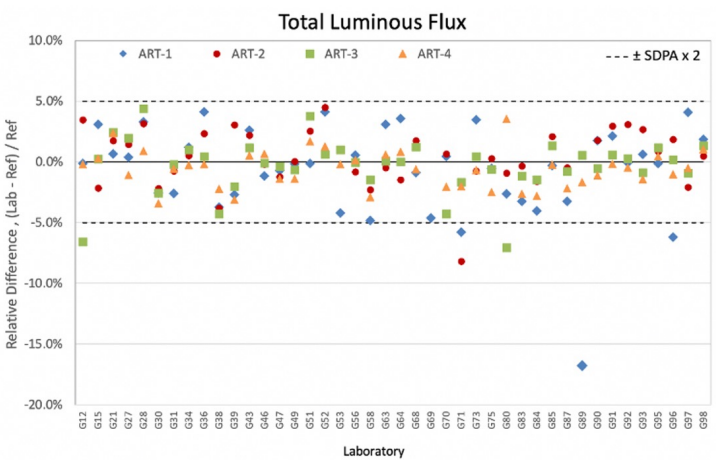
CIE 2021 Presentation – some slides

(Sep. 28, 2021 virtual)

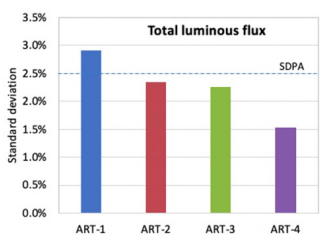
Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

Analysis I – Relative differences comparing all 42 instruments

– An example showing results of all artefacts in one graph–



SDPA: Standard Deviation for Proficiency Assessment
(pre-determined to calculate z' scores in proficiency test)



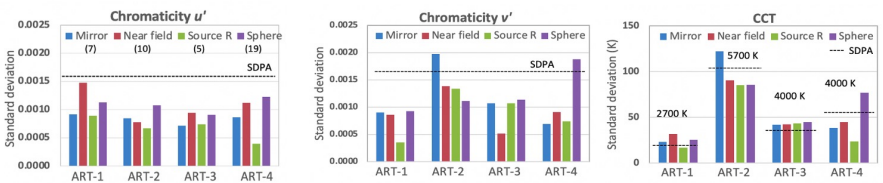
CIE 2021 Presentation – some slides
(Sep. 28, 2021 virtual)

Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

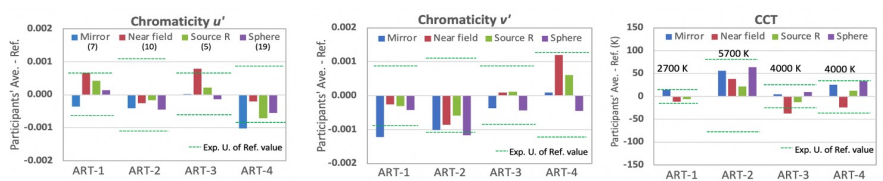
Analysis III Results (3) – Colour quantities-1

Standard deviations of the results

❖ Sphere-spectroradiometer was allowed for measurement of color quantities



Average deviations from the reference value



- Variations appear reasonable
- No notable differences between different goniophotometer types
- Variations for ART-4 with sphere system are high

14

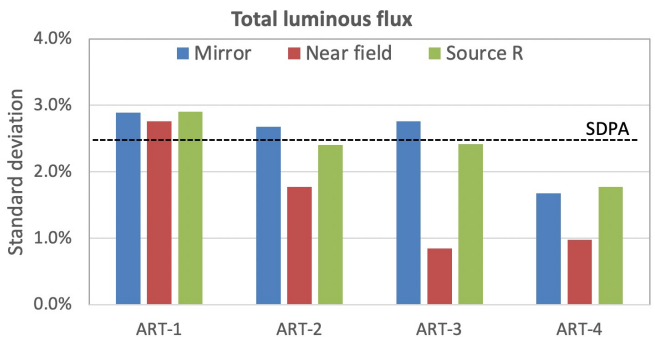
CIE 2021 Presentation – some slides
(Sep. 28, 2021 virtual)

Q&A

”Why are the values from the near-field and source rotating gonios more consistent than the mirror ones? I would expect it to be the other way around”

“ What are your conclusions with respect to the revision of CIE S 025?” (CIE D2 Assoc Director)

“how were outliers determined and excluded in standard deviations?”



For improvements of CIE S 025

- Guidance on calculation of gonio quantities
- Guidance on uncertainty evaluation of gonio quantities
- Guidance on mounting and alignment of DUT
- Verification criteria for near-field goniophotometer

Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

Outline

1. Progress since April 2021
2. Presentation of a paper at CIE 2021 Midterm Conference
3. **Structure of IC 2017 Final Report**
4. Data analysis methodology
5. Results and findings
6. Luminous intensity distributions
7. Summary of Results and Preliminary Recommendations
8. Future activities

Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

Structure of IC 2017 Final Report

Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

Structure of IC 2017 Final Report

List of Figures

2 Participants

There were 36 participating laboratories with a total of 42 instruments in IC 2017, as several laboratories participated with two or three goniophotometers. Table 2-1 shows the list of participants, all of whom gave permission to be named in this report. Table 2-2 shows the list of instruments that the participants used in this comparison.

Table 2-1. List of IC 2017 Participants

Laboratory (Company/Institute)	Country
Steve Jenkins & Associates Pty Ltd.	Australia
Municipal Department 39, City of Vienna - Research Centre, Laboratory and Certification Services / Light Laboratory	Austria
XAL GmbH	Austria
Laboratorium voor Lichttechnologie, KU Leuven R&D	Belgium
Laborelec Engie Lab	Belgium
SCHREDER - RTECH	Belgium
DEKRA Testing and Certification (Shanghai) Ltd.	China
EVERFINE Test and Calibration Technology Co., Ltd, Hangzhou	China
Intertek Testing Services Shanghai	China
Intertek Testing Services (Hangzhou) Limited	China
Lidl Hong Kong Limited	China

Table 2-2. List of Goniophotometers used by the participants (alphabetical order) [1]

Type	Goniophotometer	Counts	Total
Mirror Type Gonio	EVERFINE GO-R5000	6	19
	GMS2000 SENSING INSTRUMENT	1	
	GMS3000 SENSING INSTRUMENT	1	
	Custom-made	1	
	LMT GO-DS 2000	6	
	LMT GO-DS 1600	2	
	Oxytech T4	1	
	UL/LSI 6440T	1	
Near-field type	Custom-made	2	12
	TechnoTeam RiGO 801 (size varies)	10	
Source-rotating type	Gerh. Döbele (modified)	1	10
	Custom-made	1	
	Instrument Systems LGS1000	2	
	LMT GO-V 1900	2	
	LMT GO-R 3060	1	
	PSI model ASG-3.0, C/gamma geometry	1	
	SSL Resource Oy, SSL C-1R.1600.2A	1	
	Viso Systems / LabSpion	1	
Other type	Custom-made (detector rotates, source fixed)	1	1

[1] The company and product names are listed for technical information to assist in understanding the results presented in this report. They do not represent endorsement of any particular models of goniophotometer of any manufacturer, by the National Institute of Standards and Technology, by the IEA 4E SSL Annex or any of its member governments.

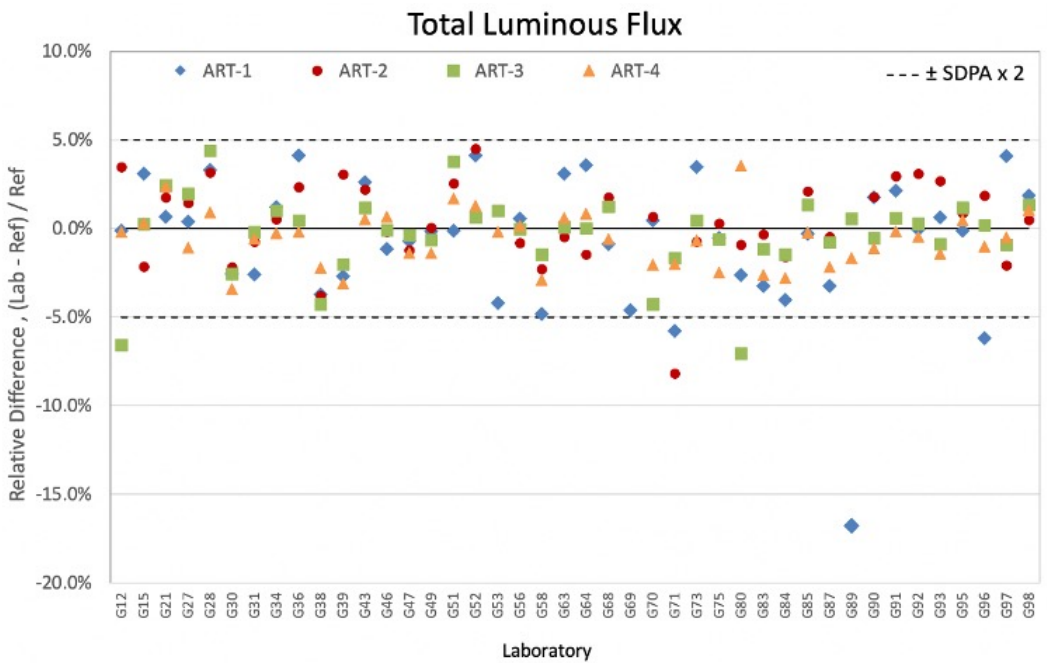
Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

Outline

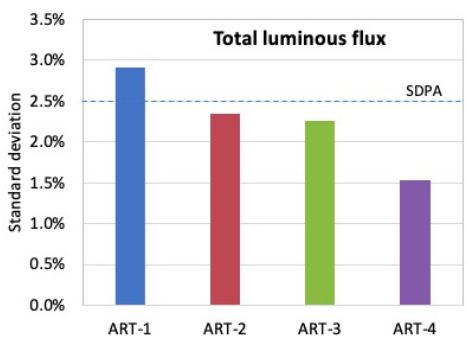
1. Progress since April 2021
2. Presentation of a paper at CIE 2021 Midterm Conference
3. Structure of IC 2017 Final Report
4. **Data analysis methodology**
5. Results and findings
6. Luminous intensity distributions
7. Summary of Results and Preliminary Recommendations
8. Future activities

Analysis I – Relative differences comparing all 42 instruments

– An example showing results of all artefacts in one graph–

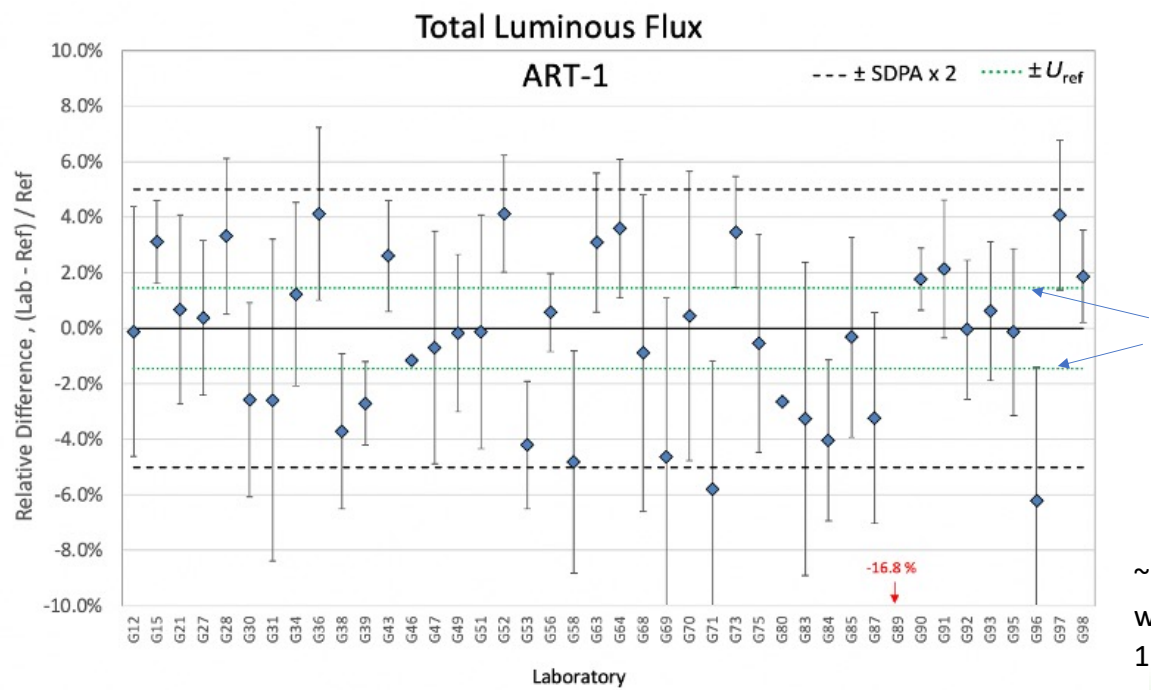


SDPA: Standard Deviation for Proficiency Assessment
(pre-determined to calculate z' scores in proficiency test)



Analysis I – Relative differences comparing all 42 instruments

– An example of results for each artefact –



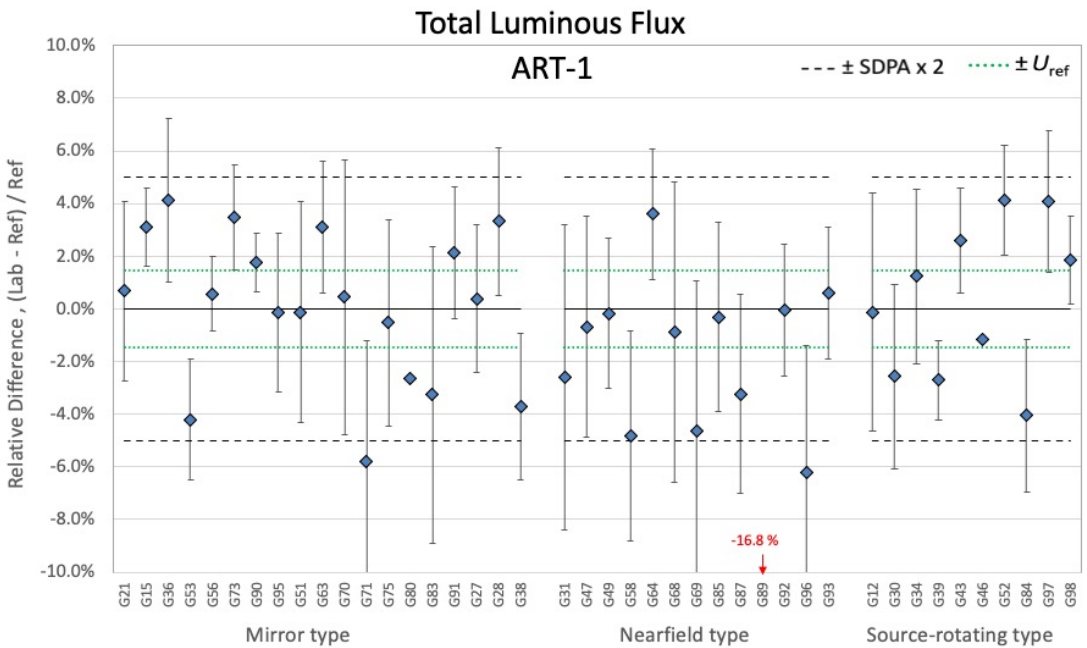
Error bars: each participant's reported expanded uncertainty (*k*=2)

Range of expanded uncertainty (*k*=2) of Reference value

~60 figures of these were produced for all 16 quantities.

Analysis II – Relative differences sorted by goniophotometer types

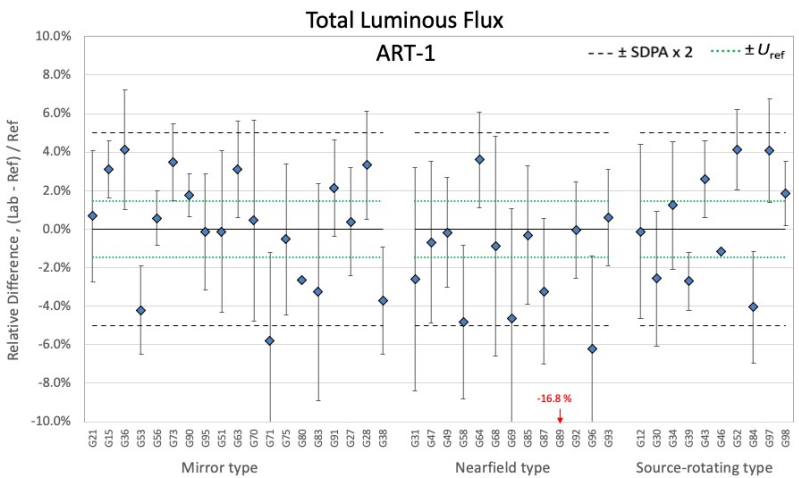
– An example of results for each artefact –



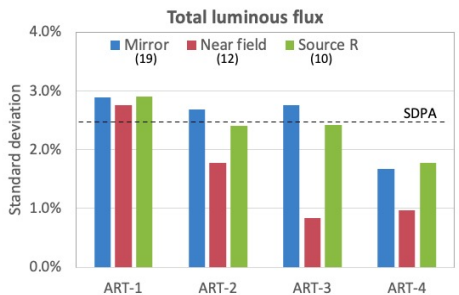
~50 figures of these were produced for all 16 quantities.

Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

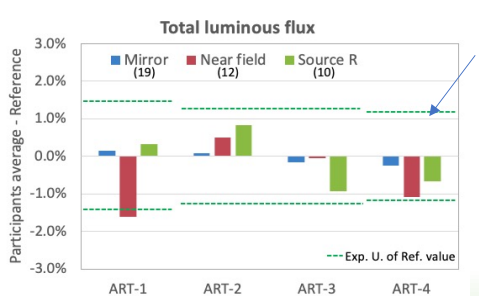
Analysis III – Standard deviations and Average deviations for each instrument type



Standard deviations of the results for each goniophotometer type



Average deviations (bias) from the reference value for each goniophotometer type



Expanded U(*k*=2) of Reference value

34 figures of these were produced for all 16 quantities.

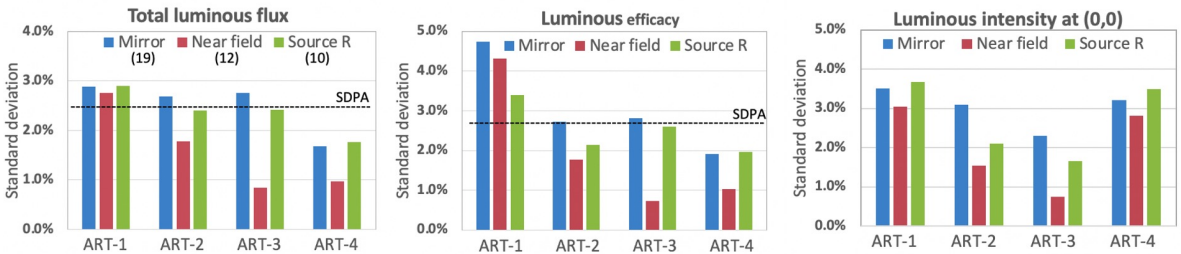
Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

Outline

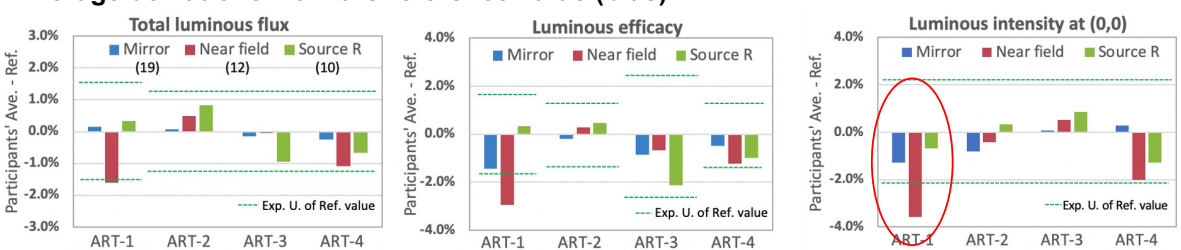
1. Progress since April 2021
2. Presentation of a paper at CIE 2021 Midterm Conference
3. Structure of IC 2017 Final Report
4. Data analysis methodology
5. **Results and findings**
6. Luminous intensity distributions
7. Summary of Results and Preliminary Recommendations
8. Future activities

Analysis III Results (1) – Photometric quantities

Standard deviations of the results

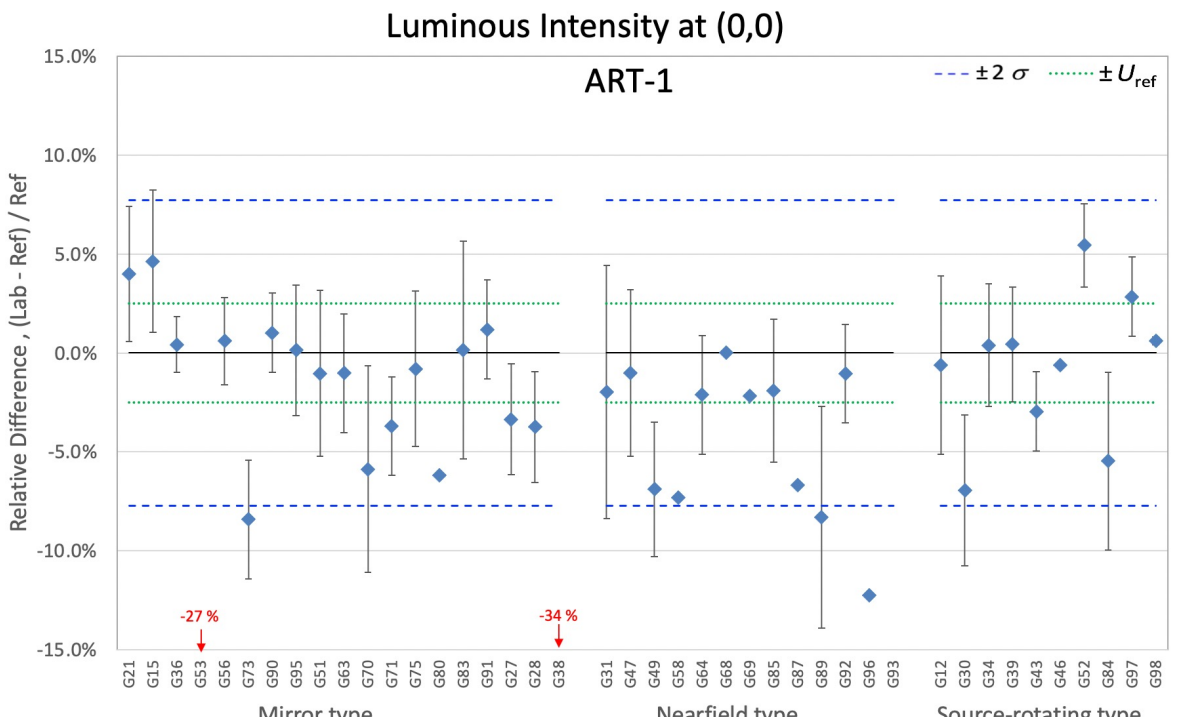


Average deviations from the reference value (bias)



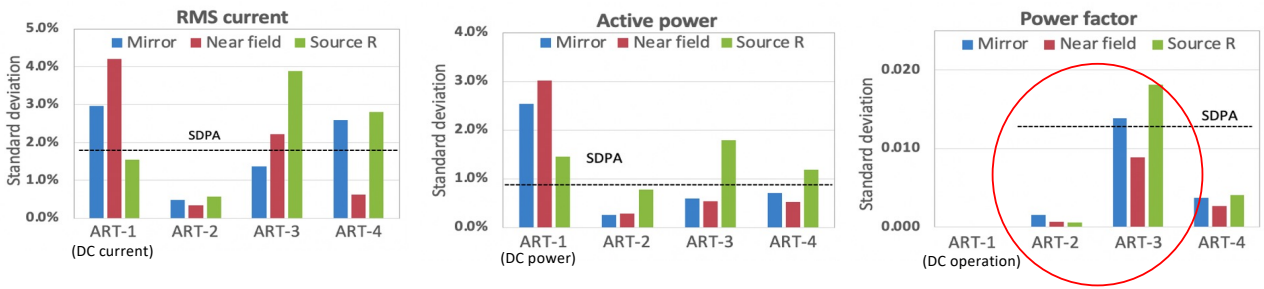
- Total luminous flux: variations appear to be reasonable
- Luminous intensity at (0,0) for ART-1: Near-field type shows notable deviation (negative bias) though this may be still at acceptable uncertainty level

Analysis III Results (1) – Photometric quantities

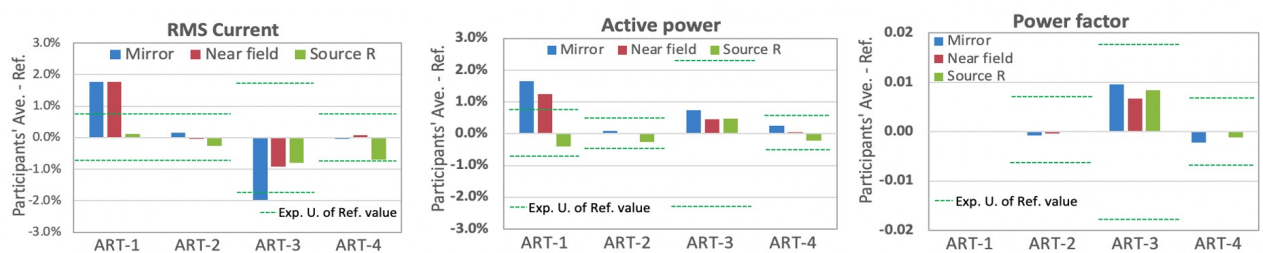


Analysis III Results (2) – Electrical quantities

Standard deviations of the results



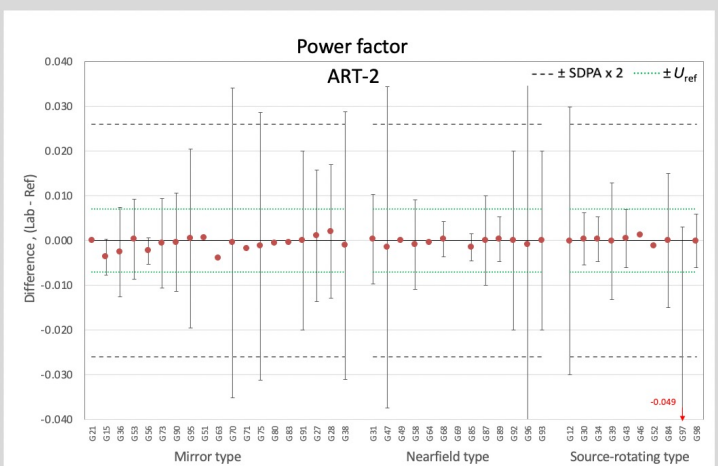
Average deviations from the reference value

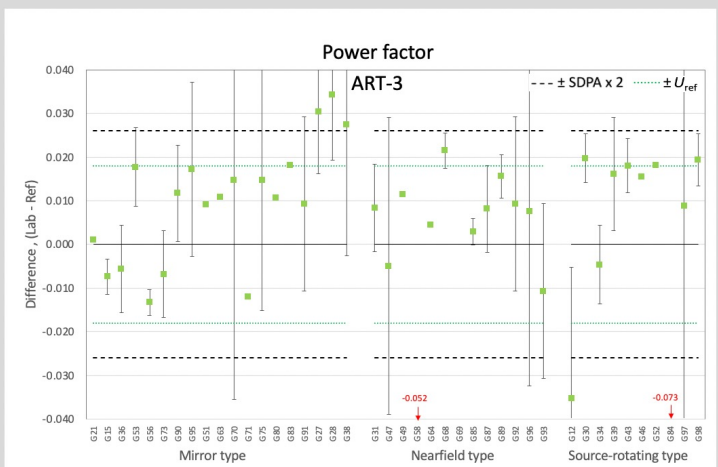


- Variations are often much higher than expected (except ART-2)
- Large differences between different artefact types (e.g., power factor)
- Variations of ART-1 are high probably due to small pins and low voltage (DC 12V) thus higher current

Analysis III Results (2) – Electrical quantities

Power factor

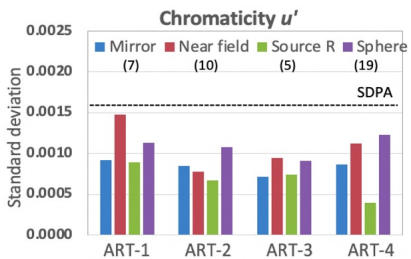


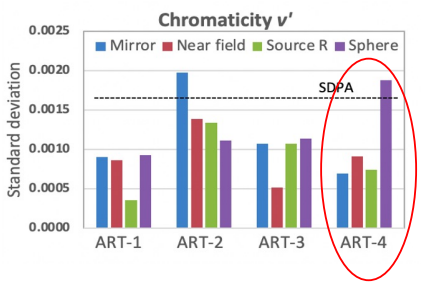


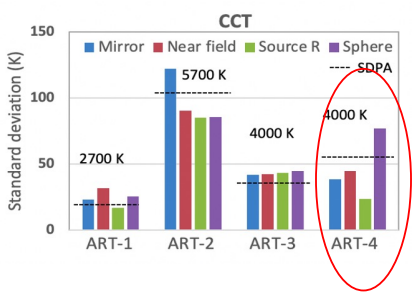
Analysis III Results (3) – Colour quantities-1

Standard deviations of the results

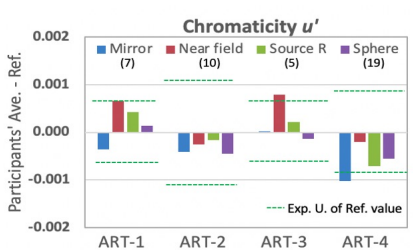
❖ Sphere-spectroradiometer was allowed for measurement of color quantities

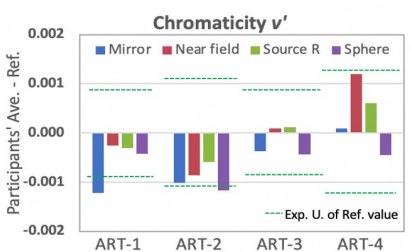


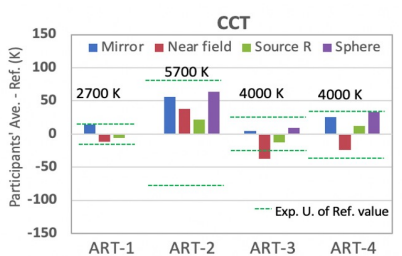




Average deviations from the reference value



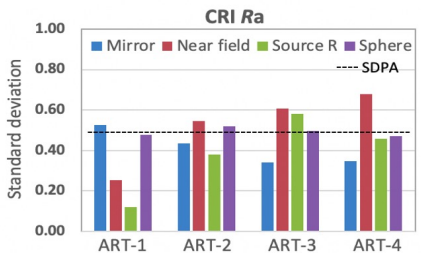


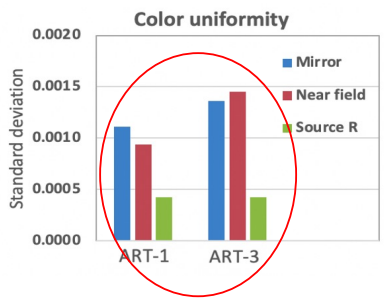


- Variations appear reasonable
- No notable differences between different goniophotometer types
- Variations for ART-4 with sphere system are high

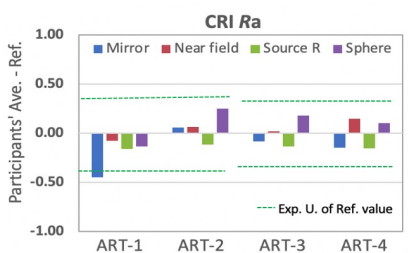
Analysis III Results (4) – Colour quantities-2

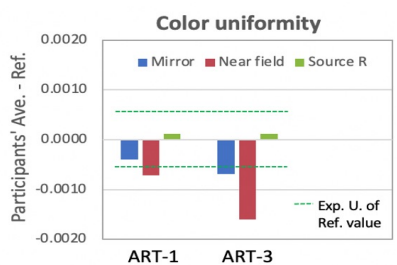
Standard deviations of the results



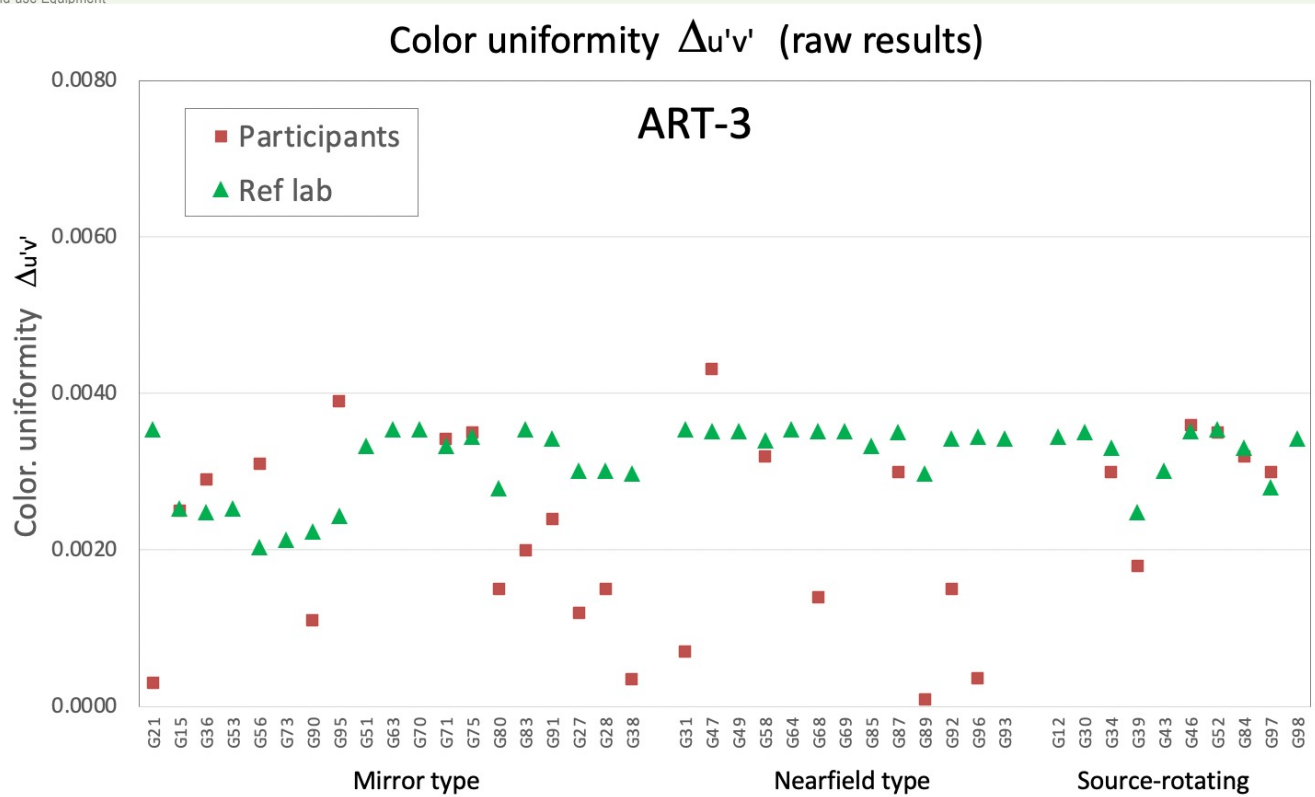


Average deviations from the reference value



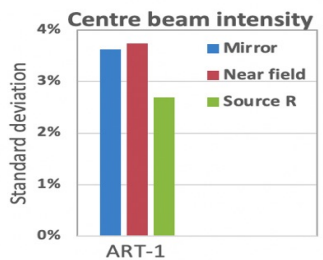


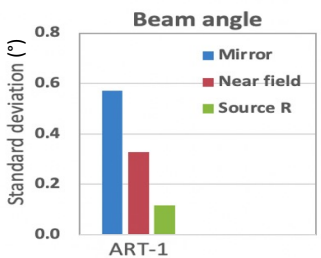
- Results of CRI R_a appear reasonable
- Colour uniformity: variations are very high, considering that these are relative color measurements

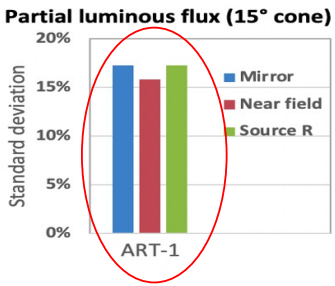

Color uniformity Δu'v' (raw results)
ART-3
Participants
Ref lab
Color. uniformity Δu'v'
0.0080
0.0060
0.0040
0.0020
0.0000
G21 G15 G36 G53 G56 G73 G90 G95 G51 G63 G70 G71 G75 G80 G83 G91 G27 G28 G38
G31 G47 G49 G58 G64 G68 G69 G85 G87 G89 G92 G96 G93
G12 G30 G34 G39 G43 G46 G52 G84 G97 G98
Mirror type
Nearfield type
Source-rotating

Analysis III Results (5) – Goniophotometric quantities (ART-1)

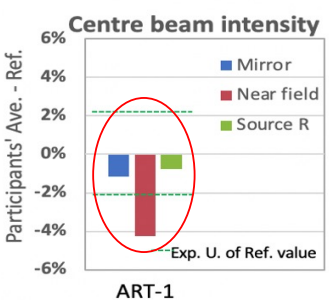
Standard deviations of the results

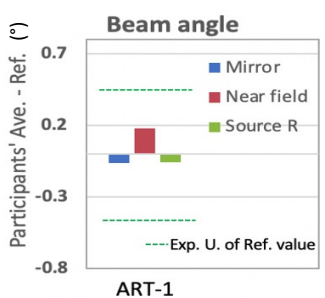


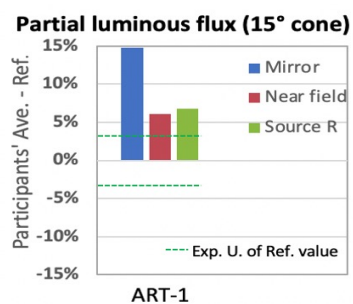




Average deviations from the reference value

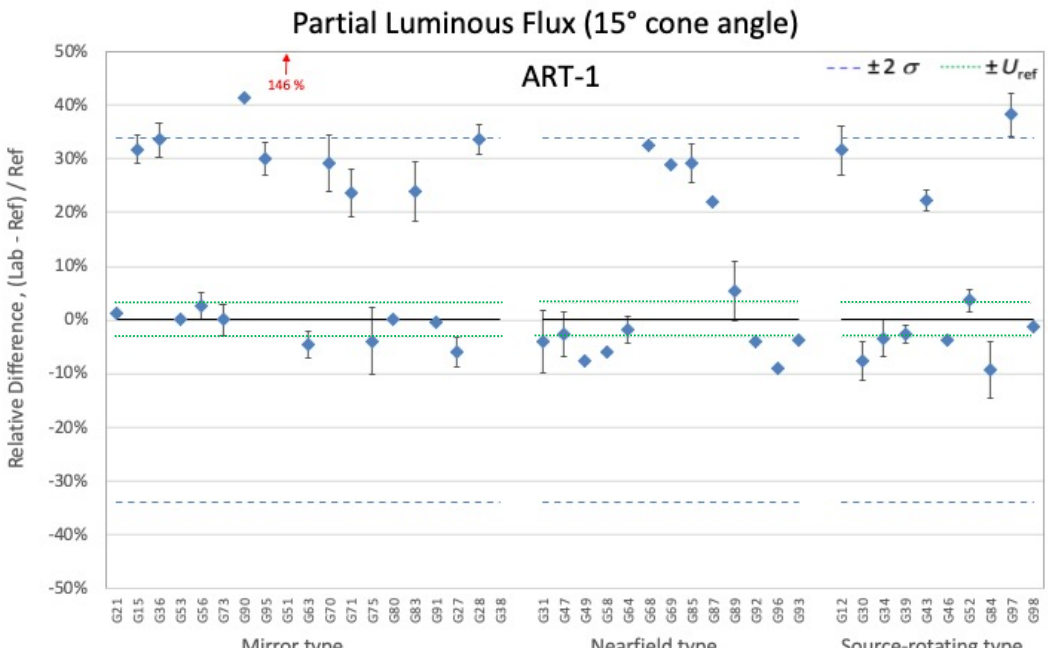






- Center beam intensity: notable negative bias for near-field type, similar to luminous intensity at (0,0)
- partial flux (15° cone angle): Variations are extremely large. It seems many labs calculated 30° cone angle

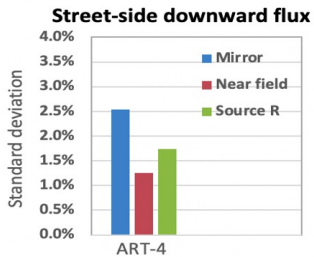
Extremely large variation in partial luminous flux (15° cone angle) results

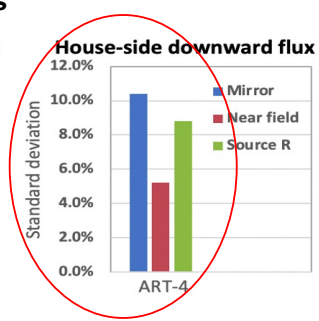


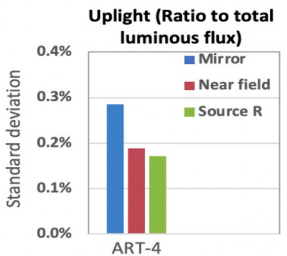
← 30° cone angle

Analysis III Results (6) – Goniophotometric quantities (ART-4)

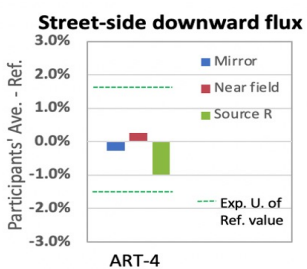
Standard deviations of the results

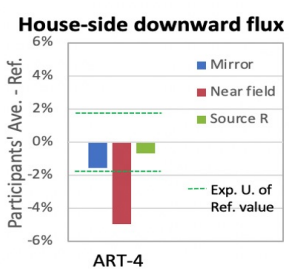


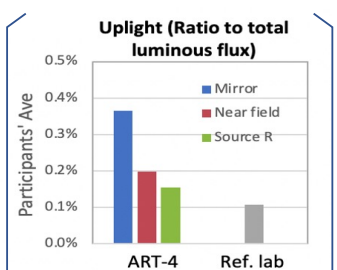


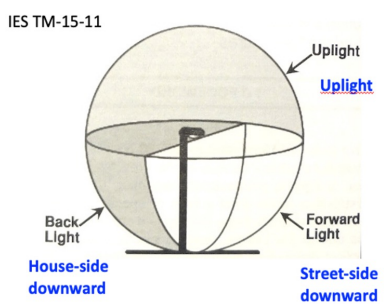


Average deviations from the reference value









- House-side downward flux:
  - Large variations (4 x than street side) – due to sharp decline of intensity on house side
  - Notable negative bias of near-field type (but uncertainty is also high for this quantity)

Analysis III Results (6) – Goniophotometric quantities (ART-4)

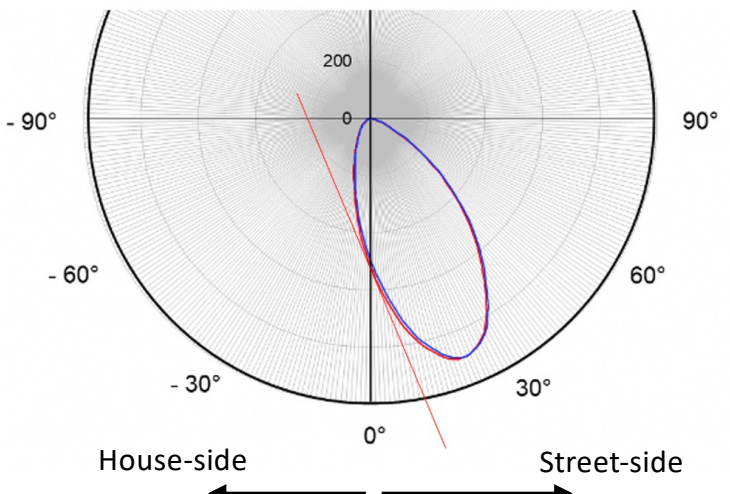
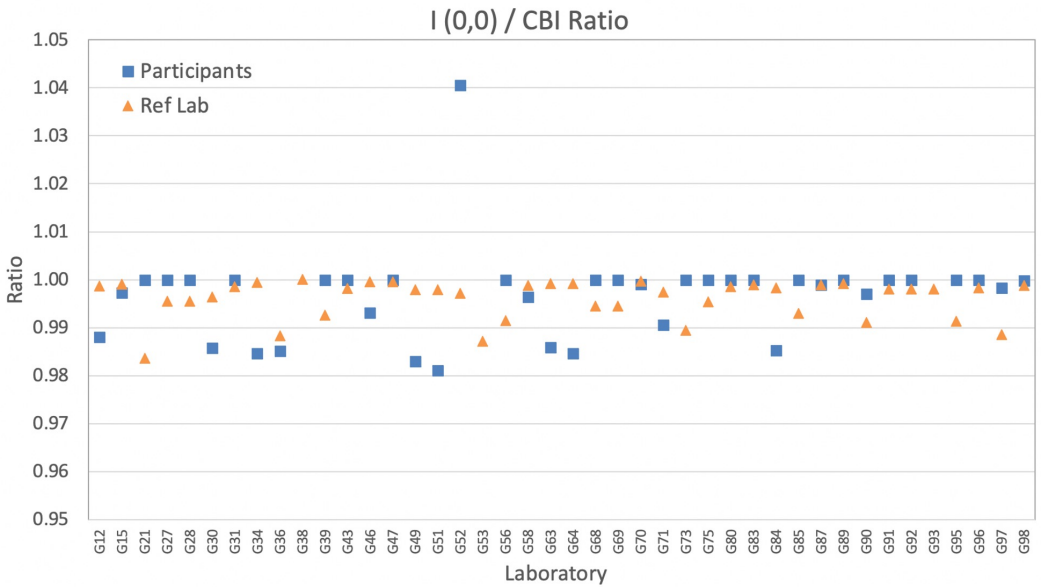
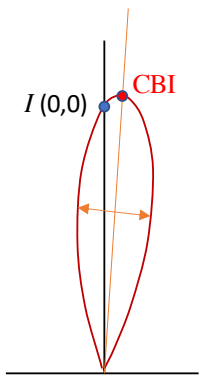


Figure 7-69. Luminous intensity distribution of ART-4 in the plane perpendicular to road direction

Ratios of luminous intensity at (0,0) to centre beam intensity (CBI)





- 21 out of 42 labs reported exactly the same values for I(0,0) and CBI. (Many participants did not calculate CBI as defined)

Results of z' score

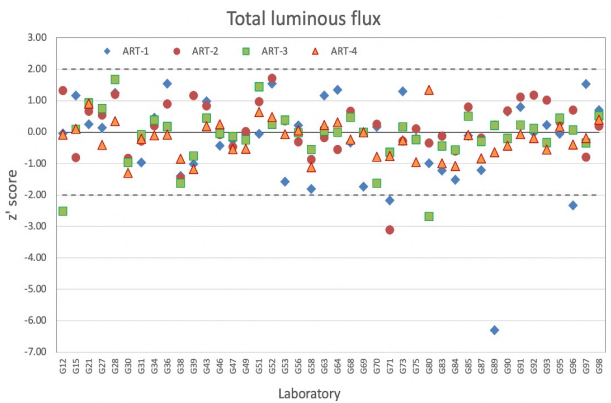


Figure 7-156. z' score results for total luminous flux for all artefacts

|z'| < 2 satisfactory
2 <|z'|<3 questionable
3 ≤|z'| unsatisfactory

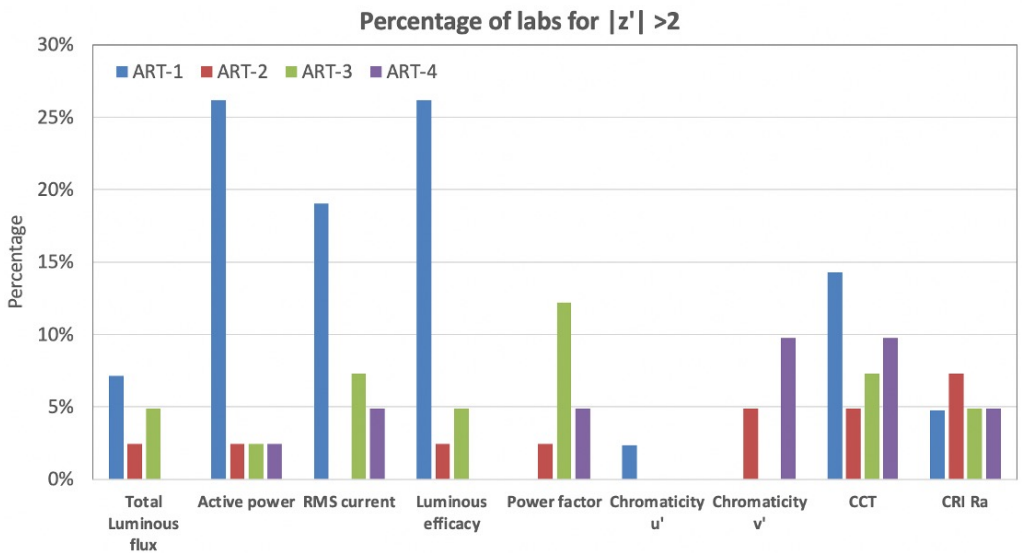


Figure 7-160. Percentage of labs that had z' scores outside -2 ≤ z' ≤ 2.

Results of En number

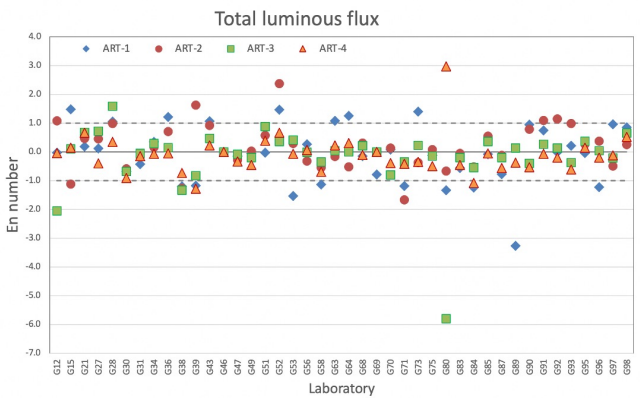


Figure 7-157. E_n number results for total luminous flux for all artefacts

$|E_n| \leq 1$ satisfactory
$|E_n| > 1$ unsatisfactory

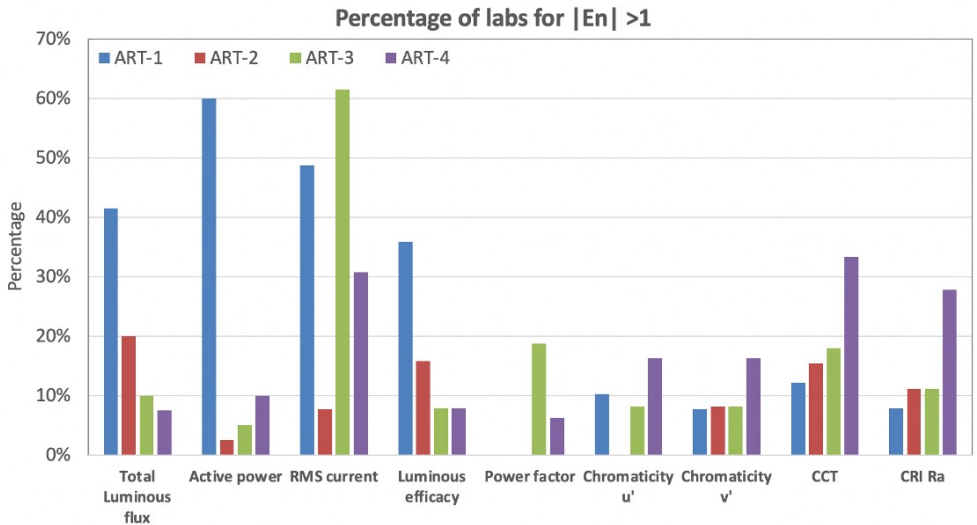


Figure 7-161. Percentage of labs that had E_n numbers outside $-1 \leq E_n \leq 1$.

Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

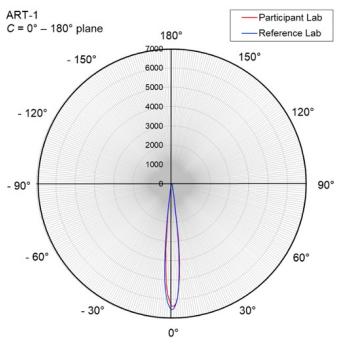
Outline

1. Progress since April 2021
2. Presentation of a paper at CIE 2021 Midterm Conference
3. Structure of IC 2017 Final Report
4. Data analysis methodology
5. Results and findings
6. **Luminous intensity distributions**
7. Summary of Results and Preliminary Recommendations
8. Future activities

Analysis IV – Luminous Intensity Distributions

Example data (mirror-type, source rotating type)

(ART-1)



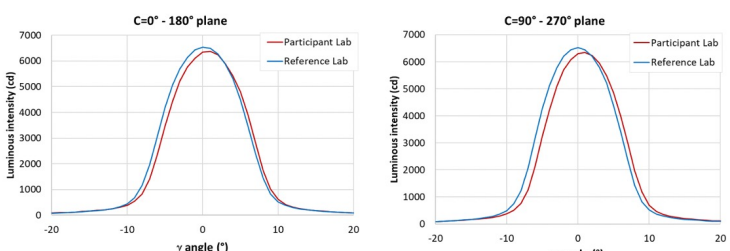
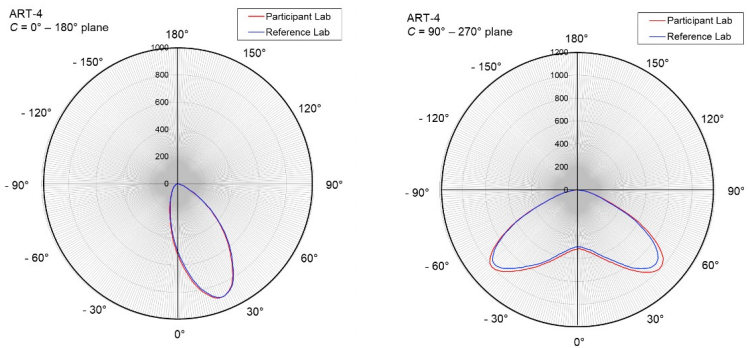


Figure 7-146. Example of luminous intensity distribution comparison of ART-1 (participant: source-rotating type goniophotometer)

(ART-4)



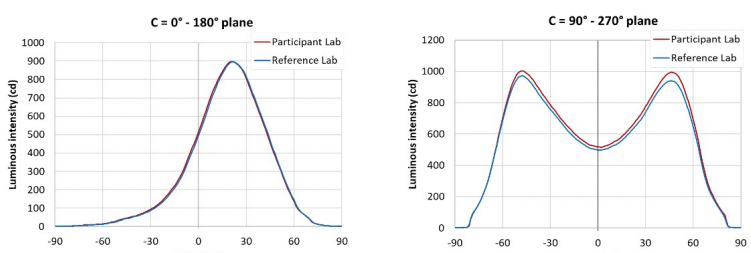
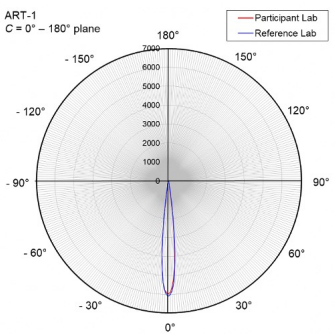


Figure 7-149. Example of luminous intensity distribution comparison of ART-4 (participant: source-rotating type goniophotometer)

Analysis IV – Luminous Intensity Distributions

Example data (near-field type)

(ART-1)



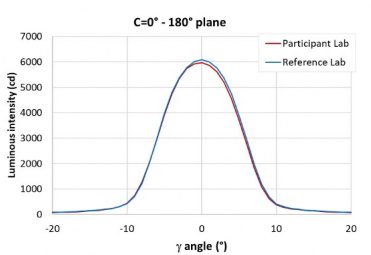
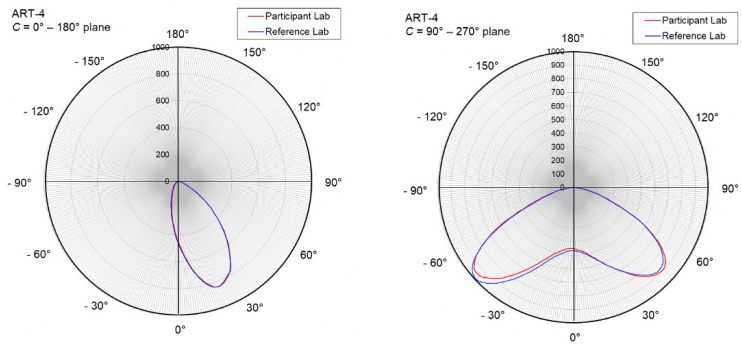


Figure 7-150. Example of luminous intensity distribution comparison of ART-1 (participant: near-field goniophotometer).

(ART-4)



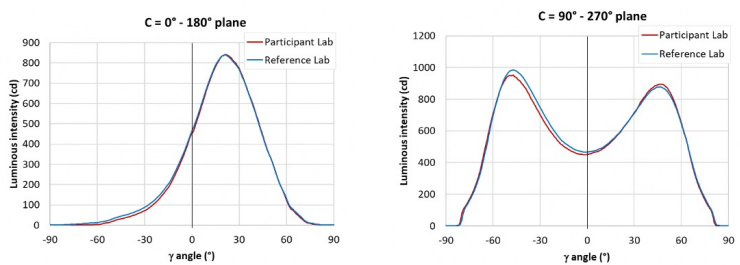
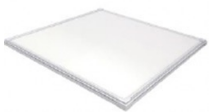


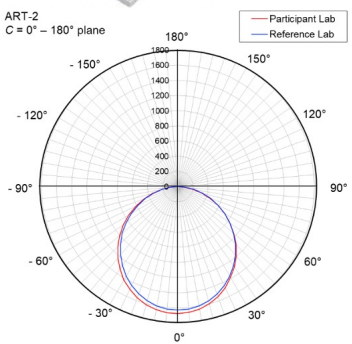
Figure 7-151. Example of luminous intensity distribution comparison of ART-4 (participant: near-field goniophotometer).

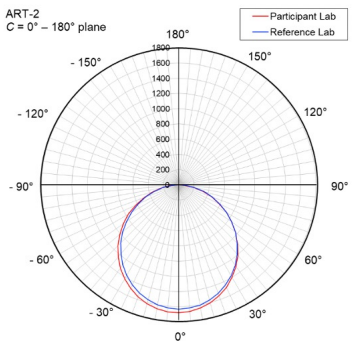
Analysis IV – Luminous Intensity Distributions

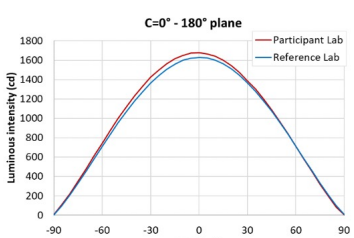
Example data (mirror type)



(ART-2)







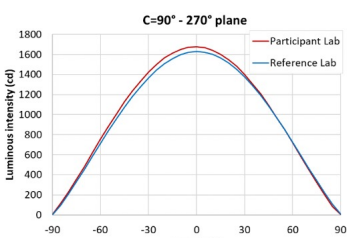
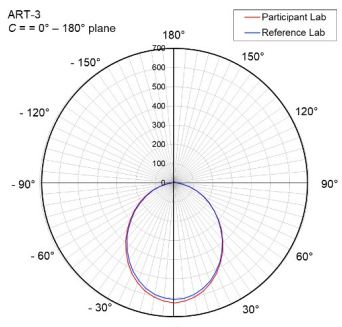
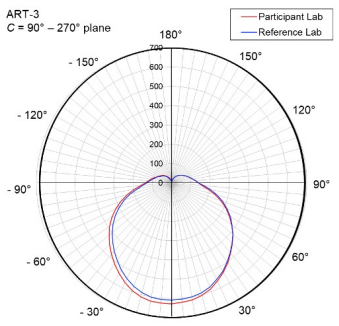
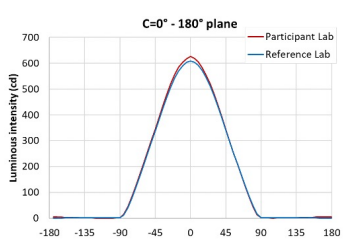


Figure 7-147. Example of luminous intensity distribution comparison of ART-2 (participant: mirror type goniophotometer)

(ART-3)







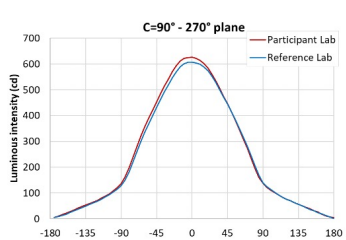


Figure 7-148. Example of luminous intensity distribution comparison of ART-3 (participant: mirror type goniophotometer)

Analysis IV – Luminous Intensity Distributions

Problematic data examples (poor alignment)

(ART-1)

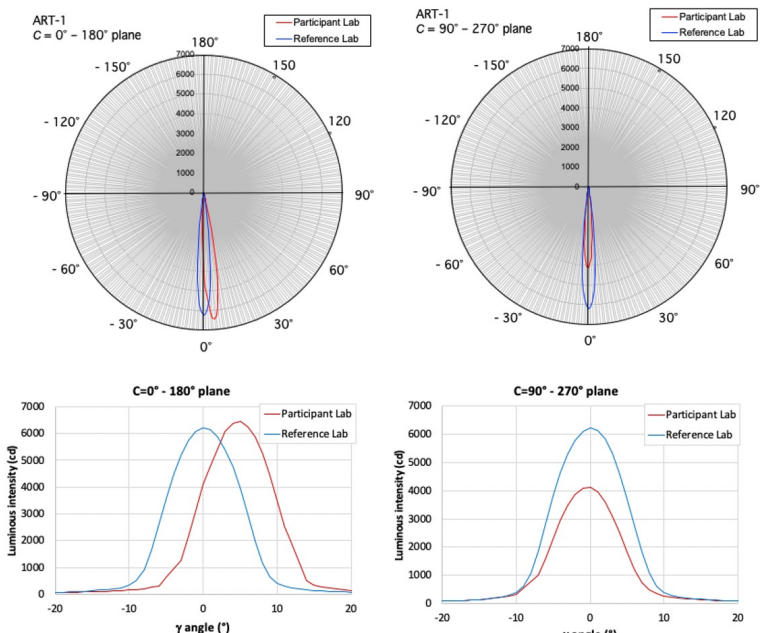


Figure 7-152. Example of a problem in poor alignment of the artefact (ART-1) (participant: mirror type goniophotometer)

(ART-4)

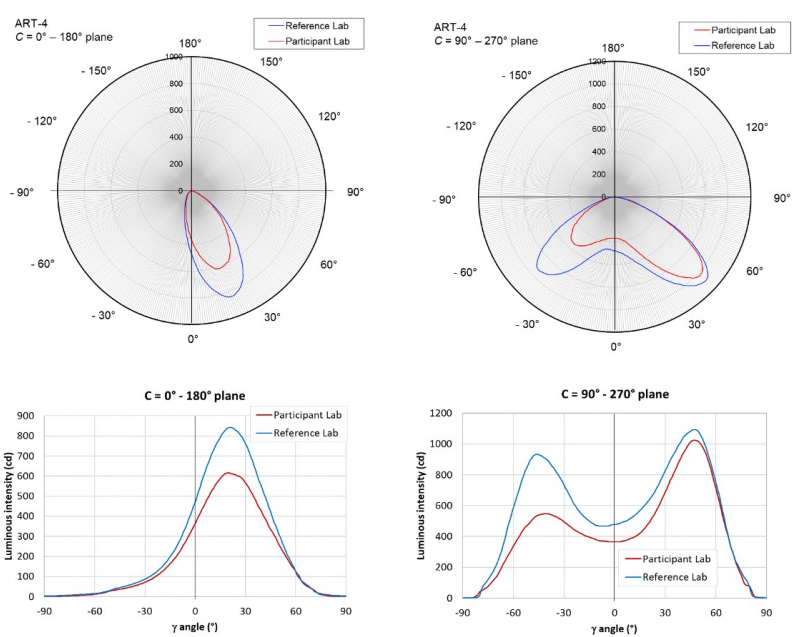


Figure 7-153. Example of a problem in poor alignment of the artefact (ART-4) (participant: mirror type goniophotometer)

Analysis IV – Luminous Intensity Distributions

Problematic data examples (noise, dead angle)

(ART-2)

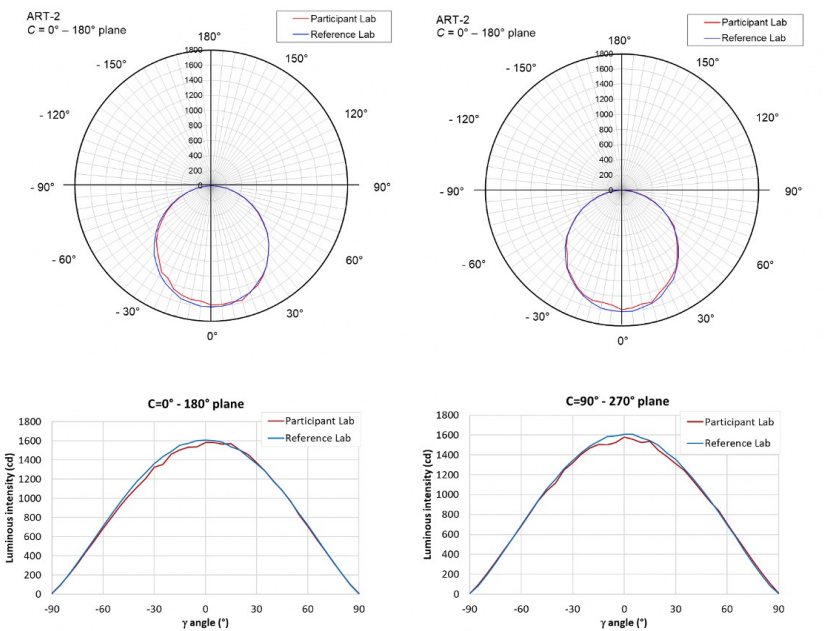


Figure 7-155. Example of noisy intensity distribution curves (ART-2) (participant: mirror type goniophotometer)

(ART-3)

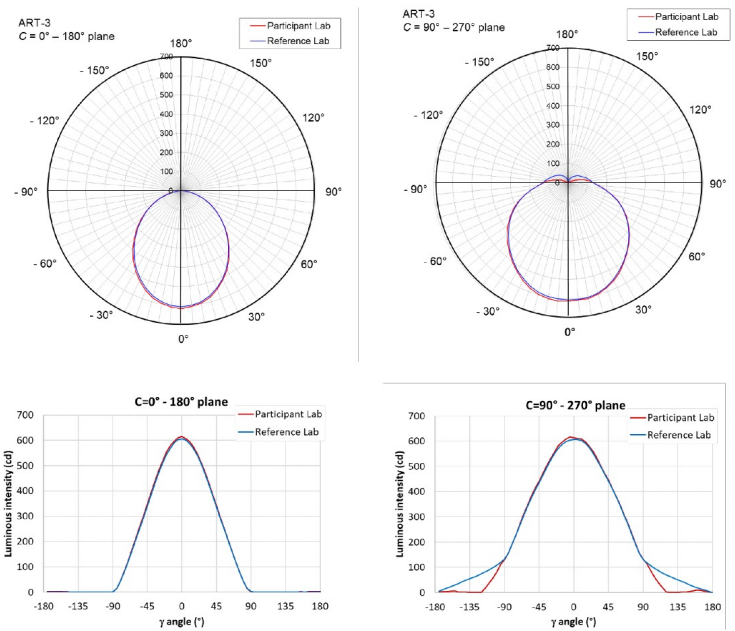


Figure 7-154. Example of a problem in dead angle of the goniophotometer for ART-3 (Participant's curve beyond γ = ±150° is shadowed) (participant: source-rotating type goniophotometer)

Analysis IV – Luminous Intensity Distributions

Summary

- Comparisons of LID curves were done only visually because LID data of only four C-planes (0°, 90°, 180°, 270°) were collected from participants.
- More rigorous analyses could have been possible if full LID data had been collected.
- The results of near-field type goniophotometers showed reasonable agreement with the reference lab results (on visual comparison) though ART-1 and ART-4 were considered challenging for near-field goniophotometers.
- The submitted data in many cases did not match with the **C-plane angles** of the reference lab. The C angle rotation was opposite in some cases (CIE coordinate system was not followed) or the origin was different (not following the IC 2017 protocol).
- Comparisons of LID curves for **ART-1 and ART-4** were difficult due to significant variation of **angle alignment of the artefacts**.
- Results of ART-3 revealed **dead angle problems** in upper directions for some goniophotometers. Some source-rotating type goniophotometers are designed for only 2 π.
- Some participants reported results in cd/1000 lm (not compliant with CIE S 025).

Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

Outline

1. Progress since April 2021
2. Presentation of a paper at CIE 2021 Midterm Conference
3. Structure of IC 2017 Final Report
4. Data analysis methodology
5. Results and findings
6. Luminous intensity distributions
7. **Summary of Results and Preliminary Recommendations**
8. Future activities

Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

Summary of Results

8.1

- Total luminous flux results were mostly within ±5 % (±2 x SDPA) from the reference value, which was an expected level of variation
- Electrical quantities show some unexpected results. RMS (or DC) current showed much larger variations than expected. The variations of results depended very much on the artefact
- Color quantities were overall in good agreement
- Goniophotometric quantities (centre beam intensity, beam angle, partial fluxes, colour uniformity) had larger variations than expected in many cases
- Some specific problems were identified for 15° cone angle partial flux and beam angle. House-side partial flux had very large variations (due to sensitivity to alignment)
- Color uniformity showed very large variations and indicated serious problems with some labs.
- In the result of each quantity, there are often a few outliers with very large deviations, which indicate some mistakes made by the participants. These should be investigated by the participants.

8.2 Comparison between different goniophotometer types

- The differences in results measured by the three different types of goniophotometer were overall insignificant for all the quantities, and both near-field type and source-rotating type goniophotometers that participated in this IC are considered to have equivalent accuracies within typical acceptable uncertainties, for the types of artefacts used in this comparison.
- near-field type goniophotometers for ART-1 (and ART-4) showed notable negative biases for luminous intensity at (0,0) and centre beam intensity, though the magnitude of the deviations is considered an acceptable level. This indicates that the near-field type goniophotometers that participated in IC 2017 had slightly larger uncertainties for very narrow beam or structured intensity distributions.
- The source-rotating type goniophotometers did not show any issues in results, and it rather showed better results for beam angle, colour uniformity, and uplight flux (stray light), than mirror type goniophotometers on the average. (photometric distance can be variable)
- The source-rotating type goniophotometers require correction of results for operating position change of the artefacts per CIE S 025, however, the effects for the artefacts used in this IC were reported to be insignificant. This effect should be investigated for more varieties of products and such correction may not be required for common products by adding an uncertainty component.
- Near-field goniophotometers other than the manufacturer/models used in this comparison also need to be tested.

8.3 Future improvements on test methods and guidance

- Though CIE S 025 refers to CIE 121 for (C, γ) coordinate system, many participants in IC 2017 reported the C angles incorrectly. In some cases direction of rotation is opposite. Giving more guidance will be useful.
- Further guidance is needed on how to calculate **centre beam intensity** and **beam angle** of a beam lamp.
- The definition of beam angle is available in CIE S 025 only for one plane. A further guidance or specification may be needed on how to **determine the beam angle of a lamp**
- More guidance is needed on how to mount and align a narrow-beam lamp to a goniophotometer for the mechanical axis (or optical axis) of the lamp.
- In goniophotometric quantities there were many cases where the participants **did not report uncertainties**. 15 to 20 labs (out of 42 labs) did not report uncertainties for beam angle, centre beam intensity, and partial flux, while only 2 did not report uncertainty for total luminous flux and 5 for colour quantities. Guidance for practical uncertainty evaluation for goniophotometric quantities is needed.
- In CIE S 025, **near-field goniophotometers** are accepted if equivalence to a far-field goniophotometer is demonstrated, but no details and no acceptance criteria are given. It is desired that such criteria will be developed and included in the test method.
- **Source-rotating type goniophotometers** is allowed in CIE S 025 if corrections are applied for the effect of operating position change, however, this type is not allowed in some other regional test methods (e.g., IES LM-79 [10]). Goniophotometers of this type, with appropriate correction, are encouraged as they have big advantage of not requiring a large darkroom space.

Conclusions

- This comparison verified reasonable agreement overall in total luminous flux and chromaticity
- The variations of **electrical quantities** were larger than expected and depended mainly on the comparison artefacts
- This comparison revealed **a number of specific problems** in measurement of **goniophotometric quantities** of SSL products and indicated that more guidance is needed for these measurements
- This comparison also verified that, overall, **near-field type and source-rotating type goniophotometers** used in this comparison **had equivalent accuracies** to far-field goniophotometers for the types of products used in this comparison. (Note: near-field type showed slightly higher uncertainty for a very narrow beam intensity distribution, though it may be within acceptable uncertainty levels)
- Verification in this comparison did **not cover all types of products** in the market and goniophotometric instruments of all manufacturer/models
- The results of this comparison may be useful for **future improvements** in metrology, standards and practice in measurements of SSL products

Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

Outline

1. Progress since April 2021
2. Presentation of a paper at CIE 2021 Midterm Conference
3. Structure of IC 2017 Final Report
4. Data analysis methodology
5. Results and findings
6. Luminous intensity distributions
7. Summary of Results and Preliminary Recommendations
8. **Future activities**

Solid State Lighting Annex
Energy Efficient End-use Equipment
International Energy Agency

Future activities

- IC 2017 Final Report is expected to be published in early November (finally!)
- On-line public webinar on IC 2017 Final Report
- Letter to accreditation bodies
- Feedback to CIE (effort for revision of S 025 starting)
- Publish a journal paper

Acknowledgment

Thank you to everyone who worked so hard to complete this challenging IC and those who continued to give strong support and encouragement.

Nucleus Labs (KILT, LNE) JS, SK, Jean, Jimmy
Mike Scholand
Steve Coyne
Carsten Dam Hansen
SSL Annex leaders (Nils, Goerges, David, Peter)
SSL Annex Management Committee
Other Experts members