Final report

1.1 Project details

Project title	Global Test af SSL Produkter - IEA-4E-SSL
Project identification (program abbrev. and file)	EUDP 2014-II Journalnr.: 64014-0526
Name of the programme which has funded the project	EUDP International collaboration (IEA)
Project managing company/institution (name and address)	DTU Fotonik, Frederiksborgvej 399, 4000 Roskilde
Project partners	Energy Piano
CVR (central business register)	DK 30 06 09 46
Date for submission	9-9-2019

1.2 Short description of project objective and results

The purpose of the project was to actively use the national expertise on LED technology, Solid State Lighting (SSL) and test facilities in continuation of the IEA 4E SSL Annex, working together to address common challenges and activities relating to SSL product performance and quality. Application of the new international LED test standard CIE S025 has been in focus and used in the IC2017 and the national interlaboratory comparison using goniophotometers for SSL product testing. Danish lighting laboratories benefits from this in showing compliance with CIE S025. Comprehensive testing of LED smart lamps and LED filament lamps resulted in reports on issues with standby power consumption and temporal light modulation. In all a good transfer of knowledge between the Danish stakeholders and the SSL Annex have been achieved.

Kort beskrivelse af projektets formål og resultater

Formålet med projektet var at aktivt udnytte den nationale ekspertise indenfor LED teknologi, Solid State Lighting (SSL) og testfaciliteter i fortsættelsen af IEA 4E SSL Annex, hvor der arbejdes sammen om fælles udfordringer og aktiviteter relateret til SSL produkters ydeevne og kvalitet. Anvendelse af den nye internationale LED test standard, CIE S025, har været i fokus og benyttet i IC2017 og den nationale interlaboratorie sammenligning med goniofotometre til SSL produkt test. De danske lyslaboratorier drager fordel af dette ved at kunne vise overensstemmelse med CIE S025. Omfattende test af LED smart pærer and LED filament pærer har resulteret i rapporter omkring problemstillinger med standby energiforbrug og tidlig modulation af lys, også kaldet flimmer. Overordnet set er der skabt en god overførsel af viden imellem danske interessenter og SSL Annexet.

1.3 Executive summary

This report concludes on the project entitled ”Global Test of SSL Products - IEA-4E-SSL”, which has been carried out over five years from 2015 – 2019. The project has facilitated the active Danish participation in the Solid State Lighting (SSL) Annex, where eight countries work together since 2010 to address common challenges and activities relating to SSL product performance and quality. Casper Kofod, Energy Piano and Carsten Dam-Hansen, DTU Fotonik, with expertise on policy and quality specification, and metrology and SSL test, re-

spectively, have participated as Danish experts in the work of the SSL Annex. This has consisted in attending the biannual meetings, writing and commenting reports and both have had the responsibility as task leaders. The tasks in questions are on smart lighting where new features impact energy consumption and on development of an internal benchmarking database for SSL products.
The application and use of the new international LED test standard CIE S025[1] has been in focus of more than half of the dissemination work. A workshop on this, gathering around 100 participants was arranged and was held by DTU Fotonik in Roskilde. Two interlaboratory comparisons, a national and the international IC2017, both using goniophotometers for SSL product testing has been arranged and executed. The Danish comparison showed a high degree of equivalence yielding expanded uncertainties of 6.3% and 3.3 %, on luminous flux and luminous intensity, respectively. DTU Fotonik participated in the IC2017 with two types of goniophotometers representable for the Danish industry laboratories, who will be able to utilise the results to document their compliance with the new international test standard, CIE S025 and the identical CEN standard EN13032-4. At the end of this project we are awaiting results on the IC2017 for four types of LED lamps and luminaires.
In the benchmarking of SSL products DTU Fotonik has concentrated the work on LED smart lamps and LED filament lamps and have included temporal light modulation measurements. The results of this work is a report on temporal light modulation investigation of LED filament lamps under dimming conditions. Other member countries laboratories have done testing of LED smart lamps, and this has been used in the first SSL Annex Report on Smart Lighting – New Features Impacting Energy Consumption, where a new overall efficacy of smart lamps is introduced.
A widespread dissemination work directed towards Danish stakeholders, consultancies and lighting industry has been carried out, to ensure a good transfer of knowledge to and from the SSL Annex. The SSL Annex work will be continued in a third term of the SSL Annex, 2019-2024, which has been approved by the SSL Annex Management Committee and the 4E Executive Committee. The Danish participation continues in the EUDP project ”Global SSL quality requirements and test - IEA-4E-SSL”.

1.4 Project objectives

The main objectives of the project was to actively use the national expertise on LED technology, Solid State Lighting (SSL) and test facilities, established as a part of a global network of test laboratories, in continuation of the IEA 4E SSL Annex. This was to be done by having two Danish experts, Casper Kofod (CK), Energy Piano and Carsten Dam-Hansen (CDH), DTU Fotonik, actively participating in the work of the SSL Annex, in the biannual meetings, writing and commenting reports and doing work on specific tasks as task leaders. Project meetings have been held prior to the SSL Annex expert meetings.
The project has evolved according to the plan and all milestones have been accomplished. CK and CDH have participated in all the nine experts meetings. At one occasion, due to personal reasons they had to cancel the travel to the meeting venue. At this meeting they participated through web conference calls. This is possible but cannot be recommended since you lack the important interaction with the other experts at the meeting and visits to the participating laboratories. CK and CDH have contributed to the work with expertise on policy and quality specification, and metrology and SSL test, respectively.
The application and use of the new international LED test standard CIE S025 has been the focus of or included in more than half of the dissemination work. And this was also the main focus of the workshop and one-day conference held in Roskilde gathering around 100 participants.
A major objective for DTU Fotonik was to assist the task leader in T4 to prepare the IC2017 interlaboartory comparison using goniophotometers and further to ensure a Danish participation in this. This was important since many Danish testing and industrial laboratories are using goniophotometer systems that are not compliant with the new international test standard, CIE S025 and the identical CEN standard EN13032-4. In order to be compliant it is necessary to show equivalent results for different types of SSL products, when compared to a traditional far-field mirror type goniophotometer.

[1] CIE S025/E:2015 Test Method for LED lamps, LED luminaires, and LED modules

Partly due to the high fee for participating in the IC2017, no industrial or testing laboratories in Denmark participated besides DTU Fotonik. This problem was remedied by running a similar national interlaboratory comparison and by DTU Fotonik participating in IC2017 with two types of goniophotometer systems. These covered the types of goniophotometer systems used by the majority of the laboratories in Denmark, and it makes it possible for the Danish laboratories to utilise the results. Unfortunately, the results of the IC2017 in form of participant results reports has not been issued and the final report or published, at the end of this project. It will be part of the work in the third term of the SSL Annex, 2019-2014

CK has been task leader for T7, and have lead the work on SSL products with new features that impact energy consumption which in many cases are called smart lamps. A test protocol has been developed and used in a comprehensive testing of smart lamps and luminaires. This work resulted in a SSL Annex report on standby energy consumption of smart lamps. The second report on this including smart luminaires will be published in end of 2019. DTU Fotonik have tested smart lamps purchased on the Danish market, contributing to the overall testing by the member countries laboratories. DTU Fotonik has concentrated on smart lamps and LED filament lamps and have included temporal light modulation (TLM) measurements in the benchmarking of SSL products. TLM have become a very important issue in SSL quality assessment and regulation. This was also the reason for the commencement of a fast track research investigation on the visibility of stroboscopic effect. This was not planned and shows the strength of the collaboration within the SSL Annex and ability to bring new results to issues of high importance, quickly.

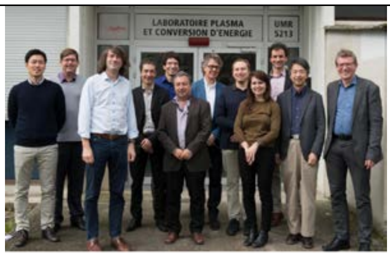
Most of the SSL Annex tasks have succeeded in doing the planned work, mostly through the publication of reports on the SSL Annex homepage. Additional work like the stroboscopic visibility investigation have also been done. The plan in T9 to make an international lighting facts database for on SSL products for consumers information had to be abandoned due to several reasons including the partial closing of the lighting facts database in the US. Instead it was decided to make an internal database to enable member countries to share performance data and test results for SSL products like LED lamps and luminaires. This was to be used as background data for setting performance tiers in T6 and also valuable for T7 and T8. It was made part of T8 to develop this internal SSL Annex database and CDH was appointed task leader for this task. This was an extra task not planned in the project.

The overall objective was to disseminate the results and gained knowledge of the SSL Annex work to Danish and international stakeholders, like consultancies and the lighting industry and in this way put it into use. This has been achieved to a high degree through a widespread dissemination work including six articles published in Danish trade magazines, four invited talks at national events, four workshops where two were in Denmark, four reports published on webpages, eight papers in conference proceedings, fourteen talks at conferences/workshops and 4 poster presentations at conferences. The results and the dissemination work are described in more detail in the following.

1.5 Project results and dissemination of results

A large part of the work have been to participate in the IEA SSL Annex experts meetings which have been held biannually. The table below list the meetings and places, and the additional events, seminars and workshop arranged in connection to the SSL Annex meetings. At all the meetings all the tasks of the SSL Annex are worked on through the task leaders presentation and subsequent discussions. Prior to the meetings the task leaders send out documents for commenting and inputs from all experts. At all the meetings the individual member countries gives updates on the state of SSL, with regards to research, industry, market and policy measures.

Date	Meeting	
25-28 May 2015	IEA 4E SSL Annex's 10th Expert Meeting, Sydney, Australia	
2-4 November 2015	IEA 4E SSL Annex's 11th Expert Meeting, Department of Energy and Climate Change (DECC) , London, United Kingdom	

26-28 April 2016	IEA 4E SSL Annex's 12th Expert Meeting, National Lighting Test Laboratory (NLTC), Beijing, China	
7 and 8 - 10 November 2016	One-day conference "Nordic light quality – International standards" https://conferencemanager.events/ledmet2016/ and IEA 4E SSL Annex's 13th Experts Meeting, DTU Fotonik, Technical University of Denmark Roskilde, Denmark	
3–5 May 2017	IEA 4E SSL Annex's 14th Expert Meeting, Stockholm, Sweden	
20 to 22 and 23 November 2017	IEA 4E SSL Annex's 15th Experts Meeting in Canberra And Experts Conference in Sydney, Australia	
27-29 March 2018	IEA 4E SSL Annex's 16th Expert Meeting University of Toulouse and ADEME, France	
30 October – 1 November 2018	IEA 4E SSL Annex's 17th Expert Meeting National Research Council Canada (NRCC), Ottawa Canada	
1 - 4 April 2019	IEA 4E SSL Annex's 18th Expert Meeting and International LED Conference, Seoul Korea	

Photos included in the report are not to be published in other context.

The work in the project and in the SSL Annex has been divided into 11 tasks. In the following sections the work and results of the individual tasks are described.

1.5.1 T1 – Application of new Test Method

The SSL Annex is reviewing the application and relevance of the new test standard (CIE S025:2015 Test Methods for LED Lamps, LED Luminaires and LED Modules) to determine its potential to be used as a test standard for governments and product regulators. The main work and output from this task is a report that discusses the findings of the evaluation and a recommendation on how governments could best use the new test standard to support their voluntary and regulatory programmes. The document was published on the Annex homepage, and here is a direct link to the report: Application Study of CIE S 025/E:2015.

After the publication of the new international test standard CIE S025:2015 nine copies of this document have been purchased by DTU Fotonik, and have been distributed to Danish industry partners who participated in the goniophotometer interlaboratory comparison in the LEDMET project. The remaining copies are distributed to other Danish stakeholders, and comments for the coming revision of the CIE S025 document have been received.

A large part of the work carried out has been to disseminate the content and the use of the new test standard CIE S025. This also incorporates the EN13032-4[2] which is the European test standard, and which in technical terms are identical to the CIE S025 and have been developed jointly. This has been done by giving talks at various occasions, this includes but are not limited to; industry partners events, courses, conferences both in Denmark and also at international CIE conferences. Furthermore articles have been published in magazines, trade journals, scientific journals and conference proceeding. The list of disseminations work is given in Table 3 in T11 - Dissemination on page 17, and the related task number are given.

The 13th SSL Annex expert meeting was held in Denmark on 8-10 November 2016. The meeting was held at Risø campus by DTU Fotonik, and the host for the meeting were Casper Kofod, Signe F. Christensen and Carsten Dam-Hansen. In order to get the full benefit of having all the Annex experts meeting up in Denmark, it was decided to arrange a seminar with focus on light quality and standards.
On 7 November 2016 the one-day conference ”Nordic light quality – International standards” was held in the Niels Bohr auditorium at Risø campus, DTU north of Roskilde. See http://conferencemanager.events/ledmet2016/ for programme. The aim was to disseminate knowledge on Solid state lighting, new test standards and demands. It succeeded in gathering around 100 participants, see the photos in Figure 1. The main talks were by Thor Nørretranders and Yoshi Ohno.

Figure 1 Photos from the the one-day conference ”Nordic light quality – International standards”, in the Niels Bohr auditorium.

The conference constituted a part of T1 in the SSL Annex and the fulfilment of the milestone M1, through the talks on test standards by Yoshi Ohno, panel discussion and demonstrations in the photometric laboratory at DTU Fotonik. The conference was further combined with a

[2] EN13032-4:2015+A1:2019 Light and lighting. Measurement and presentation of photometric data of lamps and luminaires. LED lamps, modules and luminaires

number of talks on OLED Lighting and on SSL metrology from participants in the innovation consortium LEDMET.

As a part of the work on dissemination of S025 DTU Fotonik invited NIST Fellow Yoshi Ohno to come and visit Denmark and DTU Fotonik for a week, 9-17 Aug 2018. This included several talks at workshops on photometry, colorimetry and measurement uncertainty related to CIE S025.

1.5.2 T2 - Characterisation of Product Lifetime and T3 - Guidance on product lifetime

In the SSL Annex a large amount of work has been put into making a draft for a report, however it has not resulted in a published report yet. The report seeks to describe degradation and failing mechanisms of SSL products and to give an overview of the standard test methods.

DTU Fotonik has in the project provided measurement results from the long term investigation of LED lamps with more than 20.000 hours of continuous operation[3]. The data was part of the scientific results collected on lifetime investigations in the SSL Annex. The lumen maintenance shown to the left in Figure 2, illustrate the slow degradation in the luminous flux. Two of the lamp types have more than 90% at 19.000 hours, while one degrades to 70 % after 12.000 hours. The total dataset delivered to the task leader had 48 LED lamps of up to 28.000 hours of operation.

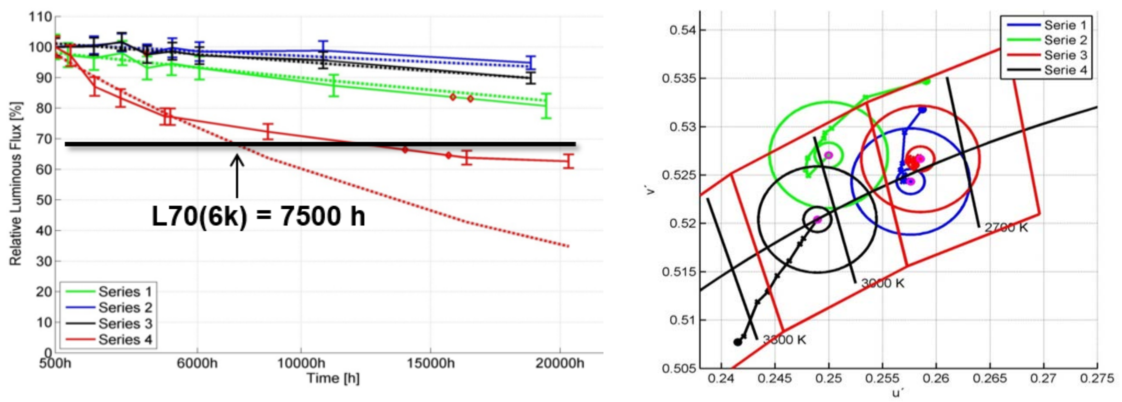


Figure 2 Measurement results of long term operation of 4 types of LED lamps. Left: Luminous flux as a function of time measured relative to the luminous flux at 500 hours. Right: chromaticity coordinates as a function of time

The most promising results of the work carried out in Task 2 and 3 is the new endurance test that is described in “ANNEX V Functionality after endurance testing” of the draft of the new EU omnibus regulation for lighting products, see documents here. It uses a switching cycle that will stress the SSL products more than the continuous operation used in the investigation shown in Figure 2. In the endurance test the light source is operated for 1 200 cycles of repeated, continuous switching cycles without interruption. One complete switching cycle consists of 150 minutes of the light source switched ON at full power followed by 30 minutes of the light source switched OFF. The hours of operation recorded (i.e. 3.000 hours) include only the periods of the switching cycle when the light source was switched ON, i.e. the total test time is 3.600 hours. This procedure ensures that the SSL product will switch between states of ambient temperature and its maximum operating temperature, which stresses the SSL product much more that other lumen maintenance and on/off switching tests.

This method is being implemented at DTU Fotonik in order to be able to perform this type of endurance test and to provide measurement results to document the effect of the endurance test on linear LED lamps, in the EUDP project “Energy saving LED smart tube”, journal no.

[3] Corell, D. D., Thorseth, A., & Dam-Hansen, C. (2014). Luminous flux and colour maintenance investigation of integrated LED lamps. In *Proceedings of CIE 2014: Lighting quality and energy efficiency* (pp. 408-414). CIE - International Commission on Illumination.

64017-05144. The project has further given comments and inputs to the reports under development, but it still needs more work.

1.5.3 T4- Interlaboratoy comparison (Goniophotometer)

Establishment and execution of the interlaboratory goniophotometer comparison (IC2017) was the main goal of SSL Annex task T4. In this project the goal was further for DTU Fotonik to participate and preferably to have other Danish laboratories participate in the comparison. In this way DTU Fotonik had a double role both as part of the organizing and participating as a test laboratory. The organising work was led by Yoshi Ohno from NIST in USA, who prepared drafts for the various documents which were circulated to all Annex experts for their inputs and comments.

Along with this work DTU Fotonik established and executed a Danish goniophotometer interlaboratory comparison in synergy with the innovation consortium "LEDMET Centre for LED metrology". This served as a pre-study to IC2017, and a good way to involve more Danish industry photometric laboratories. Four laboratories participated with three different types of goniophotometers, a near-field goniophotometer, a far-field mirror type goniophotometer and a horizontal type C goniospectroradiometer. In March 2018 the results of the LEDMET laboratory intercomparison was published on the LEDMET webpage; http://ledmet.dk/wp-content/uploads/2018/03/LEDMET-laboratory-intercomparison-report.pdf. It constituted part of the milestone for T4.

As an example of the results of the Danish interlaboratory comparison the measured luminous flux as a function of the measurement number is shown in Figure 3 to the left.

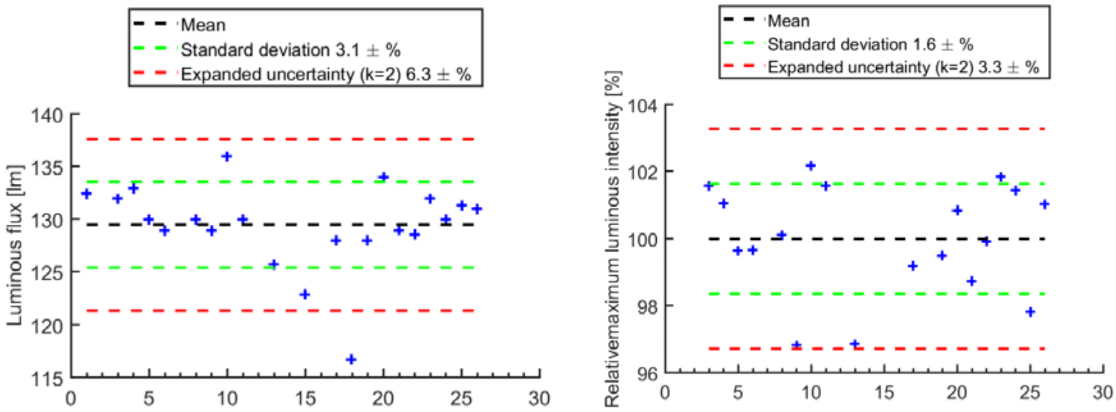


Figure 3 (left) Measured luminous flux and (right) relative difference between measured values of maximum luminous intensity as a function of the measurement number

This shows a low standard deviation of 3.1 %. The relative difference between measured values of maximum luminous intensity as a function of the measurement number is shown in Figure 3 to the right. This shows a lower standard deviation of 1.6 %. Expanded uncertainties with a significance level of 95% have been estimated from the standard deviations by multiplication with a factor of 2, yielding uncertainties of 6.3% and 3.3 %, respectively. A thorough analysis of the full measured 3D luminous intensity distributions was carried out. The raw data from the measurements and the rotated and resampled data are shown in Figure 4. This showed equally good agreement between the measurements.

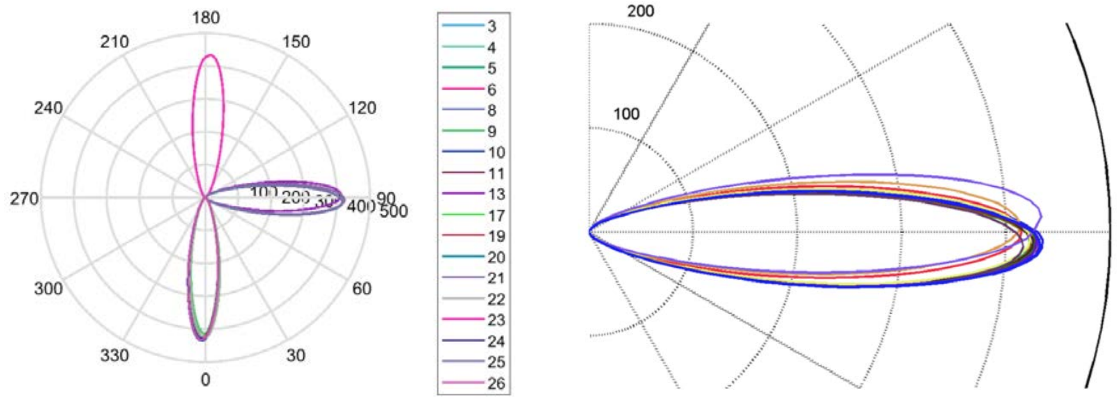


Figure 4 Polar plot showing the intensity distribution in candelas [cd] for the C0 and C180 plane of all the measurements (left) raw data (right) rotated and resampled data for comparison.

Hence, the Danish interlaboratory comparison was a good pre-study for the IC2017 and the results will be compared when the participant´s results reports of the IC2017 have been received.

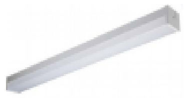
IC 2017 was organised to compare measurements of LED luminaires (including street lighting luminaires) and narrow-beam LED lamp, which were not covered in the previous IC 2013[4]. The IC2017 interlaboratory comparison will study the equivalence of measurements by different types of goniophotometers, 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. IC 2017 uses the CIE S025[5] as the test method. If recognised by accreditation bodies, the test report may be used by the participating laboratories as a proficiency test (PT) for CIE S 025.

The Technical protocol was published on the SSL Annex website on 30 June 2017, https://ssl.iea-4e.org/files/otherfiles/0000/0117/IC_2017_Technical_Protocol_v.1.0_final.pdf describing the test standard, procedures to be used and the artefacts to be measured, see Table 1. These include a narrow beam spot lamp, and larger luminaires with different type of intensity distribution patterns, which normally, are measured using goniophotometer systems.

[4] https://ssl.iea-4e.org/files/otherfiles/0000/0067/IC2013_Final_Report_final_10.09.2014a.pdf

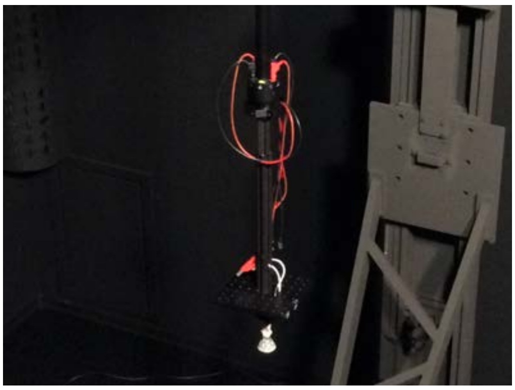
[5] CIE S025/E:2015 Test Method for LED lamps, LED luminaires, and LED modules

Table 1 Artefact set for IC2017

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

Partly due to the high fee for participation, no industrial partners in the LEDMET project or any other laboratories in Denmark signed up for the IC2017. Therefore, DTU Fotonik was the only Danish participant and we decided to participate with two types of goniophotometers that are installed at DTU Fotonik's photometric laboratory. They are the RiGo-801 near-field goniophotometer from Technoteam and the Far field type C horizontal gonio-spectroradiometer called LabSpion from Viso Systems. With these two types of goniophotometers there is a good overlap to the lighting industry in Denmark. The RiGo-801 is being used at SG Armaturen, and the LabSpion from Viso Systems, being used by Bolls, Ingemann Components, LEDiBond and DELTA (Force Technology). The results of DTU Fotoniks participation is therefore relevant for these companies and the results will be disseminated to them. This is important because both types of goniophotometers need to show equivalence to the traditional far-field mirror type goniophotometer which is possible in the IC2017 comparison since the reference laboratories are using traditional far-field mirror type C goniophotometers.

The non-compliance of the near-field goniophotometer is in that it is using a camera which implies that the measurement distance is infinite. The four different artefacts mounted in the near-field goniophotometer is shown in the photographs in Figure 5. The strength of this type of goniophotometer is that the device under test is fixed in position during the measurement and may be measured in any direction of operation. In this case the orientation should be with the optical axis point downwards as in Figure 5.



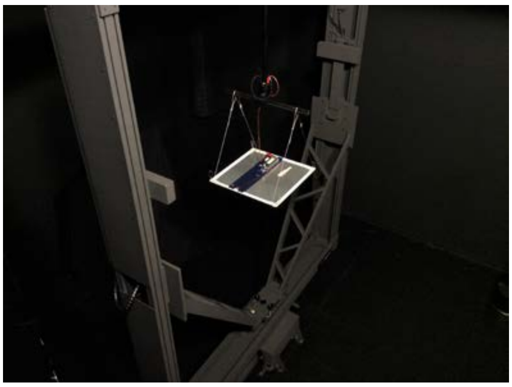


Figure 5 The four artefacts in IC2017 as mounted in the near-field goniophotometer at DTU Fotonik, top left: ART-1, top right: ART-2, bottom left: ART-3, bottom right: ART-4.

In Figure 6 the same four artefacts mounted in the Far field type C horisontal gonio-spectroradiometer is shown. The major difference from the near-field goniophotometer is that the artefacts are mounted horizontally, and hence not as described in the protocol.

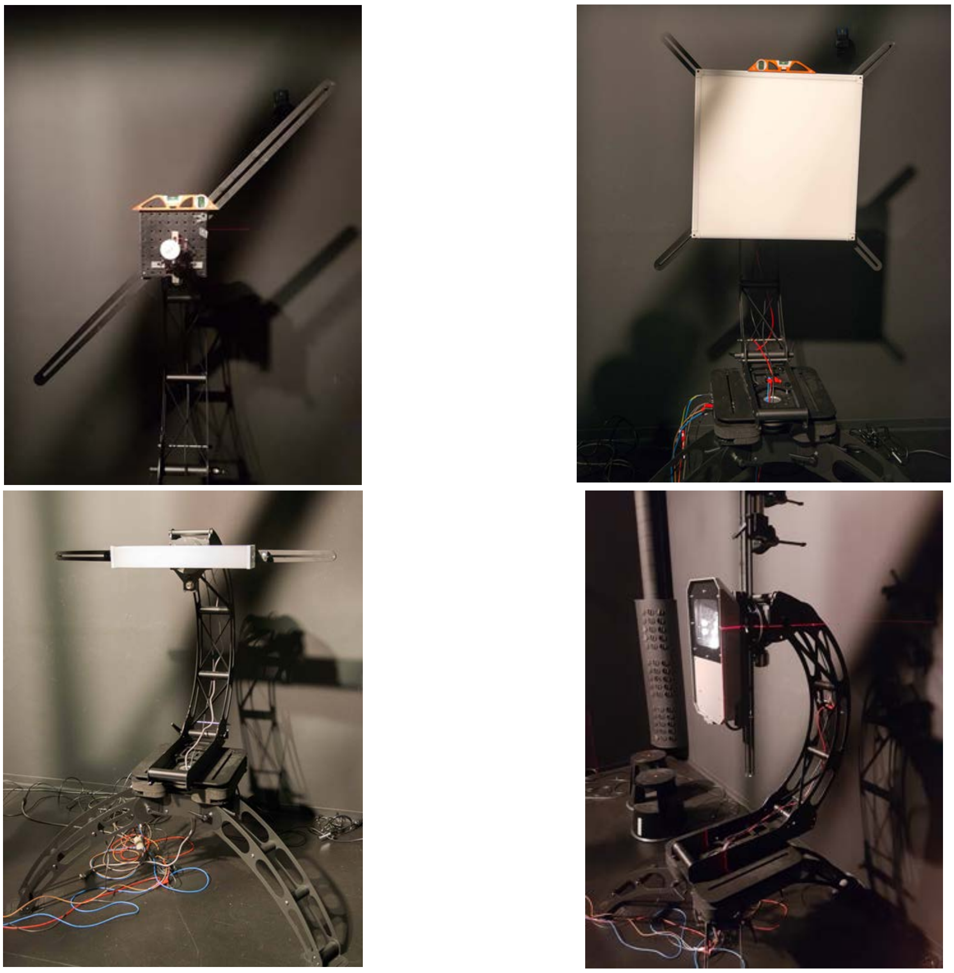


Figure 6 The four artefacts in IC2017 as mounted in the Far field type C horisontal gonio-spectroradiometer at DTU Fotonik, top left: ART-1, top right: ART-2, bottom left: ART-3, bottom right: ART-4.

This gonio-spectroradiometer is rotating the DUT around a horizontal axis. It does therefore not comply to S025, in 5.3.1 Operating Orientation. However it may comply if equivalence is demonstrated with traditional far-field goniophotometers, see 4.1.1 Standard Test Conditions. Corrections for the erroneous orientation are made. After measurement the change in intensity in direction (0,0) is monitored from a stable condition of the artefacts pointing downwards changed to a horizontal position. The change in intensity is used to make corrections for total luminous flux and partial flux, luminous effiicacy, and intensities. The corrections applied are ART-1: -0.25%, ART-2: +0.2%, ART-3: -0.5%, ART-4: 0, which are small compared to the measurement uncertainties.

As an example of the internal results at DTU Fotonik on the four artefacts the measured total luminous flux are shown in Figure 7. The graphs show both the absolute total luminous flux in lumens (left) and the relative difference to mean (right) of the total luminous flux. Results are compared for measurements in the near-field goniophotometer, the far-field gonio-spectroradiometer and the 2m integrating sphere spectroradiometer. The latter was used for reference measurement of colorimetric parameters.

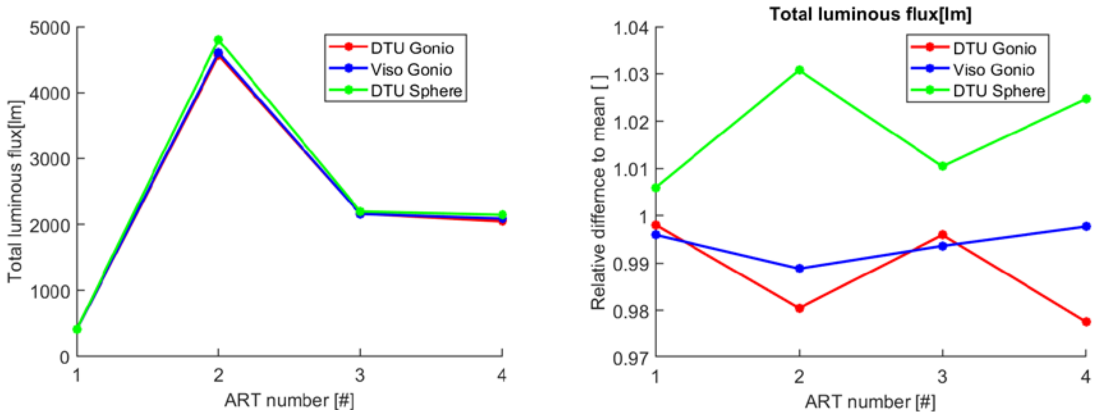


Figure 7 Measured absolute (left) and relative difference to mean (right) of the total luminous flux for the four artefacts, 1 to 4, of IC2017, measured in the near-field goniophotometer (red), far-field gonio-spectroradiometer (blue) and the integrating sphere spectroradiometer (green).

Taking the expanded uncertainty of 4.1 % that is estimated for the total luminous flux measurement into consideration, these results show a high degree of equivalence between the goniophotometer measurements, and also with the sphere measurements even if they are consistently 1-3 % higher. Work is ongoing to investigate the calibrations of the systems and non-uniformity corrections in the sphere measurements.

Three rounds of measurements were carried out in the IC2017 with two reference laboratories, KILT in Korea and LNE in France. The first round of IC2017 started in the end of 2017 and DTU Fotonik participated in round three of the IC2017, referring to LNE as the reference laboratory. The measurements were carried out in July and August 2018, and the two participant results reports were sent to LNE on 10 August 2018. These constitute the last part of the milestone for T4, however they are confidential. The final report of the IC2017 will be used for dissemination of the results.

Due to problems with artefacts that showed to large variations in the testing, some participants needed to redo some of their measurements. The status in June 2019 is that the participants reports are in the process of being issued and will be sent out in autumn 2019. Therefore DTU Fotonik has not by the end of this project received the results of the participation with the two types of goniophotometers. The final report covering all the results of the IC2017 is expected to be published on the SSL Annex website by the end of 2019.

1.5.4 T5 – Market lessons learned T10- Best practice in international MV&E Programmes

This Annex task have worked to compile all the lessons learned by the SSL Annex member governments on the introduction of LED products into their respective markets. This includes, for example, how the markets developed and evolved, what approaches helped to ensure quality LED products, and important pitfalls to avoid (avoiding mistakes). Denmark has contributed through the Danish Energy Agency and the “Sekretariat for Ecodesign og Energimærkning af Produkter” participating in interviews.

This has resulted in the publication of the report "Lessons Learned Bringing LEDs to Market" June 2017, which is available at https://ssl.iea-4e.org/files/otherfiles/0000/0106/Task_5_-_Lessons_Learned__Report_v9_final.pdf.
This report summarise the market experiences and lessons learned, offering policy-makers a guide to making appropriate choices as they work to promote quality SSL products in their respective markets.

1.5.5 T6 – Quality and performance tiers

The SSL Annex has prepared voluntary quality and performance tiers to address product attributes such as color, lifetime, power, and efficacy for common SSL applications. These product performance tiers are a limited number of proposed performance levels, agreed upon by IEA SSL Annex members, which could be utilised by government, non-profit and donor agencies when designing programmes and policies. The objective is to provide a limited number of levels that can be utilised by programme designers to reduce costs of writing specifications and to facilitate economic advantages for industry/trade. Further, they help minimise compliance costs with SSL programmes and policies. Member countries are not obligated to use the tiers, and they are not international standards.

In this task work on the performance tiers documents are carried out. This is continued work in determining the type of SSL products to be considered and the quality parameters to be included and setting the tier levels. Measured and rated data for SSL products on the market is the backbone for the analysis leading to the tier levels. DTU Fotonik has provided measurements results for more than 250 LED lamps to this work. This work first resulted in a revision of the documents in November 2016, accessible on https://ssl.iea-4e.org/product-performance. These cover the types of SSL products shown in Figure 8.

Figure 8 Image from the webpage https://ssl.iea-4e.org/product-performance showing the different types of SSL products covered in the tiers documents.

Work in ongoing to update the documents and gathering more test data and rated data for SSL product on the market.

1.5.6 T7- New Features that Impact Energy Consumption

The IEA 4E SSL Annex launched a study on the energy performance of smart wireless lighting to show the extent of standby power consumption. Examination of the lamps as well as the communication protocols and gateways provides an evidence base for making policy recommendations to governments. This work on LED lamps and luminaires with new features, often called smart lamps and luminaires is led by Casper Kofod.

A measurement scheme has been developed for consistent measurement of smart lamps including and determining in which setting the lamps are to be tested in. These are to cover e.g. the dimming and tuneable white settings, of the individual lamps. Measurement parameters must include photometric, colorimetric and power parameters for the light in ON state and standby power consumption in standby mode and for additional gear like gateways. Photometric and colorimetric measurements of the lamp shall be carried out according to CIE S 025/E:2015, using an integrating sphere spectro-radiometer, including total luminous flux, correlated color temperature, chromaticity coordinates, color rendering index, power and efficiency.

Indicative Testing by laboratories in the participating countries have been performed, in Australia, Sweden and Denmark. In the project 23 different types of smart lamps have been purchased in Denmark and tested at DTU Fotonik in the 2m integrating sphere-radiometer system. These have been tested in a number of different settings in more than 90 measurements. In total, 34 different lamp models were tested. The sample size for each model tested is 1– 3 lamps but several models are tested at different laboratories so grand total is higher for some models.

The first report was published in September 2016 on the SSL Annex homepage, https://ssl.iea-4e.org/news/stand-by-of-smart-lamps with a description of the findings in the report, Task 7: Smart Lighting – New Features Impacting Energy Consumption that is downloadable on the same page. This constituted as part of the milestone M3. It was decided to make only two publications and the second will be published in autumn 2019, in the third term of the SSL Annex, in which the work is continued in task 7: Smart Solid-State Lighting.

In the following selected results on measurement of 34 smart lamp models are shown with respect to standby power consumption, efficacy, annual energy consumption and overall efficacy. The testing has revealed that the standby power consumption for the 34 different lamp models varies substantially between 0.15 W and 2.71 W as shown in Figure 9.

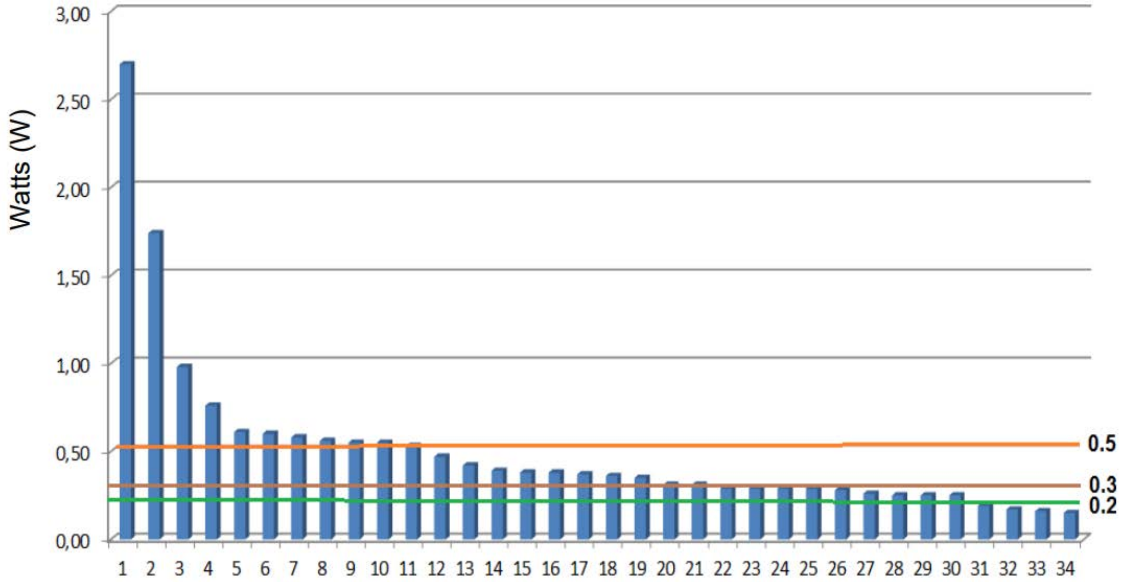


Figure 9 Measured standby power consumption for smart lamps

In homes in IEA 4E SSL Annex member countries, most lamps are used 1–2 hours/days[6]. When the lamp operation time is 1 hour per day (and 23 hours in standby mode), on average 51 % of the yearly consumption is used in standby mode. For 44 % of the lamps, the standby consumption is over 50 % of the total consumption.

[6] Assessment of the initial situation in the participating countries, PremiumLight, IEE/11/941/SI2.615944, Energy piano, 2013.

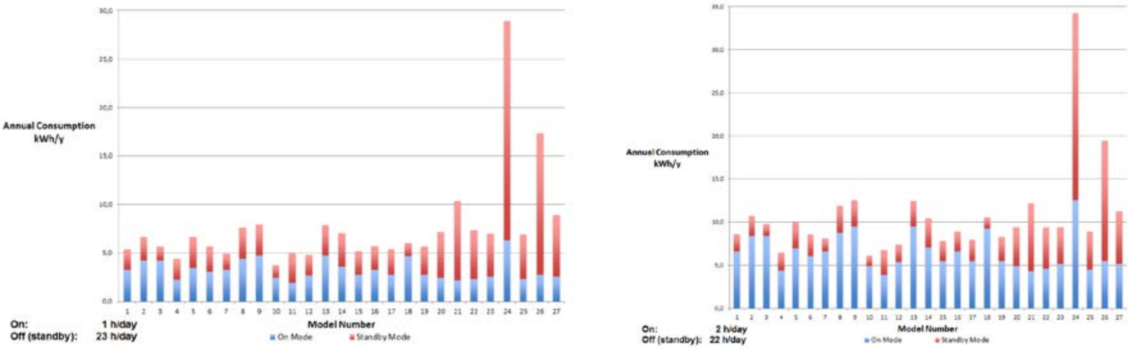


Figure 10 Annual energy consumption for 27 smart lamps models in operation 1 hours/day (left) and 2 hours/day (right)

For the ON mode, the lamp efficacies range between 34 and 87 lm/W which is lower than for standard LED lamps models of equivalent light output operated by the normal on/off switch. This is due to the additional internal electronic components associated with the 'smartness'. In this work the IEA 4E SSL Annex has defined a new key term: overall efficacy. The overall efficacy express luminous flux (the light output) per unit energy consumed taking into consideration both the energy consumed in ON plus in STANDBY mode. The duration the lamp is ON is called $Time_{ON}$ and the duration it is in standby mode $Time_{STANDBY}$. Using the measured total luminous flux and the ON and standby power measured the overall efficacy is given by:

$$Overall\ Efficacy = \frac{Luminous\ flux\ x\ Time_{ON}}{Power_{ON}\ x\ Time_{ON}\ +\ Power_{STANDBY}\ x\ Time_{STANDBY}}$$

The overall time period for the evaluation of the overall efficacy has to minimally be per day, but the accuracy improves with longer periods such as a week or a full year.

The measured efficacy and overall efficacy for the 27 smart lamps models are shown in Figure 11. The graph to the left shows the case when the lamp operation time is 1 hour per day (and 23 hours in standby mode). Here the overall efficacy varies between 9 and 51 lm/W, with an average 30 lm/W. For four of the lamp models tested, the overall efficacy is lower than the efficacy of incandescent lamps. The graph to the right shows the case when the lamp operation time is increased to 2 hours per day (and 22 hours in standby mode), and here the overall efficacy varies between 16 and 64 lm/W, with an average of 40 lm/W.

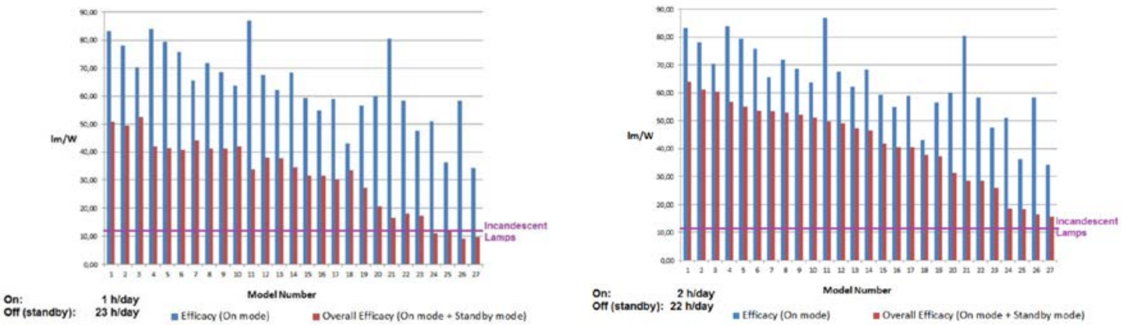


Figure 11 ON efficacy and overall efficacy for 27 smart lamps models in operation 1 hours/day (left) and 2 hours/day (right)

With 2 hours of operation per day, the overall efficacy of all lamps are higher than for incandescent lamps.

In the future, there may be dozens of wirelessly controlled smart lamps in every home, which taken together could result in very high standby power consumption. With these results the IEA 4E SSL Annex is working to raise awareness of standby energy consumption, and has issued a press release (http://ssl.iea-4e.org/news/smart-lighting) and given a number of presentations at conferences, seminars and workshops on this topic, see the list with entries marked with T7 in section T11 - Dissemination. In raising awareness on this important topic, manufacturers will be encouraged to make design improvements that lower the standby power consumption associated with smart lighting. It is suggested that policy makers state overall efficacy performance requirements for smart lamps.

This work is ongoing and many more lamps and luminaires have and are going to be tested. Data from the USA and Canada will be included. The results of these will be included in the 2nd report, which is expected to be published in late 2019.

1.5.7 T8 - Benchmarking Performance of SSL Products

In this Task an internal benchmarking database of solid- state lighting products has been produced and maintained. The purpose of the database is to enable member countries to share performance data and test results for LED lamps and luminaires. This database is to not be published in the public domain, but has been developed and used internally by SSL Annex member countries only. It would be populated with test data provided on a voluntary basis from member countries, and/or may also include other sources of data if deemed appropriate by the Task Leader. Carsten Dam-Hansen has taken the task leader work on this task. This is an additional task not included in the project from the start.

The database has a limited set of data fields that are of interest to policy makers, and will provide member governments with an on-going assessment of SSL product performance over time. The goal of the work is to make it possible for the SSL Annex members to share data, making decisions based on real data, provide data for updating performance tiers (T6), share measured data on smart lamps (T7), make comparisons of products between markets, evaluate performance over time, compare catalogue values to test results.

A database structure have been setup in excel, with a structure as shown in Figure 12, making it possible to relate Products (P#), (e.g. model info, rated data) with Artefacts (A#) (e.g. purchase info) and Measurements results (M#) (e.g. photometric, colorimetric data).

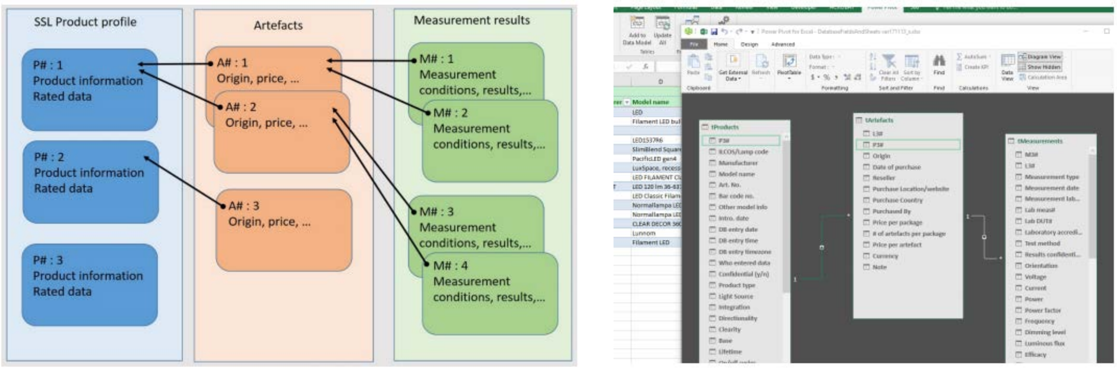


Figure 12 Structure of the internal SSL Annex database and implementation in excel power pivot tables.

A one-to-many relationship of products to artefact and artefacts to measurements has been established. This is set up using power pivot tools in excel and makes it possible to do excessive and powerful data analysis. The database and analysis tools are on a secure share site hosted by DTU Fotonik.

Data included is Lighting facts data (count 73733, no longer updated), TLM datafiles/rated data (approx. 1000 LED lamps), TLM (Flicker) measurements (approx. 200 LED lamps). The work is ongoing also in the third term and will include data from Design Light Consortium, the Australian dataset used in T6, and measured data for Smart lamps with new features in T7. This work is ongoing and will be continued in the third term.

One important issue identified under the SSL Annex work is temporal light modulation (TLM) from SSL products, and the effects it may have on humans, called temporal light artefacts

(TLA)[7], which may cause e.g. headache. This may be a problem due to the driver electronics in SSL products, like pulse width modulation drivers. New metrics for characterizing TLM, P_{st}^{LM} short-term light modulation and the SVM stroboscopic visibility measure, have been established and test methods published, see Table 2.

Table 2 List of TLM metrics and the related test methods.

Metric	Test Method
P_{st}^{LM}	IEC TR 61547-1:2017 "Technical Report: Equipment for general lighting purposes – EMC immunity requirements – Part 1: An objective voltage fluctuation immunity test method."
SVM	IEC TR 63158-1:2018 "Technical Report: Equipment for general lighting purposes - Objective test method for stroboscopic effects of lighting equipment."

In relation to the draft EU regulation for lighting products to be enforced from 2021, limits will be set on these two TLM metrics for SSL products. Due to the lack of research results on the visibility of stroboscopic effect for low values of SVM, the SSL Annex decided to initiate a research investigation on the visibility of stroboscopic effects of LED lamps. This has been conducted in 2018/2019 by Jennifer Veitch from NRC Canada and Christophe Martinsons from CSTB France. The project have supported this investigation in the construction of the experiments and commenting of reports. A report on these results and a scientific paper will be published in autumn/winter of 2019, as part of the third term of the SSL Annex.

In relation to TLM of LED lamps DTU Fotonik has done a comprehensive test of a number of filament LED lamps purchased in 2017 on the Danish and Swedish market. One of the important issues to be studied was the TLM under dimming conditions. Eight of the filament LED lamps were dimmable and the measured SVM (Visibility measure) is shown Figure 13 as a function of dimming level for the eight dimmable lamps. Here, 100 % dimming level means full power and light.

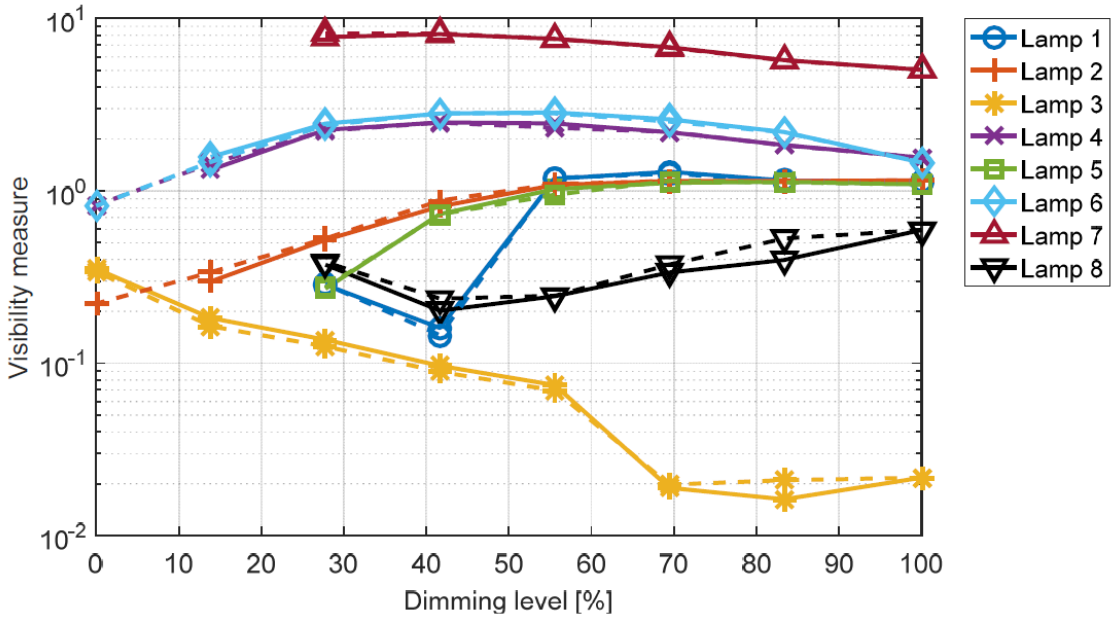


Figure 13 Stroboscopic visibility measurement results as a function of dimming level for the 8 dimmable lamps. Note that the y-axis is logarithmic.

From this it is seen that most of the lamps has quite stable SVM value as dimming level is adjusted. One exception though is Lamp 3, which possesses what could be called dimming

[7] CIE TN 006:2016 Visual Aspects of Time-Modulated Lighting Systems – Definitions and Measurement Models

introduced TLA, with an SVM of 0.02 at 100 % dimming level and 0.35 at 0 % dimming level. It remains under 0.4 for all dimming levels. Six of the eight LED lamps have higher SVM value than 1 at full load, which increased some under immediate dimming levels.
This work resulted in publication of a conference proceedings paper "Assessment of filament led bulbs with respect to temporal light artefacts", see Table 3 in T11 - Dissemination on page 17, which constitutes the second part of the milestone M3.

1.5.8 T9 Lighting Facts international database

The intent of the SSL Annex was to make an international version of the Lighting Facts database, as is used in the USA. However the Lighting Facts has been discontinued for LED lamps and it was not possible to produce the intended database. Therefore this task was closed and it was decided to investigate the possibility of making an internal database for the SSL Annex. This new task was transferred to task 8 and Carsten Dam-Hansen was appointed task leader for this task, see T8 - Benchmarking Performance of SSL Products.

1.5.9 T11 - Dissemination

The project results have been disseminated though reports, scientific journal articles, talks, posters and proceedings at conferences and also articles in trade magazines and through talk at events for a broader group of stakeholders. The SSL Annex reports are published on the website: https://ssl.iea-4e.org/ and direct links to these are included in the list. Table 3 contains a list of the dissemination work carried out in the project, with direct links to available documents and with indication of the related tasks and milestones.

Table 3 List of dissemination work carried out in the project, with direct links to available documents.

	Description	Type of dissemination	Related Task (Milestone)
	Carsten Dam-Hansen, "Status for standardiseringsarbejdet omkring LED", DCL arrangement hos Philips, 14. september 2014	Invited talk	T1
	Casper Kofod, "IEA fremmer global LED harmonisering", LYS, 2014.	Article	
	Casper Kofod, "New Features impacting LED Energy Consumption", Joint workshop at IEA 4E EXCO meeting, 5. Nov. 2014, Jeju Island, South Korea,	Talk at IEA 4E EXCO meeting	T7
	Carsten Dam-Hansen, "LED Lunch Talk: Properties of LED - for museum lighting applications", 24 Feb. 2015, DTU Library, Kgs. Lyngby https://www.bibliotek.dtu.dk/Kalender/Arrangement?id=3e4f08a5-d479-4c19-8859-10c56bcefd39	Invited talk with online view	T11, T1
	Anders Thorseth og Carsten Dam-Hansen, "Giver LED-pærer det samme lys i Kina. Danmark og USA?", LYS 3, 2015	Article	T1, T4
	Carsten Dam-Hansen, "Test og karakteristik af LED-lyskilder og lamper", gå-hjem arrangement om "LED belysning" på DTU Fotonik, Risø for KASER – Efteruddannelsesudvalget 16 Sep 2015 https://orbit.dtu.dk/files/116552829/Test_og_karakteristik_af_LED_lyskilder_og_lamper.pdf	Invited talk	T11, T1
	Anders Thorseth, " LED teknologi og smarte energibesparelser" ved KlimarKlar Gladsaxe, møde om belysning, 11 Nov 2015, Søborg https://orbit.dtu.dk/files/117860128/20151029_KlimaKlar_m_de_om_LED_11._november_2015.pdf	Invited talk	T1, T7, T8
	2nd Stakeholder Workshop of EMRP ENG62 MESaIL, Anders	Workshop	T1

	Thorseth, 26 Nov 2015 http://www.eng62-mesail.eu/typo3/index.php?id=115		
	Dam-Hansen C., Amdemeskel M., Thorseth A., Corell D., Lindén L., Markussen T., and Krause C, "Analysis of Compact and Portable Goniospectrometer System for Test of LED Lamps", in Proceedings of 28th CIE Session 2015., OP10 131, 28th Session of the International Commission on Illumination, Manchester, United Kingdom,	Conference poster and article in proceedings	T8
	Thorseth, A, Lindén, J, Corell, DD & Dam-Hansen, C, "Goniometric characterization of LED based greenhouse lighting". in Proceedings of 28th CIE Session 2015., OP10 131, 28th Session of the International Commission on Illumination, Manchester, United Kingdom,	Talk and article in proceedings	T4
	Casper Kofod, "Is Smart Lighting Energy Smart", EEDAL, 8th international conference on Energy Efficiency in Domestic Appliances and Lighting", 26-28/8 2015, Lucerne, Switzerland.	Talk at conference	T7
	Nils Borg, Casper Kofod, "New Features impacting Energy Consumption", Prepared for and presented by at IEA 4E EXCO Breakout Meeting, 5 October 2015, Tokyo, Japan.	Talk at IEA 4E EXCO meeting	T7
	Anders Thorseth, "Auxiliary correction in goniophotometry, simulation and measurement", 25 Nov 2015, CIE Tutorial and Expert Symposium on the CIE S025 LED Lamps, LED Luminaires and LED Modules Test Standard, http://div2.cie.co.at/?i_ca_id=974	Talk at symposium and article in proceedings	T1, T4
	Casper Kofod, "Is Smart Wireless Lighting also Energy Smart", Strategies in Lighting Europe, 18 Nov 2015, London, UK	Talk at conference	T7
	"LED-pæren er blevet boligegnet", Article in Berlingske Boligen, 28 Feb 2016	Article	T6, T7, T8
	Anders Thorseth, "DTU Fotonik, SSL activities, DOLL green lab", Japan Lighting Manufactures Association visit to DOLL labs 17 Mar 2016, https://orbit.dtu.dk/files/122736405/Amg2016_03_16_2445_2.jpg	Talk and Lab visit	T1
	Thorseth, A., Lindén J., Dam-Hansen C., "A comparison of goniophotometric measurement facilities" in Proceedings of CIE 2016 "Lighting Quality and Energy Efficiency". CIE - International Commission on Illumination, 2016. p. 547-554. https://orbit.dtu.dk/files/127706234/gonio_comparison_CIE_2016_full_paper_submitted.pdf	Conference poster and article in proceedings	T4
	Casper Kofod et Al, "Task 7: Smart Lighting – New Features Impacting Energy Consumption", IEA SSL Annex, Sept. 2016, http://ssl.iea-4e.org/files/otherfiles/0000/0085/SSL_Annex_Task_7_-_First_Report_-_6_Sept_2016.pdf	Report published by IEA SSL Annex	T7 (M3)
	LED Conference 2016 "Nordic Light Quality – International Standards", 7 Nov 2016, Roskilde, Denmark http://conferencemanager.events/ledmet2016/	Conference, workshop	T1, T7, T6, T8
	Carsten Dam-Hansen, "Measuring angular light distribution of lamps and luminaries", Nordic Light Quality – International Standards – LED Conference, 7 Nov. 2016, Roskilde, Denmark.	Talk at conference	T1, T4 (M1)
	Casper Kofod, "Smart Lighting Impacting Energy Consumption", Nordic Light Quality – International Standards – LED Conference, 7 Nov. 2016, Roskilde, Denmark.	Talk at conference	T7, T1 (M1)
	Lotte Krull, "Koldt LED-lys truer nordisk hygge", DYNAMO, 26 May 2017, https://www.dtu.dk/om-dtu/nyheder-og-presse/dynamo1/2017/05/koldt-led-lys-truer-nordisk-hygge?id=ff8776ff-c85a-431f-83a3-06be858c69c7	Article	T1, T6, T8
	"Lessons Learned Bringing LEDs to Market" June 2017	Report pub-	T5, T10

	https://ssl.iea-4e.org/files/otherfiles/0000/0106/Task_5_-_Lessons_Learned__Report_v9_final.pdf	lished by IEA SSL Annex	
	Casper Kofod, "Smart Lighting – New Applications and Power Use", IEA 4E SSL Annex Conference on Promoting High Quality, Energy-Efficient Solid State Lighting, 23 November 2017, Sydney, Australia https://ssl.iea-4e.org/files/otherfiles/0000/0123/8._Kofod_Smart_Lighting_-_Sydney.pdf	Talk at SSL Annex conference	T7
	Y. ohno et Al, "Task 1: Application Study of CIE S 025/E:2015", IEA SSL Annex, June 2017, http://ssl.iea-4e.org/files/otherfiles/0000/0110/Task_1_Application_Study_-_Final_Report.pdf	Report published by IEA SSL Annex	T1
	Lindén J, Thorseth A, Corell DD, Dam-Hansen C. "Assessment of filament led bulbs with respect to temporal light artefacts." In Proceedings of the Conference on "Smarter Lighting for Better Life" at the CIE Midterm Meeting 2017. CIE - International Commission on Illumination. pp. 718-727. Available from: 10.25039/x44.2017.PP38	conference poster and article in proceedings	T6,T7 and T8 (M3)
	Thorseth, Anders and A. S. J. Bergen "Light source characterization and air movement under CIE S 025". *Proceedings of the Conference on "Smarter Lighting for Better Life" at the CIE Midterm Meeting 2017.* CIE - International Commission on Illumination. 2017, 63-72. https://doi.org/10.25039/x44.2017.OP07	Talk at conference and article in proceedings	T1
	Yoshi Ohno, Geust lecturer, DTU Fotonik is hosting NIST Fellow and CIE President Yoshi Ohno, "Measurement uncertainty and color rendering metrics", 9-17 Aug 2018	Workshops	T1, T4
	Anders Thorseth and Carsten Dam-Hansen,"LEDMET Laboratory intercomparison", March 2018, http://ledmet.dk/wp-content/uploads/2018/03/LEDMET-laboratory-intercomparison-report.pdf	Report published on LEDMET.dk	T4, (M2)
	"CIE Practical Workshop on Goniophotometry under CIE S 025", Anders Thorseth, Tony Bergen, 5-7 November, 2018, Moscow, Russia, http://cie.co.at/news/cie-tutorial-and-practical-workshop-cie-s025	Workshop	T1, T11
	Anders Thorseth, "Introduction to CIE S 025, Introduction to the Standard, CIE Tutorial and Practical Workshop on CIE S025 7 November, 2018, Moscow, Russia	Talk at workshop	T1
	Anders Thorseth, "Electrical Measurements of SSL Lamps and Luminaires", CIE Tutorial and Practical Workshop on CIE S025 7 November, 2018, Moscow, Russia	Talk at workshop	T1, T4
	Carsten Dam-Hansen, Anders Thorseth, "Internationalt samarbejde om LED-belysning fortsætter", LYS 1, p.34, 2019	Article	All
	Carsten Dam-Hansen, Johannes Lindén, "Nyt om farvegengivelse", LYS 1, p.34, 2019	Article	T1, T6
	Lindén, Johannes, Carsten Dam-Hansen, and Anders Thorseth "Beat Flicker – A Temporal Light Artefact due to Multiple Sources of Time Modulated Light". *Proceedings of the 29th CIE SESSION.* CIE - International Commission on Illumination. 2019. https://doi.org/10.25039/x46.2019.PO079	conference poster and article in proceedings	T6, T8
	Thorseth, A, Lindén, J & Bergen, "Measuring and Comparing Waveforms of Temporal Light Modulation." in *Proceedings of the 29th Quadrennial Session of the CIE.* CIE Commision Internationale de L'eclairage , pp. 7-16, 29th Quadrennial Session of the International Commission on Illumination , Washington DC, United States, 14/06/2019. https://doi.org/10.25039/x46.2019.OP02	Talk at conference and article in proceedings	T6, T8

1.6 Utilization of project results

The project has through the international collaboration in the SSL Annex gained knowledge and results that is applicable to the partners directly in their consultancy, testing and research work. It has further been valuable for the lighting regulation work of the Danish Energy Agency and the "Sekretariat for Ecodesign og Energimærkning af Produkter". On the other hand the SSL Annex has also gained from the Danish participation through the two Danish experts who has brought their inputs to the joint work on behalf of the Danish Energy Agency.

DTU Fotonik's and Energy Piano's work in consultancy has been boosted though the gained knowledge and we are able to give better advice for the Danish lighting industry and consumers on both quality and testing of SSL products. This goes especially for LED smart lamps and LED filament lamps on issues of standby energy consumption and temporal light modulation.

New research projects have been initiated by DTU Fotonik on background of the work in the SSL Annex, in new lighting technologies and lighting metrology. Further research applications for work on Temporal Light Modulation and associated artefacts of SSL products are in are in the writing process.

The Danish lighting industry have through the project work gained valuable knowledge on the application of the new international LED test standard, CIE S025 and the identical CEN standard EN13032-4, to be able to get and/or make more reliable and consistent measurements on SSL products. The Danish testing and industrial laboratories using goniophotometer systems have tested their proficiency in measurements of SSL lamps and luminaires. This was done in both the national and the SSL Annex IC2017 interlaboratory comparison. Many of the laboratories are using non-compliant goniophotometer systems. They can use the comparison results to show that they get equivalent results as the reference laboratory and hence demonstrate compliance to the test standard. This is important for testing laboratories and especially for Viso Systems, the Danish manufacturer of goniospectroradiometer systems.

1.7 Project conclusion and perspective

The project has provided the active Danish participation in the second term of the SSL Annex, 2015 – 2019, through the work of Casper Kofod, Energy Piano and Carsten Dam-Hansen, DTU Fotonik. This has been done through attendance and involvement in the SSL Annex work, including expert meetings, task leaderships, data analysis, document and report writing and proof reading.

A widespread dissemination work directed towards Danish stakeholders, consultancies and lighting industry has been carried out, to ensure a good transfer of knowledge to and from the SSL Annex. A listing of all the dissemination work done in the project has been given, including articles in Danish trade magazines, invited talks at national events, workshops, talks and poster presentations at conferences. The application and use of the new international LED test standard CIE S025 has been in focus of more than half of the dissemination work. A workshop on this, gathering around 100 participants was arranged and held by DTU Fotonik in Roskilde. Two interlaboratory comparisons, a national and the international IC2017, both using goniophotometers for SSL product testing has been arranged and executed. The Danish comparison showed a high degree of equivalence yielding expanded uncertainties of 6.3% and 3.3 %, on luminous flux and luminous intensity, respectively. DTU Fotonik participated in the IC2017 with two types of goniophotometers representable for the Danish industry laboratories, who will be able to utilise the results to document their compliance with the new international test standard, CIE S025 and the identical CEN standard EN13032-4. The results on the IC2017 for four types of LED lamps and luminaires are pending and expected to be delivered in autumn 2019. This will be analysed by DTU Fotonik and transferred to the participants of the national interlaboratory comparison, in relation to their goniophotometer systems.

In the benchmarking of SSL products DTU Fotonik has concentrated the work on LED smart lamps and LED filament lamps and have included temporal light modulation measurements. Results of this is a report on temporal light modulation investigation of LED filament lamps under dimming conditions. Other member countries laboratories have done testing of LED

smart lamps and this has been used in the first SSL Annex Report on Smart Lighting – New Features Impacting Energy Consumption, where a new overall efficacy of smart lamps is introduced. This work has been continued and a second report on this is expected to be published late 2019, including new results on smart LED luminaires.
The SSL Annex work will be continued in a third term of the SSL Annex, 2019-2024, which has been approved by the SSL Annex Management Committee and the 4E Executive Committee. The Danish participation continues in the form with two Danish experts, Casper Kofod and Carsten Dam-Hansen This will be financed through the EUDP project "Global SSL quality requirements and test - IEA-4E-SSL". The Danish Center for Lighting will be part of the work in order to strengthen the dissemination of project results to Danish stakeholders, in the lighting industry.
The task list for the third term of SSL Annex the new task are listed in Table 4.

Table 4 List of task in the third term of the SSL Annex, 2019-2024.

Task #	Title
1	Human Centric Lighting, Health and Comfort
2	Lifetime of SSL Lamps and Luminaires
3	Lighting and the Environment
4	Interlaboratory Comparison for Temporal Light Modulation
5	Test Method Assessment
6	Quality and Performance Tiers
7	Smart Solid-State Lighting
8	SSL Annex Product Database

Casper Kofod and Carsten Dam-Hansen are appointed task leaders for task 7 and 8, respectively. Hence, the work on smart lamps and luminaires and the database for rated and tested parameters for SSL products, will be continued.
A third interlaboratory comparison of measurement of Temporal Light Modulation of SSL products are planned. This is a very important issue in SSL at the moment, and the first lighting regulations setting limits on parameters for Temporal Light Modulation will be enforced from 2021. Further collection of evidence based research results on the health effects is an important aspect of the work to be done. In the coming project collaboration with the Danish Safety Technology Authority will be prioritised, since they have been appointed to undertake the market monitoring, verification & enforcement work in Denmark.

Annex

Relevant links have been included in the text and in Table 3.