Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 78 (2015) 2675 – 2680

Energy Procedia

6th International Building Physics Conference, IBPC 2015

European EMRP Projects About LED Lighting

Paola Iacomussi, Michela Radis, Giuseppe Rossi*

Department of optics, INRIM, Strada delle Cacce 91, 10135 Torino Italy

Abstract

Industrial and testing lighting laboratories underestimated the intrinsic metrological peculiarities of LED sources: concerns about performances, efficiency, ambiguous data and visual perception "de facto" slowed down their widespread implementation and their use in innovative systems in the first years of marketing. EU recognized these problems and funded projects with the European Metrology Research Programme (EMRP) to give a strong metrological basis to their optical, photometric and radiometric characterisation. The European Commission and the participating countries within the European Association of National Metrology Institutes (EURAMET) jointly support the EMRP. The overall goal of the EMRP is to accelerate innovation and competitiveness in Europe, enabling European metrology institutes, industrial organisations and academia to collaborate on joint research projects within specified fields. Among the EMRP programme two different 3 years projects about LED Lighting were funded in two different "Energy" calls: in 2010 "EMRP ENG05 Metrology for Solid State Lighting", and in 2014 "EMRP ENG62 Metrology for Efficient and Safe Innovative Lighting".

Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL

Keywords: LED lighting, metrology, efficiency, European Community

1. Introduction

LED lighting is a very promising light source, indeed the recent Nobel Prize for blue LED emphasizes the expected role of LED lighting in worldwide economy. EU knows that the energy demand for lighting is about 20% of electricity use, so in the recent years, different research programmes about LED lighting were funded. This paper focuses on two different projects funded by EU trough EURAMET, to improve LED knowledge, measurement methods and LED characteristics evaluation, including quality, standard and safety.

* Corresponding author. Tel.: +39 011 3919 228; fax: +39 011 346384.
E-mail address: p.iacomussi@inrim.it

Peer-review under responsibility of the CENTRO CONGRESSI INTERNAZIONALE SRL
doi:10.1016/j.egypro.2015.11.345

EURAMET [1] is *"the European Association of National Metrology Institutes a Regional Metrology Organisation of Europe. It coordinates the cooperation of National Metrology Institutes (NMI) of Europe in fields like research in metrology, traceability of measurements to the SI units, international recognition of national measurement standards and related Calibration and Measurement Capabilities (CMC) of its members"*. EURAMET is responsible for the elaboration and execution of the European Metrology Research Programme (EMRP) [2] funded by EU and participating countries.

The overall goal of the EMRP is to accelerate innovation and competitiveness in Europe, enabling European metrology institutes, industrial organisations and academia to collaborate on joint research projects within specified fields.

EMRP Programme started in 2008 with a seven years durations and a budget of about 400M€: in 2015 EURAMET launched the new research programme EMPIR (European Metrology Programme for Innovation and Research), the scope of this new programme is to increase focus on innovation activities to target the needs of industry and accelerate the uptake of research outputs.

Among the EMRP programme two different 3 years projects about LED Lighting were funded in two different "Energy" calls: in 2010 "EMRP ENG05 Metrology for Solid State Lighting" [2], and in 2014 "EMRP ENG62 Metrology for Efficient and Safe Innovative Lighting" [3].

2. The research programme JRP ENG05 "Metrology for Solid State Lighting"

The project ENG05 [3] was coordinated by the Dutch Metrology institute, VSL, and had the participation as funded partners of the NMI of Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, Netherland (project leader), Portugal, Slovakia, Spain, Sweden, Switzerland and United Kingdom. University of Sussex and of Delft received funding for participating in the project trough dedicated grants while the Centro Restauro "La Venaria Reale" participated as an unfounded partner.

The project started in April 2010 and had a duration of 36 months with a budget of 3,5M€. The project supported the large scale implementation and application of energy saving SSL through the development, validation and dissemination of adequate metrology for the unambiguous and reliable characterization of solid state lighting products. National and International standards are under development. Indeed industrial and testing lighting laboratories underestimated the intrinsic metrological peculiarities of the of LED sources: concerns about performances, efficiency, ambiguous data and visual perception "de facto" slowed down their widespread implementation. ENG05 had the task to develop the metrological background and infrastructure to correctly characterize LED. It was organized in four different workpackages:

- WP1: Traceability for SSL measurements;
- WP2: Measurement methods for SSL characterization;
- WP3: Human Perception of SSL;
- WP4: Quality metrics for SSL characterization.

2.1. WP1 Traceability for SSL measurements

WP1 focused on traceable measurements of electrical and optical power, of mesopic quantities, of spectral quantities, and methods of calibration for near field goniometers.

The main results are about traceability of electrical quantities, pulsed LED and mesopic devices.

In the future more and more pulsed SSL will be available on the market, NMI must be ready for calibration of new devices for pulsed sources: a calibration facility and a measurement method for tristimulus meters up to 200 kHz were developed during the project.

For mesopic measurements, the publication in 2010 of a CIE Technical Report about Mesopic [4], finally allowed the development of new instruments able to measure light quantities considering the function of adaptation of the human eye in the mesopic transient state. In ENG05 project, two different mesopic measurement devices, luminance and illuminance meters, were designed and build and the traceable calibration procedure provided. This is very interesting because the expected major use of SSLs is for street lighting, where the light conditions are different than for photopic (daylight) vision. Using mesopic meters to measure road lighting condition could assure the best energetic performance. This situation was not completely recognized in the new European standard about road lighting prEN 13201:2013-5 [5] also for the lack of instrument of this type.

2.2. WP2 Measurement methods for SSL characterisation

WP2 focuses on the measurement methods for SSL characterization and improvement on the measurement accuracy of electrical, spectral goniometrical and life time characteristics.

About electrical measurements, the main results were on electrical power and power factor measuring, considering the impact of the source impedance on current waveform and the high frequency current emission of SSL. Depending on the complex impedance of the current source used for the measurement, errors of up to 9 % were observed. A special stabilisation network was designed to reduce the effects of current source impedance to better than 0.02%, allowing electrical measurements with an unprecedented accuracy.

SSL devices are claimed to have long lifetime, most rated with 50 % - 70 % lumen maintenance after 30.000 to 50.000 hours of operation. Verifying such long lifetime claims is not practical and therefore alternative methods for predicting the lifetime of SSL products are needed. The approach taken in the project was to monitoring junction temperature and spectral changes of SSL products, as these are believed to be intimately connected to SSL lifetime.

2.3. WP3 Human perception of SSL

The human perception is a key factor for the widespread implementation of LED sources on the market especially for interior lighting. Results highlighted that available glare metrics seems to be applicable for SSL luminaires if they do not significantly differ from linear or compact fluorescent lighting (so with LED not clearly visible or with some kind of diffusing surface). Existing criteria seems not to be applicable for non-uniform sources with LED clearly visible.

Several subjective experiments were set up to investigate SSL influences on human perception: it was proven that radiometric influences (SSL emitted spectrum) on glare are negligible with respect to incandescent light source spectrum, SSL spectrum always gives a smaller pupil diameter, if compared to other two tested sources (incandescent and metal halide lamps).

A very big experiment was set up to suggest a mathematical model to describe parameters that directly influence visual comfort, four different lighted environments were tested. This experiment showed that the UGR formula is well correlated with subjective rating in a simple lighting set-up, lamps in uniform background, and also in a complex environment of a living room with wall and ceiling luminaries.

Because a widely accepted definition of human comfort does not exist, the results were used to attempt a mathematical model able to link quantitative parameters to a discomfort index. The first step was to define a weight to influences on visual comfort of interior lighting measurable parameters The following synoptic table provides a ranking of the most relevant parameters as emerged from experiments on visual comfort with SSL. Set up coming from experiments gives to glare the maximum weight, so it is clear that glare is one the most effective parameters people uses to judge the comfort of a lighting installation Available literature, like [6] did not provide a ranking but only a list of parameters to satisfy for assuring visual comfort, the main parameters for indoor lighting are described in [7]. Only IESNA document [8] provides a ranking of parameters for assuring a good lighting quality in indoor lighting but is valid for traditional lighting (i.e. fluorescent lamps). Following the precaution already described with LED sources a good accordance can be achieved.

Table 1Ranking of relevant parameter of visual comfort model for SSL lighting

Taskrelated lighting		Livingroom lighting		Compartment lighting		Office lighting	
Parameter	Weight	Parameter	Weight	Parameter	Weight	Parameter	Weight
Light distribution (uniformity on target)	100	Glare (low UGR value)	100	Glare (low UGR value)	100	Glare (low UGR value)	100
Contrast object/background	100	Contrast object / background	27	Lighting levels	33	Light distribution (uniformities)	17
Background uniformity	100	Luminaire appearance	27	Contrast object / background	33	Contrast object / background	12
Target averaged luminance	80	Lighting levels	18	CCT effects	11	CCT effects	12
Lightinglevels	75	CCT effects	9	Colour rendering	6	Lighting levels	6
Luminaire appearance	50	Colour rendering	5	Light distribution (uniformities)	not relevant	Mixing effects of CCT in the visual field	6
Glare (low UGR value)	50	Mixing effects of CCT in the visual field	not relevant	Luminaire appearance	not relevant	Colour rendering	3
CCT effects	not considered	Light distribution (uniformities)	not relevant	Mixing effects of CCT in the visual field	not relevant	Luminaire appearance	not relevant
Colour rendering	not considered	Target averaged luminance	not considered	Target averaged luminance	not considered	Target averaged luminance	not considered
Mixing effects of CCT in the visual field	not considered	Background uniformity	not considered	Background uniformity	not considered	Background uniformity	not considered

2.4. WP4 Quality Metrics for SSL characterization

WP4 aims to harvest from the metrological and research work carried out in WP1, WP2 and WP3 and translate this into the language of pre-standard guidelines, manufacturers and users, producing understandable metrics. □

As SSL technology continues to improve in light output, efficacy, durability, colour quality, product offerings, and cost, SSL luminaires are becoming available for a broader range of lighting applications. Application specific quality metrics are unfortunately lagging behind. Next to that, new innovative SSL installations such as in street and tunnel lighting require new maintenance and optimisation procedures to exclude inefficient use. □

The WP produced as quality metric result a set of parameters able to characterize performances of SSL as:□stand-alone devices, luminaires and performances of the lighted environments and lighting instalaltions.

The parameters could be physical or psychophysical quantities, quality factors and performance criteria and are strongly related to the lighting application. As example we present the case of spatial distribution of Correlated Colour Temperature (CCT) and of Colour Rendering Index (CRI).

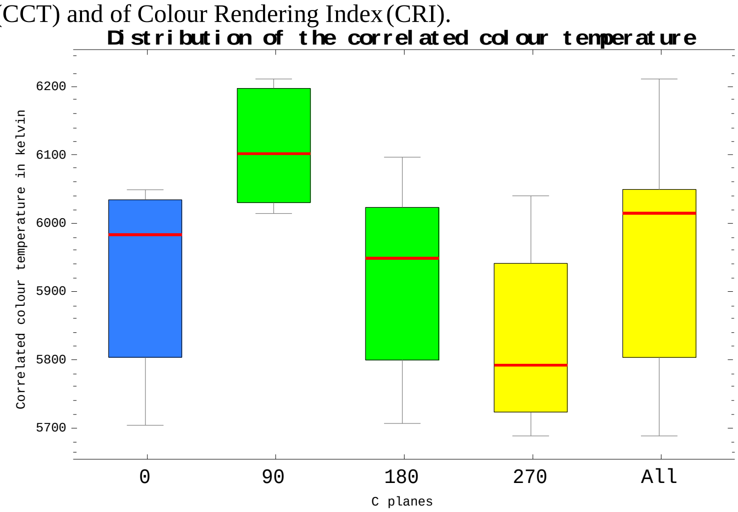

Figure 1 Spatial distribution of CCT of a LED luminaire, in the 4 main C planes (Spatial reference system CIE Cγ)

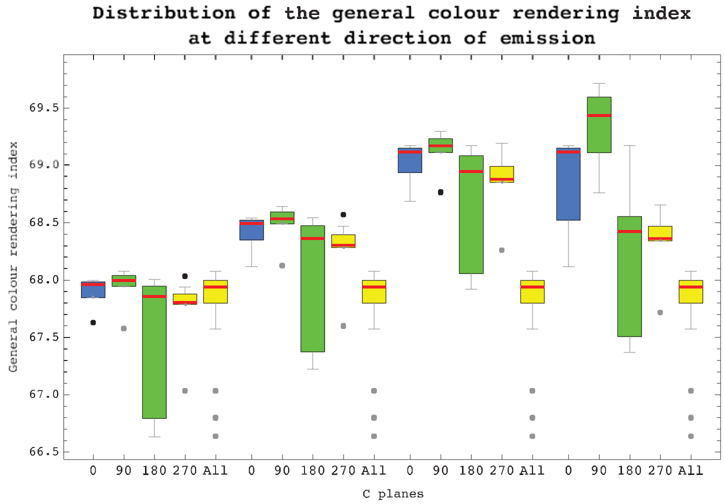

Figure 2 CRI distribution among the γ angles for 4 different LED luminaire, for the main 4 C planes (Spatial reference system CIE Cγ)

Available standard and technical documents suggest only to evaluate the CCT and CRI properties of SSL sources and luminaire without any additional specification about spatial condition of measurement: the research highlighted differences up to 2 CRI units and 3000 K in CCT depending on the γ angle of emission. These differences lead to big difference in the perception of lighted environment.

2.5. ENG05 dissemination

For a detailed list of documents, please refers to the project web site [3]. The main products of the projects are:

- 2 public reports, available for download on the project website [3];
- 24 peer-reviewed journal articles;
- 62 conference presentations, articles in trade journals or popular press, exhibitions at trade shows or network events, and other dissemination activities;
- 8 recommendations submitted to standardization bodies;
- 2 patents.

3. The research programme JRP ENG62 "Metrology for Efficient and Safe Innovative Lighting"

EU community recognized the advanced in metrology achieved with JRP ENG05, but also recognizes the importance of new researches to quantify the needs for novel SSL, like OLEDs/OLED arrays, pulsed SSL nano-structured and flexible LED systems. This project has the participation as funded partners of the NMI of Czech Republic, Finland, France, Germany, Italy, Netherland (project leader), Spain, Sweden, Switzerland and Turkey. University of Delft, of Braunschweig and the Istitut National de la Santé et de la recherché médicale received funding for participating in the project trough dedicated grants. The NMI of Brasil and OSRAM contribute to the project as unfunded partners.

The project started in June 2014 and will go for 3 years, all information up-to-date are available on the project website. The technical objectives of this JRP are:

- Develop sets of optical and electrical reference standards to calibrate as well as to characterise the setups used in testing laboratories and to verify their capability to perform particular measurements of novel SSL;
- Improve measurement methods and decrease uncertainty in photometrical parameters of OLED measurements, electrical power measurements of AC-operated (developing an impedance stabilization network) and pulsed SSLs.

- Study the feasibility of using standard measurement equipment for 3D complex goniometric measurements of large area and complex SSL (3D nano-structured);
- Deliver a full set of metrics for safety and comfort aspects of novel SSL through development of full measurement solutions and by performing physiological studies on (a) flicker/stroboscopic effect, (b) blue hazard, (c) well-being/comfort experience and (d) lighting quality perception.
- Develop measurement solutions and establish traceability for lifetime and reliability testing of SSL products. Investigate various aging mechanisms involved in material degradation of novel SSL devices.
- Create high impact through: 1) close collaboration with – and promotion of developed measurement solutions (for pulsed SSL and lifetime) among – industrial stakeholders, 2) promotion of the developed transfer standards for testing laboratories worldwide, 3) establishment of a reportership in CIE to recommend creation of a technical committee and publication of international CIE recommendations based on the work of Objective 1, and 4) delivery of guidelines and matrices for safety and comfort aspects to the relevant TCs in CIE /CEN.

A particular emphasis in this JRP will be on providing input to standardisation activities. Efficient knowledge transfer to International and European standardisation organisations (CIE, ISO and CEN) is embodied in the JRP. Several dedicated reports, relevant guidelines and recommendations will be delivered. For instance, a formal reportership to CIE Division 2 will be established to facilitate the dissemination of the results.

The project is arranged in five different work packages:

- WP1 will develop transfer standards for test laboratories that can be used as references not only in performance measurements of the key optical and electrical parameters of novel SSL products but also to validate the facilities/setups;
- WP2 will develop traceable measurement methods to measure important but challenging properties of novel SSLs such as the 3D light distribution from large area OLEDs and next generation SSL (e.g. 3D nano-structured LED and flexible Chip on Flex) and the electrical and optical characteristics of AC/DC/short pulse driven dimmable SSLs;
- WP3 will address the metrological needs for safety: such as photo-biological safety and flicker aspects, and metrics for comfort/well-being aspects;
- WP4 will bring traceability to lifetime prediction and reliability measures, but also will probe the physics of ageing mechanisms, allowing uncertainties to be assigned to the measured parameters for the first time;
- WP5 will incorporate a range of activities designed to maximise stakeholder interaction and the uptake of JRP results;

Because the project just started it is a good opportunity for people interest in to follow the project as stakeholder in order to not miss the opportunity of having direct access to all project results.

Acknowledgements

This work is part of the European research project “Metrology for Solid State Lighting” EMRP Project ENG 05 and European research project “Metrology for Efficient and Safe Innovative lighting” EMRP Project ENG62. The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

References

[1] http://www.euramet.org
[2] htttp://www.emrponline.eu [
3] htttp://www.m4ssl.npl.co.uk
[4] CIE 191:2010, Recommended System for Mesopic Photometry based on Visual Performance, CIE , Wien
[5] prEN 13201:2014-Part 5, Road lighting- Energy performance requirements,
[6] CIE 2013 CIE 205:2013 Review of lighting quality measures for interior lighting with LED lighting systems, Vienna: CIE
[7] EN 12464-01:2011 Lighting of work place – Indoor work places
[8] IESNA 2000,*IESNA Lighting Design Guide* in *The IESNA lighting handbook. Reference & application*. 9th edition. New York: Mark S. Rea
[9] http://www.eng62-mesail.eu