Publishable JRP Summary Report for Project ENG05 Lighting "Metrology for Solid State Lighting"

Need for the project

Solid-State Lighting (SSL) has the potential to revolutionize the efficiency, appearance and quality of lighting as we know it. SSL is the most efficient lighting technology available; although current products are still in their early stages of development, it is predicted to become twice as energy efficient as fluorescent lamps and more than ten times as efficient as incandescent lamps. As one fifth of global electricity consumption is for lighting, a considerable reduction in energy consumption could be obtained by replacing conventional lighting products by SSL technology. However, both professional users and consumers have been reluctant to embrace solid-state lighting, often due to previous unjustifiable or simply false claims about "low energy" lighting product performance.

To improve user confidence in manufacturer's claims for this technology, and to encourage its use, an extensive program is required including new research, measurement capabilities, and Standards that will allow unambiguous data on SSL to be determined. Existing conventional photometric guidelines work well for incandescent lighting sources, but when applied to SSL, do not provide unambiguous results for efficacy, light intensity distribution, lifetime and colour rendering.

Project objectives

This project supports the large scale implementation and application of SSL through the development, validation and dissemination of adequate metrology for the unambiguous and reliable characterization of solid state lighting products.

The measurement capability developed will enable measurement laboratories to provide unambiguous information on SSL products, based on new technical guidelines and methods. This in turn will enable

- designers, producers and importers of SSL products to make reliable and verifiable product claims;
- policy makers to develop fact-based policy;
- market surveillance authorities to combat unfair trade practices based on faulty claims;
- users to select the best-fit products for their application.

The project develops essential measurement facilities and basic measurement methods, but also carries out application focused research to understand practical problems and to develop relevant quality metrics. By combining both aspects, a measurement infrastructure is being created which is both scientifically sound and corresponds to the real needs of the users. Through interaction with standardization organizations and accreditation bodies, the infrastructure is cemented into place.

EMRP European Metrology Research Programme Programme of EURAMET

The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

Project structure

The technical work within the project is divided into four aspects:

Traceable measurement facilities

- Electrical measurement systems
- Time-resolved measurements
- Mesopic photometers
- Spectral effects in measurement systems
- Near-field goniometry
- Environmental influences

Measurement methods

- Electrical characterisation
- Efficacy
- Goniometric measurements
- Lifetime

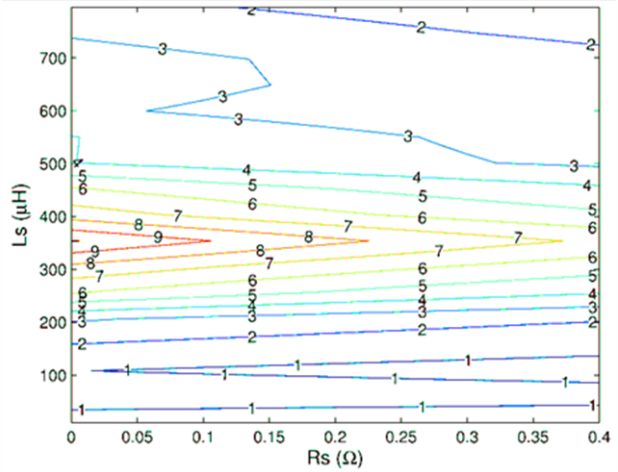
Human perception

- Colour quality
- Visual comfort
- Mesopic and scotopic vision

Application specific quality metrics

- Measurement equipment
- Indoor lighting
- Road lighting
- Greenhouses
- Art

Project highlights

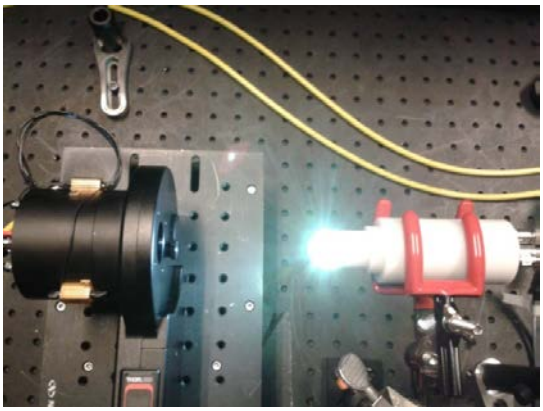


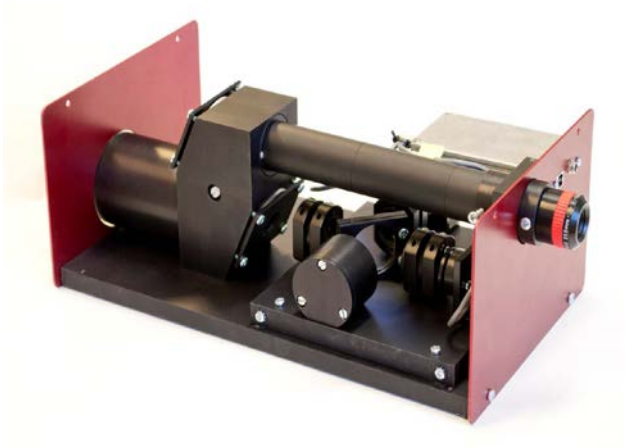
Electrical measurements

The project not only looks at optical aspects of SSL; electrical issues are investigated as well. For this, traceable measurement facilities were developed at three partners to measure the electrical power and power factor of SSL products, including the impact of the source impedance on current waveform and the high frequency current emission of such sources. By using these facilities, significant deviations in electrical power compared manufacturer specifications were found, even for A brand SSL products. 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.

Pulsed-mode operated SSL

SSL sources can be switched on and off at very high frequencies. A calibration facility for the dynamic behaviour of tristimulus meters up to 200 kHz was developed using monochromatic lasers of different colours, an acousto-optical modulator and fast photodiodes. Tristimulus meters calibrated on this facility are currently being used to study the effects of pulsed-mode operation on the colour of SSLs.



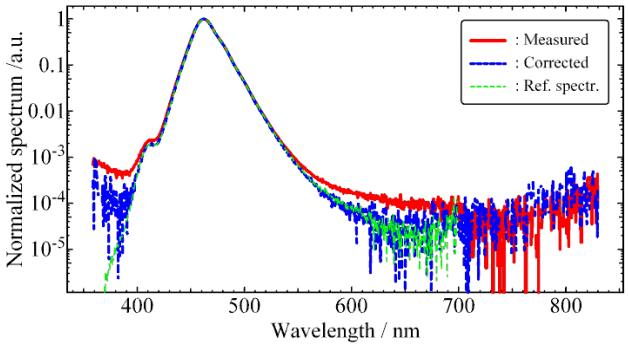


Mesopic and scotopic photometry

A major use of SSLs is for street lighting, where the light conditions are different than for photopic (daylight) vision. Traceable instruments for the measurement of light under scotopic (night-time) and mesopic (intermediate) conditions were lacking. For this reason, traceable mesopic and scotopic luminance and illuminance meters were designed and produced. Traceable calibration procedures were also developed. This work has been done in collaboration with LMT, who will bring onto the market commercial instruments based on this work.

Spectral measurements

Due to the narrow peaks in the SSL spectrum, accurate spectral measurements are very important. A common measurement setup for SSL consists of a integrating sphere in combination with an array spectroradiometer. Development of guidelines on the calibration and use of such setups, including uncertainty estimation, is part of the project. An important aspect of array spectroradiometers is the correction for band-pass and stray light. A correction method based on a calibration with tunable lasers and the calculation of a correction matrix was developed, using a new approach to ensure numerical stability.

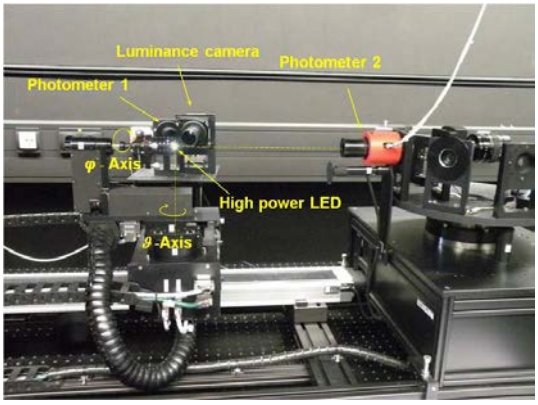


Influence of environmental conditions

Environmental conditions have a strong effect on SSL performance. The measurement of these effects however is difficult. A special instrument has been constructed as part of the project, which allows for the instantaneous capture of a 2D illumination profile, using multiple parallel detectors. With this, real-time investigations were made of the effect of temperature on the illumination profile of indoor and street lighting.

Goniometrical aspects

Lighting design depends heavily on models which takes as input ray files containing the angular and spatial distribution of light coming from a source. Traceable facilities for the determination of such ray files were developed and these were used to validate and improve models for the light distribution from high-power LEDs. An important issue is the reliability of the modelling predictions against deviations from the input ray files due to e.g. aging or temperature effects. This will be investigated in the project and recommendations to standardization bodies on how to include uncertainty aspects in ray files will be formulated.



Life-time estimation

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 this project will focus on monitoring junction temperature and spectral changes of SSL products, as these are believed to be intimately connected to SSL lifetime. Also existing ageing tests capabilities will be used in to evaluate current state-of-the-art in lifetime measurements.

Human perception

As human perception is key to the widespread acceptability of SSL products, this project is also developing methods for assessing key qualities like colour rendition, visual comfort, and mesopic vision. A test suite has been built resembling a normal living room where subjects can be asked to perform tasks under different lighting conditions and then assess the suitability of the lighting for that task. This subjective evaluation is then compared to various proposed objective quality parameters.

Application studies

The project looks into general quality metrics, but also application-specific quality metrics in a few key areas, such as greenhouses, road lighting and art expositions. In greenhouses, the focus is on optimizing plant growth, whereas at art expositions, colour rendering is the paramount quality criterion. The studies will be published on the project website.

Comparison on SSL efficacy measurements

As part of the project, the first comparison on SSL efficacy between the European national metrology institutes was organised. Ten participant measured an E27 replacement lamp, a directional lamp, a tube lamp and a conventional incandescent lamp. The comparison results will be published on the project website.

Exhibition stand

To promote the project and generate awareness of the special properties of SSL, a portable exhibition stand has been developed. This stand has been successfully displayed at several SSL events. The stand provides a comparison between SSL products and existing lighting technologies, such as incandescent and compact fluorescent lamps and it illustrates many of the key issues involved in choosing energy efficient lighting.

Dissemination output

As dissemination output, the project has produced to date:

1 Project website (www.m4ssl.npl.co.uk)
2 public reports, available for download on the project website
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

ENG05 Lighting

Metrology for Solid State Lighting

Report Status: PU Public

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LNE	France
MKEH	Hungary
NPL	United Kingdom
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