2nd HI-LED WORKSHOP | SEPT 21| BREGENZ | AUSTRIA
" Spectrally - tunable LED and OLED lighting"
LED professional symposium + Expo LPS 2016. Festspielhaus Bregenz, Austria

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P.02: Aleksandra Cvetkovic, Simone Sorgato, Maikel Hernández, Julio Chaves, Ruben Mohedano, Juan Vilaplana. Advanced color mixing for a new generation of SSL lamps. LPI-Europe, Madrid, Spain.

P.03: Aleix Llenas, Francisco. J Campoy, Josep Carreras. Feedback controller for accurate spectral fidelity against thermal junction variations and LED luminous flux depreciation. Ledmotive Technologies. Lighting Group, Institut de Recerca en Energía de Catalunya (IREC), Barcelona, Spain.

P.04: Alonso Rodríguez Trujillo, Jorge Higuera. Multifunction VLC light engine for human centric lighting and data communication. Universitat Politècnica de Catalunya (UPC), Barcelona Spain, Smart Lighting Laboratory, Lighting Group, Institut de Recerca en Energía de Catalunya (IREC), Barcelona, Spain.

Horticulture lighting

P.05: Daria Casciani, Fulvio Musante, Maurizio Rossi. LEDs lighting + food growing: design application for domestic indoor agriculture. Politecnico di Milano, Italy.

P.06: Xavier Aranda, Juan Ignacio Montero, Pere Muñoz, Assumpció Anton. Tuneable luminaires for tomato quality enhancement. IRTA, Environmental Horticulture Program. Cabrils, Spain.

P.07: Gamze Cakirer, Koksal Demir. Light color mixing. Ankara University Faculty of Agriculture Department of Horticulture, Turkey.

P.08: A. Elings, E. Meinen, J.A. Dieleman and P.H.B. de Visser. The modelled photosynthetic effects of different light colours on tomato crop growth and production. Wageningen UR Greenhouse Horticulture, The Netherlands.

P09: J.A. Dieleman, K. Weerheim. Applications of spectral composition of light in greenhouse horticulture. Wageningen UR Greenhouse Horticulture, The Netherlands.

P.10: P. Hendrix, M. Brok. Development of HORTILED Top modular Light engine. Hortilux Schréder, The Netherlands.

Museum lighting

P.11: Ferenc Szabo, Kéri Renáta, Péter Csuti. Impact of LED lighting on the selected historical pigments. Department of Electrical Engineering and Information Systems, University of Pannonia, Veszprém, Hungary.

P.12: Péter Csuti, Ferenc Szabó. Photometric and Colorimetric Properties of the HI-LED Luminaire for Museum Lighting Light and Colour Science Research Laboratory, Faculty of Information Technology, University of Pannonia, Veszprém, Hungary.

P.13: Mariano Perálvarez, Andres Chueca, Sara Fuertes, Jorge Higuera, Pilar Borja, Marc Torrell, Violeta Sicilia and Josep Carreras. Tunable White-light emission based on cyclometalated Pt(II) complexes. Lighting Group, Institut de Recerca en Energía de Catalunya (IREC), Barcelona, Spain.

OLED Lighting

P.14: Michael Törker. Peak wavelength adjustment in green top emitting OLED structures. Frahunhofer FEP, Germany.

Poster exhibition area

Booth numbers: S3 + S4.
http://www.led-professional-symposium.com/expo-floorplan

Human centric lighting

P.01: Gaurav Gupta, Yvonne Lai, Naomi Gross, Michael Catt, and Anya Hurlbert. Analysis of the effects of light spectra on human activity, alertness and body temperature. Institute of Neuroscience, Newcastle University, UK.

Abstract

Biometric data is important to the assessment of changes in human performance in response to different spectral conditions of ambient light. This work develops computational methods to analyse skin surface temperature and activity data from wrist-worn biometric watches in order to identify patterns in condition-dependent attentional task performance, sleep quality and during-/post-condition alertness levels. An optimal temporal smoothing window is determined from the characteristics of the data to suppress local noise while exposing local effects and temperature readings are baselined by a local temporal average to account for differences in ambient temperature and per-individual differences. Skin temperature and activity data are combined to perform a) automatic activity phase detection (useful for periods of undirected activity or to indicate similar periods within directed activity), and b) post-condition sleepy state detection from which sleep periods are derived. We consider task-based performance measures and several sleep quality and alertness level indicators (e.g. van Hees et al. PLoS One 2015) to assess the effect of condition on performance and also to group participants by type using unsupervised high-dimensional clustering. Mean daily temperature and activity data are combined to split the typical daily pattern into five distinct segments against which individual days per participant can be compared. We additionally analyse the relationship between task-based activity and skin surface temperature. Temperature changes closely follow the activity cycles, but are slightly offset and asymmetrical in comparison. Finally, several derived measures based on activity and temperature are assessed with respect to their ability to better isolate condition-dependent effects from the interrelationship of activity and temperature.

P.02: Aleksandra Cvetkovic, Simone Sorgato, Maikel Hernández, Julio Chaves, Ruben Mohedano, Juan Vilaplana. Advanced color mixing for a new generation of SSL lamps. LPI-Europe, Madrid, Spain.

Abstract

High-end lamps based on LEDs show advanced performance features such as high light output ratios (lower consumption), controlled beam characteristics and aesthetics (angles, uniformity, cutoffs shape) or controlled emission spectrum. The latter require the use of multi-color chips LED packages, picked to produce light in the widest possible spectral range, and arranged together in the light engine.

Such arrangements challenge the luminaire optics that should be designed well to avoid projecting color fringes and shadows that would compromise the goal of achieving a smooth illumination pattern. In this work we will present novel LED lamps based on advanced optical architectures able to accomplish with all the goals mentioned above (like in the case of the so-called free-form shell mixer) or with many of them and showing other practical advantages (chameleon, hybrid LED-OLED lamp).

P.03: Aleix Llenas, Francisco. J Campoy, Josep Carreras. Feedback controller for accurate spectral fidelity against thermal junction variations and LED luminous flux depreciation. Ledmotive Technologies. Lighting Group, Institut de Recerca en Energía de Catalunya (IREC), Barcelona, Spain.

Abstract

Smart lighting is gathering a lot of attention in the last years because of the huge possibilities in the creation of dynamic spaces. Due to the importance of the spectral composition of light in professional applications and human health, the benefits of multi-channel LED light engines with accurate spectral fidelity are now starting to emerge for residential, commercial and industrial sectors.

However, when dynamic or sequential spectral changes are taken into account time-dependent signals applied to the LEDs bring about a distribution of different junction temperatures, which in turn result in spectral shifts and optical power variations. In the end, the total output spectrum cannot be tracked down and corrected with compact modeling due to the overall complexity of the resulting system that needs to be solved in real time by the relatively small on-board microcontroller of the LED engines.

In this work we implemented a close-loop control system to monitor changes in the emitted spectrum and to compensate for spectral shifts due to temperature changes or wear out of the LEDs. Results showed a reliable and fast method able to preserve the emitted spectrum stable in time. The techniques developed give tools and robustness to novel SSL tunable light sources that can be used to boost different applications in lighting, automobiles, transportation, communication, imaging, agriculture or medicine.

P.04: Alonso Rodríguez Trujillo, Jorge Higuera. Multifunction VLC light engine for human centric lighting and data communication. Universitat Politècnica de Catalunya (UPC), Barcelona Spain, Smart Lighting Laboratory, Lighting Group, Institut de Recerca en Energía de Catalunya (IREC), Barcelona, Spain.

Abstract

The concept of Visible Light Communications (VLC), also called Li-Fi when is bidirectional, concerns the technology aiming to transmit data while providing light for illumination. In this work a novel portable VLC system for illumination containing RGB LEDs and Phosphor-converted white LEDs for data communication and sensing purposes was implemented and tested in a case study for human centric lighting.

The transmitter module is designed to support up to three different LED channels while illuminating an indoor space changing the light spectrum. The light emitters contain different colour correlated temperatures CCT and also different colour rendering index CRI

The hardware architecture in the transmitter includes a dc-dc constant-current LED driver with external dimming containing high speed MOSFETs for fast switching for the different strings of LEDs, and a programmable 32 bit ARM microcontroller to manage the encoded data to be transmitted in a digital format.

The receiver module allows detection of optical signals, decoding and recovering the complete information with a circuit containing three stages: transimpedance amplifier, serializer and deserializer stages controlled by a microcontroller unit. The VLC link has been tested in a laboratory environment to operate for distances up to 8 meters with data rates up to 4.50 Mbps with bit error rates (BER) below 10^{-3} and Q-factor values above 2.32.

The system has also shown its capability to provide a VLC communication link in a wide aperture angle up to 75º at a very practical case in which the link distance is 2 meters.

Horticulture lighting

P.05: Daria Casciani, Fulvio Musante, Maurizio Rossi. LEDs lighting + food growing: design application for domestic indoor agriculture. Politecnico di Milano, Italy.

Abstract

Lighting is a vital factor for plants inducing photosynthesis, phototropism and photo-morphogenesis. Detailed experimental studies have already shown the importance of customizing lighting receipts for different species in order to obtain good plants productivity and nutritional quality formation. In this regard, LED-based lighting system with digital controls represents a perfect solution for tailoring lighting receipts and for dynamically changing the spectral power distribution (SPD) to better enhance the plants' growth and development. Applications can range from laboratorial research experimentations, aero-spatial and industrial food production to indoor (domestic) food growing. This is currently an increasing trend derived by both the interest in eating healthy, genuine, km-0 and origin controlled food combined with a raising necessity of nature reconciliation through sustainable behaviours and responsible choices. LEDs lighting engines can be a feasible solution for urban agriculture especially in latitudes lacking natural lighting or good climatic conditions and with limited outdoor spaces due to polluted and high-rise areas. The research would focus on the requirements and features of a lighting system for indoor food growing deriving scientific insights from a multidisciplinary literature review about agriculture, lighting engineering and food science in order to define the favourable characteristics of lighting for food growing in terms of quantity (Irradiance), quality (SPD), spatial distribution and direction, temporal distribution (Photoperiod). Further design specifications for the overall lighting system were derived by a qualitative/quantitative survey by proposing user-oriented features in terms of simplicity (use, installation, cleaning/maintenance), domesticity (compatibility with environmental features such as dimensions, location, temperature), aesthetics (pleasantness and interest), functionality (effectiveness in food production), intelligence of the solution (flexibility, modularity, upgradability), economy (energy, costs) and control/management. The paper aims at presenting a design application for domestic indoor agriculture in form of a lighting engine (prototype) by discussing the results and insights gathered from comparing performances and experiences obtained from different solutions through an iterative design process. The domestic design application would be discussed by detailing its features and performances, by describing the design approach, by explaining all the engineered components (optical, mechanical, thermal, electrical) with a particular focus on the efficacy and quality of the lighting system. The conclusions would presents comparison in terms of efficacy (PPF/Watt – Delivered PPF/Watt), CU (Coefficient of Utilization), controllability of the SPD, angular distribution of the radiation, colour mixing.

P.06: Xavier Aranda, Juan Ignacio Montero, Pere Muñoz, Assumpció Anton. Tuneable luminaires for tomato quality enhancement. IRTA, Environmental Horticulture Program. Cabrils, Spain.

Abstract

The information on morphogenetic effects of light is rather abundant. However, there is relatively few information on effects of steering light (light of certain spectrum with morphogenetic effects) on vegetables and fruit quality (e.g. Folta et al. 2011), and specifically on tomato fruit quality (Dorais et al. 2009). Some of the scarce papers on this subject use LEDs to produce the steering light (blue, green, red, far-red). However, this light is either added over a background light, or given alone in contrast with a control light (background light, as in Terashima et al 2009, Brazaitytė et al. 2009, or an alternative luminaire, as in Sabzalian et al. 2014). As a consequence, either total radiation is not maintained, or spectra are completely different, or the interaction between different wavelengths is ignored. Moreover, generally low output luminaires are used, especially for indoor use (Fan et al 2013, 300 µmol m^{-2} s^{-1}; Piovene et al.2015 200 µmol m^{-2} s^{-1}). We used prototype, tuneable LED luminaires of high output that can follow sun intensity course along a day and can reproduce any sun light spectrum. The luminaires were tuned to different spectra, relatively enriched in the red or blue region but keeping total radiation constant. Tuneability allowed to avoid the potential interference of different luminaire form factors, different optics, manual adjustment of the number of LEDs, or electric power supplied to the LEDs. We observed no statistically significant effect of blue or red steering light on tomato antioxidant characteristics (ascorbic acid, licopene, β-carotene, α-tocoferol, γ-tocoferol, total polyphenols, Trolox equivalent antioxidant capacity). These results are consistent with the hypothesis that when irradiation is kept constant in a background of a sun spectrum, there is no effect of specific wavelengths. It follows that the reports of effects of blue or red light in fruit quality (Dorais et al. 2009; Terashima et al. 2009, Brazaitytė et al. 2009, Sabzalian et al. 2014) are probably related to changes in total light intensity (Alba et al. 2000), or to a very restricted spectrum. From a practical point of view, in a greenhouse environment with luminaries operating and the solar background light is present, any contribution of lighting will be supplemental and the consequence would be that any wavelength or combination of wavelengths of the PAR range would be effective to produce the different effects described in the literature such as the increase in light intensity would drive the effect in plants. However, in confined environments such as growth chambers, were luminaries are the only source of light, fruit antioxidant content would only be related to the achievable light intensity, not to its spectral characteristics, although, other effects on plant morphogenesis should be taken into account.

References

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Brazaitytė et al. 2009. Zemdirbyste-Agriculture 96, 3, 102-118.
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Terashima et al. 2009. Plant Cell Physiol. 50(4): 684–697 doi:10.1093/pcp/pcp034.

P.07: Gamze Cakirer, Koksal Demir. Light color mixing in Plants. Ankara University Faculty of Agriculture Department of Horticulture, Turkey.

Abstract

Light is very effective factor in plant growth and development stages. Plant growth and physiology are affected strongly according the light spectrum. Therefore there is significant relationship between light dosage and crop production. Light can be effective in many aspects such as yield and quality in crop production or morphological and photochemical events of plants. The effects of light under different peak wavelengths on plant also have been gaining importance working area in recent years. Many physiological processes such as seedling development stem elongation, photosynthesis and flowering can be controlled with different wavelength light sources. Also, it is known the important relationship between light wavelength and various metabolites. The necessary light source in growth and plant development may be due sunlight or only due to artificial lighting sources or a mixing of both. In addition, crop production can be made in environments, where sunlight may not be available. Thus, the use of artificial light sources comes to the fore. For example, High pressure sodium lamps, incandescent lamps, fluorescent lamps and particularly LED lamps are the most widely used light sources for artificial lighting by plant growers. The effect of artificial light on plants may be different in a day and the light dosage and light spectrum under time creates a important research study area. The mixture of different light sources that we call light color mixing is also investigated in our studies. In this case, it is of great importance both, the light color mixing and the effective light source for plant growth purposes and to increase the crop production. In this research, artificial lighting containing different wavelengths for plant growth are evaluated and also, the effect of light mixture on crop production.

P.08: A. Elings, E. Meinen, J.A. Dieleman and P.H.B. de Visser. The modelled photosynthetic effects of different light colours on tomato crop growth and production. Wageningen UR Greenhouse Horticulture, The Netherlands.

Abstract

Photosynthesis characteristics of tomato plants grown under LED modules that produced blue, green, red, and white light were determined. Photosynthesis rates at low light intensity of plants grown and measured under the same colour related to each other as: white > red > green > blue. However, rates measured under red/blue light also related to each other as: blue > white > red = green. Photosynthesis rates at high light intensity measured under red/blue light related to each other as: blue > white > red > green. The INTKAM crop growth model was used to quantify the potential effects of light colours and levels on crop photosynthesis and seasonal growth and production. INTKAM was extended with 1) spectral composition of light, 2) light extinction profiles for different wavelengths, 3) colour effects on initial light use efficiency, and 4) on maximum carboxylation capacity. Various scenarios were examined, in which light colours provided with LEDs were or were not combined with solar radiation, and varied over the day. Daily PAR and initial light use efficiency were important causes of simulated differences in total dry matter production. The effects of differences in maximum carboxylation capacity proved small during the winter season with low light levels. A longer duration of lighting period also proved effective, even if the total light input was kept the same, due to the non-linearity of the photosynthesis-light response curve at lower light intensities.

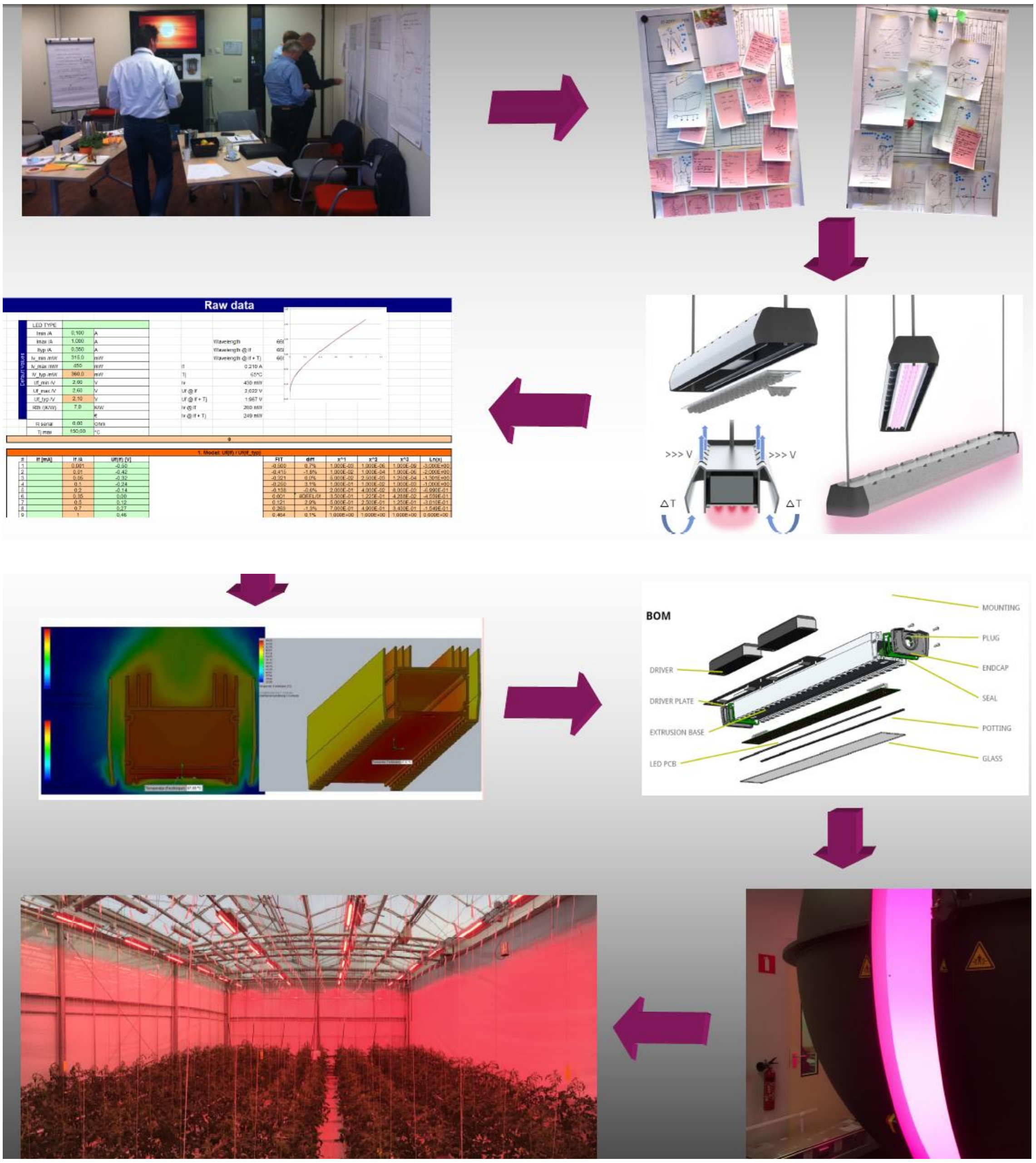
P09: J.A. Dieleman, E. Meinen and K.C. Weerheim. Development of dynamic lighting strategies for greenhouse horticulture. Wageningen University & Research, Business Unit Greenhouse Horticulture, P.O. Box 644, 6708 PB Wageningen, The Netherlands.

Abstract

Over the last decades, the interest in LED lighting for greenhouse applications has increased considerably, due a number of advantages of LEDs: high efficiency (µmol/J), low heat emission and the possibility to emit light of different spectral compositions. These different light colours trigger plant responses, resulting in changes in plant morphology and physiology. To optimize these effects for plant production systems, the spectral composition of the light should be adjusted to the plant's needs, both during the course of the day and during the course of plant development. In this study, we aim to develop dynamic lighting strategies to optimize tomato growth and production. Growing young tomato plants under 200 µmol m-2 s-1 blue, green, amber, red, white or red/blue LED light during 15 h per day affected plant height, leaf area, inter-node length, leaf architecture, rate of photosynthesis and biomass accumulation. When only 2 h of blue light were given, plant processes such as elongation and rate of photosynthesis were not significantly affected. Giving 2 h of 50 µmol m-2 s-1 green light at various moments of the day affected elongation compared to the reference. However, other plant processes were not affected. In a validation experiment with a fruit-producing tomato crop, plants were grown at 220 µmol m-2 s-1 supplementary red LED light, or red light preceded by 3 h of 85 µmol m-2 s-1 blue or green light. The total tomato fresh fruit production of the plants grown at blue light followed by red light was 8% higher than in the reference treatment. This shows that the application of a dynamic lighting strategy can be beneficial for greenhouse horticultural production systems.

P.10: P. Hendrix, M. Brok. Development of HORTILED Top modular Light engine. Hortilux Schréder, The Netherlands.

THE CONCEPT OF GROWLIGHT



Museum lighting

P.11: Ferenc Szabo, Kéri Renáta, Péter Csuti. Impact of LED lighting on the selected historical pigments. Department of Electrical Engineering and Information Systems, University of Pannonia, Veszprém, Hungary.

Abstract

Today LED-based lighting systems are more widespread in many museums, because of their favorable properties such as high luminous efficiency, long lifetime or reliable operating characteristics. In terms of the artworks further advantage of LED lighting solutions is that they have no radiation in the damaging (ultraviolet – UV and infrared – IR) spectral range. But the long-term effects of LED lighting on artworks and on the structure of pigments have not been studied deeply. At the University of Pannonia pigment ageing tests are carried out in order to determine the effects of LED lighting on several artistic pigments from different art periods. The historical pigment samples are prepared by adding different binding materials and using various varnishes.

The pigment samples are aged artificially in a spectrally tunable LED lighting booth, which contains 20 different colour channels, having peak wavelengths separately between 414 nm and 691 nm. In order to accelerate the ageing process the illuminance level is set to 10 000 lx in the ageing chamber.

Several techniques are used to measure and compare the aged and non-aged pigments: surface spectral reflection measurements, which take place at each 1000 hours, Fourier Transform Infrared Spectroscopy (FTIR) and Raman Spectroscopy measurement. Colorimetric analysis highlights a relevant change in colour during the ageing treatment; furthermore, Fourier Transform Infrared Spectroscopy technique allowed us to identify specific difference in absorption, while by Raman Spectroscopy can identified the individual pigments and their degradation by the ageing process.

Currently the results of the 5 000-hour reflection measurements are available. Visible change can be seen in case of the majority of pigments, primarily in case of Egg tempera, Linseed oil and Secco binders, furthermore blue pigments show the greatest changes. For most of the pigment (blue, white, green pigments) the colour difference can be observed in the form of yellowing (increased b* value) and these samples became mostly darker (decreased L* value). Furthermore colour change can be seen not only in the ageing part of the pigment plates, but also in the covered parts as well. Physical/chemical reactions between organic binders/varnishes and inorganic pigments can cause modification in chromophore/auxochrome chemical groups resulting in colour change.

P.12: Péter Csuti, Ferenc Szabó. Photometric and Colorimetric Properties of the HI-LED Luminaire for Museum Lighting Light and Colour Science Research Laboratory, Faculty of Information Technology, University of Pannonia, Veszprém, Hungary.

Abstract

One of the main goals of the HI-LED project is to develop a multi channel LED luminaire with enough colour channels to realize spectral power distributions (SPDs) usable by the targeted tasks like horticulture, human centric lighting including museum lighting. The poster will introduce the most important characteristics and performance of the HI-LED 2nd prototype luminaire including photometric, colorimetric and electronic parameters measured at the photometric laboratory at the University of Pannonia. The instruments and measurement equipments of the laboratory allowed carrying out goniophotometric measurements with photometric quantities traced back to international standards. The colorimetric parameters are based on a high quality spectroradiometer operating in the visible spectral range.

The HI-LED luminaire

One of the outputs of the research work in the HI-LED consortium is a ten channel LED luminaire with primaries covering the visible spectral range. The SPD of the primaries can be seen in Figure 1.

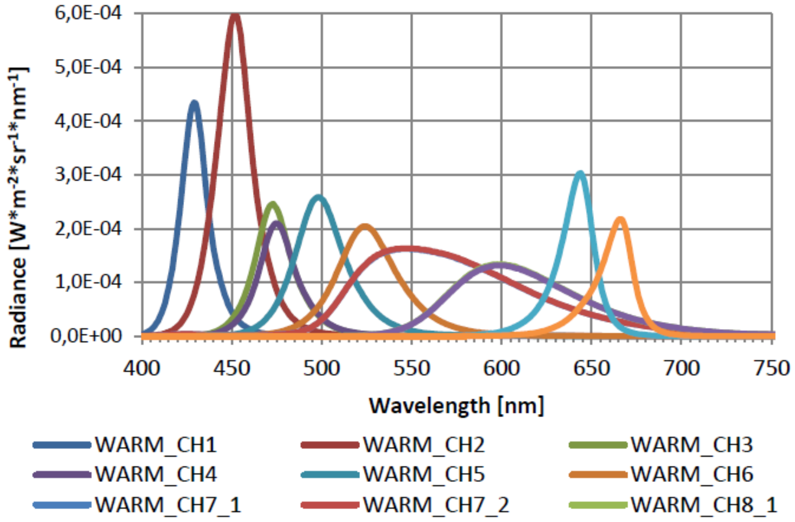


Figure 1: SPD of the primary channels of the HI-LED 2nd prototype luminaire

The selected individual LED spectra and the applied LED quantities resulted a luminaire which is capable to realize the visible spectral part of CIE standard illuminants [1] like the CIE D65 or even the CIE A in good quality.

References

[1] CIE Technical Report (2004). Colorimetry. Publication 15:2004 (3rd ed.). CIE Central Bureau, Vienna. ISBN 3-901906-33-9.

P.13: Mariano Perálvarez, Andres Chueca, Sara Fuertes, Jorge Higuera, Pilar Borja, Marc Torrell, Violeta Sicilia and Josep Carreras. Tunable White-light emission based on cyclometalated Pt(II) complexes. Lighting Group, Institut de Recerca en Energía de Catalunya (IREC), Barcelona, Spain.

Abstract

Nowadays, two main strategies are available within state-of-the-art SSL to generate white luminescence. On one hand, there are the so-called PC-LEDs (phosphor-converted LED). In these devices, short-wavelength emission (typically blue) from a LED die is partially downconverted by the phosphors. White light results then from the combination of the phosphors re-emission and LED non-absorbed light. The second approach is the multi-chip or colour mixing architecture in which light from multiple LEDs with different colours is mixed thereby enabling chromaticity point tunability. However, even if multi-chip devices provide dynamic control of emitted spectrum, most of general lighting applications are dominated by PC-LEDs. First, the efficiency of direct electroluminescence exhibits important variations across the visible spectrum. Whereas current external quantum efficiency is around 75 % in the blue range and 64 % in the red, the efficiencies at the green and amber ranges are 32 % and 11 % respectively [1]. Thus, at least for green and yellow light, it is more efficient to obtain these contributions under the PC strategy. Second, since LEDs of different colours, depending on operating temperature, have different behaviours in terms of peak position and optical power delivered, close-loop control strategies are needed in order to maintain device chromaticity. PC-LEDs, in contrast, are far less sensitive to temperature allowing simpler (and cheaper) control strategies. Phosphors used in mainstream LED technology are typically inorganic and are based on the emission of an activator ion, in most cases Ce^{3+} and Eu^{2+}(rare-earths). It is foreseen that the use of rare-earths can represent for PC-LEDs a potential weakness in the next decade due to the global shortage of these materials that is currently having a direct impact on availability and pricing. After DOE (U.S. Department of Energy) [2], Europium could be in short supply in the next years, while in the case of Cerium, the stocks are under moderate risk. In the light of this, it is clear the necessity of new approaches and materials capable of replacing in the next future these rare-earth based phosphors, thereby overcoming the availability risks and potential cost overruns. We report here on phosphors based on cyclometalated Pt(II) complexes whose luminescence under UV/blue light pumping can be compositionally tailored within the visible range. Furthermore, we also show that such phosphors can be easily placed on commercial short-wavelength LEDs providing us with efficient down-conversion, giving rise, in combination with non-absorbed pumping light, to bright white light emission.

References

[1] National Renewable Energy Laboratory (NREL), 2013, “Amber LEDs for Solid-State Lighting: White light with unprecedented efficiencies”

[2] U.S Department of Energy, 2011, “Critical Materials Strategy”

OLED Lighting

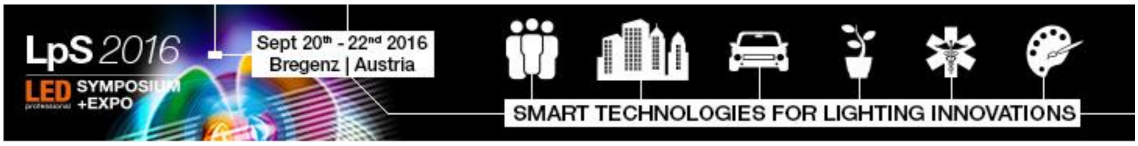
P.14: Michael Törker. Peak wavelength adjustment in green top emitting OLED structures. Frahunhofer FEP, Germany.

Abstract

Organic Light Emitting Diodes (OLEDs) can be used as light sources for different applications like flat panel displays, lighting and signage. Specific emission characteristics are needed depending on the application. Top emitting OLED structures typically consist of organic layers sandwiched between a highly refractive metal bottom contact and a semi-transparent thin metal top contact, thus forming a strong optical micro-cavity. Tuning the micro-cavity in top-emitting OLED structures gives the opportunity to adjust peak emission wavelength, spectral width and angular dependence of the emission spectra. Emission spectra based on different OLED cavities were calculated using simulation Software SETFOS. The thickness of the organic layers was optimized for peak emission wavelength of 545nm and 565nm, respectively, integrated over all emission angles. The corresponding devices were then fabricated. Emission spectra obtained from integrating sphere measurements showed good agreement with simulated data. A compact modular OLED design was developed enabling stable operation of the OLEDs at high brightness of 5000cd/m2.

2nd HI-LED WORKSHOP | SEPT 21 | BREGENZ | AUSTRIA
Room: SAAL BODENSEE

Workshop opening	
Dr. **Josep Carreras**, IREC (Catalonia Institute for Energy Research), SPA *"HI-LED EU-Project"*	
Session 1: Human-centric lighting	
Keynote 1	Professor **Anya Hurlbert**, Newcastle University, UK *"Sculpting the spectrum of light to influence human visual and non-visual behaviour "*
Keynote 2	Prof. Dr. **Christian Cajochen**, Head Centre for Chronobiology, University of Basel, CH *"Light beyond vision: effects on the human body clock, alertness and sleep "*
Demo session 1	Tuneable digital light-engines for human-centric purposes
Session 2: Horticulture	
Keynote 3	Dr. **Phillip Davis**, Stockbridge Technology Centre, UK *"Plant light responses and their manipulation for horticultural purposes"*
Keynote 4	Dr. **Tom Dueck**. Wageningen UR, NL *"Optimizing horticultural production with light spectra"*
Demo session 2	Tuneable digital light-engines for horticulture
Poster session and coffee break	
Session 3: Art-work and museum lighting	
Keynote 5	Dr. Ferenc Szabo. Pannonia University, HU *"LED museum lighting: challenges and solutions"*
Keynote 6	Dr. Sérgio Nascimento, Department of Physics, University of Minho, PT *"Best lighting for visual appreciation of artistic paintings"*
Demo session 3	Tuneable digital light-engines for museum lighting and hybrid LED-OLED engine
Round table and poster award	



This project has received funding from the European Union's Seventh Framework Programme for research; technological development and demonstration under grant agreement no 619912