LED professional Review

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LpR
Trends & Technologies for Future Lighting Solutions
Jan/Feb 2015 | Issue 47

International Year of Light 2015

Tech-Talks BREGENZ: Mehmet Arik

Well-Being in Office Applications

Light Measurement & Quality Parameters

Historical Year 2015

The International Year of Light 2015, a milestone in the history of light, has begun! The UNESCO initiative for the International Year of Light 2015 coincides with the Nobel Prize for Physics that was awarded for the research done in solid-state lighting, namely, the blue LED light developments. On the 19th and 20th of January the official opening of the International Year of Light will take place at the UNESCO headquarters in Paris. This year will have a tremendous impact on the awareness of light – both daylight and artificial light. All around the globe hundreds of lighting dedicated activities will take place that will gain a lot of momentum for the whole lighting sector, market and business.

The year 2015 is also an anniversary year for LED professional. This year we'll publish our 50th LED professional Review (LpR) in July/August and we're celebrating our 5th LED professional Symposium +Expo, the LpS 2015, on September 22nd to 24th in Bregenz, Austria.

In lieu of this historical year, LED professional has made some updates and modifications. The LED professional logo has been updated, the style of the LED professional Review (LpR) is much fresher and the LED professional Newsletter (LpN) was given a facelift and new functions. Subscribers can now select the kind of information they are looking for. In addition, subscribers can now access the newsletter archive and translate every newsletter directly into their own language with the integrated Google online translator.

This year, members of the LED professional team will be traveling around the globe to actively keep in touch with the lighting community. The IYL 2015 opening in Paris is the first stop on our list, with LightFair International in the USA, the GILE in China and LED Lighting Taiwan in Asia and, of course, our own LpS 2015 in Europe being some of the most important events of the year that we will be attending.

Our first LpR issue in 2015 is dedicated to the International Year of Light with a commentary from one of the IYL initiators, Prof. John Niemela, a leading article about SSL by Dr. Prasad and articles about further *trends and technologies for future lighting solutions*.

Have a great read and a Happy New Lighting Year 2015.

Yours Sincerely,

Siegfried Luger
CEO, Luger Research e.U.
Publisher, LED professional
Event Director, LpS 2015

PS: The Call for Papers for the 5th International LED professional Symposium +Expo, the LpS 2015 is open now. Please follow this link www.LpS2015.com/Call for further information.
Deadline is February 20th, 2015

LEADING ARTICLE

32 2015 Year of (LED) Light
by Dr. Amrita Prasad,
LED professional

ADVERTISING INDEX

Joseph J. Niemela
Joseph J. Niemela is a Senior Research Scientist and member of the permanent scientific staff of the Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste, Italy. He is Head of its Applied Physics group as well as the Office of External Activities (OEA). In addition to coordinating optics research and training activities at ICTP, he is co-Director of the UNESCO Active Learning in Optics and Photonics (ALOP) program and Global Coordinator of the Secretariat for the International Year of Light and Light-based Technologies 2015 (IYL 2015).

IYL 2015 - LIGHT IS LIFE, LIGHT IS CULTURE, SOLID STATE LIGHT IS PROGRESS

On 20 December 2013, the United Nations General Assembly proclaimed 2015 as the International Year of Light and Light-based Technologies (IYL 2015). This was the culmination of a long and concerted effort by a large consortium of scientific bodies, working together with the United Nations Educational, Scientific and Cultural Organization (UNESCO), where the initiative was adopted by its General Conference in November of the same year.
In proclaiming the Year, the UN resolution recognized the importance of light and light-based technologies in bringing about future development of global societies and of the importance of enhancing global awareness of and education in those technologies, in order to address critical challenges in sustainable development and the health, well-being, and quality of life of citizens in developed and developing countries. It noted that applications of light science and technology are vital for advances in medicine, information and communications, and energy, pointing out that light technology and design can play an important role in the achievement of greater energy efficiency and the reduction of light pollution.

Indeed, it is a good congruence that the Nobel Prize in Physics in 2014 was awarded jointly to Isamu Akasaki, Hiroshi Amano and Shuji Nakamura for their invention of blue light-emitting diodes, a feat that enabled energy-efficient sources of white light, with immediate and profound benefits for mankind. If we consider this, as well as the overall goals outlined by the UN, it is clear that the lighting industry is situated centrally within the themes of IYL 2015. That many affordable solutions already exist for enhanced quality of life through proper lighting and design may not be fully appreciated by potential users worldwide - let alone future possibilities - and indeed, IYL 2015 can provide an effective means to raise global awareness of and appreciation for the way in which light technologies and design can affect our sense of well-being, and how easily that can be achieved. This applies to our homes and offices, but also to our streets and parks: good lighting design can bring life back to inner city neighborhoods after dark, make parks safe for children and their parents, and bring about a sense of community. In the poorest villages, solid state lighting can enable study after sunset without the known hazards associated with the use of kerosene lamps in tightly enclosed spaces.

But this is only the start: Research and development in so-called human centric lighting promises continuing advances in terms of “good light,” where the spectral composition of artificial light can be tuned to enhance our productivity and physical health. It can also be tuned to enhance our perception of artworks and to protect those same artworks over the course of time, something that adds an important component to the human condition. In fact, we can expect an ever-increasing process of innovation. But innovation needs both invention and market, and the latter means raising awareness with potential users who can drive the innovation forward. The International Year of Light and Light-based Technologies provides an educational platform that can reach deep into the pool of potential beneficiaries of advances in light technologies and design.
It is indeed a rare opportunity to raise awareness of the potential of light technologies with ordinary citizens, stakeholders, and policy makers on a truly global scale. ■

J.J.N.

Small is Big

The Range of SMD Terminal Blocks

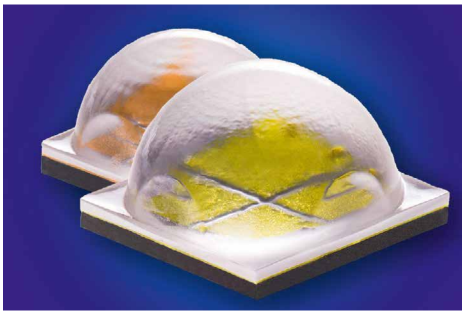
www.wago.com/SMD

WE INNOVATE!

WAGO®

Cree Releases First SC5 Technology™ Platform Based Extreme High Power LEDs

Cree is excited to announce the commercial availability of the industry's first Extreme High Power (XHP) LEDs, a new class of LEDs that enable a system cost reduction of up to 40% for lighting applications. The first LEDs powered by Cree's revolutionary SC5 Technology™ Platform, XLamp XHP50 and XHP70 LEDs provide twice the lumen output and improved reliability compared to previous LEDs of the same size.
The groundbreaking technology of the new XHP LEDs will help drive the next major innovations in lighting system design.



Cree's first SC5 Technology™ Platform based products, the XLamp XHP50 and XLamp XHP70 LEDs are now available

"Cree's new technology is game-changing compared to the incremental advances of other LED suppliers. The breakthrough performance of XHP LEDs enables both new design possibilities and dramatically lower system costs for LED lighting," said Nate Heiking, Advanced Lighting product manager, Kenall Lighting. "We're excited that Cree's new class of Extreme High Power LEDs will accelerate customer adoption of LED lighting."

XHP LEDs allow lighting manufacturers to drastically reduce the size and cost of their lighting system design by using fewer, more reliable LEDs to achieve the same brightness. XHP LEDs enable new lighting designs that require fewer optics, a smaller printed circuit board, a smaller housing and less handling. XHP LEDs also achieve longer lifetimes even at higher operating temperatures and currents than previous LED technology, allowing lighting manufacturers to reduce heat sink size and cost without impacting the rated lifetime.

In addition, XHP LEDs enable other cost reductions at the system level not possible with other LED solutions. For example, in roadway and outdoor area lighting, on top of the luminaire cost savings, XHP LEDs can produce a radically smaller and lighter luminaire that requires a less expensive pole. Similar dramatic cost savings over existing solutions may be achieved in a wide variety of lighting applications, including track, stadium and high bay.

"Cree's new Extreme High Power LEDs demonstrate our belief that high-power LEDs are what will drive the industry towards the next generation of lighting system designs," said Dave Emerson, vice president and general manager for Cree LEDs. "Leveraging our groundbreaking SC5 Technology™ Platform, Cree's new XHP LEDs deliver not only exceptional performance, but also enable up to 40% system level cost reductions."

As the first LEDs to incorporate the SC5 Technology Platform, the new XHP LEDs introduce significant advancements in light output, color consistency and design flexibility. XLamp XHP50 and XHP70 LEDs shatter the industry's perceived limit of LED lumen density by delivering up to 2546 lumens at 19 W from a 5.0 x 5.0 mm package and up to 4022 lumens at 32 W from a 7.0 x 7.0 mm package, respectively. Through improvements in the light conversion process, Cree has reduced LED-to-LED color variations and, among other options, offers XHP LEDs in 2-step and 3-step EasyWhite® bins for 3500 K through 2700 K in 80 and 90 CRI. The XHP LEDs introduce a new, innovative package that allows manufacturers to choose either 6 V or 12 V configurations from the same LED through the solder pad design on the circuit board. ■

Everlight Electronics Adds Advanced CoB LED Series

Everlight Electronics, a leading player in the global LED and optoelectronics industry, announces two new Chip-on-Board LED families, the XUAN series of high-power CoBs and the Color Choice® (Color on Demand) CoB series CHI.

Everlight's new CoB lines. The first samples consisting of highly efficient 36 V XUAN high-power series and the fully white tunable 9-29 W Color Choice© series were displayed at the LpS 2015

Everlight's high-power (36 V) XUAN CoB series offers the dual benefit of high efficiency and easy assembly. Covering a wide wattage range at customers' preference from 2-50 W the MCPCB device can achieve > 130 lm/W. Designed with high thermal conductive Mirror-Aluminum substrate, it can be easily attached to the heatsink by a holder or screws. Another feature of the XUAN series is its wide driving operation range, ensuring a super high efficacy in the typical driving state. In an over-driven state, however, it can still deliver a high lumen output and, with proper heatsink, also remains stable to bring about an economic lighting design. Seven different designs on EVERLIGHT's XUAN LED are currently available in 1313 and 1919 dimensions with color temperature options from warm to cool (2700-6500 K) and CRI ratings of 82 (>80), 92 (>90) and > 97 Ra. EVERLIGHT's XUAN LEDs are a best fit for LED single light source applications like spotlights and downlights.

Another option is color on demand. The Color Choice® Series CHI CoBs (9-29 W) are designed on a Ceramic PCB package and is based on two color temperatures 2700 K and 5700 K which, when thoroughly mixed, can take on every ANSI color temperature in this CCT range. All mixture points achieve >110 lm/W and a CRI >80 (R9> 0). Everlight's Color Choice® Series directly targets indoor retail, hospitality and residential lighting applications. Offered with wattages of 9 W, 19 W and 29 W, CHI LEDs can supplement direct luminaires and spotlights with dynamic color temperature variability and allow the seamless setting of any desired color temperature between 2700 and 5700 K. The Color Choice® Series' seamless color temperature tunability is achieved by subdividing the CoB into two electrically insulated segments for warm white 2700 K and cool white 5700 K which can be controlled/driven independently

NEW PRODUCTS

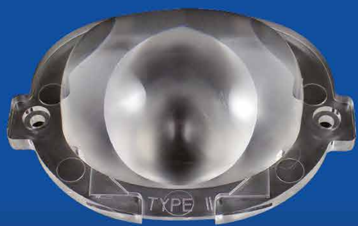
Ledlink Optics,Inc.

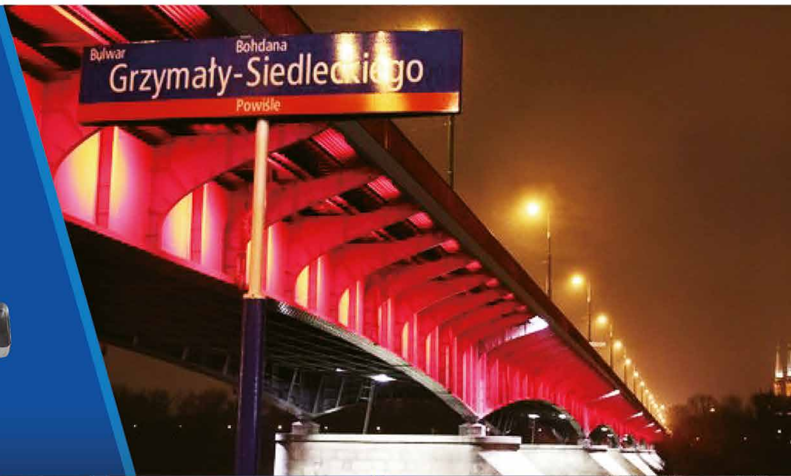
High power street lens

DxH(mm) 100x78x30

TYPE II. Short

Citizen CLL050





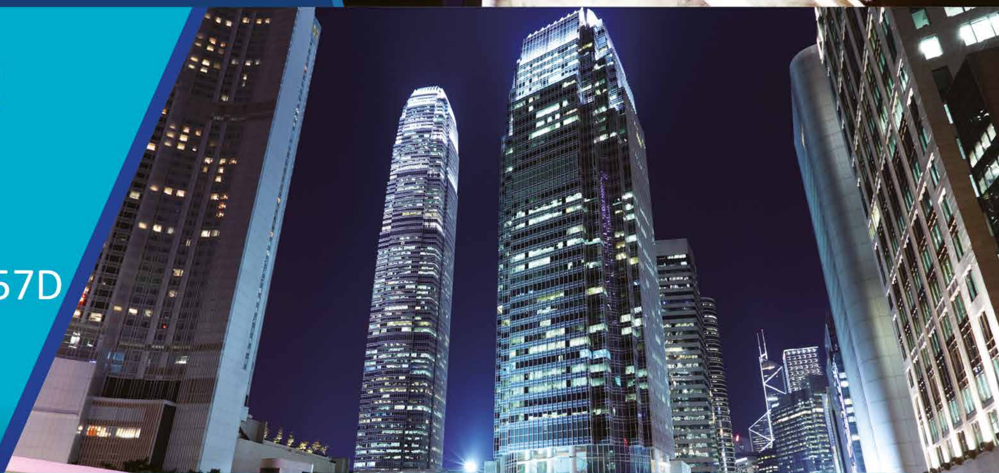
LL01NI-BYKxxL19

DxH(mm) 16x8.6

FWHM 30° 40° 60°

Cree XPE2/XPG2

Nichia NVS19B/NCS19B/757D



LL01CT-BZN15L02-P

DxH(mm) 88.5x12.7

FWHM 15° (24°/38°developing)

Citizen CLL030

Our Services

▸R & D ▸Precision Mould ▸Manufacture

▸Component solution ▸Customerization

Further technical information is available, please contact us for more details.

| www.ledlink-optics.com | service@ledlink-optics.com

LedLink

Linking LEDs to The Real World

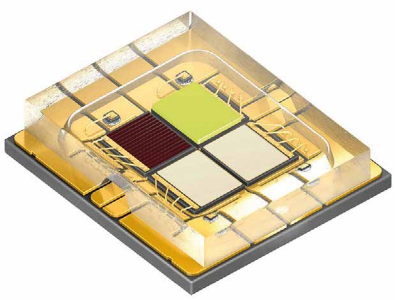
from each other. Each circuit requires a separate power supply unit or a co-channel power supply.

This makes the Color Choice® Series ideal for elegant and simple mood lighting, adjustment to changing daylight and decorative lighting aspects in private homes, stores, hotels and bars. CHI CoBs are suited for large spot lights in retail applications or smaller directional lamps like MR16, PAR20, PAR30, PAR38lamps for general lighting use.

All Chip-on-Board LEDs from Everlight have completed LM80 lumen maintenance testing. A complete line of accessories such as standardized holders, appropriate reflectors and more is available in the aftermarket.

Osram's New Ostar Stage for Even Brighter Stage Lighting

Osram Opto Semiconductors presents a new LED for stage lighting. Compared with previous members of the product family, Osram Ostar Stage offers more than twice the lumen output. At the same time, the component surface is only 30% larger. The new version contains 2 mm² high-current chips per color which can handle a maximum of 4.5 A per chip. This will enable moving heads for stage and exhibition lighting to be more compact and more powerful.



Osram Opto's new Ostar Stage - Much greater output from an area only one third larger than its predecessor

The new Osram Ostar Stage is equipped with four high-current chips based on the latest thin-film and UX:3 chip technologies. With an area of 2 mm² each, the chips are twice as large as the previous ones but at 5.7 x 6.4 x 1.3 mm the package size is only slightly larger. Thin-film chips in red and UX:3 chips in green, blue and white are used. Up to 4.5 A can be applied to each chip, which allows more light to be produced from such a small surface area. With a binning current of 1.4 A the red chips achieve typical values of 140 lm, and the green chips 280 lm. The "deep blue" chip provides a light output of 1.8 W. If the LED is operated at the maximum current of 4.5 A, the brightness per color increases by factor 2.6. The white chip in the new Osram Ostar Stage will have a lifetime of 20,000 hours (L50/B50) at full output thanks to a new ceramic converter, achieving a brightness of more than 1000 lm.

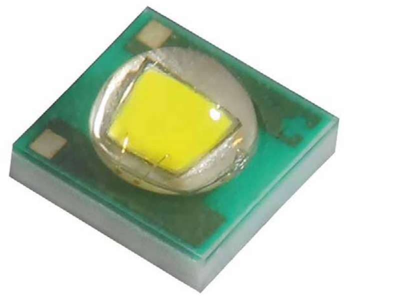
Quality products in different output classes:
The new Osram Ostar Stage from Osram Opto Semiconductors is the latest high-output addition to the company's LED product family for stage, exhibition and architecture lighting. "We are continually developing the chips and the package for the Ostar Stage family so that we can offer our customers high-quality products in different output classes", said Wolfgang Schnabel, Product Marketing LED Industry at Osram Opto Semiconductors. "Our aim with this new LED is to raise the standard for moving heads in the high-output category."

Compact spotlights thanks to high luminous intensity:
The new Osram Ostar Stage is the latest step by the Regensburg based company on the path toward high-power LEDs for stage spotlights which emit a large amount of light from a small surface area, leading to more compact spotlight designs. This family of products is ideal not only for stage lighting but also for moving heads and spotlights for trade fairs and architectural lighting.

Kingbright Announces High-Powered KTDS-3536 Series of LEDs

Kingbright's KTDS-3536 Series is the latest SMD LED range to be released, featuring a 3.24 x 3.45 mm molded silicone lens package that allows optimal reliability and light extraction efficiency.

For decorative and general lighting applications, the many color options include three shades of white – cool, neutral and warm – as well as red, green and yellow. Ultraviolet and infrared versions are also available for industrial and surveillance applications.



Kingbright's latest 1 W LED is available in white and a variety of colors

The new KTDS-3536 Series features a moisture sensitivity level of 1, assuring zero damage during reflow, and provides an electrically neutral thermal path. All parts in the KTDS-3536 Series are RoHS compliant.

Samsung Completes Its Line-Up of CoB LEDs

Samsung Electronics Co., Ltd., a world leader in advanced component solutions, introduced new chip-on-board (CoB) LED package products, the LC006B and LC008B, with six and eight watts of power respectively. The new packages join five others in Samsung's popular LC series (LC013B, LC019B, LC026B, LC033B and LC040B), to complete its CoB package line-up.

Samsung's full CoB lineup covers a very broad range of wattages

"With the introduction of our new under-10 watt CoB packages, we are signaling our intent to aggressively target the indoor LED lighting market," said Bangwon Oh, senior vice president, strategic marketing team, LED Business, Samsung Electronics. "Samsung will continue to advance its LED technology and business objectives by providing lighting manufacturers with the best in LED lighting components, delivering exceptionally high-quality LED package and engine products and services that reliably meet customer needs," he added. "We remain dedicated to increasing our breadth of market solutions, to further grow our LED lighting component business."

A CoB LED package provides a single light source that combines multiple LED chips to achieve higher light intensity and uniformity, while simplifying luminaire design.

The LC006B and LC008B offer high-efficacy levels of 140 lm/W and 142 lm/W at 5000 K CCT, respectively. The new packages will support a wide range of CCT (Correlated Color Temperature) specifications from 2700 K to 5000 K with a CRI (Color Rendering Index) over 80. They also feature a compact package size with an 8 mm LES (Light Emitting Surface) and a package structure that can be easily connected with holders or screw mounts for greater installation convenience.

Samsung's LC series has gained widespread attention for delivering high luminance from a small LES, as well as low heat resistance and outstanding light efficacy. The LC packages also feature high color uniformity with 3-step MacAdam ellipses and consistently superior light quality. The new CoB LED lighting solutions can be used in a significantly wider range of applications, including downlight for home lighting, flood light for industrial lighting, and spotlight and downlight for commercial lighting. ■

Osram Adds Compact High-Flux P 13 Version to the Soleriq P Series

At the electronica 2014 in Munich, Osram Opto Semiconductors has unveiled the P 13 as the latest addition to its Soleriq P series of LEDs. The Soleriq P 13 has a brightness of up to 6800 lumens, making it the highest-power LED in the Soleriq P series. Together with a small light-emitting surface measuring just 13.5 mm in diameter, the P 13 is a highly compact and powerful light source for multiple lighting applications, suitable for high-powered spotlights used in retail, museum and commercial lighting.

Osram Opto's new Soleriq P 13 compact high-flux LED is intended to boost the performance of indoor spotlights

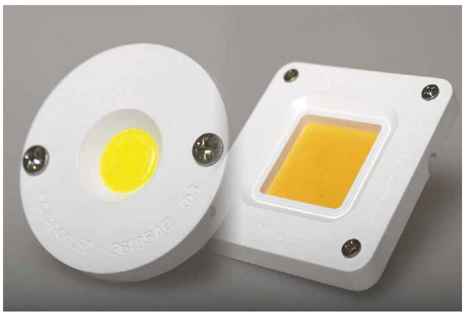
The P 13 is available in two versions with different color rendering indexes (CRIs). The CRI 80 version delivers a brightness of 4000 lm even at high temperatures (85°C, 1050 mA) and can be overdriven to deliver up to 6800 lm. The entire package measures 18 x 18 x 1.5 mm, facilitating compact and bright lighting solutions for indoor spotlights and high-bay lighting. Alternatively, for ambitious spotlight applications demanding high color quality, small beam angles and a high lumen output, the CRI 90 version delivers 3300 lm on average and up to 5600 lm in overdriven conditions.

The P 13 has similar light output to the existing 4000-5000 lm Soleriq S 19. “In fact, the new Soleriq P 13 has smaller dimensions and is therefore the right choice for more compact lighting solutions,” says Marc Dyble, product marketing manager for General Lighting at Osram Opto. Compared to other products in the Soleriq P series (the P 9 or the P 6), fewer LEDs are needed to achieve the same light output. The small light-emitting surface permits a simpler lens design, costing less and enabling more compact lighting solutions. Binning of the LEDs (at a current of 1050 mA) takes place at 85°C (‘hot binning’). This high temperature very closely matches normal operating conditions and enables the brightness and color values of the LEDs to be precisely determined in line with their subsequent use, says the firm.

Products in the Soleriq family have certain features in common. The LEDs are all based on chip-on-board (CoB) technology (ensuring uniform color and light appearance), while their light-emitting surface is compatible with the international Zhaga standard. ■

ParagonLED Offers Dimmable High Efficiency Driver-on-Board CoB Series

In order to give clients improved products and friendly user experience, ParagonLED® keeps developing better and multi-functional products. The latest dimmable high efficiency driver-on-board CoB is such an example. It is not merely AC power input directly CoB with a dimming functionality.



ParagonLED’s driver-on-board AC CoB series offers dimming functionality while maintaining a THD below 15%

The new CoB has low Total Harmonic Distortion (THD<15%). We design it as a perfect match for the Triac dimmer, which is tailored to worldwide lighting industry usage. Products are designed following regulations, like CE, UL, DLC, CSA, CCC, ENEC, and CNS, etc.

The characteristics of dimmable high efficiency driver-on-board CoB are summarized as below:

- Direct AC power input
- No electrolyte capacitor
- High power factor > 0.99
- Low total harmonic distortion < 15%
- Triac dimming
- PWM dimming
- Operating temperature: -60~85°C

This dimmable high efficiency driver-on-board CoB series, designed to be in accordance with European (220 V~240 V) and USA (120 V) market needs and is available in 12, 18, 36 and 54 W.

aragonLED® also controls the CCT strictly according to DLC, Energy Star and ErP regulations. The CRI can be made at 70, 80 or 90, depending on the customers’ requirements.

The non-dimmable high efficiency driver-on-board CoB series is also available in different wattage, from 7 W to 108 W, and also for worldwide market needs.

The dimmable/non-dimmable high efficiency driver-on-board AC CoB series are already in mass production, and samples are available for further testing. Customizing specification is available as well on request. ■

Everlight Electronics Presents New 5630D HE, 2835 and XI3030 Series

Everlight Electronics, a leading player in the global LED and optoelectronics industry, introduces two new low/mid-power LEDs especially suited for use in light tubes – retrofits and new designs – with excellent lm/w and lm/price characteristics. The Everlight 5630D HE (EU) is an ultra-efficient low-power LED (0.2 W, capable of up to 0.5 W operation), while the Everlight 2835 EU series (0.2 W and 0.5 W) is an upgrade from standard 3528 packages. The popular compact and high lumen XI3030 1 W series is extended by an ultra warm white EU version (2200 K - 2400 K).

Everlight’s latest low and mid power LEDs are characterized by a very high efficacy

The Everlight 5630D HE (EU) offers a high Lumen/Watt ratio ranging from 170 lm/W (warm white) to 180 lm/W (cool white) and achieves an outstanding 175 lm/W at 4000 K. The 5630D High Efficiency low-power LED is primarily intended for linear light designs. With its optimized performance combined with the quality of light needed for linear light source applications, it provides an optimal solution to achieve 130 lm/W or more in final product LED tubes. Other suitable lighting applications for the 5630D HE package include panels, downlights and bulbs. EVERLIGHT’s 5630D HE (EU) package (5.6 x 3.0 x 0.65 mm) is sampling and available in production quantities now.

Due to a newly designed heat slug, the Everlight 2835 EU series maintains the compact size of 3.5 x 2.8 mm with a thinness of flat 0.7 mm but can be over driven to achieve a high efficiency of 116 lm/W at 2700 K warm white and 127 lm/W at 6500 K cool white. Superior product characteristics and cost effectiveness turn this white LED device into a real cost and energy saver.

Everlight’s high performance low/mid-power 2835 series with a fabulous low Euro/Dollar per Lumen ratio is a top solution especially for tubes and downlights, eventually for any general lighting application. This new product is sampling and available in production quantities now.

Everlight’s new ultra warm white high lumen XI3030 1 W EU version (with 2200 K to 2400 K CCT replicates the warm color temperature of dimmed traditional incandescent or halogen lighting. This LED is ideal for use in candle lights and other bulbs to create natural warm white lighting environments. With an efficiency of 90 lm/W or more, the Everlight XI3030 Ultra WW (EU) 1 W LED series provides a favorable lumen/cost option for many applications. This new product is sampling now and will be available in production quantities in Q1/2015. ■

Xicato Delivers First XIM with Integrated Dimming Driver

Xicato, a leading manufacturer of intelligent light sources, releases its XIM intelligent module that debuted at Light + Building earlier this year. The XIM module provides extremely smooth dimming, as low as 0.1% in DALI systems and can be connected via DALI or 1-10 V systems. The module also monitors and records its own performance and "health" using on board microelectronics and software that Xicato has pioneered in the light source. To ensure maximum performance and lifetime, the onboard diagnostics allow Xicato's XIM to monitor real-time temperature of the LEDs and electronics and to autonomously enter protection modes if the module's maximum temperature is exceeded.

Xicato's XIM modules integrate microelectronics, a dimming driver and onboard diagnostics

"Lighting marketing is witnessing a complete paradigm shift," said Menko de Roos, CEO at Xicato. "We have been comfortable, but not always effective, at trying to attach intelligence to the light source. We have external drivers, probes, sensors. But the computer and consumer electronics industries have clearly shown us that the path to better, more cost effective solutions is through integration. Everyone with a modern smartphone knows this to be true."

Integrated Dimming

Xicato's XIM integrates the dimming driver within its very small, 50 mm diameter footprint. All that is needed is a 48V, constant-voltage power supply which, depending on wattage, can power one or many modules. The module can be connected to either a 1-10 V or DALI system from which dimming can be controlled. The dimming engine and software have been specifically designed to mitigate the risk of flicker detection, even at very low light levels.

"Quality of light drives our thinking," said Thor Scordelis, Global Manager of Product Marketing, "so for us, making sure that we could offer extremely smooth dimming was essential. This means that the light turns on and off smoothly, that you can actually dim across the entire dynamic range of the control system and that we eliminate stepping of the light as it's adjusted."

Diagnostics and Autonomous Temperature Management

Onboard diagnostics are new to lighting though fairly common in other electronics systems. Xicato is essentially doing what's already done in cars and planes where operating conditions and performance parameters are monitored and recorded for future analysis if needed. When light sources are removed for any reason, they can be returned to Xicato where technicians can retrieve the data.

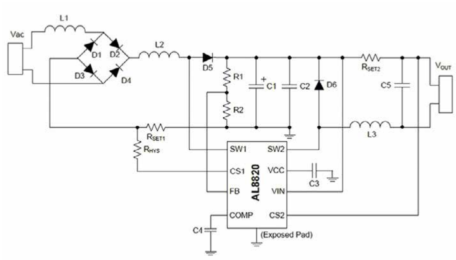
These diagnostic electronics also enable the company's autonomous thermal management. If the module senses that the LEDs are getting too hot and exceeding operating parameters, the light source will gradually dim itself by 15% so that the temperature decreases. This level of dimming cannot be seen by the human eye so room or store occupants are completely unaware of the change. When the temperature has decreased for a predetermined period of time, XIM will automatically increase the light to its original setting. If the temperature is still above the threshold, it will be dimmed down to 5% and enter a self-protection mode.

Efficiency and Cost Effectiveness

The need for affordable, more efficient lighting is a key driver in lighting today. This is addressed by Xicato with XIM. Breakthroughs over the last two years have enabled Xicato to shrink its Corrected Cold Phosphor Technology and to increase the efficiency of the light source without sacrificing any quality of light. As a result, XIM can produce light at nearly 100 lumens per Watt at operating conditions - performance that exceeds all other competitive modules available today. Because size and complexity have been reduced, costs have also been reduced. Coupled with the integration of the dimming electronics, XIM is now the most efficient and cost-effective deep dimming solution the market has seen. ■

LED Driver from Diodes for Non-Dimmable MR16 Lamp Design

Diodes Incorporated, a leading global manufacturer and supplier of high-quality application specific standard products within the broad discrete, logic and analog semiconductor markets, introduced the AL8820 LED driver converter. This device is a compact, two-stage, boost/buck non-dimmable MR16 lamp design solution that is simultaneously characterized by high power factor, low total harmonic distortion (THD) and low-output current ripple. For example, in a 6 W MR16 application, the device operates flicker-free with most common LED lighting transformers at a power factor of 0.9 and THD of 30%.



Typical Diodes AL8820 LED driver application circuit

Applications:

- MR16 Lamps
- AR111
- General Illumination Lamps

Features:

- Wide input voltage range: 5 V to 36 V
- Internal 40 V NDMOS switch
- 2 A output current
- Continuous Conduction Mode (CCM) operation
- Up to 1 MHz switching frequency
- High PF > 0.9 and low THD < 30%, and low ripple < 20%
- Internal protections
- Under Voltage Lock Out (UVLO)
- Output open/short protection
- Over Temperature Protection (OTP)
- SO-8EP
- Totally lead-free & fully RoHS compliant
- Halogen and antimony free "green" device

Combining two DC-DC regulators in the 5 mm x 6 mm SO-8EP package, the AL8820 operates in continuous-current mode and employs an innovative control scheme to ensure high compatibility with most commonly used electronic transformers. An ultra low RDSON internal 40 V / 2 A

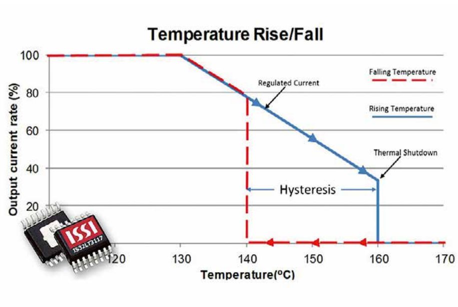
NDMOS switch helps minimize power losses while supporting the delivery of large output powers in a wide range of 5 W to 7 W MR16 LED lamps.

The device features a wide 5 V to 36 V input voltage range and an output current up to 2 A can be achieved. A switching frequency of up to 1 MHz means that smaller-sized external inductors and capacitors can also be used with the device for MR16 solutions, helping to further minimize overall circuit footprint and BOM cost.

The AL8820's comprehensive integrated protection features include: under- voltage lock out, output short circuit, output open-circuit, over-current, over-voltage and over-temperature protection. ■

ISSI Introduces Cost-Cutting 4-Channel High Brightness LED Driver

ISSI introduces the IS31LT3117, an industry unique, four channel linear driver for high brightness LEDs. With an operating voltage range of 6 V to 53 V it can sink up to 350 mA per channel. If a higher current is required, the four outputs can be connected in parallel for a whopping 1.4 amps (4 x 350 mA) of combined current.



ISSI's new IS31LT3117 LED driver IC offers thermal control

Operating at such high currents presents thermal challenges which are addressed in the IS31LT3117. First it is packaged in a thermally enhanced 16pin TSSOP to mechanically disperse heat to the PCB. Then it integrates thermal protection features and supports external transistors to offload any excess heat away from the device and onto the transistors.

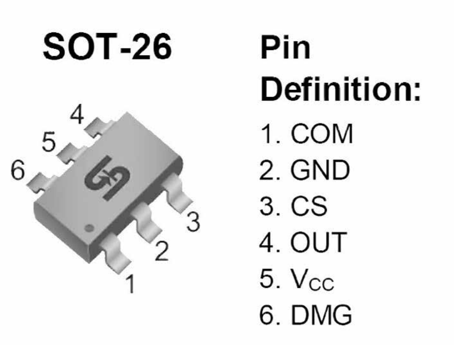
The IS31LT3117's silicon junction temperature is constantly monitored to keep it below 160°C and shuts down should this threshold be exceeded. However, to avoid a complete shutdown, the output current is reduced at a rate of 2.22%/°C when the junction temperature increases beyond 130°C. Should the die temperature continue to rise and exceed 160°C then the device will automatically shut down with no current to the LEDs.

Linear drivers are a simple and cost effective solution for driving LEDs; if their heat generation is properly managed. The IS31LT3117 is the right LED driver solution for high brightness LED lighting applications since it provides all the benefits of a linear driver while addressing the thermal issues.

With the new IS31LT3117 high cost savings are possible i.e. running at 48 VDC. Compared with single channel 24 V solutions the component count could be reduced from more than 25 components to a handful. ■

Taiwan Semiconductor LED Drivers Deliver LED Currents up to 2 A and up to 91% Efficiency

With their TS193x, TS194x and TS197x LED constant current drivers, Taiwan Semiconductor is introducing high-efficiency, buck-boost-converter based solutions for the control of white LEDs.



The TS19310 is Taiwan Semiconductor's latest amendment to the TS19xx LED driver IC series

Features:

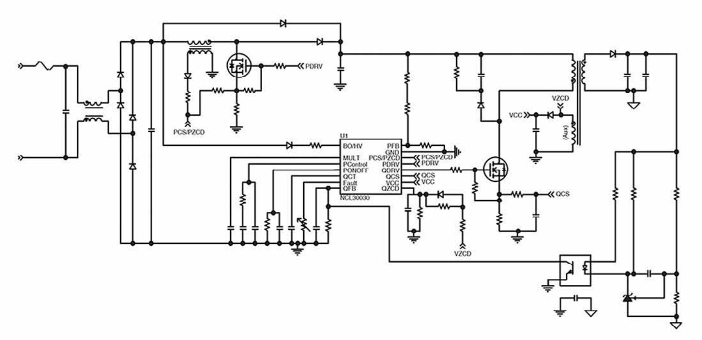
- Operation with low supply voltage (9 V to 15 V)
- Fast switching frequency (1.2 MHz)
- High efficiency (up to 89%)
- Extremely stable, adjustable LED operating current (up to 350 mA)
- Flexibility (various LED configurations can be operated)
- Dimmability (0% to 100%, 3 options)

The TS19371CX6 step-up converter/driver (boost) for white LEDs meets all the demands placed on a modern LED drivers. With a supply voltage of 15 V, for example, the TS19371CX6 can drive 126 LEDs in 14 parallel-switched strings of 9 LEDs, each with 20 mA and efficiency of almost 89%, and also just a single LED string consisting of six white 1 W HP LEDs with 350 mA (efficiency 88%). The required LED operating current is established using a very small feedback resistor (e.g. 0.22 Ohm for 350 mA) in the LED chain, ensuring that power dissipation from resistance is kept to a minimum. For operation, the TS19371CX6 only requires four external components (two capacitors, one choke and one diode).

The TS19377CS is a high-efficiency buck converter, able to supply switch output current of 2 A at 91% efficiency and switching frequency of 330 kHz, while the TS19451CY is an LED driver IC that ensures efficient, precise current limiting and current setting for LED strings operating on mains voltage. Housed in the small SOT89 package, the TS19451 can be operated directly on 230 V mains power using either an upstream bridge rectifier with a smoothing capacitor, or directly connected to a DC source up to 400 V to drive long LED strings with well over 200 V total forward voltage. The only additional external components required for the LED control are one diode, two further capacitors and a choke. An integrated 475 V power MOSFET drives the LED chain so that the operational current of the chain amounts to a constant 50 mA (fixed internal preset), independent of voltage fluctuations. ■

ON Semiconductor Extends NCL300xx Series LED Drivers

ON Semiconductor announces two new series of power factor corrected (PFC) offline AC/DC drivers for high performance LED lighting applications. Extending the NCL3008x family of products, the NCL30085, NCL30086 and NCL30088 address single stage design implementations up to 60 W that require high power factor. The NCL30030 broadens the existing solutions which support higher power (up to 150 W) two stage topologies that require low optical ripple and wide LED forward voltage variation.



ON Semiconductor has introduced two series of power factor corrected (PFC) offline AC-DC drivers for high performance LED lighting applications - NCL30030 typical application circuit

Common General Features:

- Wide VCC range from 9 V to 30 V with built–in overvoltage protection
- High–voltage startup circuit
- Integrated high–voltage brown–out detector
- Fault input for severe fault conditions, NTC compatible (latch and auto–recovery options)
- 0.5 A / 0.8 A source / sink gate drivers
- Internal temperature shutdown

PFC Controller Features:

- Critical conduction mode with a multiplier
- Accurate overvoltage protection
- Optional bi–level line–dependent output voltage (2:1 / 1.77:1 versions)
- Fast line / load transient compensation
- Boost diode short–circuit protection
- Feed–forward for improved operation across line and load
- Adjustable PFC disable threshold based on output power

QR Flyback Controller Features:

- Valley switching operation with valley–lockout for noise–free operation
- Frequency foldback with minimum frequency clamp for highest performance in standby mode
- Minimum frequency clamp eliminates audible noise
- Timer–based overload protection (latched or auto–recovery options)
- Adjustable overpower protection
- Winding and output diode short–circuit protection
- 4 ms soft–start timer
- These are Pb–free devices

Typical Applications:

- High power LED drivers
- Commercial LED ballasts
- LED signage power supplies
- Adapters
- Open frame power supplies
- LED electronic control gear

The NCL30085, NCL30086 and NCL30088 utilize a power factor corrected current control algorithm which makes them suitable for flyback buck-boost, and SEPIC topologies. By operating in quasi-resonant mode these devices are able to deliver optimum efficiency across wide line and load levels. The innovative control methodology they employ allows strict current regulation to be achieved (within 2 percent typically) solely from the primary side.

The non-dimmable NCL30088 is complemented by the "smart-dimmable" NCL30086 supporting analog and/or pulse-width modulation (PWM) dimming with a single input that controls the average LED current. Completing the series is the NCL30085 which supports three levels of log step dimming (70%, 25% and 5%). As a consequence, it permits light output reduction by toggling the AC switch on/off to signal the controller to lower the LED current. All three devices feature user configurable current thermal fold-back mechanisms that help prevent overheating and enable manufacturers to support longer lifetime.

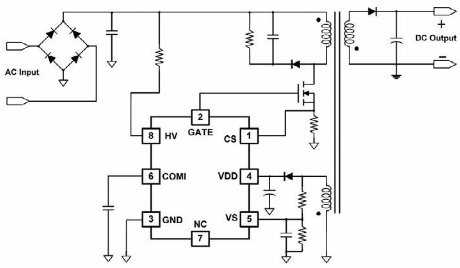
The NCL30085 and NCL30088 are offered in SOIC-8 packages, while the NCL30086 is offered in SOIC-10 package.

The NCL30030 is a two stage PFC controller plus quasi-resonant flyback controller optimized for medium and high power LED lighting applications up to 150 W. This device is best suited for commercial lighting such as lowbay, highbay and streetlighting. The NCL30030 makes use of proprietary multiplier architecture to achieve low harmonic distortion and near-unity power factor while operating in critical conduction mode (CrM).

The NCL30030 is in an SOIC-16 package with 1 pin removed for high voltage spacing. ■

Fairchild's New LED Driver Delivers Best-in-Class Solid State Lighting Performance

Fairchild, a leading global supplier of high- performance power semiconductor solutions for making the world a cleaner and smarter place, announced the FL7733A Single Stage Primary-Side-Regulated (PSR) Flyback LED Driver for delivering constant brightness and instant flicker-free turn-on of LED lighting. The new low-power LED lighting driver is built for a variety of 5 W to over 60W, indoor and outdoor LED applications so that designers can easily overcome the challenge of meeting global standards and regulations for LED lighting with a single, scalable solution.



Typical application schematic of the FL7733A, having excellent THD performance and tight output tolerance

With the new driver, designers can:

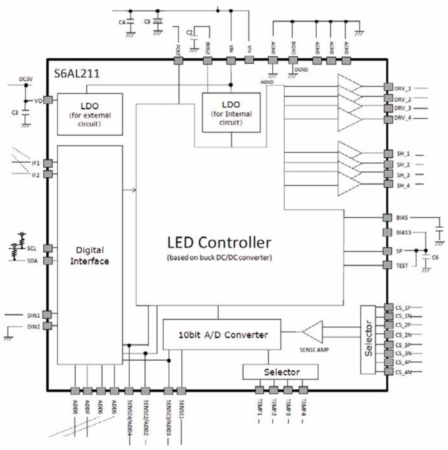
- Easily meet global standards with <10% total harmonic distortion (THD) and protection functions
- Simplify supply chain with one solution supporting >60 W designs with thermal management and short circuit protection
- Ensure maximum compatibility with High Voltage LED modules with an ultra wide output voltage range of 10% ~ 100%
- Deliver flicker-free constant brightness over wide operating range with < ±3% constant current tolerance and < 0.2 second start up performance.
- Enable compatibility with a variety of LED modules with output driving power of over 60 W, twice that of competing solutions

The FL7733As, a key component of Fairchild's overall LED solutions that reduce component BOM, enable smaller lamp sizes, eliminate design complexities, is ideal for SSL downlights, PAR, A19 bulb applications.

The best-in-class THD of less than 10% at universal line voltage conditions is significantly less that the 30% THD that makes up most regional regulations. This gives designers plenty of headroom to scale product offerings for various regions of the world. In addition, the FL7733A uses dual over voltage protection (OVP) to meet UL SELV under 60 V output regulations. ■

Spansion Brightens LED Lighting Market with Intelligent, Single-Chip LED Driver IC

Spansion Inc., a global leader in embedded systems solutions announced a new series of intelligent LED driver IC solutions. Integrating the necessary components for intelligent lighting into a single chip solution, the S6AL211 series is designed to reduce development costs and speed time to market. The series support industry-leading communication standards including DALI, DMX and Bluetooth® Smart.



Spansion S6AL211Axx block diagram

Features:

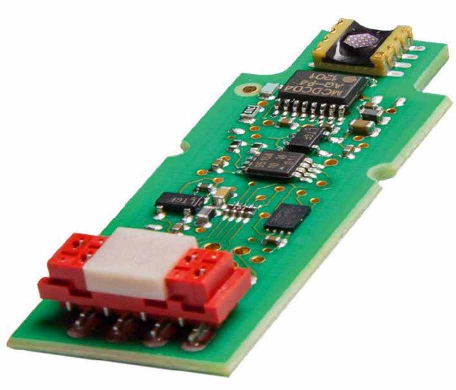
- S6AL211A31 (compatible with DALI standard)
- Output: 72 W (18 W x 4 ch), 5-LEDs in series, 1 A
- Dimming: 100%-0.1%, (>1%: current control, <1%: PWM control) 254 steps 1 color
- Communication: DALI, IEC62386-101/102/207
- S6AL211A94 (compatible with Bluetooth® smart module)
- Output: 72 W (18 W x 4 ch) , 5-LEDs in series, 1 A
- Dimming: 100%-0.1%, (>1%: current control, <1%: PWM control) 256 steps 4 colors Linear and logarithmic dimming
- Communication: UART, sensor interface (motion, Illuminance)

"LEDs are clearly on a growth path to outpace legacy lights and will be used in everything from indoor lighting in office buildings, hospitals and displays in shops and museums to outdoor lighting," said Tom Sparkman, SVP of Spansion's Analog Business. "Our new integrated IC brings intelligence, power savings and ease-of-design for customers, allowing them to design solutions rapidly and with the ability to control and change dimness and colors via wired and wireless communications."

The product series feature a 4 ch buck DC/DC LED driver IC and can dim brightness down to 0.1% with the ability to adjust up to 100%. The S6AL211 integrates all the peripheral components including pre-drivers, sensing amps, and LDOs needed to configure the LED driver circuits. This integrated solution minimizes PCB by up to 25% compared to competing solutions, reducing the bill of materials and delivering a cost-competitive offering. ■

New Jencolor Sensor Solutions for Lighting Applications

MAZeT GmbH, a leading provider of Electronic Design and Manufacturing Services introduces a new sensor board, the MTCS-INT-AB3, which is based on two new IC solutions, which are specially developed to solve tasks in LED lighting control - for example: feedback color control of LED light sources. The new Jencolor color sensor solutions for lighting applications solution was present during the trade show "electronica" in Munich.



Jencolor's new MTCS-INT-AB3 is an OEM sensor with smart color control

The true color sensors IC in implemented on the board performs color measurements based on the standard CIE 1931 - the human eye perception. It is possible to directly process the data as XYZ values or within the Lab/Luv color space. The XYZ filters of the sensor show no temperature or aging drift effects and are long-term stable throughout the entire lifecycle of a product.

The on-board signal converter IC MCDC04 consists of an ADC with high bandwidth and I2C output. The IC processes via charge-balance method and converts lowest photocurrents at high accuracy (16 bit). Its full-scale range can be customized to the specific application beforehand and during operation via programming. Therefore it is possible to realize a sensitivity of 20 fA/LSB at a dynamic of 1 to 1,000,000. The IC is temperature compensated and features the possibility of external measurement synchronization.

The board is an ideal OEM color sensor solution within the Luv/Lab color space with simple implementation based on the two modules on the board in addition to a power supply and I2C interface. Together with a µC or FPGA it is possible to directly implement the XYZ sensor values within algorithms for measurement or control tasks at an accuracy of Delta u'v' <0,003. Therefore the OEM sensor is an ideal addition to all applications that require a high accuracy and stability of colors, even in harsh environmental conditions like temperature shifts. Examples are the calibration of cabin lights in airplanes, or the color management of backlights in displays or video walls. ■

Lumotech Announced the Release of New LED Drivers from 30 to 150 W

Last autumn saw the release of several significant new Lumotech LED driver products. These include 3 new drivers in the rapidly growing and strategically important 30 W range as well as our first collection of outdoor rated drivers. As with all Lumotech drivers, these new products have been engineered for best fixture performance.

Lumotech is coming up with a line of new LED drivers between 30 and 150 W

L05031
Introducing the most versatile 30 W driver on the market with an extremely compact form factor. This new product offers excellent value for money and has a very wide operating window, ensuring that one driver can be used for multiple fixtures. The L05031 is particularly ideal for (track) spot applications as fixture designs become smaller and more streamlined.

L05033
A highly cost-effective new 33 W fixed 700 mA LED driver, ideal for non-dimmable lighting applications where excellent reliability and stability are required. The L05033 delivers renowned Lumotech quality and performance at a very competitive cost point.

L05025
This new 30 W DALI driver extends our portfolio of award-winning DALI drivers. Housed in the same form factor as our 40 W DALI driver, it offers customers a cost-effective alternative for applications where lower wattages are sufficient. As with our 40 W DALI driver, this new product has a wide voltage range, meaning that it can be used with multiple fixtures which reduces supply chain complexity for lighting OEMs. Our low ripple design ensures flicker-free lighting and perfectly smooth dimming. Ideal for troffer lighting applications as fixtures in this market segment become more energy-efficient.

L05055
A compact and flexible solution for 60 W fixtures. The new L05055 is a 60 W driver in our 40 W form factor and is very flexible in current and voltage range. The product supports an external temperature sensor and cooling fan which are valuable features for higher lumen track spots where gas discharge light sources are being replaced with LEDs.

L05175 & L05176
A pair of fully programmable outdoor-rated drivers - 75 W and 150 W DALI I-set IP65 for excellent performance in high bay and outdoor lighting applications. These are Class 1, non-isolated products supporting output voltages up to 280 V. ■

Mean Well's LPC-150 Extends the Power Range of the LP Family to 150 W

The LP family, a typical series for the economical line, is widely adopted by the entry-level lighting market; for constant current output applications, this family has offered LPLC-18/LPHC-18 (18 W), LPC-20 (20 W), LPC-35 (35 W) and LPC-60 (60 W). In order to fulfill the requirements for the higher wattage, Mean Well extends the wattage up to 150 W, unveiling LPC-150 series. With the Class II (no FG), and non-PFC design, as well as the plastic case, LPC-150 is highly competitive in terms of cost.

The LPC-150, 150 W LED power supply, is available in 10 versions from 350 to 3150 mA

Features:

- 180~305 VAC input range
- Constant current (C.C.) output: 350 / 500 / 700 / 1050 / 1400 / 1750 / 2100 / 2450 / 2800 / 3150 mA
- 90% high efficiency for entire series
- Fanless design, cooling by free air convection
- Working temperature: -25~+50°C
- IP67 design
- Class II power unit (no FG)
- 94V-0 flame retardant plastic enclosure
- Protections: Short circuit / over voltage / over temperature
- Approvals: EN 60950-1/CE
- Dimension (LxWxH): 191 x 63 x 37.5 mm
- 2 years warranty

LPC-150 series accepts the input from 180 VAC through 305 VAC and provides ten kinds of models ranging between 350 mA to 3150 mA that the related LED applications use the most frequently. The entire series delivers a high efficiency up to 90%; moreover, the interior of this model is fully potted with heat-conducted silicone which effectively enhances the heat dissipation capability, so that without the built-in fan this series can work under -25 to +50°C by free air convection. LPC-150 series is verified for the IP67 protection level by the third-party certification institute, witnessing the ability of sufficiently preventing the internal electrical components from the damages of dust and moisture. Other functions cover the short circuit protection, the over voltage protection and the over temperature protection. Suitable applications include decorative/architectural lighting, LED wash wall lamp, and other constant current LED lighting related applications. ■

RECOM Introduces New Dimmable 25 W and 35 W LED Drivers

RECOM expands its already robust portfolio of dimmable LED drivers with the addition of two new 3-in-1 dimmable LED drivers: The 25 W RACD25-A and the 35 W RACD35-A. Each series features 3-in-1 dimming, allowing the modules to be dimmed with an analog signal (1-10 V), PWM, or external resistor. These drivers round out RECOM's already comprehensive portfolio of dimmable LED drivers, and fulfill the demand for midrange LED power supplies.

RECOM's new RACD25-A and RACD35-A are so-called 3-in-1 dimmable LED drivers allowing different dimming methods

Due to a wide input voltage range (universal AC input 90-305 VAC), these versatile drivers are well suited for power grids worldwide. Each is available in 1 of 5 different types of output current, ranging from 350 to 2100 mA, making them capable of powering a wide range of CoB LEDs.

Each unit offers an excellent power factor (>0.98 at 120 VAC, >0.93 at 240 VAC and >0.9 at 277 VAC) and an efficiency of more than 81% for the RACD25-A and 83% for the RACD35-A. Both modules are just slightly larger than a deck of cards (102x73.5x33 mm), and integrate easily into almost any application.

Fully protected against short circuit, overload, and over-temperature, these units carry double-isolated wires and come housed in IP67-rated casing, making the drivers environmentally versatile, usable both indoors and outdoors, in damp and in wet areas. Ideal applications include general lighting, public buildings, retail, outdoor lighting, architectural lighting, and bathrooms.

These new LED drivers are UL8750 and EN61347 certified, and also comply with the European harmonics standard EN61000-3-2 Class B. ■

EM powerLED BASIC - Emergency Lighting and Mains Operation in a Compact Package

The EM powerLED BASIC FX 80 W and the EM powerLED CPS FX 80 W units combine basic emergency lighting functions and mains operation with an integrated simple CORRIDOR FUNCTION (sCF) in a compact low-profile casing. With a cross-section of 21 mm x 30 mm they are designed for installation in slim LED luminaires. Each unit covers a wide range of LED applications with output power of up to 80 W and both offer considerable potential for energy savings thanks to the integral sCF feature.

Tridonic's new EM powerLED BASIC FX 80 W for mains operation provides simple emergency lighting functionality

The combined EM powerLED BASIC FX 80 W module not only enables LED modules to be operated from the mains supply but also provides simple emergency lighting functionality from a local battery. It covers a power range from 25 W to 80 W and the output current can be set via the Tridonic i-Select system in 25 mA steps between 150 mA and 500 mA.

The LED emergency lighting unit is suitable for a wide range of LED modules with forward voltages from 50 to 230 V. In mains operation the integrated sCF, in combination with a presence sensor, enables the lighting level to be reduced from 100% to 10% in the absence of people. This reduces energy consumption and leads to considerable cost savings.

In emergency lighting mode the operating time can be set between one and three hours via a jumper. Standard output or high output for emergency lighting can also be selected via a jumper and integrated power control ensures maximum output for the required operating time in an emergency.

The CPS version, EM powerLED CPS FX 80 W, has the same electrical parameters but is designed for operation on both AC mains and central DC battery systems.

In emergency lighting mode, from the central system, a lighting level of 100% or 10% can be set at the output. Depending on the application, the size of the central battery can therefore be reduced or, if required, a maximum light level can be achieved. The same simple corridor function sCF is available to reduce power in the absence of people.

Mean Well - Potted DC-DC Constant Current Buck-Boost LED Driver for Harsh Environment

Mean Well is pleased to introduce a buck-boost type DC-DC potted module type constant current LED driver - LDB-L/LW series. This series offers multiple models of different current levels, 300 / 350 / 500 / 600 mA. A very wide input/output range is provided, and regardless of the voltage difference between output and input, the drivers can operate ideally.

Mean Well's new DC/DC LED drivers can also be applied in harsh environments

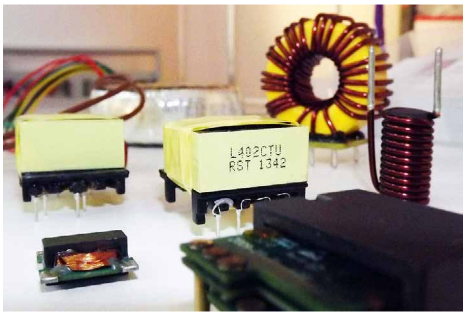
Features:

- Buck-boost design, constant current (C.C. mode) output
- 9~36 VDC input / 2~40 VDC output
- High efficiency up to 91%
- Built-in PWM dimming function and remote ON/OFF control
- Protections: Short circuit / over temperature
- UL 94V-0 flame retardant plastic case
- -40~+70°C working temperature
- IP67 design
- Approvals: FCC / CE (EN55015)
- Dimension (LxWxH): 31.8 x 20.3 x 12.2 mm
- 3 years warranty

With the built-in EMI filter, LDB-L/LW can comply with the lighting standard EN55015 without the need for additional external anti-electromagnetic components. In addition, the potted design makes it workable in a harsh environment with high dust and high moisture. LDB-L/LW series is recommended to be used for the LED lighting modules, such as street lighting, landscape lighting, tunnel lighting, household lighting, and backlighting.

Components Bureau's Precision Range Fulfils LED Driver Design Requirements

Components Bureau targets the LED lighting industry with its Precision range, which includes both high- and low-frequency transformers and inductors. The Precision range of products is designed to fulfil the lighting industry's needs in terms of flexibility, quality and value, while meeting these short lead time requirements.



High- and low-frequency transformers and inductors from Components Bureau

"Manufacturers of lighting solutions, such as LED lighting systems, require the appropriate converters for switching, protecting, and regulating. Therefore, considering the most common converter topology in LED markets, constant voltage or constant current power supplies, the components at the heart of the power converter systems need to be sourced easily and efficiently. Our specialization is in wound components for SMPS (switch mode power supplies), LED drivers and electronic ballasts," explains Ruggero Ravazzini, Precision range product manager at Components Bureau. "However, when you need a transformer or inductor urgently and lead times start from 6 weeks, it can cause major headaches. Increasingly long lead times are a common problem facing many at the moment."

"We guarantee response times within 14 days from drawings to samples as standard and production volumes from as little as 3 weeks ex-factory," adds Ravazzini.

Specific to LED driver designs, the Precision range includes PFC chokes, common mode chokes and switch mode transformers.
In addition to wound component supply, Components Bureau offers supporting services in terms of materials sourcing, metalwork and some PCB assembly.

Both standard and fully-custom products are built at the company's affiliated ISO9001:2008-certified plants in China and are fully designed and tested in accordance to international standards (UL (cURus) / CENELEC / IEC EN standards) prior to dispatch. Custom marking and packaging options are available upon request.

MechaTronix Announces Standard LED Cooler for High Bay Lights

Since most LED package manufacturers have launched recently CoB LED modules with output lumens far exceeding the levels needed for spot and down light applications, the need for standard high bay LED coolers became a fact.

Example of a high bay sub assembly with the Mean Well HBG-100 LED driver, ModuLED Mega 134100 LED cooler, Laird TPCM phase change thermal pad, Cree CXA3070 CoB module and BJB Zhaga LED holder

As a reaction MechaTronix announces its first standard high bay cooling platform with the ModuLED Mega passive LED cooler. In a diameter of 134 mm, a height of 100 mm and a weight of 1.5 kg, this passive LED cooler keeps luminaires up to 10,000 lumen on the required case and junction temperature. With a thermal resistance Rth of just 0.6 K/W the ModuLED Mega 134100-HBG can cool down 80 watts dissipated power or the equivalent of 115 watts electrical power. Furthermore the ModuLED Mega is designed in this way that after work like drilling holes or tapping screw threads can be avoided in the design.

On one side there is a standard mounting pattern for direct assembly of the Mean Well HBG-60 and HBG-100 high bay LED driver.

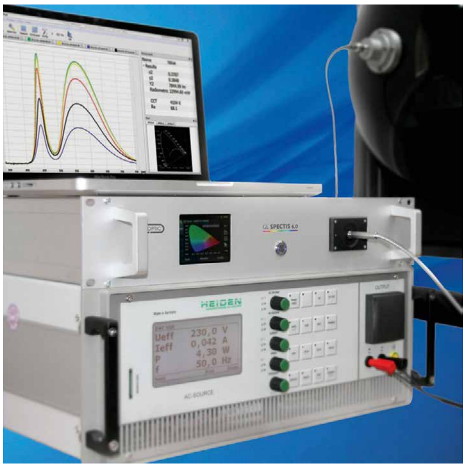
On the other side this cooler has its typical modular ModuLED design, with a variety of mounting patterns for each Zhaga LED module and the top 15 LED manufacturers of CoB LED engines.

The ModuLED Mega is again an example of the ideal balance between conduction, convection and radiation cooling and with this guarantees an optimal performance to space ratio. Besides the 100 mm high model for high bay designs, this LED cooler will also become available in a limited height of just 20 mm with a cooling performance up to 4000 lumen. Typically in the down light market there are many projects with limited ceiling heights, and up to now performance for low profile LED coolers where most are time limited to 3000 lumen or below. A third variation is the 50 mm high model with a thermal resistance of 0.8 K/W or suitable for lighting designs up to 7000 lumen. ■

GL Spectis 6.0, GL Opti Sphere 500, and Compact LED Reference Light Source

GL Optic announced that it has GL Optic has developed a robust, laboratory-grade product engineered for large scale purposes. The GL Spectis 6.0 is the optimal match to the GL Opti Sphere 500. Furthermore, GL Optic enhanced their GL Opti Light LED 127 reference light source.

Industry Grade and Laboratory Spectrometer and Integrating Sphere:
In the realm of LED measurement and testing, a lot of attention has, as of late, been given to the development of small, mobile phone size devices, allowing for the quick and easy assessment of any light source. GL OPTIC has therefore been continually developing its range of hand-held state-of-the-art spectrometers. Yet the need for top performing spectrometers in industrial or extensive laboratory settings has by no means diminished.



The GL Spectis 6.0 is a laboratory-grade product engineered for large scale purposes

The growing number of quality requirements introduced by new standards for lighting has made it necessary to ensure constant control of LED products as they are being produced. It is in response to this particular need that GL Optic has developed the GL Spectis 6.0. It comes in a rack-mountable 2U 19" housing (480 x 262 x 88.9 mm) which can be easily integrated into a standard data cabinet and supports measurements in a wide spectral range of 200 nm to 1050 nm, spanning from ultraviolet (UV) through visible range (VIS) to near infrared (NIR), offering a high resolution.

This high-end spectrometer is specifically designed to meet the demands of production process control in the manufacture of LED chips or lamps and adheres to the requirements of ever more strict international lighting standards, such as CIE 127:2007 for LED measurements which defines techniques for assessing photometric and radiometric quantities such as total radiant flux or partial LED flux or IESNA LM-79-08 which describes procedures to perform reproducible measurements of total luminous flux, luminous intensity distribution or chromaticity of SSL products.

The Spectis 6.0 also meets the eco-design requirements for LEDs in accordance with EU Commission Regulation no. 1194/2012 which enforces minimum efficiency levels and labeling requirements of LED packaging. Another key characteristic of LED lighting is the issue of energy efficiency which is often compared to conventional light sources. This is typically characterized using luminous efficacy (measured in [lm/W]) and is determined by quantifying spectral characteristics of respective luminous elements assessed mainly on the basis of luminous flux and radiant power.

These measurements can be made by coupling the spectrometer with an integrating sphere, such as the GL Opti Sphere 500. Spectrally calibrated and featuring a 500 mm diameter, it is the ideal tool to measure radiant power and spectral distribution in medium-sized LED arrays. A variety of photometric parameters can be assessed simultaneously and include color coordinates, color temperature or CRI. This in turn forms a basis to calculate the extent to which electronic components, drivers or power supplies influence the characteristics of the LEDs.

The geometry of the GL Opti Sphere 500 allows for the installation of a variety of adapters to measure individual LEDs and all other types of light sources. To conform to CIE recommendations, front-emitting diodes can be measured at the wall of the sphere in 2π geometry, while other types are measured at the center of the sphere in 4π geometry. The port of the sphere features a precise 80 mm aperture which can be used in partial flux measurements of LEDs.

An auxiliary light source is also provided to compensate the self-absorption effect of the test LED. In addition, the walls of the sphere are coated with barium sulfate ($BaSO_4$) which ensures high reflectance properties of up to 97%. As with all GL Optic integrating spheres, the Opti Sphere 500 with a spectral range spanning 240 nm to 2600 nm can be used with any GL Optic spectrometer, yet matching it with the high-end GL Spectis 6.0 will optimally meet the development and quality assurance needs of many user groups like lamp manufacturers, scientific institutes, consultants, material researchers.

GL Opti Light LED 127 Reference Light Source:
The consumer electronics sector has been experiencing a boom in the ever-expanding offering of smartphones or tablets. Currently, practically each of these devices features high-quality cameras. This trend is, in turn, creating increased challenges for manufacturers of such products which, faced with quality control requirements are expressing a need for reliable test systems to ensure consistent quality. A wide range of testing is required and may include setting or validating camera gain and offset, camera gamma and especially white point. In fact, most consumer and professional cameras need their white point verified for more than one type of illumination.

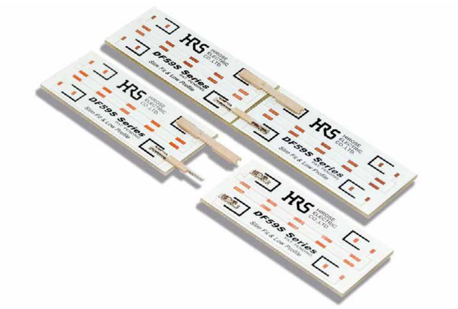
The enhanced GL Opti Light LED 127 is an integrating-sphere-based uniform light source. It is a fast and fully tunable device which offers a comprehensive test system in a compact size. It uses the tried-and-tested JUST LED Technology to provide high stability, making it a flexible solution for luminance purposes. The technology has achieved the ability to control the properties of LEDs. To this end, we have developed a complex multilevel calibration procedure that calibrates each single LED light source and stores the spectral properties in the unit's electronic controls. This process is unique and is therefore patented by JUST Normlicht.

The GL Opti Light LED 127 can be used as a calibration reference for cameras and other optical instruments, especially in industrial electronic testers, in addition to being a reference light source in laboratory applications. The Opti Light LED 127 CLC version features closed-loop calibration using a high-accuracy photodiode. It also features an electronic control system and thermal stabilization in order to achieve extraordinary colorimetric stabilization. This means that in addition to being an excellent luminance or radiance standard, the product is also a color standard which can be programmed to any color output in a specific gamut. Therefore, when using the GL Opti Light, camera manufacturers do not need to use a color checker when they are calibrating equipment. In a current project, the products were used to calibrate cameras installed in smartphones. The device provided 2 varying color temperatures (including D65 and D50) and several levels of radiance. Indeed, the device provides near-perfect replication of light sources like D50, D65, D75, A or TL 84.

The GL Opti Light's active multilevel calibration system is divided into basic factory calibration and permanent online calibration during operation without the need to use an external metrological device. Unlike other calibration sources available on the market, the product features a no flicker driver system which ensures absolute stable light, a feature which is particularly critical for camera calibration. The GL Opti Light LED can be controlled via the unit's LED control panel or from a PC connected via USB cable. The GL Opti Light Control Professional allows for more sophisticated control of light coordinates according to the users' needs. The optional LDL SDK packet provides even more customization potential. ■

Hirose Introduces High Current, Low Profile, Multifunctional, Mono-Pole Connection System

Hirose would like to announce the new DF59M/S/SN series. It is primarily dedicated to the LED lighting market but also for other applications where ultra-small connectors are required. The multifunctional connector is applicable for wire-to-board power supply connections and board-to-board coplanar connections.



Hirose's DF59M/S/SN series low profile connectors are primarily dedicated to LED lighting applications

The board-to-board option consists of a joining plug and a board mounted receptacle. A slim profile plug (DF59S) or an ultra slim profile plug (DF59SN) are available. The receptacle is not molded to significantly reduce the depth profile to minimize board space. The low mated height profile is only 1.18 mm (DF59S) and 1.2 mm (DF59SN). The receptacle is common for both plug types and features a friction lock that provides a positive tactile sensation and an audible click when mated. This confirms the connector is fully engaged guaranteeing complete electrical and mechanical connection.

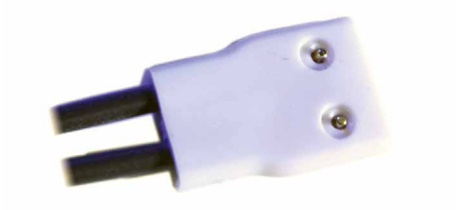
An additional feature of the board-to-board version is a unique 3-Axis floating structure. This permits movement of +/- 0.5 mm in X and Y directions, and +/- 0.2 mm in Z direction to compensate for any tolerances during the mating process. Innovative, robust, stress free contacts protect the contact area from any mechanical stress during the floating process.

The DF59M wire-to-board version consists of a crimp plug and receptacle. The DF59M receptacle has a different design to the DF59S/SN receptacle, however the PCB layout has a double footprint so that both receptacles can be mounted on to the same PCB pattern. The crimp plug features an enhanced 3-point contact with a spring feature to ensure high contact reliability.

The positive lock feature provides 16 N (Newton's) of lock retention force to ensure a secure connection that is confirmed by an audible tactile click to ensure correct engagement. A higher current rating of up to 6 A can be applied to the DF59M wire-to-board version. ■

Bender & Wirth Introduces High Voltage Ultra Low Profile LED Connection System

Bender & Wirth extends its successful LED connector line with the new version 425 for high-voltage applications.
The system is suitable for 250 VAC / 450 VDC and keeps an insulation distance of 3 mm, as recommended by the ZVEI for mains volt applications. The connection system is characterized by its extremely low profile of 1,5 mm in SMD technology to avoid shadows inside the lighting fixture.



Bender & Wirth's new low profile connection system in SMD technology is designed to avoid shadows inside the lighting fixture

The system includes:
- Board-to-board connector (425) for space-saving connection of PCBs
- Feeder(424) as wire-to-board connector
- SMD pins (423) belted in pairs for automatic SMD mounting

The feeder 424 serves as wire-to-board connector. The wires are welded to the contact element and provide a very robust and reliable connection. Cable type and length can be modified.

The connectors are easily assembled from the top onto the preinstalled SMD pins (423). The solderless connection allows efficient assemble processes and easy maintenance in the field. The system is available in a two-pole version with a pitch of 5 mm. ■

Molex Introduces SlimRay™ Pre-Wired LED Chip-On-Board (CoB) Array Holders

Molex Incorporated announced that its first SlimRay™ Pre Wired LED Chip-On-Board (CoB) Array Holders reduce assembly time while increasing reliability, with compression contacts that eliminate hand soldering and simplify the LED installation process. The holder for 13.35 by 13.35 mm CoBs comes as a single piece in a 25.0 mm diameter, low 3.15 mm profile height, rated at 300 VDC and 3.0 A. This design allows optics to be mounted closer to the light emitting surface (LES) and the gold plated compression contacts interface with array pads for stable power connections across a wide range of environments and conditions.

Molex's SlimRay™ pre-wired LED CoB array holders to deliver industry leading electrical and thermal LED connections

"Soldering wires directly to LED arrays is a time consuming process that can cause reliability concerns. Molex has designed a solderless, pre-wired system that provides lower heights and excellent wire-to-holder retention," said Dave Rios, new product development manager.

Quality and reliability issues that arise from hand-soldering directly to LED arrays are resolved by means of SlimRay's crimped, pre-stripped, and pre-installed color-coded power wires. The results are reduced installation time and improved overall process consistency and long-term reliability.

A robust housing design helps ensure stable long-term mechanical attachment even in high ambient temperatures.

The integrated LED pre-hold tab secures the CoB array prior to mounting the assembly to a heat sink for final assembly, minimizing installation time. The stripped wire ends can be easily terminated according to customer preference.

"For lighting manufacturers using LED CoB arrays, the Molex SlimRay pre-wired LED CoB holder enables quick, easy and reliable installation in all types of fixture applications," adds Rios. ■

Soraa Completes and Further Improves Its Product Lines

From mid of November until mid of December, Soraa, the world leader in GaN on GaN™ LED technology, extended its product lines, improved efficiency and dimmer compatibility. Soraa announced the extension of its line of PAR and AR111 lamps to offer a full range of halogen replacement lamps from 50 W to 120 W halogen equivalent. Furthermore, Soraa has introduced a perfectly compatible version of its award-winning MR16 LED lamp and has upgraded the performance of its award winning MR16 GU10 base 120 V and 230 V LED lamp line with the world's most efficient LED - the company's third generation GaN on GaN™ LED.

The latest members of Soraa's PAR30 and AR111 LED lamps also take advantage of the Violet-Emission 3-Phosphor (VP_3) LED technology for perfect color rendering and whiteness

Soraa's entire line of new products feature the company's Point Source Optics for beautiful, high intensity, and uniform beams and the unique Violet-Emission 3-Phosphor (VP_3) LED technology for perfect rendering of colors and whiteness. Utilizing every color in the rainbow, especially deep red emission, Soraa's VP_3 Vivid Color renders warm tones beautifully and accurately, and achieves a color-rendering index (CRI) of 95 and deep red (R9) rendering of 95 at color temperatures ranging from 2700 K to 4000 K. And unlike blue-based white LEDs without any violet/ ultra-violet emission, the VP_3 Natural White is achieved by engineering the violet emission to properly excite fluorescing agents including natural objects like human eyes and teeth, as well as manufactured white materials such as clothing, paper and cosmetics.

Extended Line of Brilliantly Efficient PAR30 and AR111 LED Lamps

The newly launched 12.5 W line features a lower wattage addition to its award winning, full visible spectrum PAR30 and AR111 LED lamps, while maintaining the high Center Beam Candle Power (CBCP) characteristic of Soraa's lamps. Featuring the world's most efficient LED - Soraa's third generation GaN on GaN™ LED - the company's new 12.5 W PAR30 lamps are the perfect lighting solution for 75 W to 120 W equivalent lighting applications in retail, hospitality and museum environments; while the 12.5 W AR111 lamps offer an efficient choice for retail applications.

The Point Source Optics technology enables the offering of an 8 degree narrow spot version with a CBCP of 20,000 Cd - twice the CBCP from other LED manufacturers.

Soraa's Violet-Emission 3-Phosphor (VP_3) LED technology allows for perfect rendering of colors and whiteness. Utilizing every color in the rainbow, especially deep red emission, Soraa's VP_3 Vivid Color renders warm tones beautifully and accurately, and achieves a color-rendering index (CRI) of 95 and deep red (R9) rendering of 95. And unlike blue-based white LEDs without any violet/ ultra-violet emission, the company's VP_3 Natural White is achieved by engineering the violet emission to properly excite fluorescing brightening agents including natural objects like human eyes and teeth, as well as manufactured white materials such as clothing, paper and cosmetics.

Soraa's PAR30 and AR111 lamps are available in 50 W to 100 W (Soraa 95 CRI Vivid) and 60 W to 120 W (Soraa 80 CRI Brilliant) halogen equivalent light output; 8 degree, 9 degree, 25 degree, 36 degree, 50 degree, and 60 degree; as well as 2700 K, 3000 K, 4000 K, and 5000 K CCT. Both lamps are highly compatible with a broad range of enclosed, non-ventilated, indoor and outdoor fixtures. Additionally, Soraa's 8 degree lamps work with its award-winning magnetic accessory Snap System. With a simple magnetic accessory attachment, beam shapes can be altered and color temperature can be modified, allowing endless design possibilities.

New Constant Current MR16 LED Lamp without Compatibility Issues

Featuring the company's signature elements of full-visible-spectrum light, Soraa's constant current MR16 LED lamp is the ideal lighting solution for restaurants, retail, high-end residential, and office environments where superior light quality and dimming are essential.

Equipped with a standard GU5.3 two-pin base, Soraa's constant current MR16 LED lamp fits into any MR16 fixture and fully conforms to the ANSI/ IECE compatible form factor. Unlike other MR16 LED lamps, the constant current LED lamp is designed to accept an external driver which supplies the lamp with low voltage DC input current, eliminating the need to fit a transformer in limited space.

Providing enormous dimming and control flexibility, light output can now be programmed to the desired level when using a programmable or remote driver. The lamp also achieves zero flicker when used with a DC driver and is available in 10 degree, 25 degree and 36 degree versions.

Soraa Improves Efficiency of GU10 LED Lamps by 40%

Soraa's new GU10 LED lamps are the perfect lighting solution for retail, hospitality, high-end residential, and museum environments where superior light quality and smooth dimming are essential.

With a 40% improvement in efficacy over Soraa's previous generation of GU10 LED lamps, these new lamps raise the bar on performance. The lamps are not only exceptionally efficient and bright, but they also render the entire visible spectrum, making white fabrics and paper goods pop, plastics and smiles whiter, and colors more natural and beautiful. Plus, they are true retrofit sized, making them highly compatible with a broad range of fixtures.

Soraa's Point Source Optics technology enables the offering of a 10 degree narrow spot version with a peak intensity or CBCP of 7,300 cd, not available in halogen or from other LED manufacturers. Soraa also offers 25, 36 and 60-degree flood versions that have a peak intensity higher than halogen and all other GU10 LED products in the market place today.

Soraa's GU10 LED lamps are available in 50 W (Soraa 95 CRI Vivid 400 lumen) and 65 W (Soraa 80 CRI Brilliant 500 lumen) halogen equivalent light output, and with 2700 K, 3000 K, 4000 K, and 5000 K CCT. Additionally, Soraa's 10 degree lamps work with its award-winning magnetic accessory Snap System. ■

Litecool Achieves Light Density Breakthrough with LineX Module

Litecool, a leading innovator in LED packing and thermal performance, announced that its LineX modules achieves new levels of light output, efficiency and light intensity. This enables more high powered lighting applications with minimal form factor and maximum reliability. The Litecool's LineX module is ideal for a wide range high performance linear lighting applications in industry, architecture and retail display.

Litecool's new linear module delivers 3000 lumens at 135 lumens per watt, with color consistency and uniformity

Based upon Litecool's proprietary thermal packaging around Intematix remote phosphor technology, LineX modules can achieve 3000 lumens per meter, 4000 K Ra 90 at 135 lumens per watt. The minimal form factor produces a uniform lighting effect with no hot spots or variance in color.

"LineX modules enable luminaire manufacturers to produce a new generation of lighting fixtures for high lumen output applications" said James Reeves, Litecool CEO, "Not only are they exceptionally bright, but they are also very uniform in appearance and combined with our thermal engineering can create miniature form factors helping luminaire manufacturers reduce bill of material costs across the entire system."

Litecool's Linex modules are available now in 2500, 3000, 3500, 4000 and 5000 K corrected color temperatures (CCTs) and standard lengths of 300, 600 and 1000 mm. ■

Megaman® Introduces Perfect White LED Series Luminaires

Megaman, a leader in LED lighting innovations, announced the launch of a brand new LED technology, Perfect White, which enhances textiles bringing the whites to life while still offering superb efficacy and energy efficient LED lamps it is ideally suited for retail lighting as well as general applications. The Perfect White range has been showcased at the Hong Kong Int. Lighting Fair 2014 (Autumn Edition).

Megaman now also offers a "Perfect White" series to bring whites to life

Including Megaman Vito LED Downlight, Carlo LED Downlight, Modena LED Tracklight and LED AR111 Reflectors, the Perfect White range produces a high quality and vibrant light that makes an object even whiter and brighter. The technology behind the effect modifies the spectrum in the near visible range to make the object appear to stand out more from the background with increased contrast and adds a clean, cool feel to the object itself.

- Megaman Vito LED downligh is an ultimate energy saving solution for shop and general lighting with 35° accent and 60° medium beam optics
- Megaman Carlo LED adjustable downlight is a perfect 50 W metal halide replacement which offers excellent lighting performance
- Megaman Modena LED tracklight has an aluminum reflector that delivers clean and precise beams
- Megaman's LED AR111 reflector saves up to 78% of energy use while delivering long lasting excellent light output

To meet retailers' requirements for high quality light sources on goods, especially fabrics, Perfect White is developed to deliver the perfect light that not only makes the color of white in fabrics stand out but at the same time renders the true colors of other hues. Retail shops, in particular fashion stores, will find their merchandise more attractive and convincing when exposed to Perfect White's light source. ■

Thermoresponsive PDLC Coating for Smart CCT-Tunable LEDs

Researchers from the Netherlands propose a novel way to ensure the lights of the future not only are energy efficient but also emit cozy warmth. Cornelissen and his colleagues from the Eindhoven University of Technology, Netherlands describe their new LEDs in a paper published in The Optical Society's (OSA) open-access journal Optics Express.

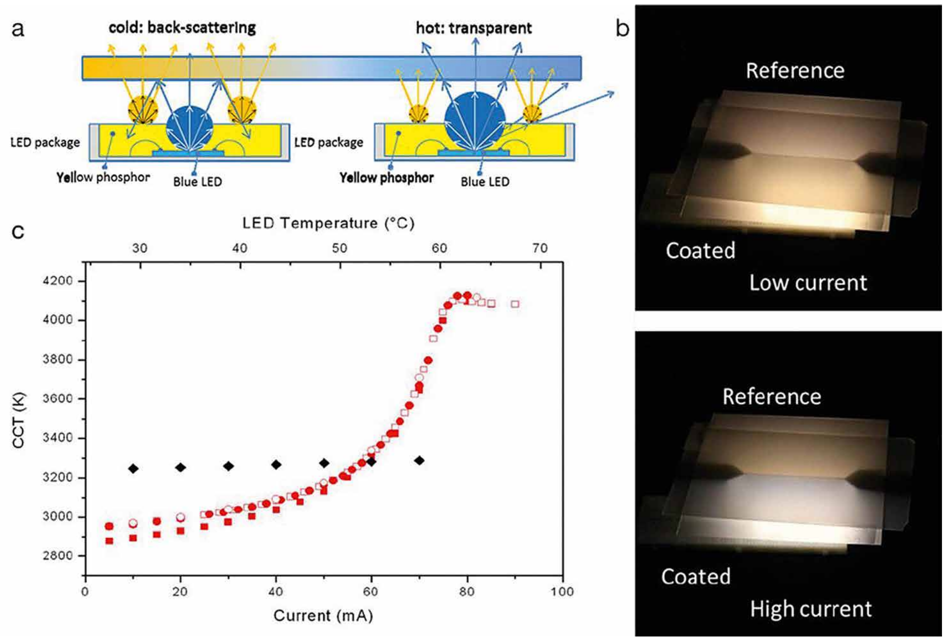
Incandescent lamps naturally emit warmer colors when dimmed, and Cornelissen said our general preference for redder colors in low-light situations might even have developed far back in time, when humans "experienced the daily rhythm of sunrise, bright daylight at noon, and sunset, each with their corresponding color temperatures."

LEDs, however, don't normally change color at different light intensities. Common solutions use multiple color LEDs and more or less complex control circuitry to make lights that turn redder as the power is turned down. The added complexity comes with its drawbacks: multiple components can increase the cost and the risk of failure, and mixing the light from multiple LEDs without creating color shadows and other light artifacts is a tricky business.

The Dutch research team tried an entirely different approach to creating cozy LEDs. The scientists had noticed that when they embedded LEDs in coated textiles or transparent materials, the color of the emitted light would sometimes change.

"We demonstrated a seemingly simple - but in fact sophisticated - way to create LED lights that change in a natural way to a cozy, warm white color when dimmed," said Hugo Cornelissen, a principal scientist in the Optics Research Department at Philips Research Eindhoven. "After finding the root cause of these effects and quantitatively understanding the observed color shift, we thought of a way to turn the undesired color changes into a beneficial feature," Cornelissen added.

They began with cold white LEDs, which can be made from blue LEDs surrounded by a material known as a phosphor. Part of the blue light is absorbed by the phosphor and re-emitted at a different color. The multiple colors combine to form white light.



Thermoresponsive scattering coating for smart CCT-changing white LEDs: a) basic working mechanism; b) demonstrator using coated (bottom) and uncoated (top) warm white LEDs operating at a low current (~20 mA/LED - top picture) and at a high current (~80 mA/LED - the bottom); c) associated CCT vs. current diagram

Cornelissen and his colleagues knew that the color of the white light could be shifted toward the warmer end of the spectrum if more of the blue light is absorbed and re-emitted by the phosphor. What they describe in the new paper is how they developed a novel - and temperature-dependent - way to create this shift.

The scientists made a coating from a composite of liquid crystal and polymeric material. The composite normally scatters light, but if it is heated above 48°C, the liquid crystal molecules rearrange and the composite becomes transparent.

When the team covered white LEDs with the coating and turned up the power, the temperature increased enough to make the coating transparent, and the LEDs emitted a cold white color. When the power was turned down, the coating reorganized into a scattering material that bounced back more of the blue light into the phosphor, generating a warmer glow.

The scientists later fine-tuned the LED design and used multiple phosphors to create lights that comply with industry lighting standards across a range of currents and colors.

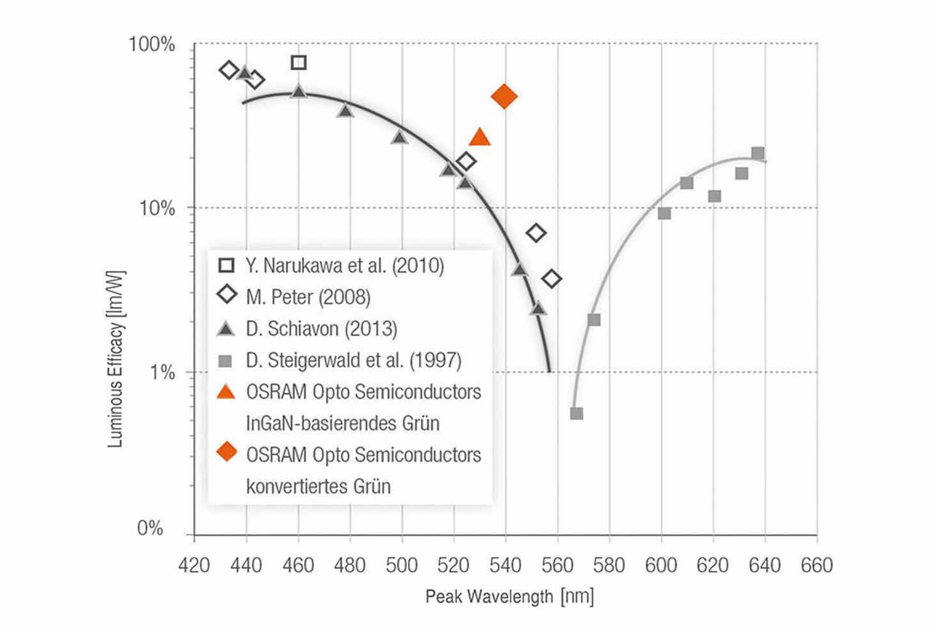
The team believes the new lights could speed up the acceptance and widespread use of LED technology in the household and hospitality markets, where there is a need to create a warm and cozy atmosphere. ■

Source:
American Institute of Physics (AIP). Note: Materials may be edited for content and length. - Based on "Thermoresponsive Scattering Coating for Smart White LEDs. Optics Express, 2014; 22 (S7): http://dx.doi.org/10.1364/OE.22.0A1868

Osram Reports Record Figures for Green InGaN-Based and Conversion LEDs

The "Hi-Q-LED" project funded by Germany's Federal Ministry of Education and Research (BMBF) has made pioneering advances with green LEDs, greatly diminishing what is known as the "green gap" phenomenon – the significant drop in efficacy in the green spectral range.
The result is a green-emitting indium gallium nitride (InGaN) based LED which achieves a record efficacy of 147 lm/W at a wavelength of 530 nm and a spectral width of 35 nm. In addition, another green LED developed by combining a blue chip with a phosphor converter has achieved a record-breaking efficacy exceeding 200 lm/W.

As part of the "LED Lead Market Initiative" funded by the BMBF, the working group for "Efficient LED Solutions with High Color Rendering Indices" has developed two pathbreaking green LED prototypes.



LEDs show a significant efficacy drop in the green spectral range – an effect known as the "green gap" phenomenon

Green InGaN LEDs Close the "Green Gap":
Conventional LEDs show a significant efficacy drop at wavelengths above 500 nm - a phenomenon known as the "green gap". Research activities in the framework of the project have enabled the development of a narrowband green LED with a record efficacy of 147 lm/W for a chip size of 1 mm^2 and a driving current of 350 mA (current density: 45 A/cm^2). The LED has a central wavelength of 530 nm and a forward voltage of 2.93 V at this current density. A reduction of the carrier density in the light-emitting layers and a significantly improved material quality were the key factors behind this breakthrough. Thanks to a significantly reduced dependency of the efficacy on the operating current compared to conventional green LEDs, the LED prototype shows significantly improved performance at higher current densities and achieves as much as 338 lm at 125 A/cm^2.

InGaN-based LEDs, in which the light output is generated by an InGaN semiconductor exclusively, offer a much more narrowband emission with a spectral width of approximately 35 nm compared to green LEDs that are based on phosphor conversion. This breakthrough is an enabling technology for highly efficient projection systems requiring a high color rendering index. After all, a high color rendering index or an increased color gamut means a more vivid, higher-quality image.

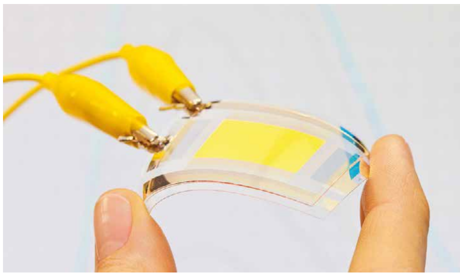
Record-Breaking Efficacy of >200 lm/W Green Full Phosphor Conversion Solution:
The second approach of the project, which was to create a new, even more efficient green LED, comes into play in cases where the spectral bandwidth of the LED is not critical. Record-breaking figures demonstrated were 209 lm/W (210 lm) with a chip size of 1mm^2, a central wavelength of 540 nm, a forward voltage of 2.88 V and a driving current of 350 mA (current density 45 A/cm^2). For a current density of 125 A/cm^2, it proved possible to increase the light output to above 500 lm. Despite this high current density, the efficacy of these devices amounts to 160 lm/W. The efficacy peaks at 1.5 A/cm^2 with a maximum of 274 lm/W.

These exceptional performance figures have been achieved thanks to the optimized interaction of chip and converter technologies: Continuous improvement of the blue LED chips, an optimized excitation wavelength and an increased degree of conversion of the phosphor converter are the winning combination underlying the new record-breaking LED.

From prototypes to series production: At the moment, the unprecedented figures achieved by the two LED prototypes still can only be ranked as development data. Further time will be needed to develop products based on the findings of the research project with optimized price and performance and which are well suited for mass production.

Light in New Shape - BMBF-Funded Joint Project R2D2

The research progresses of the last five years have proven the technical feasibility of the vision of a transparent and flexible light sources with very low energy consumption in the form of first demonstrators. Now the BMBF-funded joint project R2D2 started in November 2014 aiming at the investigation of production-related processes and technologies for the manufacturing of flexible OLED.



The progress of research over the last five years has proven the technical feasibility of transparent light sources with very low energy consumption. This can also be applied to flexible and pliable substrates

The organic light-emitting diode, in short OLED, is characterized by specific features, which distinguishes it significantly from other light sources. The OLED is able to light up the entire area, whereas light bulbs, energy-saving lamps and classical LED are point light sources. It allows for transparent light sources with very low energy consumption, which furthermore, can be applied to flexible and pliable substrates. The innovative world of light and design possibilities related to this progress had an important influence on the efforts for the development of OLED lighting technologies worldwide.

In the meantime leading lighting manufacturers have established pilot fabrication capacities for lighting-OLED on rigid glass substrates, e.g. the consortium partner OSRAM OLED.
A significant penetration of the general lighting market can only be achieved if on the one hand the hitherto high production costs for OLED lamps can be reduced and on the other hand new fields of application and design can be opened up, which could not be served so far.
The combination of the specific design characteristics planarity and flexibility with cost-effective manufacturing techniques provides an even economically promising alternative to the established lighting technologies.

“The BMBF-funded project R2D2 investigates production-related processes and technologies for the manufacturing of flexible and shapeable OLED.
The piecewise manufacturing as well as the roll-to-roll technology approaches will be pursued,” says the consortium leader Dr. Christian May from Fraunhofer FEP. “The advantages and disadvantages of these manufacturing concepts as well as possible synergies shall be identified.
Current challenges of the OLED, like durability, efficiency and homogeneity of the luminance will be addressed at the same time.”

The system integration of the manufactured flexible OLED modules is one of the main subjects of investigation within R2D2.
According to the demands of these application fields durable, highly efficient materials, assembly and connecting technologies adapted for each application as well as system integration technologies will be researched and investigated. With the participation of Novaled a worldwide leading expert for OLED materials and technologies is member of the consortium. Moreover the consortium will be supported by VON ARDENNE GmbH, which is one of the market leaders for equipment for the highly productive roll-to-roll coating of flexible substrates and thus ensures the industrial feasibility of the developed technologies.
Application and product studies including a detailed analysis of the manufacturing costs will be compiled.

R2D2 consortium:
Fraunhofer FEP
OSRAM OLED GmbH
Novaled
VON ARDENNE
Audi Group
Hella KGaA Hueck & Co
Diehl Aerospace

The consortium would like to thank the BMBF for the project funding, which provides a subsidy of EUR 5.9 million over a period of 2 years.

{iaps}
international association of physics students

The International Association of Physics Students is an organization of young volunteers that aims at establishing a network of young scientists for both academic and social exchange beyond national borders. Its growing success is bringing together students from many countries and enriching the work of the association with their activities and enthusiasm about physics.

LIGHT ON THE YOUNG - THE IYL 2015 EVENTS OF THE INTERNATIONAL ASSOCIATION OF PHYSICS STUDENTS

by Matthias Zimmermann, iaps

The International Year of Light 2015 is a unique opportunity for the different member societies of IAPS to collaborate and to show the general public our enthusiasm for light!

Many events are planned and supported by our member societies all around the globe on a national and local level, to raise the awareness of how optical technologies influence our daily lives. At an International School Day on 10 November 2015, physics students in various countries will visit schools and encourage children across the globe to carry out their own simple experiments related to light. Available resources like light and laser education kits provided by several partners of the IYL are aiming at primary and secondary school students and can be used for this purpose. Moreover, IAPS plans to create a booklet of simple and cheap light related experiments, which will be written by and shared with physics students all over the world. An example of such an inexpensive experiment is the exposition of a film through pinhole cameras. We are planning on starting an international pinhole photo contest and collecting pinhole pictures from different regions of the world.

Furthermore, light and light-based technologies will also play an important role during the two main events of IAPS in 2015. These are the International Conference of Physics Students (ICPS) in Zagreb and the PLANCKS physics competition in Leiden. With special multidisciplinary lectures and exercises focusing on light, we also want to directly promote the year and its different aspects among the physics students.

IAPS also coordinates, informs and encourages its members to get involved in the IYL in other ways. Some events will raise the interest and curiosity of physics students to study light and light-related technologies as a summer school close to Lake Balaton in Hungary and a winter school on Gravity and Light in Linz.

Others events, like an excursion to observe the Northern Lights in Sweden, will aim at showing the connection between physics and nature in its most impressive phenomena.

A special focus also lies on informing the general public about the IYL, with events such as a physics show named "Light and Night" and different exhibitions like "Light at the Museum" in Canada. There will also be public lectures focusing on optical illusions, slow light or other interesting features of electromagnetic waves. Hands-on experiments will be presented to the general public at various events in Mexico, Germany and the Philippines. With these events we aim to show that light is important in different aspects of our lives and everywhere in the world. During 2015, IAPS will collect the ideas and activities of its member societies online and share them on an international level. In addition, IAPS will arrange for international student volunteers to assist at the official IYL 2015 Opening Ceremony. This will be an occasion where young scientists will be able to collect impressions and ideas on what can be done within the framework of the IYL 2015.

In order to show the multidisciplinary character of the year, we also plan on collaborating in specific events with other international student organizations with which we are connected through the Informal Forum of International Student Organizations (IFISO).

For all these different kinds of projects, we aim to attract physics students from all over the world. With their spirit, ideas and motivation, they will strongly support the IYL. ■

M.Z.

2015 Year of (LED) Light

The advent of artificial lighting has revolutionized society. 2015, in particular, will go a long way in establishing solid-state light-based technologies as a vital area of innovation for the 21st century. Dr. Amrita Prasad from LED professional gives an overview of the technical evolution of (LED) lighting and how this may have triggered UNESCO's decision to make 2015 the Year of Light.

In December 2013, the United Nations General Assembly 68th Session proclaimed 2015 as the International Year of Light and Light-based Technologies (IYL 2015). This worldwide initiative brings the topic of light and its applications to the forefront, raising worldwide awareness about how light-based technologies promote sustainable development and provide solutions to global challenges in energy, education and health. Furthermore, the 2014 Nobel Prize in physics honored the inventors of the blue Light Emitting Diode (LED) - a significant milestone that, in the spirit of the Nobel Prize itself, is of great benefit to mankind. Isamu Akasaki and Hiroshi Amano working at Nagoya University and Shuji Nakamura employed at Nichia Chemicals successfully obtained blue light using layers of Gallium Nitride and increased the efficiency by mixing indium and aluminum. While red and green LEDs were invented almost half a century ago, blue LEDs completed the trio to create white light that can be used for general illumination. The invention and commercialization of these solid-state devices (organic and inorganic LEDs) has created solid-state lighting (SSL) and revolutionized the lighting industry. Artificial lighting has a significant impact on global energy demands and human well-being. About one fourth of the world's energy consumption is used for lighting purposes and LED light sources are already finding various applications and contributing to sustainability, energy efficiency and improving quality of life.

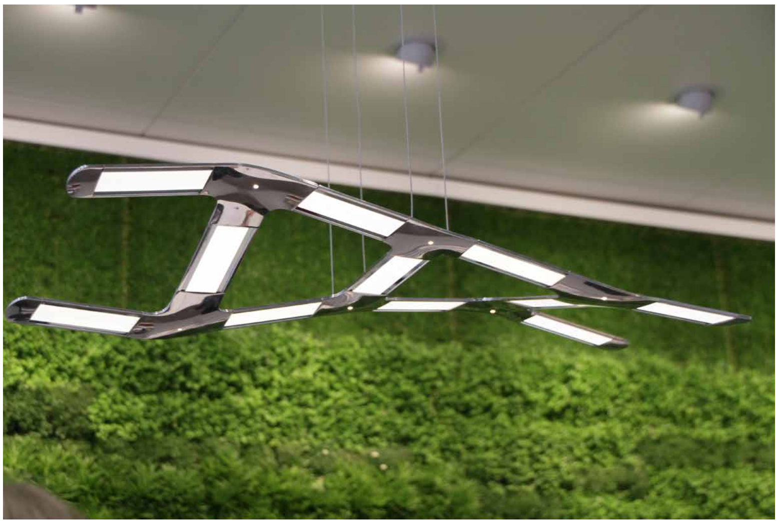
The evolution of SSL technology has, so far, followed the Trends of Engineering System Evolution (TESE), demonstrating the natural progression of technology and manufacturing trends. While LEDs have been around for over 50 years, initial applications were only limited to indicator lights in various devices. Developments of the technology in the last two decades has led to more applications such as in traffic lights, exit signs, flashlights etc. The last decade has seen a critical penetration of the LED into the general lighting market from homes to commercial enterprises, largely driven by high efficacies in excess of 150 lumen/Watt, low maintenance, smaller sizes, durability and possible long-term energy savings. This has established the LED as a functionally disruptive technology with the potential to entirely replace conventional light sources. Further, stringent regulations by governmental authorities worldwide are encouraging a wide up-take of solid-state lighting in view of its "green" and sustainable nature.

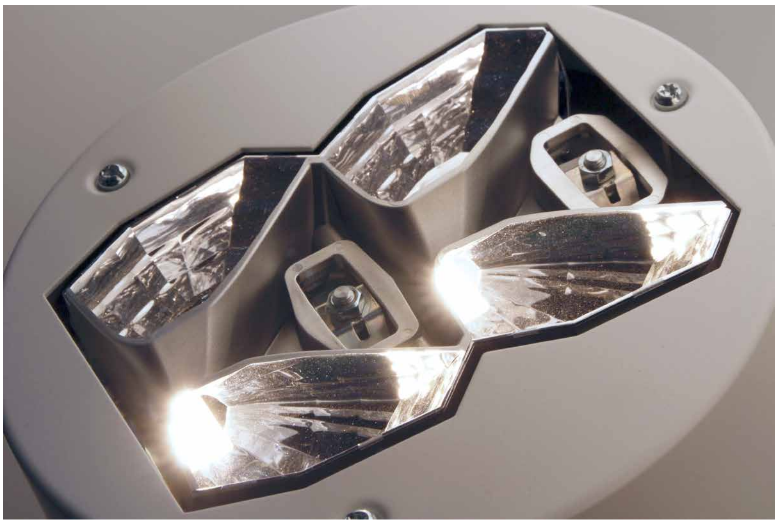
SSL is a vital link between electronics and photonics. LEDs produce more light per watt than conventional sources and have lifetimes of over 50,000 hours compared with 1,000 - 2,000 hours for incandescent lamps and 5,000-10,000 for standard fluorescent lights. The efficiency of LEDs is continuously improving, with current energy efficiencies comparable to the most advanced fluorescent or halogen lamps. Further, LEDs do not contain any toxic elements such as mercury (commonly found in fluorescent light bulbs) and offer high quality lighting with the, hitherto unforeseen, potential to control various parameters such as color temperature, spectral power distribution, spatial distribution and polarization properties. As such, solid-state lighting provides the opportunity to create sources that can adapt to specific environments and requirements - the so-called "smart lighting" revolution. This could result in lighting that is optimized to working and learning conditions and that can positively influence people's concentration, circadian rhythms and alertness. Additionally, with about 20% of the global electricity consumption being accounted for by lighting, LEDs can contribute significantly towards lowering global CO_2 emissions. As such, it is projected that the LED lighting market penetration rate will reach 56% by 2016.

Having overcome the 1st stage of engineering system development, where the main bottlenecks that make a system unmarketable are eliminated, SSL technology has also passed the "transitional stage" described by TESE. The technology has been launched on a wide-scale on the market and all its parameters are acceptable. High efficiency, long lifetimes and cleaner energy demands champion the SSL cause. The technology is continuously evolving, mostly to be adapted into existing resources and infrastructure. Currently, the SSL industry is in the most dynamic, 2nd stage of engineering system evolution. This is characterized by rapid growth of production volumes with significant investment, the technology expanding into new applications, custom manufacturing and added value propositions. Understandably, research into solid-state lighting has so far mainly concentrated on replacing conventional lamps with retrofit LED light sources that can be easily integrated into existing electrical infrastructure. However, new innovations are giving industry and lighting designers unlimited opportunities to explore new lighting concepts and develop user-centric solutions.

As the SSL industry becomes competitive to mainstream lighting, additional requirements are being considered to provide added value such as beam properties, color temperatures, color quality and lifetimes. However, challenges still need to be overcome to achieve fully controllable, adaptable, smart systems.

The two most common methods to generate white light for general lighting are color-mixing using RGB LEDs or using "phosphor down conversion" where phosphors are excited using blue or UV LEDs to emit wavelength down-converted white light (RGB). One of the major bottlenecks has been the Color Rendering Index (CRI), which is a parameter that measures the ability of a light source to faithfully reproduce the colors of objects, compared to natural light. Most LED light sources achieve a CRI of over 80 (the sun has a CRI of 100). Current research focuses not only on innovative methods to achieve high CRI and high efficiency sources but also on developing more accurate metrics to assess the color rendition and improving binning strategies (categorization of LEDs



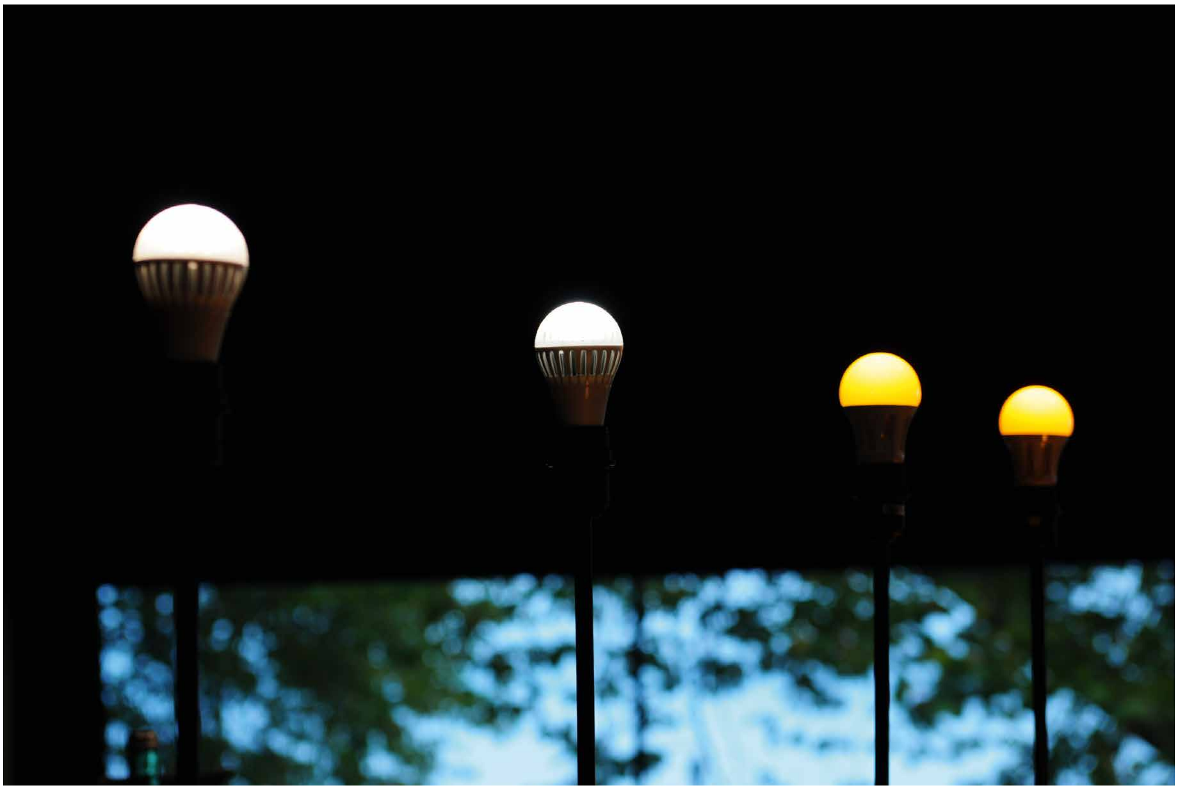


Figures 1-3: While industry has largely concentrated on developing retrofit LED lamps that integrate into existing infrastructure, new applications are emerging that allow engineers, designers and industry to explore the potential of SSL technologies

Figures 4&5:
The color quality of light is, for example, an important consideration in retail lighting. It ensures that the colors of objects are faithfully reproduced

into 'bins' based on variance in color, flux, forward voltage etc. in the production and supply chain). Significant industrial research focuses on new products with CRIs of 93-95 with efficiencies exceeding 65 lumen/Watt as well as innovative light generation methods combining both the color-mixing and phosphor down-conversion techniques. Traditionally, the Commission d'Eclairage International (CIE) color-rendering index has been used as a measure of the CRI of white light sources. However, more recently, a new Color Fidelity Index (CFI) has been proposed to overcome the shortcomings in the CIE measurement, particularly in terms of color fidelity and color quality. Further, new chromaticity binning strategies are being formulated to address the visually acceptable chromaticity differences within a bin and establish a common basis of white LED binning communication between manufacturers and customers (New Binning Strategy for White LEDs to Improve the Color Quality of Interior Lighting, LpR Issue 46, p. 48, 2014).

A major factor contributing to the color quality of white light sources is the Correlated Color Temperature (CCT). Manufacturers in Europe produce white LEDs classified as "warm white" (2,700-3,000 K), "neutral white" (3,500-4,500 K) and "cool white" (5,000 K and above) grouped into "bins" comprising devices of very similar color output. A major challenge with phosphor converted LEDs is overcoming the chromaticity drifts during operation and lifetime due to thermal effects. Solutions using sensors and driver control are common, however, current research is focusing on achieving this without significant efficiency and reliability trade-off (Direct Current Supply Grids for LED Lighting, LpR Issue 48, Mar/Apr 2015). More recently, solutions by modifying the thermo-optic coefficients of materials used in the color conversion element itself, where phosphors are typically embedded in a silicone matrix (Self-Compensation Approach to Reduce Color Shift of Phosphor Converted LEDs upon Temperature Variations, LpR Issue 49, May/June 2015) as well as ceramic phosphors and Al_2O_3 coated phosphors are being considered (Al_2O_3 Coated Europium-Activated Phosphor for Use in COB Technology, LpR Issue 51, Sept/Oct 2015).



Figures 6&7:
From home lighting to commercial buildings, long lasting, non-toxic, energy saving LED sources are becoming increasingly popular

While the SSL industry strives to develop and provide highly efficient, long lifetime and aesthetically pleasing lighting solutions, a key factor influencing almost all reliability parameters is the temperature sensitivity of LEDs. Therefore, thermal management is an ongoing challenge and an area of significant research and innovation. Operating these semiconductor devices over 100°C can drastically reduce their lifetime and adversely effect the output parameters. Both industry and academic research is actively engaged in finding active and passive cooling solutions, the latter being preferred, most commonly with heat sinks. Current advances in thermal management technologies concentrate on reducing the size and weight of heat sinks using novel materials with high thermal conductivities and innovative heat sink designs (further insights on this topic can be found in the Tech-Talks Bregenz on page 38 in this issue).

Carbon based solutions such as plastics filled with graphite particles and ceramics are widely considered, while more recently liquid cooled systems have been introduced. An additional challenge is the efficient thermal management of the whole system, integrating the source with the electronics and drivers.

Additionally, a system in the 2nd stage of system evolution also concentrates on minimizing disadvantages (as a system evolves towards the ideal). In the case of LEDs, this includes the "blue light hazard" that is being widely researched, lifetime concerns and most importantly the cost factor. There is a common consensus among experts in the field that future innovations will be driven by reliability, added functionality and lowered costs. Further, the system seeks more of a co-ordination with the environment and a tendency towards miniaturization and automation. In the case of LEDs, packaging can represent 40% to 60% of LED total cost and, as such, it represents a large opportunity for cost reduction. Chip Scale Packages provide the opportunity for miniaturization and current packaging trends are gearing towards a simplified, single device, modular approach, reducing the complexity. While the main emphasis in the general lighting market has been on inorganic LED sources and devices, the organic LED (OLED) technology has also rapidly evolved in recent years, most often for niche applications. However, in terms of gaining broader use and acceptance in general lighting, OLEDs would need to become significantly cost effective, with options for mass manufacturing and processes (Flexible OLED Technologies for Lighting Applications, LpR Issue 50, July/Aug 2015).

The "system approach" is gaining momentum, especially with emerging new trends such as Human Centric Lighting, Smart Lighting, Internet of Things and Smart Cities - innovations that promise tremendous benefits. A joint study by LightingEurope, the German Electrical and Electronic Manufacturers' Association (ZVEI) and consulting firm A.T. Kearney estimated human-centric lighting as a business that could reach an estimated EUR 1.4B (billion) by 2020.

Human-centric lighting goes beyond the basic visual needs of people. The biological effects of light on people's health, well-being, moods and performance is well-known and with people increasingly spending a significant portion of their day indoors, the need for quality light, adapted to human needs is fast becoming a necessity rather than a luxury. Several initiatives are underway world over to increase awareness about "good light" among the general public, especially its effects on elderly people, school children and office workers (Field Study of LED Office Lighting for Improved Well-Being and Performance, Current Issue, p.40). On the industry side the need to provide integrated user-centric solutions has led to evolving value chains and business models. In order to realize lighting solutions that meet individual needs and provide the right light at the right time, various areas of engineering such as sensor technology, wireless communications, adaptive controls, drivers and software are being integrated. There is also a need for standardization for large-scale market acceptance and broad dissemination of this technology and the opportunities that it offers. Apart from adopting SSL at the individual level, large-scale changes implemented by policy makers in conjunction with city planners and architects will go a long way in addressing the issue of "light pollution". Light/photo/luminous pollution is excess, misdirected, or glary artificial light usually found outdoors. Apart from the health hazards, wastage of energy and carbon footprint, extensive light pollution can result in washing out starlight in the night sky, adversely impact astronomical research and disrupt ecosystems of nocturnal fauna e.g. insects that cluster around artificial lights. Better lighting designs with more directed light (less stray light) that is need-based, better shielded and energy efficient can significantly contribute towards lowering light pollution.

Finally, TESE recommends that a system at the second stage of evolution must concentrate on providing engineering level improvements, minimize disadvantages further and adapt and expand to new fields and applications. In the case of Solid-State lighting these trends are already well underway and the SSL industry as a whole is constantly and creatively tackling optimization challenges. Initiatives like the International Year of Light 2015 will go a long way in raising the qualitative and quantitative understanding of the worldwide community about the driving forces, key opportunities and challenges afforded by this technology. This, in turn, will drive the trends and technologies for future lighting solutions. ■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Tech-Talks BREGENZ - Dr. Mehmet Arik Ozyegin Univ., Associate Prof.

Prof. Mehmet Arik

Dr. Arik holds a PhD degree from the University of Minnesota (USA). Focusing on the thermal management of advanced electronic components, he has worked at the General Electric Global Research Center in Niskayuna, NY. Dr. Arik joined the department of mechanical engineering at Ozyegin University as a full time faculty member in 2011. His current research interests include solid-state lighting, electronics cooling, microfluidics devices, energy, medical, defense systems, and Six Sigma. He is an ASME fellow and holds over 100 US/EU/Asia and world patents and serves as associate editor for IEEE.

Thermal management is an ongoing challenge and a topic of continued research and innovation. Prof. Mehmet Arik from the University of Ozyegin, Istanbul, also known as the 'Edison of the 21st Century', discussed core thermal issues and new innovative solutions, trends in cost reduction, packaging and how we can learn from electronics to achieve better thermal management of the system as a whole.

LED professional: Could you tell us about your basic research and findings from your former activities in the USA?

Professor Arik: I worked at the GE Research Centre from 2000 to 2011. We started working on LEDs in the year of 2000 and my first assignment was on the thermal management and packaging of the chip and light engine levels of an LED lamp. I drove this research quite a lot and looked at problems at chip level, local hot spots and packaging to minimize the chip junction to board thermal resistance. As you know blue light to white light conversion is not 100% efficient, and we were looking to see if we have local hot spots in the LED chip as well as phosphor particles because of this.
Later on, we also published a lot of papers on thermal management. My very first paper on thermal management of LEDs was published around 2002 and was one of the most cited papers on this topic! We also started looking at system level issues like how to place an LED light engine on top of a heat sink, what kind of materials we need to utilize and how to reduce the heat sink size by novel microfluidics cooling technologies like synthetic jets. If you want to produce 1500 lumens you needed to use 10-15 LEDs and if some of them are not attached well, some are getting more electrical current; some will heat up more than other components. The only way to abate this problem is using a liquid cooling system.
We published a lot of papers on this research. For the last three years of my time at GE, I was supported by the Department of Energy (DOE) to develop the first LED active cooling luminaire to generate 1500 lumens and it was published by DOE as a success story. In 2008, we were able to get half the size, half the volume, half the number of LEDs and develop the whole system for a bright demonstration. Right now, I have started a research group (ARTgroup) at the University of Ozyegin, Istanbul, working on new and novel ideas like active cooling for LEDs, fluid mechanics, heat transfer, liquid cooling systems and looking at local phosphor particles cooling to name a few.

LED professional: Did you get the name 'Edison of the 21st Century' based on your research at GE?

Professor Arik: When I developed the LED lamp, GE selected my technology as one of the best technologies at the time. They made a press release on the day of the invention of the first Edison light bulb, so Jeffrey Immelt, CEO of GE, gave me this title!

I may not be as smart as Edison but I was able to drive a technology from scratch to product and GE was very supportive of the journey. I will always be thankful to GE and the great team behind these inventions.
I always tell my students: if you have an idea, go ahead and never turn back. Always try, work hard and make it happen.

LED professional: We have heard time and again that rather than exploring new ideas or new applications, a lot of research tends towards replacing the incandescent light bulb. What would you say to this trend?

Professor Arik: I attended DOE meetings in the USA, and I see it as a great research, application and implementation vision-driven meeting. It is not easy to change people and adopt radically different technologies! In the USA, people change homes very often and some houses are over a hundred years old. There is an existing infrastructure for retrofit lamps. New constructions may take into account new LED bulbs or designs but would you really spend thousands of dollars replacing old structures to install new and bright LED lamps? I think retrofit can win only if it is made cost effective or by better educating people of its clear advantages.

LED professional: It is a common consensus that LEDs are getting more and more efficient. This will continue and maybe plateau by the end of the decade. So do we really need thermal management if the efficiency keeps rising?

Professor Arik: Yes, LEDs are getting more efficient, but at the end of the day they are solid-state devices and they are temperature limited. We have learned our lessons from electronics when we went from vacuum tubes to bipolar and CMOS technologies, and today even though we have very advanced manufacturing techniques for transistors, we still have thermal problems getting more and more aggressive each day. LEDs will come to a certain efficiency level and we will then look at how to drive them harder, get the number of LEDs lower and lower the cost.

LED professional: So would you say that engineers would always go to the limit and try to find cost optimization etc. but that thermal management issues will always exist?

Professor Arik: Basically we want better and better in compact volumes! The comment that I made to Marc McClear, VP Sales of CREE, at the LpS 2014 opening ceremony is that electronics is a very old and a more mature industry. So we can look at electronics to see what they had done and learn from them. LEDs are a relatively young technology and there are some differences but a lot of similarities. We will still have thermal problems because we will never have 100% efficiency. The problems will be different and we will need cost effective solutions.

LED professional: Could you elaborate on some options for thermal management and the limits?

Professor Arik: These are semiconductor devices with temperature limitations and if operated over 100°C, lifetime is drastically reduced. You can operate them at 150°C or 200°C, but they will die faster because high temperatures are always difficult for many materials and engineering. I believe 100°C is the allowable temperature for electronics but higher temperatures will cause reliability issues. If we are able to, we will always use passive cooling in any design and we will tend to avoid active cooling e.g. synthetic jets, fans, piezo fans, thermo electrics, etc. If you don't have enough surface area to remove heat by convection combined with radiation, you need a heat sink and we will

Despite all the technical progress and improvements in the efficiency of LED lighting systems, thermal management will be a challenge in the future and heat sinks will stay a relevant part of the system

almost always use a heat sink over 400 lumens tight space LED applications. The majority of current heat sink technologies are based on metals that are heavy and large. Therefore, we need to come up with an unconventional way of cooling, leading to innovations, like lightweight heat sinks.
Some companies are working on plastics filled with graphite particles or some boronitride or metal particles. Ceramics may also be an option. We would like to reach a certain thermal performance goal, and it needs to be lighter weight with a compact size option.
Thermal technologies are progressing very rapidly for electronics, and we can leverage that for LEDs. When I am asked about cooling solutions, I offer that electronic cooling equals to LED cooling. It is all connected and we need a solution that is highly reliable, low cost, easy to use, easy to maintain and available everywhere.

LED professional: One part is the light source and LED itself, but what about the quality of the driver and electronics at the moment?

Professor Arik: The weakest part in the electronics, to the best of my knowledge, is the capacitor and capacitors need to be reliable.
You have to keep the capacitors at 80°C unless you use very expensive ones. At the end of the day, you are selling a product that is competing with a 30-cent incandescent light bulb or $2.00 (US) fluorescent bulbs, so you need to make sure you can bring cost down or provide something else that people will buy.
A lot of times when I look at systems, they are not very well thermally managed as a whole!
We do have some research programs where we would like to integrate LEDs with driver electronics and have a whole system level thermal management to reach ultimate lumen and lifetime goals.

LED professional: Do you have any comments on the power LED trends and thoughts on significant lifetime improvement options?

Professor Arik: I think it is great that we can talk about 50,000 hours; that is 8 hours a day for over 17 years! I don't think we have to go further but we have to work on making it cheaper. If you consider the analogy, a computer chip costs less than 5% compared to the cost of the whole system. The cost should be reduced by advanced manufacturing techniques and we should be able to drive them harder, thereby reducing the number of LEDs needed in a system. About four years ago we were only driving them at 400 mA now we can drive over 1000 mA. So power LEDs are the way to go, and in the future we may only use one LED to get 500 - 700 lumens and it may be 2 x 2 mm^2 or even smaller in size! It will be a thermal and optical challenge and that will also be a major advancement in LED technology.

LED professional: We had a presentation at LpS 2014 about LiFi and combining light with communications. What do you think of this trend?

Professor Arik: LiFi or visible light communications is an amazing technology and I believe that it will provide tremendous advantages in some areas! It also does not have the health hazards, compared to current electromagnetic waves and WiFi and it is very secure. I think it is the future and will be a part of the system. I would expect some products in a 3-year time frame.
I could imagine smart controls, LiFi and maybe a technology using a bird's eye camera to take into account human factors.
Each person needs or likes a different kind and amount of light. Light and color affect our performance and could help or hinder our lives, giving us better or poorer quality of life. What if you could control the lighting with your smartphone? LiFi would be limited

in the beginning, but if we can find a way to generalize that, and if we can use this for communication, then why not.

LED professional: Could you comment on communication standards and what might be the direction to go?

Professor Arik: I am not a controls expert but I will comment from an engineering point of view. There are a lot of control standards and methods in thermal management, reliability or lifetime and we already have a vast amount of knowledge in the electronics industry. We shouldn't reinvent the wheel. We can do smart controls. I have seen some good examples at the LpS 2014 Exhibition. It is just fantastic that people are working in this field and sharing their knowledge with the community.

LED professional: You are also working in packaging trends. What can you tell us about these?

Professor Arik: I like Chip on Board (CoB) and we first proposed CoB in 2002 at GE. Package on board is fine but we just need an LED light engine and a PCB. In earlier days, people had a hard time handling 1mm^2 chips; today you have affordable pick-and-place machines that can handle small chips in the thousands! If you look at conventional packages from well-known companies, the thermal resistance is 5-7 K/W. However, if you put the LED on the PCB directly, you can get rid of that. That means if you drive an LED at 2.0 - 2.5 W, in the first case you could have a 15°C temperature drop! That is a lot of sacrifice. It could increase the light output by 5%! As long as we can get the best chip, I would use it in CoB.

LED professional: On a more general level, after over a decade in an industrial research laboratory working very closely with lighting, medical, energy and aviation industries, you have now started teaching and performing research at a university. Do you still work with the industry and how is this synergy working out?

Professor Arik: It is working out great and is very fulfilling! For the last two years, I have been very busy looking to grow my network especially in Europe, for research funding and training students. Very few people knew about the fundamental of LEDs when I first moved to Turkey so I am teaching the basics to a lot of students and industrial partners through the EVATEG center at Ozyegin University. We just spent over 1.1 million dollars to put in the infrastructure at the university. The Turkish government, Turkish National Science Foundation (TUBITAK), European Union FP7 program, Istanbul Development agency (ISTKA) and a number of local companies mainly funded this. The lab is used for LEDs and electronics packaging. If I want to look at a 10-micron hot spot on a chip, which is similar to a 10-micron hot spot on a computer chip, I can use the same IR thermography.

We don't work with many European or US companies yet, but we are just opening up our doors towards Horizon 2020, US collaborations and Asian companies. So EVATEG is really a global center for anyone that wants to come and do groundbreaking research, or work on a practical problem. We are encouraging researchers, graduate students and support staff, trying to give them some exceptional incentives to solve problems.

Professor Arik, a compelling speaker at the LpS 2014, engrosses his audience when explaining and demonstrating thermal management and LED lighting technology

LED professional: You are at the LpS 2014 for the first time. How has your experience of the Symposium been and what are your comments?

Professor Arik: I think it is very nice, well thought out and very professionally organized. The quality of the conference and presentations are very high and the speakers are well selected. The Expo is nice in terms of the companies and I am certain it will grow to bring more people from around the world and become even more impactful.

LED professional: Thank you very much for your comments and insights!

Professor Arik: Thank you! It has been a great experience to be at LpS 2014 in Bregenz.

LED Office Lighting for Improved Well-Being and Performance

The influence of artificial light in industry has been a topic of conversation for a while now but opportunities provided by LED lighting have made this subject even more important. Katrin Möller, Junior Researcher at the Competence Center Light, her research partners, Vincent Grote from the Human Research Institut, and Birthe Tralau from Zumtobel Lighting, investigated the effects of LED and fluorescent lamp lighting on human well-being and performance in an office environment, in a comparative laboratory study.

The effects of lighting with LED and fluorescent lamps on human well-being and performance have been studied in a In a comparative laboratory study. Two different lighting scenarios (static and dynamic lighting) were implemented and evaluated for both light sources. Twenty-eight subjects between the ages of 20 and 59 years (16 male, 12 female, 30±11) spent one day for each light source in the laboratory, the lighting scenario being constant. The subjects were tested on their feelings of well-being, concentration and performance as well as having their heart-rate-variability measured.

The results show that LED lighting was rated more interesting, colorful, comfortable, warm, inviting and beautiful than fluorescent lighting (evaluation, $p = 0.004$) as well as more casual, private and pleasant than fluorescent lighting ($p = 0.058$). No significant differences were found between LED lighting and fluorescent lighting concerning well-being, performance and concentration. The HRV-parameters shows no significant effects during the test day for the light source and the lighting situation, while the interaction shows significant effects. During the night following the test day significant effects can be seen: The night after fluorescent lighting shows higher heart rates and respiratory rates and variability is significantly lower than during the night after LED lighting.

Introduction

The lighting community has seen two major changes over the past few years. A new light source, the LED, appeared on the scene and an - up until then - unknown third photoreceptor, the intrinsically photoreceptive ganglion cell (ipRGC) was found. The ipRGC has been identified as the link between lighting and many biological functions, especially endocrine and circadian rhythms [1-3].

Since then numerous studies have been undertaken to investigate the link between lighting and its impact on human health and well-being. We now know that blue-enriched light, as well as high levels of illumination and dynamic lighting, enhances alertness and vigilance [4-9]. The activating effects of high color temperature lighting can be improved by planar light sources or indirect lighting using the ceiling or walls [10]. But we also know that one should not increase vigilance and alertness of people ignoring the time of day and the natural rhythm, since this could create several disorders [11].

With dynamic lighting during the day it is possible to enhance the

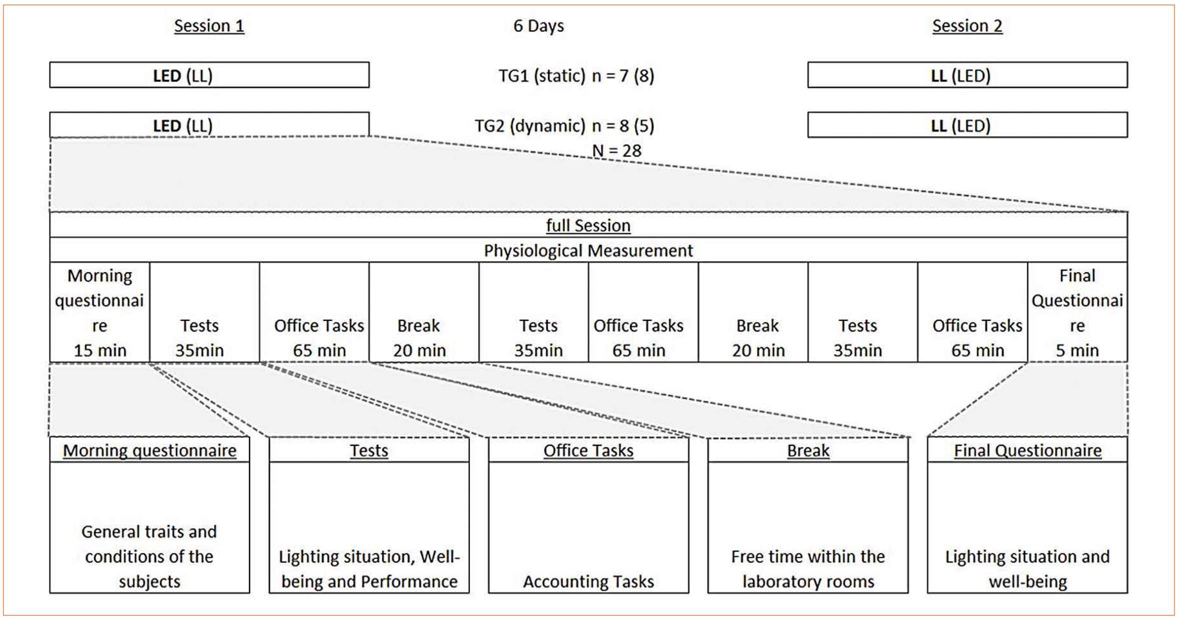

Figure 1:
Study design

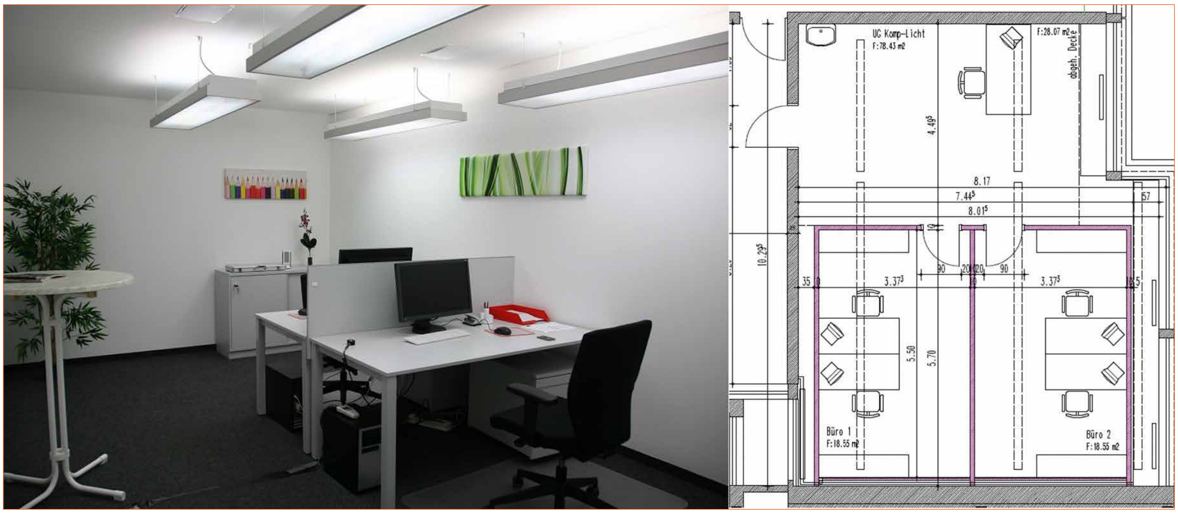

Figure 2:
Setting and layout

well-being of people. Increased illuminance levels and high color temperature in the early afternoon, together with a relaxing atmosphere generated through warm white light and low illuminance levels in the evening will help to stabilize the circadian rhythms [12, 13].
This does not only lead to increased performance during the day but also to improved sleep quality at night [14].

Besides the paradigmatic change in indoor lighting due to increased knowledge about the biological effects, the difference of the spectral light distribution of LED compared to conventional lamps has to be taken into account. The new light source is now not only used in event lighting and media applications.
It has started to capture the market of indoor lighting and will soon be used in various applications, e.g. offices, schools and nursing homes.

The above-mentioned studies were performed using conventional light sources, such as fluorescent lamps. LED have different characteristics, the most prominent difference is the continuous light spectrum of LED compared to the spectrum of fluorescent lamps. Therefore it has to be questioned whether the results of former studies on the impact of light on humans can be replicated using LED lighting.

This study investigates the effects of different lighting scenarios (static and dynamic lighting) in a comparison of the innovative light source LED with conventional lighting (fluorescent lamps).

Method

Study design

Twenty-eight subjects ranging in age between 20 and 59 years (16 male, 12 female, 30±11) participated in the laboratory study. The subjects spent one entire workday per lighting situation in the laboratory, with a break of exactly one week between test days. Each test day consisted of office work, specific test phases and breaks. Additionally, heart rate variability was continuously recorded throughout the test days and the following night. (Figure 1)

Setting

In a laboratory setting, two mirrored rooms were set up. The rooms were identical except for the light source

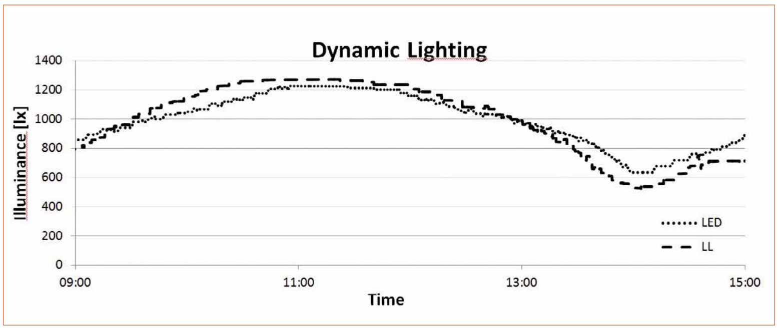

Figure 3:
Dynamic lighting scenario

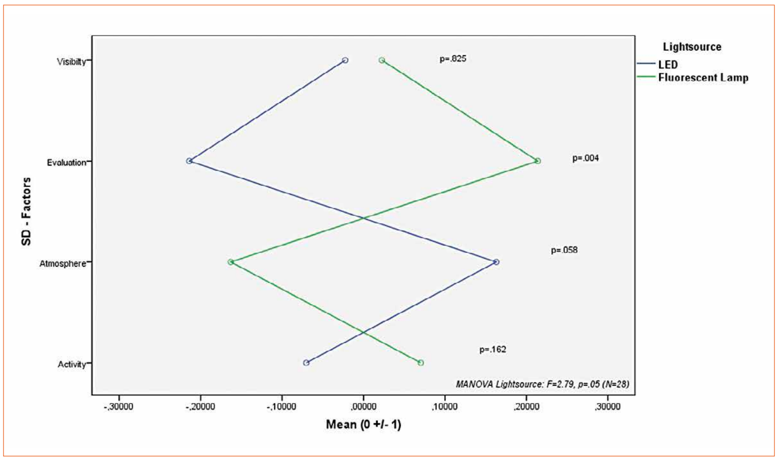

Figure 4:
Perception of the lighting situation

used in the luminaires. Figure 2 shows one of the rooms as well as the layout of the laboratory. The size of each office room was 18,5 m^2 and consisted of two desks. Therefore two subjects could be tested for each lighting situation. The laboratory rooms were set up without windows to avoid daylight.

Lighting

Four lighting scenarios were investigated within this study: one static (4000 K, 500 lx) and one dynamic scenario (3000 K - 5600 K, 600 lx - 1000 lx; Figure 3) were realized with both light sources LED and fluorescent lamps. The dynamic lighting was designed according to needs due to the human circadian rhythm.

To prevent effects from sources other than the differences in spectra, both types of luminaires were designed to appear identical. Warm white and cold white sources were implemented in both LED and fluorescent lighting. This concept was used for LED's too, to emulate the same affects of color mixing that occurs for dynamic lighting with fluorescent lamps.

Test material

The subjects spent an entire workday in the laboratory for each light source, two workdays altogether. To avoid biased results due to different weekdays, they were in the laboratory on the same weekday within a time span of two weeks.

The day started with an evaluation of the subjective sleeping quality (HRI-Sleep [15]), the general Well-Being (BSKE [16])and health (SF-12 [17]; MKSL [18]) of the subject. During the day the subjects were tested on concentration (KLT-R [19]), sleepiness (Karolinska Sleepiness Scale [20]) and well-being as well as perception of the lighting situation; three times in total. At the end of the test day the subjects were tested using the MKSL-questionnaire on physical complaints once again and rated their subjective well-being during the day, in general. Heart rate variability was continuously measured for objective data on stress and recovery each day that the subject spent in the laboratory.

Results

Psychological tests

Perception of lighting situation

A factor analysis results in four factors of perception of the lighting situation: visibility, evaluation, atmosphere and activity. LED lighting is perceived as more interesting, colorful, comfortable, warm, inviting and beautiful than fluorescent lighting (evaluation, $p = 0.004$ - Figure 4).
The atmosphere of LED lighting is perceived as more casual, private and pleasant than fluorescent lighting ($p = 0.058$).

A separate questionnaire confirmed that LED lighting is perceived as more pleasant (p=.003) than fluorescent lighting.

Well-being

No significant differences in well-being could be found for the within-subjects-factor light source (LED or fluorescent lamp) and the between-subjects factor lighting situation (static or dynamic lighting).

Concentration and performance

No significant differences in performance and concentration could be found for the within-subjects-factor light source (LED or fluorescent lamp) and the between-subjects factor lighting situation (static or dynamic lighting).
The interaction light source x lighting situation shows lower error ratios for static lighting for LED and fluorescent lighting and higher rates for dynamic lighting especially for LED (Table 1).

Physiological tests

No significant effects have been found in the HRV-parameters concerning the vegetative activation during the test day in the laboratory for the light source (within-subject) and the lighting situation (between-subject). The interaction light source x lighting situation shows significant effects for nearly all HRV-parameters: In contrast to the dynamic lighting, the heart rate is lower for LED lighting than for

Mean Laboratory	IV1: Light Source (within-factor)							IV2: Lighting Situation (between-factor)							Interaction (IV1 x IV2)	
N=28	LED			LL				static (n = 15)			dynamic (n = 13)					
Parameter	mean		SD	mean		SD	p	mean		SD	mean		SD	p	F	p
pos. Well-Being (BSKE)	3.73	+/-	0.94	3.78	+/-	0.69	0.660	3.81	+/-	0.75	3.70	+/-	0.81	0.715	0.000	0.988
neg. Well-Being (BSKE)	0.58	+/-	0.53	0.59	+/-	0.46	0.905	0.58	+/-	0.45	0.59	+/-	0.53	0.944	0.168	0.685
Sleepiness (KSS)	3.62	+/-	1.36	3.9	+/-	1.53	0.241	3.67	+/-	1.49	3.87	+/-	1.12	0.688	0.013	0.909
Brightness	3.24	+/-	0.85	3.11	+/-	0.83	0.298	3.38	+/-	0.76	2.94	+/-	0.76	0.135	0.000	0.984
Light Color	3.54	+/-	0.54	3.19	+/-	0.71	0.023	3.24	+/-	0.52	3.50	+/-	0.48	0.189	2.180	0.152
Pleasantness	2.51	+/-	0.87	2.98	+/-	0.71	0.003	2.78	+/-	0.64	2.71	+/-	0.78	0.788	0.642	0.430
Performance	116.50	+/-	33.23	118.8	+/-	35.35	0.442	121.5	+/-	28.90	113.22	+/-	38.24	0.520	1.207	0.282
Error Rate	8.55	+/-	7.8	7.46	+/-	4.66	0.173	6.77	+/-	3.59	9.44	+/-	7.8	0.245	3.984	0.057

Table 1: **Psychological tests - results**

Mean Laboratory	IV1: Light Source (within-factor)							IV2: Lighting Situation (between-factor)							Interaction (IV1 x IV2)	
N=26	LED			LL				static (n = 14)			dynamic (n = 12)					
HRV-Parameter	mean		SD	mean		SD	p	mean		SD	mean		SD	p	F	p
Heart Rate	75.81	+/-	10.8	75.98	+/-	9.89	0.948	75.12	+/-	9.65	76.81	+/-	11.11	0.673	8.414	0.008
Respiratory Rate	15.95	+/-	2.73	16.48	+/-	2.96	0.042	16.49	+/-	2.57	15.90	+/-	3.19	0.601	1.571	0.222
SDNN	73.76	+/-	23.81	71.62	+/-	22.69	0.370	77.00	+/-	24.03	67.67	+/-	21.87	0.304	7.514	0.011
lnTOTrr	8.24	+/-	0.74	8.19	+/-	0.69	0.354	8.33	+/-	0.72	8.08	+/-	0.70	0.380	8.440	0.008
lnHFrr	5.91	+/-	1.06	5.86	+/-	0.93	0.645	6.04	+/-	1.02	5.72	+/-	0.98	0.423	7.108	0.014
lnLFrr	7.13	+/-	0.75	7.07	+/-	0.72	0.244	7.23	+/-	0.74	6.95	+/-	0.73	0.322	3.151	0.089
VQrr	1.22	+/-	0.47	1.20	+/-	0.44	0.613	1.20	+/-	0.43	1.23	+/-	0.49	0.877	5.011	0.035

Table 2: **Physiological measurements (laboratory) - results**

Mean Sleep	IV1: Light Source (within-factor)							IV2: Lighting Situation (between-factor)							Interaction (IV1 x IV2)
N=26	LED			LL				static (n = 14)			dynamic (n = 12)				
HRV-Parameter	mean		SD	mean		SD	p	mean		SD	mean		SD	p	p
Heart Rate	60.27	+/-	6.94	63.76	+/-	8.05	0.007	62.78	+/-	7.78	61.12	+/-	7.26	0.553	0.143
Respiratory Rate	15.51	+/-	2.31	16.00	+/-	2.38	0.050	16.48	+/-	2.35	14.90	+/-	2.11	0.075	0.466
SDNN	96.26	+/-	24.15	84.37	+/-	27.04	0.013	88.56	+/-	25.56	92.37	+/-	26.32	0.684	0.231
lnTOTrr	8.63	+/-	0.56	8.31	+/-	0.74	0.018	8.41	+/-	0.67	8.54	+/-	0.63	0.595	0.149
lnHFrr	6.80	+/-	0.78	6.57	+/-	0.96	0.162	6.64	+/-	0.92	6.74	+/-	0.80	0.752	0.105
lnLFrr	7.34	+/-	0.56	7.01	+/-	0.78	0.023	7.12	+/-	0.69	7.24	+/-	0.65	0.617	0.246
VQrr	0.54	+/-	0.48	0.44	+/-	0.49	0.083	0.48	+/-	0.52	0.50	+/-	0.46	0.918	0.123

Table 3: **Physiological measurements (sleep) - results**

fluorescent lighting in the static lighting situation. Considering the psychometric results (comparable well-being and performance - Table 2), the implemented static LED-lighting and the implemented dynamic FL-lighting can be rated better than the static FL-lighting and the dynamic LED-lighting, respectively.

During the nights following the test days, significant effects could be shown for the within-subject-factor light source (LED, fluorescent lamp -Table 3). The night following the testing with fluorescent lamps shows higher heart rates and respiratory rates, respectively during sleep and variability (SDNN, TOT, LF) is significantly lower compared with the night after testing with LED-lighting. The lighting situation (static vs. dynamic) shows no influence.

Discussion

The results in the vegetative regulation during the laboratory day cannot be distinctly explained by the authors. These effects (interaction between light source and lighting situation) did not originate in the recorded and controlled moderating factors such as general traits of the subjects (e.g. age, gender) or methodical influences of the test procedure.

The sleep parameters of the HRV show that possible nonvisual effects of artificial lighting during the day take effect and appear significantly during the following night's sleep.

The perception and evaluation shows a significantly better rating of LED lighting compared to fluorescent lamps in two factors, while all other factors do not show significant differences.

From these results we conclude that nonvisual effects of lighting need to take into account the effects on sleep and especially long-term and longitudinal studies are needed to answer questions concerning health related questions on the biological importance of artificial lighting in work environments.

Outlook

Currently the authors are conducting a field study in an office environment. Considering the results of the laboratory study, the lighting scenarios consist of only LED lighting. Three lighting situations are investigated: static lighting (4000 K, 500 lx), static lighting with increased illuminance (4000 K, 900 lx) and dynamic lighting as described above. Each lighting scenario is run for four weeks in consecutive order. The subjects are tested once a week on well-being, concentration, performance and perception of the lighting situation. Heart rate variability is measured for physiological data on vegetative activation. ■

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A New Approach to the Design of Driverless AC LED Light Engines

Driverless AC LED light engines have now become a commonplace item of commerce in the lighting industry. Nearly all of them use high voltage integrated circuit switching chips to intelligently change the number of LEDs in a string during a power line cycle so that the voltage of the LED string matches the instantaneous power line voltage. However, customers are demanding higher efficiency, lower cost, and especially a reduction in the flicker content of the emitted light. Peter W. Shackle, president of the consulting company, Photalume, describes some new circuits for AC LED light engines [1] that provide a non-dimming solution with reduced cost, increased efficiency and better light quality as perceived by the human eye.

Up until now, the principle practice for AC LED Light Engines was to use switches during the voltage variations of the power line voltage cycle to adjust the number of LEDs present to roughly equal the instantaneous power line voltage, and then use resistors and/or current limiters to keep the LED current at a desired level until the next switch operation. This principle has the disadvantage that some power is always being dissipated, limiting the efficiency to 75%-80%, and inevitably the output current comes in the form of a series of half sinewaves. In particular with 50 Hz power, the presence of these half sinewave pulses of current at twice the power line frequency produces a flicker effect which some people can see out of the corner of their eye, and in the worst case may produce eye strain and headaches.

The alternative principle introduced here is to have the LED current limited by resistance for a part of the time, and limited by capacitance for the remainder. Thus, in every power line half cycle there are two pulses of current through the LEDs, first a pulse of displacement current and then a pulse of galvanic current. In each complete power line cycle there are four peaks, so the resulting ripple can be mainly at four times the power line frequency. For power levels below 5 W, where the US Energy Star rules do not require a minimum power factor, it is possible to have continuous DC current with the entire ripple at four times the power line frequency. At higher power levels where a minimum power factor of 0.7 is required, the output LED current ripple has a superior flicker index compared to the conventional circuits, with 87% efficiency and without using any expensive high voltage integrated circuits.

Introduction to the Field of AC LED Light Engines

IAC LED light engines are attractive because of their simplicity and relatively low cost for the luminaire designer. Today they are becoming ubiquitous in hallway lighting, decorative lighting, parking lots and an increasing host of other applications. As will be explained in detail below, most of these products are using high voltage integrated circuits which, for each part of the power line voltage cycle, automatically connect the correct number of LEDs to match the power line voltage. An electronic current limiter is used to maintain a constant current between switch operations. Commonly, three stages of switching are used, although two stage and four stage products exist. Since voltage is being dropped across the current limiter, power is being dissipated, which limits the efficiency attainable. Dimming can be achieved by varying the current level programmed for each stage of switching.

The design of AC LED light engines involves numerous compromises. For example, efficiency, power factor and light quality as measured by flicker index all trade off against each other, such that if one is optimized the others usually suffer. Including dimming capabilities requires additional compromises and usually increases cost and complexity. It has become conventional to adopt a set of trade-offs that accompany the use of a high voltage integrated circuit required to allow dimming. Typical of such a compromise in today's marketplace would be a flicker index (see below) of 0.32, efficiency of 78% and power factor of 98%. This compromise, namely poor flicker index and average efficiency, is affected heavily by the inclusion of dimming, which is not needed for a large number of applications. Without the dimming requirement, the expensive high voltage chip can be eliminated, reducing cost, the flicker index can be reduced and the efficiency can be increased to over 90%. The power levels involved dictate the best way to accomplish this. Below 5 W of input power, Energy Star in the USA does not have a power factor requirement. In this case a solution is described which has superb light quality and over 90% efficiency. When the input power is over 5 W, the power factor for consumer products must be greater than 0.7. In this case a solution is described which also has greater than 90% efficiency and still has superior flicker performance compared to today's conventional products.

Terminology Used in Characterizing AC LED Light Engines

In the discussion below we shall repeatedly use the terms "efficiency", "power factor" and "flicker index".

Efficiency =

$$100 \; \frac{\text{power delivered to LEDs}}{\text{Input power to the device}}$$

expressed as a percentage.

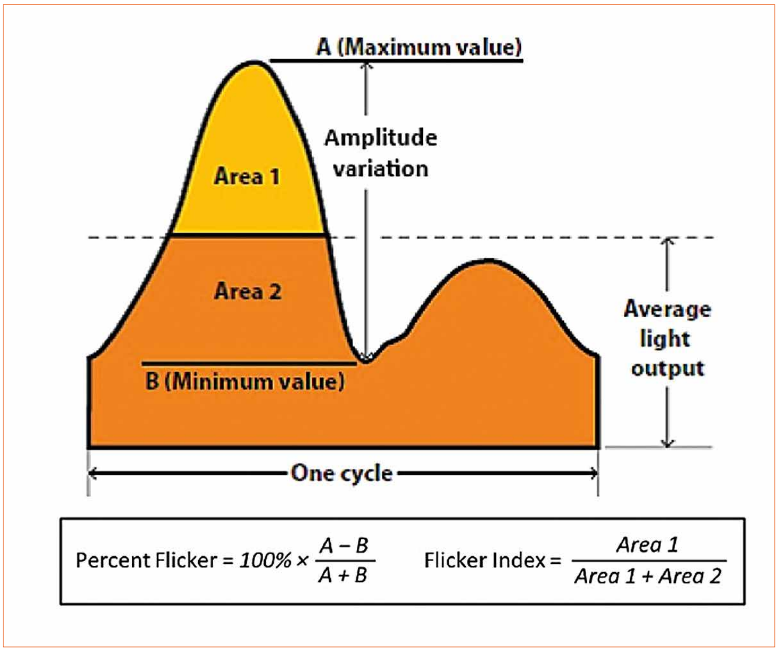


Figure 1: Definition of flicker index (modified from the IESNA handbook, 2010)

Power factor =

$$\frac{\text{input power}}{\text{rms input voltage * rms input current}}$$

This is customarily expressed as a fraction, although sometimes you may see it as a percentage. A perfectly sinusoidal power line voltage driving a resistor will have a power factor of 1.0. A perfect capacitor or inductor connected across the power line, drawing no power, would have a power factor of zero. If the power factor of a device is low, it means that the power being drawn is not commensurate with the current being drawn, because the current is out of phase with the voltage. Energy Star rules in the USA have no power factor requirement for input power below 5 W, and above 5 W the minimum that will be approved is 0.70 for residential/consumer applications.

Flicker index is defined in figure 1.

At low power levels the light output from LEDs is directly proportional to the LED current. A square wave light output with 50% duty cycle will have a flicker index of 0.5, whereas an LED light running off DC will have a flicker index of zero. For reference, an incandescent light bulb typically has a flicker index of 0.15. The flicker index does not have any frequency dependency, whereas the human eye has sensitivity which declines with increasing frequency. For this reason there is need for a new, frequency dependent measure of flicker, but currently none exists. For the time being the flicker index is widely used as a point of reference.

The History of AC LED Light Engines

The earliest circuit used for AC LED light engines is shown in figure 2.

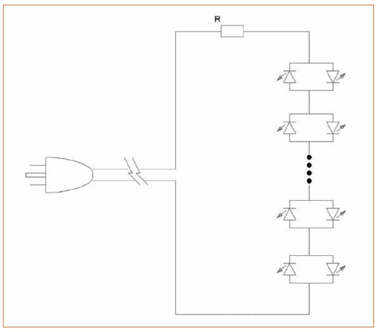


Figure 2: The earliest AC LED circuit

In this circuit the LEDs are arranged in antiparallel to each other. A sufficient number of these antiparallel mounted pairs are connected in series so that their forward voltage is comparable to the peak of the power line voltage. At the peak of the power line voltage waveform current passes through the LEDs and is limited by the resistor R. Such circuits can have high power factor because the current passes in phase with the power line voltage, and if R is relatively small then the efficiency can be as high as 95%. However the flicker index is typically up around 0.45, because most of the time no light is produced and then a brilliant flash is released at each power line voltage peak. This kind of circuit is widely used for Christmas tree lights. A disadvantage of this circuit for general lighting is that a lot of LEDs are being used, and at any one time, half of them are dark. These circuits were replaced in general lighting by the circuit shown in figure 3.

In this second generation circuit, a bridge rectifier is used to halve the number of LEDs needed. As before, a resistor is used to limit the current at the peak of the line. The efficiency, power factor and flicker index are essentially unchanged. In this and all the AC LED circuits described in this article, it is necessary to have surge protection circuitry of some kind present to protect the LED circuit from power line surges which may arise from power line switching, lightning induced surges, etc.

The third generation of AC LED circuits uses high voltage integrated circuits (ICs) to short out some of the LEDs such that at any time the voltage of the LEDs in the circuit is roughly comparable to the power line voltage. A current limiter in the IC serves to keep the current constant between switching operations. The third generation of AC LED circuits is shown in figure 4.

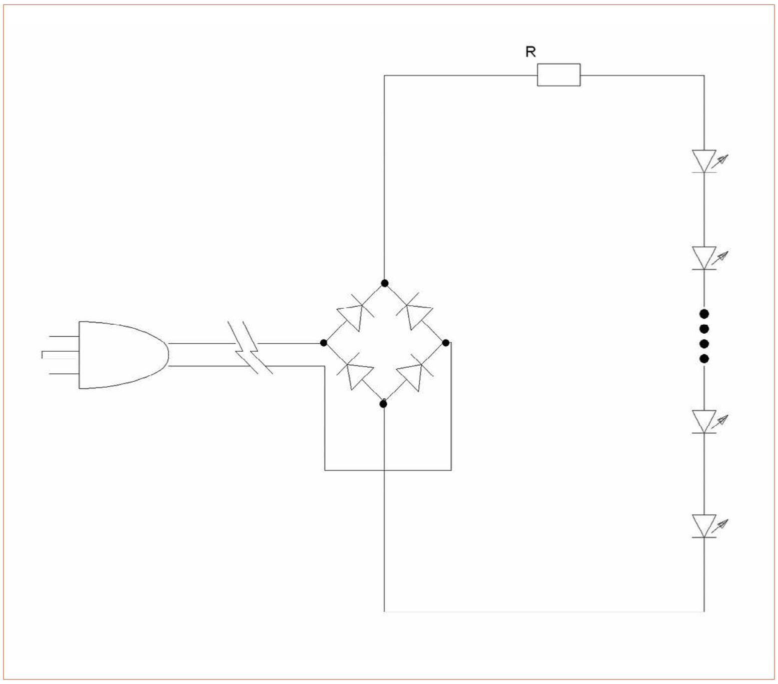


Figure 3: The second generation of AC LED circuits

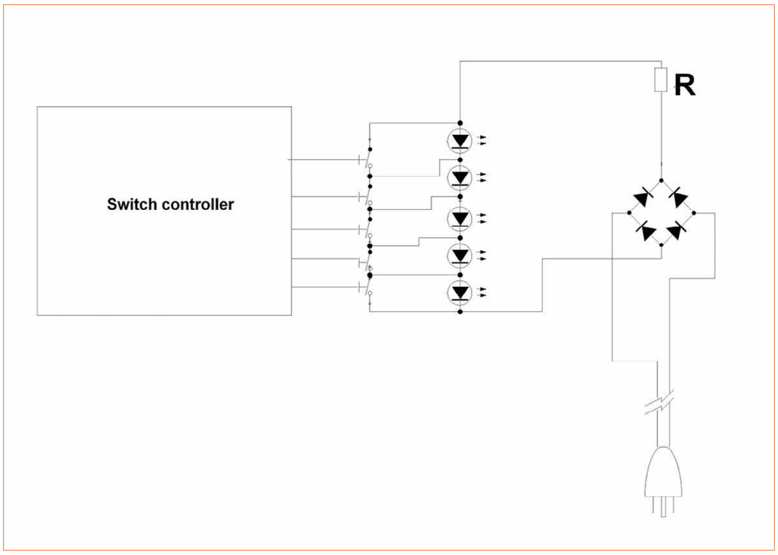


Figure 4: The third generation of AC LED circuits

In the third generation of AC LED circuits, the LEDs shown are typically high voltage LEDs now manufactured by numerous companies. Internally they contain multiple junctions so that the forward voltage might be around 30 V. Instead of the resistor shown, an electronic current limiter may be provided as part of the switch chip. The light output waveform from such a product is shown in figure 5.

The efficiency of such a circuit is typically about 80%, the flicker index 0.32 and the power factor 0.98. The power factor is extremely high since no energy storage is present and the current is drawn from the power line exactly in phase with the power line voltage waveform. The useful property of such circuits is that the current limiter can be externally adjustable so that the products can be dimmed. If the application requires dimming this is clearly an advantageous circuit.

Introducing The Fourth Generation of AC LED Circuits

Many applications do not need dimming. When this is the case, it is possible to improve the efficiency from say 80% to 90%, and decrease the flicker index while reducing the cost through the elimination of the expensive high voltage integrated circuit switch chip. The principle used is to put two current pulses through the LED string per line voltage half cycle - the first a capacitively limited (displacement) current and the second a resistively limited (galvanic) current. By storing a small amount of energy on each half cycle for use on the next half cycle, the two pulses can be evenly spaced so that the ripple in the output current is to a great extent at four times the power line frequency. The best way to accomplish this depends upon the power level. This is because in the USA, Energy Star has no requirement on power factor for lights of less than 5 W. Only a few years ago, this might have corresponded to relatively dim lights; however, with steadily increasing LED efficacy, 600 lm can be produced today. Similarly, a 5 W, 900 lm light can be foreseen in a few years. To distinguish them from the conventional AC LED light engines, these products are referred to as "Driverless AC LED light engines." A circuit for a driverless AC light engine of under 5 W is shown in figure 6.

This deceptively simple and very inexpensive circuit produces an output total LED current waveform with a flicker index of only 0.03. The vital waveforms representing operation of the circuit are shown in figure 7. The efficiency is just over 90% and the power factor is 0.45. In this case, poor power factor in return for high efficiency and excellent quality of light is an acceptable compromise being as there is no power factor requirement for consumer products under 5 W in Energy Star.

To understand how this circuit works, consider the first current pulse through the top string. This pulse starts at the positive peak of the incoming power line voltage waveform (With respect to the right side of the bridge rectifier, which for reference is used as common). At this point current is passing through R1, through the two strings of LEDs and R2, hence back to the bridge rectifier. This phase of the operation stops after about a millisecond, and then the falling power line voltage conveyed through C1 starts to pull charge out of C2 (charged in a previous half cycle) and then increasingly out of C4. When C4 is finally discharged there is a very abrupt fall in LED current, which is stopped by galvanic current starting to pass through the whole LED string as the power line voltage waveform approaches the negative voltage peak. All the capacitors used are smd ceramic capacitors of 2.2 uF or less and of 250 V rating, which are both small and inexpensive.

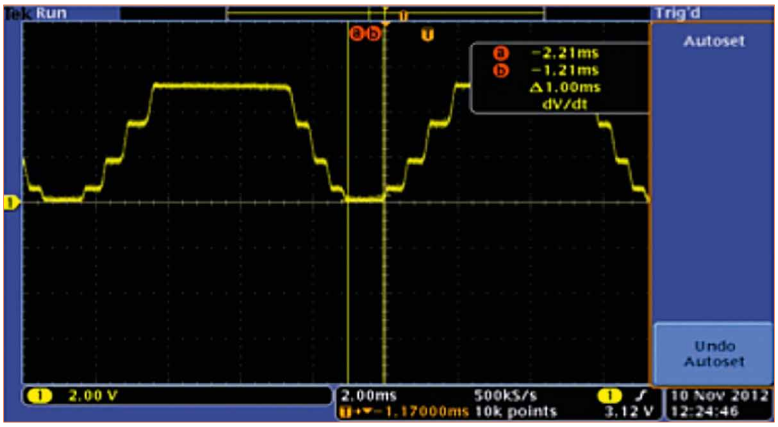


Figure 5: Waveform of the light output from a third generation AC LED circuit

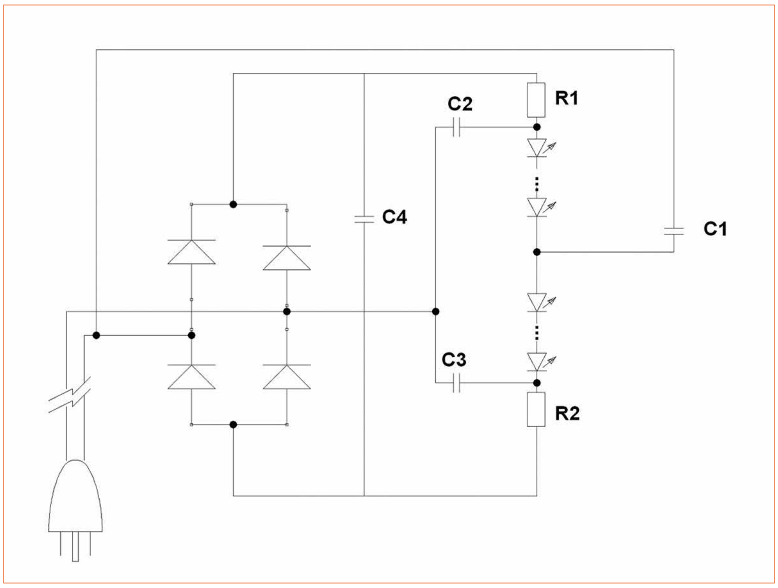


Figure 6: A driverless AC LED light engine circuit for under 5 W

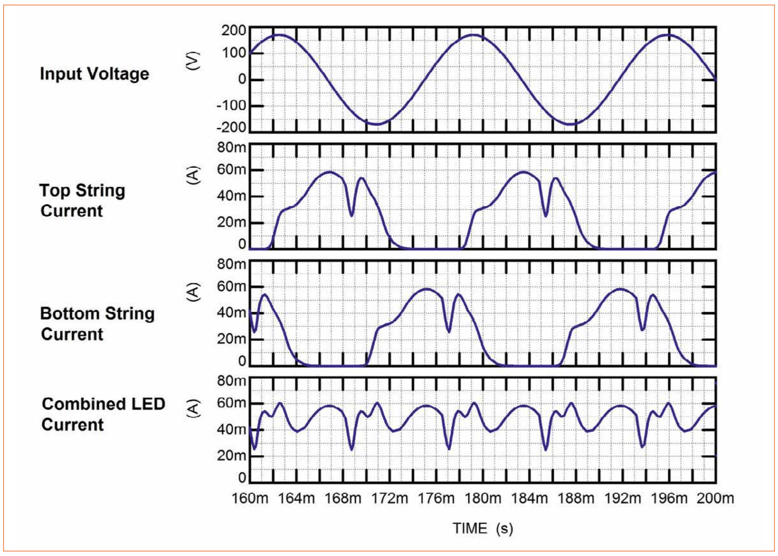


Figure 7: Important operating waveforms for the under 5W driverless AC LED light engine

During the beginning of the next power line half cycle, C4 and C2 are recharged. It can be seen that C1 acts like a charge pump capacitor, alternately pulling current out of the top half of the LED string and pushing it back into the bottom half. Because of the presence of C2 and C3, about half of the LED current does not go through the resistors at all, which is why the efficiency is over 90%. The efficiency, input power and output current of a prototype design are shown in figure 8.

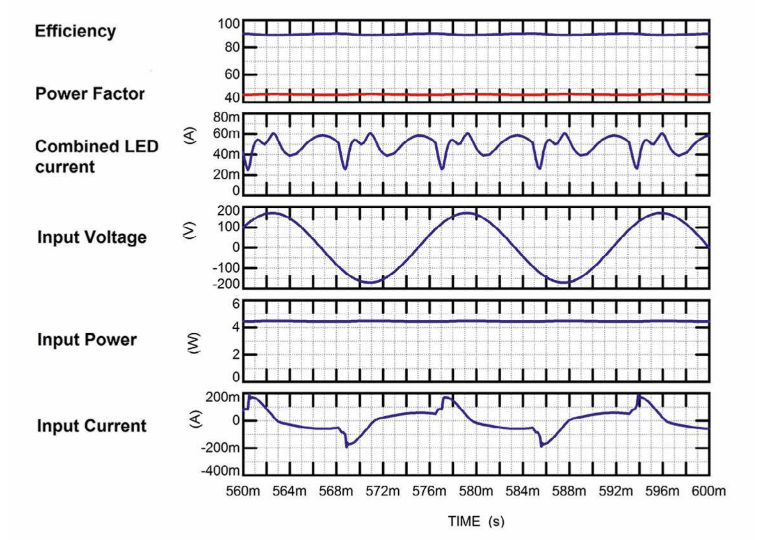


Figure 8:
Input and output currents of a prototype under 5 W driverless LED light engine

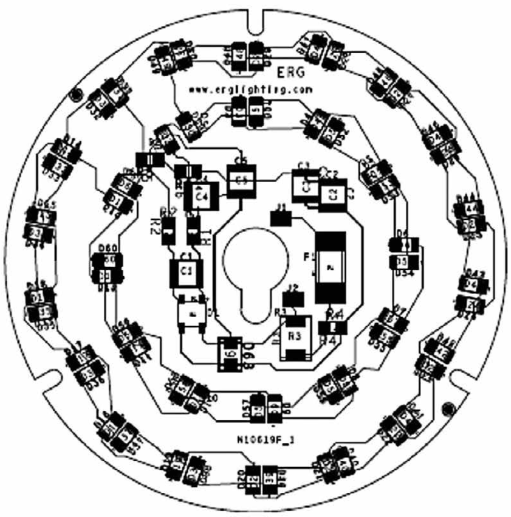


Figure 9:
Example of a sub 5 W driverless LED light engine

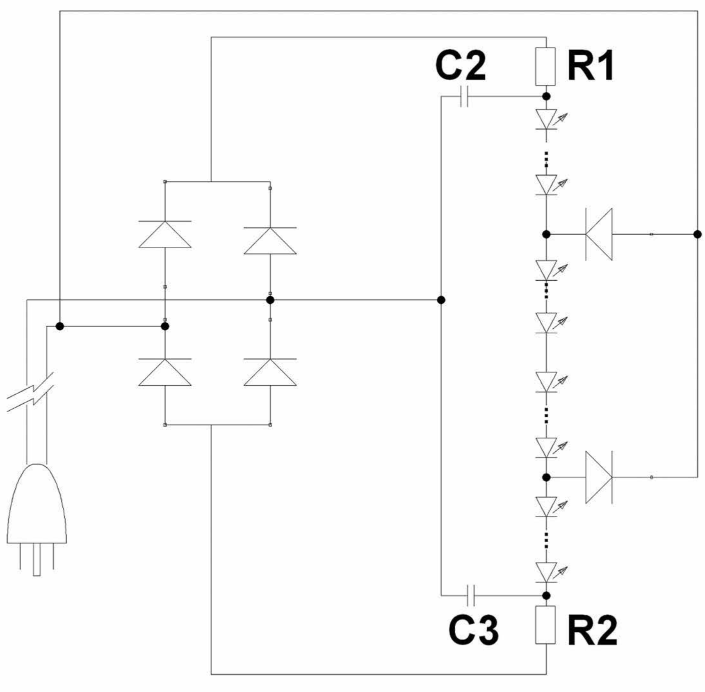


Figure 10:
A driverless AC LED light engine for power levels above 5 W with power factor > 0.7

A picture of a complete under 5 W driverless LED light engine is shown in figure 9.

This example includes a fuse, and surge voltage protection as required for long life on the public power grid.

Since the light is produced alternately by the upper and lower strings of LEDs, a feature of the design is the way that each LED from the upper string is located close against a corresponding LED from the lower string, so that the combination of the two produces light continuously. This ensures that no flicker can be perceived from the complete light engine, even though individual elements of the array are only activated at a frequency of 60 Hz (in the USA).

As already mentioned, the flicker index of this product is 0.03. This compares with 0.32 for the best IC controlled AC driven light engines available today, or 0.15 for an incandescent light bulb. The efficiency is just over 90%, compared to 80% for most IC controlled AC driven light engines available today. The cost is lower because no expensive high voltage IC is needed to control it. This design is ideal for low cost non-dimming applications at the under 5 W power level.

A Driverless AC Light Engine Solution for 5 W and Up

At power levels over 5 W, Energy Star rules in the USA require a power factor in excess of 0.7. A circuit to meet these requirements is shown in figure 10.

The important operating waveforms for one of these circuits operating at a power level of 12 W are shown in figure 11.

This circuit is in some respects analogous in its operation to the previous one. The LED strings are now subdivided into four equal sub segments. During positive half cycles the top sub segment is shorted out, and during negative half cycles the bottom sub segment is shorted out. When the input voltage starts to turn positive, C2 starts to charge up through R1, while simultaneously C3, which was previously charged to the negative peak of the line voltage, is receiving current passing through the lower three strings. This produces the first hump in the total LED current waveform characteristic of displacement current. When C3 is charged sufficiently to get to zero volts, then galvanic current starts passing through R2 instead, and this causes the second hump in the total LED current waveform. An exactly complementary series of charging and discharging events happens during negative half cycles. C3 gets discharged to a negative voltage equal to the negative line voltage peak. This is the reason why at the beginning of the positive half cycle the LED current starts immediately as the line voltage turns positive, giving such a short duration between the current pulses.

The main performance characteristics of one of these circuits operating at a power level of 12 W are shown in figure 12. The flicker index of the output current waveform is 0.29, lower than is achievable by the best performing light engines using high voltage switching chips, which have a flicker index of 0.32. The efficiency is 87.5%, compared to the 80% or so characteristic of today's AC LED light engines. The power factor is 0.72, sufficient to meet Energy Star requirements for consumer products in the USA.

At a power level of 12 W, capacitors C2 and C3 are 2.0 uF / 250 V, a convenient size for surface mount assemblies. Obviously much larger light engines can be produced this way, and surface mount capacitors can be placed in parallel to facilitate higher power levels.

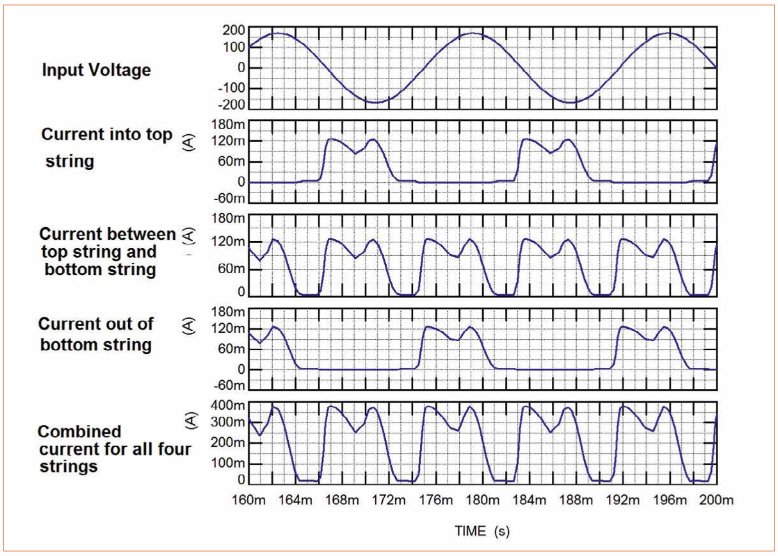


Figure 11: Important operating waveforms for a 12 W driverless LED light engine

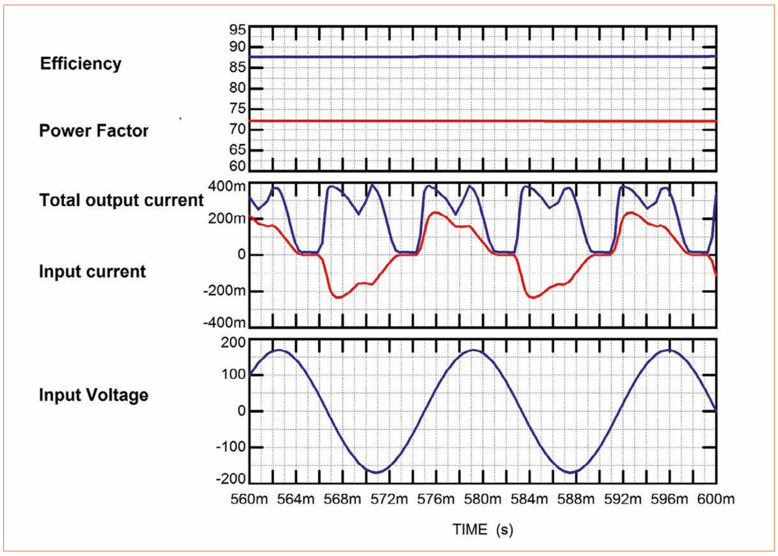


Figure 12: Main performance characteristics of a 12 W driverless LED light engine

Conclusions

From the two products that have been described above, it can be predicted that simple, non dimming LED drivers may become less common in the future, because the LED arrays themselves can so easily be arranged to be driverless AC LED light engines which run directly off the AC power lines with lower cost, higher efficiency and adequate power factor. These simple, low cost circuits outperform the existing conventional AC LED products with higher efficiency and lower flicker index. The exceptions to this prediction may be the cases where for some optical reason the light source needs to be just one high power LED as opposed to an array of LEDs. Also dimming applications will likely continue to be engineered as they are at present. Although this option has not yet been explored, the high voltage LEDs now available from numerous manufacturers lend themselves well to these driverless AC LED light engines, as long as the forward voltages of the devices are engineered to meet the needs of the circuit.

References:

[1] United States provisional patent application 61940830, February 17th, 2014. Peter W. Shackle,
pshackle@photalume.com

Practical Estimation of Measurement Times in Goniospectroradiometry and Goniophotometry

The angle-dependent characterization of LED modules and lights often raises the question about typical measuring times. In particular, the comparison of spectrometer-based systems with photometer-based systems is of considerable interest here. Dr. Günther Leschhorn, product manager for spectroradiometers and SSL measurement equipment from Instrument Systems GmbH, considers different measurement set-ups in a study and makes recommendations for various application cases.

Two typical SSL-sources with different spatial radiation characteristics and different total luminous flux values are investigated in this study. A goniometer is used in a turning-luminaire and a turning-detector type setup for goniospectroradiometric and goniophotometric measurements on the samples. The study puts a particular emphasis on the required measuring times for the different configurations and validates the data according to the quality of the measurement. The results are used to give some practical guidance on how to choose the measurement setup with respect to detector, resolution, size of the sample and compliance with corresponding standards regulations in the daily laboratory routine.

Introduction

When performing angular-resolved measurements on Solid-State-Lighting (SSL) products, one question is most typical: What is the measurement time I have to consider? The interest lies, in particular, in the different time scales one has to take into account when deciding between spectroradiometer-based and photometer-based systems. Typically, goniospectroradiometry is slower but allows all important performance characteristics such as luminous intensity distribution curves, luminous flux, color coordinates and even color rendering index to be measured with maximum precision. In goniophotometry on the other hand, fast photometers are used which typically reduce the measurement time. Goniophotometry is faster compared to goniospectro-radiometry but is restricted to purely photometric quantities.

In most cases, the application defines the need for one detector type or the other. Nevertheless, saving valuable measurement time in the daily laboratory routine is important for most of the users. A photometer as, for example, an add-on to a goniospectro-radiometric system has the potential to reduce the overall measuring time significantly. An estimation of the measurement time is therefore valuable information that helps in this decision process.

The time scales of the measurement depend on numerous factors, like spatial radiation characteristics (and with that resolution), number of performed C-planes, applied standard regulations, type of goniometer and size of the sample - just to mention a few. In this study, two showcase SSL-sources are evaluated. These two specimens differ in their spatial radiation characteristics and are measured with different detectors in different measurement geometries. With this data, it is possible to estimate the typical measuring time, the associated errors and to give a few rules of thumb that are of help for the user when it comes to questions concerning measuring times.

Experimental Setup

All measurements are performed with the LGS 1000, the largest goniometer by Instrument Systems. The goniometer is based on the C-γ coordinate system (CIE 121-1996) and accommodates samples up to a diameter of 2 m and a maximum weight of 50 kg. It can be operated with a photometer as a conventional goniophotometer or with a spectrometer as a versatile goniospectroradiometer. For the measurements an array spectrometer (comprising a CAS 140CT with an optical probe) and a photometer is used. The device under test is stabilized according to the procedures described in IES LM-79-08 and EN13032-4. Measurements are performed in a completely dark room featuring matt black walls, floor and ceiling to eliminate undesired stray light.

For the measurements, two different configurations of the goniometer are used, which will be described in the following paragraphs.

Figure 1: The goniometer in standard turning-luminaire configuration (left) and detector with stray light tube on stand (right)

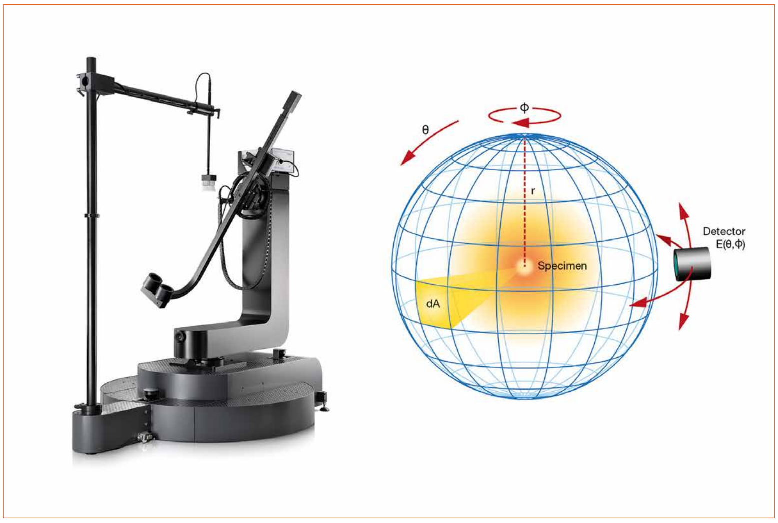


Figure 2: Turning-detector type goniometer (left) and illustration of operating principle (right)

Turning-luminaire setup

The standard configuration is a so-called turning-luminaire goniometer conforming to the C-γ coordinate system with a horizontal optical axis. During the measurement, the luminaire is rotated in the horizontal C-axis and the vertical γ-axis. An optical probe for use with the spectroradiometer or alternatively a photometer head is mounted on a tripod stand and aligned with the horizontal optical axis of the test specimen. A baffle-tube to minimize stray light is mounted in front of the detector. The stand accommodating the detector is set up at a distance where the sample can be considered as an approximated point light source (photometric distance) to maintain the far-field condition for luminous intensity measurements. Figure 1 shows the setup of the goniometer in the turning luminaire configuration.

The goniometer provides the possibility to adjust the angular speed of both axes. The faster C-axis can be rotated with 16 selectable speeds ranging from 3.1°/s to a maximum speed of 50°/s. The speed of the γ-axis can be selected from 1.8°/s to 30°/s respectively.

Furthermore, the goniometer can be operated in two different measurement modes, the start/stop and the continuous mode.

A sequence measured with start/stop functionality means that each pair of angles to be measured will be approached by the goniometer with the selected speed of the corresponding axis. Once the goniometer has come to a full stop and the angles are reached correctly, the measurement will be triggered. This procedure continues with all angle pairs defined in the resolution requested by the operator. Due to time-consuming acceleration and brake phases, this mode is slow and commonly used with spectroradiometric measurements where longer integration times are needed.

On the other hand, for a continuous sequence a photometer is used. In this mode, the goniometer has only one acceleration and one brake phase and moves with a continuous velocity through the defined angular region. Passing the angles to be measured, the system triggers a measurement "on-the-fly". This means that the light distribution is measured by the photometer while the goniometer is moving and the digital signal processing of the measurement amplifier ensures optimum adjustment of the integration and filter parameters during the recording. The overall measuring time is significantly reduced compared to the start/stop mode, but yields only purely photometric quantities.

Turning-detector setup

With the help of an additional option, the goniometer transforms into a turning-detector type with vertical optical axis. The setup is illustrated in figure 2.
The position of the sample remains unchanged during the measurement and the detector moves around the test specimen on a spherical envelope surface. A spectrometer as well as a photometer can be used as detector. With this option, the sample size that can be used for measurements that require the photometric distance to be maintained is reduced in comparison to the standard configuration. For measurements completely compliant to IES LM-79-08, the diameter is reduced to a maximum of 18 cm. For luminous flux measurements, this restriction does not apply.

Due to the transformation in goniometer type, the axes are switched. The γ-axis that is more frequently used in typical measurements of SSL-sources can now reach a maximum velocity of 50°/s and the C-axis can reach a maximum velocity of 30°/s. With this, a further reduction of the overall measurement time can be achieved.

SSL-light sources

To illustrate the dependence of the overall measuring time on the spatial radiation characteristics of the used sample, two different light sources are investigated in this study.

One LED downlight has a rather broad angular distribution with a half angle of approximately 80° (FWHM). A relative luminous intensity distribution curve of this light source is given by the blue line in figure 3 on the left side. The total luminous flux is approximately 670 lm with a CCT of 3500 K and a high CRI of >95.

With approximately 403 lm, the second source has a lower total luminous flux and different spatial radiation characteristics. With a half angle of approximately 29°, this light source is more directional. A relative luminous intensity distribution curve is given in red in figure 3 on the left for comparison. The Cartesian representation of one C-plane in figure 3 right side, shows the absolute difference in luminous intensity of the two light sources. Although the total luminous flux of the more directional light source is significantly smaller compared to the downlight with broad angular distribution, it has a higher peak luminous intensity by more than a factor of 3. Consequently, the gradient of luminous intensity with angle is much higher.

Estimation of Goniophotometric and Goniospectroradiometric Measuring Times

For the two light sources discussed in the last section, a study of the total measurement time versus resolution with different detectors and settings is performed.
The standard turning luminaire configuration is used with a spectrometer as well as a photometer as the detector.
The distance between the light source and the detector is set to 3.2 m, in order to maintain the photometric distance.

Spectroradiometric measurements

For the measurements with the spectroradiometer, two different methods to define the integration time are used. The dynamic range in luminous intensity of the light sources over the angular range makes it necessary to adjust the integration time of the spectrometer. Each change in integration time is time consuming, because a dark current measurement is necessary; so changes in integration time should be limited. On the other hand, a high-quality spectroradiometric measurement needs a good signal level. Therefore, a tradeoff has to be found that limits the changes in integration time to a minimum while

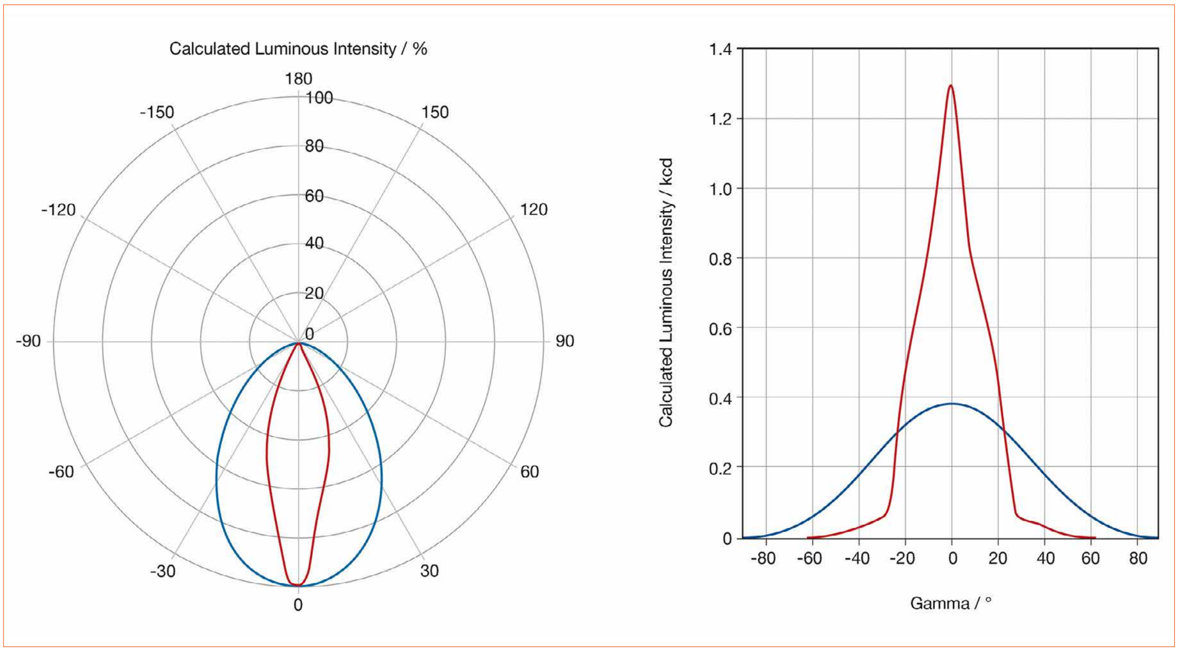


Figure 3: Relative luminous intensity distribution curves (left side) of the two SSL-sources used in this study. The blue line represents a light source with a rather broad angular distribution and the red line represents a more directional downlight. Absolute luminous intensity distribution of one C-plane in Cartesian representation is given on the right side. The total luminous flux associated with the blue curve is higher than that of the red curve, but the peak luminous intensity is lower

still maintaining the quality of the measurement. This tradeoff, however, can only be found when the spatial radiation characteristics are already known in the beginning of the measurement which is the case when testing batches of samples of the same kind. In this case, an optimization of the measurement time with a spectroradiometer can be realized. In this section, a worst case scenario is analyzed, assuming that the spatial characteristics are not known.

In order to optimize acquisition, two different approaches are used:

- The integration time of the spectrometer is set to a high signal level near saturation at the peak of the luminous intensity (this peak is assumed to be at the center of the light source). The integration time is fixed and used for all other angles
- The auto-ranging function of the spectrometer is used to adjust the integration time dynamically. Signal levels between 50% and 100% are automatically adjusted. To avoid unnecessary long integration times, the maximum value is set to 3 seconds

With these two approaches, one C-plane in the lower half plane (-90° to 90°) with different increments are measured using the start/stop mode of the goniometer. The total measuring time is recorded. Figures 4 and 5 show the results for the light sources with broad and narrow distribution. The blue (green) line represents a spectrometer with fixed integration time and a spectrometer using its auto-ranging mode, respectively. As expected, the spectrometer in auto-ranging mode generally needs more time to complete the measurement. In general, the curves look very similar. For increments larger than approximately 2° to 3°, the curve evolves into quite a long plateau with increasing increments (equivalent to decreasing resolution). Overall measurement times of a few minutes are typical for this regime. For smaller increments, the measurement time rises steeply. Overall measurement times of tens of minutes up to half an hour must be expected when working in this regime. These data only represent one C-plane. The measured time has to be multiplied by the number of C-planes required for the actual measurement. If an extreme resolution of ≤0.5° is necessary, the overall measuring time might expand to several hours for a typical value of 4 to 5 C-planes.

On the right side of figures 4 and 5, the deviation of the total luminous flux calculated from the measurements is presented. The measurement at 0.2° increment with the spectroradiometer serves as a reference. Due to the rather broad angular distribution light source, no significant deviation can be found up to 8° increment. In figure 4, all measured flux values stay within ±0.2%. The much more directed nature of the distribution of the downlight in figure 5 leads to a different behavior. Up to a resolution of 2° increment, the situation is similar to the situation in figure 4 with a deviation of 0.2% maximum. For larger increment values, the deviation rises and can be clearly above 1%. This will contribute to the user's measurement uncertainty budget. In praxis, an adaption of the chosen increment to the spatial characteristic of the source can reduce the measurement time as well as the associated component in measurement uncertainty.

Photometric measurements

The measurements described above also have been performed with a photometer as the detector. Therefore, the continuous mode of the goniometer could be used, which allows recording of spatial radiation characteristics "on-the-fly". The recorded data is plotted in red in figures 4 and 5.

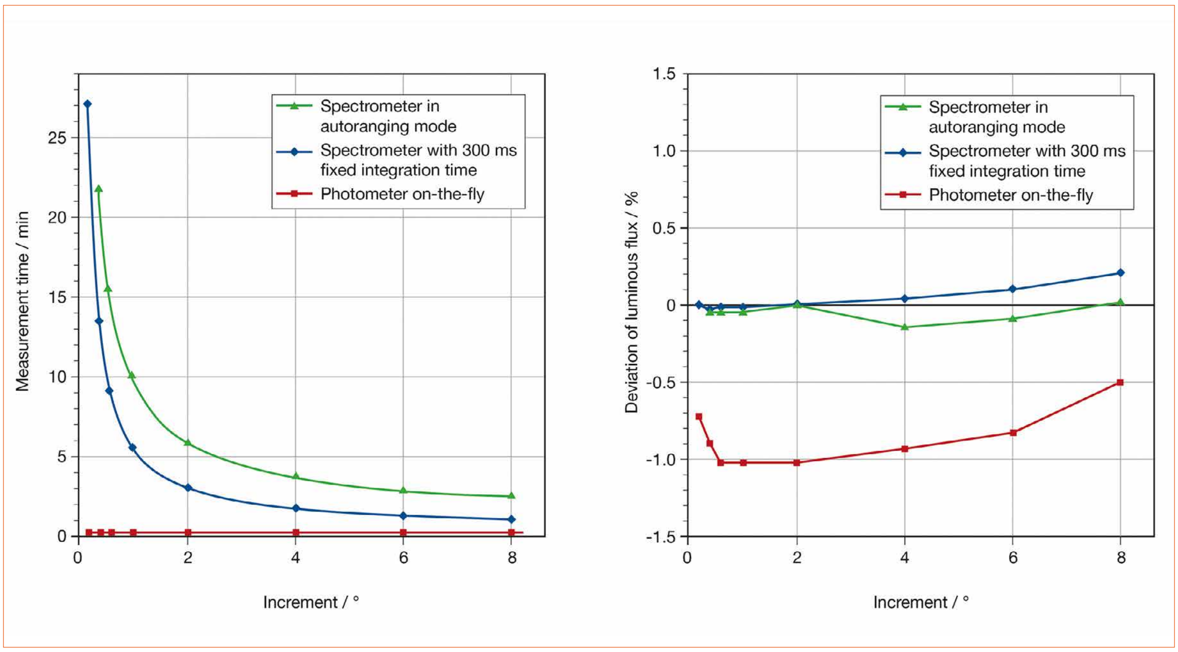


Figure 4: Overall measurement time versus increment for different measurement modes (left) and the corresponding deviations of luminous flux (right) for the sample having a broad angular distribution

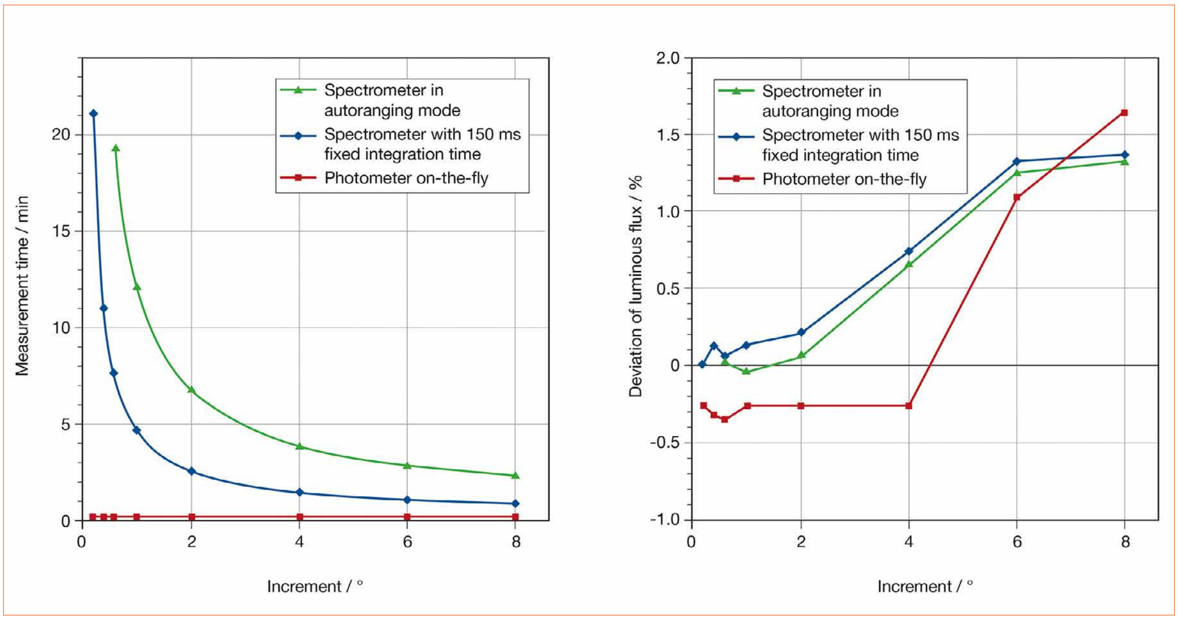


Figure 5:
Overall measurement time versus increment for different measurement modes (left) and the corresponding deviations of luminous flux (right) for the sample having a more directed angular distribution

In contrast to the spectroradiometric measurements, the results of the photometer show no dependency of measurement time on the chosen increment. In fact, all values lie on a constant line at 13 seconds measuring time for both light sources and all increments. This is due to the adaptive adjustment of the digital signal processing of the photometers electronics which ensure a good signal level at all increments. As visualized on the right side of figures 4 and 5, the photometer data show qualitatively the same behavior as the spectroradiometric data for the deviations in luminous flux. Since the measurement with the photometer is so fast, a high resolution measurement with typically 4 to 5 C-planes lasts around one minute.

Summary and practical guide

This section conveys some practical aspects from the results of the last two sections.

If only photometric values like luminous intensity distribution or luminous flux are of interest, it is recommended to use a photometer together with the on-the-fly function of the goniometer. With this type of setup, fast and high resolution measurements can be performed. The photometer should always be used with a low increment like 0.5° or even 0.2°. The measurement time is not affected by the choice of resolution and errors due to the spatial radiation characteristics of the light source are minimized. One C-plane with 0.2° increment last typically 13 seconds with the maximum angular speed. For more C-planes a simple multiplication is possible to estimate the measuring time.

A measurement with a spectroradiometer is essential for analyzing angular variations in the correlated color temperature, color rendering index or color coordinates. If this type of measurement is required, care should be taken not to reduce the increment too much. In order to minimize the measurement time, one should stay in the regime where the measurement time does not rise dramatically. For typical SSL-sources, this is in the region of 2° to 5° increment. For increments higher than 2° the typical measuring times are around a few minutes and this resolution is usually enough to ensure a high quality measurement. Also, the recommended scanning resolution cited in applicable standards is typically coarser than this. For example, IES LM-79-08 recommends an increment of 5° and 16 C-planes (22.5°) for a typical wide-angle and smooth intensity distribution. The emerging European and International standards for test methods for LED lamps and luminaires (EN13032-4 and CIE S025 with identical content) even abstain from stating a quantitative guidance on the scanning resolution. In fact, for total luminous flux and luminous intensity distributions, the standards only recommend an angular interval that should be determined by the nature of the distribution regarding to symmetry or irregularity. Only for partial luminous flux in a cone of 90° or larger, the standards state the same 5° minimum for the γ-angle as IES LM-79-08. Therefore, as a rule of thumb, 2° to 5° minimal increment is a good reference and starting point.

The auto-ranging function of the spectrometer is not always the best choice and does not necessarily lead to a better result. For unknown spatial radiation characteristics, a fixed integration time of the spectrometer set to a signal level near saturation at the peak of the luminous intensity, is recommended. For a typical SSL-source, one C-plane with an increment equal or higher than 2° lasts between one and three minutes. As in the case of continuous photometer measurements, a simple multiplication to estimate the measuring time for more C-planes is possible.

When the spatial radiation characteristics are known - at least to some extent - in the beginning of the measurement, a further optimization of the measurement with a spectroradiometer can be done. This might be the case when a number of products of the same model are measured or if a low resolution measurement has been performed in advance. The chosen increment can be adapted to the spatial characteristic of a particular angular range. The characteristic of the directional downlight, for example, makes it possible to choose a much lower resolution for |γ| > 40° without affecting the measurement uncertainty significantly.

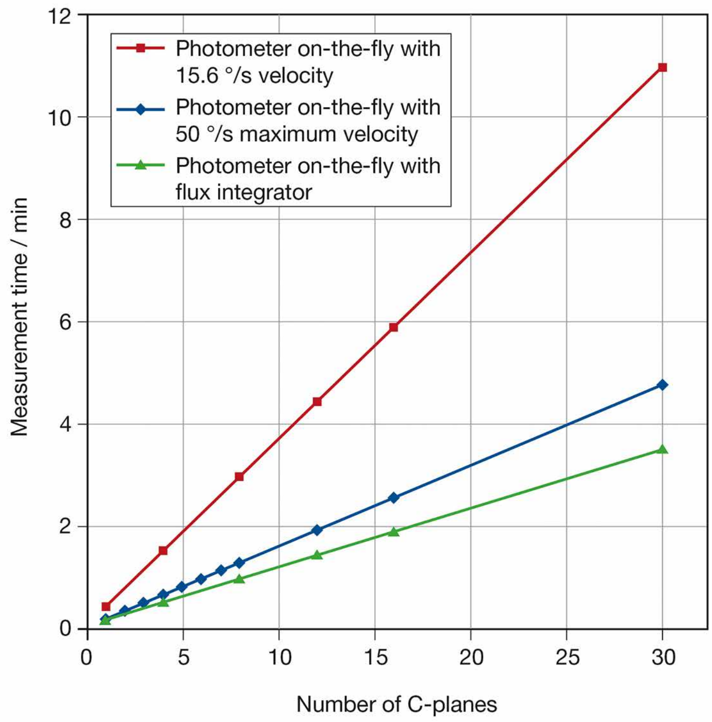


Figure 6:
Overall measuring time versus measured C-planes for different on-the-fly measurement geometries and velocities. The blue and red lines represent continuous measurements in the standard turning luminaire configuration with maximum and with reduced (15.6°/s) velocity. The green line represents a continuous measurement with the turning-detector option and maximum velocity

Optimization of On-The-Fly Functionalities

In the last section, the use of the continuous mode of the goniometer together with a photometer as detector was recommended for purely photometric measurements. When heading towards faster measurements one should bear in mind that movement of air around the device under test can change its effective operating temperature. As a consequence, the photometric values might change, too. The speed of the axis of the goniometer must therefore be adapted to the used sample size and restricted to reasonable values.

The recommendations of applicable standards are not consistent. IES LM-79-08, for example, just states that the air flow around the SSL-product should be such that normal convective air flow induced by the sample is not affected. EN13032-4 and CIE S025 are more precise in this respect. In those standards, the tolerance interval for air movement is 0 m/s to 0.25 m/s. This means that in order to avoid a correction to the standard test condition and therefore an additional component in the final uncertainty budget, the user should choose the velocity of the goniometer axis such that the stated tolerance interval is met. For this purpose, the goniometer can perform continuous measurements with different velocities as described above.

The velocity that meets the tolerance condition depends on the size of the sample when using a turning-luminaire setup. For samples with a radius smaller than 28 cm, the maximum speed (50°/s) of the goniometer can be used. When measuring only one C-plane, the sample size can be extended to r < 47 cm and still the maximum speed can be used. This is due to the different velocities of the axis. The maximum velocity of the γ-axis is lower than the maximum velocity of the C-axis. In general, for the maximum sample size the goniometer`s maximum speed of 14°/s should be used in order to meet the tolerance interval of the standards.

In figure 6, the overall measuring time for all C-planes is plotted for continuous measurements with a photometer. For each configuration there is a clear linear relationship with characteristic slopes for the different velocities. The red line represents a measurement in the standard turning-luminaire configuration at a maximum velocity of 15.6°/s, corresponding to nearly the full possible sample size. As a rule of thumb, the number of measured C-planes must be multiplied by 22 seconds in order to obtain the overall measurement time. This means approximately 6 minutes for a measurement with 16 C-planes which is fully compliant to the recommendations in the IES LM-79-08 standard.

The blue line represents a continuous measurement with maximum velocity in the turning luminaire configuration. The measurement time per C-plane is 9.5 seconds. The measurement stated above can be performed in approximately 2.5 minutes.

The green line stands for a continuous measurement using the turning-detector option of the goniometer. In this case, no restrictions in the sample size have to be considered concerning the used speed of the axes. The full speed of all goniometer axes can be used. In addition, the option switches the horizontal and vertical axis. The more frequently used γ-axis is now also the faster one. This leads to an improvement in measuring time compared to the blue line. In this case, the number of measured C-planes must be multiplied by 7 in order to estimate the overall measuring time in seconds. The measurement of 16 C-planes according to the guidelines of LM-79 needs only 113 seconds to be performed. For luminous flux measurements where the photometric distance requirement is not critical, this method is the fastest and does not put any restrictions on the sample size. For measurements of luminous intensity distributions, however, the sample size must be restricted to meet the photometric distance. Following LM-79-08, the sample size has to be restricted to approximately 18 cm in diameter for SSL-products with a broad angular distribution.

Conclusion

In goniospectroradiometry or goniophotometry, saving valuable measurement time in the daily laboratory routine is important. To accommodate the clear trend towards high quality light in Solid-State Lighting applications, users of a goniophotometer have to choose a measurement routine that provides a suitable balance of the two key targets “time” and “quality”.

The decision for a spectral (spectroradiometer) or integrating (photometer) detector type plays an important role in this respect. In addition, the measurement time and the achieved quality of the measurement depend on numerous factors, like the spatial radiation characteristics of the source, the applied scanning resolution and the type of the goniometer used. An estimation of the measurement time for two showcase SSL sources and the validation of the recorded data regarding quality, gives some practical guidance to successfully bridge the gap between a fast and a high quality measurement. ■

Street Lighting Evolution through LED Technology

Standard electronics is usually based on a relatively simple straight-forward technology. Outdoor lighting is more challenging in several aspects, especially robustness. This is also true for the electronics. Sandra Solán, R & D Manager from ELT Electronic Division has studied this technology in depth. To celebrate the IYL 2015 she will explain technical advances, benefits, strengths and technical challenges of current and future street lighting systems for an electronics manufacturer.

We are living in a new and exciting era of changes regarding outdoor lighting. Major changes are being experienced in most of the cities as a result of the technological advances which are being promoted by the lighting industry. Nowadays, those responsible for lighting in cities looking for a high quality light committed to the new values of the 21st century, such as energy efficiency or eco-friendly designs. This means that a street light is no longer that point of light that used to illuminate and had no further interaction than a simple ON/OFF. Now, it has become a dynamic point of light with the possibility of adapting to the user's needs regardless of the date or place where it is installed.

Manufacturing processes and designs have radically changed in last 5 years because of dynamics in the LED industry. These changes have forced electronic manufacturers to modify R&D and Industrial Departments in order to be able to face the new design challenges. A few years ago the R&D departments had expertise in power electronics and dominated topologies as the Buck Boost, Half and Full bridge topology, with skills in microprocessors programming or ASICs designing. Currently, knowledge of power electronics has to be critical. New topologies as Flyback, Buck or resonant LLC converters have appeared requiring greater precision in the magnetics design. For the trendiest LED driver designs, power electronics is the trunk of a tree whose branches are new technologies such as digital communication, telecommunications or the internet connectivity. This is a challenge for companies in which experts in telecommunications, software and firmware developers and experts in mobile technologies should be incorporated to their research groups.

Regulations & Requirements

Factors such as energy saving, CO_2 emissions reduction or the use of eco-friendly designs that are recyclable and are manufactured according to the latest directives without including prohibited materials like mercury, are intended to be implemented in a few years in each country or State by means of directives, regulations or standards. For example, since 2008 in Spain there is the Royal Decree 1890/2008 of 14 November, about the regulation of energy efficiency in outdoor lighting installations, and that requires the regulation of lighting in low traffic hours for installations of more than 5 kW. In the same way, in 2017 the new regulation of energy efficiency 347/210 will become effective in Europe. This regulation will establish compliance of a greater energy efficiency than the existing (EEI=A2) and it will probably mean the beginning of the electronic control gears up to 150 W instead of conventional ballast.

This is the very moment in which electronic control gears became really important in outdoor lighting. In former years, most of the outdoor lighting systems were made with high-intensity discharge lamp technology and conventional ballasts. Electronics were installed as auxiliary equipment for

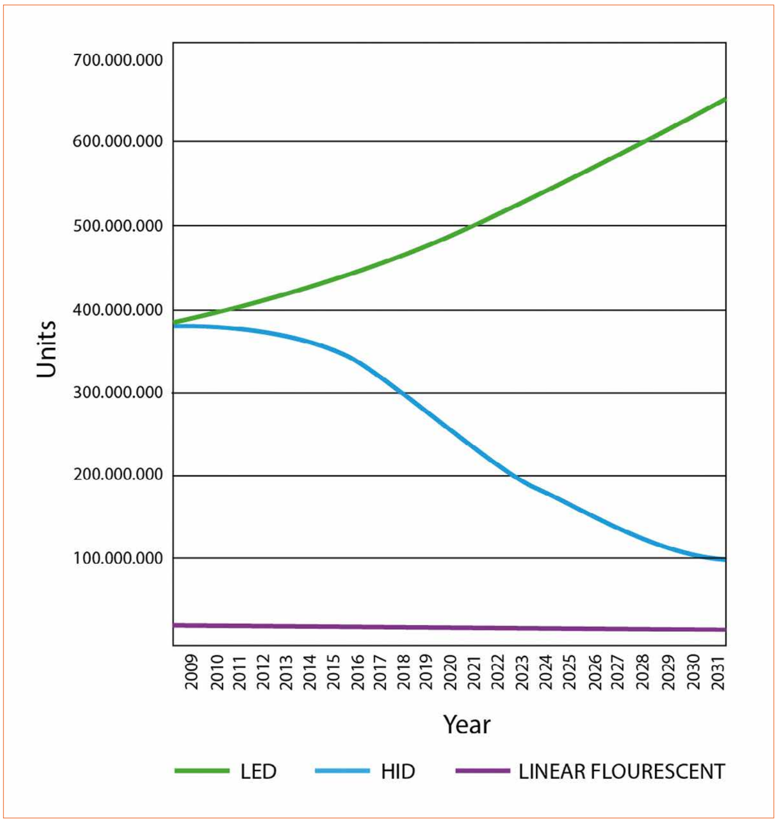
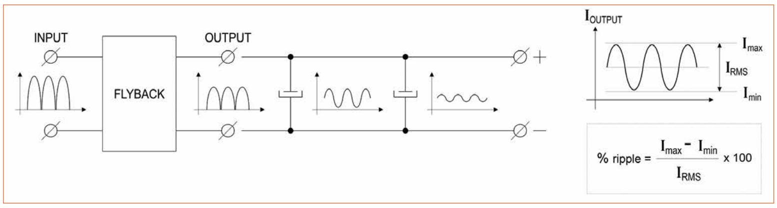
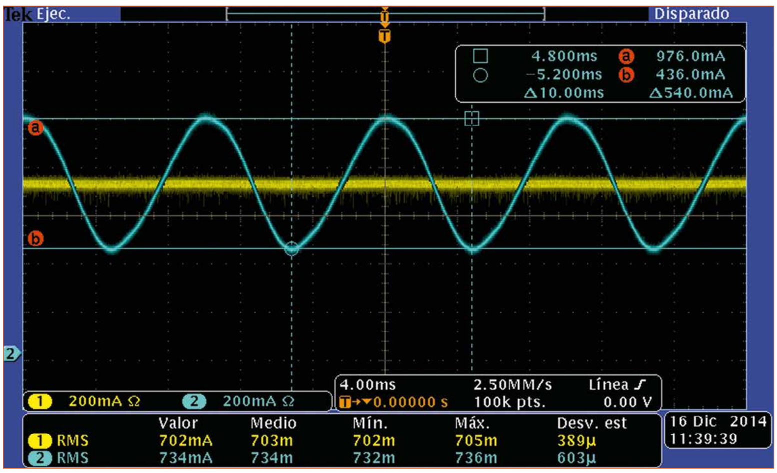


Figure 1:
Global lamp installed base in street lighting & illuminated traffic signs by lamp technology (Source: Datapoint Reseach from Global General Lighting Market)





Figures 2&3:
Normally, a flyback stage without primary regulating stages has a big output current ripple. The ripple can be compensated by electrolytic capacitors acting as components that store energy

conventional ballasts to allow double power level and reduce energy consumption. Afterwards, the integrated solution appeared on the market: ballast and dimming system in the same electronic control gear, which provided greater energy efficiency and longer life lamps, reducing costs in terms of energy consumption and maintenance service.

Finally, LED technology has been the one which has definitely revolutionized outdoor lighting, turning from a conventional street lighting fixture into an efficient and intelligent point of light. The constant improvement in the field of LEDs has improved the performance of the luminaires in terms of lm/W. Also, the constant upturn of the optics has made it possible to manage the light to where one wants to illuminate, taking advantage of most of the luminous flux and obtaining significant energy savings. Adding the long lifetime of the whole system, one can find out an optimal solution for public lighting that allows councils to be more environmentally friendly and respectful.

Efficiency

There is a new challenge for electronic equipment manufacturers in designing and manufacturing rugged and reliable solutions with the least possible energy losses. In addition to this, they should take into account and take care of other aspects like constant current to the output waveform, since it affects the LED luminous efficiency. The higher the output ripple current, the lower the light efficiency. For example, comparing lumens output in the same module driven by a control gear with an output current ripple of 35%, LED module luminosity is 16% less than if the LED module is driven by a control gear with an output current ripple of 3%. Some countries are already demanding less than 5% output current ripple.

Robust Design and the Right Topology

Electronic equipment designed for street lighting is robust when they suffer no damage in extreme operating conditions. Therefore it is very important to incorporate protection against lightning and over voltages, thermal protection to prevent overheating situations under abnormal operation or cases in which the equipment is improperly installed or protection against humidity, putting the printed circuit board where electronic components are mounted.

The reliability of electronic equipment begins in R&D with a good electronic design and a correct choice of components, and ends with manufacturing processes using a high quality control. A good failure rate of 0.2% of failures every 1000 hours of operation can be considered.

Good energy efficiency in electronics is achieved when the chosen topology is the correct one and the design of the components is optimized. Considering a design with an isolated topology (galvanic isolation between primary and secondary side), one usually thinks of a Quasiresonant Flyback converter up to 150 W output power reaching efficiencies of about 92%. For higher output values, it is recommended to design with a resonant output stage, for example, an LLC converter. In this case one can get up to 95% efficiency with an output of 400 W power. Both of the cases have similar key points in the design, as a good choice for switching components or the optimal design of the magnetics, essential to good energy efficiency.

In addition, the great challenge in terms of lifetime of the whole system is that the life of any electronic equipment has to be equal to or above the LED module. To get this, the use of film instead of electrolytic capacitors is a must.

Smart Controllability & Intelligence

Basic Controls

Comparing the different technologies used in street lighting, the first advantages of LED technology that come to mind are light efficiency, long lifetime, the high quality of light with CRIs between 70 and 90, and the high percentage of the luminous flux throughout the life of the module. But in addition to these features, LED brings along other advantages over other technologies such as sodium high pressure or metal halide lamps that make the use of this technology more inviting. First, LED technology gives 100% of the required luminous flux from the first switch-on moment, avoiding having to turn the streetlight on a few minutes earlier.

In addition, in the event that a soft-start is required, LED control gears allow configuring all possible turn on ramp parameters. On the other hand, LED can be dimmed down to 1%, having the possibility to dim the light in the desired range and down to a percentage very low in required situations, for example, car parks or public parks providing greater energy savings when presence is not detected (parking functionality).

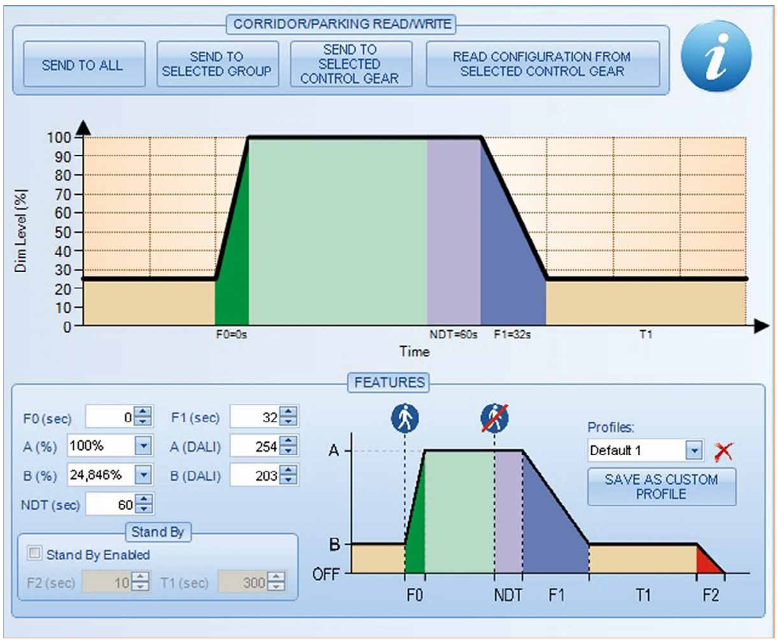


Figure 4:
Parking function: A dimming system that controls the light level when a presence is detected by a conventional mains on/off sensor, connected to the DALI/Touch and DIM connection. Output levels, delay time or fade time are all fully programmable by the end user

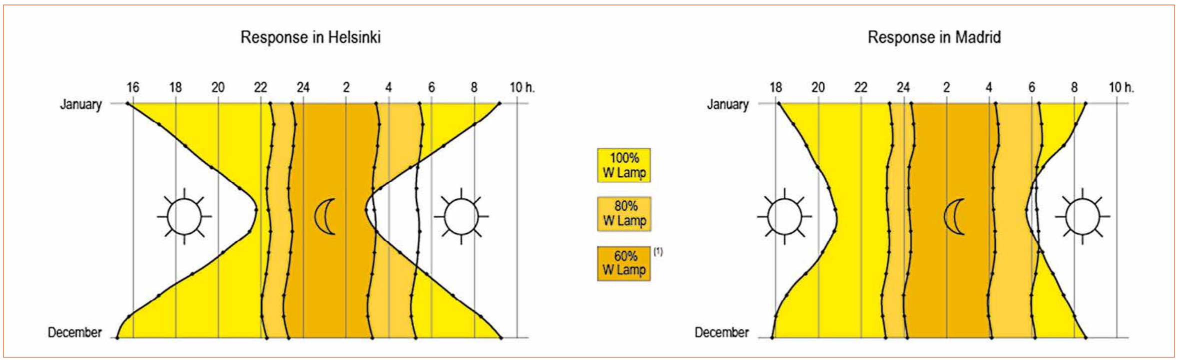
Advanced Controls

Beyond the benefits of this technology in terms of energy efficiency and lifetime of the control gear, LED has been accompanied by electronics that gives the luminaire with the ability to handle light “à la carte”. Depending on the needs of the client, each point of light can be configured to adjust dynamically to the night length (SMI System), handling it with a command line (AC, DC or Touch systems) or even to dim a set of luminaires depending on presence detection by sensors. In control gears with the SMI system configured, the mains switch-on and switch-off is controlled by the photocell or astronomic clock and the control gear makes the light level dimming automatically. The control gear’s microprocessor measures and memorizes the duration of the previous four nights. With this data it calculates the average “on” period necessary to establish its medium time point. Reduced levels are then activated some hours before and after this medium time point. These parameters are completely programmable.

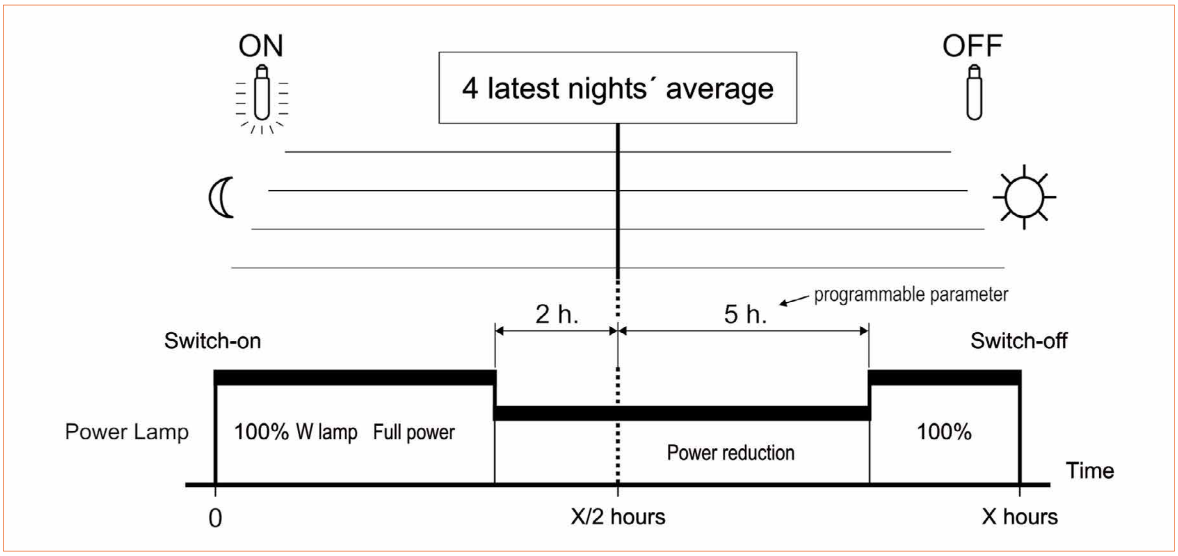
Throughout 2015, leading manufacturers of electronic equipment for lighting will offer drivers for LEDs fully programmable by the user. That means that parameters such as the current output, turn-on time and fade, LED module thermal protection or lumen level maintenance (LLM) option will be fully configurable by the end user in a fast and easy way. In addition, different methods of regulation may be selected, with the possibility to connect sensors, maintenance notices when approaching the end of life electronic equipment or LED modules, etc.

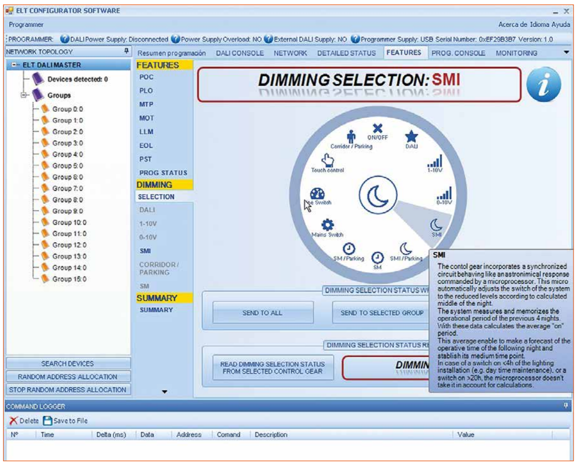
Intelligent High End Controls

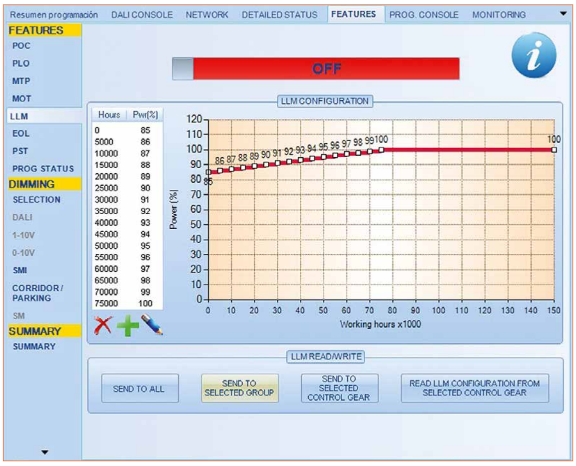
One step further up in the technological scale are the wireless lighting systems. The wireless management allows for participating on a bi-directional communication channel to control each point of light and obtain information about it as



Figures 5&6:
SMI technologies with astronomical response has automatic changeover to lower light levels







Figures 7&8:
Leading equipment manufacturers will offer their own software to program electronic control gears (left). Lumen Level Maintenance - this feature allows for the gradual increase of the light level over time to compensate for known luminous flux depreciation of the LED module (right)

the status of the LED module, the network, consumption, etc. in real time. It is just not about providing a greater flux, more efficient and with a higher quality, but also about supplying when necessary, just in the desired when and where, allowing the best and greatest energy savings for councils and the most comfortable atmosphere for citizens. The point-to-point wireless management gives us the chance for complete control over the installation to save energy and maintenance costs.

Conclusions

When technology seems to reach the highest peak in public lighting, the question of how future lighting is evolving arises as well as other questions about the importance of lighting in future cities and the kind of new features that will be included. The answers can be found in the concept of the “Smart Cities”. At the same time, other dreams come along like being able to manage all the city services from the same system, something that has always been on the lighting professionals’ mind. However, the success derived from integrating all these possibilities in lighting will come not only from those research groups that have key ideas, but also from the companies’ ability for getting new strategic partnerships and also from developing and imagining new innovative and, up until now, unimaginable solutions.

Guidance on Specifying Solid State Lighting Luminaires

Certification marks of renowned test institutes are useful tools for end users to easily estimate the quality of a product. They are also a good marketing tool for manufacturers to generate user trust and confidence in a product or the brand. The authors, Jaap Nuesink and Michael Schoof from DEKRA Certification B.V. explain what is needed and which parameters have to be covered in order to be certified, ending up in a guideline of how to qualify for the DEKRA Solid State Lighting Certification Mark.

DEKRA Certification introduced a performance mark for solid state lighting products in 2011, but the high level of initial interest did not translate into certifications. Therefore, at the end of 2012, a survey among OEMs and end users has been conducted to discover the reasons why. The outcome was clear: a performance mark is required, but its program must be better aligned with market needs. Consequently, a solid state lighting forum to explore those market needs together with several manufacturers and end users was established. This process ultimately resulted in a guide to specifying solid state lighting.

Introduction

The guide promotes the use of a standard datasheet which lists the most important parameters for Solid state lighting from the perspectives of OEMs and end users. The parameters are divided into four main groups - namely photometric, electrical, environmental and lifetime - and they are presented in a clear and logical order on the datasheet to enable products to be compared quickly and easily.

Photometric Data Parameters

- Luminous flux
- Efficacy
- Color temperature
- Color coordinates
- Color consistency
- CRI
- Light distribution

System-level specification

Many specification sheets currently available on the market begin with various assumptions. For example, the luminous flux of a module is specified while the losses in the luminaire are not accounted for. In addition, efficacy is often based on the LED modules alone instead of on the full system. To prevent such misinterpretations or misleading data, a quick and easy-to-understand guide on how to specify the efficacy and the luminous flux has been set up.

All parameters, including color temperature and color coordinates should be specified under operating conditions and the temperature of the full system should be stabilized.

When taking these measurements, it is important to take into account any potential elevated ambient temperatures as they are specified in the environmental conditions section of the datasheet.

Please note: the ErP directive requires a label showing the efficacy of the light source, which is based on light source measurements. In the case of a solid state lighting luminaire, efficiency can be based on the luminaire. In the ErP directive system-level measurement is not required; however, removal of all elements of a luminaire that could lead to light losses is prermitted - such as the translucent covers, reflectors, etc. - until only the bare, functional part of the luminaire remains. This can be the LED module, cooling and driver system alone. Although this is acceptable practice according to the ErP directive, this does not give the efficacy of the complete luminaire and could thus lead to false conclusions and underperformance of products/installations.

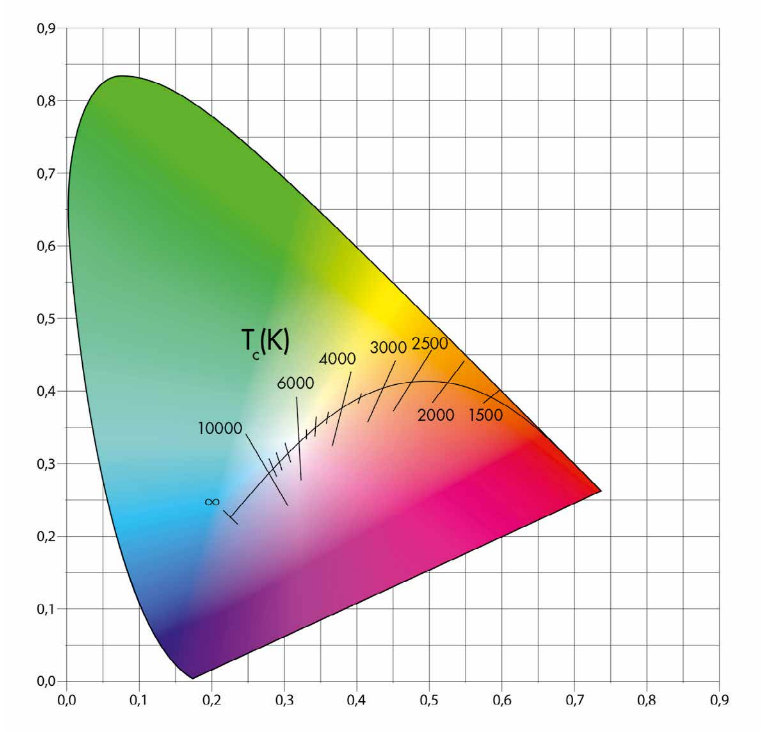


Figure 1:
The CIE x/y color space with the Planckian locus and CCT values

Color coordinates and temperature

There are several reasons why the color coordinates and the Color Temperature (CCT) should be specified.

It is necessary to specify both because the color temperature is not defined as a single point in the color space. The CIE has defined the areas close to the Planckian locus where the same CCT can still be used. As a consequence, the color point does not have to be right on the Planckian locus but it can also be in the proximity.

Needless to say, this poses a real problem when specifying different light sources from different manufacturers - and sometimes even different light sources from the same manufacturer - especially in the case of extending or renewing sources in an existing installation. Specifying color consistency requires specification of the actual, exact color point. Another advantage is that the specification sheet can be used to indicate not only white light luminaries, but also every type of colored light fixture. In this case only the color coordinate and its consistency are specified, and not the color temperature.

The main references for photometric parameters:

- LM79
- IEC62612
- CIE84
- CIE15
- LM82

Photometric code

A photometric code and is it relevant when comparing products.
The code is a six-digit number that contains information about the light quality of the source and its behavior over time.

The values and when to use the photometric code

The code gives an approximation rather than exact values, but that in itself is not necessarily a problem and will mainly depend on the actual application.
The main factor to take into account is the estimated lifetime of the installation, bearing in mind that the code specifies values for up to 6,000 hours. In many cases this is a very low number for solid state lighting and may not prove useful if the lifetime is as much as 10 times this value.

Format and meaning of the standard photometric code XXX/XXX (123/456):

- The first digit (1) indicates the initial CRI value of the source
  - CRI code range:
    6 57 - 66
    7 67 - 76
    8 77 - 86
    9 87 - 100
- The second two digits (23) indicate the initial CCT value:
  - The value is obtained by dividing the actual CCT value by 100, e.g.
    3000 K = 30 or
    2700 K = 27 or
    5600 K = 56
- The first digit behind the forward slash (4) indicates the initial spread of chromaticity coordinates:
  - The number is given in MacAdam ellipses, which is an indication of the spread in color between different light sources from the same make and type, e.g.
    1 = very narrow > no difference between sources
    2 = narrow > potentially very little differences between sources, etc.
- The second digit (5) after the forward slash indicates the maintained spread of chromaticity coordinates:
  - This number is also given in MacAdam ellipses and explains more about the spread in color measured after 25% of the actual lifetime (with a maximum of 6,000 h)
- The third digit (6) after the forward slash indicates the maintained luminous flux:
  - This value is determined after 25% of rated life or 6,000 h

Examples:
930/339, or 827/358

Electrical Data Parameters

- Rated Voltage
- Rated Input
- Rated Frequency
- Power Factor
- THD
- Surge Protection
- Run-Up Time
- Inrush Current

The first three parameters are self-explanatory.

Power factor

The power factor: there are several points to take into account. The European power factor requirements are laid down in two different directives.

European power factor requirements:

- The EMC directive:
  - Products with power > 25 W: required minimum power factor ≥ 0.9
  - Products with power < 25 W: no requirement
- The ErP directive for products with power of less than 25 W:
  - 0 - 5 W: no requirement
  - 5 - 15 W: required minimum power factor 0.4
  - 15 - 25 W: required minimum power factor 0.5

The requirements for all products below 25 W are very low power factors resulting in not very efficient installations. Moreover, many tenders specify higher demands. Hence, a higher power factor can be a sales argument for luminaire manufacturers.

THD

THD (the harmonic distortion) is a percentage that indicates the distortion the system causes on the net, and hence should be limited. THD and power factor are closely linked in practice.

Surge protection

Surge protection is the capability of a system to protect itself against sudden spikes in the net. The requirements, which are set out in the EMC directive for drivers, were relaxed recently. Spikes can lead to situations in which the surge protection of drivers is no longer sufficient to protect the luminaire. This was not a big problem in the past with conventional control gear, but today's increasingly electronic control gear is more vulnerable to these effects. Therefore, more and more OEMs are fitting a separate unit in the luminaire to prevent damage and costly aftersales maintenance.

When surge protection is typically a problem

- In areas with aboveground supply systems. Such systems are characteristically more susceptible to discharges than underground systems
- In areas with heavy industrial activity: switching on and off contributes to main disturbances, creating fast transients

Run-Up Time

Run-up time is the actual time it takes before the luminaire produces light, i.e. the speed with which it responds to an action (e.g. flip of the switch). The slight delay is due to the driver, which needs time to start up. Although this may not be relevant in some areas, in other applications users expect something to happen almost immediately after their action. For example, if no light is produced within a minimal timeframe after the switch being flipped, users may think the luminaire or switch is defect.

Inrush Current

The current specification contains two different values for the inrush current.

Inrush current values:

- The maximum current the driver is taking out of the net, measured in amperes
- The number of luminaires that can be connected to one single fuse. For example: a D-type fuse, 16 A, can only serve a certain number of identical luminaires because the inrush current can cause a problem when switching on several fixtures at the same time.

This has already caused problems in public lighting applications where installations had not been adapted to cope with the high inrush currents, resulting in malfunctions and all drivers having to be replaced. As a rule, a well-designed system specification should take into account the potential inrush currents that can occur.

The main references for electrical parameters:

- EN60598- 1
- EN55015
- EN61000- 3- 2
- EN61000- 3- 3
- EN61547
- Directive 2009/125/EC with 1194/2012

Environmental Data Parameters

- Ambient temperature
- IP (ingress protection)
- IK (impact resilience)

Ambient temperature

The ambient temperature is a key parameter, in particular for Solid state lighting products. According to the standard, the ambient temperature for a standard indoor luminaire is 25°C and for an outdoor fixture it is 15°C. These are the values to be taken into account unless the luminaire is marked otherwise. However, these values are clearly not always sufficient for the environment in which the product will be used, such as in spaces with high ceilings and elevated ambient temperatures where the actual ambient temperature at luminaire level can be considerably higher. The effect of this higher ambient temperature is an increased LED module temperature and an increased driver temperature, both of which can seriously affect the lifetime of the luminaire.

Ingress Protection (IP) Ratings			
Solids (First Number)		Liquids (Second Number)	
0	No protection	0	No protection
1	Protection from objects greater than 50mm (hands)	1	Protection against dripping water or condensation
2	Protection from objects greater than 12mm (fingers)	2	Protection against water spray 15 degrees from vertical
3	Protection from objects greater than 2.5mm (tools/wires)	3	Protection against water spray 60 degrees from vertical
4	Protection from objects greater than 1mm (small tools)	4	Protection against water spray from all directions
5	Protection against large dust particles	5	Protection against low pressure jets of water
6	Totally protected against dust	6	Protected against temporary flooding of water
7	N/A	7	Protection against immersion from 6 inches to 3.3 feet
8	N/A	8	Pressure watertight

Table 1: Meaning of the two digits of the ingress protection code

IK code	IK00	IK01	IK02	IK03	IK04	IK05	IK06	IK07	IK08	IK09	IK10
Impact energy [Joule]	*	0.15	0.2	0.35	0.5	0.7	1	2	5	10	20

* not protected according to this standard
Note 1: When higher impact energy is required the value of 50 Joules is recommended
Note 2: A characteristic group numeral of two figures has been chosen to avoid confusion with some former national standards which used a single numeral for a specific impact energy

Table 2: Minimum impact energy requirements in Joule for the 11 IK code levels

Ingress protection

IP values are specified for two reasons: Firstly for actual safety, and secondly to ensure that the product is suitable for use in the intended conditions. For example, street lighting will have to comply with at least IPX3 (rainproof). Other considerations must also be taken into account. For instance, dust protection should be considered for luminaires that are used out of normal reach or are not easily accessible for cleaning purposes.

This could be IP5X or IP6X:
6 is dust-tight whereas
5 lets in some dust, albeit very little. If the aim is to minimize cleaning, code 6 should be considered. In terms of cleaning the outside of the luminaire, a code of IPX5 or IPX6 can be considered since both are spray-proof.

Please note: since the current IP coding system does not contain a code which denotes that it is safe to clean a luminaire using high pressure, the use of high-pressure washers is not advisable.

Impact resilience

The IK rating denotes the impact resilience, or 'vandal resistance', of a luminaire. The IK code is an important parameter when specifying luminaires for use in public spaces.

The main references for environmental parameters:

- EN60598- 1
- EN60529
- EN50102

Lifetime Indicators:

- L value
- F value
- Driver life

The L value indicates the expected lifetime of a product and the F value indicates the predicted failure rate over that lifetime. Hence, the two values are closely linked and both should be specified based on the information about the solid state lighting module. This gives a clear view of the expected reduction of light output and occurrence of failures over time. The timing should be clearly mentioned on the modules, and the preferred values are linked to the IEC PAS standard as follows: L at 90%, 80% or 70%, and F at 10% or 50%. Many other values are currently still being used in the market, which may cause confusion. More problematically, not all manufacturers publish the complete set of data and, even more significantly, it is not always clear if the module conditions in the luminaire are in accordance with the claim. The key for the luminaire manufacturer is to confirm the conditions for the solid state lighting module in the luminaire.

Please note: a 50% failure rate for a luminaire is not a realistic value to work with. Consider an investment that requires replacement of at least 50% of the luminaires due to malfunction within the planned operational time. This can hardly be a satisfactory proposition.

The lifetime problems in today's solid state lighting fixtures are no longer caused by LEDs - if the LED fitting is installed correctly and used in an accurately designed luminaire, it is possible to achieve

Standard Luminaire data sheet

Basic information

General description	Luminaire for Streetlighting; Cycle roads, Parking lots, Residential area's
Trade name	Fantasy
Model reference	Fantasy XYZ

Safety

Low voltage directive	ENEC 05
EMC Directive	DEKRA test report

Environmental

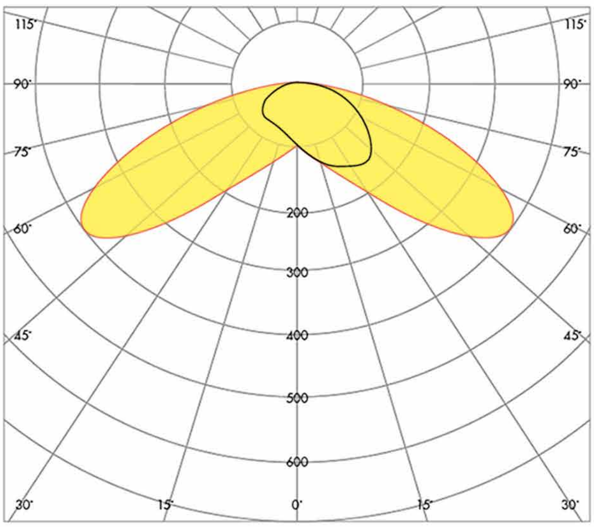
Ambient temperature	25	°C
IP	68	
IK	10	

Electrical

Rated voltage	230	V		
Rated input	30	W		
Rated Frequency	50	Hz		
Power factor @	100% Pn	75% Pn	50% Pn	25% Pn
	0,95	0,9	0,85	0,85
THD	4	%		
Surge protection	2	kV		
Run-up time	<0,5	s		
Inrush current	2	A		
Circuit breaker type	C10	C13	C16	
Number of devices	30	35	40	

Photometric

Luminous flux	3800	lm
Efficacy	126	lm/W
Color temperature	4000	K
Color coordinates	0,380	
	0,375	
Color consistency	2	SDCM
CRI	80	%
Light distribution		



Maintenance

Lx	90	%
Fy	10	%
At	100.000	h
Driver life	80.000	h

Figure 2: The luminaire data sheet must show the specifications shown in this example of a standard data sheet if they want to use the DEKRA performance mark

very long lifetimes. Instead, the main issue is the lifetime of the driver; components that are used to build drivers generally have limited expected lifetimes that can be well below those of the LED modules. In some products on the market that are specified for long lifetimes, the LED module part of the solid state lighting luminaire will not have a problem achieving it but the driver definitely will. A good design ensures that both driver and LED module are cooled sufficiently.

Please note: for long lifetimes, it is essential to keep the components as cool as possible and ensure that both LED module and driver have similar expected lifetimes.

The main references for lifetime indicators:

- LM80
- TM21
- LM82
- IEC PAS 62717
- IEC PAS 62722

When examining these basic parameters it can be argued that other parameters play a significant role in specific situations. There is no reason to limit the datasheet to the parameters described here, and manufacturers should provide more information wherever it is relevant. This is still a topic of discussion with the aim of preparing further extensions and additional parameters for specific usage cases. One example is the list of parameters for public lighting purposes, where more information is needed and very long lifetimes are important. Furthermore, although the basics remain the same, the environmental conditions are completely different for a luminaire used outdoors than for one for office use.

Conclusions

Of course, the use of the datasheet will help in promoting the quality of solid state lighting. But the new voluntary LED Performance mark adds further value by demonstrating that the parameters have been verified by a certified third-party testing house. The certificate issued to the manufacturer confirms that all parameters are correct and are being monitored through a program of market surveillance and factory inspections. ■

Making Light Work – Light Sources for Modern Lighting Requirements

Solid state light sources are the core of modern lighting installations. To get in the right mood for the IYL 2015, Dr. James Gourlay, Chief Technology Officer with Design LED Products, looks at the ways to make LED lighting more efficient, satisfy user demands and to bring SSL design to the next evolutionary level.

Light emitting diodes (LEDs) have come a long way since the 1960s and 1970s when they were used as small indicators or made up into seven-segment displays in watches and early calculators. Today, the range of colors and the intensity has seen them find applications in everything from environmental lighting to automotive lamps. But with that maturity comes a range of different problems, not the least of which is controlling light output, especially in environmental applications.

A lot of effort is put into making LEDs and LED light sources look good and achieving the right quality. If LEDs are used in offices or homes, they need to have low glare so they do not dazzle the occupants. This is normally done using some kind of enclosure and lens system, but that can have an adverse effect on the efficiency of the light, and given efficiency is one of the main selling points of this type of illumination that is obviously not desirable.

LEDs also provide the ability to integrate the light into the fabric of a building. They can replace ceiling tiles or be embedded in pillars and posts; they can be fixed into concrete and wood and be made part of the structure of the space being illuminated. However, using conventional techniques, they still need some optical system to reduce the glare and direct the light. This adds to the thickness, making the aesthetic element more difficult.

Typically, an optical element would be attached onto the LED itself. This would normally be some kind of plastic lens, and that has become the standard way of doing this. Also available are flexible circuits containing the LEDs and these can be cut to length and embedded into the building material, but again some sort of plastic lens is needed. This makes it thicker and removes some of the flexibility, turning it almost back into a normal light fitting. It becomes clunky again.

A more recent development that gets round some of these problems are light tiles that mount the LEDs into transparent plastics, which can have the necessary optical characteristics preinstalled, thus retaining the flexibility without a dramatic increase in thickness.

Edge-Lit LED Technology

One of the better-known LED technologies is edge-lit. This can be effective in delivering thin lighting panels with a Lambertian output beam distribution. This was the technology that brought LED televisions to the consumer market. Typically, this consists of a PMMA (polymethyl methacrylate) light-guide plate covering the extent of the LCD panel. LED light sources are placed along one, two or four edges of the PMMA light-guide plate. The light from the LEDs is coupled into the light-guide plate and guided by total internal reflection (TIR). Light extraction features disturb the TIR and allow light to escape. The pattern of the light extraction supports uniform distribution of the escaped light behind the LCD panel when configured with a rear reflector.

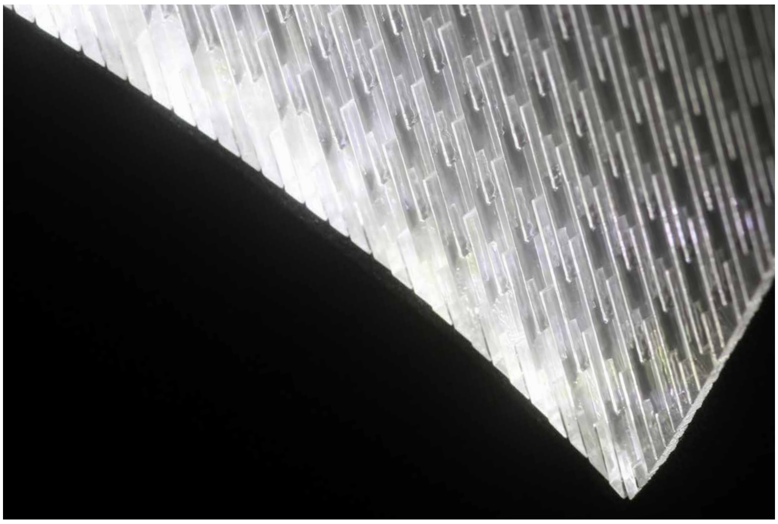


Figure 1: **Flexible edge-lit LED solutions are allowed by using different approaches like this laser-cut acrylic light guide**

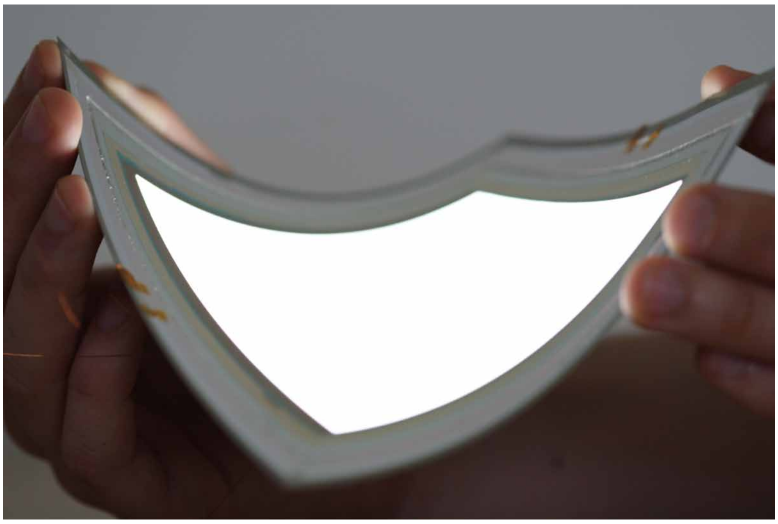


Figure 2: **Flexible OLEDs are a technology lighting manufacturers and lighting designers are hoping will mature**

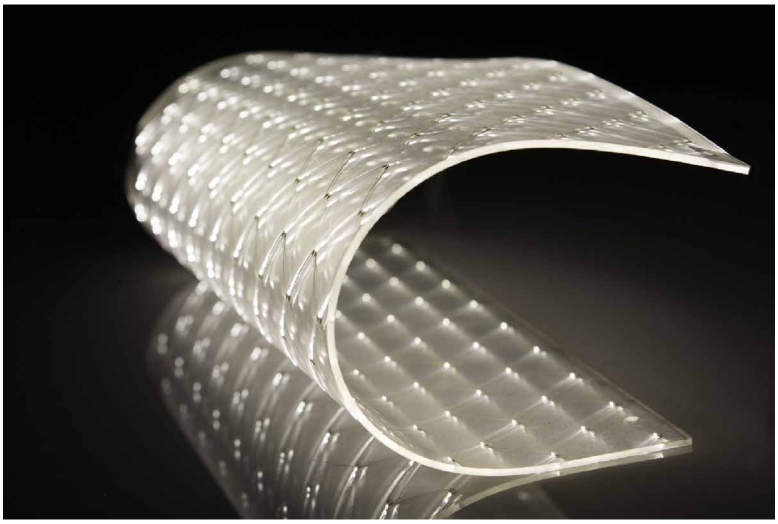


Figure 3: **The integration of LEDs in a polymer film to manufacture "light-tiles" is another promising solution for flexible light sources**

In recent years, edge-lit LED technology has been used in lighting applications, for example 600 by 600mm Lambertian ceiling tiles. However, its main advantages of uniformity with a thin system thickness are best deployed for backlighting applications like in signage.

A disadvantage of this technology is its power consumption. As the area of the backlight increases, the power consumption rises non-linearly due to the increased optical absorption and scattering losses within the light-guide polymer as the distance from the edge to the center grows. Because of the optical losses due to scattering, coupling and light-guiding, optical efficiency falls into the 40% to 60% range, in other words 60% to 40% of the light energy is lost. Coupling losses come from surface scattering and Fresnel reflection. Wave guiding losses are because of absorption in the PMMA.

Additional prism films are needed for beam shaping. It is also symmetrical only; narrow beam is not possible. And because the heat is concentrated round the edge, there can be a bowing problem.

OLEDs

Organic LEDs (OLEDs) use an organic compound to emit the light in response to an electric current. They can be used without a backlight, can display deep black levels and are thinner and lighter than an LCD, and with a higher contrast ratio. Though OLED is a technology mostly associated with display applications from televisions to mobile phones, there is a lot of research in making it a more suitable method of solid-sate lighting. Desk lights using OLEDs are on the market –though quite expensive – and many predict that luminaires using OLED panels will become commonly available. Already, there are companies offering OLED panels as samples for research purposes and for some more expensive installations.

At the current development stage, technology does still have several drawbacks to being solved, though. Notably the limited lifetime and degradation over time is not constant across the colors, in that blue degrades more quickly, damaging the color balance.

There are also still serious efficiency problems, and therefore they have higher power consumption. Without a proper extra sealing, they can easily be damaged by water and moisture. However, ongoing research is addressing these issues.

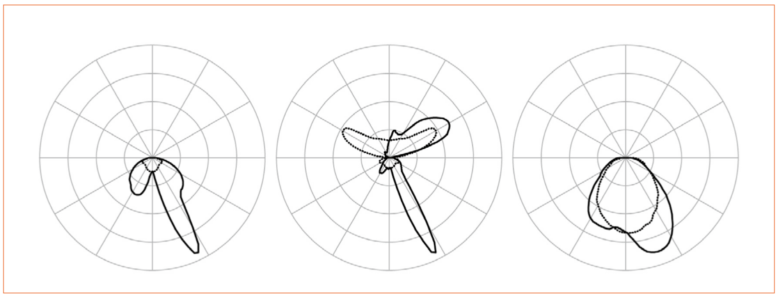


Figure 4: High efficacy LEDs encapsulated in a thin light-guide which is mechanically flexible. Optics on a light-guide surface enables both narrow (>10°) asymmetric beam angle control for lighting and uniform illumination for backlighting

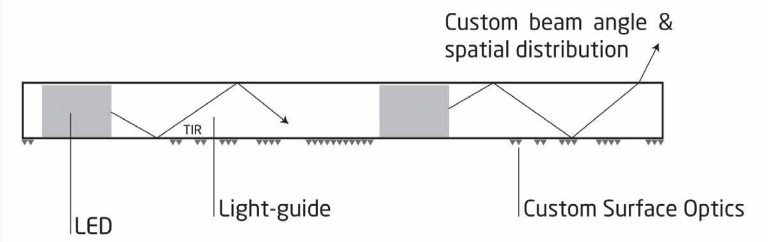


Figure 5: Design LED lighting technology features a 2-D LED array in a multi-layer structure. Encapsulation of LEDs maximizes optical coupling, which is reflected from the optical medium interface by total internal reflection (TIR). Surface features disrupt TIR and extract light. Control of pattern and form of surface features provides control of relative light extraction

Light Tiles

Light tiles are polymer films with the LED embedded inside. They are mechanically flexible and transparent, and form a light guide with the optics integrated onto the film surface. This allows functional, narrow asymmetric beam formation from the tile surface for lighting and a uniform spread of light across the surface for thin and optically efficient back lighting.

The light tile technology patented by Design LED Products integrates the LEDs and optics in a thin and mechanically flexible form factor. A composite light-guide structure is used to embed the LEDs into thin, mechanically flexible transparent films with surface optics. This technology evolved from large backlight panels for LCD televisions, which were used because they were cheaper and more efficient than the edge-lit LED method.

A single light tile can contain a range of high efficacy LEDs with a high color rendering index and various correlated color temperatures. The LEDs are embedded in a 2D array within multi-layer polymer composite films, which act as a light guide structure to spread the light inside the tile using TIR. The transparent substrate mounts the LEDs mechanically and electrically, and they are encapsulated to form the two-layer light guide structure.

The light is emitted parallel to the surface of the polymers and is trapped inside the composite layer by TIR. Refractive optical surface features can be on one or more surfaces of the light guide structure at the air interface. These disturb the TIR and allow the light to escape in a way that controls the illumination uniformity for backlighting applications and the beam angle distribution profile for lighting applications. For example, high quality prisms and a single LED orientation can create narrow emitted asymmetric beam angle distribution or a regular 2D pattern. Graded light extraction features can achieve uniform spatial distribution to a backlight graphic or screen. The tile can be transparent and the light output can be single or double sided.

An added advantage of this method is that good thermal management is inherent because the LEDs are distributed across a large surface area. This means designs are possible where the LED junction temperature does not exceed 20°C above ambient. Thus often no external heat sink or spreader is needed.

The resultant illumination panels are typically less than 1 mm thick including the flexible circuit, light guide and outer graphics. Because they are solid-state products, lifetime is typically longer than ten years. They require low voltage power supplies and are intrinsically safe.

For lighting and backlighting modules, different shapes and sizes up to one meter square are possible. For curved form factors, a bend radius of more than 50 mm is achievable as is a luminous flux density up to 20,000 lumens per square meter. Beam angles range from narrow asymmetric to Lambertian.

Comparing Technologies

Light tiles have up to 90" optical efficiency, which can be up to two times more efficient than edge-lit LEDs, and they are more mechanically flexible and have an asymmetric beam angle down to just ten degrees. They score even better when compared with OLED in that their lifetime is around five times longer, they are up to four times more efficient and again, are more mechanically flexible.

The alternative of mounting the LED on a PCB with secondary optics can be up to five times thicker and is less mechanically flexible. The narrow asymmetric beam angle in light tiles improves lighting control and they provide uniform illumination for backlighting. Light tiles are also modular and cut-able.

Electroluminescent lamps can also provide thin uniform lighting but they need a higher power supply and have limited color range and light output.

On power consumption, with light tiles this increases linearly with area as opposed to non-linearly with edge-lit technology. Direct-lit LED technology is also better than edge-lit for power saving and optical efficiency but not as good as with light tiles. For lifetime and thermal management, direct-lit and light tiles are similar, and both better than edge-lit.

Design Challenges

The challenge for the lighting designer is to achieve an acceptable level of brightness while still maintaining a uniformity of light. Uniformity can be key to the user experience as it creates an impression of higher quality. Bright spots need to be avoided and the light has to be directed to where it is needed.

Sometimes this can involve sacrificing the LED efficiency gains, say when the light is emitted in an unwanted direction it is often absorbed rather than redirected to where it is more useful. Diffusers are also often used to reduce hot spots and create uniformity.

The norm is for the diffuser to sit over the direct point source of LED light and damp down the differences between the hot spots and darker areas. This can lead to efficiency losses above 50 per cent of the emitted light. When this is added to other absorption losses, efficiency can be reduced by more than 70%.

This is one area where the light tiles can really help as the light is injected into a light guide, which allows the gradual and controlled escape of the light throughout the length of the guide. There are no hot spots and no need for light absorbing diffusers. Printed dots on the light guide control the location and uniformity of the escaping light. Uniformity can be above 70 per cent, a level beyond which the human eye cannot detect any variations.

Rear reflectors can prevent the system absorbing light and redirect it to increase efficiency even more. Light-blocking features can be added to increase optical isolation and contrast.

Printed light guides can also be easily modified if there are late changes to the design. Displays can be flexible or can be formed into curves. They can use any combination of red, green, blue and white light sources to create features such as color fading and secret-until-lit effects.

Easily customized, the tiles can be made in different shapes, sizes and colors. They can also be integrated into furniture or architectural materials. The size, shape, lumen density and beam angle are all under the control of the designers, who thus have the freedom to put light of any color where and when they want.

Future Developments

Technologies like the described liones already extend the design options for luminaire and lighting designers. But future technologies will further improve the opportunities. For instance, the current research into light tiles is looking at integrating microLED and nanoLED technology to achieve a narrow device beam profile that will improve light coupling. This will lead to further cost reduction as well as improved performance. There is even the possibility to create uniform and diffuse sheets of light that would look like illuminated paper. ■

LEDs are Revolutionizing Light – The Past and Future of Lighting

Light is a basic part of life as such and modern living relies on artificial light. Lighting is a constantly developing, even accelerating technology, with LEDs representing the current zenith. On the occasion of the beginning of the IYL 2015, Stephan Wegstein representing VESTEL, a leading contract manufacturer in Turkey, has been asked to explain the challenges this poses and how suitable strategies and technologies can assist in staying on top of developments.

Today's modern world is unthinkable without light and without artificial sources of light. Thomas Edison's invention of the light bulb in 1880 and its introduction onto the market changed society radically. We are now due for a drastic change once again: not only is the LED a lamp, it also has a huge impact on our planet's natural resources.

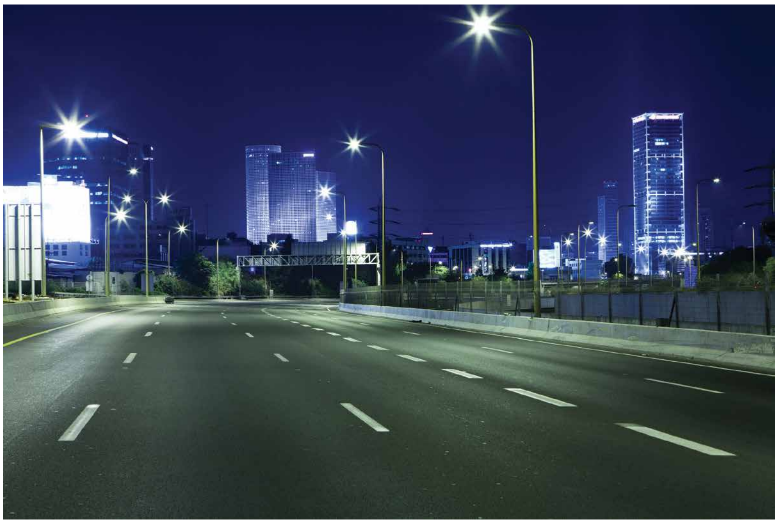
The development of LEDs to replace classical incandescent bulbs may be compared to the evolution of automobiles. Gottlieb Daimler and Carl Benz invented the "car" as a motorized carriage in 1886. This vehicle actually had nothing in common with the vehicles we are familiar with today. One hundred and twenty-eight years ago, the two inventors simply started off from what they were familiar with: horse-drawn carriages. They did away with horses and shafts, mounted an engine on the remaining body and replaced the reins with a steering wheel.

But neither Benz nor Daimler had the faintest idea of what was to come; today's cars crammed with driver assistance systems, comfort and electronics. Body, steering wheel and engine are the only items our vehicles still have in common with their ancestor.

Thomas Edison and Heinrich Goebel invented their light bulbs virtually at the same time the car was developed. In 1889, the chemist, Carl Auer von Welsbach, replaced the original carbon filament in light bulbs with a metal filament made of Osmium. A drawn tantalum wire made its debut in 1903 and after about 1910, tungsten became the metal of choice. Up to now, the bulbs of incandescent lights contained a vacuum, but in 1910 the American, Irving Langmuir, started filling these bulbs with a neutral gas and also spiraled the wire.

Incandescent lamps matured to the standard lighting solution in many areas of our lives for the next century. Poor efficiency and more innovative solutions were catalysts to the ban of some incandescent light bulbs in the European Union after September 1, 2012. They are being replaced by energy saving or LED lamps and the ban of most halogen lamps is now imminent.

But now, however, even energy saving lamps are on the retreat. Most consumers consider the risk posed by mercury, should a light bulb break, too high. Not to mention the energy balance when including the energy consumed in their production. LED lamps and lights are catching up across-the-board and in many fields. The step from incandescent light to LED needed 100 years. And even though engineers are producing innovations virtually every six months, we are just on the brink of developments. The potential is phenomenal here and the growth rates enormous. The market prospects are outstanding and investments are pouring in. Fading into obscurity all too often, however, are many aspects important to the structured development of this market.



Figures 1 & 2:
Modern life evolves around artificial lighting

Electronic Controllers - a Basic Requirement

Electronic controllers are the heart of every LED lighting solution. Simply switching LEDs on and off is still conventional practice today. The DALI bus system (digital addressable lighting interface) is often used to network individual lamps, especially in simple installations. Up to 64 devices may, in this way, be operated on one bus. Communication is via two conductors of the power cable, with all DALI components connected to this conductor pair.

KNX and also DMX systems are used for larger installations with more complex demands. Main areas of application include show stages, music clubs, theatre stages, museums and architectural lighting. DMX systems are the ideal partner to lighting using color and effects, with fluorescent lamps and LED deployed where control must happen in real time. DMX is capable of controlling up to 512 lighting channels simultaneously, with 250 kbit/s data rates. This allows excellent illumination of lighting settings demanding large numbers of RGB light pixels and fast, dynamic color change.

Wireless solutions also support the development of new lighting scenarios without major efforts of installation, especially in the consumer industry. Bluetooth and ZigBee are two well-known approaches here. Many major companies have formed alliances for the uniform development of the two standards in order to ensure the compatibility of their products. One fly in the ointment: for reasons of cost, the drivers for these products are generally based on analogue technology and are not the cheapest solution.

Because these lights were designed for mostly smaller control applications such as dimming or bus connections, microcontrollers remain the exception here.

The Future Belongs to Even More Intelligent Systems

Innovative circuit designs, with the digital control concept already in place, will force the introduction of “intelligence” in LED drivers. Companies will then be able to use protected firmware to protect their IP from competitors and also to react flexibly to customer demands. The implementation of these intelligent drivers is inevitable, especially in view of new “tunable white” solutions. The advantage of tunable white LED modules is that they, in combination with light management systems, may be set up or programmed to produce dynamic light management scenarios such as automatic brightness control or different color temperatures continuously variable between 3000 and 6500 K. This range is typically between 2700 and 6500 K for spotlights and between 3000 and 6000 K for area lighting. This is the basic prerequisite for contemporary and biologically effective solutions to lighting designed to reproduce natural light conditions in a room. Well-being and productivity benefit by lighting that is close to daylight, especially for persons spending many hours in artificial lighting.

Sustainability Based on Standardization

Apart from new technology, one of the main objectives of large and responsible manufacturers is to deploy manufacturing processes to optimally preserve resources. Standardized interfaces and components are important steps to more efficient production.

The I^2C bus used in automotive electronics demonstrates an approach to this. This is a synchronous two-wire bus with a wire each for data and clocking. It is an excellent solution to communication between ICs over short distances, developed in the early 80s by Philips. Transfer rates are between 100 kbit/s in standard mode and 3.4 Mbit/s in high-speed mode. Manufacturers of automotive ICs such as the American semiconductor manufacturer ISSI are using this system in their RGBW LED driver solutions. The I^2C bus would also be very suitable as a standardized interface, but unfortunately no adequately standardized modules exist yet. This repeatedly renders the use of microcontrollers for lighting control a challenge to manufacturers, since the processors must, in each case, be programmed to suit the customer.

Customer requirements are wide ranging and many LEDs recurrently need special nozzles to enable automatic SMD manufacture. The high quality standard cannot be guaranteed unless tools are matched to suit the individual LEDs. Unsuitable tools may damage primary optical components or their fastening means when these are sent for automatic placement. This may lead to loss of performance or even complete failure. Standardization is inevitable here. Not only would this allow gripping different LED types with the same tool, thereby minimizing set-up times, but production could also switch to alternative LED brands. Approval and use of different suppliers of the same light would clearly reduce the delivery times of modules or luminous sources and also the production costs. This would be a logical step. LEDs, after all, are increasingly becoming commodities, i.e. components such as resistors or diodes that are interchangeable between manufacturers. A few manufacturers of secondary optics have already implemented such standardizations. Some module manufacturers and luminaire manufacturers make already use of this advantage, such as VESTEL with the latest streetlights, which are using configurable optics by a Finnish manufacturer. This enables flexible responses, such as offering customers the light distribution pattern they need. Corresponding simulation data, which should accompany the light just like its datasheet, may also be compiled fast and effectively. Fully equipped laboratories with photogoniometers allow fast verification of the theoretically calculated results.

The same LEDs and optical families are also deployed for industrial lighting in halls (high bay), again reducing the variety of components.

Companies are implementing this on a small scale already and the important step of optimizing all processes should logically follow.

The comprehensive experience of a manufacturer is manifest in the production and development of LED products. Corresponding products are therefore 100 percent recyclable and free of Mercury, offering a long service life and the reduction of energy consumption by 80% compared to conventional lighting. Production sites must, to this end, be sure to deploy state of the art technology. Modern laboratories and quality standards are sine qua non. Therefore, laboratories need to be certified, for instance UL accredited like the Turkish Mega-factory in Manisa. Close cooperation with certification institutes of the different countries is a matter of course and also important in order to reduce the time-to-market. Experience gained in the production of, among other things, 50,000 TV sets with LED backlighting per day, is extremely useful since everyone is familiar with the concept of LED lighting.

Figure 3: These street lights and high bay lights are an example of the beginning of component standardization. The optics used can be easily re-configured due to the standardized format. As demonstrated here, they can be used for different applications with similar requirements

Figure 4: Besides the certified test labs, it is mandatory to have an efficiently organized and structured manufacturing environment with a solid and clear manufacturing process

Figure 5:
Experts agree that intelligent lighting modules like this Xicato XIM module that offers additional features and which can be integrated in the IoT will soon be an integral part of our technical lives

Networking in Many Ways

Increased networking in all spheres of our lives will also affect the way in which we illuminate our environment. The trailblazer was Philips; they equipped their TVs with "Ambilight" years ago. Rows of LEDs on the back of the TV will illuminate the wall behind to match the current TV image, creating an aura surrounding the screen.

A lot of suppliers are now also offering a complete lighting system, i.e. the Hue system, based on the ZigBee standard and controllable via an app. A bridge, connected to the router and functioning as the link between the lighting system and lights, is required for control. The system is controlled via an app on a smartphone or tablet PC.

Other manufacturers introduced Smart Bulb series comprising app-controlled LEDs, at the IFA 2014 in Berlin. Apart from the ZigBee version, a Bluetooth controlled series is also available.

These, however, are only the first and tender beginnings of "networked lighting". Our home controller will in future recognize that the TV is in operation and change to a lighting scenario more suitable for this purpose than for reading, for instance. Since the Internet of things will manifest itself here as well, various apparatus and applications will be interlinked and lighting will be highly customizable.

Added Value through Integration

Key players in the market for brown and white goods will have important functions in future. New and innovative solutions are in the offing already and Özcan Karadogan, MD of VESTEL Germany announced: "We will be incorporating LED lights in TV controllers in time for the next IFA. We will soon introduce the first TVs onto the market, which, in addition to normal remote control, will also include a tablet PC. The tablet will then come with an app to control the lighting in the room as well. Why should we need to get up if the lighting can also be controlled via a tablet?" This concept appears reasonable, considering that about 13 million TVs are leaving only this factory in Turkey each year, heading for the European market. This corresponds to more than 50,000 potential customers per day who require lighting control. The introduction of tablets as remote controllers takes integration of lighting control in home automation to a new level in everyday life.

Whatever the operation, customer satisfaction is the key to success and should be top priority. Newcomers are in a position to bring their new ideas to bear in the lighting market, even coming from other fields of business. Survival in this new business and its enormous potential, however, requires the development of a wide and steadily growing range of products.

Precisely this ongoing change and continuing development must lead to the introduction of standardized LED components and modern digital technology in order to ensure the required flexibility in the face of market demands. At the other side, lighting manufacturers nod not only to be fit in lighting technology, in this new era, they need to understand and implement new technologies for being competitive in this volatile market.

Waiting Will Not Pay

With technology developing at today's breakneck pace, it will certainly not be 100 years to the major breakthrough, as with the automobile. The first automobiles with laser light are on the road already today. For this task, laser light is more efficient than LED light and will probably also find its way into applications demanding high intensity illumination such as aircraft landing lights and possibly lighting of aprons or sport stadiums. Even the upper efficiency limit of 276 lm/W for LEDs is a thing of the past. Waiting will not pay – we do not have the time! In many aspects of our environment it is evident already that we should take better care of our resources - saving more energy and reducing CO_2 emission. Another aspect of this endeavor is moving our production facilities closer to the target markets - highly innovative manufacturers and premium industrial partners producing brown and white goods for Europe have for many years been minimizing transport costs and reducing the volumes of aircraft fuel and extremely toxic fuel oil for ships. These companies are prepared to invest millions and could also be reliable partners in Europe's lighting industry. ■

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Cover-page

Artwork: Thomas Klobassa, ©LED professional 2015

Main Image: Arno Grabher-Meyer, LED professional

Product: Xicato XIM Module

Xicato provided LED professional with one of the early engineering samples of the XIM module for testing and demonstration

Next LpR

Costs & Processes
Issue 48 - March/April 2015 - Short Overview

TECH-TALKS BREGENZ

Ewing Liu, Technical Marketing Manager at Evelight

Recently, Everlight introduced several new product lines and revised existing products with new features based on new technologies. Their motives for designing new products with these features, technologies and specifications as well as future trends were discussed in Bregenz. ■

TECHNOLOGIES

Solving the Phase-Cut Dimming Challenge

The evolution of dimmable LED lighting is an ongoing subject and phase-cut dimming is often dissatisfactory. While some weaknesses may be acceptable in residential applications, they are definitely not acceptable in professional applications. Stage lighting, studio lighting, TV and movie lighting set the highest standards. Which developments helped to overcome limiting obstacles and led to a solution that also satisfies stringent requirements will be discussed in this article. ■

RESEARCH

"Best Papers" at LpS 2014: Direct Current (DC) Supply Grids for LED-Lighting

Most electrical devices operate on direct current (DC) internally, but are supplied by alternating current (AC). A power supply with DC makes the rectifier electronics unnecessary, which, in turn, makes the devices simpler and more reliable and generates less power loss. LED-lamps can especially benefit from the reduction to a few reliable components. ■

SPECIAL

EnLight Project Results

The EnLight project partners recently announced that they have achieved their goals by improving the energy efficiency of the light sources and by improving the intelligence of the control system, providing the right light, in the right amount, at the right place, at the right time. The innovations cover:

- Decentralized intelligence
- Digital modular luminaire architecture
- DLT (Digital Loadside Transmission Lighting Protocol) for compatibility with existing installations

A bundled series of comprehensive articles will disclose details and technical guidelines for system architecture, advanced sensor and controls, the modular luminaire architecture, new possible form factors and light effects as well as application scenarios with demos and user validation. ■

subject to change

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