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LED professional Review

LpR

Trends & Technologies for Future Lighting Solutions

Mar/Apr 2016 | Issue 54

Research: Thin-Film Optics

Connected Lighting: PoE & BLE with iBeacons

Technology: RGBW Dimming

Tech-Talks BREGENZ: Karl Jónsson

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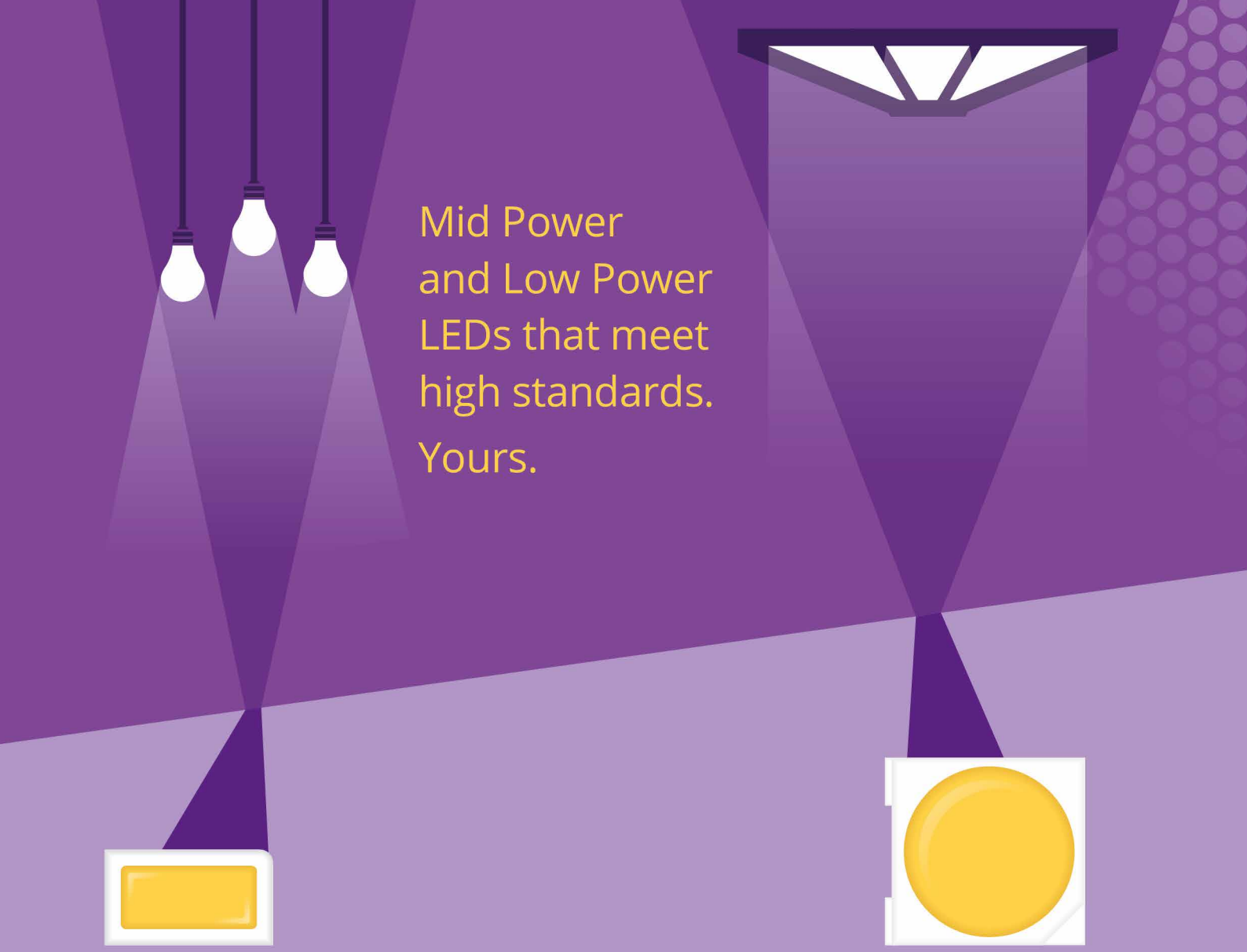

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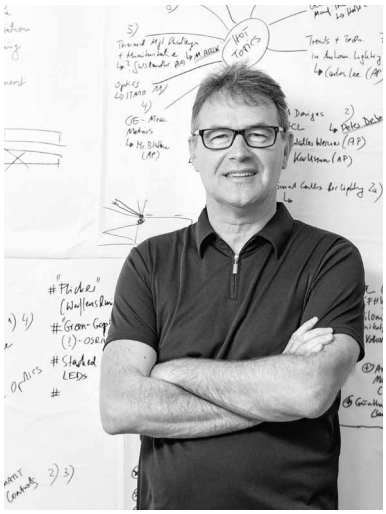

Systems & Applications

This issue of LED professional Review (LpR) is dedicated to Systems & Applications, because it's associated with the Light+Building in Frankfurt, the world's largest lighting exhibition covering new lighting systems and its applications.

Dee Denteneer, the newly elected secretary general from the Zhaga Consortium, covers the topic of smart lighting in his commentary. The newest Zhaga specification, which is still at the proposal stage, continues a trend towards interchangeability, and is directly related to smart lighting. It will enable interchangeability of sensing/ communication modules that are used to control LED luminaires for outdoor lighting applications.

Dr. Walter Werner has commented on the Light Flicker article in LpR 53. He refers to the Wilkins, Pawan and Lindner idea that there is more flicker than is visible to the eye and comes to conclusions that are worthy of more discussion and possibly research in this area.

The Tech Talk BREGENZ with Karl Jónsson touches on the world of IoT in lighting. Mr. Jónsson is an IoT system architect who points out how IoT and smart lighting could be a part of future lighting systems for things like remote monitoring, space management or Li-Fi controlled systems.

Another important technology for connectivity is Bluetooth 4.0. Saara Guastella from Casambi writes about Bluetooth Low Energy (BLE) technology and compares it to other established communication technologies for smart lighting. The fact that BLE is integrated into smart phones and tablets makes it a very cost-effective wireless technology.

Giovanna Frezza from Molex discusses Power over Ethernet (PoE) for commercial buildings. In the future PoE may allow for up to 95W of power to be transmitted. This would dramatically change lighting installation system architectures.

Further articles in this issue include "Safety Concept for LED Street Lighting", "Illuminating Education" and "The Value of Dark Skies".

The developments and creation of future lighting systems require an overview and understanding of the environment, the applications, the technologies and, last but not least, the needs of human beings. We are looking forward to what the Light + Building in Frankfurt will reveal this year.

The LED professional team would be happy to meet with you in Frankfurt to talk about future trends. We will be in Hall 4.1 at Booth B11.

Yours Sincerely,

Siegfried Luger
CEO, Luger Research e.U.
Publisher, LED professional
Event Director, LpS 2016

PS: Early Bird Tickets for the LpS 2016 are available until July 1st.
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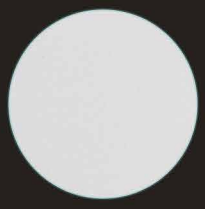

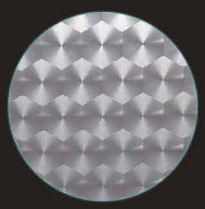

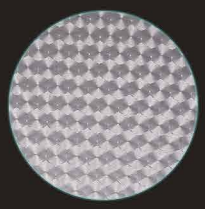

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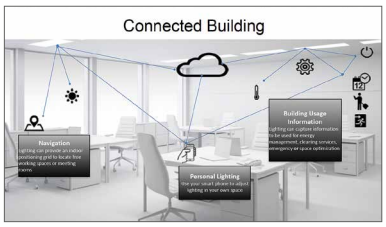

ADVERTISING INDEX

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Dee Denteneer

Dee Denteneer was elected as Secretary General of the Zhaga Consortium during the most recent gathering of the Zhaga General Assembly in Shanghai. Dee has held positions at the University of Utrecht, the Statistical Office of the Netherlands, and Philips Research. He has a PhD in mathematics, and a background in wireless connectivity, lighting, project and program management, and finance. Currently, he is Director of Standards at Philips Lighting, focussing on strategy and governance in industry alliances. Along side of his position in the Zhaga Consortium, Dee is a member of the executive team, treasurer and chair of the Finance Committee of the ZigBee Alliance; Technical Working Group Chair of the Fairhair Alliance; and non-executive member of the Board of the Philips Pension Fund.

ZHAGA MEETS SMART LIGHTING

At first glance, the standardization of LED lighting components seems to be quite remote from the rise of smart, connected lighting and the Internet of Things (IoT). But the projected growth in penetration of smart lighting can only be realized through developments in high-volume electronics and standardization. Such standardization is intended to remove arbitrary variations in components, making design and implementation easier for manufacturers of smart LED luminaires, and enabling a supplier ecosystem. This is where Zhaga comes in.

Zhaga is an open industry consortium that aims to simplify the design and manufacturing of LED luminaires and accelerate the adoption of LED lighting solutions. It does this by writing specifications for the interfaces between LED luminaires and different component types.

While Zhaga's early specifications focused on complete LED light engines, there has been a change of focus to enable independent interchangeability of LED modules and LED drivers.

Different module types are now covered by their own individual specifications. Examples are the new Zhaga Book 12 specification, which defines a family of six chip-on-board (COB) LED arrays, and the LED drivers, which are now specified in Zhaga Book 13.

The newest Zhaga specification, which is still at the proposal stage, continues this trend towards interchangeability, and is directly related to smart lighting. It will enable interchangeability of sensing/communication modules that are used to control LED luminaires for outdoor lighting applications.

In the outdoor lighting market, the industry is seeing a transition to LED-based light sources in parallel with a demand for smart lighting enabled by connectivity and control. This type of functionality can significantly improve the efficiency, maintenance and running costs of outdoor luminaires. For example, light levels can be controlled in response to input from motion and other sensors. Also, energy usage can be monitored, and operational problems can be detected and reported.

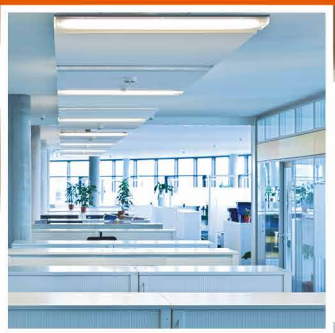
Typically, a smart luminaire will have a sensing and communication module on the exterior of the luminaire that can provide control inputs to the driver. The proposed Zhaga specification will define the interface between a sensor/connectivity module and the LED luminaire. Specifically, the module will fit into a receptacle on the luminaire, using a 4-pin connector. The Zhaga specification will define this connector interface but will not place any unnecessary restrictions on, for example, the design or functionality of the sensor/connectivity module itself.

A standardized connector interface enables interchangeability. This means that the luminaire maker is able to fit different sensor modules, from different suppliers, according to the needs of the customer. Or, the luminaire could be supplied with a sealed cap on top of the receptacle, allowing the sensor module to be added later. And, perhaps most significantly, the standardized interface will allow the module to be easily upgraded in the field, adding new intelligence and extending the useful life of the luminaire.

The new proposal aligns with Zhaga's central goal of simplifying the design and manufacturing of LED luminaires. The use of a standardized connector interface can reduce the design effort for the luminaire maker while enabling a broad choice of modules from different sources, according to the requirements of the application.

Going forward, Zhaga will continue to respond to requests from its members and the wider lighting community, and will investigate areas where component standardization is the smart option. ■

D.D.



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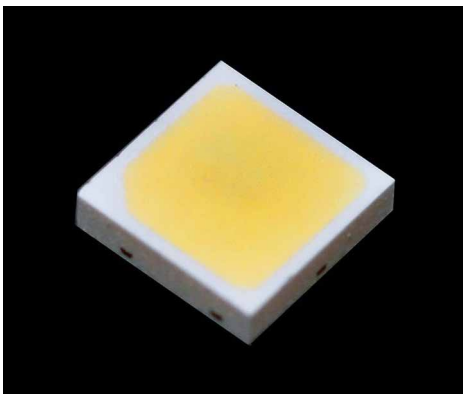
Toyoda Gosei Develops High Efficiency LED for Lighting

Toyoda Gosei has developed a new LED package for lighting that produces up to 200 lumens per watt (lm/W), while maintaining color fidelity. The LED package is designed for general lighting applications, such as bulbs, tubes, downlights, and ceiling lights. This new package gives our clients cost-effective alternatives to fluorescent and lower CRI (Color Rendering Index) LED products and can help reduce overall energy consumption.



Toyoda Gosei's new 3030 LEDs will be available in two versions, one high performance 200 lm/W version, and one more cost optimized 185 lm/W version

Product Summary:

Name	TG White 30 H	TG White 30 E
Package type	3030	3030
Size (mm)	3.0x3.0x0.65	3.0x3.0x0.65
No. of dice	2	1
Efficiency (5000 K, CRI 80+, If = 65 mA)	200 lm/W	185 lm/W
Start of sample shipments	March 2016	
Planned start of mass production	April 2016	
Use	Lighting	

The new package is a surface mount LED component that combines blue LED die with phosphors. Toyoda Gosei achieved this increase in efficiency, as compared to its prior LED package, through improvements to both die and package materials.
The package combines high efficiency, low thermal resistance to enhance the performance of the LED, and uses thermosetting plastics to provide high reliability while maintaining a superior gas barrier.

Samples of the 200 lm/W package have been available since March. Additionally, Toyoda Gosei will release a 185 lm/W package that is cost competitive. Further development of an even higher efficiency package is planned for the fall of 2016.

Lumileds Launches Gen 3 Luxeon CoB Core Range

Lumileds introduced its third generation of CoB arrays, the Luxeon Core Range (Gen 3), extending its market leadership in the CoB space with a breakthrough in efficacy.
With the Luxeon CoB Core Range (Gen 3), luminaire designers can enjoy 10% higher efficacy at constant flux compared to previous generations.

Achieving significant improvements in efficacy, the Luxeon Core Range (Gen 3) arrays provide the industry's best CoB performance with efficacy reaching more than 160 lm/W

All Luxeon CoB developments are engineered to produce the highest flux with the smallest light emitting surface (LES). "This performance upgrade is the result of significant improvements in both die development and our industry-leading phosphor solutions that give us industry leading performance," said Eric Senders, Product Line Director for the Luxeon CoB Family. The Gen 3 Luxeon CoB upgrade spans the company's full range of products from the smallest LES of 6.5 mm (Luxeon CoB 1202s), which delivers cost effective spotlights, to an LES of 23 mm (Luxeon CoB 1216), for efficient replacement of 100-150 W HIDs in indoor or outdoor applications.
The Luxeon CoB Core Range is offered over the widest range of color temperatures (2200 K to 5700 K) and CRIs (70, 80 or 90).

Lumileds also attributes its industry leading performance to its low thermal resistance substrate, which is up to 4X lower than other commercial products. The lowest thermal resistance enables smaller heat sinks and optics, delivering lower system cost. 100% of Luxeon CoB Core Range (Gen 3) arrays are hot tested at 85°C to ensure performance in real world operating conditions and to minimize additional testing.

For ease of upgrade, the Luxeon CoB Core Range (Gen 3) products are fully compatible with the Luxeon CoB Gen 1 and Gen 2 arrays. The company's ecosystem of compatible drivers, optics and holders help speed the time-to-market of all directional lamps.

LED Engin Doubles the Flux Density from tiny RGBW Emitters

LED Engin, Inc. has launched a new 4-die, high current, RGBW flat lens LED emitter that sets a new standard for best-in-class flux density in stage, entertainment and architectural lighting. The LZ4-04MDPB emitter delivers more than twice the light output of the company's previous version because each individually addressable green, blue and white die can be driven at up to 3 amps and the red die up to 2.5 amps from the same 2.15 x 2.15 mm light emitting surface as its predecessor. It produces everything from tungsten-effect white light to a full spectrum of brilliant colors in fixtures such as moving heads with zoom optics, directional effect lighting and wall washes.

LED Engin' s new LZ4-04MDPB emitters set a new standard for industry-leading performance narrow-beam stage and architectural lighting made twice as bright without increasing fixture size

The tiny emitter, which has a 7 x 7 mm footprint, rapidly and effectively dissipates up to 40 watts thanks to a thinner, 4-channel, multilayer ceramic substrate which cuts thermal resistance to just 0.9 °C/W.

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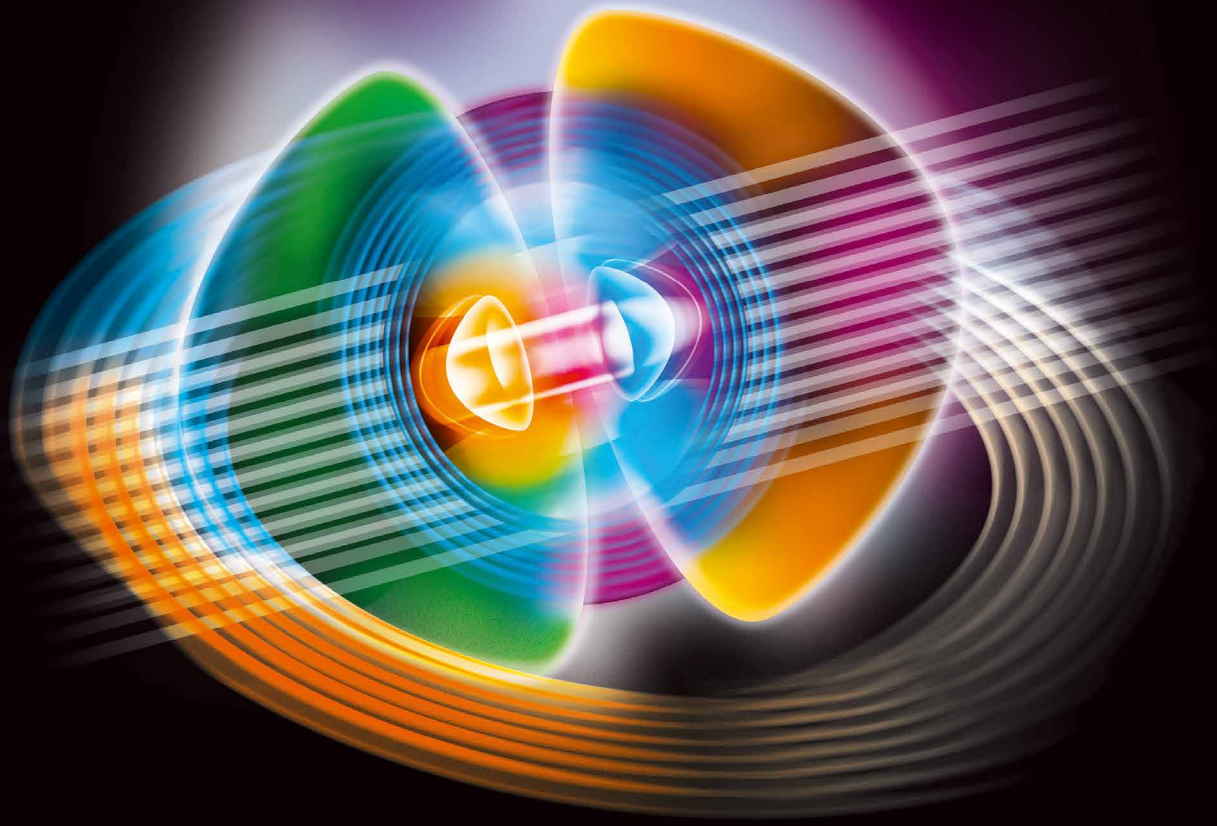

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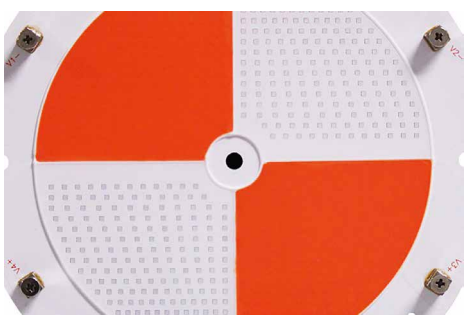
It has a lower profile substrate and thinner flat glass lens than the previous version. Secondary optics can therefore be positioned closer to the surface, maximizing coupling efficiency to deliver powerful, punchy illumination from fixtures with tightly controlled beam widths down to 4 degrees. Fixture designers can adopt the same secondary lenses and optical design used with existing LED Engin flat top RGBW emitters, providing the lenses are rated for the increased temperatures that result from higher power operation.

The breakthrough performance of the LZ4-04MDPB emitter has been achieved by developing a thinner, 4-channel, multilayer ceramic substrate. This facilitates better heat dissipation, allowing each die to be driven to a higher current without compromising reliability or operating life.

LED Engin CEO, David Tahmassebi, said, "Once again, we've advanced our proprietary technologies to deliver exactly what customers in these demanding lighting applications have asked us for: ever higher light output without increasing the emitter size. Most importantly, we've done so in a way that ensures sustained performance and long-term reliability." ■

Flip Chip Opto - Special Horticulture Flip Chip COB

Flip Chip Opto releases a first-in-class 2400 watt high powered horticultural flip chip COB. This COB is part of their new Duet series geared towards the grow light industry based on the company's 3-PAD Pillar Metal Core Printed Circuit Board technology. This technology allows a breakthrough in high powered horticultural flip chip LEDs, reducing junction temperatures to 0.003˚C/W on Duet 2400 at a max. power of 2433 watts.



Flip Chip Opto's Duet 2400 features 4 independent 608 watt illuminating sections

The Duet series represents Flip Chip Opto's horticultural solution to the Flip Chip COB market. Duet 2400 features 4 independent illuminating sections with customizable light spectrums; the standard product line will run a peak of 450 nm of royal blue, and 660 nm of broadband red. The two different light spectrums compliment the peak absorption rates of chlorophyll in most plant organisms. The Duet series also allows the substitution of other light spectrums for applications with plant organisms that do not absorb 450 nm or 660 nm spectrums.

Duet 2400 is unique due to its thermal properties; allowing designers to reduce the form factor of their cooling solutions while maximizing output. It is ideal for extreme applications such as greenhouses, commercial grow facilities, indoor farming, supplemental tree lighting, and other applications which require high powered, energy efficient LED grow lighting. ■

Samsung Mid-Power LED Series, LM561B+, for Superior Performance and CRI 90+

Samsung Electronics Co., Ltd., a world leader in advanced components, announced that LM561B+, the company's new mid-power LED package line-up with high light efficacy, is now offered with 3-step MacAdam ellipse bins and quarter bins across the range of all CCTs (from 2700 K to 6500 K), for use in premium luminaires. By leveraging the chromaticity control standard with the LM561B+, manufacturers will be able to make lighting products that deliver greater uniformity and consistency in light color without any visible difference in the color output between packages.

Samsung's new phosphor control technology leads to approximately 15 percent higher flux while providing CRI 90+ in their latest LM561 LED packages

"To date, we have achieved outstanding performance in all of our mid-power LED packages," said Jaewook Kwon, Vice President of Lighting Marketing Group, LED Business Team at Samsung Electronics. "By offering premium light quality to a greater number of customers with our LM561B+ LED packages, we are able to now provide superior performance on a much wider scale."

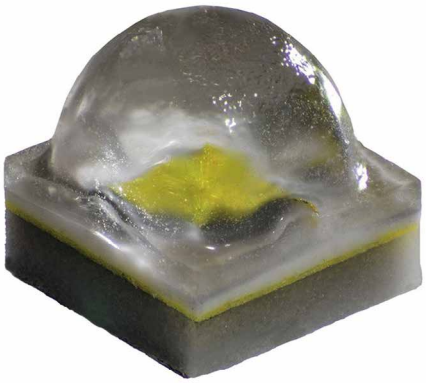
Since 2013, Samsung has been introducing high-performance mid-power LED packages such as the LM561 series for indoor lighting applications including LED Lamps, L-Tubes, ambient lighting and downlights. Its latest LM561 LED packages – the LM561B+ and LM561C – provide 190 lm/W and 200 lm/W of light efficacy respectively, an industry-leading performance level. Later this year, Samsung will also extend its offering of 3-step MacAdam ellipse bins and quarter bins for the LM561C across all CCT levels.

In addition, for its high color rendering LM561B+ packages with over 90 CRI, Samsung plans to apply advanced phosphor control technology, which will lead to approximately 15% higher flux performance.

Samsung is also strengthening its product certification program around the globe. Through cooperative relationships with recognized certification companies, Samsung is working to help minimize any difficulties that customers could encounter due to varying certification requirements for lighting quality, safety and power efficiency. The partnerships reduce the time to market and have a positive impact on overall costs. ■

Cree Expands XQ LED Family to Deliver Lower System Cost

Cree, Inc. expands its industry-leading portfolio of lighting-class LEDs with the addition of the XLamp® XQ-A LED to the XQ LED family. The compact, ceramic-based XQ-A enables lighting manufacturers to quickly and cost-effectively expand their product portfolios by leveraging an LED design that is similar to that of the proven and reliable XQ-E. With a broad range of color options and optical symmetry, the XQ-A LED is the smallest LED building block available for designs that use white and color LEDs.



According to Cree, the XQ-A LED is the smallest LED building block available for designs that use white and color LEDs

"Unlike mid-power color LEDs, the compact, ceramic-based XQ-A LED will allow us to put two, three or even four LEDs under our new silicone lens technology where we could only use one LED before. This generates more light for industrial applications without compromising lifetime," said Matt Pinter, co-founder and lead design engineer for Smart Vision Lights.

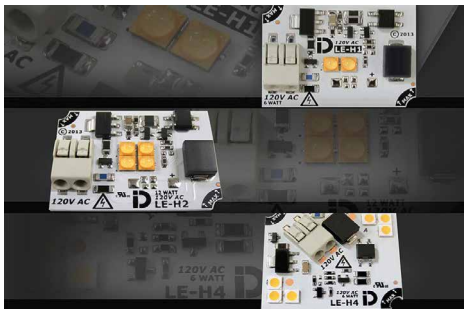
The ceramic XQ-A LED delivers lighting-class reliability, quality and long-life performance comparable to Cree's other ceramic high-power LEDs such as the high performing XP and XT. The new LEDs leverage the proven XQ platform to provide optical symmetry, consistency across all colors and tiny 1.6 mm footprint to improve color mixing and simplify the production process.

"The ceramic-based XQ-A LED family allows designers to offer high quality solutions that do not compromise lifetime or affordability," said Dave Emerson, Vice President and General Manager for Cree LEDs.

The XQ-A delivers up to 89 lumens and is characterized at 85°C. It is available in white color temperatures ranging from 2700 K to 6200 K and CRI options of 70, 80 and 90. The LED is also available in red, red-orange, PC amber, green, blue and royal blue. ■

Illumination Devices - LE-Hx Standard Line of LED Light Engines

Illumination Devices, innovator and manufacturer of high performance LED light engine technology, has announced the immediate availability of its new LE-Hx standard range of light engines. The LED technology is designed to facilitate lighting manufacturer's assembly for a wide range of applications.



Illumination Devices' new miniature series reduces system costs in a wide range of general lighting applications

The LE-Hx line is a series of three miniature AC light engines designed to reduce system costs in low-level light applications. They are available in various color temperatures, from 2200 K to 6500 K with a minimum 80 CRI, and are dimmable (Triac compatible).

Features:

- Direct AC connection - no external power supply required
- 2200 K to 6500 K CCT
- 80 CRI minimum
- Small size reduces fixture cost
- Triac compatible (dimming)
- On-board thermal management - prevents overheating
- Designed to meet Energy Star requirements for certification
- UL Recognized Component; File No. E362275
- Conformal coating available

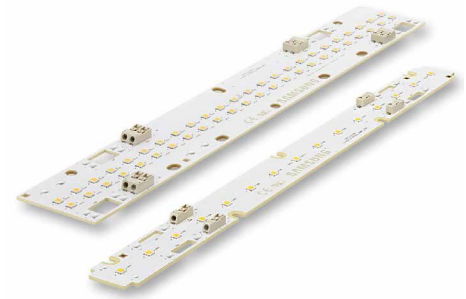
The new light engines are designed to integrate easily into new and existing fixtures in a wide range of general lighting applications. They feature embedded circuitry that provides optimum power to the LEDs while regulating the temperature to prevent over-heating and ensure long lifetimes. The light engines connect directly to the mains power (110-130 VAC), eliminating external drivers and reducing system costs.

"We have spent the last decade developing custom lighting solutions for many well-known lighting manufacturers. We have learned what works and have innovated to build solutions that solve the most common manufacturing challenges," said Josh Niebling, president of Illumination Devices. "Our new LE-Hx light engines are already proven in the field. With these light engines, our customers can benefit from years of focused research and development."

The new LE-Hx line of standard light engines is supported with a 5 year warranty.

Samsung Launches inFlux Linear LED Modules for High-flux Industrial Lighting

Samsung Electronics, a world leader in advanced components, introduced inFlux, a new lineup of high-flux (extremely bright), linear LED modules optimized for industrial lighting applications such as plants, parking lots and warehouses. The LED modules serve as a replacement for conventional T8 and T5HO (high output) tubes and are suitable for high-flux LED luminaires covering up to 40,000 lm (luminous flux*).



Samsung's inFlux Linear LED modules allow a replacement of FL tubes for luminaires covering up to 40,000 lm

"By providing a wide variety of installation layout options and brightness intensities, our new inFlux linear module will deliver greater design flexibility and convenience for lighting designers, as well as high performance and reliability for fixture manufacturers," said Jaewook Kwon, Vice President, Lighting Marketing Group, LED Business Team, Samsung Electronics. "We will continue to reinforce our well-differentiated LED lighting engine lineups to be able to meet more diverse market needs."

The inFlux LED module incorporates the company's mid-power LED package, which features advanced "flip chip" technology that enables a shorter junction-to-base distance and less thermal barrier layers in each package, while avoiding the need for metal wire bonding. This leads to a lower thermal resistance of the packages, and permits each package to handle a wide range of currents with improved light efficacy. Fully embracing the flip chip LED approach, the new inFlux modules can provide better light performance, wider current alternatives and much lower heat resistance than modules using a conventional epi-up chip package. High-efficacy mid-power packages bring additional benefits to customers, compared to using high-power packages. Mid-power packages can be placed more densely than high-power packages, which results in minimizing light deviation and increasing light uniformity of the inFlux module lineup. By utilizing a mid-power package, the inFlux lineup also brings cost benefits to manufacturers.

Samsung inFlux modules are available in six product types. Each type comes in a different flux range between 1,310 lm and 9,380 lm with a length option, either 280 mm

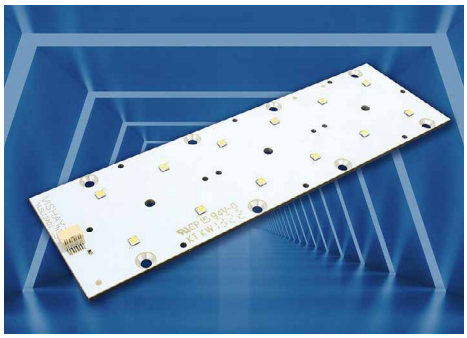
or 560 mm, and offers several CCT color variations, including 3000, 3500, 4000 and 5000 K. These product alternatives will offer lighting fixture makers more design flexibility in addressing a wide variety of application requirements. Through a combination of different module types, LED fixture manufacturers can vary their lamp flux from 6000lm to 40,000lm.

The Samsung inFlux modules have been UL/cUL certified (U.S.), as well as CE and ENEC certified (Europe), and carry a 10-year warranty.

Samsung also makes it easier for fixture makers to take their lighting products through industry certification processes, thanks to cooperative relationships that Samsung LED has established with recognized certification companies.

Vishay Intertechnology - New High-Brightness LED Module

Vishay Intertechnology, Inc. introduced a new metal-core-based cool white LED power module featuring 12 high-brightness LEDs with high luminous flux of 4000 lm each at 1 A. To simplify designs and manufacturing processes, the Vishay Semiconductors VLSL12A03-3Q3T-50A can be combined with off-the-shelf LEDiL quadruple lenses, while its integrated small thermal sensor (NTCS0603E347JHT) and fourfold plug-in connector (87438-0443) eliminate the need for additional soldering.



Compatible with LEDiL quadruple lenses, the device's integrated thermal sensor and fourfold plug-in connector eliminate the need for additional soldering. Vishay Intertechnology's High-Brightness LED module simpLi-Fies designs and the manufacturing processes

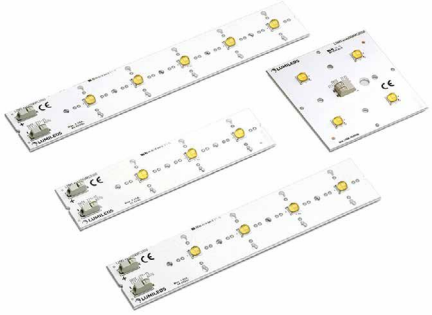
Optimized for illumination in internal building lighting, street lighting, tunnel lights, industrial lighting, and general lighting applications, the 12 LM80-certified LEDs of the VLSL12A03-3Q3T-50A are serially connected on an aluminum metal-core, single-side PCB measuring 161 by 50 by 2 mm and featuring a shiny white surface. To allow for a variety of emission patterns, this layout is compatible with LEDiL 2 x 2 STRADA and High Bay quadruple lenses.

Based on InGaN (indium gallium nitride) technology, the VLSL12A03-3Q3T-50A provides a maximum current of 1500 mA, color temperature from 4700 K to 5500 K, power dissipation of 55 W, and forward voltage from 33.6 V to 40.8 V at 1 A. The LED module offers an angle of half intensity of ± 60° and luminous flux binning. RoHS-compliant, halogen-free, and Vishay Green, the device provides ESD withstand voltage up to 2 kV in accordance with JESD22-A114-B.

Samples and production quantities of the VLSL12A03-3Q3T-50A are available now. Design engineers may request samples by sending an email to LED@vishay.com. Lead time for production quantities is six to eight weeks. Pricing for U.S. delivery is $22 per piece.

Lumileds Introduces LUXEON XR-M to Accelerate Outdoor Fixture Design

Designed specifically as a turnkey solution for outdoor LED fixtures, Lumileds introduces the LUXEON XR-M line of Matrix Platform solutions. These versatile building blocks integrate 3, 4 or 5 LUXEON M LEDs on a metal core PCB, providing a platform that enables fixture manufacturers to accelerate their design of streetlights, high bay and low bay luminaires.



Using the industry-leading LUXEON M, LUXEON XR-M can be combined with standard lenses, lens plates and easily-mounted drivers to provide the industry's simplest LED solution for streetlights and high/low bay fixtures yet

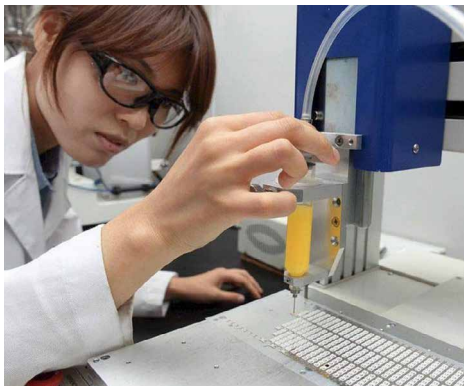
"LUXEON XR-M incorporates LUXEON M, one of our most efficient and top selling, high power LEDs. The boards can be connected in parallel or series for driver design flexibility, and the wide variety of lens options means designers have multiple turnkey options to release a full range of luminaires much faster to market," said Andrew Cohen, Product Manager of the Matrix Platform at Lumileds.

The LUXEON XR-M achieves excellent efficacy at the board level of 140 lm/W at 4000 K, 70 CRI, Tc = 85°C and 700 mA drive current. Using constant pitch between the LEDs and PCBs, combining multiple LUXEON XR-M modules achieves the most uniform, distributed light patterns.

Each LUXEON XR-M module provides 3,300 to 5,500 lumens and is available in color temperatures of 4000 K, 5000 K and 5700 K with a minimum CRI of 70. This new product is part of the Lumileds Matrix Platform of infinitely configurable LED boards, linear flex and modules featuring LUXEON LEDs. The Matrix Platform comes in both off-the-shelf and built-to-spec options, offering a virtually limitless range of solutions for any application.

Wacker Launches New High-Refractive-Index Silicones for LEDs

Wacker, the Munich-based chemical company, has developed new encapsulants for light emitting diodes (LED) and optical components. The compounds are made of highly transparent silicone elastomers with a high refractive index.



Wacker presents two new HRI silicones for encapsulating high-performance LEDs. The encapsulants stand out due to their high refractive index, excellent transparency and low gas permeability

The products withstand high operating temperatures and strong light radiation without yellowing. That makes them ideal for manufacturing LEDs with high light efficiency. They also protect the LED chip against corrosive gases, which greatly extends the component's service life. The silicone encapsulation compounds can be processed in industrial metering processes such as dispensing.

Lumisil® 590 and Lumisil® 591 are highly transparent, addition curing silicone elastomers with a refractive index of 1.53, which means they rank among the high-refractive-index (HRI) encapsulants. Such grades are particularly suitable for manufacturing highly efficient LEDs. The HRI silicone protects the sensitive LED chip against mechanical influences and corrosive gases. At the same time, the silicone's high refractive index enables optimum light efficiency.

Semiconductor chips used to generate light in LEDs have a high refractive index. To maximize the amount of light emitted by the LED chip that can pass through the encapsulation, the refractive index of the chip and encapsulant must be roughly the same value. Thanks to their refractive index of 1.53, Lumisil® 590 and Lumisil® 591 make LEDs highly efficient. What's more, the highly transparent silicones are almost completely transparent for light in the visible spectral range (approx. 400 to 700 nm) and do not yellow even when radiation is extremely intense. Transmission tests with Lumisil® 590 show that a one-millimeter-thick layer lets over 91% of visible light through.

Lumisil® 590 and Lumisil® 591 protect the LED chip reliably against environmental influences. Corrosive gases such as hydrogen sulfide can damage the LED chip and reduce its performance. Tests show that LED chips encapsulated with Lumisil® 590/591 are protected against such damage longer and have a prolonged service life.

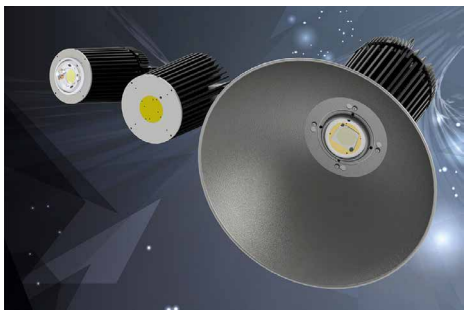
The new HRI silicones are easy to process, heat-resistant and absolutely tack-free after curing. They also exhibit optimized flow and crosslinking characteristics. With a viscosity of the mix of 2,000 and 2,500 mPa*s respectively, they enable efficient, cost-effective processing. Both products are suitable for encapsulating the LED chip via contact-free dispensing processes. Lumisil® 590 and Lumisil® 591 form cured rubber grades of varying hardness. With a hardness of Shore A 65, Lumisil® 590 is relatively soft, whereas Lumisil® 591 is formulated to be significantly harder at Shore D 40.

Lumisil®:
The Lumisil® product line comprises optical high-performance silicones with high photostability that offer cost-effective production for LED manufacturers with high requirements. They protect the LED chip reliably against environmental influences and thereby extend its service life.

Wacker offers highly transparent silicones for applications with a high (HRI) and normal (NRI) refractive index. For NRI applications, Wacker offers a wide range of products with easy workability in conventional processes such as encapsulation, mold-making and injection molding. ■

MechaTronix Launches Patented High Bay Coolers Up To 35,000 lm

While LED manufacturers are bringing more and more high power COBs to the market like Lumileds COB 1216, Citizen's CLU550, Cree's CXB3590 and Bridgelux's Vero 29, MechaTronix announces their new CoolBay® high bay cooler program. The CoolBay® is a passive round cooler based on the patented CoolTube® quadruple closed-loop heat pipe structure, which makes it the most compact design on the market cooling down with approx. 35,000 lumen.



Two CoolBay® platforms are available for up to 22,000 lm and 35,000 lm respectively

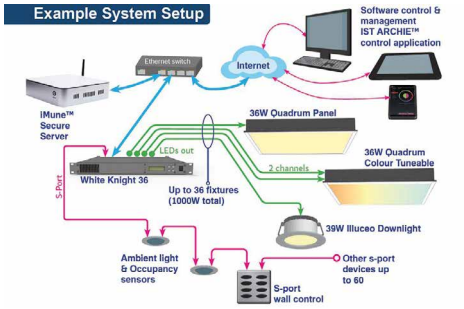
The CoolBay® comes in 2 power platforms, The CoolBay® Giga up to 22,000 lumen in a diameter of 152 mm and the CoolBay® Tera up to 35,000 lumen in a diameter of 192 mm. These sizes are specifically chosen to match the design with the diameter of the round high bay coolers from Mean Well, the HBG series.

The extreme high conductivity of the CoolTube® in the center of the cooler transports away the heat loss from high power density COB LED engines and is designed in this way, so that it can be used in any orientation, which, in addition to high bay developments, use the cooler for industrial lighting applications like high power flood lights or high mast lights.

With this new platform MechaTronix went further than keeping the LED dies at the correct temperature. In many high bay designs the lifetime of the LED array might be thermally well designed, but the drivers used in these applications are mostly integrated on top of the cooler in an IP67 box, what causes that the electrolytical capacitors of the driver experience an ambient temperature between 50°C and 60°C. The CoolBay® comes with specific mounting options so that the driver sits remote from the led cooler, what easily drops the driver temperature with 10 degrees. ■

IST's iDrive® is Leading the Li-Fi Revolution

The iDrive R&D team have developed a VLC technology platform to facilitate the mass adoption of Li-Fi, which will be available to all developers and end-users. Li-Fi or Visible Light Communication (VLC) is an enabling technology providing a means of transmitting information using LED light fixtures by modulating their light at a frequency too high to be perceptible to the human eye. The advent of Li-Fi and VLC is hugely exciting because of the high data transfer rates that can be achieved and the fact that LED lighting is a huge growth market.



The new hybrid Li-Fi enabled LED driver output stages will introduced to the entire iDrive® product range that allows setups like this one

Although Li-Fi solutions have recently been trailed by a couple of the world's largest lighting companies, the systems are based around proprietary technologies, which are closed to a wide community of developers and end-users and are prohibitively expensive, thus reducing their attractiveness and scalability.

The iDrive® team set out to resolve the issues holding back Li-Fi from being totally ubiquitous by taking a three-stage approach:

- Help create an open standard control protocol that can be used by the industry to send information within a VLC or Li-Fi system
- Build a low-cost Li-Fi enabled LED driver platform to ease deployment and reduce R&D expenditure for companies wishing to deploy Li-Fi solutions
- Create an innovative licensing support programme to take advantage of IST's granted worldwide patents

The first objective was to create an open, worldwide standard control protocol that could be universally adopted, so partnering with Wayne Howell, Art-Net inventor and Artistic Licence CEO, was an obvious choice. Art-Net is one of the most ubiquitous ethernet-based lighting control protocols adopted today, which enables transmission of DMX512 data in an open manner.

The teams at Artistic Licence and iDrive® have worked together to devise a standard method of controlling Li-Fi via Art-Net and DMX512 (the newer sACN standard is also supported). Within the Art-Net specification, there is now a packet identified as ArtVLC, which can be used for both Art-Net and DMX512.

Secondly, the iDrive® team needed to finalise the design of its new LED output driver stage to allow integration of Li-Fi and ensure compatibility with the new ArtVLC standard. The iDrive® team have, with the help of a UK Government Knowledge Transfer Partnership (KTP) research programme, developed a low-cost Li-Fi output stage with a team from the University of Wolverhampton, which extends the hybrid driver technology developed and patented by IST back in 2010.

The latest iteration of the hybrid output stage offers a breakthrough in price and performance, with features such as:

- Increased reliability of LED drivers by employing long-life, high temperature ceramic capacitors instead of the degradation issues commonly associated with the use of the electrolytic capacitors found in most LED drivers
- Meets all healthy lighting requirements through the patented adoption of high frequency anti-flicker technology, even when lights are dimmed to levels of 1%
- Removal of digital "flicker" during dimming at low levels, which is caused by poor dimming resolution of incumbent LED driver output stages
- Includes advanced algorithms to allow LED driver dimming to mimic traditional light sources, such as halogen and incandescents, to improve ambient lighting
- Overcomes intellectual property issues with traditional pulsed dimming modulation
- The ability to choose the most appropriate dimming modulation scheme for the application
- Over 98% output driver stage efficiency to increase lifetime and reduce the size of high power driver topologies
- Enables a variety of cost effective Li-Fi solutions for smart data with parameters defined by the ArtVLC standard
- Removes the chance of LED fixture damage when hot-plugged
- Super smooth time-independent dimming (from seconds to days) with software selectable forward currents of 1600 mA down to 20 uA (or a seep dimming ratio of over 81920:1)

At lower Li-Fi speeds (defined as being between 1 kHz to 50 KHz), Li-Fi has the huge advantage of being compatible with existing technology infrastructures. For example, the LED display lighting in a museum could transmit text information or video URLs about the exhibits to visitors' smart devices. Customers in a large retail store could opt to share their phones' GPS location with VLC-enabled lighting to better navigate the aisles or find special offers. All of these applications can be enabled with very little cost and the simple development of apps that use sensing technology within mobile phones or tablets, thus opening up the technology to new markets.

The new Hybrid Li-Fi enabled LED driver output stages will be introduced to the entire iDrive® product range in fall 2016.

Finally, the iDrive® team have created a flexible approach to licensing the new output stage technology, with cost competitive frameworks to encourage all companies that do not have the same R&D expertise to accelerate their Li-Fi application offerings to market.

Commenting on IST's latest development, Dr. Nina Archenhold explained, "We have worked on many iDrive® technologies over the last 17 years and the technology platform we are announcing is a culmination of all these research efforts. The latest hybrid LED technology was designed to disrupt the LED driver market and address all end-user concerns, from lifetime to dimming capabilities, and obviously create a driver that is fit for the Internet of Things (IoT)."

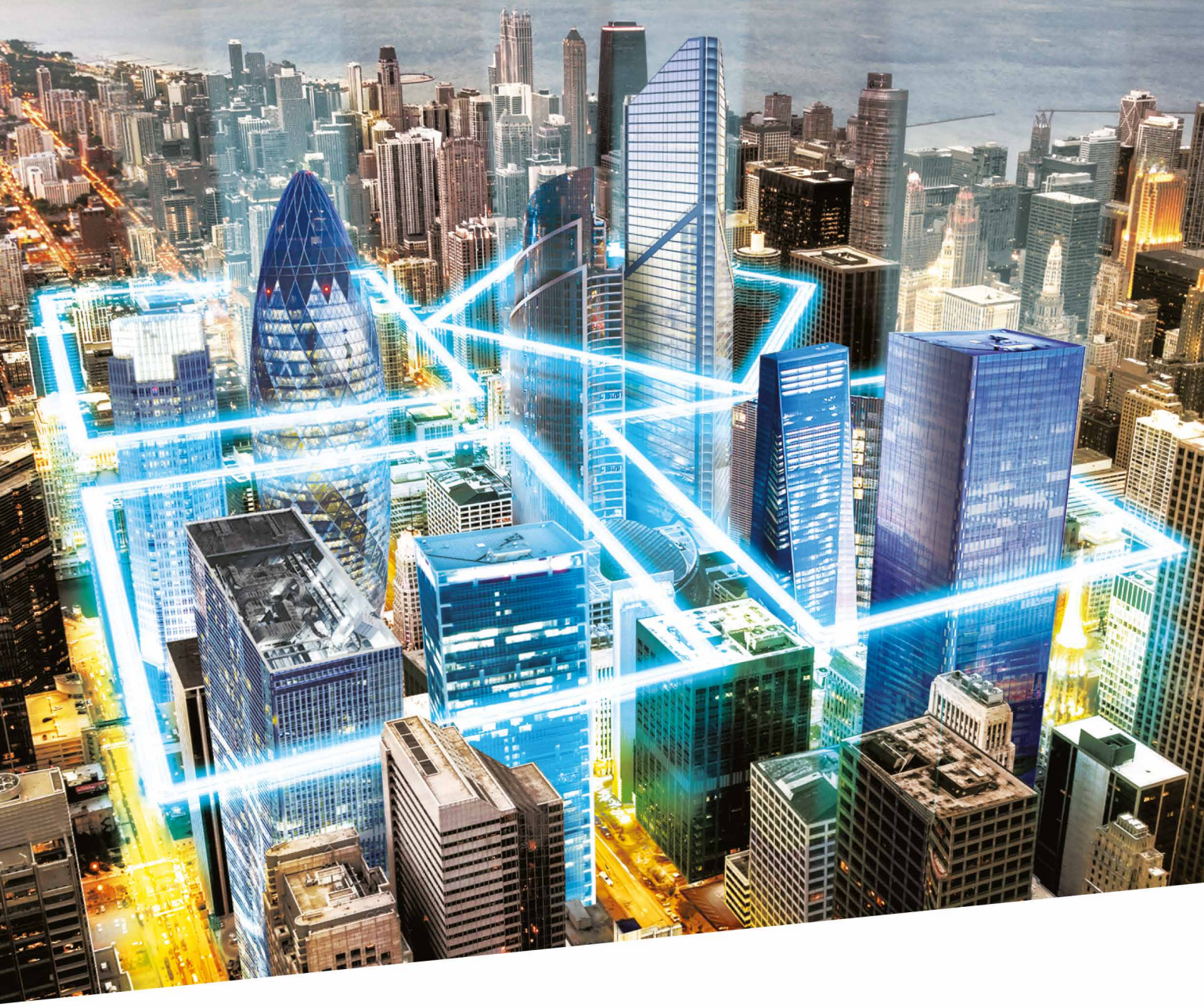
Through support from the UK Government and the University of Wolverhampton Engineering department, the latest iteration of IST's hybrid driver stages represents a paradigm shift for the industry by creating the world's first software-defined LED driver stage, configurable in real-time to allow different LED dimming and Li-Fi modulation schemes. Dr. Archenhold added, "Li-Fi is a huge opportunity in smart lighting but we wanted to make sure Li-Fi wasn't restricted to just large businesses, but available to anyone that has a great idea for a Li-Fi service."

Dr Archenhold stated further that, "The technical team have spent several years developing a cost effective Li-Fi solution which is to be launched at 'The Next Step' lighting show in Japan in March 2016, with our Japanese partners providing a demonstration of the unique driver solutions. I firmly believe this platform will become one of the most popular platforms to deploy Li-Fi solutions because it meets all the commercial, technical and user requirements."

Lighting & Beyond

Smart, Connected Illumination

Taking you beyond conventional lighting with innovative,
highly reliable Samsung LED components



Visit us at light+building 2016 (Booth B04, Hall 6.2) to experience
Samsung's advanced LED technologies and products.

B04, Hall 6.2 | Messe Frankfurt, Frankfurt, Germany | 9am - 6pm, March 13th - 17th / 9am - 5pm, March 18th

SAMSUNG

Tridonic TALEXXdriver PREMIUM OTD with High Overvoltage Protection

LED street lights and outdoor lights can be professionally dimmed with voltage-resistant TALEXXdrivers in the PREMIUM OTD series from Tridonic. These drivers for luminaire installation offer impressive surge/burst resistance of 10 kV and are extremely durable with a life of 100,000 hours.

Robustness and high 10 kV surge/burst resistance are the significant properties for Tridonic's new outdoor TALEXXdriver series

TALEXXdriver Types:

- LCA 30W 250–700 mA one4all C PRE OTD
- LCA 60 W 350-1050 mA one4all C PRE OTD
- LCA 75 W 250-750 mA one4all C PRE OTD
- LCA 120 W 350-1050 mA one4all C PRE OTD
- LCA 160 W 350-1050 mA one4all C PRE OTD

Tridonic has extended its outdoor portfolio with the addition of the TALEXXdriver PREMIUM OTD series for professional dimmable LED lighting solutions in luminaires of protection classes I and II. The drivers are housed in a fully encapsulated enclosure and are particularly suitable for use in harsh ambient conditions outdoors, providing reliable, flexible and cost-effective lighting with a high level of efficiency. There are five different versions with different outputs and variable output currents.

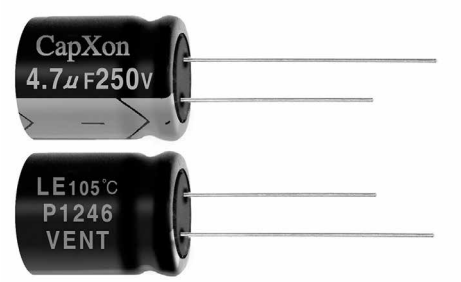
All the versions are equipped with one4all (DALI DT6, DSI, corridorFUNCTION) and ready2mains™/U6Me2 (chronoSTEP 2) interfaces. The drivers therefore have the flexibility to meet different lighting requirements. Luminaires can be easily configured via the power cable with the aid of the ready2mains programmer so there is no need for an additional communications interface. During production the ready2mains enables output currents to be set and tested, and dimming commands to be defined. Integration in automated test processes is also possible.

Outdoors, ready2mains can be used to program individual LED street lights, or entire street runs can be programmed from the switching cabinet via the U6Me2 communication protocol with a high degree of flexibility. The chronoSTEP 2 function, which is also known as virtual midnight, offers additional energy savings. It takes into account reduced traffic on the streets at certain times during the night and enables the lighting to be programmed in eight individual dimming levels and times.

In accordance with their intended use outdoors, the drivers operate reliably in an extended temperature range from -40 to +70°C. Standby mode is particularly economical with a power draw of less than 0.16 W.

CapXon's LE Series of Electrolytic Capacitors Provide Ultra-Long Life

CapXon introduces the LE series of electrolytic capacitors providing high reliability and ultra-long life in LED lighting applications. Available in the UK from Components Bureau, the products operate over an extended temperature range of -40 to +105˚C making them suitable for LED drivers powering outdoor lighting applications. This series offers a longer life alternative to the FL series used in electronic lighting ballasts and energy-saving luminaires.

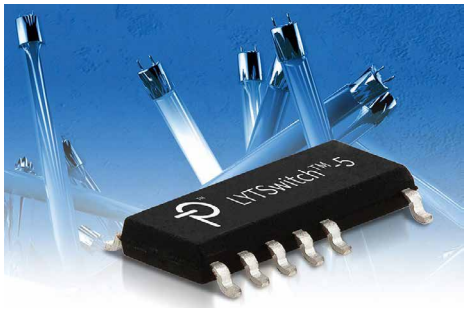


CapXon's LE Series of electrolytic capacitors is specified at 105˚C ambient temperature

At 105˚C ambient temperatures, the capacitors have lifetimes of 12,000 hours for 6.3 x 11 mm, 8 x 9 mm and 10 x 9 mm case sizes, 15,000 hours for 8 x 11.5 mm and 10 x 12.5 mm and 20,000 hours for case sizes 10 x 16 mm or larger. The radial mount series is available in industry standard capacitance values ranging from 1 to 68 µF, with rated voltages of 160 V, 200 V, 250 V, 400 V and 450 V DC. Ripple current ratings of up to 1300 mA (rms at 105˚C at 100 KHz) are available, and maximum low temperature impedance ratios range from 8 to 12 depending upon the capacitor voltage rating. ■

PI's New LYTSwitch-5 ICs Support Multiple LED Driver Topologies

Power Integrations, the leader in high-efficiency, high-reliability LED driver ICs, announced its LYTSwitch™-5 single-stage LED driver IC family. LYTSwitch-5 devices combine PFC and constant-current output, and support multiple LED driver topologies.



Power Integrations' flexible LYTSwitch-5 platform delivers high PF, low THD and highly accurate constant-current regulation

Solid-state lighting applications have highly variable driver requirements, and power engineers are often challenged to develop optimized designs quickly in response to requests from lighting designers. The LYTSwitch-5 family supports the safety-rated isolated flyback topology for ballast applications, and non-isolated topologies such as buck and buck-boost for low-cost lamps and bulbs. Additionally, a choice of low-side or high-side switching enables designers to optimize for low EMI or for reduced inductor complexity. By achieving over 90% efficiency, 0.9 PF,

less than 5% THD and +/-3% current regulation accuracy over line, load, production variance, temperature and multiple topologies, LYTSwitch-5 is the best LED driver for solid-state lighting applications below 25 W.

The high efficiency of LYTSwitch-5 LED driver designs results in smaller heatsinks, more compact implementations and increased lifetime. Highly accurate CC regulation reduces the degree of overdesign required to guarantee compliance to lumen output standards from regulatory bodies such as the California Energy Commission (CEC) and ENERGY STAR®. 650 V and 725 V MOSFET options are available to optimize surge-withstand performance for a variety of product types and geographical installations.

Hubertus Notohamiprodjo, Product Marketing Director at Power Integrations said, “LYTSwitch-5 ICs suit multiple applications including tubes, down-lights, high- and low-bay ballasts. The simple designs and low component count enabled by these new ICs result in compact, reliable, high-performance driver circuits and a platform-based design approach with increased manufacturing throughput.”

LYTSwitch-5 LED driver ICs offer up to 25 W, an extended universal input range and wide output voltage range (2:1). Protection features include thermal foldback with end-stop shutdown, short-circuit protection, input and output OVP, overcurrent protection and safe brown-in and brown-out. ■

Thomas Research Products Introduces New Lower Cost FSP3 Surge Protectors

Thomas Research Products has introduced a lower cost version of its premium FSP3 series Surge Protectors. These devices protect LED luminaires from damaging power line disturbances. Thomas Research Products manufactures complete SSL power and control solutions for OEMs.

The FSP3-NI series includes in-line fusing to shut down the luminaire when the capabilities of the surge protector have been exceeded. This not only protects the LED luminaire, it also demonstrates that the unit needs to be replaced. These models achieve a lower price point by eliminating the LED indicator included on regular FSP3 models.

TRP's new NI models are available for both 277 V and 480 V circuits

TRP's new NI models are available for both 277 V and 480 V circuits. The patent-pending FSP3 series is UL1449 Recognized and CE certified.

TRP's popular Surge Protectors provide an extra level protection for LED luminaires from dangerous power line transients in commercial applications. Avoid costly problems in 24/7 outdoor applications, including street lighting, big-box retail, warehouses, parking garages, and transportation facilities. ■

Tridonic Introduces ready2mains™ Programmer for Configuration Via Mains

With the ready2mains™ programmer, information such as configuration parameters can be quickly transmitted via the mains cabling to the LED drivers of indoor and outdoor luminaires. There is no need for an additional communications interface or any rewiring. Commands are transferred in digital format – simply via phase control.

The ready2mains™ Programmer also supports DALI and U6Me2

The ready2mains programmer enables luminaires to be configured, controlled and dimmed via the mains. All that is required is a ready2mains interface in the relevant driver. The programmer uses simple phase control for digital command transmission. Configuration commands are transmitted in this way, such as the required output current of the LED Driver or a virtual midnight function for LED street lights. The current can be configured in 1 mA steps to achieve the precise illuminance needed. Up to five drivers (maximum of 400 W) can be configured in parallel. ready2mains technology supports dimmable devices in the Premium and Premium Outdoor TALEXXdriver series and also switchable devices in the Excite series.

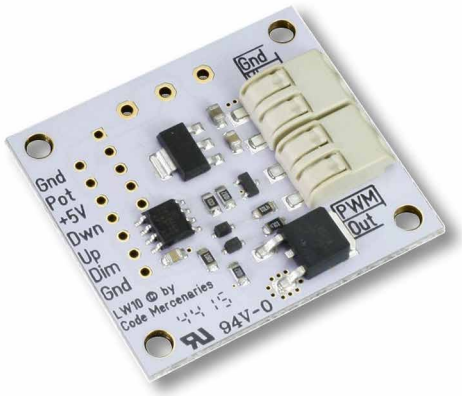
Luminaire manufacturers can benefit from using the programmer at the production stage because automated configuration of the luminaires via the mains will save time and costs. User-defined configuration scripts reduce the risk of errors considerably compared with manual entry.
With ready2mains it is possible to incorporate programming functionality in existing production lines with a high degree of flexibility. And for simple integration in automated test procedures there is a USB interface with appropriate software drivers.

The ready2mains programmer works with different protocols – in addition to ready2mains, it will work with DALI and with the proprietary U6Me2 for the outdoor sector. If required, manual programming via the integrated keypad is also possible.

Additional energy savings can be achieved for outdoor and street lighting by dimming the lighting at quiet times during the night. The chronoSTEP2 function is used to record the times when the appropriate lighting installation is switched on and off on three consecutive days – in most cases these are the sunrise and sunset times. The average of these two reference points is then the virtual midnight, which is then used as the reference point for reducing the lighting level. Eight different lighting profiles with different times and brightnesses provide the flexibility for adapting to different local circumstances. In addition to five predefined lighting profiles there are three configurable profiles available which can be freely programmed via the proprietary U6Me2 protocol. Individual street lights can be controlled, or entire street runs from the switching cabinet. ■

Code Mercenaries - LED-Warrior10 PWM LED Dimmer

LED-Warrior10 allows to control the LED brightness by a potentiometer, or one or two buttons. The high PWM frequency of 730 Hz guarantees a flicker-free operation. For button control, a power-on value and minimum value may be set.



Code Mercenaries' LED-Warrior10 is available as chip or module, for single or dual push button control or potentiometer control

Technical Specification:

- PWM dimmer for LED
- Dimming control by single or dual button or by potentiometer
- Power-on brightness programmable
- Minimum brightness programmable
- Logarithmic curve for optimal dimming
- PWM output at 730 Hz
- PWM dimming from 0.1% to 100%
- PWM power output up to 4 A
- Available as module or DIL8/SOIC8 chip

Available as chip or module

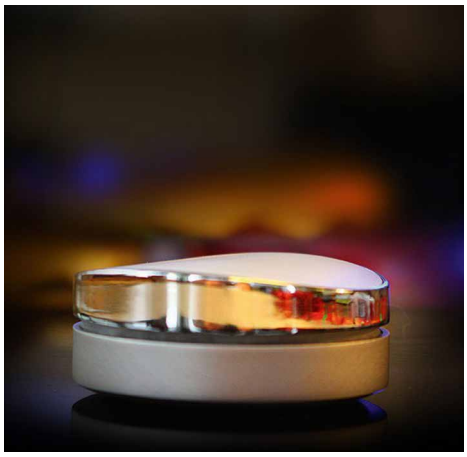
LED-Warrior10 is available as DIL8 or SOIC8 chip or as a ready-to-use module. The module (LW10-01MOD) can control LED drivers which have a PWM input or it can directly supply constant voltage LEDs with up to 4 A. LED strips, lamps, or modules working with a constant voltage in the range of 5.5 V to 40 V can be directly driven. A potentiometer may be soldered direct into the module.

AwoX SmartPEBBLE - Gesture Commands to Control Lighting

AwoX, a pure-player in connected objects and technology dedicated to Smart Homes, has expanded its ecosystem dedicated to intelligent lighting with the SmartPEBBLE: a revolutionary, wireless light switch based on intuitive hand gesture technology designed to control connected light bulbs without the use of a smartphone. Shake it to change from white light to color. Flip it to put lighting into sleep mode. Turn it to lighten or dim brightness of light. Discover our award winning innovation for the Smart Home category.

Designed by AwoX's teams of engineers in France, the SmartPEBBLE introduces a real innovation in the way to control lighting at home. It comes in two parts: a switch in the form of a pebble and a wall plate.

The choice is yours: either leave the pebble on its wall plate, or carry it with you (battery operated) throughout your home.
The SmartPEBBLE fits naturally into your hand, and its use is intuitive. It's a new way of controlling light at home that is both easy and fun.



AwoX's SmartPEBBLE comes with a simple CR2450 battery for 1 to 2 years of autonomous battery life

Among some of the possible commands with SmartPEBBLE:

- Turn light bulbs off and on with a simple click
- Turn the SmartPEBBLE to adjust brightness
- Shake it to change from white lighting to brightly-colored mood lighting
- Adjust the intensity of white or the shade of color by simply moving the pebble from left to right
- Flip it to activate sleep mode (progressively turn lighting off and on)
- Double click to change to different groups of light bulbs

With its elegant and discreet design, the SmartPEBBLE can blend into any decor wherever you need a light switch, and without the fuss of electrical wiring thanks to BLE (Bluetooth Low Energy).

Installation is done in seconds: leave it on your fridge with its fitted magnet, stick it to the wall with the sticker included with the wall plate, or simply screw it to the wall.

Product activation cannot be simpler: plug in all the products you wish to control from our range of connected objects shown below, and turn off other electronics. Then simply remove the plastic battery tab located at the back of the SmartPEBBLE; the light bulbs automatically connect to the switch.

This new generation light switch is completely independent. There is no need for a smartphone or a WiFi bridge.

The SmartPEBBLE controls the entire AwoX ecosystem and makes it possible to create 2 groups of up to 8 light bulbs for simultaneous control of different products and instantly changes mood lighting. The SmartPEBBLE allows for customizable mood lighting.

Using the latest technology in accelerometers and gyroscopes, AwoX's expertise in hardware and software integration resulted in a product with a natural user experience, both fluid and precise. The SmartPEBBLE gesture control is completely customizable through the SmartCONTROL application. ■

TRP Releases New Wireless Control Modules for LED Drivers

Thomas Research Products has introduced a series of new Wireless Lighting Control Modules designed for OEMs. Both ZigBee and RF models are available for controlling LED Drivers. Thomas Research Products manufactures complete SSL power and control solutions for OEMs.

TRP's TCM models are available as ZigBee HA and standard RF model versions

The TCM series of control modules are designed for use with LED luminaires powered by TRP's LED drivers. These devices provide wireless ON/OFF with full 0-10 V dimming control using standard protocols. These modules also store the last dim setting when powered off. They are designed to operate fixtures on 100-277 V circuits.

Two TCM models are available. The ZigBee model is ZigBee HA certified for use with input devices that utilize that standard.
The RF model has an available RF cordless remote accessory for directly controlling on/off switching and dimming of up to 4 groups of TCM controls. The small case design is easily mounted in most luminaires.

TRP's new controls provide simple OEM options for energy saving requirements and user comfort. "Easy installation" means these modules don not require running new wires or relay panels to configure. By utilizing open standards, these controls give lighting manufacturers freedom from being bound to a proprietary system. ■

LedLink
Linking LEDs to The Real World

Ledlink Optics, Inc.

NEW PRODUCT

Commercial Lighting

Convex Lens

LL12ZZ-CRC90L19
DxWxH(mm) 50x50x3.8
FWHM 90°
Lumileds Luxeon 3030
Nichia 757D

Multi Lens

LL12ZZ-CRC25L19
DxWxH(mm) 50x50x6.3
FWHM 25°
Lumileds Luxeon 3030
Nichia 757D

LL12ZZ-CRC55L19
DxWxH(mm) 50x50x6.3
FWHM 55°
Lumileds Luxeon 3030
Nichia 757D

Street Lighting

LL12ZZ-CRC45155L19 (type II-M)
DxWxH(mm) 50x50x5.3
FWHM 45x155°
Lumileds Luxeon 3030
Nichia 757D

LL12ZZ-CRC45145L19 (type II-S)
DxWxH(mm) 50x50x5.3
FWHM 45x145°
Lumileds Luxeon 3030
Nichia 757D

LL12ZZ-CRC60155L19 (type III-M)
DxWxH(mm) 50x50x5.3
FWHM 60x155°
Lumileds Luxeon 3030
Nichia 757D

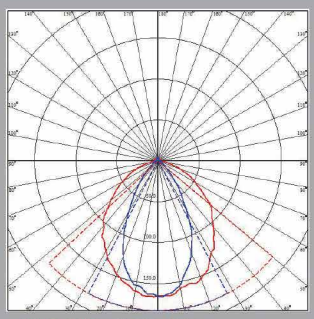
LL12ZZ-CRC60145L19 (type III-S)
DxWxH(mm) 50x50x5.3
FWHM 60x145°
Lumileds Luxeon 3030
Nichia 757D

Indoor Lighting

(Developing)

Linear Lens

DxWxH(mm) 286x32.4x6.7
FWHM 60° 90°
Seoul 5630 LG 5630
Nichia 757D



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Lens Application

Cree Lab Announces Outstanding R&D LED Efficacy Combined with Superior Color Quality

Cree, Inc. records another LED industry first with the demonstration of a single high-power LED delivering nearly 1,600 lumens at 134 lumens-per-watt (LPW) with similar color quality as an incandescent light bulb. With this result, Cree achieved a breakthrough 25% increase in lumens per watt over production LEDs of similar color quality under operating conditions found in real-world LED lighting applications.
This important milestone coupled with Cree's latest SC5 Technology™ platform will lead to LED systems with increased performance, lower cost and better light.

A CCT of 2700 K with a CRI of 90+ and also an R9 of 90+ are important properties to guarantee incandescent-like illumination quality

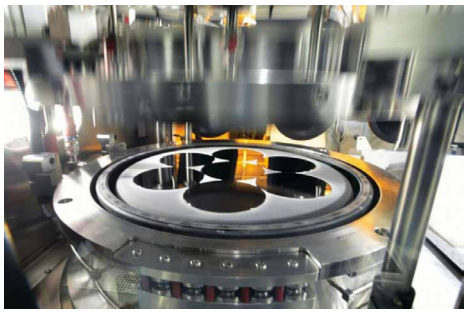
"Today, advancing LED technology goes beyond just increasing LPW," said John Edmond, Cree co-founder and director of advanced optoelectronics. "Cree is also focused on improving spectral content and the efficacy of warmer color temperatures while pursuing tremendous opportunities to increase LPW at real-world operating conditions. This R&D result continues Cree's high power LED technology innovation and provides a path to better lighting experiences at the lowest overall system cost."

Many of today's LEDs that provide excellent light quality do so by compromising LED efficacy, resulting in lower system performance or higher system cost. Cree's latest innovation demonstrates a no-compromise solution that enables high quality light at the lowest cost. As an example of what Cree's technology could achieve, a current 60W LED replacement lamp with average light quality (3000 K CCT & 80 CRI) could be upgraded to incandescent-like light quality (2700 K CCT, 90+ CRI & 90+ R9) with the same light output and power consumption levels at no additional cost. The recently approved California Title 20 appliance standard for LED bulbs highlights the importance of this type of performance without cost and energy savings compromises.

Cree reports that the R&D LED performance was measured at 1587 lumens at 350 mA and junction temperature of 85°C, delivering 134 LPW with a CRI Ra > 90 and R9 > 90 at 2700 K CCT. ■

Plessey - Cubic GaN on 3C-SiC/Si LEDs to Overcome Green Gap

Plessey, Anvil Semiconductors and the University of Cambridge announced that they are working together to fabricate high efficiency LEDs in cubic GaN grown on Anvil's 3C-SiC / Si substrates. Cubic GaN has the potential to overcome the problems caused in conventional LEDs by the strong internal electric fields which impair carrier recombination and contribute to efficiency droop. This is particularly true for green LEDs where the internal electric fields are stronger and are believed to cause a rapid reduction in efficiency at green wavelengths known as "the green gap". The availability of cubic GaN from a readily commercializable process on large diameter silicon wafers is as a key enabler for increasing the efficiency of green LEDs and reducing the cost of LED lighting.



Growth chamber for the growth of cubic GaN for highly efficient green LEDs, performed in a cooperation of Plessey, Anvil Semiconductors and the University of Cambridge

The collaboration, which is partly funded by Innovate UK under the £14m Energy Catalyst Programme, follows on from work by Anvil Semiconductors and the Cambridge Centre for GaN at the University of Cambridge where they successfully grew cubic GaN on 3C-SiC on silicon wafers by MOCVD. The underlying 3C-SiC layers were produced by Anvil using its patented stress relief IP that enables growth of device quality silicon carbide on 100 mm diameter silicon wafers. The process is readily migrated onto 150 mm diameter wafers and potentially beyond without modification and is, therefore, suitable for large, industrial-scale applications. Plessey has started to commercialise LEDs produced in conventional (Hexagonal) GaN grown 150 mm silicon wafers using IP originally developed at The University of Cambridge. Anvil's high quality 3C-SiC on Silicon technology, which is being developed for SiC power devices, provides an effective substrate, to allow single phase cubic GaN epitaxy growth and provides a process which is compatible with Plessey's GaN on Si device technology.

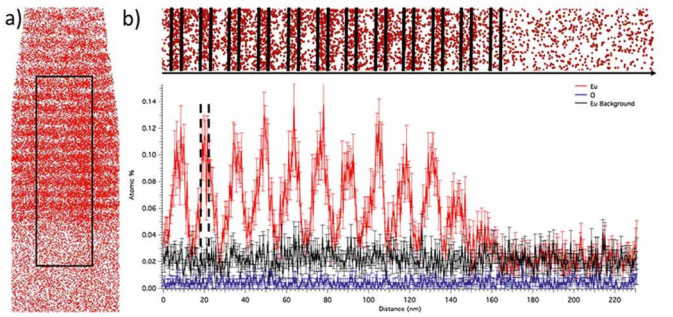
Keith Strickland, the CTO of Plessey explained: "At Plessey we are constantly striving to find novel technology that can enhance our LED products. The work that has previously been carried out at the University of Cambridge in collaboration with Anvil Semiconductors has demonstrated that high quality cubic-GaN can be grown on large area Si substrates compatible with our manufacturing process. This has opened up the possibility to develop green LEDs with high efficiency that will allow us to demonstrate a new generation of efficient and controllable lighting products."

Professor Sir Colin Humphreys, Director of the Cambridge Centre for GaN, added, "The properties of Cubic GaN have been explored before, but the challenges of growing this thermodynamically unstable crystal structure have limited its development. The high quality of Anvil's cubic SiC on Si substrates and our experience of developing conventional GaN LED structures on large area wafers have enabled a breakthrough in material quality. This latest project will build on our ongoing collaboration with Plessey to deliver, for the first time, green LED devices with efficiency approaching that in blue and red LEDs."

Jill Shaw, CEO of Anvil, added: "Our cubic SiC on Si has unlocked a route to large area growth of cubic GaN. We are delighted to be collaborating on this exciting project that offers the possibility of exploiting our technology in high efficiency LEDs as well as in our core low-cost, high-efficiency power electronics markets." ■

Uncovering Oxygen's Role in Enhancing Red Eu-Doped GaN LEDs

Oxygen is indispensable to animal and plant life, but its presence in the wrong places can feed a fire and cause iron to rust. Scientists are learning that, in the fabrication of solid state lighting devices, oxygen also plays a two-edged role. While oxygen can impede the effectiveness of gallium nitride (GaN), an enabling material for LEDs, small amounts of oxygen in some cases are needed to enhance the devices' optical properties. GaN doped with europium (Eu), which could provide the red color in LEDs and other displays, is one such case.



A reconstructed atom probe tomography image (a) shows the europium (Eu) distribution of the delta structure (DS) samples with alternating 10-nanometer gallium nitride (GaN) layers and 4-nm GaN:Eu layers. A zoomed in view (b) of the DS sample structure aligns with a plot of the atomic percentage of Eu and oxygen as a function of space. The background signal of Eu is also indicated for reference

Last week, an international group of researchers shed light on this seeming contradiction and reported that the quantity and location of oxygen in GaN can be fine-tuned to improve the optical performance of Eu-doped GaN devices. The group includes researchers from Lehigh, Osaka University in Japan, the Instituto Superior Técnico in Portugal, the University of Mount Union in Ohio, and Oak Ridge National Laboratory in Tennessee.

Writing in *Scientific Reports*, a Nature publication, the group said that small quantities of oxygen promote the uniform incorporation of Eu into the crystal lattices of GaN. The group also demonstrated a method of uniformly incorporating Eu, which utilizes only the oxygen levels that are inevitably present in the GaN.
Eu, a rare earth (RE) element, is added to GaN as a "dopant" to provide highly efficient red color emission, which is still a challenge for GaN-based optoelectronic devices.

The devices' ability to emit light is dependent on the relative homogeneity of Eu incorporation, said Volkmar Dierolf, professor and chair of Lehigh's physics department.

"Some details, such as why the oxygen is needed for Eu incorporation, are still unclear," said Dierolf. "But we have determined that the amount required is roughly 2% of the amount of Eu ions. For every 100 Eu ions, you need two oxygen atoms to facilitate the incorporation of Eu to GaN."

"If the oxygen is not there, the Eu clusters up and does not incorporate. When the oxygen is present at about 2 percent, oxygen passivation takes place, allowing the Eu to incorporate into the GaN without clustering."

The article is titled "Utilization of native oxygen in Eu(RE)-doped GaN for enabling device compatibility in optoelectronic applications." The lead author, Brandon Mitchell, received his Ph.D. from Lehigh in 2014 and is now an assistant professor of physics and astronomy at the University of Mount Union and a visiting professor at Osaka University.

Coauthors of the article include Dierolf; Yasufumi Fujiwara, a professor of materials science at Osaka University; and Jonathan D. Poplawsky, a research associate at Oak Ridge National Laboratory who received his Ph.D. from Lehigh in 2012.

A comprehensive study

Gallium nitride, a hard and durable semiconductor, is valued in solid state lighting because it emits light in the visible spectrum and because its wide band gap makes GaN electronic devices more powerful and energy-efficient than devices made of silicon and other semiconductors.

The adverse effect of oxygen on GaN's properties has been much discussed in the scientific literature, the researchers wrote in *Scientific Reports*, but oxygen's influence on, and interaction with, RE dopants in GaN is less understood.

"The presence of oxygen in GaN," the group wrote in their article, which was published online Jan. 4, "… is normally discussed with a purely negative connotation, where possible positive aspects of its influence are not considered.

"For the continued optimization of this material, the positive and negative roles of critical defects, such as oxygen, need to be explored."

The group used several imaging techniques, including Rutherford Backscattering, Atomic Probe Tomography and Combined Excitation Emission Spectroscopy, to obtain an atomic-level view of the diffusion and local concentrations of oxygen and Eu in the GaN crystal lattice.

Its investigation, the group wrote, represented the "first comprehensive study of the critical role that oxygen has on Eu in GaN." The group chose to experiment with Eu-doped GaN (GaN:Eu), said Dierolf, because europium emits bright light in the red portion of the electromagnetic spectrum, a promising quality given the difficulty scientists have encountered in realizing red LED light.

The group said its results "strongly indicate that for single layers of GaN:Eu, significant concentrations of oxygen are required to ensure uniform Eu incorporation and favorable optical properties."

"However, for the high performance and reliability of GaN-based devices, the minimization of oxygen is essential. It is clear that these two requirements are not mutually compatible."

Preliminary LED devices containing a single 300-nanometer active GaN:Eu layer have been demonstrated in recent years, the group reported, but have not yet achieved commercial viability, in part because of the incompatibility of oxygen with GaN.

To overcome that hurdle, said Dierolf, the researchers decided that instead of growing one thick, homogeneous layer of GaN:Eu they would grow several thinner layers of alternating doped and undoped regions. This approach, they found, utilizes the relatively small amount of oxygen that is naturally present in GaN grown with organo-metallic vapor phase epitaxy (OMVPE), the common method of preparing GaN.

"Instead of growing a thick layer of Eu-doped GaN," said Dierolf, "we grew a layer that alternated doped and undoped regions. Through the diffusion of the europium ion, oxygen from the undoped regions was utilized to incorporate the Eu into the GaN. The europium then diffused into the undoped regions."

To determine the optimal amount of oxygen needed to circumvent the oxygen-GaN incompatibility, the researchers also conducted experiments on GaN grown with an Eu "precursor" containing oxygen and on GaN intentionally doped with argon-diluted oxygen.

They found that the OMVPE- grown GaN contained significantly less oxygen than the other samples.

"The concentration of this oxygen (in the OMVPE- grown GaN) is over two orders of magnitude lower than those [concentrations] found in the samples grown with the oxygen-containing Eu … precursor," the group wrote, "rendering the material compatible with current GaN-based devices."

"We have demonstrated that the oxygen concentration in GaN:Eu materials can be reduced to a device-compatible level. Periodic optimization of the concentration ratio between the normally occurring oxygen found in GaN and the Eu ions resulted in uniform Eu incorporation, without sacrificing emission intensity."

"These results appear to coincide with observations in other RE-doped GaN materials. Adoption of the methods discussed in this article could have a profound influence on the future optimization of these systems as well as GaN:Eu."

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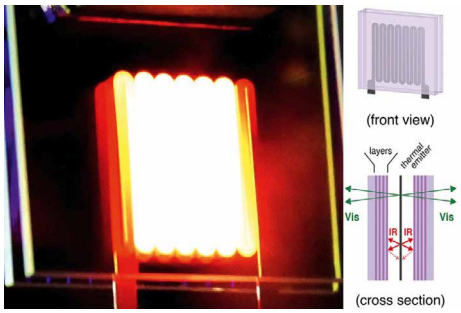
The group plans next to grow GaN quantum well structures and determine if they enable Eu to incorporate even more favorably and effectively into GaN. Toward that end, Dierolf and Nelson Tansu, professor of electrical and computer engineering and director of Lehigh's Center for Photonics and Nanoelectronics, have been awarded a Collaborative Research Opportunity (CORE) grant from Lehigh.

The other coauthors of the Scientific Reports paper were D. Timmerman, W. Zhu, D. Lee, R. Wakamatsu, J. Takatsu, M. Matsuda, W. Guo, A. Koizumi, and Y. Fujiwara from Osaka University, and K. Lorenz and E. Alves from the Campus Tecnológico e Nuclear of the Instituto Superior Técnico in Bobadela.

Innovation Could Bring More Efficient Solar Cells, Revive Incandescent Lighting

Incandescent lighting could make a comeback with a new type of filter that "recycles" infrared photons and improves efficiency, an innovation that also could enable solar cells to convert heat into electricity more efficiently than conventional photovoltaic technology.

"The biggest disadvantage of incandescent lighting has been a lack of energy efficiency," said Peter Bermel, an assistant professor in Purdue University's School of Electrical and Computer Engineering. "The way incandescent lights work is that you heat a filament to a certain temperature and it emits a broad band of light, but only about one in 20 photons or so is actually visible to the human eye; the other 19 photons are essentially just wasted as heat."



The photograph (left) shows a new technology that uses a special filter to improve the efficiency of incandescent lighting and could bring more efficient solar energy (MIT Image/ Ognjen Ilic). Schematic diagram of a new type of filter (right) that could revive incandescent lighting and make possible more efficient solar electricity generation. The schematic shows the technology from a front and side view. (Purdue University-MIT Image/Peter Bermel)

Now researchers have developed a potential solution: a new type of filter to recycle wasted photons that is made out of alternating layers of materials such as silicon dioxide and tantalum dioxide, each with thicknesses less than 1/100th that of a human hair. This approach could improve incandescent lighting efficiency by 10 times, making it equally efficient than commercial compact fluorescent and LED lighting, said Bermel, who worked with researchers at the Massachusetts Institute of Technology to develop the filter.

The selective filter designed and built by the researchers allows the passage of visible photons but not infrared photons, which reflect back to the incandescent source and are essentially recycled.

The efficiency of the new lighting source already approaches that of some fluorescent and LED bulbs, and could theoretically approach 40%. - Today, advanced LEDs can reach up to 29%.

The filter also could have applications in a new type of solar technology called thermophotovoltaics, which could improve the efficiency of solar cells. The filter can be used to select only photons with energy levels corresponding to the semiconductor band gap of the material in the solar cell for maximally efficient conversion.

The researchers have performed both detailed numerical simulations and laboratory experiments to confirm the findings. However, some practical questions remain, such as the ultimate performance, thermal stability and lifetime of the design.

The press release summarizes the results and expectations based on an article published on January 11th, 2016 in the *Nature Nanotechnology* | Letter at Nature.com.

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TECHNICAL REGULATORY COMPLIANCE UPDATE (Part 1)

Segment	Product	Standard (Certification)	Region	Technical Regulatory Compliance Information
Lighting	Luminaires	GB 7000.214-2015 Energy Efficiency	China	Standard GB 7000.214-2015 Luminaires - Part 2-14 - Particular Requirements - Luminaires for Cold Cathode Tubular Discharge Lamps (Neon Tubes) and Similar Equipment is approved and came into force on 1 January 2016. This compulsory standard is harmonized to IEC 60598-2-14:2009 establishing particular requirements for luminaires of cold cathode tubular discharge lamps and similar equipment, operating on a no-load rated output voltage from 1000 V to 10,000 V, used for indoor or outdoor general applications. The covered luminaires are those incorporating luminous-discharge tubes and supply units, of fixed or portable type, supplied by high, mains or extra low voltage (ELV) by transformers, inverters or converters. This is standard of Part 2-14 of the GB 7000 series on lighting standards.
Lighting	Electric Lamps and Lighting Fixtures	Energy Efficiency Resolution 9265	Turkey	The following changes are done to align Turkish energy labelling requirements with EU Regulation (EU) No 518/2014 which sets electronic energy labelling and product information requirements for online sales using the internet. The dealers of Electric lamps and lighting fixtures must avail an electronic energy label and fiche with a new model identifier for their products starting from January 1, 2016. Whenever the product is offered for sale-purchase or hire through the internet, this electronic energy label and fiche must be shown. Detailed requirements on the information to be provided in this form on online selling are described in the new Annex which is added to all the base Communiques.
Lighting	Self-ballasted LED lamps	Decree 692/2015	Egypt	Decree 692/2015 from Egypt which was enacted on September 15, 2015 approves several Egyptian national standards and makes their application mandatory which is coming into force on November 06, 2016. The standards include ES: 7773/2014 on Self allasted LED Lamps for general lighting services with supply voltages greater than 50 V, which are also its performance requirements.
Lighting	LED Lamps	Safety Standard 15829:2015	Taiwan	Taiwanese Standard 15829:2015 describes the safety, test methods and interchangeability requirements to be used to demonstrate compliance of double-capped LED lamps with G5 and G13 caps. It is intended for replacing fluorescent lamps with the same caps which have a rated power less than 125 W and a rated voltage under 250 V. This standard was published by Taiwan's Bureau of Standards, Metrology and Inspection (BSMI) and entered into force on September 23, 2015
Electrical and Electronics	Electric Lamps and Lighting Fixtures	Energy Efficiency Resolution No. 340, 2015	Ukraine	The resolution establishes requirements for the energy labelling of electrical lamps and fixtures including high-intensity discharge lamps, LED lamps, incandescent bulbs and fluorescent tubes. It basically aims to provide consumers with product information on energy consumption and, in turn, align Ukrainian legislation with that of the EU, in particular, Commission Delegated Regulation. -On May 27, 2015 the Ukrainian Cabinet of Ministers adopted the Resolution No. 340 and it has been in force since Dec 05, 2015
Electrical and Electronics	Electrical and Electronic products	Energy Efficiency Star Notice No. 71, 2015	China	On November 11, 2015 China MIIT published the "Energy Efficiency Star Certified Products List 2015". The list contains 141 models of products which are further distinguished into 13 categories for its acceptance in the Energy Efficiency Star Program. This voluntary program promotes high energy-efficient products like water heaters, clothes washers, LCD televisions, room air conditioning equipment, household refrigerators/freezers, transformers, electric motors, industrial equipment, welding equipment, boilers, air compressors, plastic injection machinery, fans, and pumps. The validation period for ''Energy Star'' label is 2 years for consumer products and 3 years for industrial equipment.

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TECHNICAL REGULATORY COMPLIANCE UPDATE (Part 2)

Segment	Product	Standard (Certification)	Region	Technical Regulatory Compliance Information
Lighting	All lighting products	Energy Efficiency ErP	Worldwide	The new edition of the EN/IEC 62493:2015 for EMF for lighting products was revised to make the use and application of the standard easier. Some important changes to previous edition of the standard are: cl. 4.2: Removal of the need for CISPR-15-compliance as a prerequisite for IEC 62493 compliance; cl. 4.2.2, Annex H: Identification of lighting product types deemed to comply with the standard without the need for test; cl. 4.3, cl. 7, Annex I: Inclusion of compliance demonstration method for products having intentional radiators; cl. 5, cl. 6: Adding some guidance to the Van der Hoofden test head method to improve reproducibility of results
Lighting	Electronic lamp control gear with programmable components	IEC / EN 62733:2015	Worldwide	This International Standard provides general and safety requirements for programmable components used in products covered by IEC / EN 61347. The requirements of this standard are only applicable to the programmable components in the electronic lamp control gear. A risk assessment shall be done to determine which parts of this standard are applicable. If the risk assessment shows that the used software built in, to prevent the control gear from becoming unsafe, has a risk above the tolerable risk, then this standard is mandatory. The focus of the risk assessment shall be the possible risks by the electronic control gear including the abnormal operation and fault conditions of the relevant part 2 of IEC / EN 61347. For other electric/ electronic circuits and their components in the electronic lamp control gear, the requirements of IEC / EN 61347 series apply.
Lighting	Lamps	Energy Star ErP	Europe	EPA (Environmental Protection Agency) published the specification ENERGY STAR Lamps ver. 2.0. - Some of the important changes are listed below: • Slight modification in scope: added G4, G9 type lamp base, removed ST type • Guidance on test of color tunable lamps • Update of referenced standards and harmonies with California & federal or coming federal standards • Increase of the luminous efficiency • Added CCT 2200 K & 2500 K • Reporting of spectral power distribution • Remove of rapid stress test for SSL • PF ≥0.7 for all SSL • Run-up time for CFL more strict • Standby power consumption • Connected products • Clarified and added packaging requirements • New test methods for light output for dimmer and light source flicker were announced in Dec. 2015
Lighting	LED light sources	LM-80	Europe	New version of IES LM-80-15 is published The scope of the IES LM-80-15 has been expanded to include tests for three types of flux maintenance along with tests for how chromaticity changes over time. LED drive characteristics have been updated to include pulse width modulated current, DC constant voltage and AC regulated voltage drive. The maintenance test duration and measurement interval are no longer specified but rather left for determination according to the intended usage of the data.

For further information on the latest upgrades and testing standards please contact cps@tuv-sud.com

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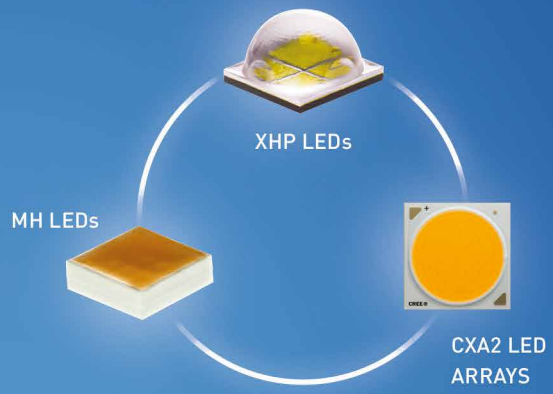

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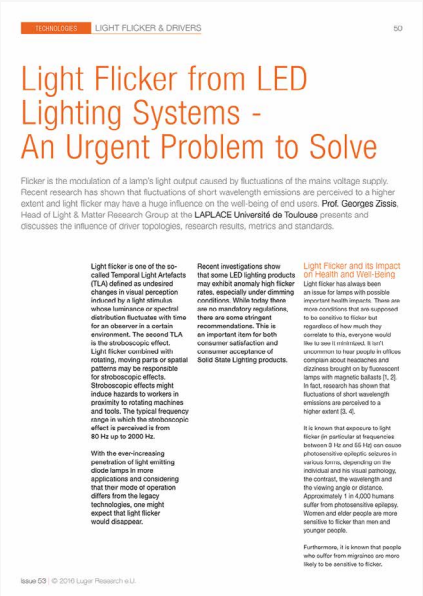

TECHNOLOGIES LIGHT FLICKER & DRIVERS 50

Light Flicker from LED Lighting Systems - An Urgent Problem to Solve

Flicker is the modulation of a lamp's light output caused by fluctuations of the mains voltage supply. Recent research has shown that fluctuations of short wavelength emissions are perceived to a higher extent and light flicker may have a huge influence on the well-being of end users. Prof. Georges Zissis, Head of Light & Matter Research Group at the LAPLACE Université de Toulouse presents and discusses the influence of driver topologies, research results, metrics and standards.

Light flicker is one of the so-called Temporal Light Artefacts (TLA) defined as undesired changes in visual perception induced by a light stimulus whose luminance or spectral distribution fluctuates with time for an observer in a certain environment. The second TLA is the stroboscopic effect. Light flicker combined with rotating, moving parts or spatial patterns may be responsible for stroboscopic effects. Stroboscopic effects might induce hazards to workers in proximity to rotating machines and tools. The typical frequency range in which the stroboscopic effect is perceived is from 80 Hz up to 2000 Hz.

With the ever-increasing penetration of light emitting diode lamps in more applications and considering that their mode of operation differs from the legacy technologies, one might expect that light flicker would disappear.

Recent investigations show that some LED lighting products may exhibit anomaly high flicker rates, especially under dimming conditions. While today there are no mandatory regulations, there are some stringent recommendations. This is an important item for both consumer satisfaction and consumer acceptance of Solid State Lighting products.

Light Flicker and its Impact on Health and Well-being

Light flicker has always been an issue for lamps with possible important health impacts. There are more conditions that are supposed to be sensitive to flicker but regardless of how much they correlate to this, everyone would like to see it minimized. It isn't uncommon to hear people in offices complain about headaches and dizziness brought on by fluorescent lamps with magnetic ballasts [1, 2]. In fact, research has shown that fluctuations of short wavelength emissions are perceived to a higher extent [3, 4].

It is known that exposure to light flicker (in particular at frequencies between 3 Hz and 66 Hz) can cause photosensitive epileptic seizures in various forms, depending on the individual and his visual pathology, the contrast, the wavelength and the viewing angle or distance. Approximately 1 in 4,000 humans suffer from photosensitive epilepsy. Women and elder people are more sensitive to flicker than men and younger people.

Furthermore, it is known that people who suffer from migraines are more likely to be sensitive to flicker.

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The article about flicker issues and drivers by Prof. Georges Zissis was the object of some discussions. Dr. Walter Werner had a very interesting point of view

THERE IS MORE TO FLICKER THAN VISIBLE PERCEPTION

by Dr. Walter Werner, Werner Consulting

In his excellent article in the Jan/Feb 2016 LpR 53 issue, Georges Zisses showed that flicker needs to be limited according to existing standards to stay well out of the perceivable range.

The main research and arguments, however, are focused on visible perception. This is sufficient if we assume that what cannot be perceived does not cause any harm. But this has not been proven, and not much research is available about long-term effects of unperceivable flicker.
Very likely, science and regulations need to rethink this type of assumption; just look at x-rays and radioactivity.

Wilkins et al. investigated medium to longer-term effects in the late 1980's (as part of the "sick building" syndrome research). The research focused on 100 Hz modulation [1]. He showed that a switch from a longer exposition (multiple months) with substantially modulated light (60%) to low modulated light (6%) reduces headaches and eyestrain within a few weeks.
These results are statistically significant. Most of the lighting industry ignored the results because the opposite effect (increased eyestrain and headaches) could not be shown within the four weeks of exposition that the research campaign allowed for.

Research on blind people that regained their sight as adults (Project Prakash [2]), showed that the visual apparatus and object recognition ability adapt to a mostly normal view after a while in adults but does not gain some of the more advanced abilities. This could point to the fact that the complex analysis ability is trained and formed during childhood.

There is also evidence that there is some influence up to about 400 Hz, and transitional effects of flicker have been claimed to be detectable up to 800 Hz.

While the latter observation has been researched with moving sources and could well be an artifact caused by the interference of the moving sources with some eye-movements, H. Lindner's research [3] proved a reduction of the ability to resolve very fine structures up to a modulation frequency of 400 Hz. This seems to be very high, given the bio-chemical nature of the sensors and the relatively low fusion frequency of our visual system. One quite obvious reason for this could be that the neural network can use the fast signals to enhance the quality of the received visual signal.

What does this tell us about flicker with frequencies below 400 Hz, and what would be the logical consequences?

- Short term exposure to higher frequency flicker seems to be no trouble, as long as no advanced visual tasks need to be performed
- Longer term exposure to higher frequency flicker should be avoided, as research cannot give evidence about the thresholds to maintain. The existing research is poor but suggests strongly that there are negative effects like stress or wear-out to the visual apparatus
- Flicker should be avoided wherever (younger) children stay longer, to make sure the possibility of interference with their later visual abilities is minimized

As a clear conclusion, we can say that there is enough evidence that flicker up to 400Hz is not harmless with longer term exposition and responsible manufacturers should keep out of this range to keep lighting that is intended to be used in offices, work areas, baby and children's' rooms, kindergarten installations and screen illumination of small children's' toys safe. As a result, more research is needed to understand where the safe zone really is. ■

W.W., February 2016

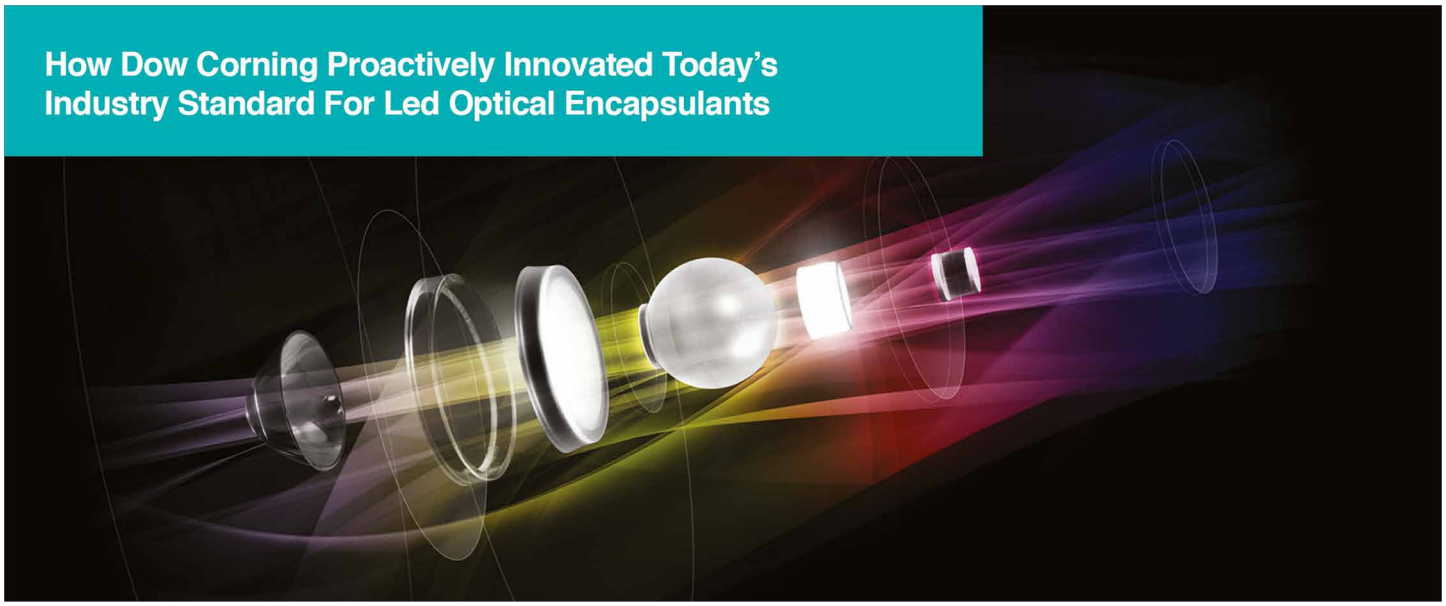
References:

[1] Wilkins A.J., I.M. Nimmo-Smith, A. Slater and L. Bedocs: Fluorescent lighting, headaches and eye-strain, Lighting Research and Technology, 21(1), 11-18, 1989

[2] Pawan Sinha: Es werde Licht, Spektrum der Wissenschaft 18.7.2014 (partly based on Held, R. et al: The Newly Sighted Fail to Match Seen with Felt, Nature Neuroscience 14, p 551-553, 2011)

[3] Lindner, Heinrich: Untersuchungen zur zeitlichen Gleichmässigkeit der Beleuchtung unter besonderer Berücksichtigung von Lichtwelligkeit, Flimmerempfindlichkeit und Sehbeschwerden bei Beleuchtung mit Gasentladungslampen, 1989, Thesis, TU Ilmenau, Germany.

How Dow Corning Proactively Innovated Today's Industry Standard For Led Optical Encapsulants



Innovation is not simply the invention of new things, it is the invention of new value. Often, the value of new things is not immediately recognized by the marketplace. So, innovation can require taking tremendous risks. Just 15 years ago, the commercial value of LEDs for general lighting applications was far from certain. Yet even in those early days, Dow Corning experts were working alongside the pioneers of LED technology to innovate the cutting-edge silicones that would help solid-state lighting become the more reliable, more appealing and more efficient illumination it is today.

At Dow Corning, innovation is more than a buzzword. It is a proven methodology for identifying new market trends, and managing the risks implicit in creating entirely new, but targeted solutions that deliver disruptive value for customers while their market is still evolving. The company's portfolio management approach invests in people and resources to explore multiple new applications, and regularly measures its relative progress as well as the changing opportunities and risks.

Few markets illustrate the success of Dow Corning's methodology for targeted innovation better than the LED lighting industry. In 2000, red and green LEDs had been a reality for decades. But blue LEDs - necessary to produce white light in combination with red and green LEDs - were just emerging, and still unproven in commercial applications. Yet, a team of four pioneering Dow Corning chemists had already recognized silicone's breakthrough potential for enabling and optimizing the disruptive new lighting technology that LEDs presented.

At the time, they were developing products for semiconductors and opto-couplers. But the team quickly shifted focus to begin collaborating with leading LED developers. Their goal was to formulate optical-grade silicone encapsulants able to withstand the heat of LED dies without diminishing in performance. Exploring both methyl and phenyl-based silicone chemistries, their early successes showed significant promise for improving the long-term reliability of LED packaging. Further development of phenyl silicones revealed the higher refractive index (RI) of these materials actually improved the optical efficiency of LEDs independently of improvements to the chip, case or input power.

In 2002, Dow Corning filed the basic patents for its optical phenyl resin encapsulants, and introduced its first commercial product a year later. Under the protection of these patents, the team and their industry partners had the confidence to accelerate innovation of new high-RI, phenyl-based silicone encapsulants for successive generations of high-brightness LEDs. Four years later, Dow Corning formalized the technology with the launch of its high-RI Dow Corning OE-66XX encapsulant portfolio. Select products in that portfolio now enable as much as 7 percent greater LED output over standard methyl-based silicones.

The same industry-leading expertise that helped innovate the company's cutting-edge optical encapsulants continues to fuel new LED advances today. Specifically, pioneering chemist Makoto Yoshitake - one of the original four team members - is helping to guide development today of advanced silicone phosphor films that target new design and manufacturing options for next-generation LED concepts, such as chip-scale packaging.

What began fifteen years ago as a controlled risk is today the industry standard for value-added optical encapsulants targeting high-brightness LEDs for general lighting applications. That tradition continues at Dow Corning. The company's generations of expertise, its proven methodology for innovation, its industry-leading silicone solutions and its strong intellectual property portfolio all offer LED-makers the freedom and confidence to collaborate on new LED lighting breakthroughs and fuel successive generations of competitive new product technologies. ■

DOW CORNING

Lighting Solutions

Tech-Talks BREGENZ - Karl Jónsson, IoT Architect, Tridonic

Karl Jónsson

Karl Jónsson joined Tridonic in 2014 as IoT Architect to pave Tridonic's way into the Internet of Things era. Over the last 6 years, as the General Manager for the Smart Lighting business unit at GreenWave Systems^ which he co-founded in 2008, he pioneered the world's first IP based lighting solution for consumers. Before that, he reported to the CTO office of Cisco Systems consumer group. In the early 90's, he started his carreer in entertainment lighting with over a 10-year track record at major TV, theater and show productions in Scandinavia. Karl Jónsson holds an M.Sc. degree in Information Technology from IT University of Copenhagen, a B.Sc. degree in Electronics Engineering from Copenhagen Engineering College and an Electrical Science Degree from the Technical College of Reykjavik. Karl has over 50 patents filed and granted worldwide in areas of IoT and lighting, and has been an active member and strong influencer of major standards bodies.

Karl Jónsson, IoT Architect at Tridonic presented some interesting facts, figures, and ideas about IoT and the future of lighting in his speeches about "The Internet of Things and Lighting" at Zumtobel's International Year of Light Event in 2015 and again at the Light + Building 2016 preview. LED professional got the chance to talk with him about his visions for IoT and Tridonic's latest developments in that domain.

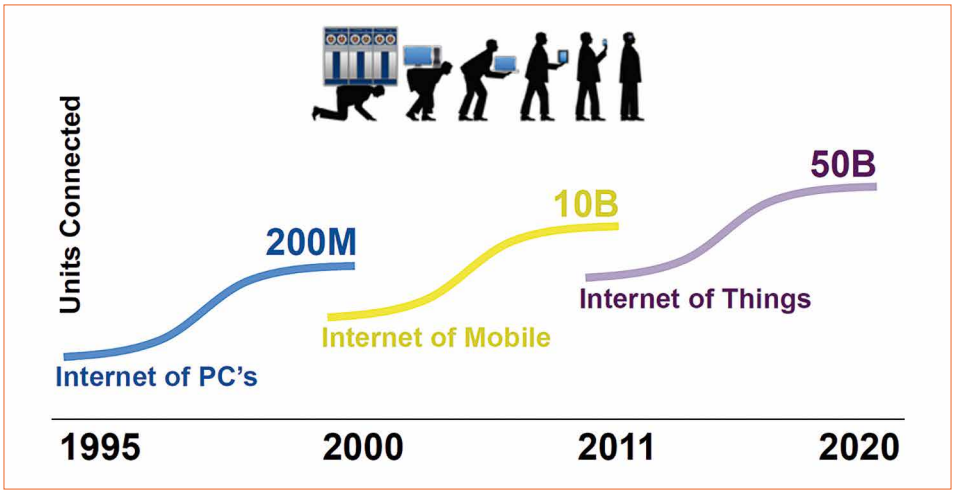
LED professional: Welcome to Bregenz, Mr. Jónsson. As a short introduction, could you please tell us what makes IoT so interesting and why lighting will become such an important part of it?

Karl Jónsson: Yes, of course. IoT offers many new opportunities to established infrastructures, especially for lighting to become the connectivity backbone for IoT sensors and devices to offer new services and automations. For example, in a big office building there might be a few hundred or even a few thousand bathrooms that have to be checked every day. Soap dispensers and napkin holders need to be checked and refilled. They could have built-in sensors to connect to the light and signal that they need to be refilled. That is just one example of what can be monitored. Retail applications is another example where digital price tags need to be managed or customer behaviors monitored in order to offer improved services. Space management and remote monitoring of energy is also a use case that is high in demand where IoT integration with lighting will be a great benefit.

IoT needs a dense network to allow these services. While we mainly use our cell phones as a bridge to the world for our apps in our private and consumer life, this is not as easy in the professional environment. Therefore, another bridge needs to be used. Light is the densest network of wired devices worldwide and this is a big chance for lighting to become the infrastructure and a core enabler for this technology.

LED professional: That means that this would go beyond lighting tasks. It would become a data collection resource, and an infrastructure for other devices. What are the main requirements to allow these new opportunities and to get it to work smoothly?

Karl Jónsson: The first thing of importance is standardization. It has been a struggle in the past and it is ongoing. But it seems that the industry is looking more and more towards



Development of the internet and the expectations for IoT

the internet protocol (IP) and moving away from individual solutions.

LED professional: This requires new developments which draw huge R&D resources. One could argue that any lighting task, sufficient control and monitoring of the lighting infrastructure could be fulfilled by connecting DALI to the web using a gateway. How would you counter that argument and what were the reasons for joining forces for this new development?

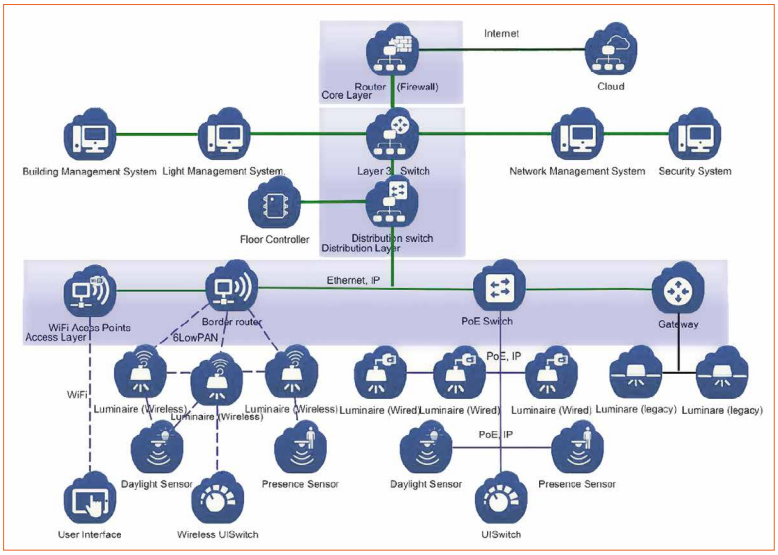
Karl Jónsson: DALI and other non-IP-based protocols are certainly efficient and good enough for today's use cases. The upcoming problem, however, is that they operate in silos and are self-contained without the possibility of interconnecting with pier building automation systems without translation. This is the case especially when it comes to support sensors, data collection and other features through the lighting network that are beyond today's use cases.

This is also true for many other systems. Lighting, building automation, security systems, retail services and other professional services still operate in vertical silos and in independent ecosystems. The operation of these systems is, therefore, very inefficient and the systems are not scalable. Creating a joint ecosystem and making systems "speak" with each other "over the top" through cloud based wrappers and gateways can go a long way, but doesn't guarantee security, reliability, operation efficiency, and, in the end, customer satisfaction

LED professional: Can you go into detail concerning silos?

Karl Jónsson: The best analogy I can give is the cell phone market. Two years before the first iPhone came out, I visited Nokia innovation lab in Oulu Finland where I witnessed a mind-blowing application and development around the Nokia Symbian OS. As an example, they demonstrated an application that used the phone camera to translate a Chinese menu to English on the fly, so the display showed the English text. There were also payment solutions and home automation use cases that, at the time, felt unreal but are a commodity today.
I believe the reason why this never became public domain at the time was not only because of the aesthetic design, user interface and business model as often referred to. I think it is much more because of the same technology silos we are trying to avoid today, which are the closed platform, a limited update strategy as the entire phone needed software update when new "apps" were added, and the infrastructure dependency.

Tridonic as well as the OpenAIS project partners recognized an internet protocol-based open system technology, especially IPv6 with its variations, to be the key element for a successful, widespread market introduction of IoT



Closed or open can mean many things. For example, you could argue that Apple is a closed ecosystem, but it's open enough that protocols are a commodity and providers can compete on the application layer. It will be hard to convince an HVAC manufacturer, for example, to support DALI. Therefore, there is an increasing demand for a common networking layer for M2M communication and centralized operations. If everyone communicates over IP, it's easy to enable interactivity both ways, when the business calls for it.

LED professional: Could you give us an example of why it is such a big advantage to use the IP-based technology approach?

Karl Jónsson: Adding a new feature in today's systems can be very difficult. For example, let's say we wanted to add a microphone that detects sound patterns for context awareness in a room like a meeting, talking, vacuum cleaning, a party, and so on. We would have to get DALI alliance to support such features or try to be creative with existing standards with a proprietary modification. Then we would need to push a firmware update to the gateway in order to support the feature. At the gateway the connection is terminated for protocol translation, which could give hackers direct access and let them eavesdrop on the audio coming from the microphone.

The communication protocol between the gateway and cloud, which is commonly proprietary, would have to update and finally the cloud, apps and application interface would have to add support for this. Not to mention QA that would have an exponentially growing test matrix of features to guarantee stability instead of just having to test the device and application itself.

In an IP world, the device would be added to the network and be told which infrastructure device, in the form or a switch or access point, it is allowed to talk to. From there, only the application and business logic needs to be updated at the other end as IP-2-IP security and interoperability is already a commodity.

LED professional: Does that mean that the IP protocol is the way to go for IoT and smart lighting for Tridonic and the Zumtobel Group?

Karl Jónsson: Yes, for the whole group it is all about following standards. And the Internet protocol is therefore very crucial for us. Currently, there are technologies offered that are bridged into the IP world that have their own benefits, like DC-String and ready2mains which are part of the company's ecosystem. But the most straightforward approach for now is net4more.

LED professional: Tridonic also belongs to the OpenAIS consortium. How is net4more related to the OpenAIS project? Is it a direct outcome of this project?

Karl Jónsson: With the development of net4more, we already started R&D activities and plans to move into IP-based lighting. Therefore, we were very happy when the OpenAIS project was initiated. Since we believe that this IP technology will pick up fastest and to the best customer satisfaction, we followed the idea to design it right from the start as open as possible. We were happy to see that the experts in OpenAIS, coming from lighting, building automation, semiconductor and IT, came to the same conclusion on how a system should be designed. And some new ideas where born!

While net4more is not a direct derivative of OpenAIS, it shares synergetic properties that we are trying to drive and align between other standards as well. We see net4more and OpenAIS moving in the same direction but at different speeds and with slightly different scopes.

In OpenAIS we hope to fill all the gaps that we have already identified in the available technical standards and technologies. Professional lighting has different requirements than the telecom industry. Lighting needs peer-to-peer communication and multicast messaging. It is also different from the home automation and, therefore, the current Thread Group specification 1.0 does not fulfill all lighting needs, like commissioning of big installations with hundreds or thousands of luminaires. In OpenAIS we do research on several layers of the communication stack in the field of security to solve these issues.

LED professional: Does that mean that customers have to wait until OpenAIS has delivered in order to benefit from an IP-based lighting solution, or is net4more already future-proof?

Karl Jónsson: No, not at all. We designed net4more as a starting point of a future-proven and upgradable smart lighting solution that is based on open standards where they exist. Once the OpenAIS solution becomes a standard, we will be able to change over and merge both solutions easily.

We are an active member of several consortia and committees (IETF, Thread Group, Fairhair, TCLA) where we want to contribute to a fast standardization process for IP-based lighting together with players from the lighting, IT, and building industry.

LED professional: Could you please give us an idea about the cornerstones of this IP-based technology and how it compares to other approaches?

Karl Jónsson: It is important to be based on end-2-end IPv6 technology, which is IPv6 for low power networks, and in case of wireless 6LoWPAN. Other cornerstones are that it offers a common, secure and open way to connect on-board and pair and secure wireless devices to a network. It is also important that no gateways are needed for native net4more devices, which offers many benefits compared to conventional solutions. For instance, scalability is not limited to a proprietary addressing scheme as IPv6 has practically "unlimited" addresses available. It is based on open standards where available. No protocol translations are necessary, and hence, infrastructure devices do not need updates to support new features. The system relies on common IETF-based standards that are already empowering today's Internet of over 8B devices, and when needed, it can virtualize DALI and other non-IP-based devices into IP.

LED professional: Not all of our readers might be familiar with the IPv6 specifications and related network technologies. Could you explain the difference between IPv4 and IPv6 and tell us some of the benefits?

Karl Jónsson: IPv6 is the 6th version of the popular Internet Protocol. Although IPv6 is becoming more dominant, IPv4 currently powers most of the 8B devices in the world today, like computers, phones, and tablets. The problem with IPv4 is mainly its addressing scheme, which is limited to 4.3B addresses. Because of this, many networks, especially home networks, are currently using Network Address Translation (NAT) which allows all devices in a home to connect by using a single IPv4 Address. IPv6 is backwards compatible and solves the addressing problem by allowing 3.4x10^{38} addresses, which should never run out. Devices can thus avoid any translation and talk directly with each other when allowed and authorized.

LED professional: Both net4more and OpenAIS support wired or wireless communication. Are there different target applications and safety issues?

Karl Jónsson: The architecture of an IP-based lighting system should always be designed to work independently of the chosen physical layer. This is a big progress compared to DALI where the protocol is entangled with the method to transmit it. Therefore yes, both wired and wireless connectivity methods are supported. While both will be very safe and secure, they will have different benefits depending on the installation and application. As an example, in a public place, it might be more appropriate to use wireless solutions to avoid people unplugging an ethernet cable to gain access to a local network. In a hospital, a wired solution might be more suitable to reduce wireless noise for potentially sensitive medical equipment.

LED professional: PoE is currently another trend and a relatively new approach for Tridonic. We've learned that currently, approximately 60 W can be supplied and a new spec to allow up to 95 W is in progress. Is PoE also an integral part of the net4more concept? Is this specification really sufficient for all applications?

Karl Jónsson: Yes, PoE is also being considered. It's ideal for IT-based installations where lighting needs to be a part of the IT network. But it is not ideal for high power applications like high bays, stadium lighting or most other outdoor lighting applications.

LED professional: This means there are some specific target applications. What are the greatest advantages?

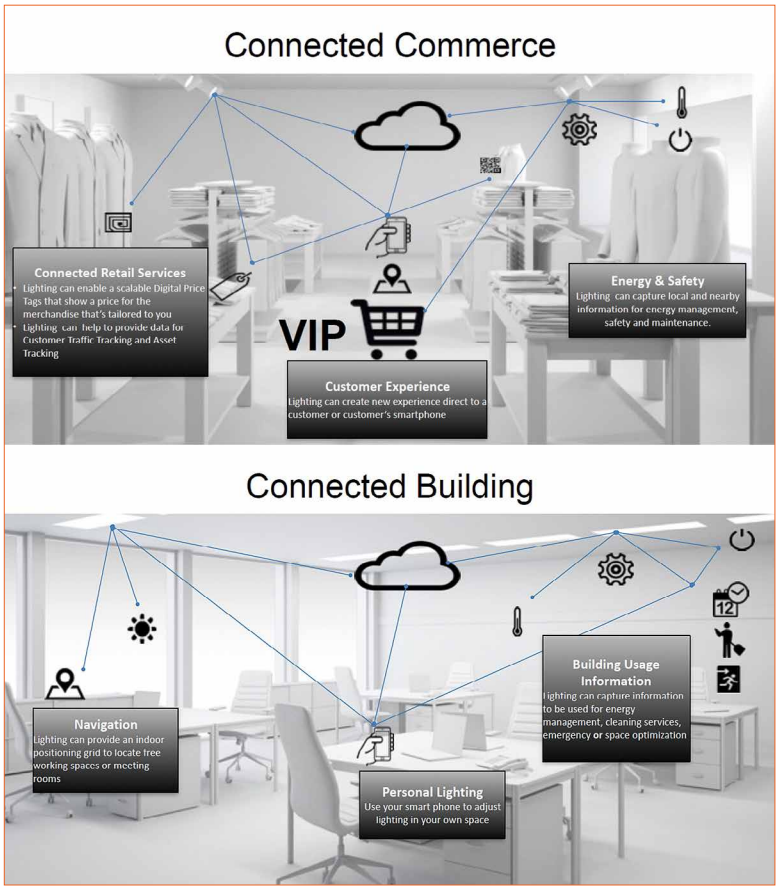
Karl Jónsson: It's mainly office panels and downlights that are being targeted. For these applications, PoE offers a strong value proposition when the lighting control system is designed like an IT system. IT planners are very familiar with this technology and it allows cost savings during installation.

LED professional: One is still fighting for any percent of increased efficiency today. But PoE has relatively high line losses because it originally was not intended for transporting that amount of energy continuously. Isn't that a significant disadvantage?

Karl Jónsson: There are pros and cons. Some or all of the line voltage can be regained by decentralizing the PoE switches that shorten the cable that runs between luminaires and switches. This lowers the line losses. Intelligent light scheduling of such intelligent systems will also contribute to savings.

LED professional: All these discussed systems are IP-based. People often associate security and privacy issues with the Internet and IP. Adding these sensors and actors from their currently "private" environment directly to the Internet could cause some uneasy feelings when they think about all this

Providing services beyond lighting like those for connected commerce or connected buildings, are new business models that are being discussed and targeted by lighting manufacturers. The topics of security and privacy are very important



information being in the cloud. Can you tell us about security and privacy?

Karl Jónsson: Looking at the pitfalls and history of smart lighting, we see that until now usability is one of the most relevant topics. But it has become much less an issue with the introduction of the smart phone, which we all know how to use. While today it is protocol and interoperability, tomorrow it will be security, data collection and privacy. This cannot be an afterthought. We have to think about it now.

Looking back at the history of data breaches we see that a lot of common mistakes can be avoided. When you are running on the IP protocol and you follow the common standards and practices in security, you are pretty safe. Please note that I am talking about security and not privacy or data collection. If you get audited by one of the major security companies it doesn't necessarily guarantee that you won't be hacked. You also need to look at the history of recent attacks. These attacks are not usually very innovative in that the same tools are usually used. Looking at the latest trends at hacker conferences like the Black Hat in Las Vegas might help to minimize risk.

LED professional: In a speech you pointed out that the biggest safety risk is the app, not the system. How could this risk be minimized?

Karl Jónsson: In this regard, the biggest risk is most often the user of the solution. Very often they don't change default user names and passwords like admin/admin, or they use simple passwords to easily remember them. Furthermore, the end device, either PC or smartphone, is typically an uncontrolled domain adding the risk of spoofing and backdoor software compromising access.

There are several ways to mitigate the risks. One of the best solutions would be to get rid of passwords and use a secure token from an NFC care, phone or fingerprint. On another level it would be helpful to design the system in a tiered approach so that one compromise only affects small parts of the systems. That could mean to build the security architecture as a "marketplace" instead of a "castle". And last but not least, simply following known standards on Internet security and to comply with the security and privacy regulations would mean a significant reduction of risk in most cases.

Since bank transactions, aviation controls and other critical applications can rely on the IP infrastructure, lighting can, too.

LED professional: This all is about security, but what about privacy?

Karl Jónsson: Privacy issues depend strongly on where a solution is located. It is, in many aspects, a legal issue. Germany has probably the most stringent law. Many German companies don't allow the use of US-based hosting services. They are worried about data collection. But there are ways to keep it anonymous. One popular trend is fog computing where data are preprocessed on site. You are not sending raw data but just relevant data, already stripped of the privacy part. For instance, from a camera for people counting, it only sends the numbers and not the actual pictures. Such technologies will become very important. One relevant side benefit of this technology is that the amount of transmitted data is drastically reduced.

There is still a certain disconnect between what is anonymous and what not. For example, when you are walking through a supermarket, and you are tracked based on the ID of your phone, all actions and reactions are collected, even when they are not tied directly to your personal information. Is that anonymous or not? You are still targeted as your personal device.

LED professional: Could we conclude that this means that the exact meaning of privacy must be agreed on and is necessary to develop or chose an appropriate technology?

Karl Jónsson: Yes, that would be the ideal situation.

LED professional: Earlier in the interview you mentioned two systems that Tridonic developed and introduced during the last few years: ready2mains and DC-Grid, which are bridging the IoT world. Are they equally well suitable for IoT and when are they the right choice?

Karl Jónsson: There are applications with less sophisticated requirements where costs are more important. Both are also developed for professional applications, but their IoT capabilities are limited. They can bridge into DALI, or later, net4more, but end points cannot feed back any information and they cannot control lights individually. Therefore, integrated sensors are not supported. They offer limited applications aside from dimming and energy savings.

LED professional: Which technologies are used for these product lines?

Karl Jónsson: These systems use the power cables for communication but have distinct technical differences to Power Line Systems and should therefore not be confused with them. For the DC-String no common standards were available because there are just a few activities in the DC domain, and most of the AC power line activities are related to high data transmission rates that are not necessary for this application. For us, stability is much more important. Therefore we had to develop our own technologies and communication standard.

LED professional: What were the major reasons and applications for developing these products?

Karl Jónsson: In the case of the DC-String it currently benefits applications where space is limited for luminaire designs and individual controls are still desired. With DC-String the power supply and control can be centrally located without compromising these requirements.

Lighting specialists are convinced that the lighting infrastructure must meet all requirements to become the backbone of the smart buildings of the future

Moving forward, we see a potential trend that buildings will be designed completely off the grid and become CO_2 neutral. Tesla's announcement of the power wall and power pack for residential and industrial buildings could accelerate this trend. DC-String has big advantages for such buildings. It does not make sense to convert DC voltage from solar panels to AC, then again back to DC for batteries and then again to AC for the lights because LEDs need DC.

Ready2mains uses a very lean way to send digital commands on the mains' wires to enable group switching and dimming via a gateway. For retrofit from conventional to LED light where no granular light control or management solution is required, ready2mains would still be the best choice if cost and energy savings are the primary goal.

LED professional: Besides end-user functionality and costs, there is another important aspect: Installation and commissioning. I know that one of Tridonics' goals is to develop a solution that also works for "uneducated" users. This raises several questions. What would this type of system or approach look like and how would it work? Is it possible to keep it simple while being secure at the same time?

Karl Jónsson: A detailed explanation would probably break the mold, but in general the millennial generation of installers and commissioners will have limited tolerance for a learning curve and will expect things are WYSIWYG. With this upcoming new generation of professionals in mind we are exploring a new visual and fun way to perform commissioning without compromising on security and still allowing experienced professionals to familiarize themselves with new and exciting features to improve and speed up the commissioning process.

LED professional: As you mentioned at the beginning, one of the most exciting issues of IoT is that it is at the starting point and may open unknown future prospects. At the same time, there are other technologies emerging like Li-Fi. If you don't mind, could we concentrate on these prospects and visions in the last part of our interview?

Karl Jónsson: Yes, of course.

LED professional: Could you please give us an idea and update of the future of IoT, related technologies and their applications?

Karl Jónsson: Aside from remote monitoring and space management, there are several other services that could benefit from the net4more infrastructure, only the imagination is the limit to what applications could be built once the lighting network is IP-enabled. Another example of driving service enablement is certainly Li-Fi where light itself becomes a physical

layer in the networking stack, which would be a natural extension of an IP-based luminaire when each luminaire becomes a Li-Fi access point. Li-Fi is focused on high-speed data transfers and is targeted to compete and compliment WiFi. The current problem with Li-Fi is that it requires a dedicated receiver on the user side so it won't be popular unless a popular device manufacturer decides to natively integrate it in their devices. However, there are already strong rumors this might become natively supported in future iPhones. That could be the breakthrough for this technology.

There are, however, other lighting modulation schemes, that operate at a lower frequency so a smart phone camera is enough to receive the signal. Generic light modulation is typically referred to as Visual Light Communication (VLC). While low speed VLC is not useful for high-speed data transfers, it is good enough for other applications such as indoor navigation and for localization during commissioning. VLC is typically used in conjunction with a smart phone's Gyro and magnetometer to determine place, angle and orientation.

LED professional: You once said, "The true benefits of IoT may not be that much for already known applications, but rather for new ones that are currently not yet known." Could you give us examples?

Karl Jónsson: IP-based lighting is often referred to as the "backbone of the IoT". A meshed wireless lighting network could give other "things" access to the Internet. Things like distributed access points that allow small-constrained battery-powered sensors or actuators to communicate with the Internet amongst themselves or with the cloud, even if their information is not needed for lighting. It could be used for logistics, climate control, safety or asset tracking. This opens up new service possibilities that can be hosted by the platform created through a connected lighting network.

Other examples I can think of are the integration of the lighting backbone with other emerging technologies like Augmented Reality and self-driving cars, where lighting could play a role in context awareness and communication.

LED professional: To close, could you tell us what is the most exciting future prospect for you, personally?

Karl Jónsson: I've been obsessed with lighting ever since I can remember and my personal passion is when a light source can be taken under complete control and the power of darkness can be appreciated. I'm excited about making lighting truly dynamic, something that's not just a statically mounted device that offers services, but a truly integrated experience that can become a part of my digital life.

LED professional: Thank you very much for your visions and insights on IoT and Tridonic's latest activities in that domain. It was a pleasure talking with you, here in Bregenz?

Karl Jónsson: My pleasure. ■

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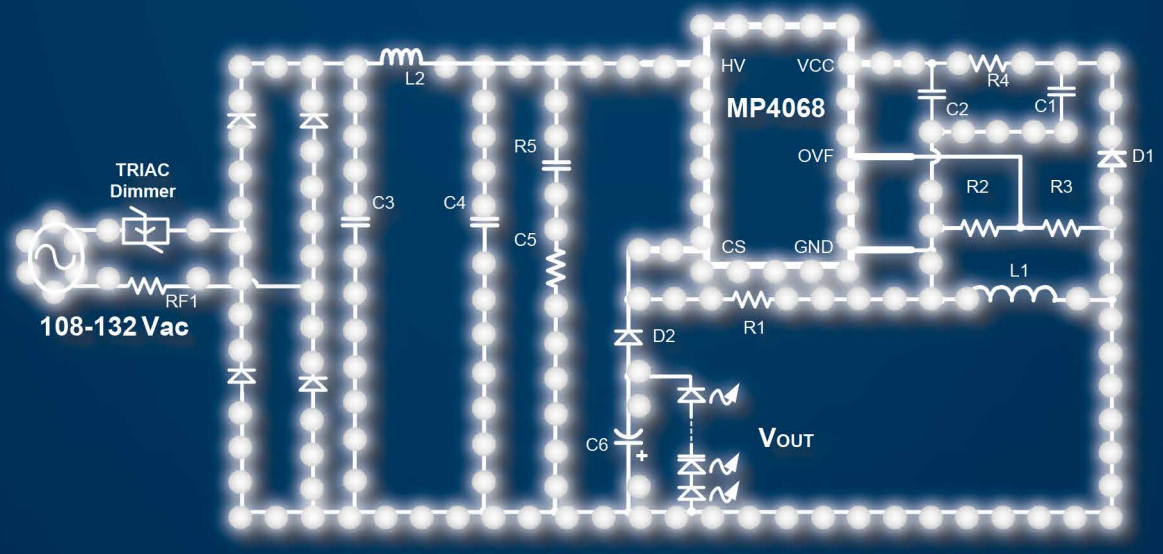

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Thin-Film Light Management System for Intelligent Large-Area LED Luminaires

The recent advances in Solid State Lighting have triggered the development of smart lighting solutions. However, the point-like nature of LEDs imposes the use of inefficient and/or bulky light scattering sheets or costly, short-pitch LED arrays to achieve acceptable spatial luminance uniformity. Ph.D. Oscar Fernandez, Senior R&D Engineer at the Centre Suisse d'Electronique et de Microtechnique SA (CSEM) shows a new approach in the form of an innovative thin form-factor light management (LM) system comprising a highly engineered combination of thin-film diffractive nano-optical and refractive micro-optical elements.

The recent advances in the domain of Solid State Lighting (SSL) and, in paxxxxrticular, in Light Emitting Diode (LED) technology has triggered the development of smart lighting solutions. However, the point-like nature of the LEDs imposes the use of either inefficient and/or bulky light scattering sheets or costly short-pitch LED arrays to achieve acceptable spatial luminance uniformity in, for example, large-area luminaires for professional lighting.

Here, we present an innovative thin form-factor light management (LM) system comprising a highly engineered combination of thin-film diffractive nano and refractive micro-optical elements. Our LM solution allows the decreasing of the LED pitch by a factor of 2-3, hence reducing the amount of LEDs for a given total emitting area and luminous flux.

The accurate prediction of the system optical response is achieved using interfaced rigorous and ray-tracing modelling tools.

Such interfacing is fundamental to account for the complex optical interplay of the different components in the system and, therefore, to ensure meaningful simulation results. The optimized system demonstrates excellent efficiency and luminance spatial uniformity even when combined with long-pitch LED arrays.

The LM system presented here has been developed in the framework of the EU-funded project, LASSIE-FP7, whose objective is the realization of a cost-efficient, large-area, efficient, intelligent luminaire with outstanding light quality.

Introduction

Lighting represents almost 20% of global electricity consumption [1], similar to the amount of electricity generated by nuclear power and equivalent to 70% of the emissions from the world's light passenger vehicles. The development and implementation of more efficient lighting systems will undoubtedly make a significant contribution to controlling global CO_2 emissions. In addition, LEDs do not contain mercury, in contrast to high efficiency fluorescent lamps.

The high efficacy values, close to 60% for commercially available high-power blue and well over 120 lm/W for commercial cool white LEDs, achieved in the last years together with standard lifetime values in excess of 50,000 hours under continuous operation makes LEDs the most convenient light source for energy savings. In fact, LED technology is expected to conquer the lighting market in the coming years with a penetration rate of 56% by 2016 [2].

Large-area light sources represent the most convenient option when a large amount of light is needed and

	Highest Luminous Flux OLED	Largest Area OLED	Highest Efficacy OLED	Large-Area LED Module
Model	Philips FL300	LG N6SD30	LG N8SA30	LG Innotek ReflectA Free
Area (mm²)	102 x 102	320 x 320	100 x 100	600 x 600
Thickness (mm)	3.0 [1]	1.0 [8]	1.97 [12]	69.5
Luminous flux (lm)	300 [2]	850 [9]	75	3000
Efficacy (lm/W)	>50 [3]	60	80	97
CCT (K)	3000 [4]	3000	3000	3500
CRI	>80	>90	>80	80
LT70 (103 hours)	10 [5] 50 [6]	40 [10, 11]	50 [13]	~50 [16]
Cost (lm / $)	2.2 / 5 [7]	1.25 [15]	0.91 [14]	25.4 [17]

Table 1: **Performance comparison of current best commercially available OLEDs and standard LED-based large-area lighting modules (effective summer 2015)**

Please Note:
[1] Including thermal back plate, housing and wiring; [2] at 340 mA and 19 V; [3] at 300 lumen ; [4] 4000 K planned; [5] at 300 lumen; [6] at 125 lumen; [7] for orders above 40 OLEDs (http://www.oled-info.com/philips-launches-new-sales-campaign-sees-oleds-reaching-mass-market-early-2017); [8] bare OLED; [9] 1700 mA, 8.5 V; [10] at 3000 cd/m²; [11] using LG proprietary "Face Seal" technology; [12] with housing and wiring; [13] initial luminance not specified; [14] https://www.maritex.com.pl/en/oled-lg-chem-lighting/olp-n8sa30-i-34063-c-33634; [15] http://www.oled-info.com/lg-details-price-their-320x320-mm-and-truly-flexible-oled-lighting-panels; [16] not quoted for the lamp, given figure is based on the lifetime information of the LED chips; [17] http://www.futurelightingsolutions.com/en/Technologies/Semiconductors/Lighting-Solutions/LED-Light-Modules/Pages/3029132-LLFML66-38K308A.aspx?ManufacturerName=LG-INNOTEK&isFLS=true&IM=0

are, therefore, widely used in a variety of lighting segments including office, shop-retail, hospitality, industrial and architectural lighting segments, which are predicted to be worth 40 billion Euros in 2020 [3].

Organic light-emitting diodes (OLEDs), the organic counterparts of LEDs are flat, thin, surface emitting devices that have been seen as the "next big thing" in large-area lighting and the natural successors of LEDs for large-area products. However, several factors exist that are causing OLEDs to struggle on their way to the general lighting market and that, according to many, will likely prevent this ever happening.

On the one hand, OLED technology lags well behind LED in terms of efficacy, lifetime, lumen output and lumen-per-dollar. Indeed, the ever promised large-area, low-cost, solution-based R2R fabrication on flexible substrates is not even close to becoming a reality in the next years. On the contrary, commercially available OLEDs today are expensive, glass-based devices, manufactured using several expensive evaporation processes under vacuum in a sheet-to-sheet process and with emissive areas of typically 100 cm² or less (Table 1).

On the other hand, non-transparent, scattering out-coupling films used to boost device efficacy and to alleviate cavity-related angular color shift, are not compatible with appealing mirror-like or transparent off-state appearance, a many-times cited advantage of OLED technology.

Finally, most of the mentioned unique selling points of OLED technology such as large-area, low-cost, transparency and flexibility have continuously been eroded by LED-based technology. In fact, large-area, 600 x 600 mm², luminaires based on LEDs have been available on the market for a few years.

A common approach is to eliminate the hot spots associated with the LEDs by using a diffusing plate located a certain distance from the light sources. Regardless of its simplicity, uniform luminance completely free of appreciable hot-spots, requires a distance of a few centimetres between the LEDs and the diffuser, an approach incompatible with thin form-factors and/or device flexibility. Although diffusers with large hiding factors can be used in closer proximity to the sources, it comes at a substantial drop in efficacy as shown in figure 1.

A way to overcome this issue is the so-called edge-lit technology where the LEDs are distributed across at least one of the edges of a thin transparent plate. The light emitted by the LEDs is coupled inside the waveguide and guided through total internal reflection (TIR). Light extraction features replicated on the emissive surface/s of the waveguide disturb the TIR and allow the guided light to escape.

In large-area edge-lit luminaires, a large part of the emitted light has to be guided across long distances, which results in high optical losses even when relatively transparent materials such as PMMA are used (PMMA absorption coefficient of 0.0017 mm^{-1} [5] leads to 17% optical losses on a 100 mm length). In addition, since the waveguide perimeter increases only as the square root of its area, high LED densities are required as the emissive area increases which

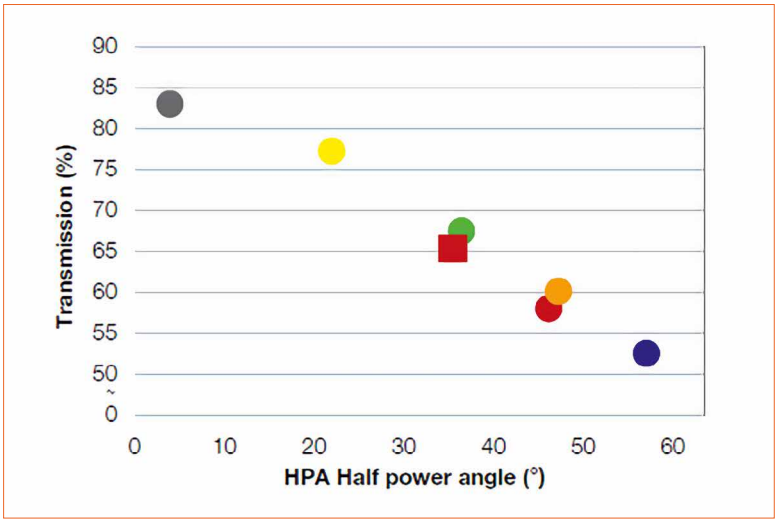

Figure 1:
Optical transmittance versus half power angle (hiding power) for diffusing plates based on volumetric scattering manufactured by Bayer; modified from [4]

demand efficient thermal management solutions to avoid excessive heat at the waveguide edges to prevent associated detrimental effects such as waveguide deformation and/or material yellowing.

A different approach consists in embedding white LEDs inside the waveguide, evenly distributed across its area [6]. This technology solves some, but not all the issues related to edge-lit. For example, moderate-to-high temperatures around the LEDs over sufficiently long time periods may degrade the waveguide material locally close to the LEDs. Therefore, unless an expensive, short-pitch LED configuration is adopted, the maximum attainable brightness of the luminaire is noticeably limited. Also, non-standard side-emitting LEDs or precisely tilted standard surface-emitting LEDs are required as otherwise most of the light will leave the waveguide without undergoing TIR, giving rise to appreciable hot-spots. Moreover, as the LEDs must be fully embedded into the waveguide, a minimum thickness of the latter is mandatory.

Our light management technology (patent pending) was designed and engineered to overcome the mentioned shortcomings. It is based on the use of diffractive elements and blue LEDs. By using diffractive nanostructures, light emitted around the normal to the LED surface can be efficiently in-coupled even for standard, surface-emitting, LEDs located outside the waveguide. The spatial separation of light emission and light guiding/out-coupling results in a minimum temperature-driven degradation effect in the waveguide material and allows the use of much thinner waveguides.

White LED emission can be achieved using the so-called multichannel or RGB approach. This approach uses a combination of red, green and blue LEDs (often 4 or 5 different “colors” are used). When appropriately driven, such combination produces a white light of a predetermined correlated temperature (CCT). Although compatible with CCT tuning, it suffers from low efficacy values at medium to low CCT values due to the low efficacy of green/amber LEDs in the so-called green gap. In addition, the spectral distribution of the resulting white light, formed by the superposition of few relatively narrow spectra, results in a substantial number of missing wavelengths and the consequent color misinterpretation, (poor color rendition) of objects with emittances around these wavelengths. Finally, the differential aging of the red, green and blue LEDs must be properly compensated to avoid undesired CCT shift during device operation.

Alternatively, in the so-called phosphor approach, a layer of a yellow phosphor-containing resin is deposited on top of a blue LED chip. Part of the blue light passing through the phosphor layer experiences Stokes down-conversion, resulting in a white emission whose CCT is determined by the composition of the phosphor layer and its thickness.

Phosphor-containing white LEDs give a much broader emission spectrum than CCT-equivalent RGB LEDs and hence better color rendition. In fact, CRI values as high as 98 have been reported using a combination of green, yellow and red phosphors [7] [8]. Moreover, with phosphors near to 100% quantum yields, phosphor white LEDs are also more efficient than RGB.

However, the phosphor approach also suffers from CCT shift and efficiency drop related to the wavelength shift of the pumping blue LEDs during operation and, more importantly, to the phosphor degradation and emission quenching observed primarily at high temperatures. For example, a 10% drop in down-conversion quantum efficiency or in the phosphor absorption coefficient (in the blue region) can cause a color shift close to a MacAdam ellipse step size 4 [9]. High temperatures also cause local delamination of the phosphor layer form the LED surface which results in a noticeable CCT shift [10]. These temperature-driven detrimental effects can be highly alleviated by locating the phosphor layer away from the emitting chip in what is known as remote phosphor approach.

Thin-Film Light Management Foil

Contrary to the continuous improvements in LED efficacy and optical power output, the secondary optics of large-area LED-based luminaires has not improved much [11]. Indeed, as mentioned earlier, today’s large-area LED luminaires, the spatial and angular distribution of the light emitted by the individual LEDs, is still controlled by thick volumetric scattering plates, distant

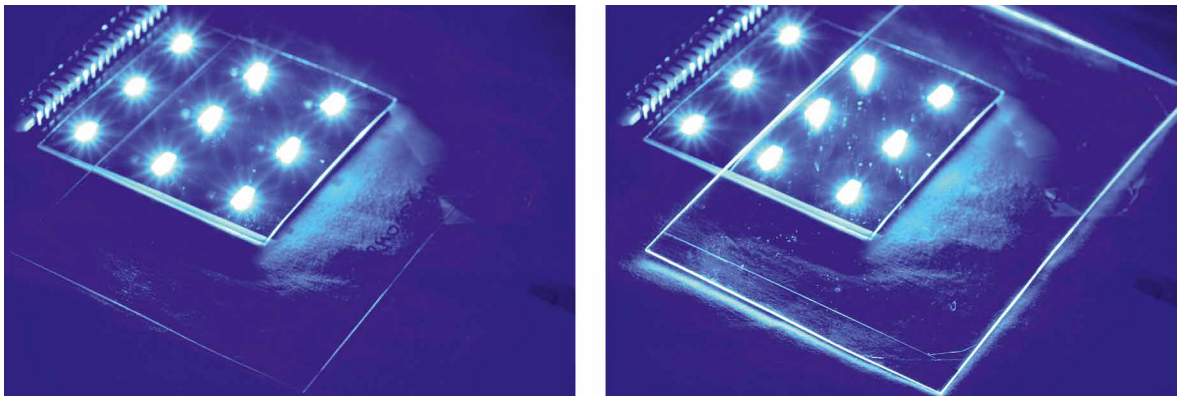

Figure 2:
Comparison of an LED array with a PC foil. The left image shows a misalignment of the gratings and the LED while the right image shows well-aligned, in-coupling diffractive elements

thin-film diffusers in combination with reflectors and/or refractors which results in bulky and heavy luminaires. Thin and light LED-based luminaires require alternative technologies.

Light in-coupling

In our solution, the light emitted by blue LEDs is in-coupling into a thin-film, flexible transparent waveguide through diffractive in-coupling elements replicated on the largest surface of the waveguide. The in-coupling diffractive elements are replicated in the form of pixels and distributed across the waveguide following the same pattern as the LEDs in the substrate. Each in-coupling pixel covers an area similar to that of the LEDs. When the waveguide is located at close distance from the LEDs and the in-coupling pixels aligned with respect to the sources, a substantial amount of the emitted light is in-coupled inside the waveguide.

This approach has the following advantages with respect to other approaches mentioned above:

- The decoupling of the light in-coupling from the waveguide edge allows using much thinner waveguides with the immediate reduction in weight and cost. In addition, the increased flexibility of the waveguide opens the door for Roll-to-Roll manufacturing
- The increased in-coupling area is compatible with higher LED density with still manageable integration of heat management solutions

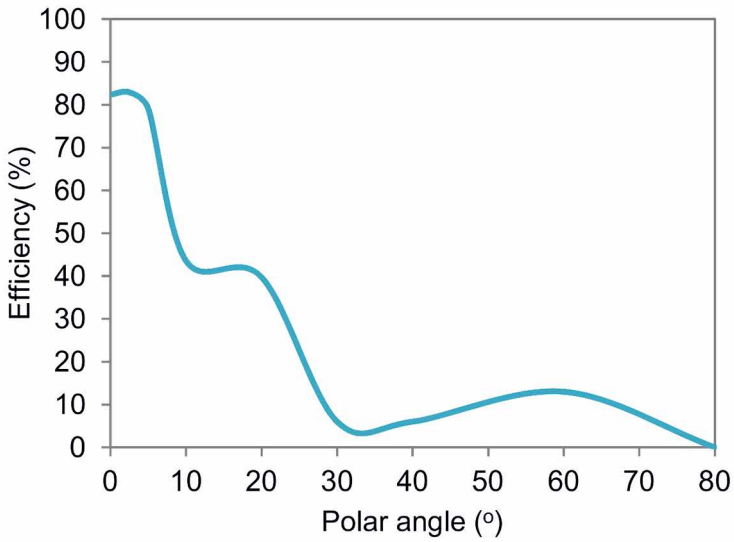

Figure 3:
In-coupling efficiency plotted as a function of the polar incident angle for 0° azimuthal incident angle

- The regular spatial distribution of the LEDs over the emissive area results in shorter light travel distances and hence, in lower optical losses in the waveguide
- The physical separation between the LED (i.e. heat) sources and the waveguide ensures the mechanical and optical integrity of the waveguide during device operation
- High in-coupling efficiency values of 50% have been theoretically predicted for optimized in-couplers in combination with lambertian blue LEDs. Higher values are expected when additional diffractive in-couplers are added on the top surface of the waveguide. Moreover, in-coupling efficiency values in excess of 80% are expected for polar incident angles between -10 and 10° with respect to the normal (Figure 3)

Figure 2 shows an array of pixelated in-coupling gratings replicated on a 0.5 mm thick PC foil located on top of a LED board (manufactured by VTT) comprising a 3 x 3 array of blue LEDs. On the left image no light in-coupling observed due to the misalignment of the gratings and the LEDs. On the right image a part of the light emitted by the LEDs is in-coupled into the waveguide by the well-aligned in-coupling diffractive elements.

In addition, each of such in-coupling pixels contains a series of 100 x 100 µm linear 1-dimensional gratings with optimum grating parameters with their grooves oriented in two perpendicular directions in a chessboard arrangement which ensures light in-coupling in two in-plane directions as shown in figure 4.

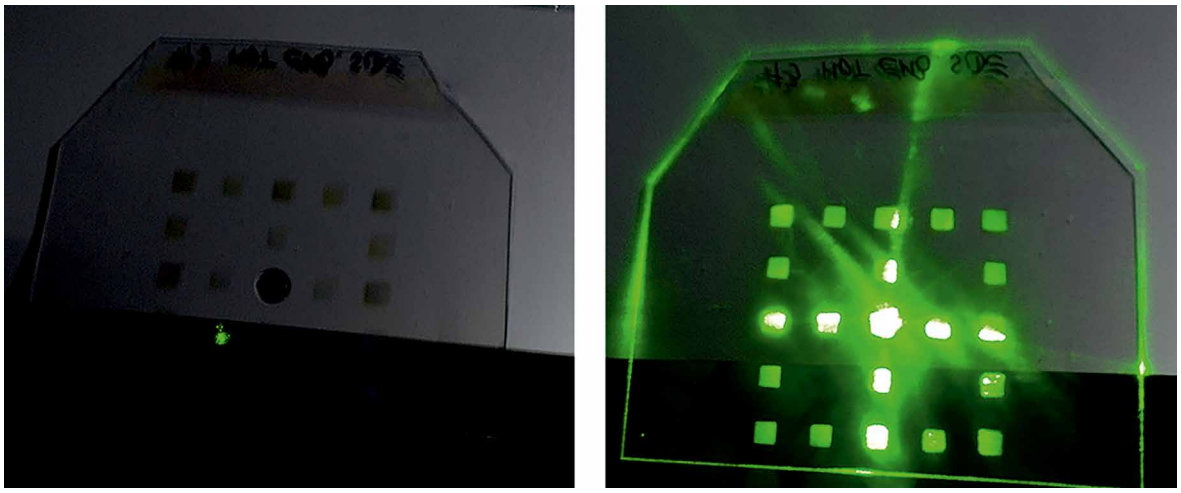

Figure 4:
Light in-coupling (and subsequent out-coupling) in two in-plane perpendicular directions as described in the article

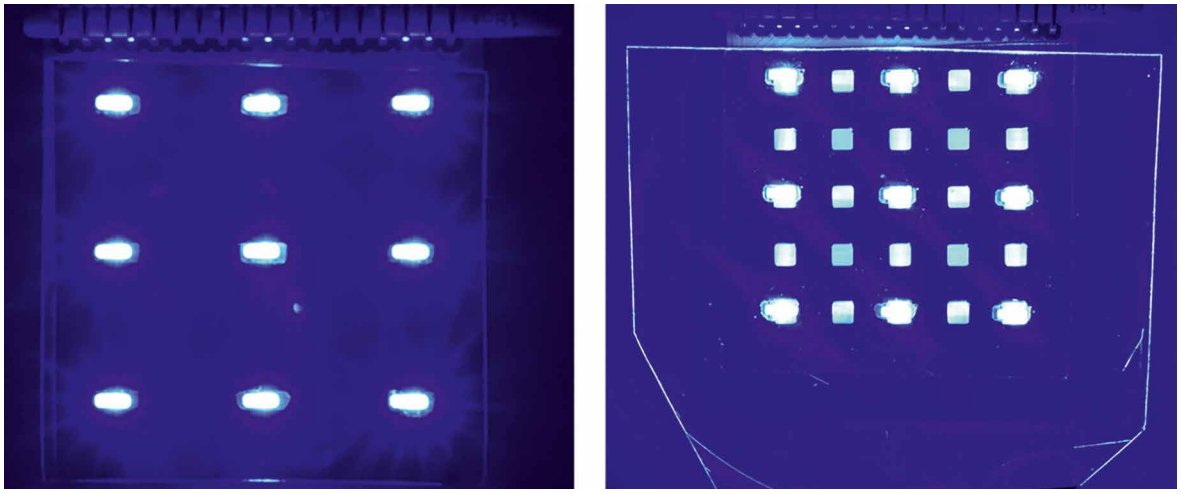

Figure 5:
Comparison of a 3 x 3 LED array without and with LM foil

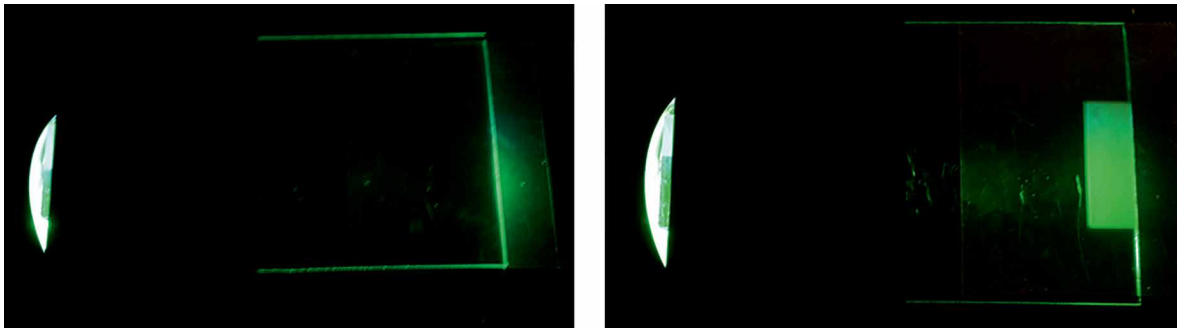

Figure 6:
Light edge-coupled into a 0.5 mm thick PC foil

Light out-coupling

The in-coupled light travels inside the waveguide based on total internal reflection, TIR, at the interface between the top surface of the waveguide and air. The TIR condition is disrupted by the presence of out-coupling structures allowing the in-coupled light to escape the waveguide.

For light out-coupling, our approach uses out-coupling pixels of similar size to the in-coupling pixels. They can be replicated on the top and/or the bottom surface of the waveguide and can comprise diffractive nano- (Figure 5) or refractive microstructures (Figure 6).

The left image of figure 5 shows a 50 x 50 mm^2 LED board with a 3 x 3 LED array fabricated by VTT. The right picture shows the same LED board an LM foil with a 3 x 3 array of in-coupling pixels aligned with respect to the LEDs and 16 out-coupling pixels; light in- and out-coupling is observed. A considerable amount of in-coupled light remains trapped and partially leaves the waveguide through its edges due to the relatively low out-coupling efficiency.

Figure 6 shows a light, edge-coupled into a 0.5 mm thick PC foil. In the left image, the light propagates via TIR through the waveguide and leaves primarily at the opposite edge. In the right image, the replicated microstructures disturb the TIR and force the light to be coupled out the waveguide; the light emitted through the opposite edge is negligible, indicative of high out-coupling efficiency.

This way, the light emitted by the LEDs is spread inside the waveguide and coupled-out towards the viewer.

CCF	Radiant power (W)	Luminous flux (lm)	u'	v'	CCT (K)	CRI	CRI9
A	0.445	128.39	0.2120	0.4753	5770	93.3	68.0
B	0.438	128.26	0.2348	0.5095	3546	93.9	77.8

Table 2: Photometric data of the down-converted white light using an array of blue LEDs (I_{max} = 460 nm) and two different CCFs from BASF

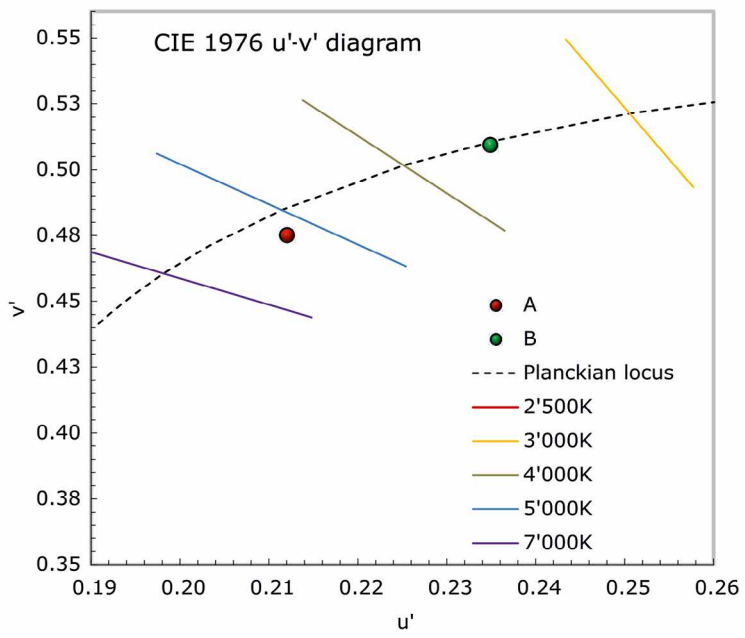

Figure 7: CIE1976 u'v' coordinates of the down-converted white light using two different CCFs from BASF in combination with a blue light of max 460 nm

Color conversion

The out-coupled blue light is down-converted using BASF (Ludwigshafen, Germany) proprietary thin-film color changing films (CCF) remotely located with respect to the LED sources.

By carefully engineering (for a given blue light source) the chemical composition of the individual dyes and their combination in the film, white light with a color of different CCTs along the Planckian locus can be produced. BASF CCFs contain organic phosphors that, due to the unresolved molecular vibrational levels, render a broad emission spectrum, which, in turn, results in high color rendering index (Table 2).

In addition, by carefully engineering the chemical composition of the individual dyes, their combination in the foil and the binding material, high efficacy and long lifetime has been demonstrated.

Conclusions

A new approach has been presented for the fabrication of thin-film efficient LED-based lighting modules compatible with R2R production. This approach has demonstrated the potential to overcome the fundamental limitations of current technologies for the fabrication of efficient thin-film lighting modules with high luminance uniformity and excellent spectral properties with a reduced number of LEDs. ■

Acknowledgements:

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References:

[1] http://www.photonics21.org/download/SRA_2010.pdf
[2] A. Prasad, "2015 Year of (LED) Light", LED Professional 47, pp. 32-36 (2015)
[3] Lighting the way: Perspectives on the global lighting market, 2nd Edition, McKinsey and Company (2012)
[4] www.plastics.bayer.com/~/media/Product%20Center/PCS/Images/5_Library/Broschueren/ LED%20Brochure/ MS00069823_LED-Brosch.ashx
[5] J-P. Lauret, "Selecting the Ideal Material for Improved Optical Solutions", Proc. LpS2014 pp. 228-237.
[6] J. Gourlay, "Making Light Work - Light Sources for Modern Lighting Requirements", LED Professional, 47 (2015) pp. 72-75
[7] J. Carey, "Intematix expands phosphor development and IP to meet demanding SSL applications", LEDs Magazine, March 2014, pp.21-25
[8] R. Mueller-Mach, G. Mueller, M.R. Krames, H.A. Höppe, F. Stadler, W. Schnick, T. Juestel and P. Schmidt, "Highly efficient all-nitride phosphor-converted white light emitting diode", Physica Status Solidi (a), 202 (9), pp. 1727-1732 (2005)
[9] C. Sommer, P. Hartmann, P. Pachler, H. Hoschopf, F.P. Wenzl, "White light quality of phosphor converted light-emitting diodes: A phosphor materials perspective of view", J. Alloys Comp. 520 pp. 146-152 (2012)
[10] R.C. Tuttle, "Method for Projecting Color Shift of High-Power LED Package", Proc. LpS2014, pp. 46-54.
[11] M. Macha, "Optomechanical Nanostructures for Overcoming Fundamentals in Optics Design", Proc. LpS2014, pp-214-219

Advanced Bluetooth 4.0+ based Smart Lighting Technology

Smart lighting and lighting controls are not restricted by hardware or traditional lighting control protocols anymore. Today, system modifications and firmware updates can all be done over-the-air. Wireless technologies enable lighting controls in places where it was not an option before. Besides Bluetooth, Zigbee and WiFi there are proprietary technologies in use. Saara Guastella M.Sc. in Lighting Engineering and Lighting Controls, is Product Marketing Manager at Casambi. In the following article she introduces Casambi's technology based on Bluetooth Low Energy, and describes, explains and compares it with other established communication technologies for smart lighting.

Many of us remember Bluetooth Classic from our first mobile phones; the battery consuming, wireless alternative to RS-232 cables, invented by Ericsson in 1994. It is important to understand that Classic Bluetooth and Bluetooth Low Energy are not the same thing. Bluetooth Low Energy is not just another Bluetooth revisionn - it is a completely new technology.

Bluetooth Low Energy, also called Bluetooth 4.0+, Bluetooth Smart or simply BLE, was originally designed by Nokia as Wibree before being adopted by the Bluetooth Special Interest Group (SIG) and published in 2010. The low energy functionality of BLE allows developers to make products that run on small coin-cell batteries or energy-harvesting devices, making BLE a good protocol to be used in wireless lighting control applications.

A New Technology Approach

The new wireless lighting control solution is based on BLE but it is not just a wireless lighting control system; it is its own technology. On top of BLE, this technology provides a mesh network where all the intelligence of the system is replicated in every node and, in such a way, creates a system with no points of failure. Such a self-healing and self-organizing wireless mesh network can control a large number of fixtures from any point. It also allows for firmware updates over the network, allowing any kind of changes to be made over-the-air and, in that way, to be truly wireless. In this kind of fully distributed and symmetric architecture, any unit can go offline and catch up to others when they return back online. Internet connection is only needed for user interface configurations for smartphones and tablets via cloud service.

An implemented firmware-over-extension-interface offers unlimited possibilities on what can be controlled/reported from the system to the client's user interface. The technology works with any manufacturer's range of existing luminaires or already installed wall switches but can also be easily integrated into LED drivers, LED bulbs or LED modules.

Essential Distinguishing Marks

No gateways

BLE was built for Internet of Things (IoT) and has been implemented in smartphones and tablets since the beginning of 2012. This means that no gateway modules or any kind of dongle is needed to control lighting via BLE, which makes a BLE - based lighting control solution more cost effective than solutions built on other wireless technologies. Other technologies, like WiFi and Zigbee, require a gateway module between the control device and the network.

Solving interference issues

WiFi, Zigbee and Bluetooth all operate on the 2.400 - 2.4835 GHz ISM band. However, BLE is more robust and not as sensitive to interferences as WiFi and Zigbee. WiFi uses Direct Sequence Spread Spectrum (DSSS) and therefore

does not hop or change frequency but remains centered on one channel that is 22 MHz wide. While there is room for 11 overlapping channels in this 83 MHz-wide band, there is only room for three non-overlapping channels. Thus there can be no more than three different WiFi networks operating in close proximity to one another.

For each WiFi channel, there are four overlapping ZigBee channels, as Zigbee breaks the band into 16 channels. Zigbee also uses DSSS as WiFi. When a WiFi network is on the same channel as a ZigBee network, the WiFi network will usually interfere with the ZigBee network. As a Zigbee lighting control solution also needs a gateway for a smartphone or tablet solutions, and as this gateway in most cases is WiFi, some serious coexistence problems are to be faced.

BLE operates in a different manner than WiFi or Zigbee. BLE uses Frequency Hopping Spread Spectrum (FHSS) which means it hops between channels to counteract interference problems. BLE specifies 40 channels, separated by 2 MHz, of which 3 channels are used as advertising channels and 37 are used as data channels.

Single point of failure

A single point of failure (SPOF) is a critical part or component of a system that, if it fails, will stop the entire system from working. SPOF are, for example, routers, proxies or other physical or virtual web or application nodes. A comparison of the network topology and setup of WiFi, Zigbee and BLE shows that WiFi and Zigbee solutions are not as reliable as BLE-based solutions, as shown in figure 1.

Proximity sensing

A technology that BLE enables, which is not possible with Zigbee or WiFi, is the Beacon technology. Beacon technology enables location awareness and acts based on proximity estimations. A beacon establishes a region around it and understands when a beacon-receiving device has entered or left this region based on proximity information. A device entering the region can determine if it wants to receive the information sent to it or not.

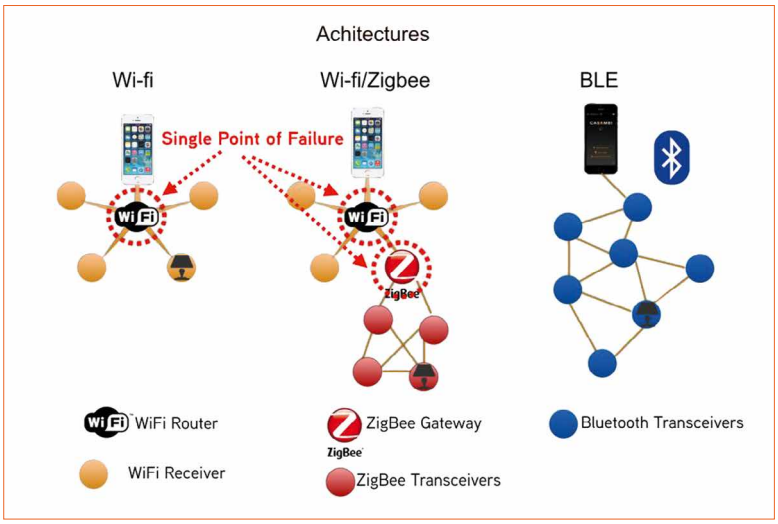


Figure 1:
Network structures and SPOFs

Beacon transmitters could be placed basically anywhere, but it is quite logical to place them inside luminaires. Luminaires already cover the whole area people move around in and they already have their power installed in the building. Luminaires also tend to light up some kind of object and whether the object is a piece of art in an art gallery or a car at a car retailer, a beacon receiver can trigger an app to display information about the object in question. If beacon technology is already integrated in lighting modules, no additional investment needs to be done for these services.

How the iBeacon Technology Works

BLE communicates on so called "advertisement channels" where small packets of data are broadcasted at regular intervals. This kind of advertising is also called beaconing. Devices like smartphones can be used to collect the sent data and use it for a variety of applications to trigger actions or push messages.

Apple introduced iBeacon, a protocol based on BLE for advertising in 2013.

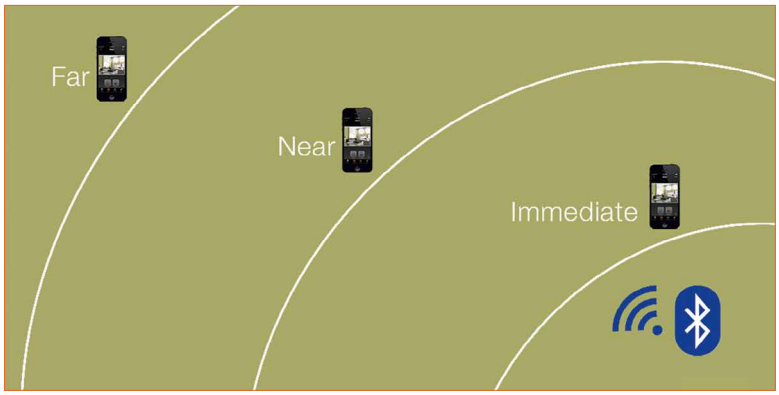
An iBeacon advertisement provides the following information via BLE:

- **UUID:** A 16-byte Universally Used Identifier string used to differentiate a large group of related beacons
- **Major:** A 2-byte string used to distinguish a smaller subset of beacons within the larger group
- **Minor:** A 2-byte string meant to identify individual beacons
- **Tx Power:** Used to determine proximity (distance) from the beacon. It is defined as the strength of the signal exactly 1 meter from the device

Example:
A computer shop chain has different discounts in different countries. The computer shop chain has an app that listens to iBeacons and the chain wants to inform its clients of the relevant discounts for the app users. The computer shop would define a unique identifier, the UUID, which only their app will react to. Therefore, the UUID would be specific for the computer shop chain, but the same in the whole of Europe. The major value of the beacon would be different depending on the country. The minor value would be different depending on where in the shop it is situated. One beacon transmitter would be by the laptops, one by the screens and one by the cables. A person entering a computer shop

Figure 2:
A typical Bluetooth 4.0 lighting mesh network configuration

Figure 3:
iBeacon technology allows different levels of interaction at each range



of that particular chain in Spain and walking by the computers would get a message that a specific computer is on discount, while a person entering the same chain's computer shop in Norway would get a discount notification on another product with another price and currency. As the same user would walk over to the area of computer screens, another message would pop up.

When a device detects a beacon signal, it uses signal strength to determine the proximity, as well as the accuracy of its estimation of proximity to the beacon.

The estimate is according to one of the following four states:

- **Immediate:** A high level of confidence that the device is physically very close to the beacon. Very likely being held directly up to the beacon.
- **Near:** Proximity of about 1-3 m
- **Far:** This state indicates that a beacon device can be detected but the confidence in the accuracy is too low to determine either Near or Immediate
- **Unknown:** The proximity of the beacon cannot be determined

Obstacles between the beacon and the receiving device can affect the signal strength. As mentioned before, the four states are not only based on proximity but also the accuracy of the estimation. For example, "Far" does not necessarily mean that the device is physically far from the beacon, it can also mean that the accuracy has been affected.

Applications

Well-suited applications for iBeacons are museums and retail. Instead of using an audio guide the museum visitor can download a museum app that is able to receive information from beacon transmitters. These units can be placed, for example, in the driver of the luminaire and the luminaire would obviously be lighting up a piece of art. When the museum visitor is in the proximity of the art piece his/her app will display the information on the piece that has been sent by beacon technology over BLE. In retail applications, beacon technology allows marketing and guidance, information on happenings and discounts in the stores to be sent to smartphone users.

In the lighting application this kind of proximity sensing technology can be used for triggering lighting scenes. Not only predefined scenes that are common in the lighting control industry but actually user-specific scenes. Lighting can be used for guidance, to find the right path to the end goal where the user is heading to or as a "follow me" functionality; meaning that lighting is turned on only where the user i s situated and needs it.

Beacon technology could be used in car parks as navigation help to find where a car was parked, in coffee shops and kiosks for ordering processes, at airports for gate navigation, in zoos to provide information on animals or at bus stops to tell the timetable for buses at that particular bus stop. As the technology enables location awareness and knows when a user enters or leaves a certain area there are an enormous amount of benefits from this technology.

Security

GPS and GSM based location services are widely used for outdoor applications. However, they do not work very well indoors. The location platforms that BLE enables for indoor applications gives a lot of opportunities. It is also important not to mix beacons with GPS locations. A beacon is not a physical location; it is a transmitter that can be placed anywhere and have its location changed at anytime, while GPS locations are always there, forever fixed and public for everyone. iBeacons have a unique identifier: If the receiver does not know this UUID, it will never know it is there.

iBeacon technology is also different from other location-based technologies as the transmitter only sends out one-way communication. This ensures that only a user that has installed an app that can

receive that particular beacon's information will receive it. The user must not only have installed the app but also given permission to the app to listen to beacons. This means that the user gives the permission to the app to track the user. As the beacon technology is not based on two-way ommunication, this means that no beacon transmitter can track users as they walk past transmitters.

Conclusion

The lighting and the lighting control industry is being disrupted by semiconductors, software and wireless technologies. New players on the market overlook traditional lighting control protocols and introduce sophisticated wireless lighting control systems to the market that provide for the same, if not for more, functionalities and with more benefits.

"Why now?" many might wonder. Before the launch of Bluetooth Low Energy there was not a well-suited wireless protocol that would have enabled all the functionalities and benefits that BLE does. The fact that BLE is integrated in smartphones and tablets is the core benefit that makes BLE a mainstream, most cost effective and the only truly future proof of the wireless technologies. ■

Power over Ethernet Lighting for Commercial Buildings

Today, information technology (IT) and lighting are separate worlds. It is necessary to create a bridge between these worlds, not only from a technical standpoint but also from the perspective of understanding what is important to each industry. Giovanni Frezza, Group Product Manager at Molex, discusses how LEDs and PoE may pave the way with new power standards: LEDs far outperform the lumens output of older lighting technologies. Today, the PoE standard for LED is 30 W. An UPOE standard for 60 W is in the works, and an expansion called BP is in progress for up to 95 W.

Power over Ethernet (PoE) lighting is beginning to transform the lighting industry and the industries it serves. While the concept is being used in commercial buildings, it is poised to break out in 2016 as large-scale projects get underway. Growing affordability and higher efficiencies are driving the use of PoE lighting in commercial buildings, making possible concepts such as the smart building and other applications that drive efficiency and productivity. Innovative owners of enterprises and buildings are beginning to perceive PoE lighting infrastructure as an asset that enables practical applications for the Internet of Things (IoT) and smart buildings while adding significant value to buildings and companies.

While still in an early stage, LED penetration in commercial buildings is reaching critical mass, making it cost competitive with other lighting technologies and enabling deeper market penetration. This represents one of the key elements driving the introduction of PoE lighting. New commercial buildings are the best candidates for PoE lighting systems, which can be designed as part of a building's infrastructure but deep retrofit projects are appropriate as well. There have been significant pilot installations of PoE lighting in commercial buildings but, as mentioned above, several larger scale installations are being developed.

New Control Methods

The adoption of LED fixtures in commercial buildings is accelerating interest in PoE lighting because more efficient and higher performance control makes it more affordable in commercial buildings. To date, the lighting industry has focused mostly on retrofitting existing lighting fixtures with LEDs to replace older technologies, such as fluorescent and compact fluorescent lighting. Controlled LED, however, not only improves efficiency but also provides better light quality, smoother intensity/dimming control, and dynamically adjustable color temperature, providing the right light when and where it is needed. This results in augmented worker comfort and more interactive and purposeful lighting and spaces for people. The ability to migrate lighting control to network IP-based infrastructure

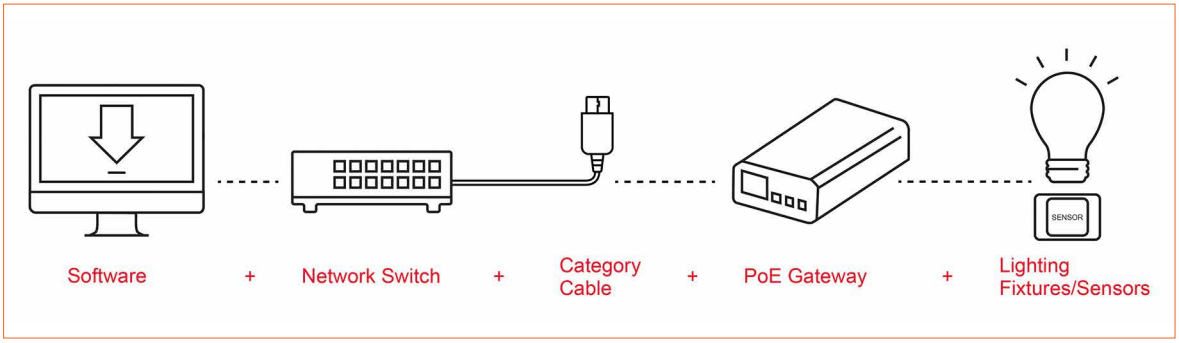


Figure 1: A schematic of the Transcend® Network Connected Lighting, a PoE lighting system. Transcend comprises software, networking technology, category cables, sensors, a PoE gateway, and can be used for lighting fixtures from various manufacturers

makes lighting a service and an IoT building asset that can be controlled synergistically along with other building functions.

It is important to note the difference between smart lighting and PoE lighting. Smart lighting does not necessarily need to be connected to a central network, and can be implemented simply by retrofitting older lighting fixtures with individual LEDs and sensors capable of simple, local control. PoE lighting, on the other hand, requires a centralized, software-based control system that coordinates all the elements in the lighting system, including luminaries, sensors, actuators and other devices. Lighting infrastructure is always present in a building and it's very granular. More integration means not only better control but also more data and information being collected by a distributed sensor system as part of the lighting network.

These data have the potential to open up a new value proposition for commercial buildings. The first application is, of course, real-time energy usage reporting, but other applications - such as sensor-based occupancy reporting, light status and environmental monitoring - provide an entirely new view into how commercial buildings are used. By analyzing this data, it is known how many people are in the building at given times, where they are located, how spaces are being utilized, the condition of those spaces and how usage of different areas of multi-floor and multi-building campuses compare to each other. All told, PoE lighting will dramatically accelerate the integration of the IoT into commercial buildings.

Key Obstacles

While progress is being made in the deployment of PoE lighting systems, several obstacles to deeper market penetration must be resolved.

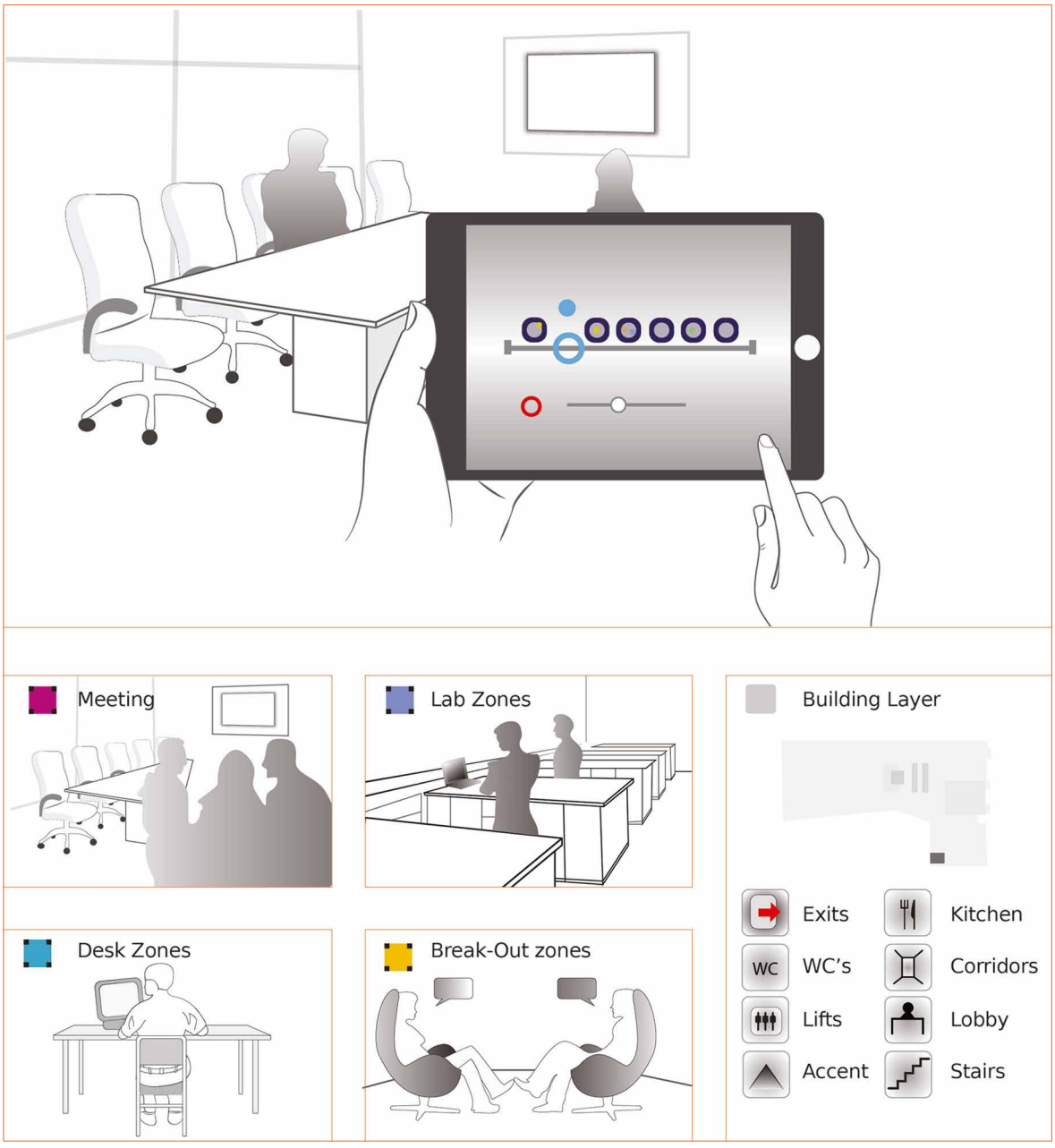


Figure 2:
Technology integrated within PoE lighting systems allows for full customization. End users can adjust lighting needs based on defined zones

Figure 3:
PoE lighting system modules (top right) allow lighting designers to implement a variety of lighting methods, including directed, indirect, ambient, and decorative

Today, traditional connected lighting systems are difficult to design and commission. The installation, configuration and commissioning process must be simpLi-Fied and standardized, which will boost adoption significantly.

Also, PoE lighting systems need to be easily understood by lighting architects, building owners, facility managers, installers and users to truly unlock the value associated with these systems. The lighting infrastructure and its installation cannot be disruptive to the management of the building. In addition, the software used to control PoE lighting systems must be very simple and user friendly.

To date, the majority of installed PoE lighting systems are based on proprietary systems, but the industry needs open standards and interoperable systems that can simplify integration with the rest of the building automation network.

New Power Paradigm

PoE is one of the most promising technologies allowing IP convergence for building automation networks (BANs) - including lighting - without the use of proprietary systems. LED technology requires low-voltage DC power in a different manner than older lighting sources, which utilize AC power that has been converted to low-voltage power. A smart PoE lighting system requires low-voltage power distribution and data communication for control. Distribution of power and data on low-voltage cabling is possible using the same infrastructure that the IT industry has deployed for 15 years, allowing growing penetration of LED lighting in indoor areas for various applications, such as data centers, office spaces, educational institutions, healthcare, and hospitality.

PoE delivers electrical power over category cabling to networked devices and is widely deployed to provide power to various endpoints in commercial buildings, including VOIP, cameras, HVAC and now lighting. PoE offers high availability for power, guarantees uninterrupted service and lowers operating expenses by providing network resiliency at a lower cost by consolidating backup power. It also offers faster deployment of new networks by eliminating the need for a power outlet at every endpoint.

PoE Requirements

PoE is a well-defined technology through IEEE802.3, which specifies the physical and data link layer media access control (MAC) for wired Ethernet networks. A PoE network includes PSEs (power sourcing equipment) and PDs (powered devices), with the PSE using two-pair or four-pair connections to transmit power. The PD negotiates with the PSE, according to a specification, to establish the appropriate communication protocol between the devices to deliver power and create a link to exchange data.

The driver of LED efficiency is its outstanding lighting output per watt of power, which far outstrips that of older lighting technologies. While already advanced, LED technology is becoming more versatile, efficient, secure and capable of supporting available wattages in PoE lighting systems according to the IEEE 802.3xx standard. This standard has been proven as a mechanism for classifying the endpoint devices needed to establish power connections.

For example, the original PoE standard IEEE802.3af, based on 15.4w per switch port of power, has increased to 30 W in PoE+ (IEEE802.3at), today's standard. However, a new de facto-standard has been developed called UPOE, which delivers 60 W per switch port. The standard is due to change again soon with the recently introduced Power over HDBaseT (POH) standard, which supports over 95 W per port. The IEEE is working to standardize the 60 W and 95 W PoE options under the 802.3bt specification, which should be completed in 2017. The technology is backward compatible and interoperable with the existing IEEE standard.

The 60 W and 95 W standards are based on using a four-pair power transfer format rather than the two-pair format used by the 30 W PoE+ standard. The new standards improve efficiency and allow a much wider range of device support while using the same low-voltage Class D (Cat5e) cable as the PoE+ standard.

In the existing PoE+ standard, a two-pair 30 W system delivers electrical power over two of the four available twisted pairs in Cat5e cabling. In this system, the pairs 1, 2 and 3, 6 are used to transport power from the PSE

to the PD and the spare pairs (4, 5 and 7, 8) are idle. The 60 W UPOE standard uses the same cabling as the 30 W PoE+ standard, but while the two-pair system uses one PSE controller to power the PD through the signal pairs of the cable, a four-pair system uses two PSE controllers to power both the signal pairs and the spare pairs.

Because it uses all four twisted pairs to deliver power, UPOE can deliver more power and is more efficient than PoE+, reducing channel losses. More specifically, a UPOE PD node can receive up to 51 W of power, enough to support lighting requirements in a wide variety of indoor applications. It also offers the possibility to optimize the low-voltage cable infrastructure by daisy-chaining multiple devices on a single UPOE port, reducing the number of ports and amount of cabling required on a system.

Cabling Architecture

In the IEEE PoE standard, the maximum allowable cabling length is 100 m (total) between the PSE and the PD, which allows the development of a single lighting system for about 15,000 square feet of space. Strategies for optimizing the low-voltage cable infrastructure required for PoE lighting have led to several system architecture innovations, allowing lighting architects to re-think interior commercial spaces and how to redesign IT closets to support BANs and traditional IT applications.

PoE lighting networks also require new expertise in the design of cabling architecture and infrastructure in order to support efficient PoE lighting deployment. Companies that develop and possess this know-how will be the ones with the capacity to efficiently scale the technology. The challenge will be to develop efficient, deployable, reliable and commercially successful PoE lighting systems on a large scale, but the tools are already available to do that. Moving forward, large-scale deployments will become more common.

The key will be optimizing the low-voltage cable infrastructure to deploy power and data in a more convenient way. This will require a hybrid deployment of technologies, including PoE and distributed power conversion. Another issue will be limiting power losses over the low-voltage cable infrastructure. Molex is implementing a PoE lighting architecture that reduces power loss to below 5% on category cables.

Power losses can also be reduced by using heavier gauge cable. While CAT 5e, 24-gauge cable is the minimum that can be specified for a PoE lighting system, as a best practice we recommend CAT 6, 23-gauge. We design PoE lighting systems that minimize the bundle size for cables (usually fewer than 48 cables per bundle). In general, the recommended maximum bundle size is no more than 98 cables to keep heat within an acceptable range; if temperatures exceed pre-specified limits, power must be reduced.

Advantages of PoE

PoE lighting is practically the only effective technology that allows power and data on the same low-voltage cable infrastructure; any other connected lighting system requires a dual layer infrastructure: one to distribute power (i.e., AC main) and another to provide communication, data and control on low-voltage cables or wirelessly.

In new construction, the installation of PoE lighting fixtures is much simpler and faster than the installation of a

traditional hard-wired AC/DC distributed lighting system. PoE lighting elements do not require the use of an electrician and are powered/connected with an RJ45 connector. Because low-voltage cabling is installed as part of an IT system, no additional costs for control are required for a PoE system, and commissioning is very simple because each lamp receives an IP address.

Also, if you need to change a control scheme or rearrange a configuration in a traditional lighting system, the wiring scheme must be completely reworked, which is a time-consuming and expensive process. PoE lighting, however, is totally configurable. If you are reconfiguring office spaces, for example creating rooms from open space or vice versa, you can change zoning and control in a PoE lighting system by simply re-assigning sensors; no re-wiring is required.

The advantages of PoE lighting can by summarized as follows:

- Power and data over single-layer infrastructure
- Uses DC power - ideal for LEDs
- Is low-voltage and safe to install; no certified electrician required
- Uses ethernet standards
- Is future proof and upgradable; each light and sensor has an IP address that can be re-configured at any time
- Software and firmware upgrades can be made from the network without the need to change hardware
- Advanced control is possible: a PoE lighting system can include tunable luminaries and incorporate dynamic/bio-adaptive control. Lights can be used to communicate information to users
- Can be integrated with other systems
- Highly secure
- Creates the possibility for new data analytic schemes

New Lighting Paradigm

Through the development of new products and new, more efficient standards, PoE lighting is rapidly becoming a key part of commercial building design, and companies that create enabling technology for this new technology will help drive the industry through the transition.

Also, keep in mind that, as with any new technology, potential new benefits of PoE lighting will likely emerge. As commercial buildings migrate to the IoT via IP protocol, that opens the door to big data analytics, and the long-term significance of that development as part of the value proposition for PoE lighting is just becoming understandable. ■

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Create Colorful and Bright LED Light with an LED Matrix Dimmer

RGB LEDs are quite common and used in many applications today. More advanced multi-color solutions like RGBW, RGBA or RGBWA offer huge advantages over RGB solutions, but several aspects are more complicated. Keith Szolusha, applications engineering section leader for power products at Linear Technology explains the advantages of RGBW systems, how they work, how to set up such systems, and how to drive them correctly using Linear Technology's LT3965 8-switch LED matrix dimmer in combination with the LT3952 boost-buck LED driver as an example.

RGB LEDs are used in projector, architectural, display, stage and automotive lighting systems that require efficient, bright output. To produce predictable colors from an RGB LED, each of its component LEDs (red, green and blue) requires individual, accurate dimming control. High-end systems can use an optical feedback loop to allow a microcontroller to adjust the LEDs for color accuracy. Adding a white LED to an RGB LED to produce an RGBW LED extends the hue, saturation and brightness values available in the color system. Each RGBW LED requires accurate dimming of four component LEDs. Two RGBW LEDs require eight "channels."

There are various ways to drive RGBW LEDs for color and brightness control. One way to drive and dim RGBW LEDs is to use four separate LED drivers, one for each color as shown in figure 1a. In such a system, the LED current, or PWM dimming, of each individual LED or string is driven by separate drivers and control signals. In this solution, though, the number of LED drivers increases quickly with the number of RGBW LEDs. Any lighting system with a significant number of RGBW LEDs requires a substantial number of drivers and synchronization of the control signals to those drivers.

A much simpler - and more elegant - approach is to drive all of the LEDs with a single driver/converter at a fixed current, while using a matrix of shunting power MOSFETs to PWM dim the individual LEDs for brightness control. The matrix dimmer and single LED driver shown in figure 1b reduces the circuit size of the figure 1a solution. Furthermore, a single communications bus to control the matrix LED dimmer makes RGBW color-mixing LED systems relatively simple and compact, while driving high current RGBW LEDs with accurate color and brightness control.

The LT3965 matrix LED dimmer enables such a design, as shown in figure 5. Each of these 8-switch matrix dimmers can pair with exactly two RGBW LEDs, allowing control of the individual brightness of each LED (red, green, blue and white) in PWM steps of 1/256 between zero and 100% brightness. Two-wire I^2C serial commands provide both color and brightness control to all eight channels. I^2C serial code to the matrix LED dimmer IC determines the brightness state of all eight LEDs and can check for open and short LEDs in case of a fault.

Since each RGBW LED is designed as a single point source, the red, green, blue, and white light combine to produce color variety, with saturation, hue, and brightness control. Each LED can be set in 1/256 steps between zero (0/256) and 100% (256/256) with this high-speed matrix dimmer.

Accurate Full Range RGBW Color and Brightness Control

RGBW LEDs can produce accurate color and brightness with PWM dimming of the individual component red, green, blue and

white LEDs. Individual PWM brightness control can support 256-to-1 or higher dimming ratios. An alternative to PWM dimming is to simply reduce the drive current for each LED, but accuracy suffers in this method, allowing only 10-to-1 dimming ratios, and incurring color drift in the LEDs themselves. A matrix dimming approach using PWM dimming outperforms drive-current schemes in accuracy of color and brightness.

The bandwidth and transient response of the LED driver (the source of the 500 mA LED current) affects the color accuracy. With over 10 kHz crossover frequency and little or no output capacitor, the compact boost-buck converter in figure 5 reacts quickly to changes in the number of driven LEDs as the matrix dimmer turns its switches on and off.

To illustrate how important this is to accuracy, red, green and blue LEDs are run separately at different PWM duty cycles and measured for light output with an RGB optical sensor. The results in figure 2 show uniform slopes of each color from 4/256 to 256/256, with a slight change in slope below that. Of course, red, green and blue LEDs are not perfect in their color, so some color from other bands sneaks out even when only one is driven. Overall, this is a highly accurate system.

Accuracy can be improved down to 1/256 PWM dimming using a very high bandwidth (> 40 kHz) buck converter LED driver, but that involves either the expense of adding another step-up converter to create a regulated, greater than 30 V output voltage, or having an input voltage source above 30 V. Unless a high level of accuracy at extremely low light is necessary, there is little reason to forgo the figure 5 boost-buck's versatility, simplicity and compact size by adding an extra converter.

The matrix dimmed RGBW LED color mixer system described here achieves a broad color gamut, as shown in figure 3. Adding additional colors, such as amber, can expand the gamut. RGBWA LEDs (with an amber LED) can produce deep yellows and oranges that RGBW LEDs cannot. These LEDs can also be driven with the matrix dimmer, but the eight channels of the matrix dimmer match well to two RGBW LEDs.

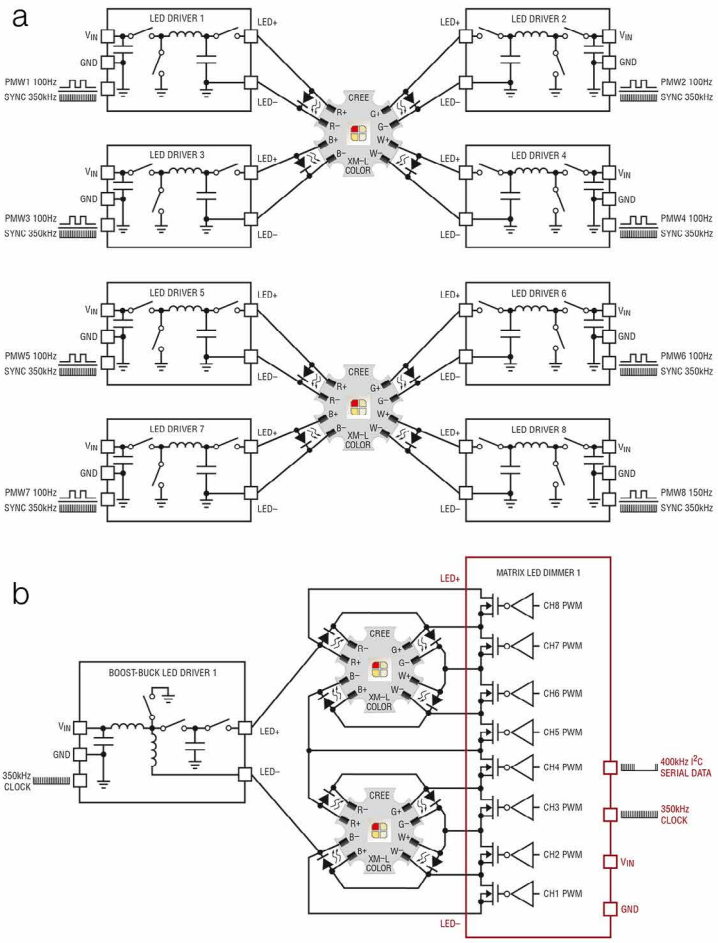
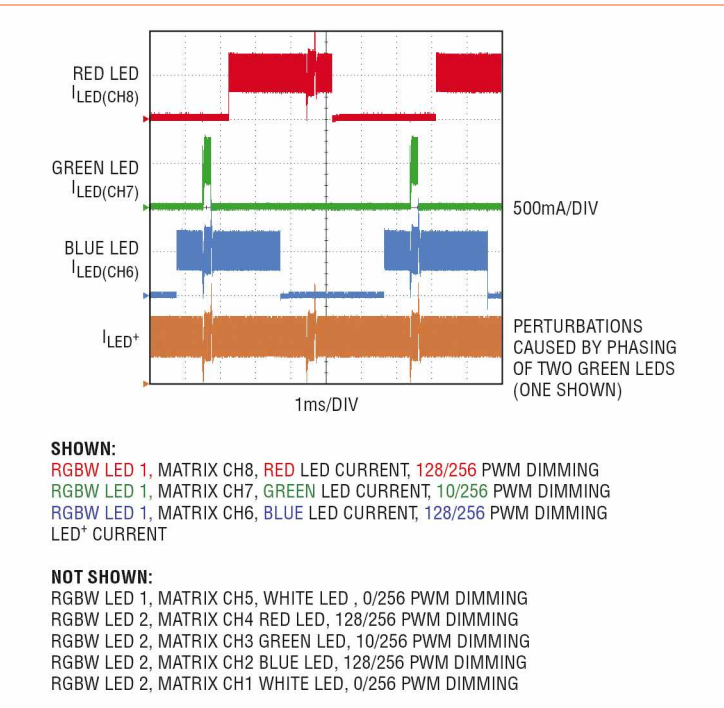


Figure 1 a&b:
(1a) Eight separate LED drivers and PWM signals can be used to drive two RGBW LEDs in a high power color-mixing application or (1b) a single boost-buck LED driver and matrix LED dimmer with serial communications can be used for a much smaller and compact solution



SHOWN:
RGBW LED 1, MATRIX CH8, RED LED CURRENT, 128/256 PWM DIMMING
RGBW LED 1, MATRIX CH7, GREEN LED CURRENT, 10/256 PWM DIMMING
RGBW LED 1, MATRIX CH6, BLUE LED CURRENT, 128/256 PWM DIMMING
LED+ CURRENT

NOT SHOWN:
RGBW LED 1, MATRIX CH5, WHITE LED , 0/256 PWM DIMMING
RGBW LED 2, MATRIX CH4 RED LED, 128/256 PWM DIMMING
RGBW LED 2, MATRIX CH3 GREEN LED, 10/256 PWM DIMMING
RGBW LED 2, MATRIX CH2 BLUE LED, 128/256 PWM DIMMING
RGBW LED 2, MATRIX CH1 WHITE LED, 0/256 PWM DIMMING

Figure 2:
Red, green, blue, and white brightness control versus 0-256 (out of 256) PWM dimming duty cycle controlled by the matrix LED dimmer when paired with the LT3952 boost-buck LED driver in figure 5

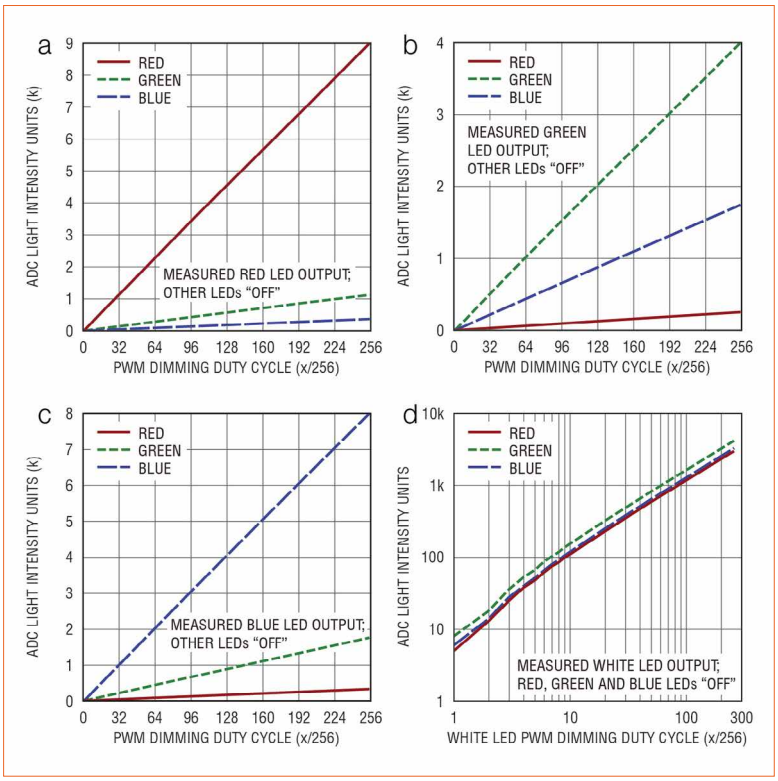


Figure 3: RGB LEDs feature a wide color gamut. Adding white is one way to simplify the algorithmic mixing of specific colors. In some mixing schemes, white is used to change the saturation, while red, green and blue set the hue

The 256-level dimming scheme easily translates to typical RGB paint programs and common color-mixing algorithms. For instance, if a standard PC paint program is opened, one will see that colors are mixed using a 256-value RGB system, as shown in figure 6. For example, the LED current waveforms in figure 4 produce purple light from an RGBW matrix LED system controlled by a basic PC-based paint program. Because the design described in this article produces accurate current drive and PWM control, RGBW LEDs can be predictably color-calibrated by adjusting the duty cycles of the component LEDs, easily accounting for inherent variations in LED brightness.

Matrix LED Color Mixer with Boost-Buck

The matrix dimmer requires a suitable LED driver to power the string of eight LEDs from a variety of inputs: standard 12 V ±10%, 9-16 V (auto) or 6-8.4 V (Li-ion). One such solution is the LT3952 boost-buck LED driver, which both steps up and steps down input-to-LED voltage, while providing low ripple input and output current. With little or no output capacitor in its floating output topology, it can react quickly to changes in LED voltage as the individual LEDs are PWM-dimmed on and off to control color and brightness (Figure 4).

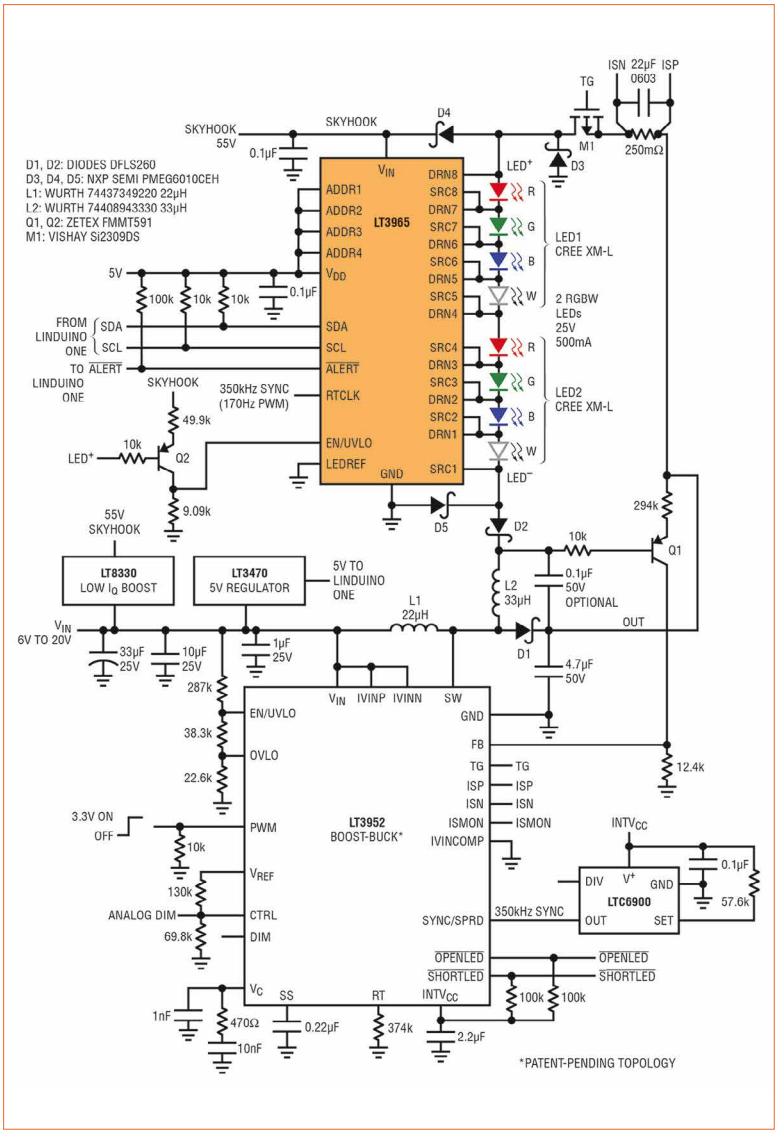
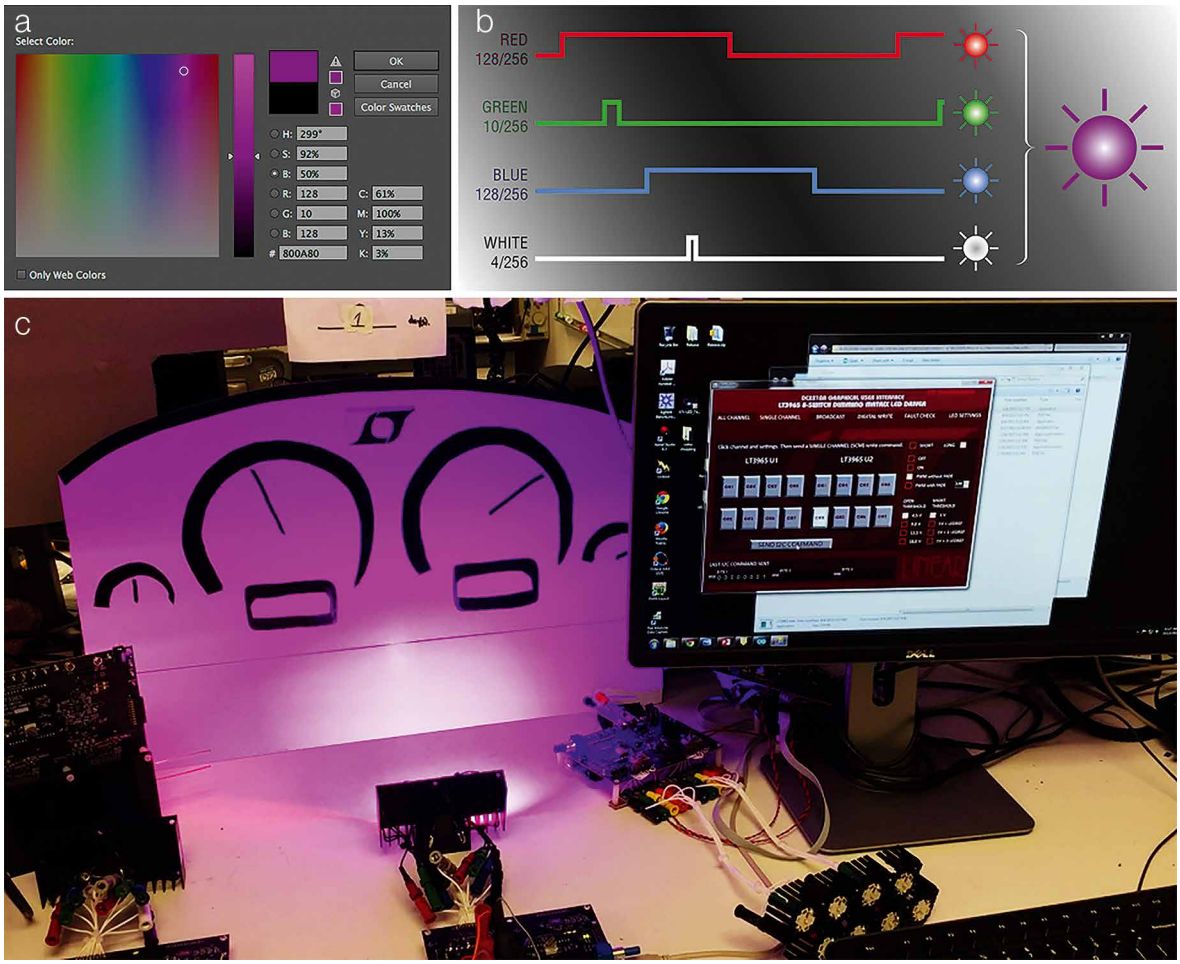


Figure 5: Together with the LT3952 boost-buck LED driver, the LT3965 matrix LED dimmer controls individual colors on two 500 mA RGBW LEDs for serial-controlled color and patterns

Figure 4: The RGBW 500 mA LED currents are PWM dimmed and phased by the LT3965 matrix dimmer to create colors and patterns. The LT3952 boost-buck converter/LED driver easily keeps up with the rapid changes in LED voltage as individual LEDs are PWM dimmed



Figures 6 a-c:
Process to set colors

The LT3952 500 mA boost-buck LED driver (Figure 5) pairs with the LT3965 8-switch matrix LED dimmer and two RGBW 500 mA LEDs. This new boost-buck topology gracefully operates over the entire range of zero-to-eight LEDs in series, with a voltage of 0 V to 25 V. The instantaneous series LED voltage changes, determined by which, and how many LEDs are enabled and disabled by the matrix dimmer at any given moment. The 60 V OUT voltage of this converter/topology (a sum of V_{IN} and V_{LED}), and the converter duty cycle, are rated for the full input range of 6 V to 20 V and output range (LED series voltage) of 0 V to 25 V at 500 mA.

The matrix dimmer controls LED brightness by shunting the LEDs with parallel power MOSFETs. The LEDs do not need to be connected to ground with either the floating output boost-buck LED driver or with the matrix LED dimmer. As long as the V_{IN} pin of the LT3965 is connected to SKYHOOK, which is at least 7.1 V above LED+, all of the shunt MOSFETs work properly. SKYHOOK can be created with a charge pump from the switching converter or it can be supplied with a regulated source that is at least 7.1 V greater than the highest expected LED+ voltage (in this case, $V_{INmax} + V_{LEDmax} = 20\ V + 25\ V$). The tiny LT8330 boost converter in a 3 x 2 mm DFN is a good choice to generate SKYHOOK.

An optional external clocking device is used to synchronize the system at 350 kHz, which is suitable for automotive environments, relatively efficient and allows the use of compact components. Although this system could just as well run at 2 MHz (above the AM band), 350 KHz (below the AM band) enables this boost-buck converter to regulate without pulse-skipping when all LEDs are shorted by the matrix dimmer and the LED string voltage drops to 330 mΩ x 500 mA x 8 = 1.3 V. This frequency also supports high dimming ratios without visible LED flicker.

Start-Up Sequence with LEDs ON or OFF

The matrix LED dimmer system can be set to start with all of the LEDs on or off. Starting up with all of the LEDs off allows them to fade on softly or to start at a programmed color and brightness, such as green-blue at 10% brightness. If all of the LEDs start with full 500 mA current before the serial communications begin telling the dimmer what to do, then full bright "white" light may be observed before serial communications start.

With either start-up method, the LT3965 should be powered up before it receives I²C serial communications, or the initial communications may be lost when it performs a power-on reset (POR). The POR occurs when the EN/

UVLO pin crosses above the 1.2 V threshold. Since this voltage is based on SKYHOOK being at least 7.1 V above LED+, this can occur at any time after a high SKYHOOK voltage is applied, such as 55 V from a small boost regulator, or it can happen after a charge-pumped voltage from the LT3952 switch node is high enough to create SKYHOOK. In the case of a charge-pumped SKYHOOK, the LED current may be present before the charge-pumped SKYHOOK, so the LEDs light up before the matrix dimmer switches can turn the LEDs off. This is a simple solution for a designer who would like the LEDs to turn on full brightness to start.

To start the LEDs off, SKYHOOK must be present at a high voltage before the LT3952 is turned on. As shown in figure 6, if the PWM pin is held low during start-up, the LT3952 will not start up until it is commanded to do so by an external source, such as the master microcontroller.
The microcontroller can send I²C setup commands to the LT3965 once SKYHOOK is present and set up its switches to the LED OFF position before current is flowing to them. Then, after setup, the LT3952 PWM can be asserted and the current begins to flow through shorted matrix LED dimmer switches, with the LEDs off. After this, a fade start can occur, or the LT3965 dimmer can jump to a particular color or brightness.

The figures 6 a-c show the standard process to set colors:
Colors can be chosen using a standard PC-based color picker. The 0-256 values used by the matrix dimmer can be related to the 0-255 values used in typical RGB systems. For instance, RGB(128|10|128) produces a purple hue. As can be seen in the photograph on page 66, the matrix dimmer can produce predictable colors with a real RGBW LED, simplifying the work of a lighting designer.

The three simple steps are:
(6a) Choose a color
(6b) Set the RGB values corresponding the LT3965 LED matrix dimming ratios
(6c) Use a PC to set the dimming values to see the results

Upon a reset, the PWM of the LT3952 must be pulled low again to turn it off and restart in the LEDs off position. In the case of figure 5, a simple micro power boost such as an LT8330 can supply 55 V from the 6-20 V input. The microcontroller receives a signal that LT3965 is powered up and ready to receive serial communications by asserting the ALERT flag. Before any of the switches are shorted out, zero current through the LEDs shows up as zero voltage across the switches - interpreted and reported as a short-circuit fault. Only after the matrix LED dimmer is powered up by SKYHOOK is the flag asserted.

Conclusion

Matrix LED dimmers can be paired with a boost-buck LED driver to form an accurate-color RGBW LED color mixer system. In our example, it can drive two RGBW LEDs at 500 mA with 350 kHz switching frequency from a 6 V to 20 V input.
This versatile system can be powered with automotive batteries, 12 V power or Li-ion batteries. High color accuracy results from the fast transient response of the patent-pending boost-buck LED driver topology and predictable dimming control via the 256:1, I²C-controlled matrix system. It can be set up to start up with all of the LEDs off and can fade to start or jump to a particular color. Although not required, optical feedback (via microcontroller) can be added to improve color accuracy. ■

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Safety Concept for LED Street Lighting

Street and building lighting has profited greatly from the advantages of LED technology. While modern LED lampposts have dielectric strengths of up to 6 kV, surge currents and voltages occurring in the grid can be significantly higher. Andreas Schamber, Product Manager for surge protection at Phoenix Contact, presents and discusses a comprehensive power surge protection concept to prevent blackouts during power surges and to protect investments in LED lighting based on the company's product portfolio.

Figure 1:
LEDs have become the common technology for street lighting. Specific protection devices are used to protect these sensitive systems

LED technology has become prevalent in many areas due to its significantly longer service life and higher energy efficiency. Street and building lighting has benefited in numerous ways from the advantages of this new technology. LED modules have also made lights much more compact and they can be dimmed by sensors, allowing them to be adapted to the needs of the user. While the dielectric strengths of modern LED lampposts is up to 6 kV, power surges in the grid caused by direct and indirect lightning strikes or switching action can be significantly higher.

The destruction of sensitive lighting electronics or the LED modules by power surges will increase the time for ROI. The cost of replacing LED equipment is also higher than replacing conventional lighting technology. Preventing downtime from power surges and to protect the investment in LED technology, a comprehensive surge protection concept is highly recommended, even for street and building lighting. The consequences in security-relevant areas can be severe (Figure 1).

Power Surges and Their Consequences

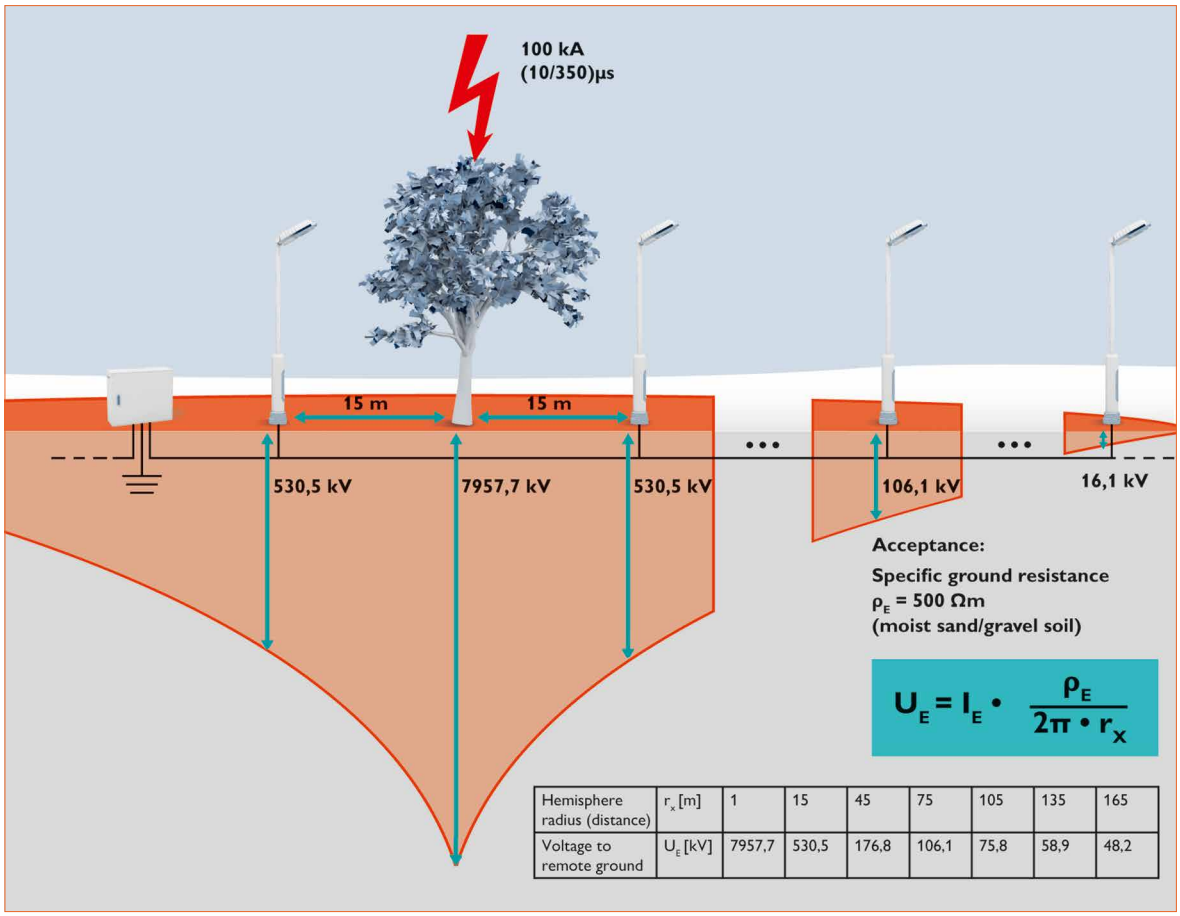
Undesirable power surges have various causes. A distinction is made between direct and indirect effects of lightning strikes and switching operations. There can be a low number of direct lightning strikes, depending on the region. Nevertheless, these kinds of strikes are always high-energy, usually resulting in greater damage. Lightning strikes can indirectly affect devices up to distances of 5 km.

Power surges typically result from:

- Direct lightning strikes to lights or power lines
- Indirect effects of lightning, ground feedbacks, or electromagnetic induction
- Switching operations in the power grid

Lampposts are generally placed in highly exposed locations, leaving them susceptible to direct lightning strikes that can affect the entire streets. If there are no suitable protective devices in place, the lightning current can be dispersed across the entire installation (due to galvanic coupling) and cause enormous damage.

Lightning strikes cause the voltage to increases by several thousand volts at the point of impact. This voltage decreases exponentially and depends largely on the soil conditions and the distance from the point of impact. For example, if lightning strikes a building with an external lightning protection system or a nearby tree, this raises the ground potential (Figure 2). If the insulation resistance of the components is exceeded,



Hemisphere radius (distance)	r_x [m]	1	15	45	75	105	135	165
Voltage to remote ground	U_E [kV]	7957,7	530,5	176,8	106,1	75,8	58,9	48,2

Figure 2:
A lightning strike directly in or close to the street lighting system raises the voltage potential and endangers the street lighting

a flashover can occur, and the insulation will be damaged.

If the insulation of the supply cables, the junction box or the electronics has been damaged, it can usually only be determined during the next routine check. Insulation failures pose a lethal risk and, in the worst case, can lead to electric shock if contact is made with metallic parts such as a light pole.

Inductive coupling in the power supply cable can also generate power surges. This is caused by the magnetic field of the lightning current flowing to the ground. For instance, the current through a downed conductor, or even a tree, generates an electromagnetic field around the conductor, which induces energy in cables running in parallel. These surges are strong enough to damage the electronic components connected to those wires.

The other main cause for power surges is switching operations in the power distribution network. These can cause power surges of several kilovolts. These transient power surges occur far more frequently than lightning strikes and have a lower energy density and shorter duration. Nevertheless, they still cause damage due to the high number of incidents that stress the components.

These transient power surges can have various causes:

- Switch-on and switch-off operations in nearby electrical devices and at large-scale plants
- Switching conventional discharge lamps on and off
- Ground faults and short circuits in the alternating current
- Triggering of the fuses
- Conductor-to-conductor errors in the medium- or high-voltage grids

Most street and outdoor lighting is connected to the low-voltage grids, which sometimes run over long distances. When it comes to conductor-to-conductor errors in the high and medium-voltage grids, sometimes the voltage impulses reach the consumer, which significantly speeds up the aging process of the components. Other occurrences, such as switching operations at large-scale plants and unforeseeable ground faults or short circuits in the alternating current, can also cause power surges to reach and overload the consumer. Grid operators work in accordance with the guidelines specified in EN 50160 to ensure the required grid quality. However, due to the limitations of the technical means currently available, grid operators are far from able to protect all consumers from unforeseeable power surges. A comprehensive lightning current and power surge protection concept protects LED lights from early failure.

Example for a Suitable Protection Concept

A comprehensive protection concept with coordinated components is necessary for protecting an entire streets' worth of LED lights with several light points. This kind of multi-level power surge protection concept revolves around three installation locations (Figure 3).

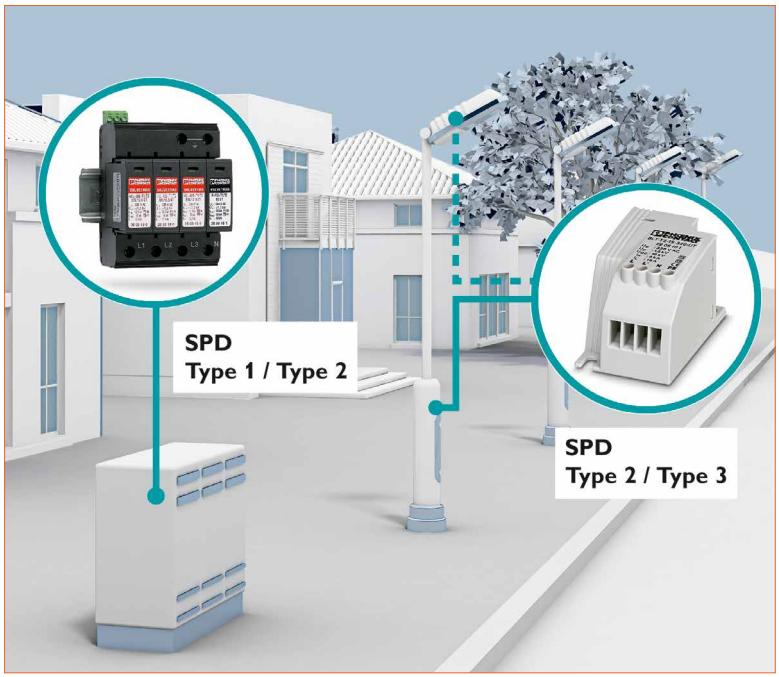


Figure 3:
Possible areas of application for power surge protection in the street lighting system - a multi-level power surge protection concept secures the entire installation for the long term (SPD = surge protection device)

The three installation locations are:

- In the control cabinet
- Directly in the LED light
- In the cable junction box at the base of the pole

Combinations of Type 1 and Type 2 arrestors are advantageous for protection installed in control cabinets - the arrestors provide protection from direct lightning strikes and transient power surges caused by the indirect effects of a lightning strike or switching operations in the distribution network. This setup ensures that all powered LED lights are protected against the direct and indirect effects of lightning.

Integrating a Type 2 or Type 3 power surge protection device protects the electronic components directly in the light from power surges caused by the indirect effects of nearby lightning strikes. The light manufacturer directly influences the positioning of matched components; he or she can protect the lights and their sensitive electronic components from unforeseeable power surges.

The cable junction box is also a suitable location for installing a power surge protection device. When a power surge protection device is installed here, there is an additional advantage - compared to when it is installed directly in the light - in that the protective ground conductor also goes into the cable junction box. The protective ground conductor, which is wired to the ground, can be used to effectively protect Protection Class II LED lights against transient power surges. This setup is also easy to access for inspection or retrofitting.

The described power surge protection devices are suitable for the entire installation concept. All of the components are optimally coordinated with one another. They are also tested and certified for security and reliability by an independent testing agency. Some of these components belong to the pluggable Type 1 and Type 2 product family and come either with or without remote signaling for use in the control cabinet. Meanwhile, the specially developed Type 2 and Type 3 arrestor product family features compact design and flexible types of wiring. Because of this, these product types are perfect to install directly in the LED light or in the cable junction box in the pole. Reinforced insulation means that these protection devices can be used in Protection Class II LED applications without additional measures.

Useful Product Features

Several million Protection Class I and II light points are installed worldwide. In the past, Protection Class II lights were frequently installed for a variety of reasons, depending on the region and country. Light installation requires double or reinforced insulation for all electrical components in accordance with IEC 60598-1. Today, these requirements can also be applied to the power surge protection devices for Protection Class II. Doing so ensures that future standard requirements will also be fulfilled.

Differences between installations mean that conductor cross sections ranging from 0.5 to 2.5 mm^2 are found in the field. This usually affects the standard lights. Because of this, devices with flexible connection technology that can take this connection area into account during retrofitting are required.

One product feature in particular should be prioritized: the visual indicator on the power surge protection device. This advantageous feature is prescribed by standards and allows the function status to be read directly off the device. The indicator needs to be easy to read even when the device is in a dead state, since maintenance work is not usually performed while the device is live. If the power surge protection devices are directly integrated into the lights and are only accessible with the help of tools, then the signal can be transmitted to the lamp. For example, if the power surge protection device's disconnect device is securely triggered due to an overload, the light is also switched off. The functions of the power surge protection device can then be recognized during routine inspection of the light (Figure 4).

Last but not least, product approval plays an important role in lighting installation. This is because the approval mark on the product indicates that the product's quality and security have been confirmed

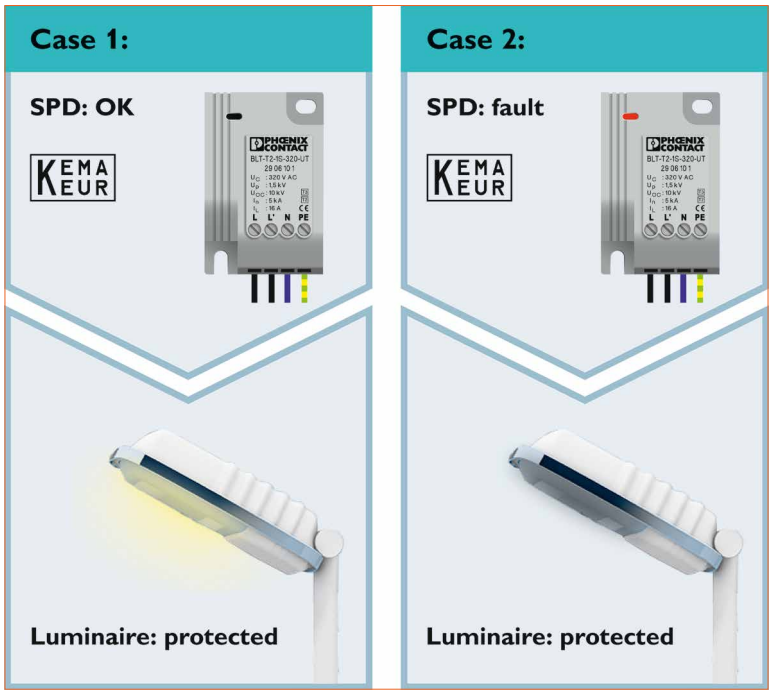


Figure 4:
Signals can be transmitted to the lamp via the so-called L connection. If the disconnect device has been disconnected from the power surge protection device due to an overload, the light is also electrically isolated from the network and thereby protected from further power surges

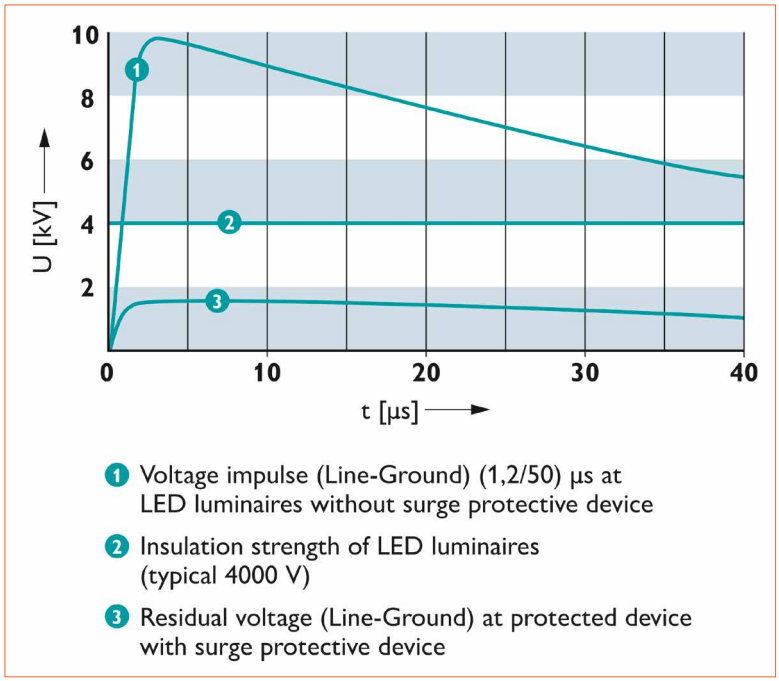


Figure 5:
Residual stress curve for a surge voltage impulse (1.2/50 µs) - power surge impulses are limited to a voltage level sufficient for sensitive devices

by an independent testing agency. As such, this approval mark lets the user know that the product's technology is state-of-the-art. Moreover, securing product approval for the power surge protection device can reduce the cost of certifying the entire light. Certification bodies typically acknowledge the results of quality tests conducted on power surge protection devices. If these bodies see that the protection devices have already been approved, then they reduce the cost of approving the entire light (for example, in accordance with ENEC, or European Norms Electrical Certification). The IEC 61643-12 installation guidelines should also be acknowledged when installing protection devices. Lightning current and power surge protection devices are only guaranteed to function properly and provide suitable protection if these installation guidelines are followed.

It is also important to take the protective effect of power surge protection devices into account during installation. A low protection level is required; it should lie beneath the surge voltage capacity of the light source and the LED driver. This also applies for the multi-level protection concept for Type 1 lighting arrestors in the control cabinet through to Type 2 and 3 lightning arrestors in the LED light. The appropriate devices are only effective if the incoming pulses through installed devices are successively limited to the reliable protection level, which thereby prevents the pulses from overloading the downstream end devices (Figure 5). And if the pulses reach the power limits of the protective devices, these devices need to be securely disconnected. When suitable protective devices - such as T2 and T3 Blocktrab components - are installed in the light or in the cable junction box, even end devices can be electrically isolated from the network (depending on the selected circuit), thereby protecting the lights from further pulses until the defective device has been replaced.

Summary

All of the components necessary for the installation must be carefully selected in order for LED lights to be operated safely and efficiently for many years. A professional lightning current and power surge protection concept is recommended for all types of lighting: indoor, outdoor, tunnel, and building lighting. Suitable protective devices protect sensitive electronic components from undesirable and unforeseeable power surges and thereby help the user reach the planned payback period. Protective devices also contribute to personal and system safety and reduce maintenance and repair costs. ■

Illuminating Education - Providing a Brighter Future for Students

Illumination is expanding its definition in the education sector. While its core tenets continue to drive primary and secondary schools to foster environments of higher knowledge and enlightenment, the influence of lighting has quickly broadened this definition to literally shine a brighter future on our students. Jay Black, Vice President of development and communications for Revolution Lighting Technologies, discusses expectations and experiences, and gives technical background information.

Since the advent of architecture, lighting has played a central role toward influencing our environment. Light allows us to perceive objects, provide safety, complete tasks, maintain a close connection with nature, and even influence our architectural designs.

The emergence of the industrial revolution during the 19th century paved the way for new scientific discoveries and technologies that would forge a new direction. For the first time in history solar was replaced with artificial light as the predominant lighting source. We created new and larger structures to live and work in, exchanging natural light for incandescent lighting. During the 20th century, newer technologies, including fluorescent, metal halide, halogen lighting were used. These solutions have now paved the way for LED lighting in the 21st century.

Today it is estimated that people spend 90% of their time indoors, limiting individual exposure to natural light, while artificial illumination from general and task lighting, including mobile devices, tablets, computers and televisions, prevails. These new tools have provided significant benefits, allowing students to improve efficiency and productivity, access information, improve study habits, and work longer to complete class projects. In addition, proper classroom design, including lighting, can have a significant effect on learning with up to a twenty-five percent positive impact on a student's performance over an academic year according to a 2011-2012 British study among 751 students in thirty-four classrooms [1]. However, recent scientific advancements are once again pushing new boundaries to broaden our understanding of light's potential to impact individual health, well-being and comfort.

Light and Humans

As light travels through the eyes, the cornea and lens refract it to converge on the retina, stimulating two different photoreceptor nerve cells, rod cells and cone cells, each independently tasked with the absorption of specific short, middle and long wave light rays through activation of photo pigments. This physiological interaction between light and the human body commonly assumed the retina's primary function was to assist with visualizing form and perception of color. However, recent medical findings have challenged this understanding, uncovering that our retina plays a much broader biological role.

In 2000, a study was published, identifying a new photo pigment, melanopsin, located within the retinal area of the eye. Unlike rod cells and cone cells located within outer retinal regions, this pigment was uniquely located within the ganglion cell layer, concluding that it did not participate in image formation, but rather is a chief candidate for circadian photo pigment. Shortly after 2001, scientific evidence suggested that non-rod and non-cone photoreceptor systems existed

that facilitated circadian rhythms. Researchers identified characteristics of a group of cells containing melanopsin within mice and rats, which are called intrinsically photosensitive retinal ganglion cells (ipRGCs), responsible for non-image forming responses and circadian synchronization [2,3,4,5,6].

Biological Effects

Humans and other mammals operate within a 24-hour biological cycle or "clock", known as the circadian rhythm. This rhythm influences various aspects of our biochemistry, endocrinology, physiology, metabolism and behavior to synchronize our internal processes as well as our external environment. While this rhythm synchronizes, close to but not exactly, a 24-hour cycle, the clock must be recalibrated each day. This is where the ipRGCs plays a vital role, responding to light, sending neurological signals to the hypothalamus, which in turn regulates localized "time-clocks" among various organs in the body, also referred to as photoentrainment [7,8,9,10,11].

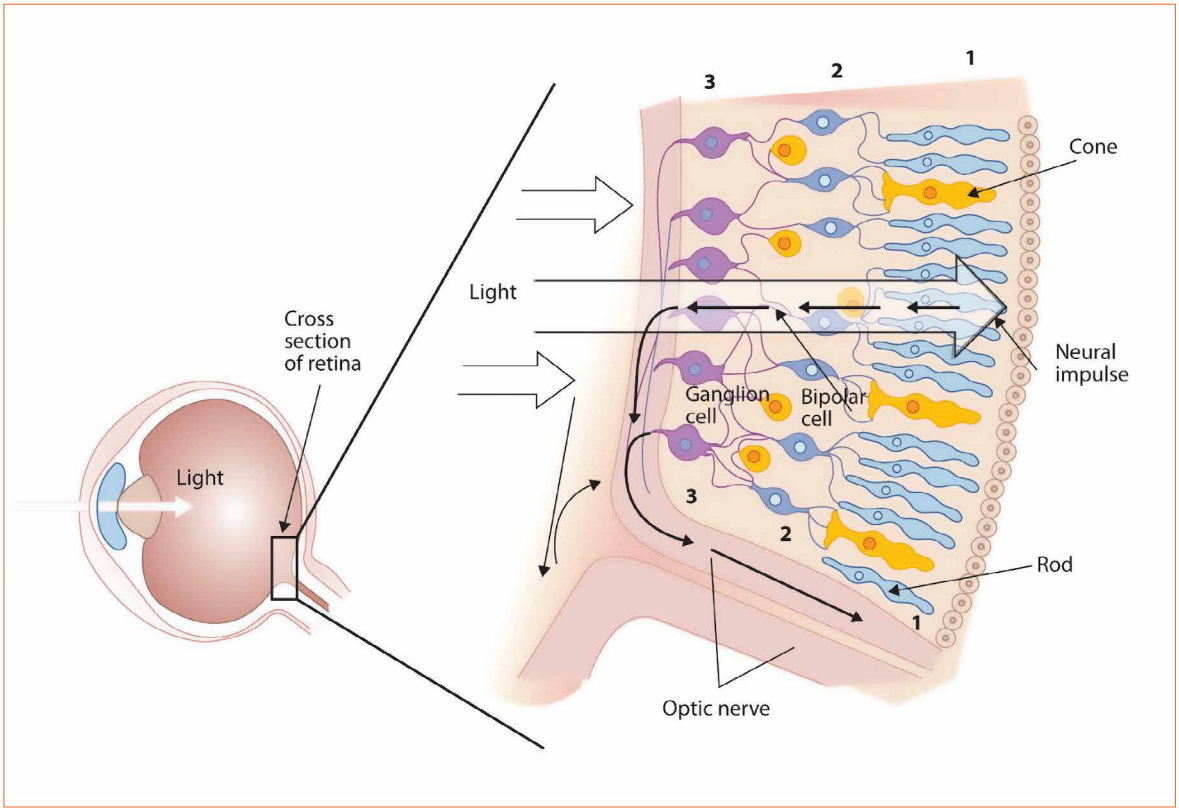


Figure 1: Diagram of the human eye – (1) light entering eye triggers photochemical reaction in rods and cones of retina, (2) chemical reaction in turn activates bipolar cells, (3) information is sent to visual cortex via thalamus (source: http://wellbeing.media.mit.edu/2014/02/12/light-and-sleep-cycles/)

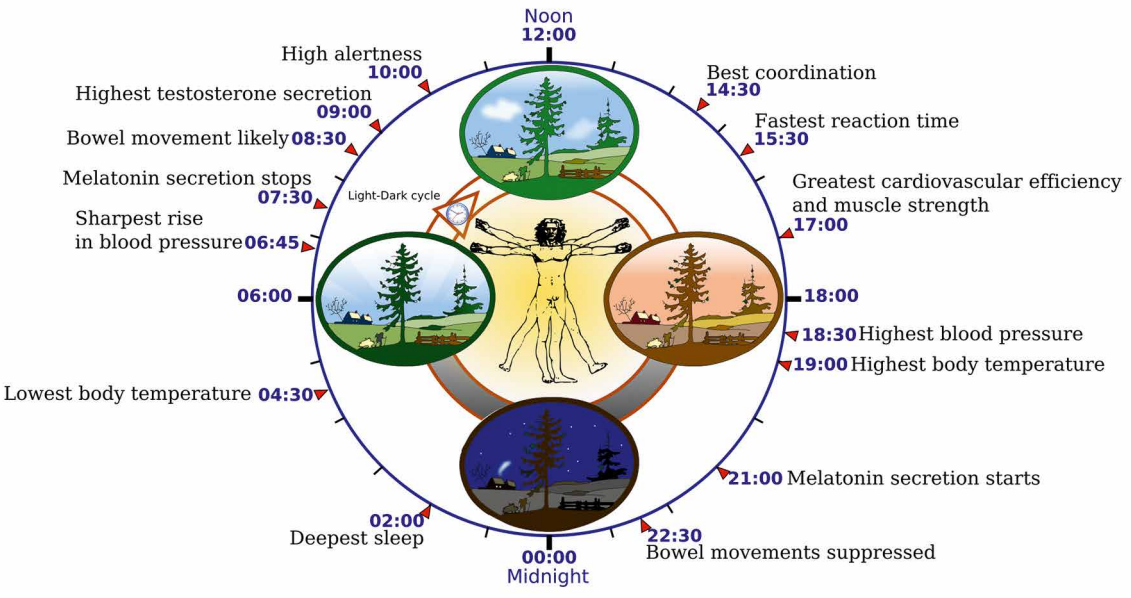


Figure 2: Circadian Rhythm in Humans (source: https://en.wikipedia.org/wiki/Circadian_rhythm)

ipRGCs are uniquely suited to address photoentrainment through a slow kinetic response to light. Unlike the millions of rod and cone cells distributed within the retina, ipRGCs, by comparison, make up only a small number. As a subset of ganglion cells, ipRGCs are distributed across the entire retina, creating a broad, yet low density, photoreceptive net. While this density creates a lower probability for absorbing photons, ipRGCs larger unitary response, compared with the other two photoreceptor cells, significantly increases the chance of activation when absorbing even a single photon, and thus initiating a physiological response. This results in the improvement of the ipRGCs' biological structure sensitivity over longer time durations, gradually modifying response despite short term light level fluctuations, and allowing measurement of daylight, determining time of day and seasonality. It is also worth noting that while all photoreceptors respond to various spectral wavelengths, each of the three photoreceptor cells show greater responsiveness to specific wave lengths. ipRGCs, for example, have the greatest sensitivity to short wavelength blue light from 464 - 484 nm [12,13,14,15,16].

Regulation of hormone levels is closely tied to circadian rhythm, which will fluctuate within the 24-hour cycle. The hypothalamus, as a primary regulator of the hormone melatonin, raises levels as night, signaling to the body that it is a time of darkness, and prepares the body for sleep. Disruption of the circadian cycle can negatively impact melatonin levels, in addition to other hormones including prolactin, parathyroid hormone, and thyroid stimulating hormone. Nighttime exposure to bright light can disrupt this rhythm, resetting the circadian clock, suppressing melatonin production, and causing the body to simulate a daytime physiological response. This includes raising body temperature and heart rate, promoting "alertness", translating to other potential issues including poorer sleep quality.

Students prone to working or studying late with general and task lighting on, using electronic devices including tablets, smartphones or those simply watching TV while going to bed can be particularly susceptible. Repeated exposure to high levels of light at night also affects metabolic functions including heart rate, shifting the timing of the circadian clock, which may impair proper cardiac function as well as negatively impacting cholesterol levels, body weight, and BMI. Health effects, including some sleep disorders, are also possible [17,18,19].

Cortisol is another key hormone regulated, in part, by the circadian clock. While studies have shown conflicting evidence on the direct correlation between cortisol and the circadian cycle, fluctuation due to light exposure appear to occur. Unlike melatonin, which is suppressed during light exposure, cortisol rises with increased light. Cortisol begins to rise at the mid-point of sleep, increasing through increased light and peaking at time of waking, in order to engage the body's metabolic processes, while also acting as a key stress hormone within the body. It is well documented that cortisol does have weakening effects on the immune system, and maintaining a healthy sleep-wake cycle, combined with proper exposure to natural sunlight can help regulate these levels [20,21,22].

The connection between light, ipRGCs and circadian rhythm has shown other non-visual effects that impact alertness, mood, cognition, and sleep quality. When considering practical applications of lighting, light is an important stimulant that signals day and night to the brain. Neuroscience studies have shown that light stimulation activates brain areas that control alertness, including the thalamus and brainstem. In addition, changes in EEG brain activity patterns that indicate a more alert state were found, leading to higher subjective alertness ratings and improvement in cognitive performance tests. Light studies have shown other positive neurological impacts, including activation of the amygdala, which helps regulate mood. As a result, forms of light treatment are beginning to be used clinically to address some mental health disorders [23,24,25,26].

Scientific research is still exploring the broad spectrum benefits from light. This increased understanding of non-visual impact of light and role of ipRGCs and melanopsin is leading to new opportunities for proper lighting design.

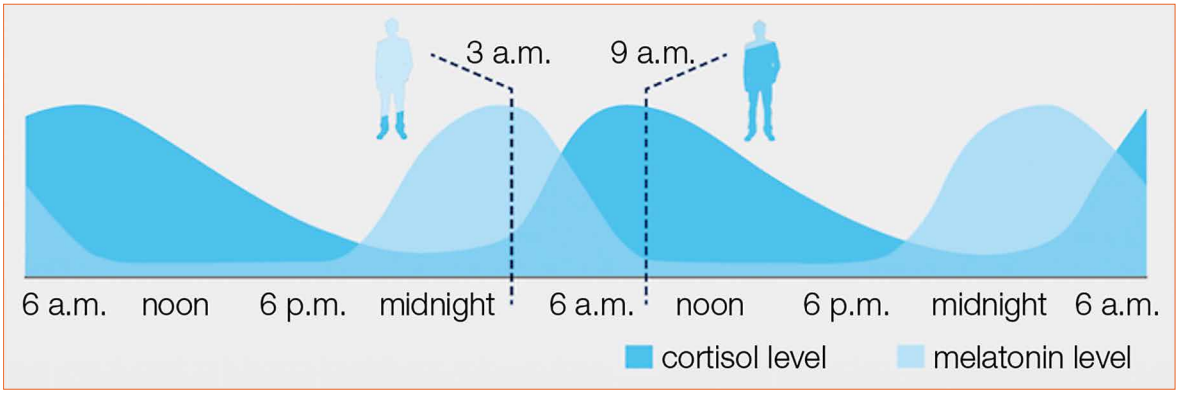


Figure 3:
Circadian Rhythm Impact on Hormone Levels (Melatonin and Cortisol Cycles)
(source: https://freyaled.com/en/blog/health-effects-of-the-light)

The Right Light

This new and much broader understanding of the relationship between light and the human body is essential to establishing new a opportunity for addressing positive biological functioning. Organizations such the Illuminating Engineering Society of North America (IESNA) have already coordinated with key groups in the U.S. including the American National Standards Institute (ANSI) and the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHREA) to establish the lighting and energy benchmark in the United States, known as ANSI/ASHRAE/IESNA 90.1. Documents such as these provide illumination targets based on the tasked performed as well as age of the individuals within given environments [27].

While current guidelines already exist for the specification of proper lighting illumination, color temperatures and energy efficiency levels, in 2014, the International Well Building Institute (IWBI) released the WELL Building Standard becoming the first performance-based system for measuring, certifying, and monitoring features of the built environment that impact human health and wellbeing, addressing categories including air, water, nourishment, light, fitness, comfort, and mind. Grounded in a body of medical research that explores the connection between the buildings and the health and wellness of its occupants, this is the first standard to solely focus on bringing human health to the forefront of building practices [28].

The WELL Building Standard Concepts, address illumination through its section titled “Light”. The intent is to minimize disruption to the body’s circadian system, enhancing productivity and provide proper visual acuity, visual and circadian light design guidelines, artificial and solar glare control, color rendering, shading and dimming controls and proper access to daylight.

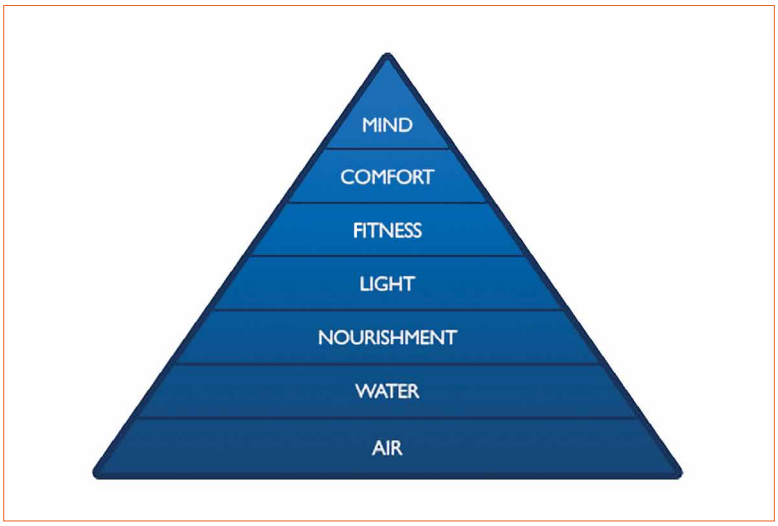


Figure 4:
The WELL Building Standard Concepts
(source: https://www.go-gba.org/resources/building-product-certifications/well-building-standard/)

Better Lighting for Better Learning

Recent findings regarding lighting’s ability to positively impact non-visual responses, now offer a new opportunity for schools to differentiate, while positively impacting the learning experience and productivity for their students.

Recent recommendations through medical research, including those provided through the WELL building standards, offer several recommendations to ensure proper design that more effectively addresses individual health, wellbeing and comfort.

Illumination Levels:
Proper general illumination is a core consideration. According to ANSI’s approval of IES standards, uniformity and well-lit general lighting, which factors illumination from targeted task lighting, to achieve illuminance levels between 150 lux to 1500 lux. They will ensure proper visual acuity and productivity, reduce eye strain, avoid circadian drift and associated negative hormonal effects. This is particularly important during afternoon hours, when lower levels of light can cause drowsiness as body’s cortisol levels lower [29]. Designers should also pay careful attention to excess illumination, reducing glare to ensure comfort while enhancing aesthetic appeal throughout the space. This can include the use of direct/indirect lighting, consideration of shielding devices on fixtures and material selection for surfaces and furniture.

LED Lighting:
Integration of proper lighting levels should also consider utilizing artificial lighting that most accurately reflects natural light’s “full spectrum output”. LED lighting is an optimal solution due to its unique capability to maximize spectral adjustment through its diodes, make it an effective lighting solution for circadian emulation. Even at different color temperatures, LEDs are able to achieve a broad spectral output, and strong “blue peaks” of light that are close to the frequencies that ipRGC retinal photoreceptors are most sensitive, and maintain suppression of melatonin during the day.

CCT:
Designers must also consider appropriate correlated color temperature (CCT) when developing appropriate illumination throughout the space. While studies suggest 6000 K – 8000 K LEDs with a spectral composition leaning toward a blue spectral focus may have the best biological impact, this is likely undesirable to occupants. 5300 K or higher lights, closer to “daylight white, may also be good for alerting affects, but proper selection must balance individual comfort and focus requirements. 3500 K – 5500 K were found through studies to be the most visually pleasing, however conclusions revealed there was not a single preferred spectrum [30,31].

CRI:
While CCT is a key consideration, it must be done in conjunction with proper color rendering to ensure colors within a space are accurately depicted. CRI of 80 or higher is suggested for general illumination through IES standards, however spaces that require precise color rendering, lighting with a CRI of 90 or higher, is suggested [32].

Reflectivity:
Surface reflectivity should also be considered to control the overall light intensity within a space.
The total potential illuminance that can reach the eye has a substantial impact on circadian rhythm.
The WELL Building Standard has developed recommended light reflectance values (LRV) for ceilings, walls and furniture systems, are derived from several sources including IES and General Services Administration's (GSA) Facility Standards [32].

Natural Light:
Design of proper lighting systems is crucial. However, integration of natural light should always be considered as a key opportunity to expose individuals to broad-spectrum light, aligning us with the solar day to benefit circadian photoentrainment. This must also be balanced with proper controls and fenestration, improving occupant comfort through diffuse light that avoids excess glare and heat gain. Many businesses promote physical activity among its employees, suggesting short walks, which may also improve individual exposure to sunlight and alertness.

School Policy:
As professionals within the lighting industry, we are not alone in providing solutions that foster more productive learning environments. School administration faculty can also play a vital role. Studies reveal that students regularly spend more than three hours per night on homework and as more students participate in extracurricular activities, many are often required to stay up late to complete assignments. Some schools are already beginning to respond accordingly through modified policy to ensure a more reasonable workload. This will reduce conflict with healthy sleep schedules and maintain a proper circadian rhythm.

Home Environment:
Quality lighting design can have a profound impact on our comfort and well-being within learning environments, and organizations such as the AMA have already made several key recommendations and solutions to address proper circadian rhythms within our homes.

AMA recommendations include:

- Evening lighting should utilize low intensity or dimmed red lighting. Similarly, night lights used for navigation during the middle of the night should also be considered
- Incorporate blackout shears on windows in bedrooms to limit light from entering the room
- Limiting or eliminating the use of electronic devices during the evening and night can avoid negative impacts to our circadian clock
- Maintain a healthy sleep schedule, including regular bed times and eight hours of sleep per night
- Students rely on social media, texting and video chat to communicate. Parents can institute boundaries around "screen time" and accessibility to ensure better focus on school obligations and improved sleeping patterns by eliminating the disruptive, and often constant chime of a smart device to announce incoming messages

While the construction of new school facilities is best positioned to maximize these qualitative benefits, this strategy is limited. Given the overwhelming number of existing educational facilities within the U.S., it is unlikely that broad sweeping measures addressing light's non-visual benefits will occur, either due to impracticality or insufficient funding available as administrations continue to address overarching budgetary challenges.

Conclusions

There is silver lining, and as we look for new opportunities within an existing puzzle, many educational facility managers are already taking first steps through the use of LED technology. While the driver remains largely economic, it offers dual benefits, delivering a more effective form of broad spectrum lighting, combined with higher CRI.
In addition, LED lighting addresses other lamp-life related concerns, limiting total light depreciation to ensure lasting acuity when compared to other lighting technologies. But LED benefits should be maximized by using advanced drivers to prevent flicker, and sophisticated control solutions including photo sensors, to regulate artificial lighting based on natural light levels to foster photoentrainment. Glare reduction strategies should also be considered through direct/indirect fixture specification and perimeter window fenestration or shading to significantly improve student comfort and unwanted heat gain. While fundamental in design, these considerations offer a cost effective first step toward supporting lighting's non-visual benefits for students.

Each opportunity will require its own solutions, however as designers, engineers and manufacturers of lighting, it is clear we are presented with a new opportunity to elevate the health well-being and comfort of individuals through an expanded understanding of light, creating a new path to transform our schools, campuses, and education facilities. ■

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References:

[1] Fast Company: http://www.fastcodesign.com/1671627/study-shows-how-classroom-design-affects-student-learning
[2] Melanopsin: An opsin in melanophores, brain, and eye. Provencio, I, Jiang, G, Grip, WJD, Hayes, WP, Rollag, MD. 1, Nov 5, 1997, Proceedings of the National Academy of Sciences of the United States of America, Vol. 95, pp. 340-345
[3] Melanopsin in cells of origin of the retinohypothalmic tract. Gooley, JJ, Lu, J, Chou, TC, Scammell, TE, & Saper, CB. 12, Dec 2001, Nature Neuroscience, Vol. 4, p. 1165
[4] An action spectrum for melatonin suppression: evidence for a novel non-rod, non-cone photoreceptor system in humans. Thapan, K, Arendt, J and Skene, D. s.l. : Journal of Physiology, 2001
[5] Phototransduction by Retinal Ganglion Cells That Set the Circadian Clock. Berson, DM, Dunn, FA, Takao, M. 5557, Feb 8, 2002, Science, Vol. 295, pp. 1070-3
[6] Melanopsin-Containing Retinal Ganglion Cells: Architecture, Projections, and Intrinsic Photosensitivity. Hattar, S, Liao, H-W, Takao, M, Bersom, DM, Yau, K-W. 5557, Feb 8, 2002, Science, Vol. 295, pp. 1065-1070
[7] Kandel, ER, et al. Principles of Neural Science. 5th. New York : McGraw Hill Medical, 2013
[8] Melanopsin-Expressing Retinal Ganglion-Cell Photoreceptors: Cellular Diversity and Role In Pattern Vision. Ecker, JL, et al. 1, July 10, 2015, Neuron, Vol. 67, pp. 49-60
[9] Acute Effects of Bright Light Exposure on Cortisol Levels. Jung, CM, et al. 3, 2010, Journal of Biological Thythms, Vol. 25, pp. 208-216
[10] Melanopsin Cells are the Principal Conduits for Rod/Cone Input to Non-Image forming Vision. Gruler, AD, et al. 1791, May 1, 2008, Nature, Vol. 453, pp. 102-105
[11] Kunz, Dieter. Impact of Light on Human Beings. Frankfurt : licht.de, 2010. 978-3-926193-60-5
[12] Melanopsin, ganglion-cell photoreceptiors, and mammalian photoentrainment. Rollag, M D, Berson, D M and Provencio, I. 3, 2003, Journal of Biological Rhythms, Vol. 18, pp. 227-234
[13] Photon Capture and Signalling by Melanopsin Retinal Ganglion Cells. Do, MTH, et al. s.l. : Macmillan, January, 15, 2009, Nature, Vol. 457, pp. 281-288
[14] Membrane Current of Single Rods Outer Segments. Baylor, DA, Lamb, TD and Yau, K-W. 1979, Journal of Physiology, Vol 288, pp. 589-611
[15] Melanopsin-Positive Intrinsically Photosensitive Retinal Ganglion Cells: From Form to Function. Schmidt, TM, et al. 45, 2011, Journal of Neuroscience, Vol. 31, pp. 16094-16101
[16] Photoreceptive Net in the Mammalian Retina. This Mesh of Cells May Explain How Some Blind Mice can still Tell Day from Night. Provencio, I, Rollag, MD and Castrucci, AM. 6871, January 31, 2002, Nature, Vol. 415, p. 493
[17] Effect of Light on Human Circadian Physiology. Duffy, Jeanne F and Czelsler, Charles A. 2, s.l. : Journal of Clinical Sleep Medicine, 2009, Vol. 4.
[18] Effects of bright light exposure on heart rate variability during sleep in young women. Kohsaka, M, et al. 3, June 2001, Psychiatry Clini Neurosci, Vol. 55, pp. 283-4
[19] Exposure to light at night, nocturnal urinary melatonin excretion, and obesity/dyslipidemia in the elderly. Obayashi, K, et al. 1, Chevy Chase, MD : Journal of clinical endocrinology and embolism, 2013,Vol. 98
[20] Light and Immunomodulation. Roberts, JE. New York : Annals of the New York Academy of Sciences, 2000, Vol. 917
[21] Kunz, Dieter. Impact of Light on Human Beings. Frankfurt : licht.de, 2010. 978-3-926193-60-5
[22] Acute Effects of Bright Light Exposure on Cortisol Levels. Jung, CM, et al. 3, 2010, Journal of Biological Rhythms, Vol. 25, pp. 208-216
[23] Effects of Light on Cognitive Brain Responses Depend on Circadian Phase and Sleep Homeostasis. Vandewalle, G, et al. 2011, J Biol Rhythms, Vol. 26, pp. 249-259
[24] Vandewalle, G, et al. 45, 2010, Proceedings of the National Academy of Sciences of the United States of America, Vol. 107, pp. 19549-19554.
[25] Aberrant light directly impairs mood and learning through melanopsin-expressing neurons. LeGates, T A, et al. November 2012, Nature, Vol. 491, pp. 594-8
[26] Light as a central modulator of circadian rhythms, sleep and affect. LeGates, TA A, Fernandez, DC and Hattar, S. June 2014, Nature Reviews Neuroscience, Vol. 15, pp. 443-54
[27] Illuminating Engineering Society. American National Standard Practice for Office Lighting. New York: s.n., 2013. 978-0-87995-262-4
[28] www.wellcertified.com
[29] Illuminating Engineering Society. American National Standard Practice for Office Lighting. New York: s.n., 2013. 978-0-87995-262-4
[30] Leuchtenmuller, Andreas. Office Lighting: Motivating and Efficient. Frankfurt : licht.de, 2012. 978-3-926193-73-5
[31] Preferred Chromaticity of Color-Tunable LED Lighitng. Dikei, E E, et al. 2, 2014, LEUKOS: The Journal of the Illuninating Engineering Society of North America, Vol. 10, pp. 101-115
[32] Well Building Standard, version 1.0. Delos Living, LLC, et al. 15, February 2015, pp. 100


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The Value of Dark Skies - About Environmentally Friendly Lighting

For many years no one worried about light pollution: on the contrary, the brighter the better. Then it became evident that darkness also has its value. J. Scott Feierabend, executive director of the International Dark-Sky Association (IDA), presents and explains in detail, the latest findings and suggestions published in the "New IDA LED Lighting Practical Guide" and "New IDA Standards on Blue Light at Night". He also discusses how to illuminate public areas while avoiding excess light pollution.

LED technology is transforming the way we light our cities and towns, offering a once-in-a-lifetime chance to radically improve how we use both energy and our outdoor spaces at night. With this opportunity comes an obligation to manage these changes responsibly and sustainably. The stakes are high and the potential rewards great, but outcomes depend critically on policymakers, professional lighting designers, and the public having access to reliable information.

Unfortunately, municipalities enticed by substantial cost savings - and reduction in greenhouse gas emissions - continue to rush into LED lighting conversions without doing their homework to ensure the conversion has the best possible outcomes for municipalities, the public, and the nocturnal environment. Too often, misinformation leads to the installation of overly-bright, potentially harmful street lighting.

It is increasingly common to read news reports that claim LEDs reduce light pollution, improve safety and security, and save money while lowering carbon emissions. While these positive outcomes are certainly possible when switching to LEDs from older lighting technologies, they are not inevitable. This is why it is essential to be armed with information that is both timely and accurate.

Color Matters

New technical capabilities often come with unanticipated consequences. Most white LED lighting on the market emits significant amounts of potentially hazardous blue light. In 2010, the International Dark-Sky Association (IDA) released a comprehensive review paper, "Visibility, Environmental, and Astronomical Issues Associated with Blue-Rich White Outdoor Lighting", detailing the hazards of blue-rich white light sources. In the years since, scientific evidence has solidified around its conclusions.

In natural settings, exposure to artificial blue light at night has been shown to adversely affect the nocturnal habitat. Every year new research is published expanding the breadth of species known to be negatively impacted by artificial light at night, and often the higher the lighting temperature, the greater the impact. For example, a 2015 study in eLife found that corals exposed to artificial light at night in the green and blue part of the spectrum delayed their spawning times by six hours to two days compared to corals exposed to ambient light or artificial light with a strong red

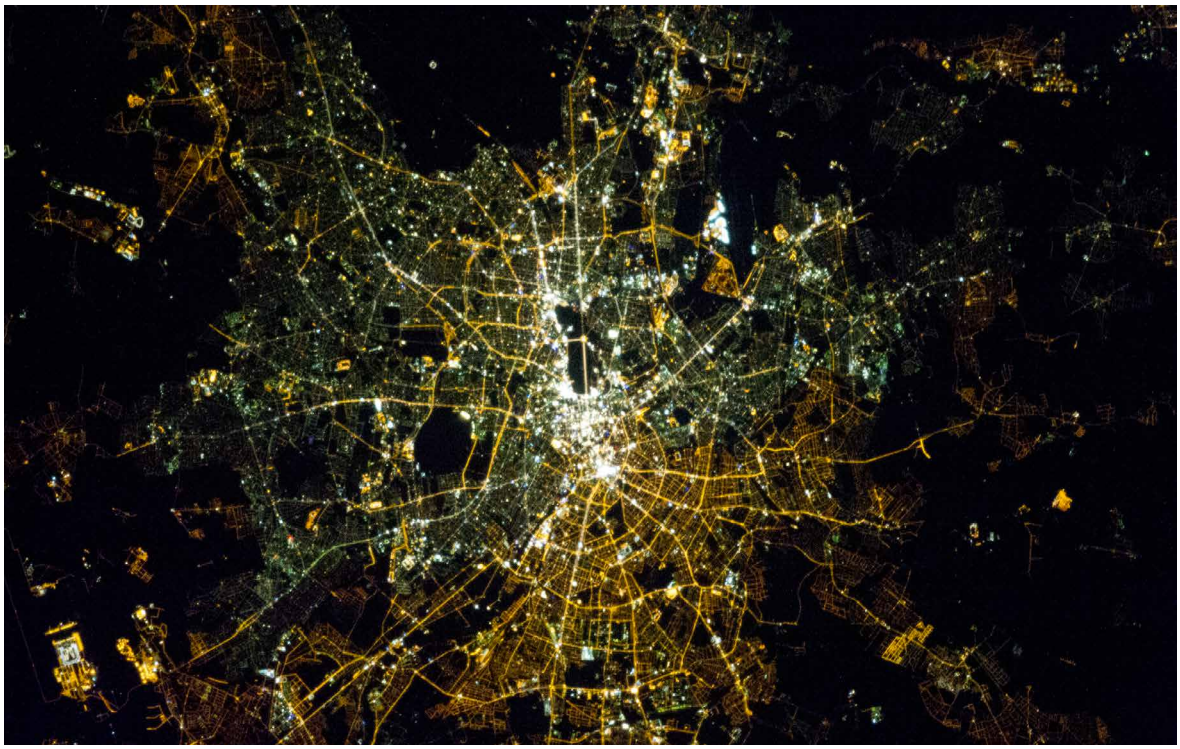


Figure 1:
The Berlin Wall has been down for decades, but the divide between East and West is still visible at night from space. This image, taken by astronaut Chris Hadfield in 2012, shows the gas lamps of the West and the orange high-pressure sodium lamps of the East, with a stark contrast between them. The image is a powerful reminder that lighting choices made by city planners are long lasting indeed. Given that many cities are now rushing to change to more energy efficient LED streetlights, this image demonstrates that smart lighting decisions is very important, as their consequences last a long, long time

component. This is significant because delayed spawning can negatively affect the reproduction of an already threatened species.

City dwelling and migratory species that often stop over in cities, are not immune to the threats posed by artificial light at night. Recent research has shown that that everything from the feeding strategies to reproductive timing of urban wildlife is altered, delayed or inhibited in the presence of artificial light at night. Millions of birds die each year in nighttime collisions with lighted radio transmission towers and skyscraper windows. Exposure to short-wavelength artificial light at night has also been been implicated in the onset of various chronic human diseases, although intensity and exposure duration thresholds are not yet well established. In 2012, the American Medical Association concluded, "Pervasive use of nighttime lighting … creates potentially harmful health effects and/or hazardous situations with varying degrees of harm," and recommended "further multidisciplinary research on occupational and environmental exposure to light-at-night, the risk of cancer, and effects on various chronic diseases."

Outdoor lighting with significant blue light content not only presents known threats to ecology and human health, but is also more likely to contribute to light pollution. Because blue light scatters more efficiently through our atmosphere than light of other colors, it has a much greater geographic reach. As a result, even if cities that convert their old municipal lighting systems to white LED at a fixed amount of light, the shift to a bluer spectrum is expected to yield increased skyglow visible at large distances from cities.

For these and related reasons, IDA issued new standards in 2014 for its Fixture Seal of Approval program, which provides objective, third-party certification for lighting that minimizes glare, reduces light trespass, and light pollution. The new requirements limit certification to lighting that has a Correlated Color Temperature (CCT) of no more than 3000 K. But, it is important to note that 3000 K still includes a good amount of blue light and may not be appropriate for ecologically sensitive places in cities such as greenbelts and riparian areas. For these fragile sites, the use of amber LEDs is most appropriate, which has a very narrow bandwidth, similar to low-pressure sodium lighting.

It is still widely believed that using low-color temperature white lighting for outdoor applications is cost prohibitive due to significant losses from low luminous efficacy. The fact is, that is simply no longer the case. While it was once true that the efficacy difference between low- and high-CCT white LED systems presented a significant financial dilemma to municipalities planning white LED conversion projects, technological advances have enabled cost-competitive solutions that minimize blue light emissions.

Road Safety

LED lighting can both help and harm motorists, pedestrians, and bicyclists who all share the road at night simultaneously. The key to public safety on streets and highways is visibility, which is enhanced by high contrast between objects and the background. Uniformity of lighting, on the other hand, reduces contrast and lowers the odds that motorists will be able to see moving objects in the road.

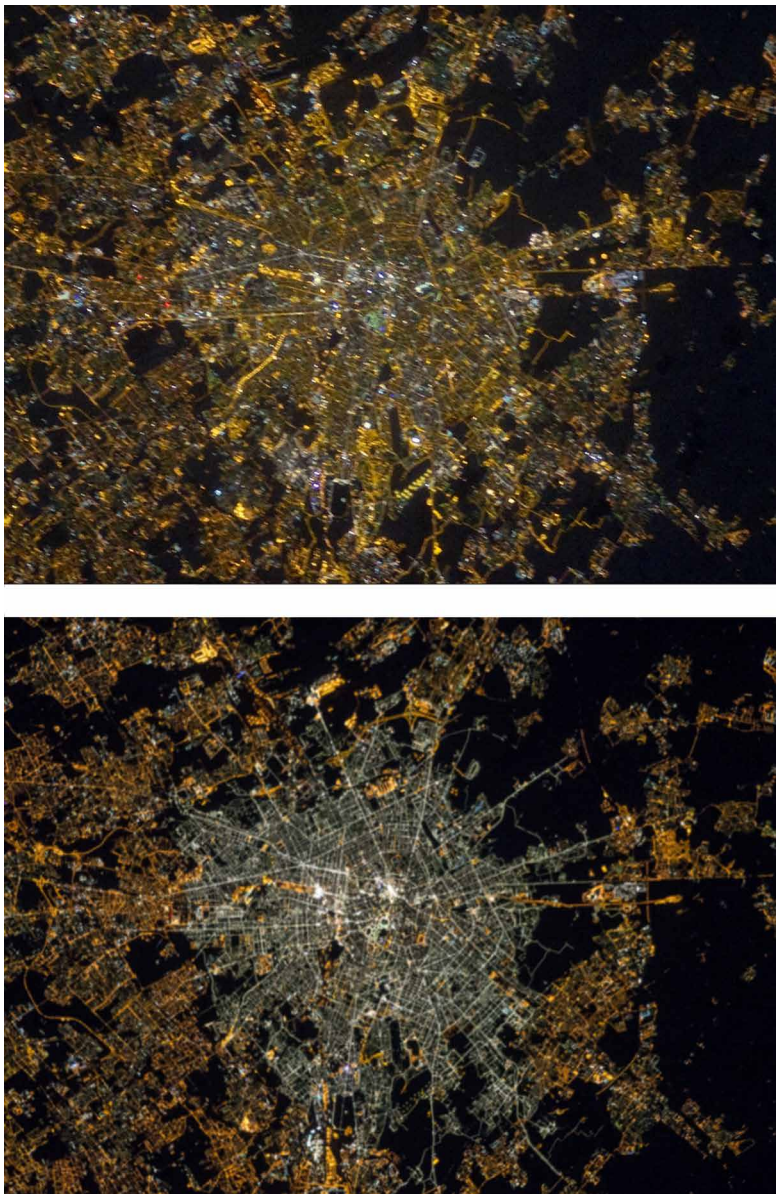


Figure 2:
Changes to cities that have adopted LED for municipal street lighting are literally visible from space. The city of Milan, Italy is shown here at night in images taken from the International Space Station before (2012, top) and after (2015, bottom) the conversion of the city center's lighting from an existing high-pressure sodium system to white LED. The new lighting system makes central Milan noticeably more blue at night

The strong directionality of LED sources enables precise control of illuminated regions. Early LED products attempted to conserve the precious lumens, due to low luminous efficacy, by controlling light distribution very strictly. As light has become cheaper to produce with LEDs, manufacturers have taken a relaxed attitude toward distribution. This makes proper luminaire design that aims to achieve good contrast more challenging.

Along with low contrast, glare presents a significant threat to visibility for all users of roads at night. Glare is a reduction in visual acuity caused by the presence of intense light sources in the field of view, and is a symptom of wasted light that illuminates the eye itself rather than a scene. Glare is never a good thing and only serves to reduce visibility. In response to glare, the pupil of the eye narrows, reducing the eye's ability to quickly react to changing illumination levels. In fact, a 2012 report of the American Medical Association Council on Science and Public Health stated: "Glare from nighttime lighting can create hazards ranging from discomfort to frank disability." The problem is more acute in older eyes whose ability to adapt pupil size is diminished.

While LED roadway luminaires are effective at controlling glare at large distances, the glare they produce at short distances can be crippling. Better luminaire design, including optics to reflect or diffuse light, particularly toward the center of the light distribution, can help reduce the negative impacts of glare.

The Crime and Safety Quagmire

Under the guidance of law enforcement, city officials and planners often elect to install bright white lighting systems under the assumption that they will increase traffic safety and deter crime. However, these claims are not backed by clear scientific evidence.

Some believe that the more vivid colors provided by white LEDs increase traffic safety, but there's no research support for this argument, either. An unpublished study by the lighting design firm Clanton and Associates showed that the color of lighting may be a factor in the ability to see moving objects at night. But no one knows yet how color influences actual traffic safety. For now, there simply is no conclusive evidence that LED lighting enhances traffic safety.

Regarding crime, research to date has mostly focused on the brightness of light and ignored its other characteristics. LED lighting has the potential to decrease safety because it is a highly directional source that can yield scene illumination with large contrast and harsh shadows. While uniformity of illumination is thought to be detrimental to traffic safety, it is of paramount importance in pedestrian situations such as parking areas. In these places, uniformity is desirable because too much contrast can lead to deep shadows in which criminals may hide. Exquisite cutoff can be achieved with LEDs like no other source, but when coupled with the great potential for glare, LED lighting may well be detrimental to our security regardless of its color. Done right, where the feathering from light to darkness is gradual, outdoor lighting creates a much safer environment and a feeling of true security.

White LED lighting need not emit large amounts of blue light in order to accurately render colors in outdoor spaces at night. Low-CCT white LED systems now achieve color rendering index values comparable to those of higher-CCT lights, further lowering barriers to their adoption. This quality addresses concerns frequently addressed by law enforcement agencies about the color of lighting and its perceived effect on public safety.

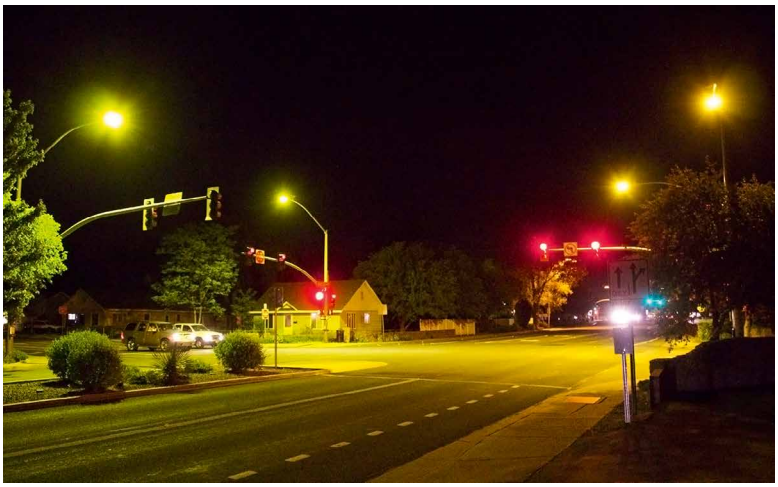


Figure 3: **Filtered LED (left) and phosphor-converted amber LED (right) are shown here in a test installation at an intersection in Flagstaff, Arizona. The City of Flagstaff is currently testing these and other low-blue-light LED technologies for the replacement of its existing low-pressure sodium municipal lighting system** (credit: IDA / John Barentine)

Listening to the Community

From Seattle, Washington to West London in the United Kingdom, news stories recount complaints from city dwellers living under new LED lighting. The recent lighting debacle in Davis, California, makes a good case in point.

In 2014, the City of Davis contracted to replace 2,600 high-pressure sodium 'cobrahead'-style lights with new white LED fixtures. A hail of complaints followed the installation of half of these new streetlights, culminating in a line of angry residents running out the door at a city council meeting. Protestors characterized the new system as "zombie lights" and "prison lighting."

Jim Benya, a lighting engineer and former member of the International Dark-Sky Association Board of Directors, wrote about the episode for LD+A. According to Benya, the city failed to consider relevant specifications including glare, light trespass, and color temperature when designing its new street lighting system. Poorly-installed, high-CCT lighting utilizing ineffective shielding resulted in bright white light shining into peoples' homes and the degradation of the nighttime ambience in a "cozy college town." In the end, Davis listened to its citizens and replaced the lighting with a 2700 K white LED system at a cost of $350,000 to local taxpayers.

The cautionary tale of Davis makes it clear: local governments that fail to adequately consider popular opinion on the specifications of proposed municipal lighting changes risk public rejection of new lighting systems. In order to avoid costly replacements, city staff should engage residents with test installations before committing to the purchase of new LED lights. Test sites must include a meaningful number and variety of LED options - including several CCT values - if they are to properly serve the public interest, and residents should be given a sufficient amount of time to evaluate the options and provide their feedback.

Lastly, cities should take care so as not to fall victim to the Jevons Paradox, a concept from economics in which the progress of technology increases the efficiency of resource use, but the rate of its consumption fails to decline because a lower cost of providing the resource spurs further demand from consumers. The Paradox is itself a form of the more familiar Rebound Effect. According to researcher Blake Alcott, who coined the term, "Governments and environmentalists generally assume that efficiency gains will lower resource consumption and are an effective

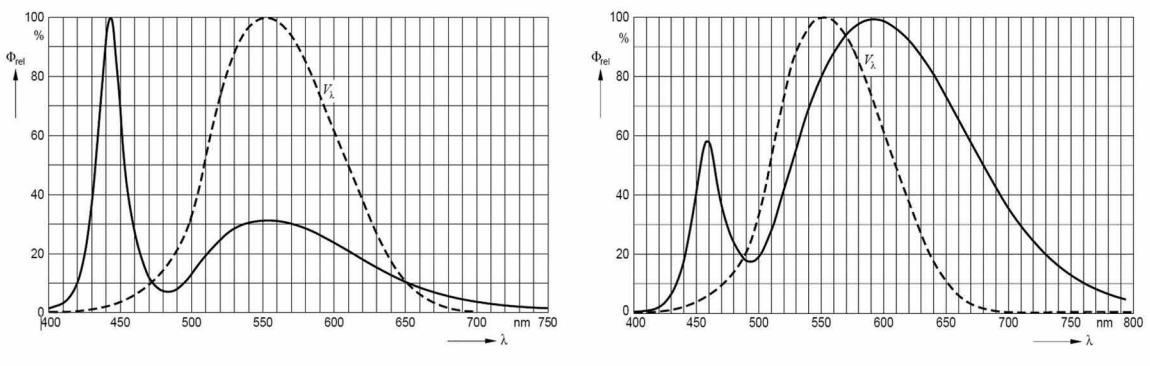


Figure 4: **A comparison of the spectrum of white LEDs (solid lines) with the response of the human visual system in the photopic regime (dashed lines) for two LED correlated color temperatures: 5500 K (left) and 3000 K (right). The curves match well for 3000 K, indicating that much of the light generated by LEDs at this color temperature is efficiently perceived by the eye, while the strong blue emission component of the 5500 K LED goes largely undetected**

policy for sustainability, ignoring the possibility of the paradox arising." The LED revolution is particularly susceptible to the Jevons Paradox because the cost reduction resulting from improved energy efficiency makes routing the savings into the purchase and installation of more (and unnecessary) lighting an attractive option.

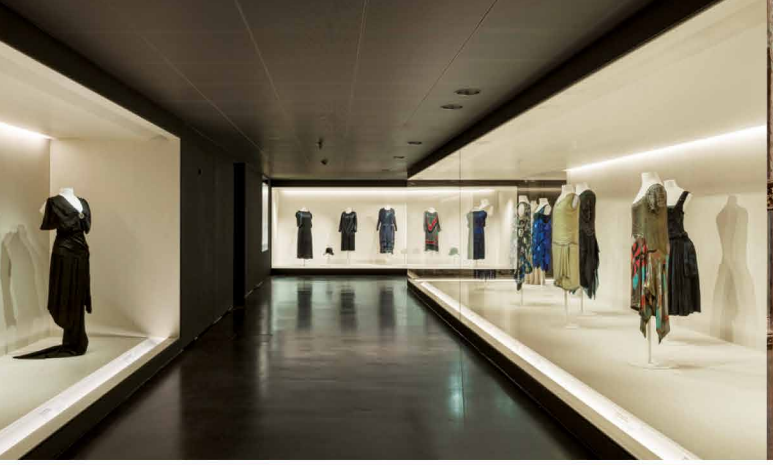
Solution and Considerations

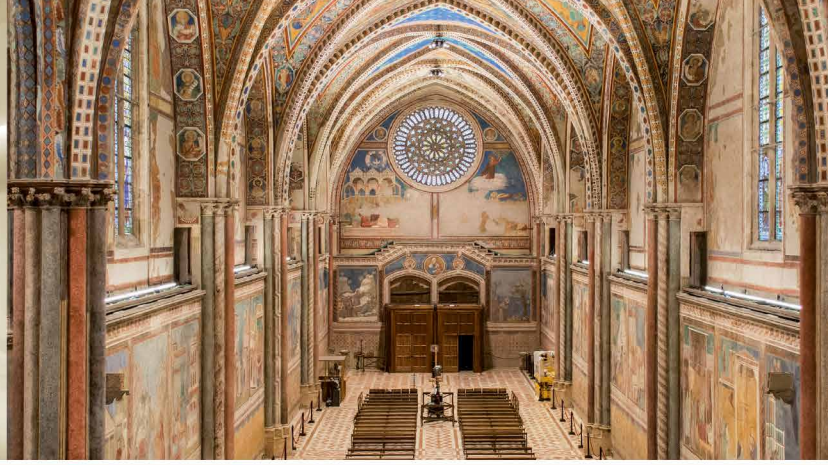
There are already many white LED options now available on the outdoor lighting market and that number will only rise in the future. IDA has developed a set of recommendations to help guide those choosing among them. These suggestions will aid in selecting lighting that is energy and cost efficient, yet ensures safety and security, protects wildlife and promotes the protection of dark night skies.

IDA recommendations include:

- Always choose full-cutoff fixtures that emit no light above a horizontal plane passing through the light-emitting element of the fixture nearest to the ground
- Use "warm-white" or filtered LEDs (CCT ≤ 3000 K) to minimize blue emission
- Look for products with adaptive controls like dimmers, timers, and motion sensors
- Consider dimming or curfew requirements during overnight hours
- Avoid the temptation to overlight because of the increased efficacy of LEDs
- Only light the exact space and in the amount required for particular tasks

LED technology is here to stay. It leads the lighting industry and dominates streetlight sales, and will continue to do so for the next decade or more. Cities that have yet to convert to LED certainly will in the next five years. By educating the public, professional lighting designers, and city officials and planners, money is saved, our carbon footprint is reduced, and a healthy, safe outdoor environment is ensured for humans and wildlife. ■





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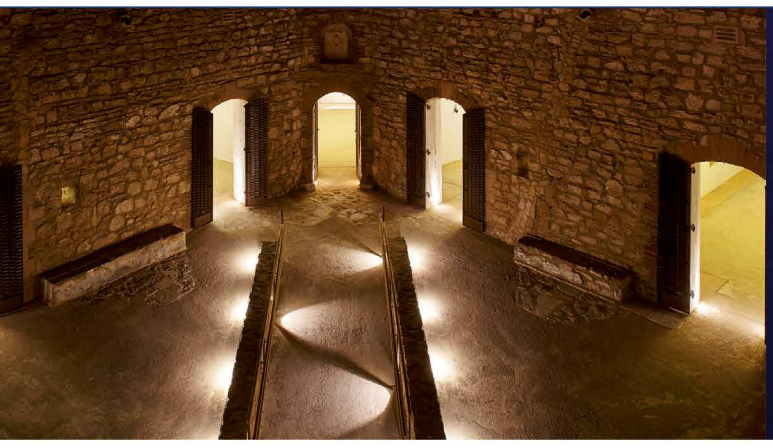

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The picture of the Zumtobel booth at Light + Building 2014 combined with a shop lighting image inspired the art team for this LpR 54 cover

Next LpR

PERFORMANCE & MANUFACTURING
Issue 55 - May/June 2016

TECHNOLOGIES

Cost and Performance Optimization of Thermal Management Solution for High Power LEDs

The LED industry has a challenge. General lighting requires very bright LEDs that can replace incandescent and halogen lights. Manufacturers need efficacy, cost and manufacturability to be "just right" but most leading solutions, especially in thermal management, are short of the mark. The article discusses ways to combine performance with reasonable costs and good manufacturability.

RESEARCH

"Best Papers" at LpS 2015: Luminescent Glasses and Glass Ceramics for White LEDs

The latest High Power LEDs with massively increased energy density call for light conversion concepts that can resist vast strain. Luminescent glasses or glass ceramics could be the solution due to their high thermal and chemical stability. The article presents rare-earth doped glasses, their potential application as photon converters for SSL, and shows how color coordinates of double-doped glass can be varied.

MANUFACTURING

Dosing of Abrasive Fluids in Manufacturing LED Lighting Products

Many manufacturing processes need very accurate dosing. One such dosing process concerns abrasive fluids with metallic, ceramic or organic content for thermal management. On the one hand, inappropriate dosing my cause reduced performance and reliability. On the other hand, a waste of material results in increased costs. The article discusses these aspects and shows technologies to avoid these issues.

EVENTS

Light + Building Post-Show Report

The most important lighting event in 2016 has closed its doors. The lighting community's expectations were high because topics like IoT, Smart Lighting and HCL were already hot before the event. Readers will found out if expectations were met.

SPECIAL

Flicker Beyond Perception Limits

Since the introduction of fluorescent lamps, the lighting industry knows about flicker issues. However, many aspects are still unclear. Especially effects beyond the flicker fusion threshold are mostly ignored, and sometimes even denied. The article gives a summary of research results indicating that further research is needed and that for high quality lighting very likely a much higher modulation frequency is required.

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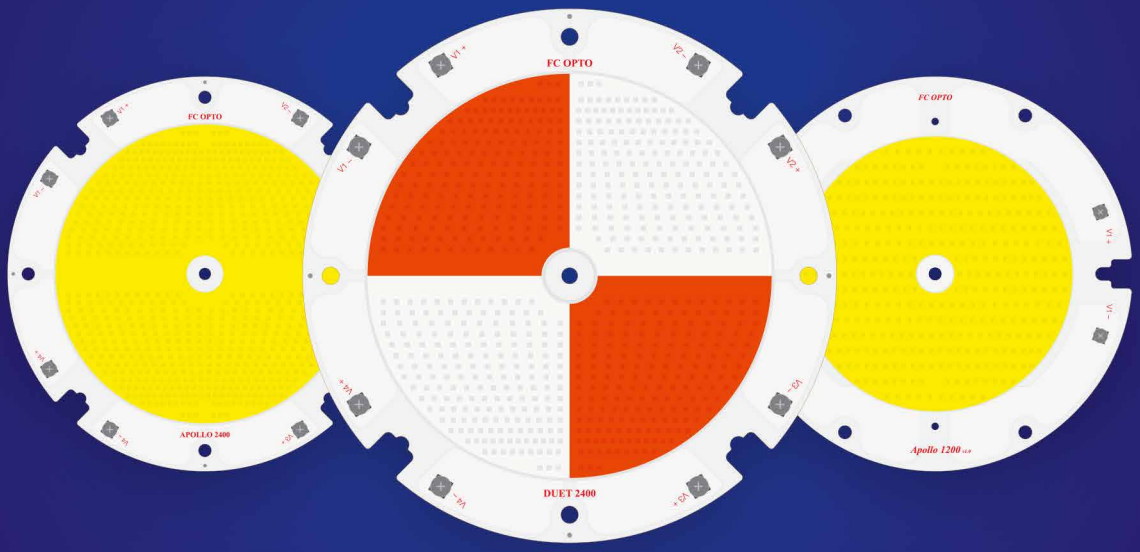

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