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LED professional Review

LpR

Trends & Technologies for Future Lighting Solutions

Nov/Dec 2016 | Issue 58

Research: Hybrid LEDs

Events: Highlights from LpS 2016

Technologies: Structured Glass & Dielectric Materials

Innovation: On-Chip Beam Forming Optics

See pages 5 and 7.

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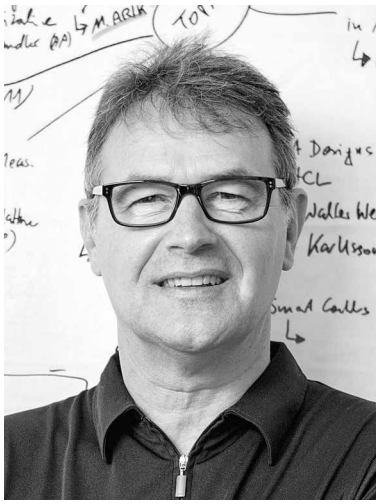

Latest Trends & Innovations

The LpS 2016 in Bregenz was, once again, an ideal platform to encounter the latest trends and innovations in the field of Solid-State Lighting. From September 20th to 22nd more than 1,500 people visited the LpS event and over 100 experts presented their findings in lectures, workshops and discussion rounds. 100 exhibitors showcased their products, equipment and services to the visitors.

While lectures in previous years were focused on light sources, this year technologies like smart lighting, connectivity and Internet of Things were added to the extended conference program. This reflects a trend moving away from pure LED hardware and towards intelligent lighting. In the field of SSL applications, current developments in Human Centric Lighting were presented and discussed.

The winner of the LED professional Scientific Award 2016 was Dr. Rubén D. Costa from the University of Erlangen-Nürnberg for his investigation of "Bio-Inspired White Hybrid Light-Emitting Diodes". This new color conversion technology might open the door for LEDs that are not dependent on rare earth based phosphors with limited availability. Munich Re, sponsor of the Scientific Award 2016, handed over the €3,000 check to the winner.

Exciting product launches were presented in the exhibition and at the international press conference. Auer Lighting introduced a new color-mixing glass optic named “Shopwhite” which was designed for multi-color LED arrays. Gigaherz-Optik launched the measuring system “TPI21-TH” for testing and binning of back-end LEDs. The IA-1200 hot melt room-temperature vulcanization adhesive by Dow Corning was formulated to achieve instant green strength. Ophir Photonics pioneered with the “FluxGage” LED luminaire measurement system, which is three times as small as an equivalent integrating sphere. An innovative approach to directional lighting application provides the new Plessey Orion™ PLWSC3000 series. Dow Corning’s MS-4002 moldable silicone retains high transparency even in harsh environments. UL introduced a verification service for lighting products with the opportunity to have an independent third-party laboratory verify the validity of claims about the level of optical flicker. “Synapse” developed by iLumTech is an innovative, intelligent and dynamic smart city control and monitoring system. Last, but not least, Flip Chip Opto released its first-in-class “Ares Series” UV-A spectrum flip chip COB.

In the field of alternative light sources, the company InovisCoat GmbH presented the world’s largest electroluminescence film at the LpS 2016 in Bregenz. A juror from Guinness World Records was there to make sure the claims were valid and then entered InovisCoat and LED professional in the Guinness Book of World Records. The use of LED lighting in Art was presented by the American artist, Clint Eccher, who exhibited his tiered paintings in Bregenz. He showed how LED lighting is used to transform static paintings into some of the most advanced paintings in the world. The dynamic, “living” pieces transform their appearance with LED lighting.

The full LpS 2016 post-show report and many other articles on SSL trends and innovations are in this issue for your reading pleasure.

Yours Sincerely,

Siegfried Luger
Publisher, LED professional
Event Director, LpS 2016

LUXEON Stylist Series

LED Light Engines to create lighting that sells for Fashion Retail, Fresh Food and Restaurants.

Fashion Retail

Showcases merchandise and makes an impact.

CrispWhite Technology
Reveals the whitest whites

- LUXEON CoB LEDs with CrispWhite Technology for brighter whites

CrispColor Technology ™
Highlights rich colors and increases contrast

- LUXEON LEDs with CrispColor Technology for saturated and vivid colors (warm)
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Accentuates the freshness and overall visual appeal of a variety of fresh food.

FreshFocus Technology ™
Accentuating freshness and overall visual appeal, making food irresistible.

- LUXEON LEDs with FreshFocus Technology for red meat
- LUXEON LEDs with FreshFocus Technology for fresh fish
- LUXEON LEDs with FreshFocus Technology for marbled meat
- LUXEON LEDs with FreshFocus Technology for produce
- LUXEON LEDs with FreshFocus Technology for bread & pastries

Restaurants

Creates the perfect atmosphere to enhance the overall dining experience.

AtmoSphere Technology ™
Elevates a restaurant's image and appeal by producing the ideal ambiance

- LUXEON LEDs with AtmoSphere Technology for the ideal restaurant ambiance
- Matrix Platform with AtmoSphere Technology for dim2warm and white/color tuning

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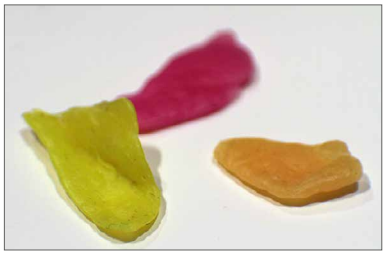

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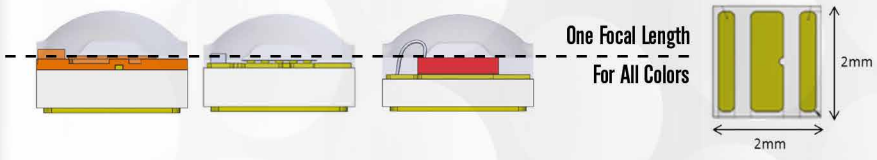
New LUXEON C Color Line

LUXEON C Color Line

Compact high power color emitters for maximum punch and flawless color mixing

- **Multiple colors, a single focal length:** this allows flawless color mixing, maximum optical efficiency and removes halos
- **Low dome design:** eliminates trade-offs between flux and source size
- **Hot tested:** removes guesswork for designers
- **Industry's lowest thermal resistance:** means greater light output and lower heatsink costs
- **Small symmetrical package:** enables dense packing and limits the impact of rotation during reflow



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  - Entertainment
- **Lamps**
  - Color Tunable
- **Specialty Lighting**
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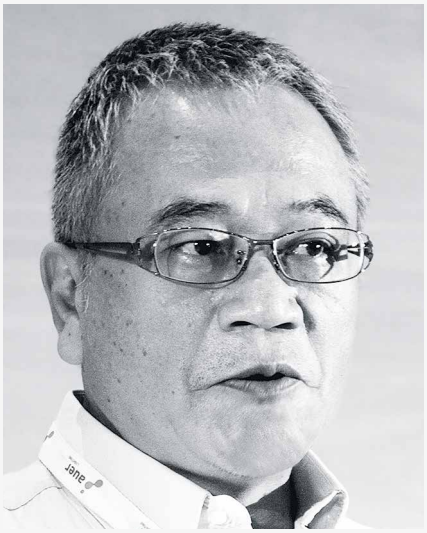

Justin Jiang
Justin Jiang owns a Master of Science in Business Administration from the Mercer University, Atlanta, Georgia, USA. He also received a Bachelor of Science in Architecture from the Fung-Chia University, Taiwan, ROC. As General Manager at UniBrite, Justin Jiang has over 20 years of experience in lighting design, engineering, new product introduction, program management and related operational functions. He has gained excellent leadership, teamwork, and communication skills in cross functional projects with an emphasis towards outsourcing technical application and production resources. In-depth knowledge and experience in LED lighting, new product designing, master scheduling and new technical solutions are additional skills.

REVIEW OF THE LED LIGHTING DESIGN APPROACH

A rapidly changing world leaves little time to react to new trends. Nokia lost its lead position because it failed to recognize market changes and take appropriate action in time. This has caused anxious industries to react quickly when changes come about. But, in some cases, such hasty reactions can also be harmful.

When LED luminaries were introduced into the global lighting in 2009, the lighting industry immediately took notice. The major lighting companies jumped on the LED lighting development train early and deployed huge resources and investments. But most did not yield a desirable business result.

Some disturbing news suggested that the LED lighting industry failed to move toward an optimistic profitable direction. The industry giants stepped down from the lighting business without an obvious successor to take the lead. This vacuum situation is definitely going to impact the lighting industry as a whole. The LED market will lose ground as a result. As the current LED lighting market has already provided low prices and low quality products, this situation of lacking leadership and powerhouse involvement, will prolong the saturated market without any possible solutions in sight.

At the beginning of the LED application development, the lighting industry promised consumers a new, affordable light source (LED) with low energy consumption and a long life. But unfortunately, instead of satisfying the consumer's desire for high quality, the market has been flooded with poor quality and low cost products. The driving force between demand and supply has led the industry in the wrong direction of cutting costs by sacrificing quality. To provide what the consumers truly want, the design revolution for a high quality product with low costs needs to be the top priority for the LED lighting industry.

The current LED bulb form/geometry in today's market is a copy of the incandescent lamp with the driver located inside the heat sink. Naturally, the temperature on the heat sink will become the operational temperature of a driver. The temperature on electrolytic capacitor is generally used as the lifetime measurement of a driver. The desirable capacitor temp is at 105°C /10,000 hr and its operation temperature is at 115°C inside of the bulb. This is fatal to an LED bulb and poor quality is a natural outcome in this case.

In the fluorescent lamp the tube shape is a reasonable design as a consequence of two electrodes on both ends to excite the light. However, the LED has different characteristics and a totally different technology. The tube shape cannot provide a sufficient heat exhaustion mechanism required for the LED packages. By forcing LED packages into the tube form, light decay and driver damage due to overheating comes more quickly. The LED bulb and tube are design failures that force new technology (new functions) into an old, existing form. These design directions have a lot to do with the current chaos of the LED lighting industry.

LED, this tiny light source, generates high lumen and high heat, which is totally different from any existing light source that man has ever seen. LED owns its unique characteristic that requires a completely new design concept to undertake the challenges it has. Existing designs have taken the "function follows form" approach. This approach has sacrificed functions by forcing a new technology into form fittings, crippled the lighting design development and left some unsolved challenges. In "form follows function", functional needs of a new technology are fulfilled before it is finalized or the form identified. In short, choosing the right approach for an application could solve many issues. It could stimulate this industry, and lead to a brighter tomorrow. ■

J.J.

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The Lighting System Creator is a free online design tool offered by Future Lighting Solutions which enables the user to seamlessly create an entire lighting system. Powered by a proprietary algorithm leveraging light source LM-80 data, the LSC automatically provides appropriate and application specific light sources based on value engineering principles, determines the optimal forward current and temperature to meet target flux, efficacy and L70 lumen maintenance values.

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OMC Launches Several New Product Lines

OMC, a pioneer in optoelectronics, introduces a range of new LEDs. The new products are surface-mount high-power ultra-violet and infra-red LED emitters, extremely compact LED emitters measuring just a fraction of a millimeter, and a series of brighter LED emitters than traditional colored LEDs based on their proprietary Active Diffuser Technology™.

OMC extends their LED portfolio with a series of new UV & IR LEDs, as well as new, colored LEDs using a proprietary technology, and the tiny Micro Series LEDs

High Power Surface-Mount IR & UV LEDs:
The high power SMD LED series is available in two package styles and suits a wide range of possible applications, including curing, data communications, inspection and sensing. The very compact 3.5x3.5 mm High Power SMD LED device is available in both UV and IR types, with a number of integral lens options providing different output beam angles and a ceramic substrate giving enhanced thermal properties. Available UV wavelengths include 365 nm, 385 nm and 395 nm and IR wavelengths include 850 nm and 940 nm.

The second package style in the series is the larger Multichip UV LED, measuring 6.8x6.8 mm. This 7 W device offers very high power output and features a glass lens for superior reliability and extended product life. As the device includes multiple LED chips, these can be configured to allow the device to emit more than one UV wavelength should the application require it.

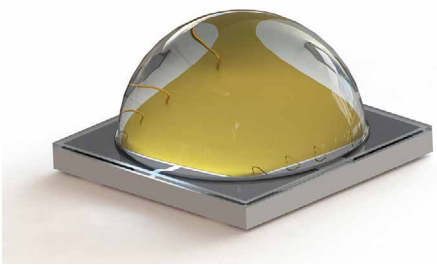
Micro Series LEDs:
OMC's new Micro Series has been developed for use in indication and display applications on miniaturized or highly compact products, which would normally be too small for conventional LEDs, in particular, consumer electronics and digital products. The smallest emitter in the Micro Series measures just 650x350x200 microns. Despite their tiny footprint, the new Micro Series emitters have a very high output, comparable to traditional-sized ultra bright LEDs. The Micro Series includes blue, green and red emitters and the devices are in production now.

Colored LEDs:
OMC's Active Diffuser Technology™ will benefit applications such as status indication and signaling, as well as color illumination applications such as mood lighting. It is a method which combines a blue LED chip with different colored phosphor-based diffuser media on top of the LED chip to manipulate the light wavelength, producing more intense, richer red, amber and green LEDs. The power output and efficiency of the emitters is comparable to blue gallium nitride based LEDs and the colors are richer than those of traditional LEDs because the output is made up of a wider spread of wavelengths, rather than a narrow peak.

As an additional benefit, the diffuser medium provides a more homogeneous output, eliminating the wire-bond and lead-frame shadows commonly seen in the beam pattern of standard LEDs. ■

Plessey - New Single Chip High Power 7070 LEDs

Plessey, a leading expert in the manufacture of lighting and sensing products and components, is pleased to announce the launch of its new 7070 high power LED range. The PLW7070 products take full advantage of Plessey's GaN on silicon MaGIC™ technology and provide a best in class high power LED component on an industry standard package footprint, complementing Plessey's existing family of i2LED™ high power products.



Plessey's new 7070 range of LEDs provide high power and improved thermal performance for demanding lighting applications

Using its proprietary GaN-on-Si high voltage technology Plessey has been able to use a single LED die to improve thermal performance, improve far field imaging and dramatically reduce cost over incumbent solutions.

Plessey provides components and solutions across the whole of the lighting value chain. Lighting system designers and specifiers can access its design, build and supply chain expertise from GaN on Silicon blue die all the way up to complete luminaires and fixtures. The PLW7070GA high power LED with multiple junctions integrated in a single chip eliminates shadow effects and provides optimized far-field imaging. Compatible with industry standard secondary optics and operating at input currents from 350 mA to 3 A, 1 W to 15 W power, Plessey's high power LEDs reset the bar for performance in low-cost single chip LEDs for demanding outdoor and commercial lighting applications, and are available in a full range of CCT and CRI options.

The PLW7070 range has been designed using our unique integrated multi-junction die architecture that provides a solution for a diverse range of high power applications in high bay, floodlighting, street lighting, spot lighting and down lighting, in addition to portable torches and lamps. The move for designers to mid-power products because of low cost can now be reversed as these new solutions allow for fixture costs that are up to 50% lower.

The key features and benefits for customers and the LED lighting market with the Plessey 7070 range is a custom Aluminum Nitride ceramic lensed package with an industry standard solder pattern and footprint. Its low thermal resistance, less than 2°C/W, combined with a high maximum junction temperature of 135°C for good thermal management in demanding thermal environments is critical in heat management. Using a single GaN-on-Si multi-junction chip for 12 and 24 V operation, Plessey is setting a new benchmark for far field imaging and the use of secondary optics in narrow beam angle applications. Superb maintenance of luminous flux is possible over a wide temperature range and the in-built ESD protection provides stable yield through system manufacture and operation. ■

Cree Introduces Industry's Brightest Horticulture LEDs

Cree announces the new XLamp XQ-E and XP-E High Efficiency (HE) Photo Red LEDs, the industry's highest performing LEDs optimized for horticulture. The new LEDs deliver up to 21 percent higher output than the previous generations of XQ-E and XP-E Photo Red LEDs, enabling horticulture lighting manufacturers to deliver higher performance products, reduce luminaire size and lower system cost.

New Photo Red LEDs deliver more than double the flux density of nearest competitor

The XQ-E family provides a unique combination of ultra-compact package, high output and wide range of horticulture-optimized colors. Using XQ-E LEDs allows to create luminaires that use half the power of conventional HPS luminaires, as well as being smaller and weighing less than incumbent technologies. The higher performing XQ-E High Efficiency Photo Red LED will enable customers to quickly reduce the power consumption of their current design even further for faster payback.

The XQ-E High Efficiency Photo Red LED sets a new performance benchmark by delivering Photosynthetic Photon Flux (PPF) levels up to 5.39 µmol/sec at 85°C from a package footprint of just 1.6 x 1.6 mm. The new XQ-E's ratio of output to size is more than double that of the closest competitor. The XP-E High Efficiency Photo Red LED delivers up to 6.08 µmol/sec PPF output at 85°C and is the first LED to break the 1 W radiant flux barrier at 85°C.

Both XQ and XP LEDs for horticulture can deliver R90 lifetimes over 100,000 hours, even at the extreme temperature of 105°C. In addition, horticulture lighting manufacturers can immediately take advantage of the existing ecosystem of drivers and optics proven to work with the XQ and XP platforms to accelerate their time to market.

Lumileds' Latest Multi-Die Emitter Drives Down Cost-per-Lumen

Lumileds introduced the LUXEON 5050, a multi-die high power package that provides high flux at high efficacy, enabling system designers to reduce LED count and cost in outdoor and indoor fixtures. The LUXEON 5050 is the superior choice for outdoor and directional lamp applications that demand high efficiency and cost effective design together with precise beam control.

The LUXEON 5050 multi-die LED provides the most cost effective solution for high efficacy outdoor fixtures, high and low bay fixtures and indoor directional lamps with a single light source

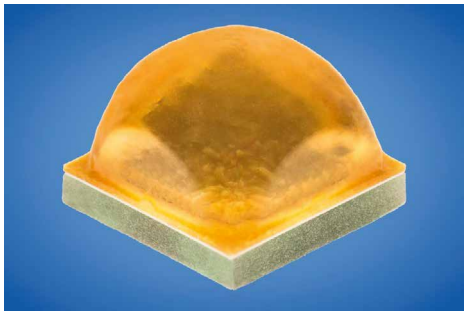
In outdoor applications, the source delivers >155 lm/W at a typical drive current of 160 mA (4000 K, 70 CRI) and >180 lm/W at 80 mA. For indoor spotlights and downlights, the LUXEON 5050 can achieve >130 lm/W at 160 mA (3000 K, 80 CRI).

The LUXEON 5050 is offered in a range of color temperatures (2700-5700 K) at 70, 80 and 90 CRI. The source is driven at 24 V, which enables the use of low cost and high efficiency drivers for all solid state lighting applications. The LUXEON 5050's surface mount device package features a thermal resistance (1.9 K/W), which greatly reduces thermal management needs. Finally, the LUXEON 5050 utilizes a small round light emitting surface (4.6 mm) which simplifies optical design and makes it easier to achieve high center beam candle power.

Cree XP-L2 Doubles the Lumen Density of Competing LEDs

Cree's high-power XLamp® XP-L2 LED delivers up to 7% more lumens and 15% higher lumens-per-watt (LPW) than the industry-leading XP-L LED. The new XP-L2 LED improves the lumen density, voltage characteristics and reliability of the XP-L LED in the proven XP package, providing an easy drop-in upgrade to achieve higher system LPW for lighting manufacturers with existing XP-L designs. It also enables reduced size and cost for new designs.

The new XP-L2 LED improves upon the XP-L LED in the same footprint, allowing customers to quickly achieve higher system efficacy in our existing XP designs without the burden of increased development time and cost.



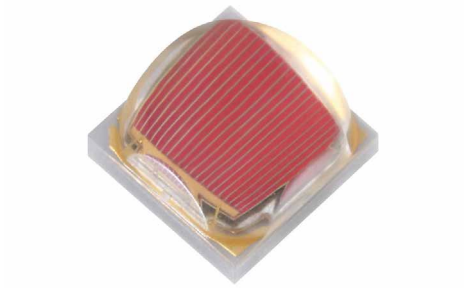
Cree's tiny XP-L LED package is again improved in efficacy and lumen output

The XLamp XP-L2 LED raises efficacy of warm white (3000K, 80 CRI) at 85°C up to 171 LPW. In addition, the XP-L2 LED is now available in EasyWhite® 2-, 3- and 5-step color temperatures from 2700K to 6500K to enable luminaire color consistency. The XP-L2 LED has LM-80 data available immediately, enabling luminaires using XP-L2 to be qualified for ENERGY STAR® and DesignLights Consortium®.

Cree created a breakthrough performance class of high-power LEDs with the XLamp® XP-L LED, and the new XP-L2 continues to strengthen this performance advantage. The new XP-L2 LED delivers twice the lumen output of other similar-size high-power LEDs, enabling lighting manufacturers to improve the performance of their lighting designs and reduce the size and cost of new designs for applications, such as industrial and stadium lighting.

LG Innotek Unveils High Power Color LED Package Line-Up

LG Innotek announced that it had developed high-power color LED Package (3535 series) for premium lighting in various areas, such as architecture or stadium. LG Innotek introduced high-power color LED Package lineup by utilizing its proprietary vertical chip technology.



LG Innotek's 3 W High-power color LED package (3535 red)

The company will finish developing three color types (Red, Green and Royal blue) of 3 W color LED packages within the month and plan to mass-produce the LED packages beginning next month.

Color LEDs can produce lights of various colors, including red, green and blue, and are expected to replace the lightings used in architecture and stage. However, the current color LED solutions are limited as it needs multiple packages to implement intensive lighting in a particular place and the LEDs had low luminance and uneven light quality.

Based on the expertise obtained from developing the world best high-power LED packages, LG Innotek succeeded in increasing the power of color LED Packages and securing stable performance. These packages can provide lower unit price of lighting application and at the same time produce a light source of high quality.

The company plans to increase the power of color LEDs from 3 W to 8 W by the end of this year. In addition to the red, green and blue lights, the company plans to produce lights of various colors, including amber and products for special purposes such as agriculture and horticulture by using wavelengths between 450 nm - 740 nm.

Xicato Launches XIM Generation 4 with New Features

Xicato launched the fourth generation of the Xicato Intelligent Module (XIM). XIM Gen 4 integrates Xicato's famously consistent and reliable LED light source and high-performing, deep-dimming driver with Bluetooth wireless communication. This tight coupling of control, driver, and LED offers performance not possible with separate components.

Xicato's XIM Gen4 has implemented lots of new features

Features:
- Individually Programmable
- Manual or Automated Control
- Secure - AES-128 encryption
- Real-time and Historical Operating Data Reporting
- 16 Groups and 16 Scenes per XIM module
- ARM Cortex M0 32 bit 48 Mhz embedded microprocessor
- 256K Non-volatile Memory

XIM Gen4 maintains compatibility with the wide array of heat sinks, adapters and optics already available with the XTM and previous XIM generations, making it easy to design a fixture around it. In fact, XIM Gen4 is a drop-in upgrade to existing XIM designs!

XIM has some serious brainpower on board. There is a fully functional control system embedded in each module, containing security keys, groups, scene and control behaviors, and more. XIM proactively reports its current operating status, and stores histogram data of temperature and intensity settings. And it can be set to transmit Bluetooth beacons to allow third-party apps and websites to provide location-based information services.

Xicato has developed Windows and iOS software that makes it incredibly easy to configure, control and manage large and small lighting environments.

Lighting Control No Longer Complicated and Expensive:
We have heard from many people that they wish they could add control to their traditional lighting installations. Unfortunately, this is usually neither affordable nor practical. Custom made track may have to be replaced. Contractors and electricians may have to be hired to embed new control wires into concrete or brick walls or ceilings, or to drill holes through wood, lathe and plaster in historical buildings, or to lay ugly conduit on the surface. Entire systems are suddenly non-compliant with local building codes. What started as a simple upgrade turns out to take months and break the budget. And when it is finally installed, the system turns out to be functionally limited or needlessly complex, with even more funds required to get it running properly.

XIM Gen4 changes all this. No new electrical wiring. No new control wires. No central hub or controller is required. It can be commissioned and controlled from near the lights, using software that is easy to understand and free to download.

How Are My Lights Feeling Today?
XIM Gen4 keeps a count of its operating hours. It tracks how many times it has been powered on and off, and how many times the LEDs have been commanded on and off. It tracks and proactively reports real-time status of intensity, operating temperature, power consumption, and input voltage parameters. The data on any device can be read on your iPhone or Windows device. XIM Gen4 also stores historical operational data, including operating hours, intensity levels, and LED temperature.

This is how XIM Gen4 supports Xicato's verifiable, 7-year, 50,000 hour warranty. More importantly, this is how you can make sure your installation lives a long and happy life!

What can you do with XIM Gen4?
There are many ways that XIM Gen4 can help you realize the vision you have for your space. Pictures can speak louder than words. That is why we created this short video clip. We hope it helps you understand, and maybe even inspires you a bit.

XIM Gen4 has serious power under the hood!
If you look "under the hood" of the XIM Gen4, you find some impressive specs.

You've grown accustomed to Xicato talking about CCT, CRI, R9, TM30, and flicker. With the evolution of Lighting to distributed intelligence and wireless networking, we are adding a few new acronyms to the lexicon.

Plenty of new terms, such as dBm, SNR, MB, and MHz, are spelled out in our new XIM Gen4 datasheets. We look forward to helping you understand the new world of wirelessly controlled, intelligent lighting.

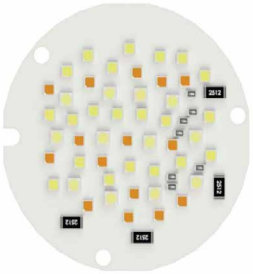
Lights As Beacons:
We sometimes get asked why we chose Bluetooth Low Energy (BLE) as the wireless protocol for XIM Gen4. While there are many good reasons for this (no hubs required, low power, great stability and single global standard - to name a few), the most important reason is that BLE is probably already in your pocket! BLE has been implemented in billions of smartphones, tablets and PCs worldwide. BLE is special because it is always ready for direct interaction, without the "pairing" that is required for Bluetooth headsets or speakers.

Open Platform:
At Xicato, we know very well that there can be other light sources that are used to illuminate a space. Also, in some cases you might want to go beyond what is offered by the Xicato software. For these reasons we are firm believers in open platforms and open standards.

Xicato Gen4 is Bluetooth 4.1 standards compliant, and is ready for for the Bluetooth Mesh standard when the standard is available and mature, which we expect will be in late 2017 or 2018. Xicato is an active participant in the standards group, and is driving it to meet the requirements of lighting professionals when is finally released. In the meantime, we have been working with third-party developers, providing APIs (application programming interfaces) that help them build software and hardware that work with XIM Gen4.

Luxtech Warm Dim LED Module Has Innovative Passive Circuitry

Luxtech's Warm Dim module creates a warm, cozy ambience by accurately mimicking an incandescent throughout its dimming range. The module's CCT seamlessly changes from 2800 K to 1600 K when dimming, with 3-step MacAdam color binning in the top 95% of the dimming range.



Luxtech's new warm dim LED module leverages innovative passive circuitry to solve the issue of high quality incandescent equivalency

The efficacy of Luxtech's Warm Dim module is higher than 100 lm/W, providing dramatic energy and cost savings as compared to an incandescent. In addition to its high color quality and efficacy, Luxtech's Warm Dim module is far superior to others on the market because of its unique patent pending warm dim circuitry. Luxtech's solution requires fewer components, resulting in

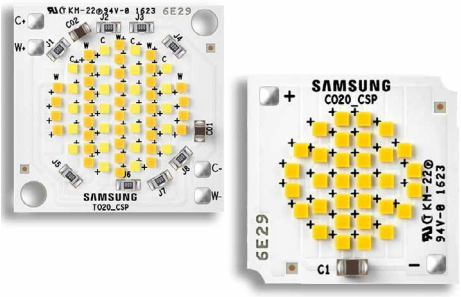
unparalleled reliability, high lm/$ ratio, and the greatest driver and dimmer compatibility in the industry.

Applications:
Luxtech's Warm Dim platform is targeted for both residential and commercial applications, especially high-end residential and hospitality. Available in a variety of form factors, Luxtech Warm Dim can be designed to fit recessed downlights, cylinder downlights, wall sconces, under-cabinet lights, wall coves, linear pendant fixtures, and more. OEM customers can now offer an easy, integrated solution that is compatible with existing systems. And end-users get the wonderful ambience that they are accustomed to with incandescent.

The Future is Bright for Warm Dim:
Luxtech's customizable Warm Dim platform opens up new opportunities to combine the efficiency of LED with the color quality of incandescent in form factors traditionally dominated by fluorescent. This technology is currently available in a standard 68 mm round module, or as a custom module solution.

Samsung Introduces CSP LED Modules

Samsung Electronics Co., Ltd., a world leader in advanced component solutions, announced a new line-up of chip scale package (CSP) LED modules for spotlights and downlights that features color tunability and increased design compatibility.



Samsung's new CSP LED modules for spotlights are also available as CCT tunable versions (left)

The new CSP LED modules provide an optimal solution for lighting manufacturers who seek highly compatible and reliable LED components.

The new LED modules are Samsung's first to incorporate CSP technology, which bring a wide range of lighting benefits such as significantly reducing the size of a conventional LED package. The combination of advanced flip chip and phosphor coating technology eliminates metal wires and plastic molds to enable more compact designs when manufacturing LED modules and fixtures.

In addition to their size advantage, the new CSP LED modules deliver characteristics that furnish seamless tunable color. A color-tunable LED module requires twice the number of LED packages in cool and warm temperature, which work in combination on the same board to create a range of tunable colors. In contrast to conventional plastic-molded LED packages that inevitably increase the size of the modules, Samsung's ultra-compact chip scale LED packages allow the module size to remain unchanged.

Samsung's new CSP LED modules are available in two form factors (19x19 mm or 28x28 mm) and are designed following Zhaga specifications, making them highly convenient in assembling. The modules also provide high-quality lighting in diverse beam angle options - spot, medium, wide - for improved compatibility with the optical solutions of Samsung's partners. The new modules are based on CSP LED packages that have successfully completed 9,000 hours of LM-80 testing, a level of proven performance that reduces the time to market for lighting manufacturers.

Samsung is now sampling six models of the new CSP LED module in CRI 80 and 90 with varying lumen output, size and CCT specifications.

Inventronics - Compact Programmable IP20 LED Drivers

Inventronics announced the release of the EBS Series of 40 W, 80 W and 160 W full-featured, constant-current programmable IP20 LED drivers that are designed to be extremely cost effective. They operate from 176-305 Vac input and the plastic housing is IP20 rated which allows for even more cost reductions when you need a full-featured LED driver but not the costs associated with an IP67 rating. The Zhaga compatible makes it the perfect choice for the slimmer European street luminaires where standard drivers form may be too large to accommodate.

Inventronics' EBS series full-featured programmable IP20 LED drivers are well suited for slimmer European luminaires

The EBS Series utilizes convenient push terminals instead of cabling that provides flexibility and easier installation while reducing production and installation costs. The EBS Series is suitable for use in outdoor luminaries of Protection Class I and II, built-in use for outdoor applications and they can also be upgraded to become an "independent" LED driver so you can mount them outside a luminaire enclosure for IP20 applications.

Each EBS Series offers 2 constant-power, programmable models delivering up to 40 W, 80 W and 160 W at output currents from 450 mA to 1050 mA. Each highly efficient model provides a 12 V / 200 mA auxiliary output and dim-to-off with low standby power consumption for even great energy savings. The EBS-xxxSxxxDTE models can be programmed for 0-10 V, PWM or time dimming with 3 timer modes.

The rugged thermal design of these drivers enable them to run cooler, significantly improving reliability and extending product life. The lifetime of these drivers is calculated to be at least 100,000 hours when operating at 80% load. These drivers also feature all-around protection which includes: over-voltage, over-temperature for both driver and external LED array, and short-circuit protection as well as thermal sensing and protection for the LED module.

You can increase your ease of installation and reduce production times even further by pairing the EBS Series with the Inventronics PRG-MUL2 programming tool. This combination furnishes fast, off-line mass programming capabilities that allows auto programming at the push of a button through user friendly PC based software.

GlacialPower Introduces New 33.6 W LED Drivers

GlacialPower announced the launch of a new pair of LED drivers for interior lighting applications, the GP-RS35P-42C and the GP-RS35P-42CA. Both drivers provide a rated power output of up to 33.6 W for LED lights from 33 V to 42 V DC.

GlacialTech's new GP-RS35P-42C(A) drivers with DC jack output and optional dimming are versatile drivers for multiple applications, offering great power efficiency

Features:

- Universal AC input from 90 to 305 VAC
- Constant Current and Constant Voltage modes
- Built-in Active PFC Function
- Protections: OVP, SCP, OTP
- 3 in 1 dimming function (DC 0-10 V, PWM, and Resistor)
- IP67 rated for environmental protection
- Compliant with ErP EU 1194/2012, Stage 2 directives for energy related products
- No Load consumption is less than 1 W
- Set up time is less than 0.5 sec at 230 VAC
- Protected by a fully isolated plastic case
- DC Jack connector easy for installation and maintenance

These new drivers' DC output to the LEDs is supplied via a DC jack connector, which allows for quick and easy installation and maintenance of the driver and its associated LED units. In addition to these features, the GP-RS35P-42CA also supports a wide range of dimming functions, while the GP-RS35P-42C is perfect for applications in which dimming is not required. A wide nominal input voltage range of 100 to 277 VAC provides easy electrical compatibility in almost any environment across the world. Both constant current mode and constant voltage modes are supported.

Both drivers are highly energy efficient and compliant with relevant EU requirements. A typical use case for these drivers would be power-saving interior LED downlighting for residential or commercial scenarios with a low installation and maintenance budget, and the drivers' versatility ensures many other potential applications exist.

Multiple LED dimming control options:
In order to support a wide variety of lighting scenarios and LED modules, the GP-RS35P-42CA version of this product provides analog DC voltage dimming controlled by external voltage from 0 to 10 V DC, and also offers PWM dimming from 500 Hz to 3 KHz, as well as resistance dimming mode controlled by a resistance from 0 to 100 KΩ.

Full range of LED lighting safety and device protection features:
The GP-RS35P-42C and GP-RS35P-42CA both offer fully isolated plastic cases, which provide IP67 rated protection against dust and moisture. Over-voltage protection (OVP), over-temperature protection (OTP) and short circuit protection (SCP) are all built in to the driver. To ensure lighting quality and prolong LED lifetime, these new drivers offer a clean, low distortion DC output with full system energy cost reductions and maximum ripple and noise of 250 mV.

Efficient, power saving LED drivers:
At full load these new drivers provide an excellent power factor of greater than 0.98 at 120 VAC, more than 0.95 at 240 VAC, and more than 0.9 at 277 VAC. In line with the latest international standards, this power factor provides electrical efficiency that is not only better than competing LED drivers, but is also a huge improvement compared to lighting technologies of the past, making these drivers ideal for legacy lighting system upgrade and replacement.

EU standards and other safety and energy efficiency directives are closely followed, thanks to GlacialPower's years of design and manufacturing experience in this field. Both drivers offer full compliancy with the important European directive on energy-related products, (ErP) EU 1194/2012, Stage 2.

For greater power efficiency, the drivers' maximum no load power consumption always remains under 1 W at 230 VAC. As well as being efficient, the power output is smooth and clean, to protect LEDs and avoid maintenance issues. Leakage current is less than 0.25 mA at 230 VAC. For responsive performance, both drivers provide a startup time of less than 0.5 seconds at full load.

Active+ Self-Learning Lighting Solution

Helvar's Active+ is an out-of-the-box standalone solution consisting of an LED driver and "our smallest sensor" yet, Active+ sense built into the luminaire.

Helvar's Active+ self-learning lighting solution

By using 60-100 hours of automatic learning, on full lighting, Helvar's new smart Active+ driver utilizes the Active + sense which is connected directly to the luminaire. The Active+ driver and Active+ sense work together learning about the surrounding environment, detecting change in lighting conditions from other light sources.

Active+ can also detect human presence. In areas with several luminaires, if the area becomes vacant and the lighting isn't needed in the environment the Active+ driver and Active+ sense signals to the luminaire to go into daylight energy saving mode. It dims the light when presence is not detected near but does this smoothly so the change of lighting level doesn't disturb other people sitting or working nearby. In areas with windows, daylight harvesting is supported.

The Active+ functionality also prevents daylight sensors in luminaires in close proximity to each other from interacting and starting to malfunction (so called waving effect). Constant lumen output (CLO) functionality reduces initial over-illumination, and ensures that the light output level can be guaranteed during the whole life time of the LED module.

The Active+ driver and Active+ sense both fit into a luminaire, which can be installed as easily as a basic switching luminaire, having no physical or electrical connection to any other external lighting components such as control panels, dimmers or common sensors. The Active+ driver has an inbuilt

power supply for the Active+ sensor which features a flat connection cable terminated with a keyed connector which enables total flexibility when mounting into the luminaire.

Luminaires fitted with Active+ self-learning lighting solution are ideal for refurbishment projects, as well as for new offices, corridors, open plan areas and storage areas. With an optional Active+ Mobile app, the end user can easily change the light levels of individual luminaires if the automatic setup needs fine-tuning. Active+ self-learning lighting solution guarantees energy saving.

Fulham - Power LED Emergency Driver with Battery Power

Fulham Co., Inc., a leading supplier of lighting components and electronics for commercial and specialty applications, has expanded its LED emergency product family with the new HotSpot Constant Power LED Emergency Driver. Easily installed in the field or factory, this emergency lighting system comes with an integrated power source that can provide more than 90 minutes of emergency lighting.

Fulham's HotSpot field-installable LED drivers offer 90 minutes of emergency illumination and can be installed almost anywhere

The HotSpot Constant Power LED Emergency Driver was specifically developed to be an easy-to-install emergency lighting solution that can adapt to most local emergency lighting requirements. The reliable emergency lighting kit elegantly combines the emergency LED driver with an NiCd battery in a single unit.

Fulham's HotSpot Constant Power LED Emergency Drivers are cULus classified and come with multiple mounting options, a conduit feed, and an LED illuminated test switch for simple testing and safety compliance. The unit can be installed in minutes and provides constant output wattage, automatically adjusting the voltage as needed.

The new emergency HotSpot LED drivers come in five models with outputs at 800, 1,250, 1,700, 2,200, and 2,700 lumens when used with typical 160 Lm/W LED modules. All HotSpot Constant Power units are UNV, 50/60 Hz input with an output voltage from 20 to 50 VDC, and come with Fulham's 5-year warranty. The products are now available from Fulham distributors.

Inventronics - 2nd Gen Programmable Outdoor LED Drivers

Inventronics is pleased to announce the 2nd generation of programmable constant-current outdoor LED drivers that will reduce design and lead time while offering higher efficiency and surge protection - without adding cost or compromising performance. The upgraded EUD 2nd generation series has added 96 W, 200 W and 240 W drivers that are extremely flexible allowing the creation of hundreds of configurations via the programming interface. This helps to drastically reduce part numbers in inventory and removes the need to design-in a new LED driver for multiple LED configurations.

Inventronics' 2nd generation programmable outdoor LED drivers offer added features and improved efficiency, surge protection and lifetime at a lower cost

The rectangular, extruded-metal housing is more compact to enable more creative freedom on luminaire design. It is IP67 rated, which is great for environmentally harsh indoor and outdoor conditions such as street, area, bay and tunnel lighting. To ensure extended trouble-free operation, the upgraded EUD product family also features over-voltage, over-temperature and short-circuit protection, plus a higher level of built-in surge protection: 6 kV line-to-line and 10 kV line-to-earth. Additionally, these drivers implement the new external over temperature protection for LED modules, enabling the whole system to run cooler, significantly improving reliability and extending lifetime.

The EUD-096Sxx series include 4 models that can supply up to 96 W at output currents from 450 to 3500 mA with a full-load efficiency up to 93.0%. The calculated lifetime at 70°C case temperature has increased to 104,000 hours. The EUD-200Sxxx series includes 4 models that can supply up to 200 W at output currents from 700-5600 mA with a full-load efficiency up to 94.5%. The calculated lifetime of these drivers at 70°C case temperature is now 120,000 hours. The 4 EUD-240Sxxx series models can supply up to 240 W at output currents from 700-6700 mA with a full-load efficiency up to 94%. The calculated lifetime of these drivers at 70°C case temperature is 83,000 hours.

They can be programmed for 0-10 V, PWM or any of 3 time-dimming modes, and have dim-to-off capability with standby power consumption < 0.5W while offering an always-on 12 V auxiliary supply sourcing up to 200 mA. This makes them ideal for operation with a wide variety of sensors and controls for even greater energy savings. These products all operate over a 90-305 Vac input range and provide excellent power factor correction.

TRP Introduces 50 W Easy-Programming T5 LED Driver

Thomas Research Products has introduced a new 50 W programmable LED driver with a T5 form factor. This new model includes 0-10 V dimming and easy programming. Thomas Research Products manufactures complete LED power and control solutions for OEMs and retrofitters.

TRP's LED50WPR2T5 driver with Class 2 output is UL Type TL certified for the US and Canada

The LED50WPR2T5 constant-current driver is easy to program. No computer is needed--just the appropriate USB programming cable

and +5 V power. Select the appropriate programming cable for the chosen current, plug it in and push the button--it's set! Output current is selectable from 500 mA to 1400 mA. It offers OEMs a flexible, easy way to reduce complex parts inventory.

TRP's new driver model provides standard 0-10 V dimming with a linear dimming curve. The LED50WPR2T5 is packaged with a narrow cross-section to match T5 fluorescent ballasts, sized to fit in low profile luminaires. The unit is also perfect for energy-saving upgrades in the field.

The UL Type TL certified driver features universal 100-277 V input and Class 2 output for US and Canada. The metal housing is rated for indoor use in dry or damp locations. The company's 5 year warranty is standard. All high-performance LED Drivers from TRP offer high quality, long life, and high efficiency and are cost-competitive.

Wacker Presents New Silicone Rubber Grades for Encapsulating LEDs

Wacker, the Munich-based chemical company, unveiled two new encapsulation compounds for light-emitting diodes. The encapsulants Lumisil® 740 and Lumisil® 770 cure to form highly transparent silicone elastomers. Both silicones withstand exceptionally high operating temperatures and strong light radiation without yellowing or becoming brittle. They are thus ideal for encapsulating high-performance LEDs.

Wacker's new Lumisil products are characterized by extreme robustness withstanding high temperatures and thermal shocks without yellowing or other significant degradation

The new LED encapsulants Lumisil® 740 and Lumisil® 770 are two-component systems. They cure at room temperature via a platinum-catalyzed addition reaction. The cured rubber grades have a refractive index of 1.41, which is typical of polydimethylsiloxanes. The two products thus belong to the group of normal refractive index (NRI) encapsulants. They effectively protect the sensitive LED semiconductor chip against environmental influences. They can additionally serve as carriers for luminescent dyes, which can selectively influence the color of the light emitted by the LED.

A special feature of Lumisil® 740 and Lumisil® 770 is their extremely high heat, light and thermal-shock resistance. Corresponding aging tests confirm this. After 500 hours of storage at 245 degrees Celsius, Lumisil® 740 test specimens display neither yellowing nor embrittlement. Even after 1,000 hours, the change in the cured rubber grades is insignificant. Lumisil® 740 has proven particularly resistant to combined heat and light exposure. In a thermal shock test going from +125 to -45 degrees Celsius, both materials withstand more than 1,000 test cycles. The encapsulation compounds are thus able to compensate thermomechanical stresses that can arise as a result of the different thermal expansions of materials.

Due to their stability, the new silicones are particularly suitable for encapsulating LED chips with strong heat generation and intense light emission. The two grades differ mainly in the hardness of the cured products. Lumisil® 740 cures to form a material with a Shore A hardness of 50, while Lumisil® 770 is formulated to be slightly harder at Shore A 70. Its property profile makes Lumisil® 740 ideal for the encapsulation of multi-chip LEDs that are applied using the chip-on-board technology - mounted directly onto the printed circuit board, tightly packed, without casing. Lumisil 770, on the other hand, is the material of choice for encapsulating single-chip LEDs.

The viscosity of the two encapsulation materials has been adjusted so that they can easily be applied by dispensing. Lumisil® 740 and Lumisil® 770 are self-adhesive. They adhere to the chip and to conventional reflector and casing substrates without pretreatment.

Electrolube Launches New Resin and Thermal Management Solutions

Electrolube has developed a number of key new products to help LED manufacturers improve upon the thermal management of LED products and ensure the desired results for heat dissipation are achieved.

Electrolube's UR5638 polyurethane resin for LED encapsulation which provides a clear, transparent finish is just one new product that will be introduced at electronica

Electrolube's newest innovations include ER2224, a thermally conductive epoxy resin system, which offers an improved method of cure and subsequent health and safety benefits for the user. Providing high thermal conductivity and excellent thermal cycling performance, the ER2224 resin is ideal for use in LED lighting units where it helps to promote heat dissipation and prolong unit service life.

The tough new UR5638 polyurethane resin provides a clear, transparent finish and is a low exotherm resin, making it ideal for LED applications involving the encapsulation of larger LED lighting units. As an aliphatic polymer, the resin also offers superior UV stability as well as excellent transmission of visible light, making it an excellent resin for white light LEDs.

UR5639 has been designed to encapsulate a variety of electrical components, but is particularly suited to LEDs. UR5639 is a clear/transparent polyurethane resin featuring low exotherm, low viscosity, low hardness and high flexibility. The level of flexibility achieved by the cured resin means that the connecting legs of components are not placed under high levels of stress during the cure.

Designed for use between heat generating components and heat sinks, the highly flexible GP300S and GP500S Thermal Gap Pads provide excellent thermal conductivity with a wide operating temperature range. With an operating temperature range from -50 to +160°C, both gap pads are ideal for applications where rapid and efficient heat removal is required and can be cut to any size. GP300S provides thermal conductivity at 3.00 and GP500S provides higher thermal conductivity at 5.00.

Electrolube will also launch two new silicone-free thermally conductive phase change materials. TPM350 provides low thermal resistance, excellent reliability and is exceptionally easy to apply. The material is similar to grease but without the mess and pump-out and is also dry to the touch, which is particularly useful for pre-apply applications. The TPM550 material features high thermal conductivity of 5.5 W/mK and becomes workable at approximately 45°C. Its advanced formulation ensures minimal contact thermal resistance and TPM550 also produces no mess due to its thixotropic characteristics, which prevent flow outside of defined interfaces.

New Materials for LED Assembly from Techsil®

From high performance LED chip packaging encapsulants and potting materials to thermal management solutions and adhesives for bonding lighting assemblies, Techsil introduces a series of new products to the market.

Techsil introduces a number of new materials for potting and thermal management of LEDs

LED Encapsulants, Potting and Protection:
The need for encapsulants for LEDs is rising dramatically and the requirements are high. Engineers looking for products offering brilliant clarity, high brightness, along with excellent thermal characteristics.
Techsil provides a wide range of materials that provides protection from harsh environmental factors such as moisture ingress, vibration, scratches and thermal shock. Designed to have an excellent refractive index, all materials have great UV stability.

New family members:

- PU22985 - a 2-part water clear potting polyurethane which cures to form a tough 85 Shore A material with good abrasion and hydrolysis resistance and thermal conductivity of 0.3 W/mK.
- MG 8322 - a clear potting epoxy which provides a tough resilient finish to environmental ingress.

Thermal Management Adhesives, Sealants, Greases and Tapes for LEDs
Techsil has a full suite of thermal management materials for the LED industry including high performance adhesives, greases and pressure sensitive adhesive tapes for bonding heat sinks and providing an excellent thermal path.

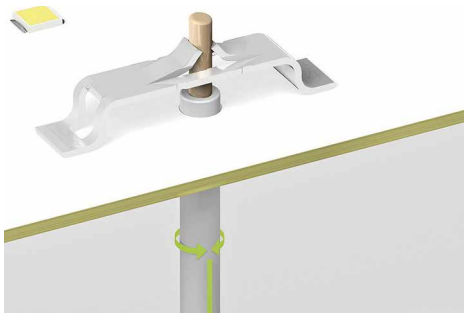
New family member:

- TIM 202331 Tape - a white, heat transfer tape for bonding heat sinks to LED strips and units. Thermal conductivity 2 W/mK. (Other tapes available with up to 3 W/mK.)

Techsil work in close consultation with engineers to ensure the correct performance specification is achieved by building on our years of expertise with these concepts. Techsil's materials are used in many LED applications such as LED light engines, linear modules, luminaires, housings, architectural lighting, security and flood lighting, outdoor LEDs, oceanic LEDs, panel mounted LEDs and PCB mountings.

WAGO Launches New 297 Series to Simplify LED Module Wiring

Launched in October, WAGO's all-new 297 Series is a through-board SMD PCB terminal block for conductor cross-sections of 0.5 mm^2 (20 AWG) that represents a significant departure from traditional designs.



WAGO's new 297 Series Through-Board SMD PCB Terminal Block maximizes cost savings while minimizing space

297 Series SMD PCB Terminal Block Advantages:

- Extremely compact design - 3.9 mm high
- Conductor cross-section: 0.5 mm² (AWG 20) “sol.”
- PUSH-WIRE® connection - push-in termination of solid conductors
- Simply “twist and pull” to remove solid conductors
- Compact design minimizes on-board LED shadowing
- Suction area for automated pick-and-place assembly
- Larger surface for uniform light distribution

The Signature Element of This New Series:
Conductors are connected on the back of the LED modules - vertically to the PCB. Both wiring on the back and a compact, housing-free design maximize space on the front side of the PCB for uniform light distribution and minimize on-board LED shadowing. The new design makes WAGO’s 297 Series ideal for both linear and square LED modules, as well as spotlights. Integrated PUSH-WIRE® connection technology provides tool-free, push-in termination of solid conductors and simple “twist-and-pull” conductor removal. The 297 Series also features a suction area for automated pick-and-place assembly.

In addition to its new connection capability, the 297-381 Terminal Block accommodates solid conductors with a cross-section of 0.5 mm² (AWG 20) and offers an extremely compact, housing-free design that’s just 3.9 mm high.

This new design not only minimizes on-board LED shadowing and maximizes space on the front side of the PCB for uniform light distribution, it makes WAGO’s 297 Series ideal for linear and square LED modules, as well as spotlights.

SphereOptics’ New High Accuracy - Easy to Use Benchtop Goniometer

SphereOptics’ new small benchtop goniometer has the capability not to only fit into almost every optical laboratory, but also to provide measurement data on a concise level. The type C setup of this instrument enables the developer of single LEDs, LED modules or chips to study angular performance in many development stages; fast and most importantly: reliable.

Measurement capabilities:

- Luminous intensity distribution with IES data generation
- Peak intensity, beam angle
- Cone Illuminance
- Color data such as x,y & CCT
- Color Rendering Index CRI
- Spectral power distribution
- Total luminous flux (lm)
- Source specific information such as power consumption and PF

The detector head of the goniometer is a high-quality, visible-range spectrometer, equipped with diffuser optics to collect all important measurement quantities over the customer required angular range. Data such as luminous intensity distribution, peak intensity, cone illuminance, beam angle, color data (x, y / CCT / CRI), spectral power distribution or total luminous flux (lm) is provided in a customizable report.

SphereOptics' new benchtop goniometer allows reliable measurement of source samples with up to 300x100 mm

In addition to the source output data, ambient temperature during the measurement (IES LM recommendation 79/82) is reported as well as source specific data such as power, power factor, lm/W or the orientation of the source during measurement, burn in and stabilization time.

With a maximum allowable source sample size of 300x100 mm and 25 kg, the new benchtop goniometer covers a wide range of LED measurement requirements.
The footprint of the instrument itself with 1.65 x0.60x1.73 m allows the usage also in small dark rooms and optical laboratories.

Optically Clear, Room Temperature Curing Epoxy Blocks UV Light

Formulated for specific optical applications, Master Bond EP30-2LB blocks UV light from 200-400 nm and allows the transmission of visible light from 450-900 nm. This two part system is optically clear with a refractive index of 1.55. It also passes ASTM E595 testing to meet NASA low outgassing specifications.

Master Bond's new EP30-2LB epoxy offers some outstanding properties like UV blocking and it passed NASA's stringent low outgassing tests

Beyond its optical properties, EP30-2LB is a reliable structural adhesive with a tensile lap shear strength of 3,000-3,200 psi and a compressive strength of 14,000-15,000 psi. It bonds well to a wide variety of substrates including metals, composites, glass, ceramics, rubbers and plastics. This epoxy has a ten to one mix ratio by weight and flows smoothly and evenly, enabling it to be used for coating, sealing and encapsulation applications. It is a capable electrical insulator, is dimensionally stable and has low shrinkage upon cure. This material also is easily machineable.

EP30-2LB resists chemicals including water, oils, fuels, acids and bases and many solvents. It is serviceable from -80°F to +300°F [-62°C to +149°C]. This compound has a shelf life of one year at room temperature in its original, unopened containers. It is available for use in ½ pint, pint, quart, gallon and 5 gallon container kits as well as gun dispensers.

Ophir Photonics Introduces FluxGage Measurement System

Ophir Photonics Group, a Newport Corporation company celebrating 40 years of excellence as the global leader in precision laser and LED measurement equipment, has announced the FluxGage, a compact, all-in-one LED luminaire measurement system. The patent-pending FluxGage measures flux, color, and flicker, important quantities for evaluating the performance of LED-based products. The measurement system is three times smaller and lower cost than equivalent integrating sphere products. It is designed for use by R&D during development and production for incoming inspection and quality control of new and replacement parts, allowing LED luminaires and modules to be sorted for consistency.

FluxGage offers the full bandwidth of measurement options from CCT to CRI, Duv and chromaticity measurement as well as flicker measurement

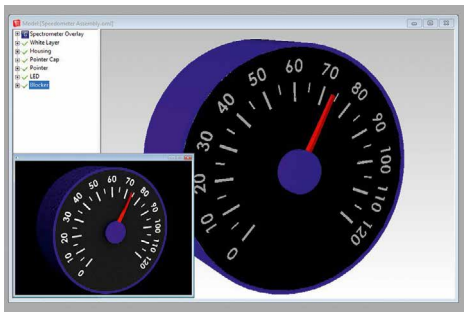
The FluxGage is an all-in-one photometric test system that uses 2-pi geometry.
A spectrometer is incorporated for color measurement of the spectrum, CCT (correlated color temperature), CRI (color rendering index), Duv, and chromaticity.
There is also a fast photodetector for flicker measurements. No fibers are needed.

The FluxGage system uses solar panels as the light detector. The panels are arranged on the inside walls of the measurement cavity and are covered with black paint and a dense array of clear pinholes through which the light passes. This design significantly reduces the reflectance of the solar panels, enabling the system to be only slightly larger than the luminaire source under test. It can measure luminaires of up to 610 x 450 mm.

Integrated software simplifies set up and operation with all the optical data from the light source displayed. The FluxGage connects to a PC via a USB cable.
A calibrated, NIST-traceable LED source is used to calibrate the system in the field.

Lambda Research Releases TracePro® Version 7.8

Lambda Research Corporation, a leading designer and publisher of illumination and optical design software, announces the official release date of its flagship TracePro software. The latest release, TracePro v7.8, i s available to download since September 30.



TracePro® V.7.8 allows a simulation of the appearance under different ambient lighting conditions

Updated features in TracePro v7.8 include the latest version of the Lighting Toolkit, new Path Sort Filtering, and new settings for all True Color plots. The Lighting Toolkit gives TracePro users a full-featured capability to analyze automotive lighting systems, including headlights/headlamps;

Illumination - Innovation - Imagination

Philips Fortimo LED Module System Solutions

LED Strip

Enabling design of high-performance slim linear LED luminaires, not possible with fluorescent lighting or Fortimo LED Line.

LED Line High Flux High Temperature

Ideal for application at elevated installation heights and increased application temperatures where more light is needed, such as trunking, battens, high-bay applications.

LED Line

Designed to replace fluorescent lighting in new luminaires for general lighting applications in office, retail, and industry.

LED Line Value Offer (VO)

Enabling most economic fixture design meeting DLC requirements for linear LED applications like troffers replacing T8 lamp equivalents.

LED Strip, LED Lines

High-end OEM's being able to sell TCO in projects

Exceptional quality of light
- High color rendering (CRI >80 and >90)
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- High homogeneity with low LED pitch (no pixilation)

Highest design flexibility
- Slim width <= 20mm
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- Life-time: up to >50,000 hours at high Tc life (up to Five year system warranty)

VO Boards Economic, Quality and Value

Enable luminaires for high volume markets

Good quality of light
- Color rendering (CRI >80)
- Color consistency of 3.5 SDCM

Essential product performance and functionality
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tail, warning, and marker lamps; as well as outdoor and indoor luminaires. The Lighting Toolkit provides visualization tools and regulation tables to certify that simulated results meet the requirements of the lighting and automotive standards, and provides pass/fail criteria for ECE, SAE, IESNA, and FMVSS regulations.

The new Path Sort Filtering in TracePro v7.8 enhances the existing Path Sort Table and allows users to apply a Boolean filter to specify the exact ray paths they wish to display and analyze. Users can analyze ray paths by building filters, starting from any source or surface and then building an entire path either surface by surface or object by object ending with a target surface. After filtering, single- or multiple-filtered paths can then be chosen to visually show rays traced through the model for that path and as irradiance or illuminance maps on the target surface. With this new feature, TracePro supports the most advanced method to find problematic areas in any design and is far superior to any commercial product on the market today.

Lastly, all True Color plots in TracePro now have settings for Brightness, Contrast, and Gamma, including Irradiancea and Illuminance, 3D Irradiance / Illuminance, and Luminance Maps.

TracePro v7.8 further enhances the most powerful and sophisticated illumination design software available for LED implementation in lamps and luminaires. TracePro streamlines the prototype-to-manufacturing process by combining an intuitive 3D CAD interface, superior ray tracing performance, advanced utilities, and seamless interoperability with other mechanical design programs.

Espen Technology - First Dimmable LED T5HO Type C Lamp & Driver System

Espen Technology, the leader in linear indoor retrofit products, has released the first dimmable LED T5HO Type C lamp and driver system, in the industry. As part of Espen's CoreTech product line, the new T5 & T5HO programmable driver systems offer advanced dimming, with 0-10V and/or AB dimming.

Espen Technology's LED T5HO type C lamp & driver system is dimmable and offers a light distribution characteristcs close to original T5 tubes

Benefits:

- DLC Listed
- 5-year Warranty
- Same wiring as a fluorescent lamp and ballast system
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- No mercury, no UV
- Suitable for Dry and Damp locations
- Instant On
- 60,000 hours with no on/off cycle limitations

The 4' LT5 lamp series is offered with real glass tubes for the true look and feel of legacy T5 and T5HO lamps. Three lumen output levels are offered: 1900, 2300, or 3300 initial lumens. All of these LED T5 lamps provide 240 degree beam angles, 82 CRI, and system efficacy of 125 lpw. The lamps ends can be reversed (no polarity) for easier installation.

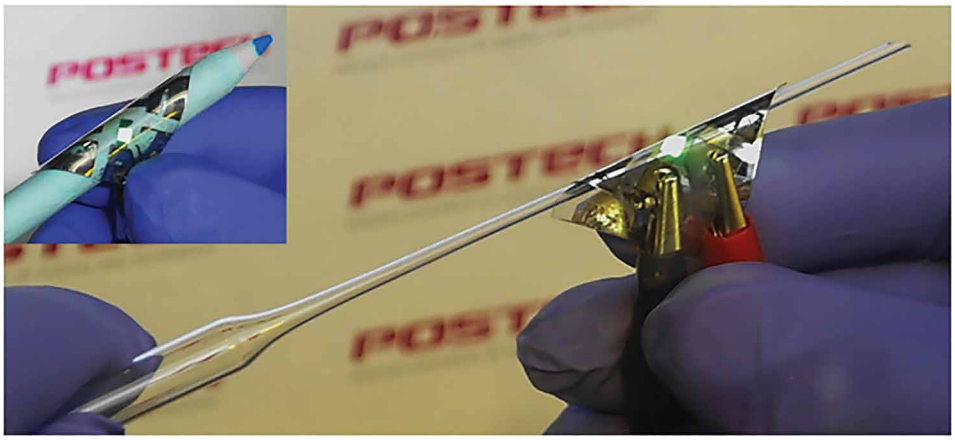
Researchers Propose Graphene Anode for Flexible OLEDs

In their research article "Approaching ultimate flexible organic light-emitting diodes using a graphene anode", Tae-Hee Han, Min-Ho Park, Sung-Joo Kwon, Sang-Hoon Bae, Hong-Kyu Seo, Himchan Cho, Jong-Hyun Ahn and Tae-Woo Lee from the Pohang University of Science and Technology and the Yonsei University in Korea respectively investigated the use of graphene anodes for ultra-flexible OLED devices.

Summary:

Ultimate flexible organic light-emitting diodes (OLEDs) should have ultra-high device efficiency, a low-efficiency roll-off at a high luminance and excellent flexibility. Here, we realized flexible tandem OLEDs using a graphene anode with a very high electroluminescent efficiency of 205.9 cd/A, 45.2% (396.4 cd/A, 87.3% with a hemispherical lens) and a very low efficiency roll-off at a high luminance of ~ 6.6% at 10, 000 cd/m^2 (3.8% with a hemispherical lens) by stacking two organic electroluminescence (EL) units. For the first time, we used an easily controlled and low-temperature processable charge generation layer with lithium nitride (Li_3N). This simultaneously provided efficient stacking of EL units and enhanced compatibility of the flexible device on a thin plastic substrate. The flexible tandem OLEDs with a graphene anode also showed great flexibility against bending up to a bending strain of 6.7%. These results represent a significant advancement towards the production of next-generation flexible displays and solid-state lighting that use a graphene anode.

The original article, "Approaching Ultimate Flexible Organic Light Emitting Diodes Using a Graphene Anode", is published in NPG Asia Materials (2016) 8, e303; doi:10.1038/am.2016.108 online on September 9, 2016.



OLEDs with a graphene anode wrapped on cylinders with different curvatures

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TECHNICAL REGULATORY COMPLIANCE UPDATE

Segment	Product	Standard (Certification)	Region	Technical Regulatory Compliance Information
Lighting	Tubular Fluorescent Lamps	Standard TIS 2337-2557, 2014	Thailand	The Thai Industrial Standards Institute (TISI) had adopted TIS 2337-2557(2014) Ballasts for tubular fluorescent lamps: energy efficiency on August 14, 2016. This standard specifies the energy efficiency requirements for ballasts for tubular fluorescent lamps for general lighting purposes in different shapes. It covers the minimum energy performance standard, ferromagnetic or electronic ballasts with a.c. supplies ranging from 10 W to 70 W, voltage of 220/230 V and 240 V at frequency of 50 Hz and ballast as a separate component or built into the lamp. This standard comes in force on August 16, 2017.
Lighting	Ballasts of Metal-Halide Lamps	Standard GB 20053-2015	China	This standard specifies the minimum allowable values of energy efficiency and energy efficiency grades for ballasts of Metal-Halide Lamps and comes in force on Jan 01, 2017. It is applicable to independent or built-in electrical inductors and ballasts with rated voltage of 220 V, frequency of 50 Hz AC and nominal power from 20 W to 1500 W. The Standard also evaluates values of energy conservation, testing methods and inspection rules for ballasts of metal-halide lamps. Section 4.3 of this Standard is mandatory, with the remaining sections to be voluntarily applied.
Electrical	Fluorescent lamps controlgear	IEC 61347-2-3: 2011/ AMD1:2016	Europe	This specifies the specific safety requirements for electronic control gear while using a.c. and d.c. supplies up to 1 000 V at 50 Hz or 60 Hz with operating frequencies deviating from the supply frequency, associated with fluorescent lamps as specified in IEC 60081 and IEC 60901, and other fluorescent lamps for high-frequency operation. The significant changes are in Clause 5 about sample size, Clause 7.1&7.2 on marking and additional information requirement, Cl. 15.4 about highest possible output voltage, Cl. 17.2 on application of tests and 17.3 regarding new test procedures
Electrical	Adapter	GS-certification, EK1-633-16, EK1-634-16, DIN 49437, DIN VDE 0620-1, DIN VDE 0620-2-1, EK1-557-13	Germany	Application guide for certification of adapters: 1. Adapters without manually operated switches or additional functions may not be GS-certified (refer to EK1 decision 633-16), this also concerns adapters with two sockets (2,5 A/ 250 V) which comply with DIN 49437. All other adapters may be GS-certified in principle. 2. Adapters with a manually operated ON/OFF switch on the adapter shall provide a two pole disconnection, if the switch is in the OFF position. Requirements from EK1 decision 634-16 must be taken into account. 3. Adapters without a manually operated ON/OFF switch on the adapter are not concerned by the requirements from EK1 decision 634-16. Depending on the additional function, requirements concerning a two pole disconnection have to be applied (e.g. RCD function) or not (e.g. timer). 4. Adapters with manually operated ON/OFF switch on the adapter and additional functions shall provide a two pole disconnection, if the switch is in the OFF position. Requirements from EK1 decision 634-16 must be taken into account. Depending on the additional function, requirements concerning a two pole disconnection have to be applied (e.g. RCD function) or not (e.g. timer).
Electrical and Electronics	Electrical and Electronics	RoHS Regulation	Singapore	The Ministry of the Environment and Water Resources in Singapore published the amendment in August 2016 known as Singapore RoHS or SG RoHS. The amendment is adapted from EU RoHS 2 and will restrict six hazardous substances in some electrical and electronic equipments from July 01,2017 (excluding spare parts and components which are sold separately). - Mobile phones, portable computers, air conditioners, panel TVs, refrigerators, washing machines. - Other types of electrical and electronic products such as industrial use equipment, medical devices and microwaves are excluded from SG RoHS.
Electrical and Electronics	Batteries	Circular No. 07/2016/ TT-BTTTT	Vietnam	This regulation is in force since October 01, 2016 and is applicable to organizations and individuals engaged in activities of production and sales of equipment. This technical regulation specifies the minimum technical requirements for lithium batteries for portable applications. It is built on the basis of international standards IEC 61 960 (06-2011): “Secondary cells and batteries containing alkaline or other non-acid electrolytes - Secondary lithium cells and batteries for portable applications” and IEC 62133 (2012): “Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary cells, and for batteries made from add, for use in portable applications”.

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Tech-Talks BREGENZ - Prof. Christian Cajochen, Univ. Basel, Head of Center of Chronobiology

Prof. Christian Cajochen

Prof. Christian Cajochen heads the Centre for Chronobiology at the University of Basel. He received his Ph.D. in natural sciences from the ETH in Zürich, Switzerland, followed by a 3-year postdoctoral stay at the Harvard Medical School in Boston, USA. His major research interests include investigative work on the influence of light on human cognition, circadian rhythms and sleep, circadian related disturbances in psychiatric disorders, and age-related changes in the circadian regulation of sleep and neurobehavioral performance. He holds a number of honors and has authored more than 100 original papers and reviews throughout his career.

Human Centric Lighting has become a catchphrase used by industry and the press. But the press has also started reporting that research emphasizes the danger of LED lighting in connection to our health and has coined the term “Blue Light Hazard”. These claims have caused confusion amongst end users and throughout the lighting community. Prof. Christian Cajochen, Head of the Centre for Chronobiology at the University of Basel - an expert on this topic - held a lecture at the LpS 2016 entitled “Light Beyond Vision”. Afterwards, LED professional seized the opportunity to talk to him personally and get some in-depth information about the risks and benefits of LED lighting.

LED professional: I would like to start by saying that we are not only interested in technologies. We want to know how technologies should be applied correctly to be of value to people health-wise and for their well-being. I know that you have a strong focus on cognition, circadian rhythm and sleep and the influence of light on different physiological aspects. So my question is, how do you see the LED? Do you think it’s applied correctly? Can it be improved?

Christian Cajochen: Chrono-biologists have been interested in light for the past 50 years, well before the LED era, because light is the most important zeitgeber for circadian rhythms of our inner clock. Now with the progress in technology - especially LED technology - it’s a wonderful way to create new light solutions. With new technologies you have more freedom that you can use or misuse. There is no good or bad way of how to apply this new technology. Having more technological possibilities gives you more possibilities to improve the light. With every new technology you can also do it the wrong way - but we learn a lot. We are still learning how to apply LED technology in human settings. But my personal view is that it is a great tool.

We know now that wavelength of light is important for different aspects of physiology in humans. With different light sources or different nanometers you can induce different responses like alertness. So the person is more awake, or you can go in the other direction and induce sleep. It really depends on what you are looking for. You can tailor your LED according to what your questions are. And that’s really new.

LED professional: Do you think that the industry understands about the biological and physiological effects of light?

Christian Cajochen: Actually, I’m very happy to be here by invitation of the industry. And because they invited me, I believe that they are becoming aware of what we call the non-visual effects of light. These are all the effects of light that are not related to vision but rather to other things like sleep and circadian rhythms. The industry wants solutions from us, but really, it’s too early. We are still not sure amongst ourselves and the industry is already asking for regulations and norms. We can give them broad recommendations but it’s too early for things like percentages. We’re still in the experimental phase. Although I think we need to move out of the laboratory quite soon and look at real life situations. For example, we’d like to investigate different light solutions with 500 people that work in a telecommunications company and find out what type of light they like in terms of well being, cognitive performance and also sleep.

LED professional: Can you recommend specific solutions right now?

Christian Cajochen: I think it’s a bit too early. I’m a bit reluctant to say “…you need to have this type of light for a certain solution …” because there are no simple solutions so far. And that makes it a bit complicated. It’s the intensity and the wavelength and the timing of light that are important. Which means you have three different degrees of freedom you can manipulate. It’s not just a pill you can give a patient and say “That’s good for you.” Of course that makes it more interesting and more innovative but harder to give simple recommendations.

LED professional: Could you give us an example of your research? You said it’s mainly experimental research - so how are the experiments set up?

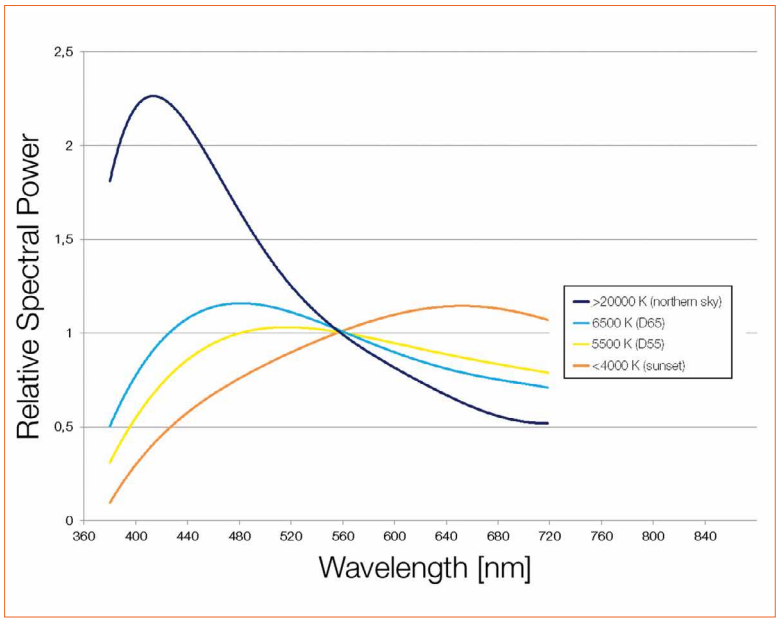
Christian Cajochen: We study people in controlled laboratory conditions. A typical set-up would be that they come to our laboratory and they spend one week there in our setting. They have an apartment where things like humidity, temperature and, of course, lighting are precisely controlled. We do very intensive physiological monitoring of the people; we monitor their heart rate, brain activity, hormonal changes and cognition (they have to do tests). They spend one week there under, let’s say, a dynamic LED daylight simulation compared against normal office lighting.

LED professional: So you’re saying that they don’t stay under controlled conditions for 8 hours and then go home; they stay there 24 hours a day, 7 days a week. Is that correct?

Christian Cajochen: That’s right. We want to prove whether this light regime, per se, is working under controlled conditions without any disturbance. That’s the first question and then if you can say yes, we see an effect, then you can gradually move to more realistic settings. And then you may discover that our lab data is wrong. But, so far, we have been able to confirm the effects mostly, also in settings that aren’t so controlled.

It’s important to have control studies in the lab, but it’s also important to have studies that are outside the labs. I think, for the industry, what counts is outside and not in the lab. What I talked about before is a typical setting in our lab. But we also do semi-realistic settings so that people can go home at night or we are adapting the light or we are just measuring the light that they perceive during the day. The light history is also very important.

LED professional: Did you ever consider the influence of the history just before they go to



Natural sunlight is often regarded to be the optimal light source because of our evolution. The spectral distribution of sunlight depends on many different factors like daytime or weather conditions. The simplified graph shows how the spectral distribution of sunlight varies during the day. LEDs can be tailored to emulate these situations. Advanced HCL systems even can dynamically adapt the light closely to these spectra

your laboratory? Is there a difference between people that come to the lab in the spring and people who come in the winter?

Christian Cajochen: That's a very important and interesting question. It's a bit difficult to investigate because you need people to come in in different seasons. It has been shown that prior light or dark makes a difference. So if you come into an experiment from a sunny day like today and we're looking at light and motivation, the results would be different than if you came in on a dark winter morning. We try to assess these influences so what we do right now is we have a dark adaptation that lasts for a half hour for everyone when they come in. We think that a half hour is enough, but we don't know.

Right now we're doing a study looking at different color temperatures and motivation. This is motivation measured by an autonomic nervous system task. It's sensitive and when they come in in the morning, we see a clear relationship to color temperature. But in the afternoon, when they've already had some different light exposures, we still see it, but it's not as obvious. So the light / dark histories are very important.

LED professional: What types of tests do you do on the people?

Christian Cajochen: We call the tests "Intensive Physiological and Psychological Monitoring". The people are wired up with 20 to 30 cables that measure brain activity, heart activity, galvanic skin response, skin temperature and the physiology behind it. We also do MRI scans sometimes with different light sources. That's the physiological part. Then we do psychology. The people do cognitive performance and reaction time tasks, emotional memory, and creativity. We measure creativity by having them draw pictures and the psychologists in my group have an algorithm to analyze creativity. And we also measure hormone levels in the blood like melatonin, or cortisol for stress reactions. Sometimes we measure more things and sometimes less, it depends on the money we have. Some of these essays are very expensive and, so far, the industry hasn't been interested in sponsoring us.

LED professional: We know that light influences the level of melatonin in the blood but I don't know about any studies that show that light directly influences other hormones.

Christian Cajochen: Melatonin is the hormone to measure the position of your inner clock. You can suppress melatonin and it also shifts with the light. That is the standard measurement.

Nobody looks at other hormones in a very consistent way. Melatonin is the only hormone where we know the exact neuro-pathway.
But cortisol also seems to be an interesting hormone to look at.
If you have light in the morning it looks like the cortisol is increased but if you give it at night it looks like you can reduce cortisol levels. So it's not very clear there. Cortisol is indirectly influenced by other brain centers because it speaks to the adrenal gland and so it can influence cortisol levels.

LED professional: At the workshop you held, Professor Anya Hurlbert presented a slide that showed, that the fact people knowing they were being experimented on made a difference in the results.

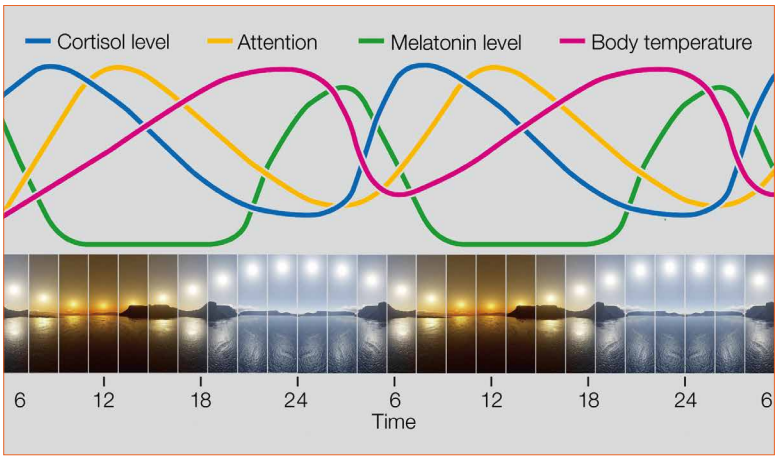
Christian Cajochen: What she showed was that she exposed people to different light levels, like we do, but she sent them home afterwards. She didn't control before - and since they knew they were a part of an experiment they were a little excited. After the experiment they slept less - but one reason for this could be that they were exposed to light in the evening, which delayed their circadian rhythm. Professor Hurlbert is not a circadian biologist - she's more into vision and looks at the visual aspects.

LED professional: So there are quite a lot of factors that you have to take into account when you set up the laboratory for an experiment.

Christian Cajochen: Yes, and we are very strict. We have to separate all these influences because humans are very complex. You have to be very careful whom you pick. Some people think that certain light is good for the soul and another light isn't. So we also have to watch out for that type of thing.

LED professional: Does the goal of the experiment also influence the people taking part?

Christian Cajochen: Yes and no. You have to tell them the setup of the experiment otherwise you won't get approval - but we then just tell them that we are going to test different wave lengths and we don't know which ones will influence their sleep. Recently we have had people come to the lab and tell us that they know the effects of blue.



It has been known for a while that light affects the circadian rhythm and hormonal balance of humans. But details on just how our health is affected still need to be clarified. Now that LEDs are spectrally tunable it is relatively simple to adapt and optimize them to reduce risks and improve well-being

And then we have a bit of a problem. They can't influence the melatonin levels but they could, if they wanted to, screw up certain tests. I personally like the people that just do it for the money because they don't have an agenda and they just deliver the data.

LED professional: If we talk about Human Centric Lighting, I guess the most important thing is that light shouldn't have a negative influence on your health. There are two other topics that I'd like to hear your opinion on, though. The first one is blue light and the concerns that it could cause cancer. The other topic is flicker.

Christian Cajochen: Well, I can't give you an opinion about flicker because I'm not an expert on that topic - I didn't even know that LEDs flicker.

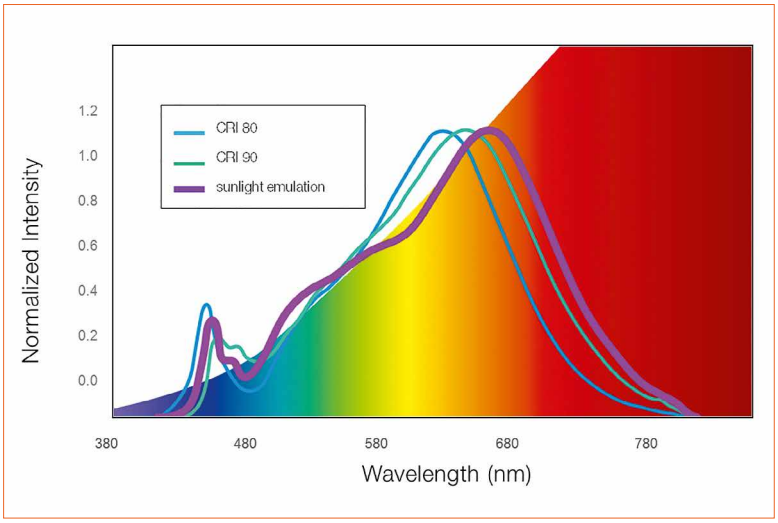
LED professional: Normally, it isn't visible, but they do flicker.

Christian Cajochen: It has never been an issue for us. I'm not aware of the problem. But I do know something about blue light or "light at night" - LAN effects and Breast Cancer. There is some physiological evidence that shows women, or night shift workers in general, are more at risk for breast cancer. The WHO has proclaimed that shift work - not light at night - is potentially carcinogenic. It may not only be related to light; it may also be related to the shift in the circadian rhythm. The shift worker works in the wrong circadian time window. I'm very critical about it because there is the fact that it reduces your melatonin level and melatonin scavenges for free radicals. It's a logical mechanism but it hasn't been proved without a doubt so far. All that has been seen is that shift workers have a higher risk for cancer.

I know that in Israel, for example, they are against LEDs and blue LEDs because they say they cause breast cancer but so far I think the evidence is for epidemiological data and not for experimental data.

LED professional: So if I understand you correctly, you're saying that it's not the LED itself that is causing the cancer, but rather the shifting of the circadian rhythm.

One of the latest trends in manufacturing LEDs is the emulation of sunlight at different CCTs



Christian Cajochen: It's a mixed effect. They receive the light at nighttime at the wrong circadian phase, which is not good, per se. And their activities have been shifted. I have some ideas how we could manage light during the night that would improve performance. I can't say that it would prevent cancer because we don't know what really causes the cancer. In my opinion, the only good control would be a blind woman that works night shift but that is not possible. However, there is some evidence that blind women are less likely to get breast cancer than women who can see.

So appropriate light at the appropriate time with the appropriate spectrum would be the ideal situation. If you don't have that, it interferes with your health. On the other hand, noise at night is also not good for you.

LED professional: Do you think that in the near future there will be studies that show how to design a "good light"?

Christian Cajochen: We are a part of a European project called "Human Centric Lighting" and we are trying to make recommendations for workplaces, educational institutes and hospitals as well as domestic domains and street lighting - whereby street lighting is more difficult. But we have come up with some agreements based on data in peer reviewed journals and we also developed the tool that I presented today that you can download. It's an Excel file that you can put in your light source - the color temperature, the intensity and then you calculate the melanopic daylight equivalent. So you know that if you install a certain light bulb it will be more or less activating.

And we can also give some recommendations. I think it's the right time to give some general recommendations. We can't yet say, "…if you want this result you have to install that light", but we can give some general recommendations. Whether the industry will follow the recommendations or not remains to be seen. I'm a little pessimistic about that because I don't believe the industry will change things unless they see that there will be a profit.

LED professional: That would have been my next question!

Christian Cajochen: Well, maybe I'm a little too pessimistic because we have gotten some positive feedback from Telecom in Germany. They said they might try some of our recommendations and also the Swiss retail companies, Migros and COOP, for example. They have a lot of workers working underground with no access to daylight and because of our recommendations they have given their workers 2 extra breaks to go up and take in some daylight. These breaks are paid so it costs the company a lot of money. We are looking for an LED solution that would mimic sunlight, which would mean the companies wouldn't have to pay for the extra breaks anymore. It's also a political issue and I think the industry might consider changing their lights if there is political pressure.

LED professional: We talked about light at night. What about light during the day? Sometimes people don't have the correct light throughout the day.

Christian Cajochen: In my opinion it would be good to bring out results to people who work during the day but don't have access to daylight. There are many people that work without daylight and that's where I think we should try to apply some of our recommendations to see whether they help or not.

LED professional: You spoke about mimicking daylight. Today everyone is talking about certain cycles in color temperature and intensity. However, if we look at real daylight, it's completely different. A normal day would have a blue hour in the morning with color temperatures up to 20,000 K and then it falls rapidly and the color temperature stays between 5,000 - 7,000 K for the rest of the day. How do you think we could mimic sunlight correctly?

Christian Cajochen: The word mimic is used very loosely. In our office, for example, we have a dawn and dusk simulation but depending on the distance from the equator, it would be different. There is a gradual change, also in the color temperature. Of course it stays stabile during the day and then it goes down again. But the thing is we don't know if mimicking daylight works. There are no studies proving that a dynamic light is better than a static light. There was a study ten years ago where they put in 7,000 K lights. People hated it at the beginning but after a few weeks they didn't want to go back to the old light. Performance was better even though the light was awful.

This is the reason that we have implemented a virtual sky in our lab. We have panels from the Fraunhofer Institute that help us simulate a more natural environment with clouds passing by and the color temperature between 4,000 K and 6,000 K but in a more dynamic way. We just started to test three variations last week. A dynamic sky, a static sky and a traditional office setting. It's a very cumbersome experiment so we will have to see what happens.

LED professional: Are there any other things that have to be considered if we look at the natural change of daylight?

Christian Cajochen: Yes, it's the duration of light, the photo periodic changes. For instance, we have patients in the psychiatric clinic that I work in that are very sensitive to the reduction of day length in fall and winter. These people develop what is called Seasonal Affective Disorder (SAD). A lot of people, including some psychiatrists, don't believe it, but it's more than just the "winter blues." These people gain weight and feel miserable - and as soon as you can extend the light duration, you can help them. When it's dark in the morning and dark in the evening, some people just don't feel good.

LED professional: Do you think that it's better to extend the duration of light instead of giving people "light therapy", a high dose of light during the day?

Christian Cajochen: Extending the duration is next to impossible, so we still treat those patients with light in the morning. You don't have to give them 10,000 Lux anymore - if you blue enrich the light, you can treat them with lower illuminances. It's a treatment of choice and it's a lot to ask someone to sit in front of a light for a half hour every morning. Most people just prefer to take a pill - an anti-depressant. But if you compare the pills to the light - they aren't better; in fact, the light treatment has been shown to be superior in some cases. So I'm a big fan of light therapy. It works in 70% of the patients - which is the same success rate as anti-depressants. In Switzerland doctors know about it and the Light Box is covered by our health insurance.

LED professional: Thank you very much for this very interesting interview. We are curious as to how "Human Centric Lighting" will develop over the next few years and look forward to hearing about the results from your research.

Christian Cajochen: Thank you. ■

The Perspective of Bio-Hybrid White Light-Emitting Diodes Based on Rubber-Like Down-Converting Coatings

At first, white LED technology seems to be mature. But in truth, the technology is still far from being perfect and research on all LED materials and components is ongoing. At the LpS 2016 the research of Rubén D. Costa, Lukas Niklaus, Katharina Weber and Prof. Uwe Sonnewald from the University of Erlangen-Nuremberg (FAU) was honored with the LED professional Scientific Award. These authors investigated the use of organic light conversion materials for white LEDs. Their research shows that these bio-hybrid white LEDs could lower costs and improve light quality. The article describes the current status of the research and future perspectives.

White hybrid light-emitting diodes (WHLEDs) consist of an inorganic blue-emitting LED that is coated with organic down-converting layers, which are easy-to-prepare and eco-friendly. The current challenge of WHLEDs is to find a universal packing matrix and stable organic down-converting compounds to maximize the device performance. In this contribution, we show the straightforward fabrication of WHLEDs by designing a novel sealing-free gel that transforms into a rubber-like material under moderate vacuum conditions without using any cross-linking and UV- or thermal-curing methods. This approach allows to compare different down-converting organic materials in the same environment - i.e., the same packing matrix, blue-emitting LED source, and environmental conditions. In detail, laser dyes, carbon nanodots, luminescent polymers, coordination complexes, and fluorescent proteins were directly compared showing the prospect of WHLEDs with rubber-based coatings.

Properties of the current WHLED generation:

- Bio-WHLEDs, featuring 50 lm/W with a loss of less than 10% during 100 h under operation conditions and
- WHLEDs based on coordination complexes, showing stabilities of more than 1000 h - extrapolated 4000 h - with luminous efficiencies of 100 lm/W and no color degradation. As such, our work provides a clear prospect of this emerging technology

Introduction

White solid-state lighting sources for outdoor and indoor applications are currently in the focus of both academic and industrial research. On one hand, all-inorganic white light-emitting diodes (WLEDs) are meant to imminently replace inefficient and environmentally harmful incandescent and fluorescent lamps [1-4]. On the other hand, WLEDs exhibit a more complex architecture than the monochromatic LEDs due to the lack of intrinsic white light-emitting semiconductors. Today the most mature approach is to coat the chip of a blue-emitting LED with down-converting materials such as yellow-emitting inorganic phosphors - e.g., YAG:Ce^{3+} derivatives - to convert the LED emission into white light [5,6].

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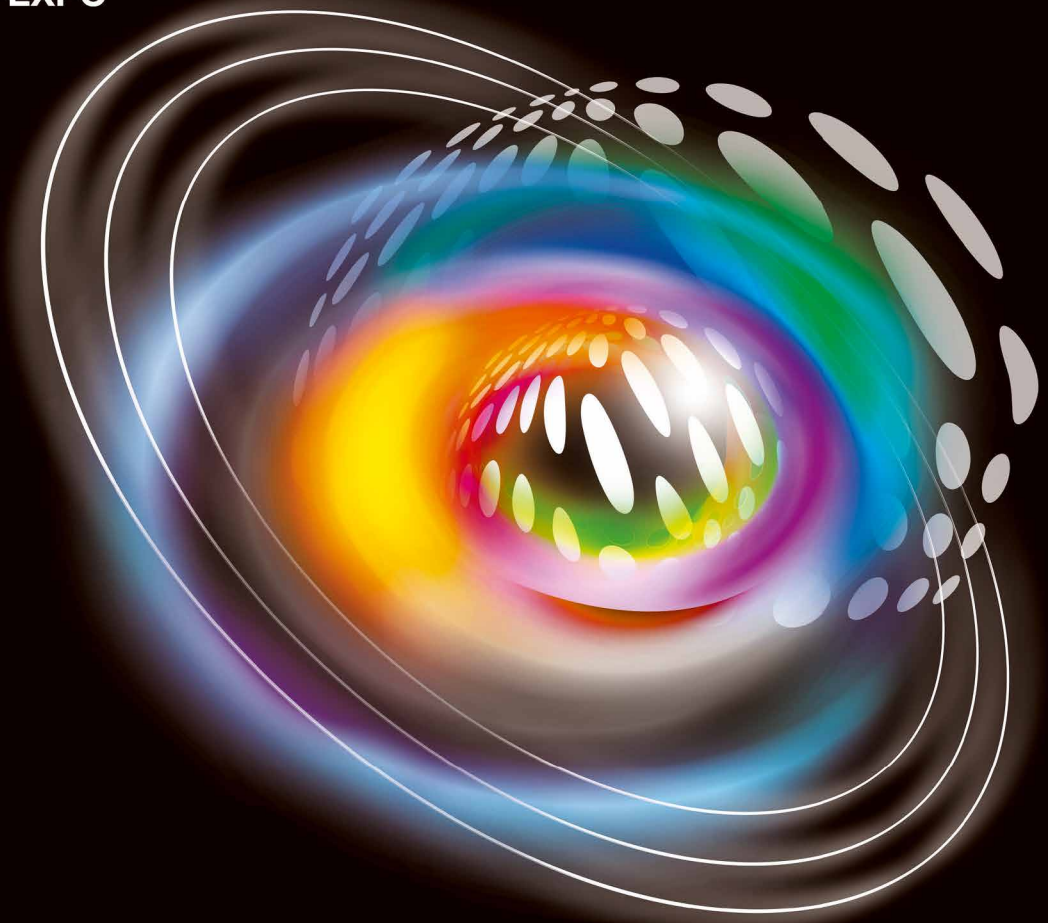

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The main bottlenecks:

- High cost concerning production and materials that are based on rare-earth components
- Lack of recycling procedures
- Poor color quality of the lighting devices, since stable and efficient inorganic phosphors that emit in the deep-red region are still missing [3,4,7-11]

In this regard, both the photonics EU commission and the US Department of Energy are encouraging the development of novel non-rare earth metal and non-toxic down-converters, targeting four major aspects.

The four major aspects:

- Photoluminescence quantum yields higher than 95% (green and red regions)
- Thermal stability up to 150 °C
- Narrow emission bands with full widths at half maximum (FWHM) of 30-70 nm
- Color shift over time of $\Delta u'v' < 0.002$ over lifetime
- Flux density saturation of at least 95% [2,4]

Therefore, the scientific community has seriously started to explore several approaches to implement environmentally friendly down-converting materials into white hybrid LEDs (WHLEDs), which are heralded as the next generation of low- and mid-power WLEDs if the device performance equals the current status (Figure 1 - [12-39]).

In this new field, one of the main challenges is the packing system. For instance, the first WHLEDs were prepared with UV- and thermal-curing polymers like silicones that promote the degradation of the down-converting compounds upon coating fabrication, and typically compromise the spatial color distribution due to phase separation issues between the matrix and the down-converting compounds [12,14,15,35-39].

Recent matrices are based on:

- Metal-organic frameworks (MOFs), in which down-converting laser dyes can be adsorbed [24-26]
- Cellulose, in which inorganic and graphitic quantum dots are embedded, have been demonstrated (Figure 1) [27,29]

They all have in common, that the used organic down-converters show a general good thermal- and photo-stability along with high photoluminescence quantum yields, an ease of color tunability covering the whole visible and NIR spectra, and well-known recycling protocols. Therefore, these WHLEDs feature an excellent color quality, but still with a low stability ranging from a few minutes to several hundreds of hours under continuous working conditions [12-39]. In addition, it is difficult to compare these matrix approaches due to incompatibility issues with the down-converting compounds. In this contribution, we present our novel approach based on the design of a rubber-like coating in which - for the first time - a wide variety of well-known environmentally friendly commercially available down-converting materials like fluorescent proteins, laser dyes, carbon quantum dots, polymers, and coordination complexes (Figure 2) are implemented and directly compared in WHLEDs, as explained in the following sections [30,31,39].

General Information about Rubber-Like Down-Converting Coatings

In stark contrast to the state-of-the-art packing fabrication, our rubber-like coatings are not based on UV- or thermal-curable cross linking approaches or adsorption procedures into the matrix. Here, both gels and rubbers are prepared by simply mixing of branched and linear polyethylene oxides. The viscous properties of the formed gels allow an excellent handling for coating purposes. As an example, Figure 2 shows different 3D forms like a spoon, knife, and fork coated with the gel-like material. Subsequent treatment of the soft doctor-bladed films under vacuum conditions for less than 1 h at room temperature leads to the final rubber-like material exhibiting a transmittance and refractive index superior to 95 % and 1.8, respectively. But there are some more important aspects.

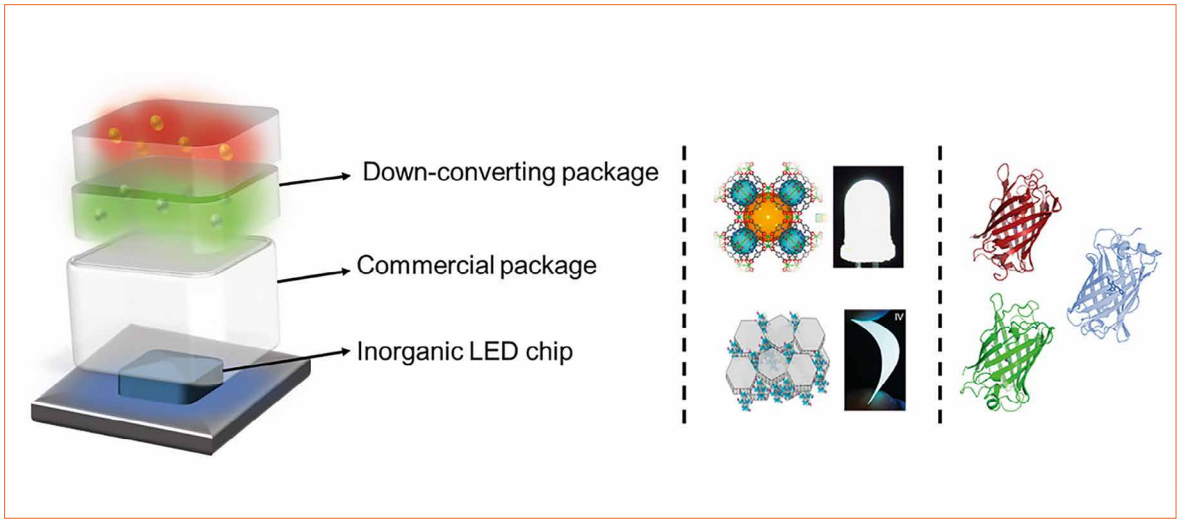
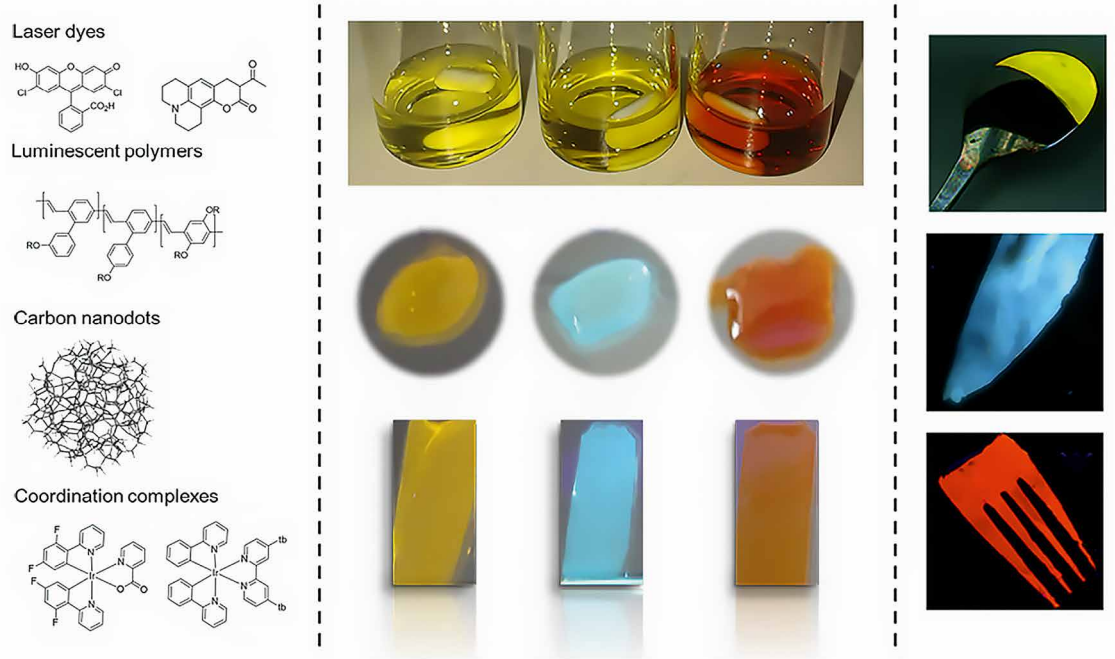


Figure 1:
Left - Representation of an archetypal WHLED. Center - Recently reported WHLEDs based on MOFs- and cellulose-based approaches (top and bottom, respectively). Right - schematic representation of the green-, red-, and blue-emitting proteins



Figures 2:
Left - chemical structures of the luminescent compounds. Center - pictures of the coordination complex-based gels (room light, with a magnetic stirrer, top), the corresponding gel drops (middle), and the rubber-like materials (bottom) under UV excitation (310 nm, 8 W). Right - pictures of exemplary luminescent rubber-like materials deposited onto irregular 3D surfaces (λ_{exc} = 310 nm), such as spoon, knife, and fork

Three more important aspects:

- Luminescent features of the down-converting compounds are preserved in both gel and rubbers compared to those in solution
- Rheological features can be easily controlled by the matrix components allowing any coating technique like R2R, 3D printing, etc.
- All luminescent compounds embedded in the rubbers show excellent storage stabilities over months and thermal stabilities up to 100 °C [30,31,39]

Comparing White Hybrid Light-Emitting Diodes Based on Rubber-Like Down-Converting Coatings

As above-explained, a commercial blue-emitting LED is coated with a multi-layered down-converting coating that features a bottom-up energy transfer process. In particular, the inorganic LED excites the bottom down-converting layer, which then emits light being partially absorbed from the next layer that further emits light (Figure 1). The combination of the emission from the LED and the several layers leads to a white emitting LED. By a simple change of the layer thickness, the emission spectrum can be adjusted to cover the whole visible spectrum. As starting conditions, the performance of the WHLEDs was measured under dried N_2 atmosphere at different applied currents. Afterwards, the devices were driven at the optimum performance concerning luminous efficiency and white color quality under inert conditions. Finally, the most stable devices were subsequently measured under ambient conditions (Figure 3). This allows us to provide a direct comparison between the different down-converting compounds. In detail, WHLEDs with different laser dyes feature and initial excellent color rendering index > 95 but a low color stability of a few hours even under inert atmosphere (Figure 3). Therefore, no further measurements were carried out with these class of compounds. The WHLEDs based on carbon nanodot coatings exhibit an initial low luminous efficiency of around 2 lm/W (Figure 3). The color quality changes after around 20 h due to the evolution of a new red-emitting component. During the subsequent 30 h under ambient conditions, the electroluminescence spectra quickly evolved until a more balanced contribution in the yellow and red parts is present, but with a more prominent blue component, while the luminous efficiency further reduces up to values of around 1 lm/W (Figure 3). After this point, the electroluminescence spectrum is constant, but the device features a low luminous efficiency. It is important to note that the changes in the electroluminescence spectrum are related to changes in the molecular structure, which is still under hot debate.

The most efficient WHLEDs were based on a thin luminescent polymer-based down-converting coating, showing white light that is stable over about 200 h under inert atmosphere with a luminous efficiency of around 200 lm/W (Figure 3). A subsequent measurement of the same polymer-based WHLED under ambient conditions showed that, unfortunately, the emission of the polymer is immediately damaged by the well-known photo-assisted oxidation process, as both the color quality and the luminous efficiency declined, which is already reported in the literature [15,40-42].

Next, the protein-based rubber-like materials were applied as down-converting coatings in order to present the first Bio-WHLEDs (Figure 3). The latter shows a perfect coverage of the whole visible spectrum with a luminous efficiency

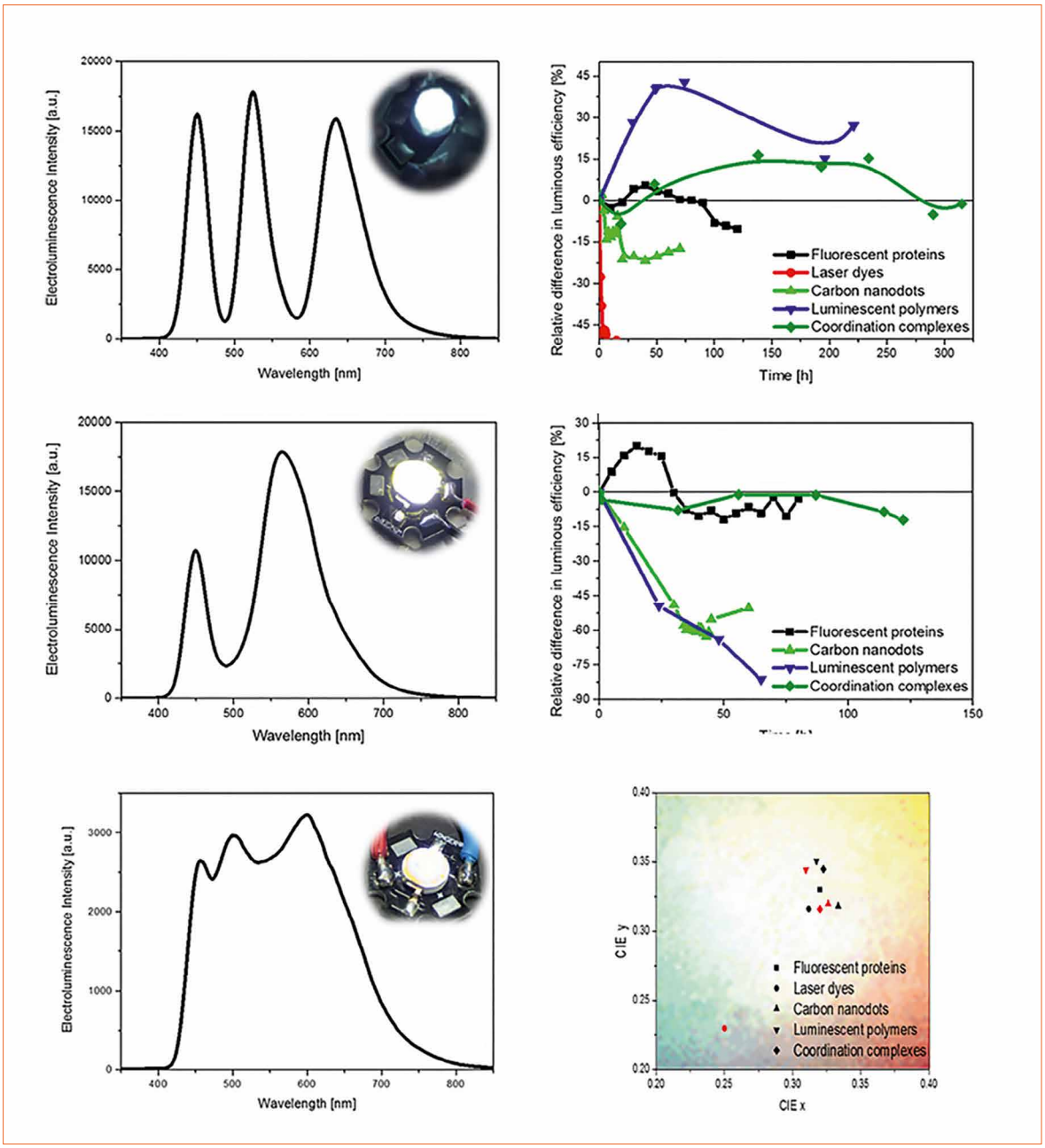


Figure 3:
Left - Electro-luminescence spectra of the most promising WHLEDs - i.e., protein- (top), polymer- (center), and coordination complex-based WHLEDs (bottom). The insets show the pictures of the WHLEDs under operation conditions. Right - Change of the luminous efficiency over time for several WHLEDs under N_2 conditions (top) and under O_2 atmosphere (center). The CIE coordinates of the WHLEDs (bottom) at the beginning (black) and after 70 % of the luminous efficiency is reached (red) are depicted

of 50 lm/W. Moreover, the loss of efficiency under working conditions during 100 h is less than 10% independently of the ambient conditions, highlighting the prospect of this type of materials (Figure 3).

Finally, we fabricated WHLEDs with thin coordination complex based coatings (Figure 3). Similar to the Bio-WHLEDs, these devices show an excellent stability in terms of both color quality and luminous efficiency (100 lm/W under N_2 atmosphere and 70 lm/W under ambient conditions) for several hundreds of hours. In addition, these WHLEDs show a remarkable stability in terms of color and efficiency over more than 1000 hours (extrapolated to 4000 h) even under ambient operation conditions.[31] Interestingly, the luminous efficiency is immediately reduced or increased when transferring the CC-WHLED from N_2 to ambient conditions and vice versa (Figure 3), which is related to the well-known phosphorescence quenching by oxygen.

Conclusions and Outlook

Despite the fact that Bio-WHLEDs exhibit a great potential to overcome most of the above mentioned bottlenecks. However, Bio-WHLEDs have also still their limitations.

Limitations of Bio-WHLEDs:

- Denaturation of the proteins owing to oxidative stress, which leads to a loss of color quality
- High thickness in the millimeter regime due to the energy-transfer cascade architecture
- Low thermal stability of up to 100 °C of the matrix as well as the proteins

However, fluorescent proteins fulfilled all the targets highlighted by the US and EU departments in terms of high photoluminescence quantum yields, narrow emission, no spectra shift upon degradation, and high photon density saturation as recently demonstrated in

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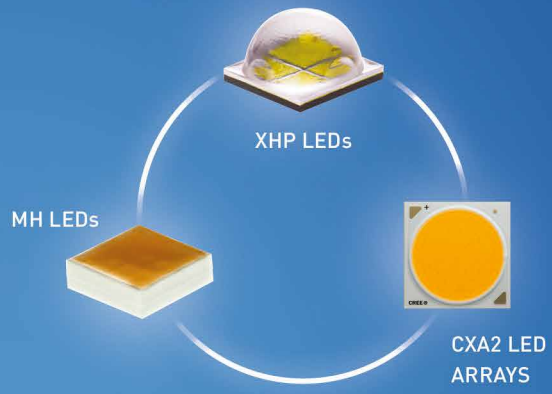

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protein-based lasers [2,3,43]. In addition, their production is cheap and can be realized around the whole world using well-known up-scaling protocols. Finally, they are non-toxic and do not produce any hazard residues. All these aspects clearly point out the potential of this material for future developments of Bio-WHLEDs.

This is even clearer when the device performances are compared. For instance, laser dyes lack stability concerning thermal and UV-treatment and should therefore be replaced by new designed compounds, while carbon nanodots exhibit an initial low luminous efficiency of around 2 lm/W that is related to the poor photoluminescence quantum yields in solid-state and the changes of the electroluminescence spectrum over long periods of time. It is important to note that a proper design of carbon nanodots with, for example, organosilane outer substituents and/or encapsulated carbon QDs might solve both problems as very promising results have been recently shown [44]. In the case of luminescent polymers, a further encapsulation system will be necessary for improving their lifespan under operating conditions with the shortcoming of a less user-friendly fabrication process. Even though coordination complex-based WHLEDs show no need for an extra encapsulation in terms of stability - i.e., when comparing the stability of our WHLEDs with the state-of-art stability that is around a few hundreds of hours - it is encouraged the design of efficient and low-cost coordination complexes, since the price of Iridium is currently too high for industrial purposes [45].

Finally, the milestone of WHLEDs is the development of down-converting encapsulation systems for high-powerful LED arrays, which hold high operation temperatures. Currently, we are working on different strategies to enhance the thermal- and photo-stability by a proper design of the fluorescent proteins along with modifications of the matrix components. Finding solutions for these roadblocks is crucial to bring the Bio-WHLED from the laboratory scale to industrial applications. ■

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LpS 2016: A Perfect Platform for New Ideas and Innovations

Like in any “Light + Building year”, there is always the question of which, if any, other shows one should attend in Europe. The visitors to the LpS 2016 knew right from the start that they had made the right decision with Bregenz. As always, the show attracted attendees, exhibitors and visitors from all over the world. Arno Grabher-Meyer, Editor-in-Chief at LED professional summarizes the highlights and shows how the newly introduced program points were received.

This year, approximately 1500 visitors and attendees came to Bregenz to hear about the latest technologies and research results from over 100 expert speakers. After the talks, many of the symposium attendees took advantage of the supplementary programs or went directly to one of the booths occupied by specialists from over 100 companies to discuss their newly gained knowledge.

More people than ever before attended the opening session with keynotes from the Nobel laureate Professor Shuji Nakamura, Diederik van Stoppelaar and Heinz Seyringer. In his keynote, Mr. Seyringer talked about the research programs within the European Community while Mr. van Stoppelar gave details about the challenges, opportunities and focus of the EU Commission as well as the impact of the latest trends in European policies within the lighting industry. This once in a lifetime chance to see Professor Nakamura live and the chance to meet him personally was probably one of the reasons such a big audience was attracted to the ceremony. And Prof. Nakamura didn’t disappoint anyone’s expectations. The audience could feel how ambitions Prof. Nakamura is when he told them how his work started and how he made his invention. He also impressed the audience with the fact that GaN-on-Sapphire blue LEDs were only at their starting point. He then went on to tell them about his GaN-on-GaN technology and also the future of white laser if the costs can be reduced. Prof. Nakamura finished by emphasizing the need to focus on light quality and tailoring LED lighting

Nobel Laureate, Professor Shuji Nakamura, held a keynote speech at LpS 2016

From left to right: Siegfried Luger (organizer of the LpS 2016), Dr. Guenther Sejkora, Dr. Rubén D. Costa (winner of the LED professional Scientific Award) and Dr. Michael Schrempp from the award sponsor, Munich Re

to the natural needs of humans - providing light that mimics sunlight as closely as possible.

The opening ceremony was also the platform to honor Dr. Rubén D. Costa, the winner of the 3rd LED professional Scientific Award. Dr. Guenther Sejkora, Innovation and Science Manager at Luger Research and Dr. Michael Schrempp, Global Head of Green Tech Solutions at Munich Re, awarded Dr. Costa a trophy and a check for 3,000 Euros. The advisory board selected his paper, entitled “Bio-Inspired White Hybrid Light-Emitting Diodes” by virtue of its novelty, good explanation, proof of concept and the potential to change the lighting scene. The original article can be read on page 32 of this issue.

The quality of the submissions was very high again this year. The top five papers after Dr. Costa’s paper can be read throughout the coming year in issues 59 to 63. In order of their publication they are: “Lifetime Calculation of White HP-LEDs from 16,000 Hours Aging Data” by Dipl.-Phys. Max Wagner, Technical University Darmstadt (LpR 59), “Optimization of Roadway Lighting Optics for Environment Adaptive Spatial Light Distribution” by Viktor Zsellér (LpR 60), “New Glass-Based Phosphors for White LEDs” by Dr. Franziska Steudel, Fraunhofer Application Center IMWS (LpR 61), “LED-Retrofit based on AlGaN/GaN-on-Si Field-Effect Transistor Drivers” by Andreas Zibold MSc, Fraunhofer Institute IAF (LpR 62) and “Measurement of Angular and Spatial Resolved Spectra Rayfiles with Conventional Nearfield Goniophotometers and Standard Optical Filters” by Ingo Roscholl MSc. Karlsruhe Institute of Technology (LpR 63).

The Governor of Vorarlberg, Mag. Karlheinz Ruedisser, welcomed Prof. Nakamura to the region

Lectures: Practical Approaches Supplement Theory

This year's symposium program was characterized by an increasing number of lectures that dealt with applicability and usability of LED lighting products. This addition to straightforward technical lectures was well received and takes the new general trend in the lighting ecosystem that was also emphasized in the keynotes, the press conference, workshops and several discussions into account. Improving light quality and not efficacy is the new top requirement that will provide the appropriate light for different applications and demands. This fact became especially apparent in the lighting design session lectures.

Dr. Peter Bodrogi from the TU Darmstadt talked about the seemingly continuous story of color quality metrics. In his lecture entitled "Color Quality of LED Illumination: Metrics and Experimental Data", he pointed out that the CRI is a measure to the "realness" or "fidelity" of color appearance. With LEDs and the current visual habits, it turned out that "color preferences" and "color vividness" are more important in most indoor lighting situations. While some new proposals like CQS, Qp/Qg, MCRI, Rf/Rg indices take some aspects into account, none of them is easily applicable and the depiction is often too confusing, especially for end-users. Therefore his team took a semantic categorization approach to find out how indices need to be compared and where the acceptance limits are. The researchers found that different combinations of preference, naturalness and vividness cause a similar acceptance. They emphasize that not any combination might be equally useful in different applications: "For office lighting and long-term stays, color naturalness implying moderate Chroma enhancement can be considered. For home lighting or shop lighting for shorter stays, color preference might be appropriate. Finally, for accent lighting (e.g. theatre scenes or discotheques), color vividness can be chosen."

Dr. Susanne Schweitzer from Joanneum Research presented the research group's findings about "Gender and Age Specific Preferences Regarding Lighting Conditions for Activation and Relaxation", another aspect of light quality. The data showed that there are clear differences in the lighting conditions preferred for these two situations. Some combined gender and age specific differences were also apparent. She confessed that the meaning about the influence of CCT on humans reported in the literature is diverse and her conclusions suggest that further research is in progress when she announced that, "…the influence of the deviation from the Planckian locus (u'v') and results from questions regarding gender-related preferences of light and light-technology will be discussed in upcoming publications."

The well-attended sessions were informative and exciting

Bartenbach's Head of Research, Mag. Wilfried Pohl, summarized his knowledge on "Light and Health - Newest Research Findings and its Applications". Based on some earlier studies that already suggest that light sources with an attenuated portion of short wavelengths may have a lower impact on nighttime circadian parameters, Bartenbach investigated such light sources and light conditions that do not meet international standards for interior lighting. The study showed that such light conditions did not impair cognitive performance (sustained attention and working memory) and mood parameters, and can reduce the disruption of circadian parameters during the night. Several research results of the team suggest that true HCL would be beneficial. Nevertheless, the researchers admit that costs and the technical implementation of the requested dynamic lighting solutions are still big issues.

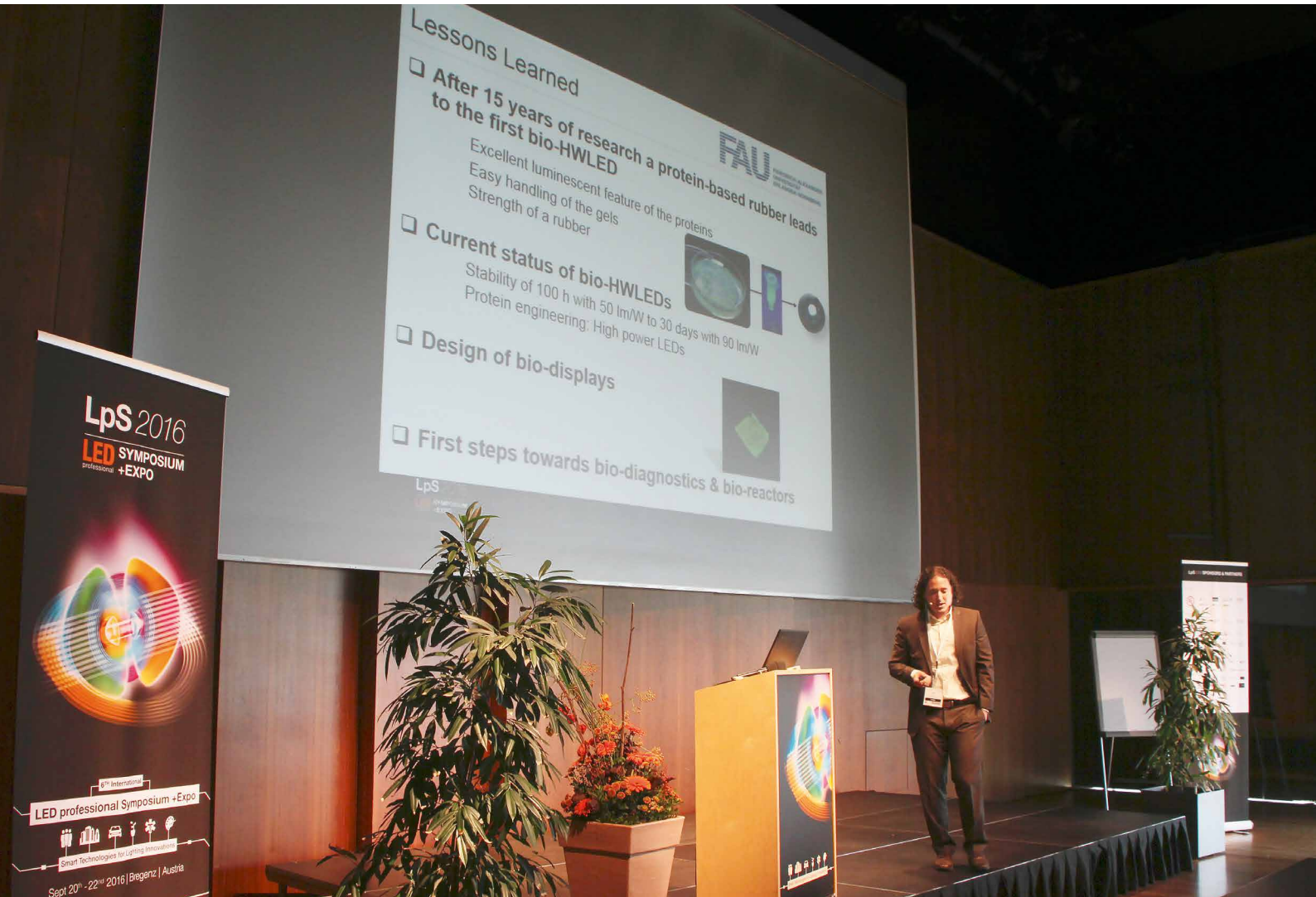
In the same session, architect and lighting designer Ruairí O'Brien's talk "High Quality Lighting Designs with SSL - Practical Examples and the New Role of Lighting Designers" focused on the responsibility of lighting designers to use the technology carefully and attentively. He told the technicians that light and illumination are more than just lux and lumens. He also emphasized the quality of light and darkness and when he pleaded for "re-darkness". Mr. O'Brien asked for a more subtle artificial illumination that does not compete with natural light, allowing "wonderful sights of architecture as it was thought in its largeness, its true dimensions, and its materiality against the immateriality of light".

"Cultural Aspects in Lighting Design with LEDs - Case Study Guzhen Town, PRC" was the topic presented by the architect Roberto Corradini. His appeal to take the culture, region, landscape and environment more into account when planning outdoor lighting in cities could give technicians and luminaire manufacturers a clue as to what lighting designers are expecting from them in the future. His concept for Guzhen Town asks for a new interpre¬tation of a Chinese historical lantern, not a simple copy of it and even less a standard street light head. The lantern has to be designed using the new technology providing modern, efficient, high quality light.

The other sessions were also characterized by numerous lectures on light quality aspects and fully covered with practice-oriented lectures.

In "System Quality" for instance, Peter Erwin presented "Theory and Practical Measurement Results of Modulated Light". He proposed a new flicker metrics, the Compact Flicker Degree (CFD) with the aim to simplify labeling of LED lighting products in respect to flicker quality. His approach also takes much higher flicker frequencies into account than current standards or labels. This is a topic that has been discussed in earlier LpR issues.

The spirit of researchers like Dr. Rubén D. Costa and lighting designers like Ruairí O'Brien inspired the attendees



In the same session, Dipl.-Ing Margret Hedrich-Goeppert from Neumueller Electronics also discussed “Flicker of LED Light Sources”.

The “Engineering” session was dominated by optics and thermal management topics that could be an indication that the technology in these fields still needs some advances to fulfill all expectations. Obviously, innovative companies are working on these topics to find solutions that eliminate current deficiencies, limitations and bottlenecks - always having the application and usability in mind. Passive and active thermal management approaches for different applications were proposed and discussed. Likewise, advanced optical coatings, microstructures and beam shaping technologies were presented.

As the session title “Applications” suggests, the presentations in this track were very practice-oriented. Especially noticeable was the fact that a good part of these lectures was about optical systems for outdoor lighting. This might also be seen as an indication of which application still has a high demand for improvements. Very interesting beam shaping solutions were presented, a comparison of refractive and reflective optics and an optimization approach for illumination under different ambient situations.

Workshops and Forums: Informative and Hands-On

In parallel to the conference, renowned speakers and discussion partners were invited by various organizations and companies to lead 8 workshops and forums covering the topics of alternative light sources, spectrally tunable LED, OLED, horticulture lighting, SSL measurement, risk management, IoT and Artificial Intelligence (AI). This broad range of topics certainly played a role in the good attendance record and positive opinions of the attendees.

The International Solid State Lighting Alliance (ISA) not only had their official meeting in Bregenz, but they also held the ISA Forum with a broad range of topics, from cooperation between countries and organizations to risk assessment and management, to IoT in smart cities and SSL beyond illumination. Several well-known personalities, among them, Ms. Ling Wu, President of ISA, Huijian Bo, Project Director at Huawei Technologies, and Dr. Norman Bardsley, Chief Analyst of ISA Research (who later agreed to a Tech Talk Bregenz about OLED technology with LED professional), shared their knowledge and were available for discussions.

The existence of alternative light sources is often ignored because LEDs have reached a very high standard and the potential has not yet been exhausted. The Photonics Cluster Austria & Switzerland covered this topic demonstrating that there are applications where other solutions still make sense. Laser light offers several advantages. No droop and better controllability are just two, which also were mentioned by Prof. Nakamura in his keynote speech. Due to the high costs, this technology is mostly used in professional or special applications like instruments or cinema projection but not in general lighting. One of the rare lighting applications is in automotive, more precise in luxury cars where costs are less important. Besides the technology and advantages, limitations were also discussed.

Minich Re invited attendees to their forum, followed by a casual get together. In collaboration with DEKRA, they informed those present about global market trends, manufacturing risks and long-term warranties to be used as unique selling propositions, and the emerging new risks that come from cyber and IoT applications. They summed up by explaining their financing models and risk transfer solutions for large-scale LED investment projects.

The APIL “Design and Technology” forum was about the impact of a lifestyle on the lighting design and also scrutinized what lighting

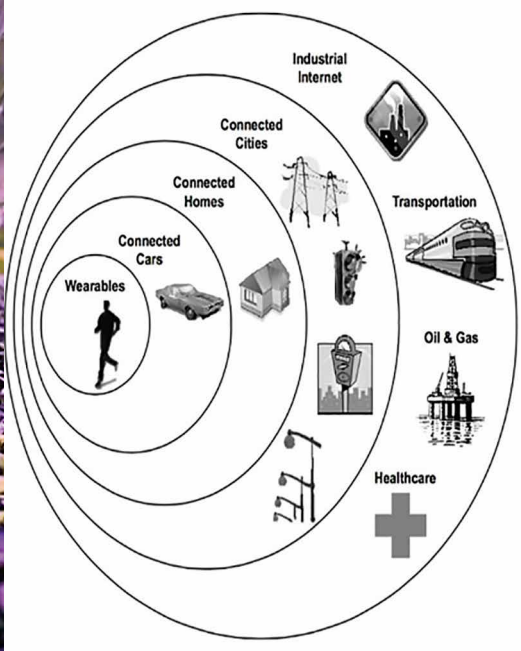
The theoretical part of the workshops were often followed by a demonstration, hands-on or practical exercise

atmosphere is characteristic of a European city and if it is the same for a Chinese, American, Arab or Indian. Maybe the answer lies in the fact that even natural light is different in different parts of the world and Professor Helena Gentili, architect, lighting designer and APIL member demonstrated this by showing the cultural differences in its use. In her conclusion she said, “Therefore, artificial lighting, as well, needs to be designed and controlled properly, according to people’s cultural and geographical references. Ms. Gentili went on to explain what lighting designers expect from LED manufacturers, luminaire manufacturers, importers and resellers. The other contributors to this forum addressed equally important aspects in various fields that need to be heard by manufacturers and the technicians that design the products.

The topic of spectrally tunable LEDs and OLEDs was organized by HiLED. It was split into three application fields: Human centric lighting, Horticulture and Museum Lighting. Whilethe horticulture session covered similar topics to the EPIC workshop; the other two subjects were concerned with visible light quality and all related aspects. A good part also covered the risks of LED lighting, especially blue light for humans and art. In this context it is important to notice that the impression that LED lighting is more critical than traditional light sources is misleading. Both the general and consumer press often misinterprets research results. The truth is that traditional light sources could be worse than high quality LED light and LEDs provide the opportunity to tune the spectrum to reduce risks. The presented research indicates that correctly applied LED lighting can be beneficial to health and well-being. In the case of shift work, which has always negative effects on people, spectrally tuned LED light can reduce the effects without compromising visual behavior like stimulation and cognitive abilities. The influence of light on the body clock, alertness and sleep was explained by Prof. Christian Cajochen who is LED professional’s interlocutor for the Tech Talk Bregenz in this issue. In the session about museum lighting applications, a comprehensive study about modern and traditional pigments, different binding material and varnish was discussed. The presenters pointed out that LED light spectra can be optimized for the perfect appearance of artworks from different periods by keeping the damage index lower than traditional light sources.

Horticulture lighting is becoming increasingly important. More workshops and lectures than ever before concern this topic at lighting conferences all over the world with some conferences being solely about horticulture. This year EPIC organized a horticulture workshop in Bregenz and the interest was enormous. The Association for Vertical Farming explained why this topic is of such high interest and what the benefits are. They said that it is expected that in the year 2050 over 80% of the 10 billion people on Earth will be living in cities. Currently 80% of freshwater is used for agriculture. Vertical farming needs up to 98% less water, reduces transportation effort and land use. Furthermore, it promises fresher food without the use of pesticides and without heavy metal contamination. Under controlled conditions, uniform quality and yield, 2-3 times higher growth rates and vitamin and mineral content are expected. Besides the CO_2 level, light is the most important key factor for this method to cultivate plants. A big part of the workshop concerned spectral tuning for plants. It was demonstrated how different spectra can change the growth and morphology of one species, resulting in compact, bushy plants with many leaves to long-branched plants with less but bigger leaves, many or no flowers, and so on. It was also emphasized that there is not one spectrum for all plants. Finally, solutions for these different requirements were presented and discussed: Single die LEDs, flexible configurable multi die LEDs, and controls for this task.

Workshops and forums covered topics like horticulture, IoT and light quality



The number of contributions and the variety in Jakajima's workshop about IoT and AI underlines the statement of Dipl. Ing. Christian Anselmi from Antevorte - Innovation in Motion: "There is not one IoT networking solution for all".
The workshop substantiated this statement by presenting a selection of solutions for different applications based on different technologies. The experts covered the following topics: LoRaWAN as a long area communication approach and Cisco's Smart+Connected Lighting system for outdoor applications, the digitalLicht concept for residential and hospitality applications, Adaptiva's wireless sensor intelligent sensor networks for environmental monitoring tasks, and ChessWise's self-organizing MyraMesh technology based networks as a highly sophisticated new solution for resilient communication, fostering the idea of building a stand-alone mesh network first and then to use the internet only if necessary.

SSL measurement seems to be a never ending story. New regulations and standards are necessary to take the properties of this light source into account, and some have become effective over the last few years. While uncertainties with how to deal with the results were an issue before, TÜV Süd and Instrument Systems concentrated on educating the attendees on the important topics of the required equipment and how to measure correctly.
The workshop covered the basics of colorimetry and spectral quantities for LEDs as well as measurement equipment and their application. The introduction to the new standards and impact on labeling and the resulting requirements, safety aspects and eco regulations were also addressed. Practical questions like interference between a PWM driven product and integration time; which data must be reported from color tunable products; or, effects of the product housing color on measurement results were gone into.

The Expo: Product Launches and Innovative Start-Up Companies

For the second year in a row, companies with product launches at the LpS could take advantage of special promotion opportunities. Even though the Light + Building tied up many resources this year, approximately 10% of the exhibitors came to the LpS with a product launch. The new opportunity for start-up companies to show their products was readily taken advantage of and visitors appreciated the innovative approaches presented.

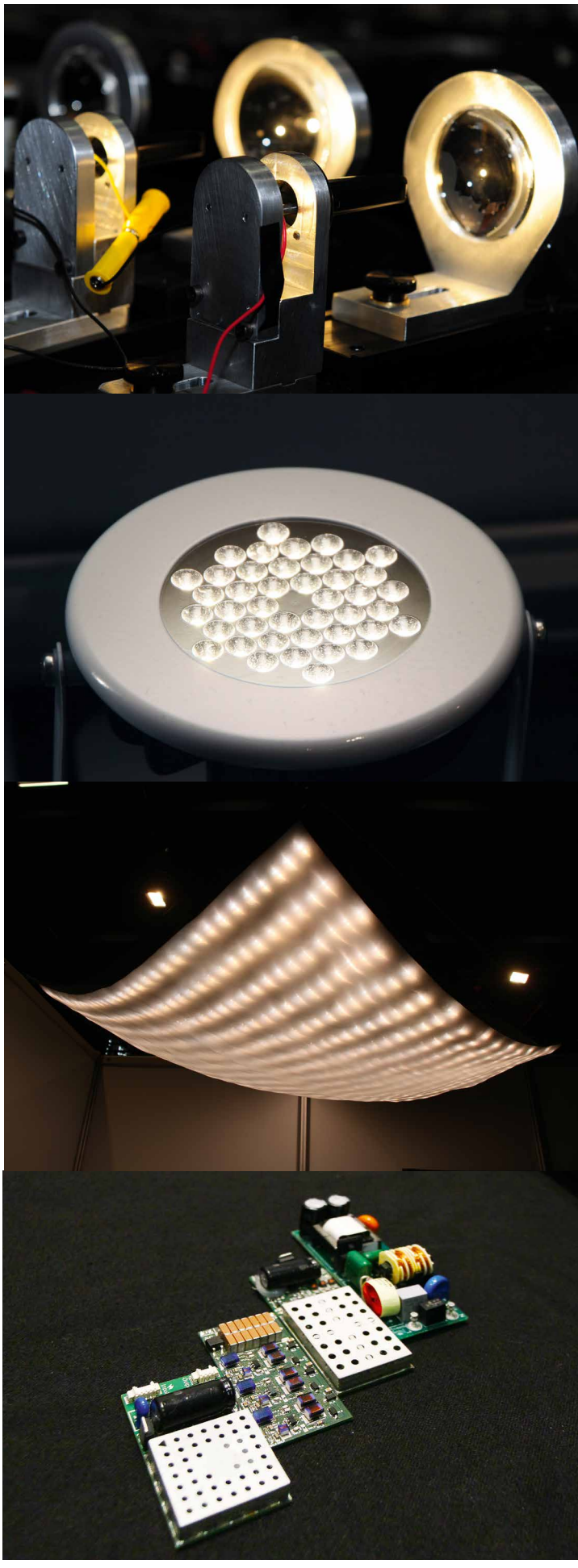
Although a preview of the product launches was published in LpR 57 there is a lot more to say than about them: The features and improvements of Dow Corning's two new products were noticeable when looking at the product samples they brought with them. The MS-4002 Moldable Silicone has an unusual appearance and provides a higher subjective quality of transparency. It gives the products a plastic-like, smooth surface, look and feel. Furthermore, this material's curing speed is optimized for the injection molding process for liquid silicone rubber, enabling the production of optics with comparatively high hardness and low surface friction. Its high light transmittance with low attenuation coefficient, combined with a high Abbe number, enables lighting companies to design optics for luminaires with high lumen efficiency. High thermal stability ensures the retaining of high transparency - even in harsh environments. The advantages that Dow Corning attributes to the IA-1200 Adhesive are not that easy to reproduce as they are concerned with more manufacturing and speeding up the process. Auer Lighting's new modular approach to replace and upgrade conventional CMH and CDM installations to SSL technology incorporates a color mixing technology that allows a color uniformity of 4 MacAdam ellipses for an 18° spot with a

Product launches were promoted during the press conference and the show

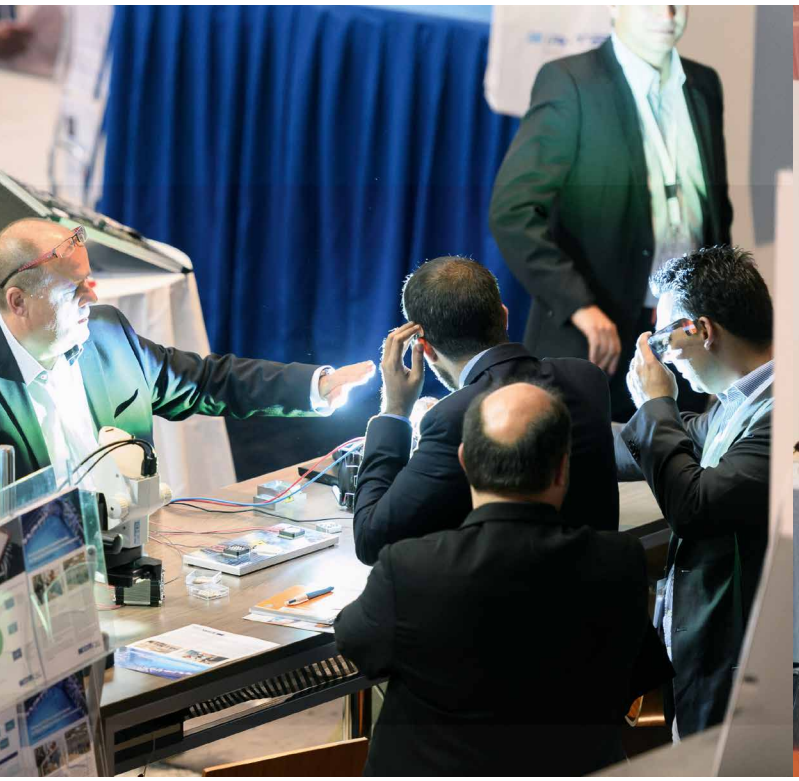
red-white LED module. Flip Chip Opto's unique high power 100 W and 200 W UV flip chip COBs for industrial applications were the technical highlight of the company while their powerful visible light products were probably more attractive to most visitors. Gigahertz Optics introduced a new product designed for LED binning tasks, the TPI21-TH. Electronic zero setting, support for fully-automated measurement sequences, and use outside of dark rooms are just some of its remarkable features.
Ophir Optronics FluxGage is intended to replace integrating spheres in automated measurement and testing systems for directional lights. The concept is based on solar cells in combination with an additional spectrometer for the color measurements and a fast photodetector for the flicker measurement. iLumTech's innovative, intelligent, and dynamic smart city control and monitoring system, Synapse, presents the IoT trend and is built around the open LoRaWAN™ specification.
Plessey introduced the Orion™ PLWSC3000 LED module based on their innovative Stellar™ Beam Forming Optics (more about the concept and technology can be read on page 60). UL introduced further details and an update to their new flicker measurement, certification and labelling service. Not officially filed in time for the product launch and therefore not taking full advantage of the promotion opportunities, some other companies also showed new products for the first time at the LpS. For instance GL Optlc presented an updated version of their GL Spectis 1.0 FLICKER that now offers flicker measurement, and Fraen extended their range of Multi-TIR Nested Lenses for domeless LEDs.

Although Kyocera didn't have a product launch, they exhibited for the first time at LpS, and showed their white LEDs. The technology might not look special at the first glance; they use purple or close to UV LEDs with a mix of multiple phosphors like others do. However, Kyocera is one of the few companies that make their own phosphor blends in combination with this technology to match natural sunlight as closely as possible to provide high quality white light.

The start-up section of the exhibition caught almost more attention from the visitors than some of the established companies.
The innovative ideas and product designs were generally welcomed and perceived as an enhancement to the show. Carpet Light (we already reported from the Light + Building) came with the latest improvements and disclosed their roadmap for the next year.
The manufacturing process has been approved now to allow the production of larger formats. One of the first 4'x4' samples was presented here. While the CCT tunable product was originally designed for TV and movie applications, the company meanwhile also sees increased interest from the general lighting market. Another interesting concept was on display from Luke Roberts. The intelligent luminaire for human centric lighting is highly adaptive. Areas can be individually dimmed, color temperature can be adapted and the color of the indirect light element can be varied.
The luminaire, which can be controlled by using a nicely designed and easy to handle app, learns from the user behavior, taking several parameters into account. Der Lichtpeter caused a stir, not only at his booth but also at his lecture. He presented his flicker measurement services and results and promoted his flicker metrics that significantly differs from current standards. He takes into account higher flicker frequencies, a subject discussed in our magazine several times. His loading of different frequencies also differs from the common standards. This is a topic



Many companies, but especially the start-ups showed innovative products



Products were presented and technologies explained in detail throughout the exhibition

The press conference ended with a Q&A session with international lighting experts including Professor Nakamura, Ms. Ling Wu, Carlos Lee, Heinz Seyringer, and Arno Grabher-Meyer

that LED professional will keep an eye on. Two absolute highlights in the electronics domain belong to the start-ups too. Nordic Power Converters is one of these companies. The company's technology has enabled this change by combining circuits from the RF industry with the design methodology of power electronics. These topologies eliminate the switching losses that limit the switching frequency of traditional SMPS's. High-frequency power converters use significantly smaller energy storage elements, thereby eliminating the use of the most unreliable electrical components such as electrolytic capacitors if required. Representatives from different well-known lighting companies showed great interest in these products. The second company, AccurIC, could also drew a lot of attention with their linear current drivers. The drivers are based on new (patent pending) technology, enabling high-accuracy constant current regulation at levels required by high-brightness LEDs and LED chains. Through the use of a completely linear regulation method, these true constant current drivers eliminate the problems associated with switch-mode noise and ripple.

Accompanying Program: Art and Networking

For the first time, the opening ceremony with Prof. Nakamura was open to visitors and attendees, alike. Afterwards, Vorarlberg's State Governor, Mag. Karlheinz Ruedisser, opened the reception, which was the perfect starting point for checking out the exhibition and networking. The Get Together Evening on Lake Constance, another great place to network, has become a tradition that nobody wants to miss. This is where people got the chance to talk with speakers and leaders of organizations or companies in a relaxed atmosphere. Munich Re, following their informative

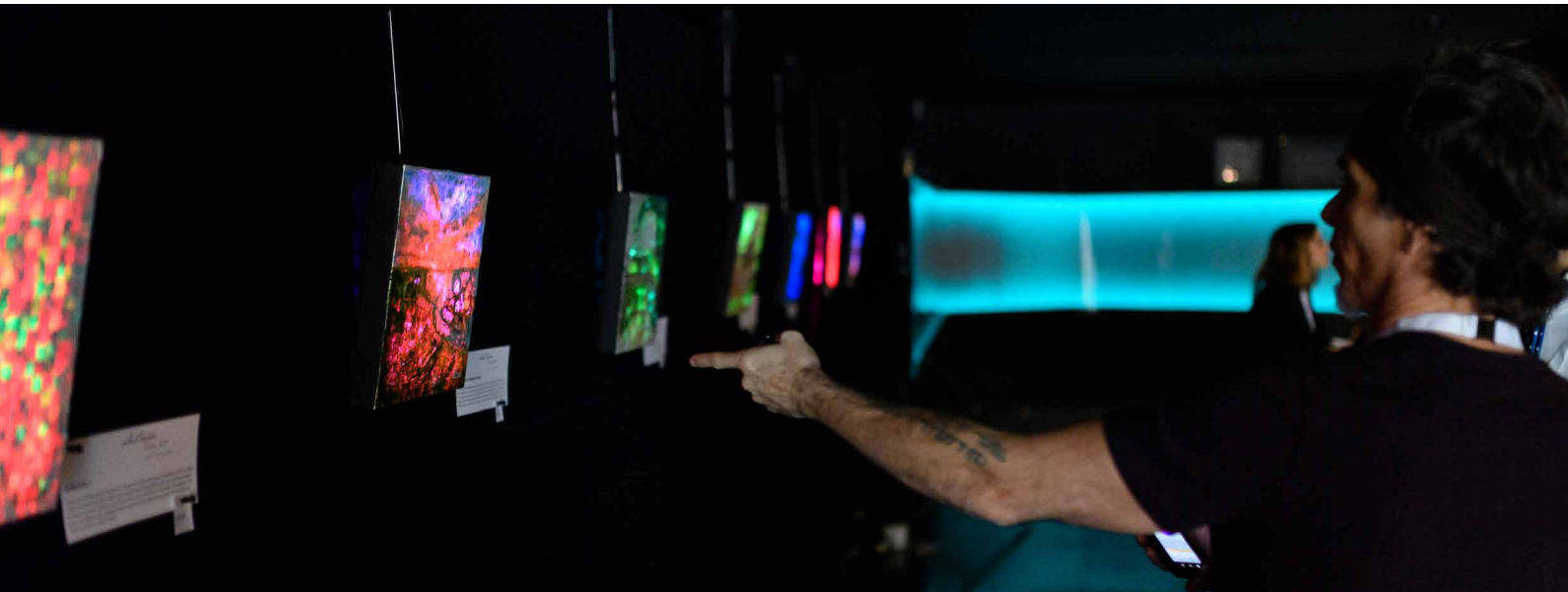
talk on “Risk Transfer and Investment for the LED Industry Forum” offered another networking event.

Clint Eccher’s impressive “Tiered Paintings” (LED professional published details of the painting technique in LpR 57) were shown in the Showroom at the Festspielhaus. Visitors, attendees and specialists were all equally amazed by these unique works of art. To pay homage to the location, this talented artist created a painting he named, “Bregenz 6000 years ago”. The image transforms from the ancient stilt houses to the lake stage of the Festspielhaus with changing LED illumination.

Summary of the Impressions

The topics of the lectures as well as the promoted products in the exhibition show the continuation of the trends from Light + Building. The lighting industry is pushing IoT in hopes of getting their share of the pie. The activities in this direction could definitely lead to a success. Both lectures and exhibition indicate a clear commitment to high quality products and substantiate the fact that light quality and illumination quality will be the major topics in the coming years. This is also recognized as the basis for true, human centric lighting, another area that promises the European lighting industry good business opportunities. It is also encouraging to see that new ideas are still being generated that could further enhance light quality or lower costs. It is especially exciting to see how small companies and/or start-up companies are able to bring new and interesting concepts to the market. Once again, LpS was the perfect platform for presenting new ideas that foster the spirit of innovation. ■

In addition to the traditional cruise around Lake Constance, the Munich Re event was another great opportunity to network



The showroom near the entrance of the Festspielhaus was a great place to relax while checking out Clint Eccher’s Tiered Paintings and the EL-foil that was entered into the Guinnes Book of World Records

Comparing New Dielectric Materials for Chip-on-Board LED Packages

Thermal management is still one of the most challenging issues in solid state lighting. With the increased application of COB LED technology, the portion of the dielectric material on the overall thermal resistance has become an important topic. Different solutions and new materials have been proposed over the last few years. Hui Zhang, Max Wagner, and Prof. Tran Quoc Khanh from the Laboratory of Lighting Technology at the Technische Universität Darmstadt compared different materials and present the results of their extensive research.

Light-emitting diodes used in automotive headlamps do not radiate much heat as they light up, but they create heat within the chip, or die, when the electricity passes through, which can compromise the cooling of adjacent assemblies and connectivity cables. For this reason, LED headlamps need cooling systems, such as heatsinks or fans. Also, although these solid-state devices will last a long time when they are operated at low currents and temperatures (as long as 25,000 to 100,000 hours), heat and current settings can extend or shorten this time significantly. High-power LEDs are subjected to higher junction temperatures and higher current densities than traditional devices. This causes stress on the material and may cause early light-output degradation.

One of the main aims in designing electronic packaging is good heat transport away from the device, downward through the package into the printed circuit board (PCB). The LED chip is connected electrically at its top and bottom, thus the electric circuit needs to be separated from the metal board by an insulator layer, which is neither electrically nor thermally very conductive.

A new chip-on-board (COB) LED-array technology has proliferated broadly in the past few years, enabling enhanced optical properties. For example, Samsung introduced several new COB lines in mid-2015 with significant white-light and color-quality innovations. We investigated the thermal behavior of this type of LED package, to compare their effectiveness with traditionally used materials. We also measured and simulated the influence of geometric parameters of the electrical layouts on thermal resistance.

Figure 1 shows the structure of a high-power LED in a chip-on-board package. The majority of the heat from the die is transferred to the outside by conduction. Most of the heat is conducted downward because the thermal conductivity of molding compounds (such as epoxy or silicone), is much smaller than that of the die-attach material (for example, silver conductive adhesive). Thermal conductivity and the geometrical structure

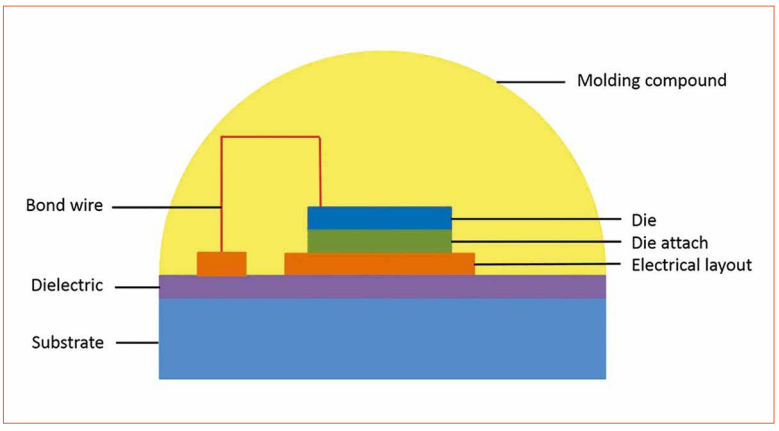


Figure 1: Structure of a high-power COB-LED package

of the interface materials greatly influence the heat flow. We used a thermal-impedance test system, the Mentor Graphics T3Ster, to measure the results when the thermal conductivity or structure was changed.

Figure 2 shows the structure function of an LED package after the evaluation of the measurement. The structure function presents all the thermal information of the tested LED-package, including thermal resistance in K/W and thermal capacity in Ws/K. Every layer of the thermal capacity represents one kind of material in the LED package. We were particularly interested in the thermal resistances of different materials and their ability to facilitate cooling of the electrical components. A lower thermal resistance translates into better overall performance.

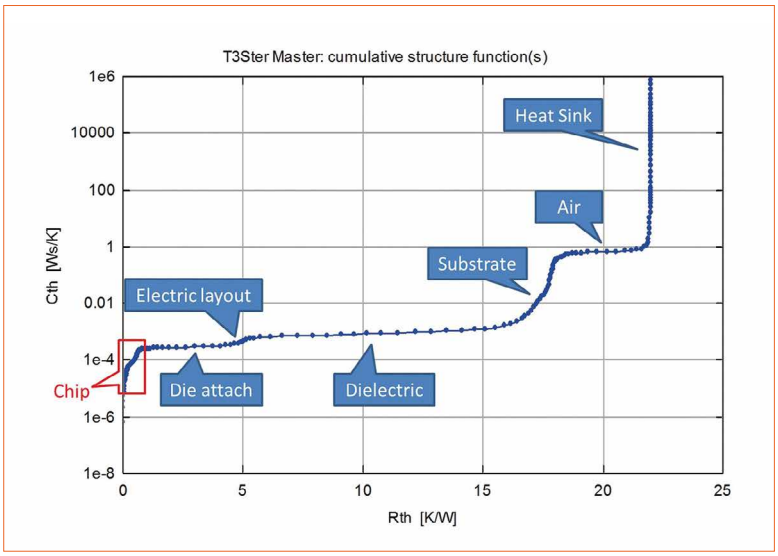


Figure 2:
Structure function of an LED package

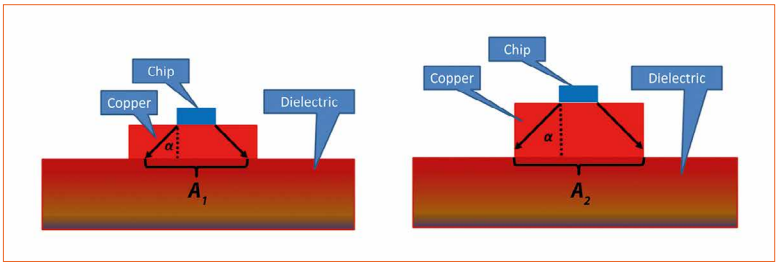


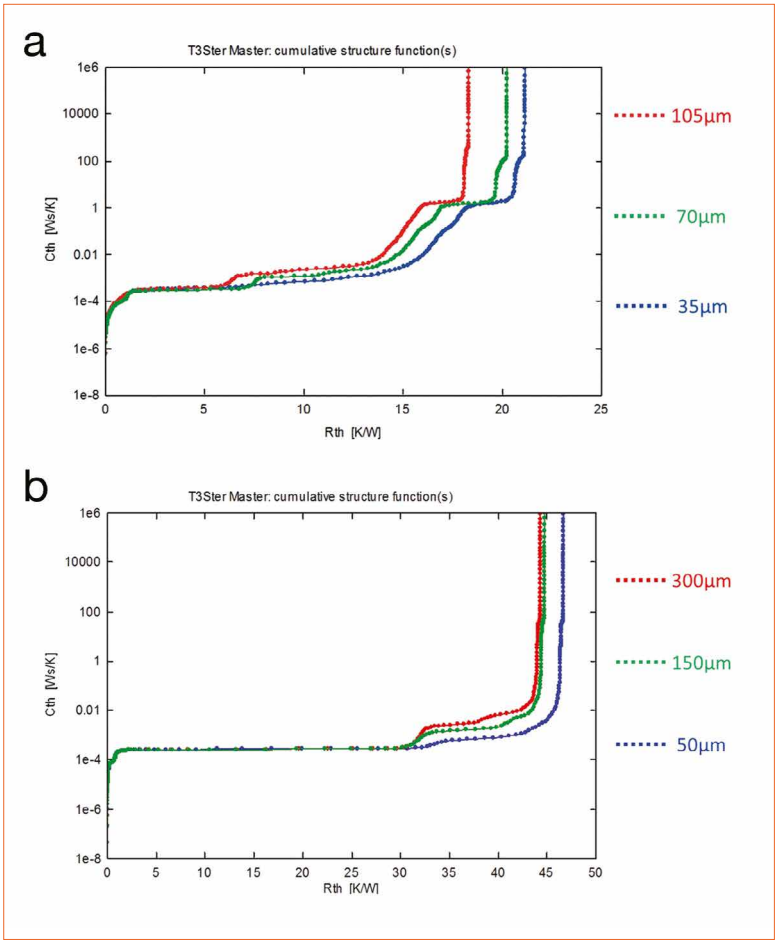
Figure 3:
Heat spreading at different thicknesses of electrical layout

How Electrical Layout Affects Thermal Resistance

The electric layout, the electrical connection between the chip and external electrodes, plays an important role in operation of an LED package, which is why we built different geometrical structures of the electric layout and analyzed them from a thermal perspective. Copper as a connector is the first choice to the manufacturers because of its good electric conductivity and cost. In addition to changing the size of the surface, we changed the thickness of the layout to 35, 70, and 105 µm. Copper has a high thermal conductivity of 385 W/mK. For a copper layout with a surface area of 5 x 5 mm and a thickness of 35 µm, the thermal resistance through the material is

$$Rth = \frac{l}{\lambda \cdot A} = 0.0036\ K/W$$

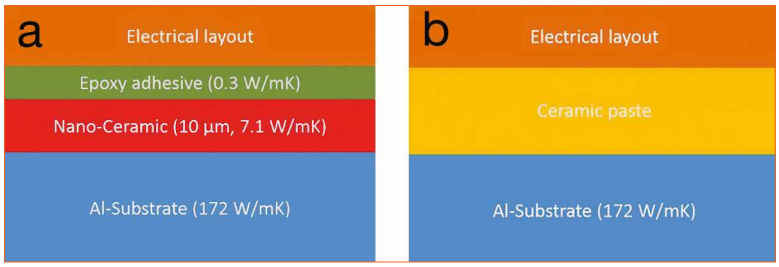
This value is so small that tripling the thickness to 105 µm leads to only a 0.01 K/W change. So why the concern over thickness?
The answer lies in the effect of heat spreading, which is not represented by the formula above, but rather



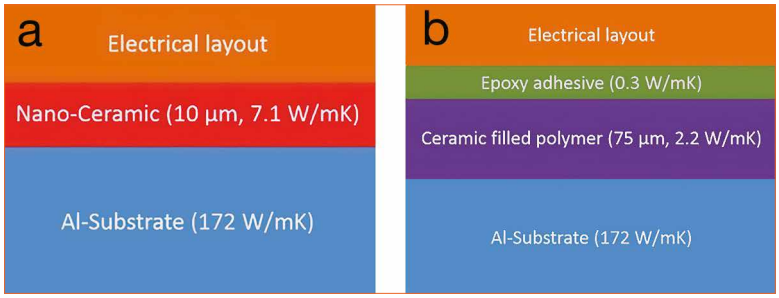
Figures 4 a&b:
(a)Structure functions (measurement data), (b) Simulation data (variation of the thickness)

detected in measurement results. Figure 3 shows the approach of the effect by using a refraction model [1].

The die's heat flow reaches the copper layer and then is spread in the material. Compared to optics,



Figures 5 a&b: Comparison of (a) Nanotherm LC (laminated circuit) and (b) ceramic paste



Figures 6 a&b: Comparison of (a) Nanotherm DM (laminated circuit) and (b) ceramic-filled polymer

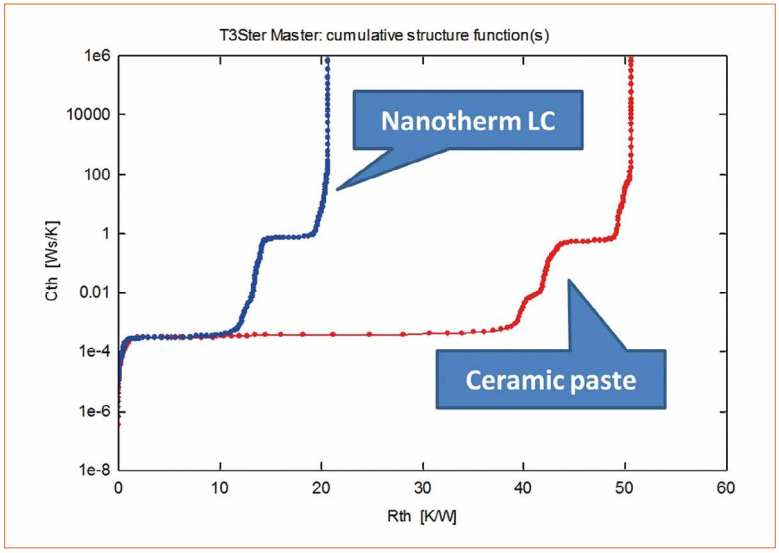


Figure 7: Structure functions of Nanotherm LC and a ceramic paste as dielectric material

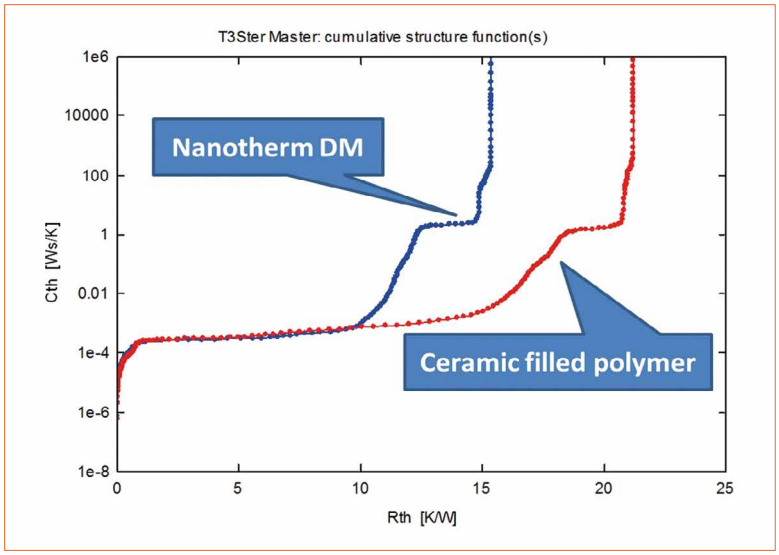


Figure 8: Structure functions of Nanotherm DM and a ceramic-filled polymer

the refraction at the boundary surface is dependent on the refraction index, which is the conductivity in the thermal picture. The chip's junction to a highly conductive material results in a high refraction angle α, so that a high spreading effect should appear. By increasing the copper layout's thickness, the surface A, through which the heat passes, gets larger. Now, we can calculate the next thermal resistance with the simple formula again.
The experimental results and transient thermal simulation with Mentor Graphics thermal simulation software, FloTHERM, are shown in Figures 4 a&b.

Both the experimental and simulation results confirm that the total thermal resistance with a thicker copper layout is lower. That is because heat flows into the dielectric through a higher effective surface area (Figure 3). So the dielectric presents a smaller thermal resistance.
A higher thermal capacity should be observed because a thicker thickness means more material.

Very thin layers take a long time to simulate, and so the thicknesses of glue and dielectric are different for the test devices. The trend of lower thermal resistance and higher capacity by enlarging the copper layout's thickness appeared in both the measurement and simulation data.

Testing and Analyzing New Dielectric Materials for Comparison

The dielectric substrate materials we used were based on polymer and/or ceramic materials. We used a non-standard technique to connect the dielectric layer with the board's substrate and electrical layout.
The usual method is to laminate the electrical layout on a ceramic-filled polymer with an epoxy adhesive. However, because the thermal conductivity of a polymer is lower than that of ceramic, we used a ceramic layer that consists of nano-crystalline aluminum oxide crystals (Al_2O_3) [2]. We laminated the electrical layout on this pure ceramic layer or used a metallization process for direct contact.

We tested samples with the same LED package, but different dielectrics, using the thermal impedance measurement system. We directly compared a thick-film

nanotherm metal-clad PCB substrate (Nanotherm LC) and a ceramic paste (Figures 5 a&b | Figures 6 a&b), as well as a thin-film nanoceramic substrate for PCBs (Nanotherm DM) and a ceramic-filled polymer [3]. Figures 7 and 8 show the results of the measurement's structure functions.

We concluded that the combined thermal resistances of the dielectric and substrate materials are what build the main part of the total thermal resistance in the investigated LED-package. The use of a laminated nano-ceramic instead of a ceramic paste reduced the thermal resistance from 40 to 10 K/W (Figure 8). One reason for this is the small thickness of the ceramic layer (10 µm). The direct comparison of pure nano-ceramic with a laminated ceramic-filled polymer of a standard PCB also shows a reduction of the dielectric's thermal resistance of about 33%. The conductivity is higher and the thickness of the direct metallized material is smaller, so the consequence must be a reduction in the total thermal resistance.

Conclusions

This exercise was useful because not every transient thermal behavior can be covered by a simple one-dimensional example. The electrical layout directly affects the measurement curves and must be considered by other models. We concluded that changing the PCB's dielectric substrate material has the biggest effect on the total thermal resistance of the LED package. In the future, the aging behavior and reliability of both materials are interesting aspects that should be studied. ■

References:

[1] David P. Kennedy. "Heat conduction in a homogeneous solid circular cylinder of isotropic media". Product Development Laboratory, Data Systems Div., International Business Machines Corp, Poughkeepsie, NY, 1959.
[2] http://www.camnano.com
[3] Datasheet from Excelitas Technologies and Cambridge Nanotherm.

Structured Glass Light Guides for Efficient Lighting

Glass injection molding technology (GIMT) for precision glass optics is a relatively new manufacturing technology. This expertise allows for producing efficient glass optics for LED lighting applications with special properties like undercut geometry or mounting flanges. A lot of progress has been made since it was introduced. Christian Passlick, Optical Engineer at Auer Lighting, shows how this improved technology supports making state-of-the-art light mixing structures for RGB/RGBW LED systems.

The relatively new glass injection molding technology (GIMT) for precision glass optics is able to form optical glass components with high length-to-width ratios, undercut geometries like mounting flanges and high quality surfaces. These attributes perfectly match the requirements for light guides, which are used in optical systems to efficiently shape and mix light from multiple light sources such as LEDs.

Back then, it was shown by coupling optical and thermal simulations that such light guides made from polymer materials will reach and even exceed their melting temperatures due to their absorption characteristics when used in conjunction with newer mid-to-high power LEDs [1]. This was also confirmed by the lighting industry, which reported temperature issues with polymer light guides in some fixtures. A change of material was partially necessary and the huge demand could be satisfied with the GIMT making it technically feasible and cost-efficient to use glass for this kind of optics.

In addition, surface treatments of glass have been developed and established for mass production, which are useful for improving light distribution and color mixing properties of the light guides.

The following article gives some general insights into the science of light guides and presents the latest developments on these precision glass optics.

Applications

Typically, light guides are used for transporting light over longer ways and/or for redirecting light into other directions, e.g. perpendicular to the optical axis. The direct addition of non-optical elements like mounting features to the optics is very helpful for a variety of applications.

In the automotive lighting business, this applies to light guides in headlamps and rear lamps as well as in interior functional and decorative lighting systems. A lot of new adaptive driving beam (ADB) headlamp modules are built on LED arrays in which each chip is separately tunable. For obtaining maximum light on the street, a light guide matrix can be used to collect the light of each single chip and to pre- or even finally shape the light distribution for the street. Such an array is produced as one part with optical and additional non-optical elements, e.g. wings for clamping the part into the holder. The advantage of having everything built into one component is, of course, the very precise and reliable spacing between the single light guides.

Another big application area for light guides is the stage lighting industry. Common moving head systems must provide homogeneous light fields with variable spot sizes and switchable colors. One optical

solution is the combination of multi-color (RGBW) LEDs together with light guides and movable projection lenses for zoom functionalities. In this case, light guides are particularly needed for mixing the different color spectra of the LED chips via multiple total internal reflections. State-of-the-art color LEDs are typically using 4 to 9 different color chips, so that their finally mixed color can be adjusted almost over the complete visible spectral range. Thus, additional cost-intensive parts like color filters/ wheels are becoming obsolete.

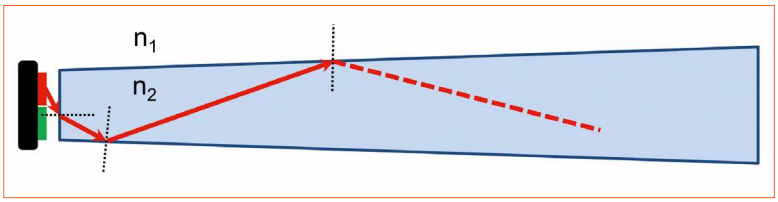


Figure 1:
Principle of total internal reflection inside a light guide

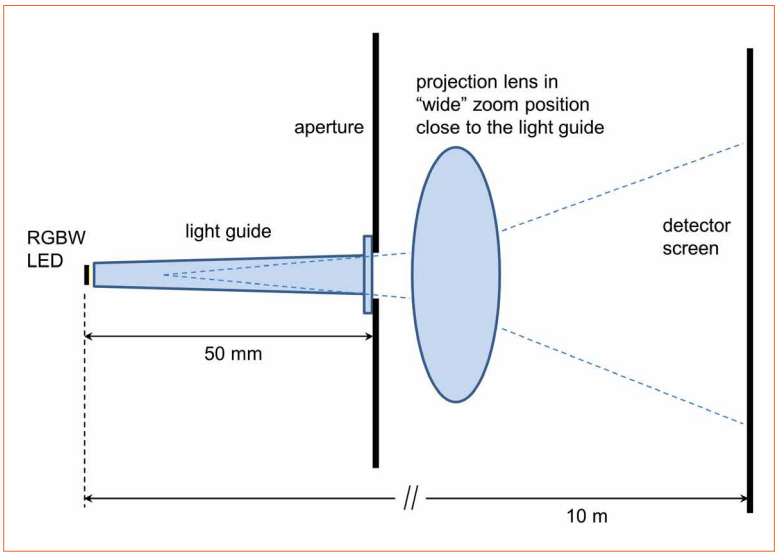


Figure 2:
Optical setup for a simple stage lighting system

Basics

Working principle

The working principle of a light guide can easily be explained by using the simplest geometry as an example: a solid rod consisting of three perfectly smooth surfaces: two parallel surfaces, one being the light entrance and one the light exit plane, and the extruded surface that occurs when both plane geometries are being connected.

The main physical principle for light mixing with a light guide is the total internal reflection (TIR). Light rays inside the optics incident to a side wall (material-to-air boundary) are total internally reflected when their incident angle exceeds a material dependent critical angle with respect to the normal to the surface (Figure 1). The refractive index, n_1, on the other side of the boundary therefore needs to be lower, which is given in case of air as the surrounding medium.

Boundary condition for TIR:

$n_1 = nair = 1 < n2$

TIR is theoretically 100% efficient; no light is lost during reflection as long as the surface is completely smooth. Subsequently, a light guide is able to effectively capture, mix and transmit a certain spatial and angular distribution of rays from multiple sources. A reflective coating on the side surfaces is not useful in this case: with each single reflection inside the material, a specific light fraction is lost depending on the coating reflectivity. This effect leads to a quick efficiency drop for multiple reflections in longer optics.

When light rays are entering and escaping the rod, they are crossing a material boundary and hence are refracted depending on the angle of incidence and the two indices of refraction for both materials. By introducing a statistical surface normal distribution on the exit surface of a light guide, exiting rays are refracted accordingly resulting in a defined scattering and mixing of the light distribution.

Optical development

The previously explained basic laws of optics are used when evaluating and optimizing light guide designs with optical ray tracing simulation software. A light source is described as a set of single light rays each having a starting position in space, a direction vector, a specific amount of energy and optionally also spectral data. These ray data are typically available from the LED manufacturers. The ray paths are then computed and typical photometric properties like illuminance, luminance, luminous intensity and luminous flux are evaluated on a detector surface.

In the following, a simple stage lighting system consisting of one 4-color RGBW LED (flat emitter), one light guide and one projection lens serves as an example. Various light guide surface structures are investigated and evaluated with regards to their optical performance.

The optical setup shown in figure 2 is implemented into the software. The light guide geometry, i.e. length, input and output aperture, is then optimized towards specific requirements. Here, several optimization targets are possible.

The most sought-after are

- Total optical system efficiency
- Color mixing
- Center illuminance at a fixed distance

A conflict might occur, if two of these targets are requested simultaneously, as they can demand for opposing optical solutions. Finally, a tradeoff between both

Table 1:
Comparison of relevant material properties [2]

Property	GLASS (here: SUPRAX®)	PMMA	PC	SILICONE	Remarks
Density (g/cm³)	2.31	1.18	1.20	1.02	
Thermal expansion coefficient (10^{-6}/K)	4.1	80	70	250 - 345	
Permanent Operating Temperature (°C)	400	<80	<110	<150	
Light Transmission (%)	92	92	89	91	D = 3 mm
Refractive Index	1.482	1.492	1.585	1.410	n_d @ 25 °C
Fresnel losses (%)	3.8	3.9	5.1	2.9	One surface
	7.5	7.6	9.9	5.7	Two surfaces
Thermo-optic coefficient dn/dT (10^{-4}/K)	~0	-1.1	-1.1	-5.0	
Abbe number	65	59	31	50	v_d
Suitability as a coating substrate	++	-	0	-	
UV resistivity	++	0	-	+	
Cleanability	++	-	-	-	
Yellowness index	0	8	9	1	30 years ASTM E313

values has to be negotiated in order to obtain an optimal working system. Due to the fact that the material plays a major role, not only for the optical properties, the following section will give some more important information on how to select the proper system.

Material selection

Solid light guides are made from transparent optical materials such as polymers (PMMA, PC, optical silicone) or glasses (BK7, B270, SUPRAX®). Each material comes with its advantages and disadvantages. Depending on the final application one has to consider limiting conditions like potentially occurring system temperatures, maximum optical powers and flux densities before choosing the optics material. In particular newer LED systems provide increased optical power densities and the possibility of driving the chips at higher junction temperatures. This pushes the thermal load on the optics to a critical point of polymer materials like PMMA (typical maximum permanent operating temperature is $T_{op,PMMA}$ = 80°C) and PC ($T_{op,PC}$ = 110°C). Optical silicone is temperature stable up to $T_{op,Silicone}$ = 150°C, but suffers from the disadvantage of being easily deformable during mechanical and temperature stress. The thermal expansion coefficient of silicone is with $345 \cdot 10^{-6}$ K^{-1} about 4-5 times as high as for PMMA and PC leading to noticeable changes in volume with increasing temperature. SUPRAX®, a borosilicate glass, shows an up to 84 times lower coefficient of thermal expansion while its permanent operating temperature is $T_{op,SUPRAX}$ = 400°C. It is possible to apply anti-reflective coatings on glass resulting in an exceptional high and long-lasting system performance. In a few cases, the higher density of glass needs to be considered if a minimum fixture weight is required. For deeper material information please refer to Table 1 and the references [1, 2].

Glass injection molding technology

For glass light guide production, a proprietary pressing technology was implemented. Contrary to direct glass pressing, where the optics is pressed directly from the liquid phase, the new glass injection molding technology (GIMT) is comparable to injection molding known from polymer optics. An example product is shown in figure 3. The method offers some advantages, e.g., possible

Figure 3:
Light guide made in one piece from SUPRAX® glass

geometric undercuts, high aspect ratios (length to width) and smooth 3D freeform surfaces with best contour accuracies. A minimum product weight of merely a few grams can be realized. All of these points allow for total geometric freedom during the design and optimization phase.

State-of-the-art mixing and structures

The number of reflections inside the light guide is responsible for the amount of color mixing. Thus, long light guides yield better results than short ones, but one has to keep in mind that the total optical efficiency suffers with increasing light guide length. Light mixing via TIR only is in some cases not sufficient to obtain a completely homogeneous light distribution. This is illustrated in figure 4 for the stage lighting example system. Multiple images of the RGBW LED are visible, caused by the multiple reflections inside the light guide.

In such a case, an additional mixing is needed and can be obtained via surface structures on the exit surface. A common surface finish for light guide surfaces is, e.g. an abrasive process like sand or glass bead blasting. These methods form a surface profile with stochastically distributed peaks and valleys. Depending on the process parameters, the profile can vary in a certain range and be tailored for specific scattering angles.
An advantage of these structures is their very small width and fine texture, which cannot be resolved anymore when being imaged onto a target area. The drawback of using this technique is the obtained high surface roughness leading to pack-scattered light and thus to a reduced total optical system efficiency.

Improved mixing

An effective way to minimize back-scattering is the utilization of defined micro structures. Contrary to general belief that smaller structures below 500 µm are only feasible in injection molded polymer optics, such defined micro lenslet geometries can also be transferred into glass surfaces by means of an imprinting process. Depending on the final system, the effect of their defined geometries and spatial arrangement on the color mixing can be predicted via straight forward ray tracing simulations.

For demonstration purpose, four different example micro structures, irregular spherical gratings with lattice constants of 500 µm and variable sphere radius, hereinafter referred to as S1 to S4, were evaluated on the output surface of a light guide. Figure 5 shows the simulated RGB color images of their light distributions on the detector screen. Depending on

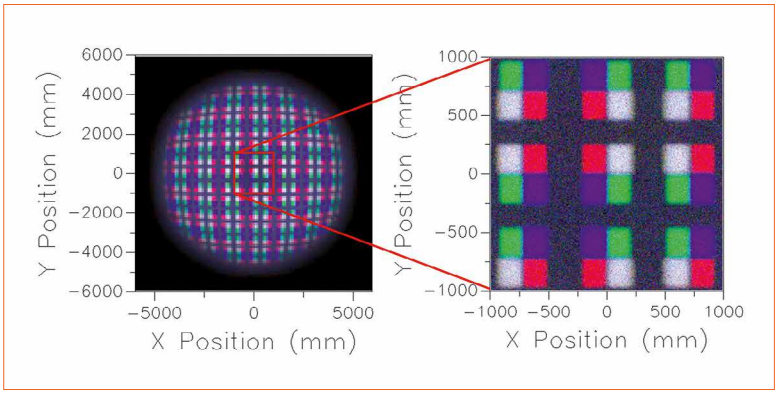


Figure 4:
Simulated RGB color images of the light distribution on the detector screen with a distance of 10 m from the LED. Multiple sharp images of the RGBW LED are visible caused by the projection lens

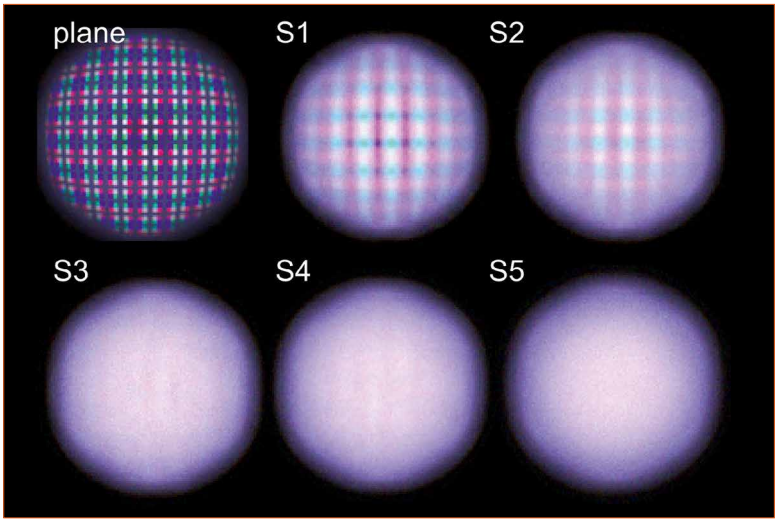


Figure 5:
Simulated RGB color images of the light distribution on the detector screen for the untreated reference and four different micro structured surfaces, S1 to S4

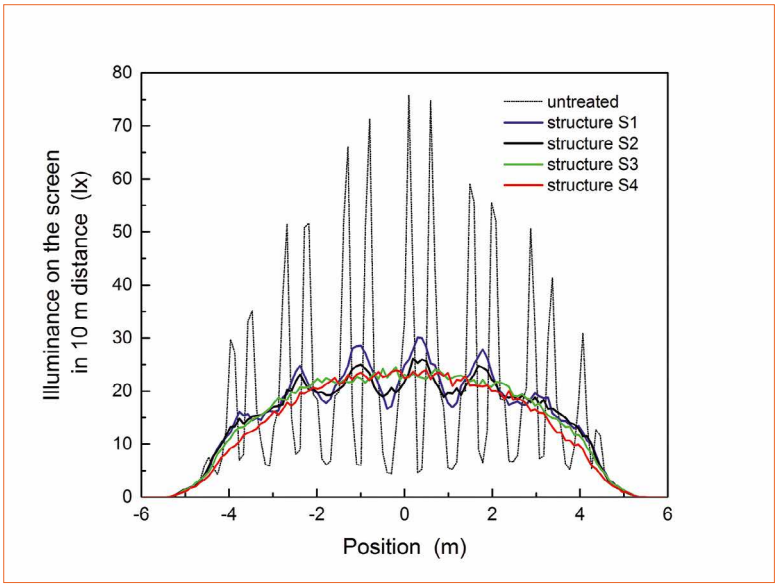
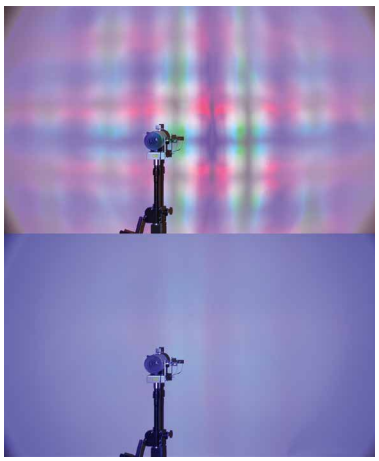


Figure 6:
Cross sections of the simulated illuminance distribution on the detector screen at a distance of 10 m for the untreated reference and structures S1 to S4

Figure 7:
S3 structure on a complex light guide exit surface



Figures 8:
Photographs taken for an untreated reference (top) and the micro structured surface S3 (bottom)

the used structure, the final color mixing is significantly influenced. Structure S4 provides the most homogeneous distribution.

This again, is shown in Figure 6, where cross sections through the illuminance distributions are compared for all structures. The untreated surface results in a large number of local minima and maxima. By introducing the irregular spherical grating with a fixed lattice constant of 500 µm, the extrema are blurred as a function of the sphere radius. As explained before, an increased light scattering often also reduces the optical efficiency of the system. Compared to the reference light guide, the efficiency of a light guide with example structure S1 is reduced by approx. 1%, while it is 14% for structure S4.

Structure S3 provides a good compromise between color mixing and efficiency. Therefore, it was transferred into a real-world glass light guide (Figure 7). A simple optical test setup similar to the setup of Figure 4 was used to test the color mixing ability of the product. An image of the obtained light distribution was taken for an untreated reference (Figure 8 - top) and for the structured light guide (Figure 8 - bottom). The real-world light distribution fits well with the simulation: a significant mixing is achieved. Yet a darker vertical center line and some neighboring stripes are visible. These are superimposed in a final product by using a higher number of light guide systems. A well-mixed light field with high optical efficiency is the result.

Overall, this example shows that surface micro structures in glass can be tailored to customized systems for obtaining maximum lighting performance.

Summary

The basic working principle of light guides was discussed and important key aspects for material choice and optical design were given. If high light output is demanded, the most suitable material for such kind of optics is glass. It was shown that recent manufacturing methods are able to produce glass light guides with integrated micro structures on an industrial scale.

By means of an example system, the additional benefit of surface structures on the light was illustrated. Optical simulations were performed and compared to a micro structured real-world product - with the very good result that defined scattering and color mixing properties are adjustable and transferable.

Also all kinds of other applications where color mixing is needed are feasible and can be addressed with these new proprietary technologies. For example, LED general lighting systems for in- and outdoor use must provide smooth lighting without any disturbing brightness deviations. Therefore, a lot of these systems currently use a primary glass optics being covered by an additional secondary diffusing polymer sheet. The use of two optical components directly reduces the total optical efficiency due to higher Fresnel losses, while they also need more space, are not easy to clean and increase system costs. Implementation of the diffusion mechanism of the polymer sheet into the primary glass optics provides significant benefits.

Current developments are ongoing to reduce the structure sizes in glass optics even further. This will in particular positively affect light mixing applications, where structured surfaces have to be imaged onto a target area without seeing there sub structures. ■

References:

[1] Paßlick, C. et al., “Stability of glass versus plastics for transmissive high-power LED optics”, Proc. SPIE 9192, Current Developments in Lens Design and Optical Engineering XV, 919210 (September 25, 2014); doi: 10.1117/12.2061854

[2] Hübner, M. C., “Long Lasting Optics for LED Devices”, LED Professional Symposium + Expo (LpS2014)

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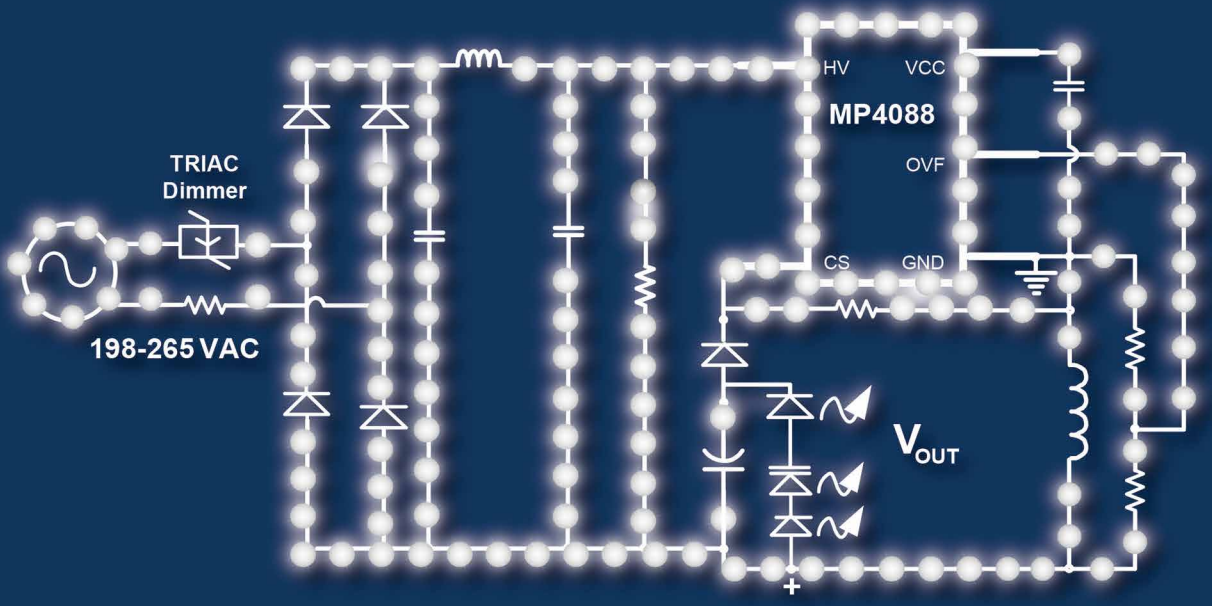

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On-Chip Beam Forming Optics Paves the Way for New Luminaire Designs

An LED luminaire's optical system usually consists of primary and secondary optics. This concept always causes a trade-off between light quality, system size, efficiency and light distribution. New concepts to make secondary optics obsolete have already been researched. Paul Drosihn, Head of Modular Products, and Samir Mezouari, Optics & Lighting Design Specialist at Plessey Semiconductors present the first of its kind chip scale beam forming technology, Stellar™. They explain how it works and how it helps to overcome the limitations of traditional optical solutions for LED lighting.

Standardization in the LED lighting industry exerts a powerful force. Thanks to the efforts of industry bodies such as Zhaga, LED-based luminaires are increasingly adopting common form factors and conforming to optical and electrical standards.

In popular product categories such as downlights, track lights and spotlights, standards-compliant luminaires might display superficial and cosmetic differences, but most will tend to share essentially the same components.

Essential standard components:

- a Chip-On-Board (COB) LED package providing a small, intense light source
- a lens mounted on top of the COB LED to shape its beam
- a reflector
- a large heat sink

Comprising so many large components, such as COB LED-based light engine will inevitably be a bulky and heavy unit. Luminaire manufacturers have to accommodate this large assembly inside their end product, giving them little scope to add their own unique design elements or to achieve any valuable differentiation.

Nevertheless, the COB LED-based light engine format has emerged as the standard. But is it actually what lighting designers, architects and users want?

In order to answer this question, it is worth returning to first principles: architects and lighting designers do not actually want to specify and buy luminaires. What they want is high-quality light where it is needed, when it is needed. If they could illuminate a space magically, without a luminaire, they would.

Lighting designers probably would not choose to fix a large, heavy unit in a ceiling void or onto a ceiling-mounted track in order to cast light on a wall or floor if they could achieve the desired illuminance less obtrusively. What if the industry were able to benefit from innovation, from fresh thinking aimed at creating a smaller, less obtrusive fixture?

In fact, today's standard form factors are simply the result of a series of technology choices - and other choices support luminaire form factors much more in tune with the preferences of lighting designers and architects. The latest LED and optical technologies available today enable the production of light engines with dramatically reduced dimensions, as well as superior quality of light and thermal performance.

New Approach To Beam-Forming

While the COB LED has become a popular type of light source, its use in luminaires which require precise beam forming is problematic.
Due to the configuration of the LED die on the board, and the way that phosphor is deposited on the die, a COB LED in a downlight or spotlight requires a very large optical assembly to achieve a directional light output and a controlled beam angle.

The sheer bulk of the optics is not, however, the only drawback. In addition, the performance of the optical assembly is compromised by the light-emitting surface, which is large and non-uniform. This results in visible differences in the color temperature of the light at the edge of the beam compared to the light at the center of the beam if complex optical design is not used.

To compound the engineering difficulties for the manufacturer of a COB-based light engine, the sapphire substrate on which a COB LED's gallium nitride (GaN) die are grown is a very poor thermal conductor.
At the same time, the heat-generating die are concentrated in a small area, creating an intense hot spot, as well as an uneven spread of heat across the light-emitting surface. This results in color variance over angle, and different rates of degradation of the LEDs' light output over the lifetime of the product. It also entails the use of a very large heat sink, to compensate for the high thermal resistance of the sapphire substrate and ensure the LED die do not exceed their maximum rated temperature.

The choice of a COB LED as the light source in conventional downlight and spotlight designs, then, makes them bulky, heavy and inflexible, and may produce noticeable color inconsistencies.

But this COB LED-based architecture is not the only way to make a light engine with a focused beam. In fact, there is an inherent advantage to an architecture which distributes multiple LED light sources over a large light-emitting surface: the heat generated by the LED die is distributed, so the heat intensity at each hot spot is less intense. This means that the temperature at each LED can be kept safely below its specified value at a much lower rate of heat dissipation. When backed by extra thermal management techniques to achieve a very low thermal resistance at module level, this can enable the use of a smaller heat sink, thus reducing the size of the light engine.

The difficulty with such a distributed architecture in the past has been principally optical; to tightly focus the typical Lambertian output from a conventional LED requires a large optical assembly over each light source. In a light engine for a luminaire such as a spotlight, with a diameter of around 100 mm and multiple LED light sources, this would clearly be difficult.
A solution to this problem combines innovative design, advances in processing capabilities for the manufacture of miniature optics and coupling this with specifically tailored LED light sources.

Miniature optics, by way of reflector arrays or collimators over large (cm) areas with precise tolerances to sub millimeter dimensions is now possible and manufacturable at low cost, however, requires coupling with a suitable light source.
As described above, conventional LED COBs are typically fabricated from GaN on Sapphire LEDs. However, if such LEDs were utilized in a distributed fashion and coupled with the collimated array they would not prove effective for several reasons. Typically such LEDs are assembled in plastic packages, which increases the effective light source area and subsequently renders the optics to a larger geometric scale, and adds to the already poor thermal performance of a sapphire based LED. Moreover, the light emission pattern is not conducive to an efficient solution with this optical approach, generally being Lambertian in nature.

LEDs based on GaN on Silicon technology offer a cost effective solution to the scale, light pattern and thermal performance required for the distributed architecture described. Such LEDs are manufacturable such that the light emission from the LED is only from the top surface of the structure and can then be modified through light conversion to produce a tailored light emission pattern to allow beam collimation with a miniaturized optic design. The LEDs have inherently better thermal performance and can be designed for a COB solution that requires no packaging, thus reducing the scale of the light source to a minimum.

Two innovative technologies, then - micro-scale beam-forming optics, and GaN-on-silicon LED wafer fabrication - appear to offer scope to luminaire manufacturers to radically rethink their product designs. How might this new design freedom play out in the field of common luminaire types such as downlights and spotlights?

Figure 1:
The optical assembly in the Orion module offers a dramatic size reduction

An example of the possibilities is suggested by a new light engine drawing on Stellar beam-forming technology.

The module produces more than 3,000 lumens, is just 5.6 mm thick and 82 mm in diameter. The tightly controlled beam has an FWHM angle of 25°, and the color temperature of the beam is visibly consistent throughout, from the center to the edge. Its housing is divided into multiple cells, with a single LED light source per cell. The multiple beams are blended at a distance of less than 1 m from the surface of the module. A comparison of the dimensions of the new module and a typical equivalent light engine based on a COB LED is shown in Figure 1.

Figure 2 illustrates the scope for luminaire manufacturers to re-imagine their product designs. The Stellar technology allows for a distributed LED architecture while still tightly controlling the beam pattern with miniature optics directly adjacent to the light-emitting surface. This in turn offers improved thermal characteristics, enabling the use of a small heat sink.

The total assembly is thus:

- Smaller
- Less obtrusive
- Easier to fit into a wide variety of end-product housings and fixture styles, supporting luminaire manufacturers' attempts to achieve valuable differentiation

Because light is emitted from a large surface area, the problems with glare that users of COB LED-based spotlights and downlights experience are eased or eliminated.

There is also a commercial benefit to luminaire manufacturers and distributors: by making a much smaller end product, they can markedly reduce shipping and storage costs, since more units can be accommodated in a ship, truck or warehouse.

Potential for Smarter, Better-Performing Lighting Equipment

This article has suggested that innovation, rather than standardization, is today responsible for important

Figure 2:
Complete light engine assemblies, including heat sink, based on the Orion module and a typical COB LED light source

product developments bringing valuable benefits to lighting designers, building operators and the users of lighting.

And the potential for innovations in luminaire design based on GaN-on-Si and micro-scale beam-forming technology does not stop with the introduction of new, smaller spotlights and downlights.

In the relatively near term, one possibility is to integrate intelligence - sensing and control - into the light engine. In a light engine with a distributed LED architecture, it should be possible to replace one LED with a photo sensor or other small image sensor. If housed in a cell, like the LEDs in the Orion module, it will be optically isolated from the neighboring LEDs, so that it will not be able to directly sense the light emitted at the LEDs' light-emitting surface, but only the light reaching the illuminated plane.

This gives luminaire manufacturers a new way in which to respond to the industry's demand for color tuning capability and human-centric lighting. With the addition of color tuning and control circuitry in the luminaire, it will be possible to adjust the color temperature and intensity of the light output in response to local changes in the ambient light or other environmental factors, as well as to attune the color temperature to Circadian rhythms, or align to other time-based patterns.

In all such endeavors, the purpose must be to provide lighting designers with what they want - the right light in the right place - rather than what they are used to getting - an obtrusive luminaire providing a light output with a pre-determined configuration.

Another development which is in sight is the implementation of optics-on-chip. That is, the lens may be fabricated on the wafer or during the chip manufacturing process, producing an LED die with a collimated light output. This offers scope for even greater space savings and even lower-profile LED lighting modules, with a tightly controlled and focused beam. This development is made possible by the use of the silicon substrate in GaN-on-silicon LEDs.

Indeed, the ability to grow GaN LEDs on a silicon substrate could be the key to a host of additional moves to integrate functions on to the chip, and thus to reduce the size and cost of the luminaire. Silicon is the material in which nearly all of today's integrated circuits (ICs) are built, and the intellectual property and fabrication know-how is readily available for integrating microcontrollers, analogue signal chains and other electronics functions into monolithic silicon devices.

In the longer term, therefore, the potential with GaN-on-silicon LEDs should be to integrate more of an intelligent light engine's light-emission, light-control and user-control functions into an integrated circuit. This offers extraordinary possibilities for space and cost saving. And by reducing the number of components in a luminaire, silicon technology also promises higher reliability and a reduced failure rate.

In this, as in most technological developments, it is innovation which delivers value to the lighting industry. And as this article suggests, there remains much more scope to innovate further, even in apparently standard fixture types such as downlights and spotlights. ■

Flicker: Standards and Test Methods

Much has been written and said about Temporal Light Artifacts (TLAs). What is essential about TLAs is that they consist of flicker and/or stroboscopic effects induced by a light stimulus whose luminance or spectral distribution fluctuates with time and causes undesired changes in visual perception for an observer in a certain environment. Walter Parmiami, Senior Engineer at UL International Italia S.r.l., discusses the current status of regulations and measurement standards and proposes a certification to help manufacturers to generate user confidence, and consumers and specifiers to find the right product for an application

Depending on the details of the fluctuations, TLAs may consist of flicker, which is directly perceived as light fluctuation or stroboscopic effects, which is the misperception of motion, or both.

Assuming this phenomenon, particularly with the SSL technology, is viewed by the industry as an issue that needs to be addressed, several grey areas require clarification. One of these areas is the creation of a standard with appropriate measurement metrics.

Where Low Flicker Is Crucial and Where It Is Not

Different situations require a different focus on flicker, largely based on location, historical experience, likely exposure time and the sort of activities taking place.

In an outdoor environment, such as a street or a parking lot, there is little documentation of flicker complaints, and light sources with a high flicker may not have a negative impact in such situations. If the outdoor environment hosts evening sporting events, however, having a low flicker light source becomes important to avoid stroboscopic effects on the field.

Moving indoors, in an office or educational environment where individuals are exposed for a length of time to artificial light, while performing complex tasks, low flicker may decrease eye fatigue and be beneficial for migraine sufferers.

In an industrial environment the situation again needs careful consideration. In a warehouse with limited objects in motion and few visual tasks, low flicker is preferred but is not a necessity. In a production facility with many moving pieces of machinery, low flicker is an essential condition to avoid a misperception of moving parts.

Energy Saving Needs

According to the different kinds of environments and light needs, the lighting industry has developed dimmable products to help save energy.

Any dimming control, from a wall-box dimmer to an automated daylight harvesting system, has the potential for system mismatch and can introduce additional flicker. A phase-cut, wall-box dimmer has the most potential for additional flicker, although other methods can introduce at least some flicker.

While the application impacts of flicker have not been well studied, a good knowledge of light source and/or luminaire flicker characteristics, together with using good practices when considering the tasks of a space and the selection of lighting, may help to avoid discomfort among users. This is particularly important for LED installations that may be operating for many years.

Although some documents providing measurements metrics have been published on this topic, there are contradictions among them. Below is a brief summary of the main documents and the key aspects of each.

IEEE 1789

"IEEE 1789: IEEE Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers" is a document describing the challenges represented by flicker and some potential health impacts. It also provides recommendations for minimizing any risk of adverse effects. The document is not a standard and the recommendations given are very conservative, to the point that some traditional lamps are unable to meet the requirements. Despite this limitation, these recommendations can be useful when minimal flicker is required.

ENERGY STAR®

EPA's ENERGY STAR program (developed by US DOE) introduced a CFL frequency requirement many years ago. Only recently has ENERGY STAR addressed specific recommendations for measuring flicker, with Lamps Version 1.0. The recommended practice for measuring requires flicker index and percentage, as well as testing with five different dimmers (in case of dimmable products). The program does not yet provide a specific requirement, but it is gathering information to introduce a specific flicker requirement in a future revision.

California Title 20 and Title 24

Shortly after ENERGY STAR released its recommended practices for the measurement of flicker, the state of California introduced its set of requirements, listed in title 24, Joint Appendix 10 test method for flicker.

California's requirements include the test method "Joint Appendix 10" (JA10) that requires measuring the light output of a source or luminaire and dimmer for two seconds and then running the data through several complex calculations to evaluate flicker at multiple frequencies up to 400 Hz. Title 24 requires high efficacy sources to be "low flicker operation", which means that the LED product will have less than 30% flicker at frequencies below 200 Hz. This requirement goes into effect in January 2017. Title 20, which also requires "low flicker operation", will cover LED lamps, requiring that lamps be tested after being paired with controls.

IEC/TR 61547-1

This document adopts the same principle PstLM (illuminance measured with the light flicker-meter) described in the EMC standard IEC 61000-3-3 about the flicker metric definition and test method, utilizing a flicker-meter, as defined in the standard IEC 61000-4-15. The principle is to detect any possible flicker, due to voltage fluctuations on the grid, generated by variable loads, e.g, washing machines. The signals captured during the measurements through a light flicker-meter are acquired for a defined period and processed.

The outcome of the measurements is basically a numeric indication:

- < 1 Acceptable because flicker is not visible (up to max 70 Hz)
- = 1 As above
- > 1 Unacceptable because flicker is visible and may cause adverse visual effects

This measurement metric is limited because it is based on a 60 W conventional incandescent lamp, currently banned from the market due to energy efficiency requirements. Furthermore, it does not include mains voltage fluctuation disturbances for voltages other than 230 V/50 Hz.

Someone may think that using a stabilized power supply is enough to solve the issue; however, ripple on the output may still cause flicker. A revision of this document has recently begun.

CIE TC 1-83

This document, which takes into account the visual aspects of time-modulated lighting systems, specifies TLA metrics and terms, and it includes the metrics PstLM (flicker) and SVM (stroboscopic effect). The metric for the detection and measurement of flicker proposed in this document is similar to that contained in the IEC/TR 61547-1 (under revision).

Japan DENAN Law

DENAN Appendix 8 and J60598-1(H26): JIS C 8105-1: 2010 + Amd. 1 (2013).

This document addresses flicker detection in these terms:
SSL products are deemed not to create a sensation that the light output is flickering if: the lighting fixture has a cyclic frequency of 100 Hz or more with no output failure (5 percent% or less of the peak value of light output) or a cyclic frequency of 500 Hz or more of light output.

Considerations

Although some of the above mentioned documents do not account for non-visible flicker (>70 Hz), which is considered stroboscopic effect, non-visible flicker has not been proven completely safe. In fact, if we assume that a small portion of the population may be affected by serious health effects, and others by less serious side effects, e.g. eyestrain or, headache, it becomes clear that we are now dealing with the quality of the light itself.

A product with no visible flicker may still cause issues in certain situations, e.g. installations open to the public where a high quality of light is required and video recording may be necessary for security reasons. Again, stroboscopic effect is an unwanted side effect in sports environments where the motion of objects may be wrongly perceived, e.g. phantom array in motorsports and games with moving balls.

One of the major issues not yet addressed by the available documents, is the evaluation of

dimmable products, e.g. phase cut dimming and PWM products. In particular, reliable measurements metrics should carefully apply limits in the SSL luminaires dimmed through PWM techniques (100% modulation depth), where the typical operating dimming frequency is in the range of 200-400, up to 800 Hz, because it can be difficult to address TLAs up to 1,25 KHz.

Many other questions may arise, particularly from lighting designers and architects who wish to combine several products and/or light sources. One of these could be "what is happening in an installation with several luminaires where one or more products are affected by flicker or stroboscopic effect issues?" A typical metric relies on type testing (except for California Title 24 that requires three samples to be tested, while one sample is usually verified). No specific tests have been conducted so far on multiple TLAs, because if several products of the same genre and model are affected by flicker, it is reasonable to assume that the flicker effect will be multiplied rather than lowered. Although no specific tests have been conducted to address the multiple flicker issue, it can be assumed that perception may be negatively affected. Unfortunately, type tests are not able to solve this issue.

In conclusion, with TLA issues reducing the quality of today's light, the lighting industry is asking for reliable metrics, and, eventually, the application of limits. Ideally, these metrics would be differentiated by the destination of use of the lighting fixtures, the type of environment (e.g. public or private) and the duration of exposure to the artificial light.

A worldwide-recognized standard with appropriate test methods would be the best solution for the lighting industry. After taking the published literature into consideration, the development of a possible metric is described below.

Flicker Percent (FP) and Flicker Index (FI)

Flicker can be more or less apparent depending on several factors, primarily the relevant amount of variation in the light per cycle, the proportions of the lighting waveform, and the frequency (or frequencies) at which the light variation occurs. To describe the variation within a cycle, there are two primary measures: flicker percent and flicker index. Flicker percent is the measure of the maximum light vs. the minimum light in a cycle. This only accounts for the minimum and maximum light outputs, and does not differentiate between waveforms. This is the simplest form of flicker to determine. Flicker index is another common metric for describing the behavior in terms of the amount of light that a product produces over a given cycle. Flicker index requires more calculations than flicker percent, as there is consideration given to the shape of the waveform. Flicker index considers the area of the waveform above and below the average light output.

The difference in perceptibility in these two metrics is one that is still in debate. However, it is generally acknowledged that the perceptibility of both is dependent on the frequency at which a product operates.

With the shift to electronic ballasts operating at 40 kHz or more for greater efficiency, flicker issues were largely eliminated from fluorescent lighting. However, flicker has reappeared with LEDs. There is a balance between size, cost and lifetime when designing drivers, and many LED drivers operate at lower frequencies or contain lower frequency components that can cause perceptible flicker.

These metrics do not quantify TLA effects correctly and objectively. Flicker percent and flicker index are not selective (i.e., they do not distinguish between "flicker" and "stroboscopic effect") and do not account for the effect of

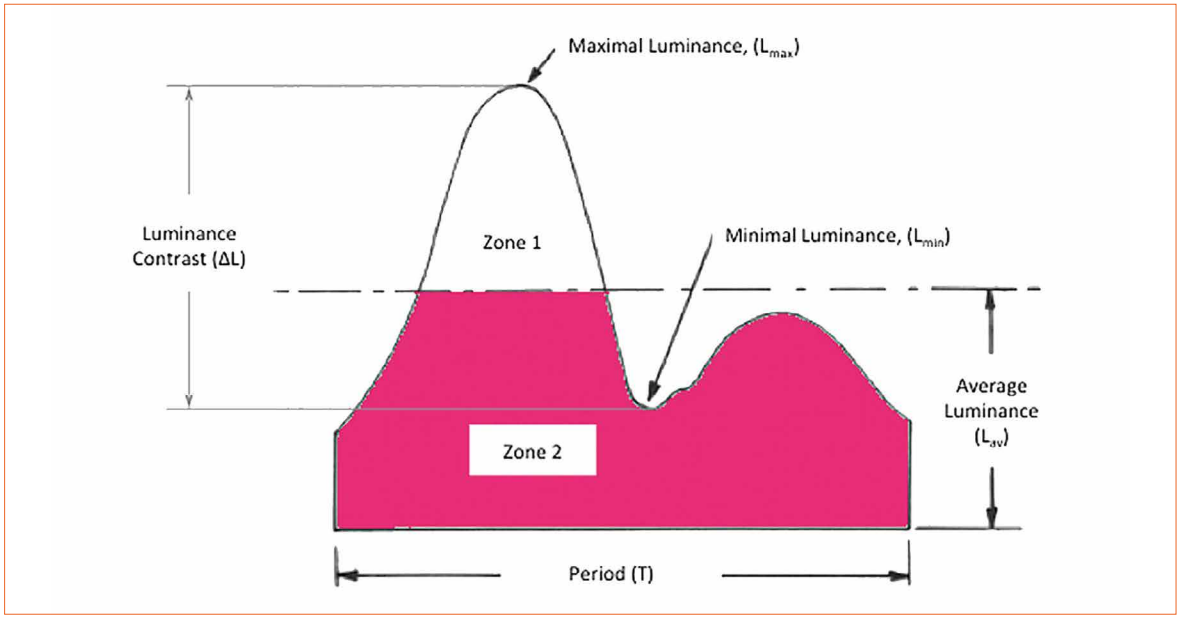

Figure 1: Example light waveform that helps to understand the definition of flicker [1]

frequency-dependent sensitivity or the wave shape of the light output, additional verifications are required to cover these aspects.

Several studies demonstrated that, even if a population has different threshold sensitivities, flicker is visible up to 70-80 Hz; above this value we need to discuss stroboscopic effect.

ASSIST metric, developed by the Lighting Research Center, is an additional metric that completes the other two, providing a numeric value that can be used to predict the flicker perception.

Testing Procedure

Test setup

The product to be evaluated requires a controlled environment consisting of a test enclosure able to maintain a constant temperature of 25°C ±2°C.

Test enclosure

The test enclosure shall not have to admit stray light. The measurements that will be obtained are relative, an integrating sphere is not strictly required, however it is ecommended to test the product in the sphere, this will help to grant better repeatability of measurements.

Photodetector

The photodetector fits the International Commission on Illumination (CIE) regarding the spectral luminous efficiency curve, linearity of response over the measurement range and response time of the sensor.

Signal amplifier

If necessary, a signal amplifier may be placed between the photodetector and the data collection device.

Device for data collection

Appropriate instruments like a digital oscilloscope with data storage capability or similar equipment able to store high frequency data from the photodetector may be needed.

Input power supply

Input power to UUT (unit under test), is required at the rated primary voltage and frequency within 0.5% for both voltage and frequency. When ballasts are labeled for a range of primary voltages, the ballasts are to be operated at the primary application voltage. The voltage will have a sinusoidal wave shape and a voltage total harmonic distortion (THD) of no greater than 3%.

Sampling parameters

Measured data are to be recorded in a digital file with an interval between each measurement no greater than 0.00005 sec (50 microseconds) corresponding to an equipment measurement rate of no less than 20 kHz. The equipment measurement period shall be greater than or equal to two seconds. In case of dimmable products, record lighting measurements (in foot-candles or volts) from test equipment with readings are taken at intervals of no greater than 50 microseconds for each dimming level after the products have stabilized. These readings are compiled for an equipment period of no less than two seconds and recorded into a comma separated data file (*.csv).

Signals acquired

These are then to be processed using the ASSIST metric, to determine the likelihood of flicker detection (as a percentage). In addition to the device-level flicker, lighting system design can have an influence on the amount and type of flicker that is experienced by an observer. Methods of dimming can introduce additional flicker into the light output. Phase-cut type dimmers alter the incoming power to the lamp, driver or ballast, which will often alter the light

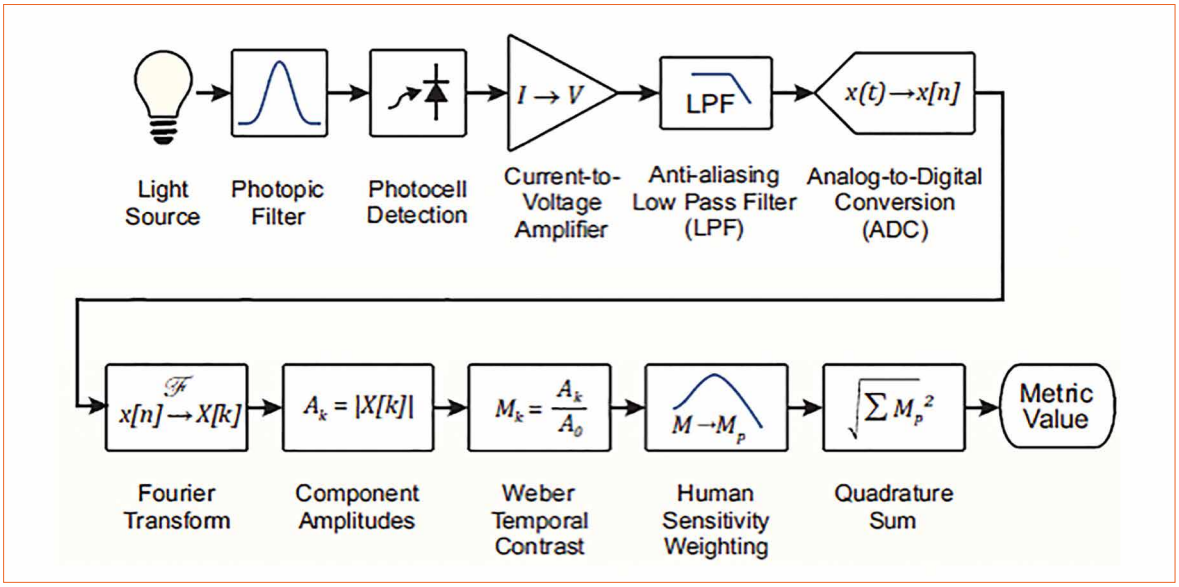

Figure 2:
The necessary steps that a good metric must include to obtain reliable data

frequency components coming out of the product. Some drivers and ballasts do a very good job of smoothing this; others transfer more of the cut wave to the light output. A common method of dimming in LED drivers is pulse-width modulation, or rapidly changing the LED light output to make the light appear dimmer, but also introducing additional moderate frequency components (typically 400-800 Hz). The above measurements must be repeated at different dimming levels.

The ASSIST metric takes into account the wave shape of the light waveform. The sensitivity curve used for sinusoids is quite similar to the PstLM sensitivity curve as recalled in the IEC/TR 61547-1. Frequency domain processing: weighted summing of spectral components. Phase information of the various frequency components is not taken into account, which is relevant for complex waveforms.

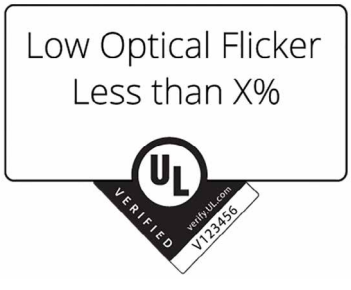

Figure 3:
The UL packaging mark

The possible limits of this metric may be:

- Duration of a few seconds of the waveform is not sufficient for detecting low-frequency flicker. Longer acquisition time is possible, but will require a measuring instrument with appropriate data processing capacity
- Flicker due to single-event modulations is not detected. This has to be thoroughly studied to determine if should be considered a random event or if it might be perceived.

UL Marketing Claim Verification Verified Program

In response to numerous inquiries and requests, UL recently introduced a marketing claim verification program that enables manufacturers to test their products for a neutral, third party assessment of flicker performance. UL Verification addresses low optical flicker in lighting products having well dfined limits.

Limits for the UL Verification:

- 10% for products powered by mains voltage with a sinusoidal 60 Hz frequency
- 8% for products powered by mains voltage with a sinusoidal 50 Hz frequency

Products that successfully have their flicker claims verified may include a packaging mark of “Low Optical Flicker Less than X%” where “X” indicates the percentage detected as a result of the tests.

Though many gray areas still exist regarding TLAs, market understanding continues to grow and evolve. A worldwide metric with standardized test methods would allow the global lighting market to better rate and understand product differences, but more work is needed before a metric can be implemented. In the meantime, UL continues to work with the global lighting community in an effort to increase understanding, improve testing, and help ensure the safety of those using artificial light. ■

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[1] Adapted from IES Handbook

Smart Lighting Market and Technology Trends

Intelligent lighting technology that enables its users to control lighting through connected devices such as smart phones or remote controls is a big topic in the industry. A new report sheds light on different aspects of this business including drivers, restraints and opportunities. Jasmine Hinduja, Research Analyst at The Insight Partners, summarizes the major findings and how the trend to intelligent systems affects the companies regarding technology skills and strategies.

The current ecological imbalance in the ecosystem has transformed the way business was done traditionally. Today, a large number of companies are adopting a "Green" strategy to support sustainable development across the globe. Furthermore, private and public sectors are joining forces to encourage various smart initiatives worldwide. The market for smart technologies is growing rapidly, and lighting is one of the major prospects in this market. The global smart lighting market had accounted for $ 9.10 Bn in the year 2014, and is expected to cross the milestone of $ 51.50 Bn by the year 2025, growing at the CAGR of 17.1%.

Background of the Trend

The smart lighting market is highly influenced by the escalating concerns for the well being of the environment. Across the globe, energy conservation is considered one of the most important concerns, and efficient or smart lighting significantly contribute to conserving energy. Europe is the leading region for lighting system technology and human centric lighting.

Presently Europe has various lighting associations rigorously working towards the deployment of smart lighting controls in the public and private arenas. Lighting Europe is one of the largest lighting associations in Europe, and has produced 400 scientific papers and conducted 19 events in smart lighting, in the year 2015.

North America is considered to be one of the best potential markets in the lighting industry for smart lighting solutions. The operating cost of lighting in commercial buildings is estimated to be significantly high in North America, and smart lighting provides an efficient and cost effective solution. Moreover, energy policies and regulations to limit the consumption of energy are appropriately implemented in North America, supporting the development and adoption of smart lighting solutions in the region. Smart lighting solutions are also experiencing significant adoption in developing countries. Asia Pacific is the fastest growing economy in the smart lighting industry, followed by South America, the Middle East and Africa.

The lighting industry has been undergoing a radical transformation fueled by rapid improvisation in semiconductor technology and the development of LED lighting as well as the demand for energy-efficient and sustainable solutions. LED is known to be the most feasible alternative to its counterparts because of its longer life span and ability to consume comparatively less energy. Also, LED lights are anticipated to remain in trend for a long time and there is nearly zero probability of a phase out or ban on this lighting technology since the amount of hazardous chemicals in it are negligible. Additionally, it is easily recyclable and can be embedded/integrated with controlling devices. It has been observed that the interest of the population across the globe in controlling lighting within their facilities (including homes, offices, and other institutions) using their phones and smart devices is continuously growing. This is strengthening the foundation for further development of connected and intelligent lighting technologies.

The growing interest of users in controlling their lights has engendered several communication

and lighting controls/technology firms to swap to the budding, smart lighting market. Although LEDs are the most prominent choice for smart lighting systems other traditional light bulbs such as High Intensity Discharge lamps, fluorescent lamps and CFLs can also be utilized in smart lighting.

Systems, Levels of Integration and Intelligence

The smart lighting systems can either be sensor integrated or non-sensor integrated. Sensor integrated lights are capable of adjusting the luminosity of lights by automatically detecting people and daylight with the help of sensors embedded in this system. Whereas non-sensor integrated lighting systems are still considered as smart as they are programmable. Due to significant development and innovation in wireless technologies such as Bluetooth, Wi-Fi, Li-Fi, etc., majority of upcoming smart lighting systems are expected to be wireless, hence the market for wireless smart systems lighting market is anticipated to grow at the compound annual growth rate of 23%.

The market for wireless smart lighting systems is mostly driven by increasing availability of open source software, advancements in developers' platforms, decreasing costs of components, maturing standards, pervasive mesh networking, multi-protocol gateway and chips, IP addressability and myriad WSN (wireless networking sensors) chip vendors. The development cycle of IoT based wireless products has enhanced from years to months. Also, the evergreen market of smart devices, such as smart phones, smart watches, tablets etc. is also encouraging the demand for wireless sensor based lighting systems. Furthermore, the wireless smart lighting market is expected to expand its presence in residential buildings, owing to the growing demand of wireless smart lighting systems for home automation and building automation.

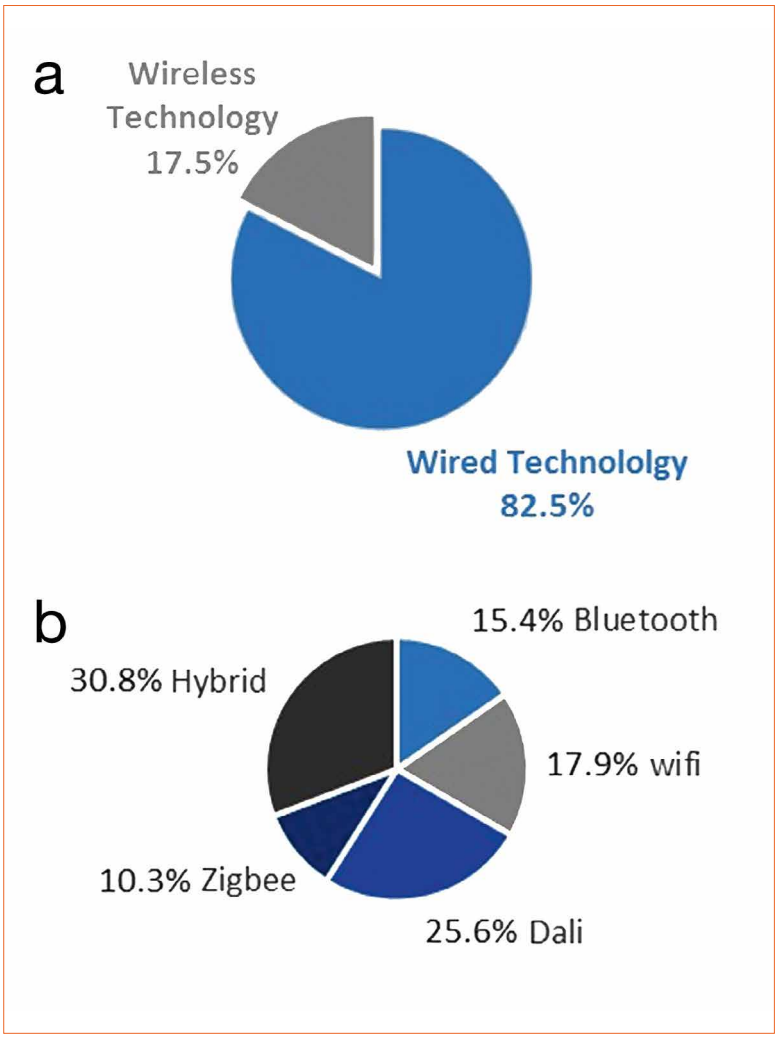

Figure 1:
Global wireless smart lighting market share breakdown 2015 [1]: Wired (a) vs. wireless (b) technologies

Wired smart lighting technology currently has the major share and will continue to dominate the market in the future. Along with the forthcoming advancements in the wireless smart lighting technology, it is predicted to eclipse the wired smart lighting technology market share during the forecast period.

The WSN (Wireless Sensor based Network) are yet to gain popularity in the commercial as well as corporate infrastructures, as their installation in these facades require huge initial capitalization, although the market for these WSN in smart lighting is predicted to increase owing to advancements in sensor technologies eliminating the complications and glitches in current technology. The WSN market is expected to have an approximate market share of 4 billion by the year 2025. Growth is expected to pump in the initial years owing to tremendous development in smart homes and building automation, and reach its saturation point later, for the most part, in developed regions across the globe. Whereas, in regions like Middle East and Africa the shipments will increase.

The wireless smart lighting market has numerous protocols and lighting networks being deployed by various OEMs as there aren't any regulatory specifications over this technology.

Presently, majority of communication in smart lighting systems are DALI based. DALI (Digitally addressable lighting Interface) products establishes communication between smart lights and controlling devices such as smart phones, smart watches, tablets, etc. Also DALI supports various smart bulbs and lighting brands that include Osram GmbH, Eaton Corporation, GE Lighting, LG electronics and many more, which makes it more flexible and

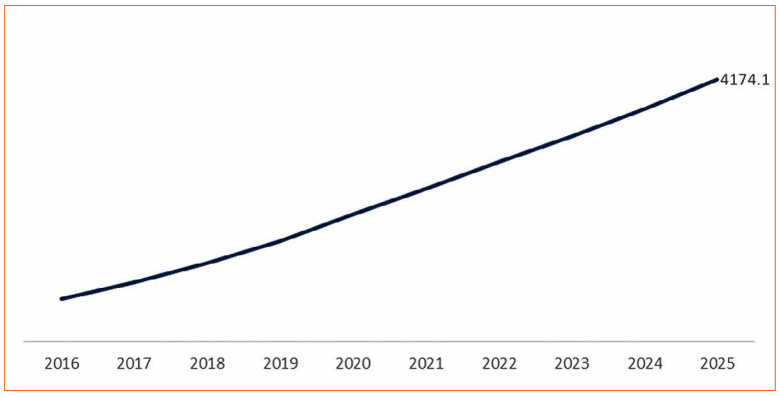

Figure 2:
Global WSN chipset shipment revenue and forecasts to 2025 (US$ Mn) [1]

user friendly. ZigBee is another such platform that enables its users to control LED Fixtures, bulbs, remotes and switches. Philips Hue is the most popular smart lighting product supported by ZigBee.

How It All Began

Phillips became a pioneer brand in smart lighting industry by introducing its first LED smart lighting starter, Philips Hue. Later on several other companies also launched smart version of their lighting systems, in order to maintain their market positions. Company's core strength comprises of its extensive focus upon R&D, supported by strong global brand image that aids the strong foothold of the organization globally. Philips face a tough competition from its other industry mates that are Osram, Acuity Brands, GE lightings and several startup companies venturing into this market.

Smart Lighting in the Different Applications

The smart lighting market is also broadly categorized on the basis of its placements, i.e., indoor and outdoor lighting. The outdoor lighting segment comprises of bikeways, parks, streets and parking lots. In recent years the segment has experienced major transformations resulting in rapid market growth. Here, LEDs are anticipated to capture approximately 85% of the streetlight market during the forecast period, whereas the smart streetlight market is estimated to reach 37% of the entire streetlight market. This development in outdoor lighting is anticipated to generate ample savings in maintenance costs and energy, gaining notable attention from both public and private sectors. The integration of occupancy sensors to the street lights has become a revolutionary innovation as it allows the street lights to operate in low intensity, saving up to 40% energy. The rate of energy conservation is predicted to increase further, considering the rising number of retrofitting initiatives taken by government and private organizations worldwide.

At the same time the indoor smart lighting market is expected to grow at a CAGR of 25% by the year 2025 driven by the demand to reduce energy consumption of the mounting population, meet the federal and state level regulations related to the environmental impact, and mitigate operational and maintenance costs. With the growing trend in Internet of Things and connected homes the residential indoor smart lighting is expected to gain a lot of popularity. In several developed countries this technology is in high demand coupled with other smart technologies like security cameras and similar home automation solutions. Companies like Zumtobel, Philips, Acuity Brands, and Daintree are some of the active players in the residential smart lighting market.

About the Obstacles

At the initial stage the smart lighting market was facing a lack of standardization, which was the major challenge hindering the growth of the future market. But now there are companies working towards building a common platform to control the smart lighting systems belonging to different brands and categories. IFTTT is an initiative taken to standardize the IoT platform. Currently, it has a limited number of supporting brands, but its ability to create a common hub for controlling all the smart devices with the help of a mobile phone is expected to flourish creating further opportunity for newcomers in the smart lighting market.

Outlook and Future Requirements

The lighting industry is currently going through a major transformation. As lighting is becoming smart it's no more just a matter of sockets, switches and bulbs. These smart lighting solutions are now sensor integrated and perform various other activities such as human activity monitoring, balancing the demand and supply fluctuations in power and much more. Currently, the technologically advanced algorithms drive smart lighting. Moreover, the rising trend of smart cities in cooperation with data analytics is anticipated to revolutionize the way the lighting industry operated a few years back. Now the lighting manufacturers are partnering/collaborating with IT organizations to fill the gaps about how the consumers perceive the latest lighting technology and make it user-friendlier, which is exhibiting a gradual shift of the lighting industry from hardware components to software and services. The upcoming smart lighting systems are predicted to be equipped with highly robust sensors for both outdoor as well as indoor lighting. The smart street lights would not only behave energy efficiently but also act as a crime detector enabled with gun-shot detectors and camera, air quality analyzer and perform data collection, analysis and offer this information to all the key executives, monitoring the city. Additionally, smart lighting will be making a huge impact on the work environment in

companies. This lighting would optimize the usage of lighting in various corners of the office, such as boardrooms and cabins and also provide the employees with information such as density of people in a particular area of the work place and an ideal or vacant space in the office. In coming years, software developers and IT companies will also become an important part of this industry, generating several new opportunities for the smart lighting market such as the smart lighting technology that is anticipated to have a wide scope of demand in various industrial areas such as healthcare, agriculture, horticulture, media & entertainment and automobiles. There are several companies that have already initiated investment in the R&D in order to understand and develop a better utility for these smart lighting systems, resulting in a high growth perspective in the future. ■

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Prototype of Escatec's latest LED module development for a client is based on their proprietary technology that allows the miniaturization of extremely powerful modules with excellent thermal and optical characteristics

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TECH-TALKS BREGENZ

Dr. Rubén D. Costa - LpS 2016 Scientific Award Winner

Dr. Rubén D. Costa attracted a lot of attention at LpS 2016 when he won the Scientific Award for his research about "Bio-Hybrid White Light-Emitting Diodes". In the interview he gives some interesting background information about why he started the product, how the approach works and what he expects in the future. He also talks about how he sees LEDs and lighting in general. ■

APPLICATION TECHNOLOGY

Technological Aspects Regarding the Equipment of Show Caves with Modern LED Systems

Caves have an almost magical attraction over people, drawing them again and again into their depths. The first electrification started in the 19th century, culminating in today's digitalization and "LEDification". The article describes the tough requirements on luminaires and the whole installation. The authors explain the advantages for the operators and the ecosystem. Finally, solutions, practical examples and future prospects will be discussed. ■

RESEARCH

"Best Papers" at LpS 2016: Life-time Calculation of White HP-LEDs from 16,000 Hours Aging Data

Based on the LM 80 testing standard method the lumen maintenance of LED packages is measured during their lifetime. The results show that differences in the luminous flux and optical power occur during the aging test. But also the spectral emission of LED packages changes over time. This effect leads to a visible color shift which should be taken as a new criterion for the lifetime. The author proposes a mathematical function that corresponds to the behavior of the color shift to predict a useful lifetime. ■

USABILITY TECHNOLOGY

Legacy to LED – Dimming in One Smooth Curve

According to latest research, the global light control switches market is expected to grow fast, driven by the convergence of the IoT and lighting, consumer demand for energy-saving solutions and government initiatives. This trend especially concerns dimmable products. With the advent of LED lighting, the relationship between legacy dimming technology and LED lamps has become an uneasy one. The article discusses these difficulties and how manufacturers are overcoming them. ■

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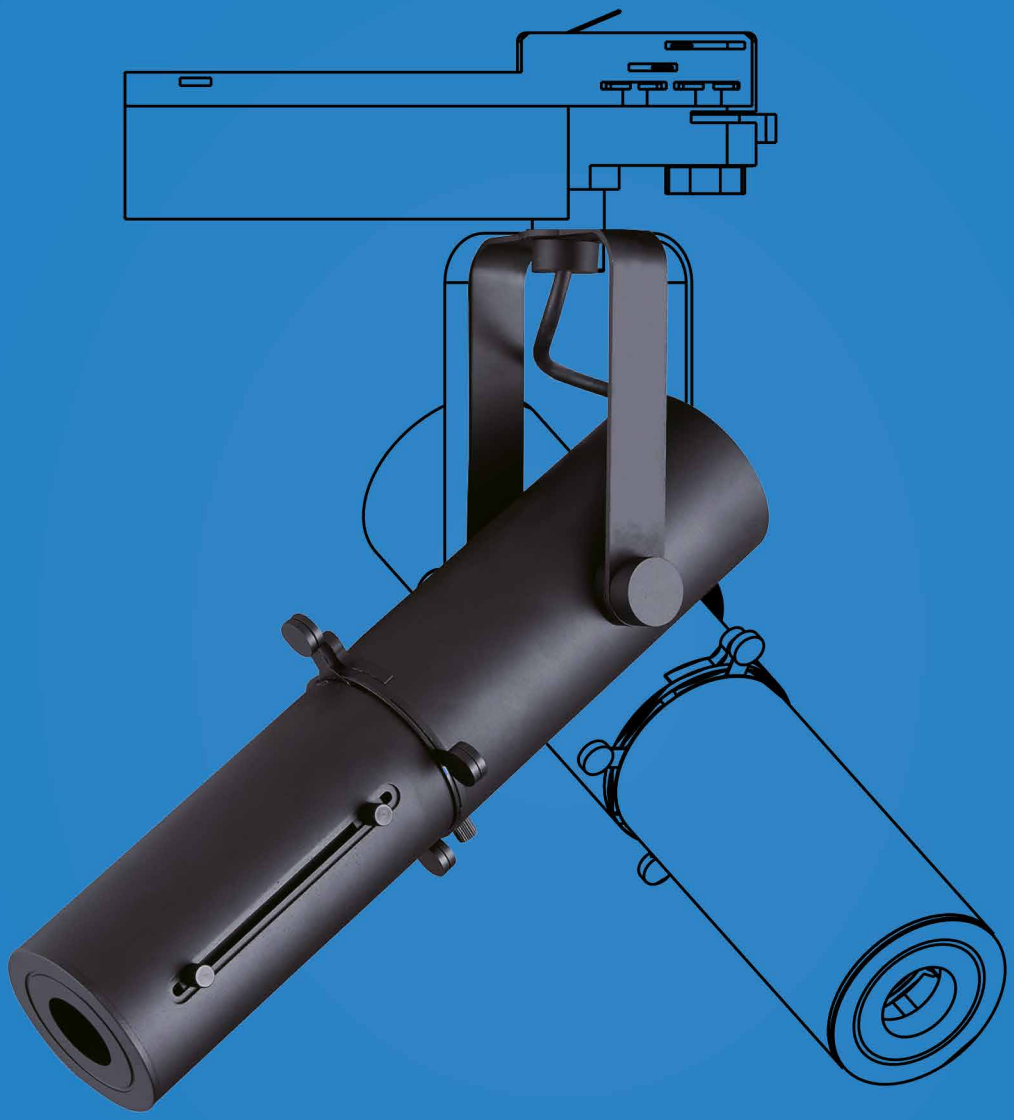

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