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ISSN 1993-890X

LED professional Review

LpR

Trends & Technologies for Future Lighting Solutions

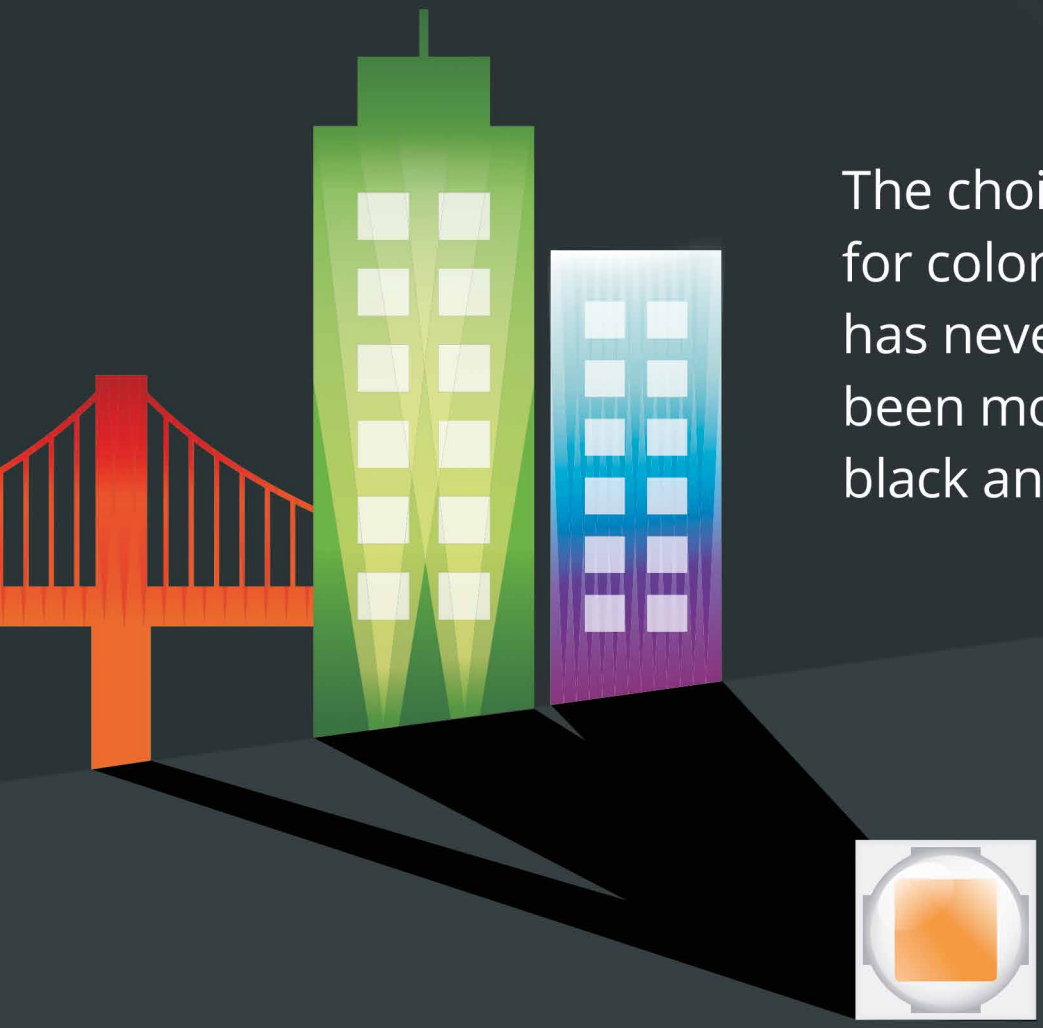
May/June 2017 | Issue 61

TTB: Dipl.-Jur. Philipp Henrici

Research: Variability in LED Production

Research: Thin-Film Optics & Wafer Level Packaging

Applications: Tunnel Lighting



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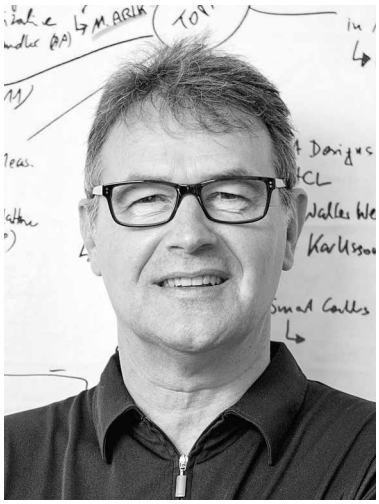

Mega-Trends

I recently had the pleasure of listening to a presentation about Mega-Trends and their influence on Architecture by Oona Horx-Strathern, a Futurist and Trend Consultant. It has to be said that these general Mega-Trends seem very far away from real life lighting system engineering. On the other hand, it might be interesting to share some information with you on this topic, but more in the sense of a big picture view.

Mega-Trends are changing and penetrating civilization, technologies, economy and value systems. They are valid for decades and influence our lives in multifold ways and areas.

The main Mega-Trends are: Globalization, Women, Individualization, Downaging, Health, New Work, Connectivity, Urbanization, Mobility and New Education.
Some aspects of these trends are:

- Globalization: Emerging Markets with more than two billion buyers and consumers are pushing for the world-market.
- Women: Reforms are required to solve the problem of “Gender Conflicts” in the direction of an emancipated society.
- Individualization: We are living in an increasingly differentiated world where people have to make decisions about their lives in more fractural parts.
- Downaging: People are getting older but are behaving younger.
- Health: The health sector is growing to the major part of the upcoming economy with markets like fitness, mindness and selfness.
- New Work: In the future we will see more mobility in our work life and work with a so-called cooperative individualism.
- Connectivity: New technologies create new networks and collective intelligence will replace older structures in organizations.

These Mega-Trends are influencing the way we build our houses and the architecture for offices and our homes. In this way lighting will also be affected by these trends and the market drivers we see today can be likened to those trends. Human Centric Lighting will be affected by Health, Downaging, and Individualization and Smart Lighting by Connectivity, Individualization and New Work.

Connectivity is an especially important game player. By 2020, there will be over 5 billion Internet users with over half of them accessing the Internet with handheld devices - and 80 billion connected devices worldwide.

If we look at the Strategic Roadmap 2025 by LightingEurope, we see the phases; LEDification, Intelligent Lighting Systems and Human Centric Lighting are defined over the next 10 years. It is also important to mention that the aspect of circular economy is a business driver and that we develop lighting systems from Energy Efficient Light over Light for Sustainability to Light for Well-Being.

The different views from Mega-Trends to Lighting Roadmaps are coherent and it gives a better understanding of why we are working and developing in those directions. In the end, it comes from big changes in our society. Our services, products and solutions are just a small piece of the puzzle. We are confident that lighting will greatly influence the society that is derived from these Mega-Trends.

Have a good read.
Yours Sincerely,

Siegfried Luger
Publisher, LED professional
Event Director, LpS & TiL

NEW CREE® XLAMP® LEDs CAN:

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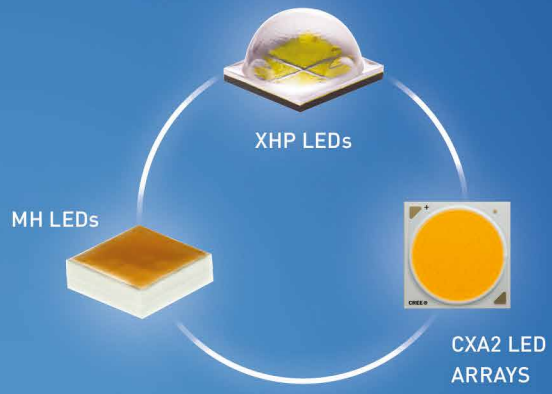

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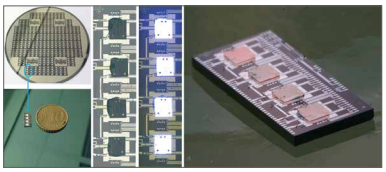

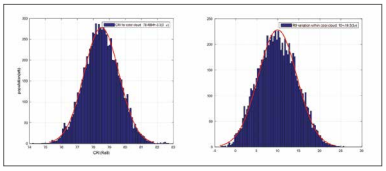

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Sven Horsmann
Dr. Sven Horsmann studied media science with a major in Journalism in Germany, the USA, France and Italy. After his studies he worked for various newspapers, public and private TV and radio stations as well as a few foundations. His main focus from 2005 onwards was architecture. In 2012 he founded the luxlumina publishing house in Switzerland and published a magazine with the same name that focuses on architecture and light.

A LIGHTING DESIGNERS RELATIVITY OF LIGHT PERFORMANCE

The LED will always be the superstar of light sources. Their precise and clear lighting possibilities have been targeted by lighting planners and architects for the past ten years. The coming years will see the performance of the LED getting progressively closer to the spectrum of daylight and that will, in turn, generate biologically effective LEDs that are even higher in contrast and promise a new kind of feel-good light.

Is that true? Questions like: What is good light and which light compositions were adjusted in a room/office/factory/parking garage would have different answers depending on whether they were answered by the contractor or the customer. In addition, lighting planners have to orient themselves on norms and coefficients. On the other hand, it is rumored that if you uphold the norms, you won't be able to have a good lighting design. Norms cripple any good light plan, pull them apart and make lighting concepts a farce. It's no wonder that lighting designers are grossly underrepresented in most conservative norm finding groups throughout the world. What are left are the coefficients, CRI, Kelvin, lx, lm and LVK. These have become the standard acquirement with which lighting architects differentiate when reading offers or typeset a light themselves. But coefficients are in second place when it comes to feel-good light.

Light should be evaluated on location, e.g. by using samples on site. This can convince the customer and would also be an important step in regards to implementation. The meta levels for choosing good light, like architecture, psychology and application, could be explained and shown on location. Those that don't know the difference between the work of a light designer and a light planner are quick to judge and will conceive the group as producers of light and dark – which is utterly ridiculous. Lighting designers concern themselves with artificial light in a building and works with the position of the sun. They assess the function, creation and sense and create a complex lighting concept with diverse lighting styles. It isn't the product that makes light, but rather an independent lighting concept that makes the benchmark.

The reason for such a relatively complicated lighting measure is simple. The LED light sources that are offered are still very different. Why? Say hello to the Plankian distribution curve. Every manufacturer has a different approach. No wonder that every one of them present their white as the most pure and efficient white. But we aren't talking about laundry detergent here – we're talking about feel-good light. A 2700 Kelvin color temperature with 82 CRI, warm white, dimmable LED must be turned on differently than a 2700 Kelvin with 97 CRI that has something similar to daylight dissemination spectrum. That is the difference that even Lisel Mueller sees. Feel-good light depends on a lot of things. Finding the right LED light source as well as the fitting light concept is the A&O in the Light Designer scene right now. I hope that in five years I don't have to tell my children what terrible LEDs we started out with that everyone thought were perfect, and today they are in the index. ■

S.H.

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Luminus Gen 2 XH LED Delivers More Punch

Luminus Devices, Inc., a global manufacturer of high-performance LEDs and solid-state light sources, announced its superior alternative to metal halide, the Gen 2 XH Series chip-on-board (COB) LED array. With substantial increases in light output and density, as well as color rendering, Luminus' Gen 2 XH Series directly addresses the requirements of lighting designers and retailers for punch and the ability to create dramatic scenes.

Color rendering, light output, efficiency, center beam candlepower, all improve on the performance of conventional metal halide

"The punch and light quality necessary to create dramatic visuals are now available from an LED package," said David Davito, Senior Director of Global Product Marketing, Illumination. "Our Gen 2 XH will finally enable retail users to eliminate metal halide across the board. Along with our 'below the black body' Sensus COBs, our customers can now create a full portfolio of retail lighting solutions."

Gen 2 XH Highlights:

- Center beam Candlepower greater than 35/70W metal halide
- 98 CRI at 2700, 3000, 3500, and 4000 CCT
- Light Emitting Surfaces of 6, 9, 11 and 14mm
- Instant on
- Instant restart
- 50,000 hour lifetime LM80 and TM21 at 85°C

With fully qualified LM80 and TM21, lumen maintenance is certified to at least 50,000 hours. Gen 2 XH is available in four standard light emitting surface (LES) diameters including 6, 9, 11, and 14 mm.

Luminus continues to evolve and refine LED technology so that designers and visual merchandisers can replace conventional lamps with more efficient light sources that are better targeted to their needs and more cost-effective over time.

Complete specifications for the Luminus Gen 2 XH are available here and the products can be purchased now through Luminus' global distribution network. ■

Cree - Industry's Brightest and Most Efficient Royal Blue LED

Cree, Inc. announces the new XLamp® XP-G3 Royal Blue LED, the industry's highest performing Royal Blue LED. The new XP-G3 LED doubles the maximum light output of similar size competing LEDs and delivers breakthrough wall-plug efficiency of up to 81 percent. This superior performing Royal Blue LED expands Cree's leading high power portfolio, enabling lighting manufacturers to deliver differentiated LED solutions for applications such as horticulture, architectural and entertainment lighting.

Cree's new XLamp XP-G3 Royal Blue LED is optimized for horticulture applications

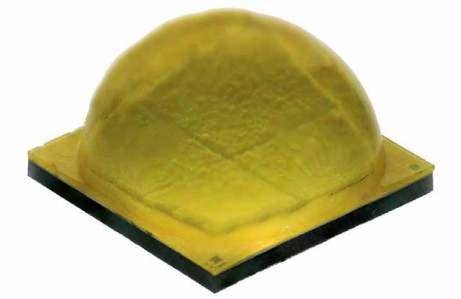
Using the new XP-G3 Royal Blue LED and the recently introduced XP-E High Efficiency Photo Red LED, Cree has created a new horticulture reference design that achieves a Photosynthetic Photon Flux (PPF) efficiency of up to 3.2 µmol/J at steady-state, which is over 50 percent more efficient than the traditional high pressure sodium solutions in use today. The XP-G3 Royal Blue LED delivers up to 3402 mW radiant flux, which corresponds to 13 µmol/s PPF, at its 2 A maximum current and 85°C junction temperature.

The XP-G3 Royal Blue LED is built on Cree's ceramic high-power technology, which can deliver excellent lifetimes even at the extreme temperature of 105 C. Additionally, horticulture lighting manufacturers can immediately take advantage of the existing ecosystem of drivers and optics proven to work with Cree's other 3.45 mm footprint XP products to shorten their time to market.

Product samples of the new XP-G3 Royal Blue LEDs are available now and production quantities are available with standard lead times. ■

Cree's Second Gen. XHP LED Delivers Unmatched Efficacy & Lumen Density

Cree, Inc. introduces the XLamp® XHP70.2 LED, the second generation of the highest output Extreme High Power LED, which delivers up to 9 percent more lumens and 18 percent higher lumens-per-watt (LPW) than the first generation XHP70 LED. The XHP70.2 LED provides up to 58 percent higher lumen density than the closest competitor LED of the same size, enabling smaller luminaires and better optical control for high-lumen lighting applications than ever before.



Cree's new second generation XLamp® XHP70.2 offers improved parameters for high-lumen lighting applications

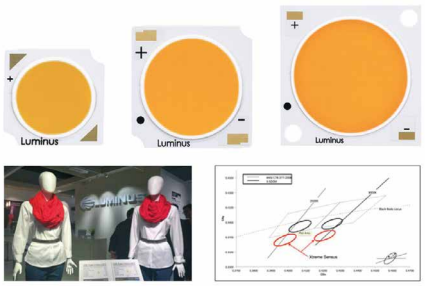
The XHP70.2 LED features the same 7.0x7.0 mm footprint as the previous generation and provides an easy drop-in upgrade for customers with existing XHP70 designs. In addition to light output and efficacy enhancements, the XHP70.2 LED improves optical uniformity through secondary optics, enabling lighting manufacturers to deliver better lighting performance. The XHP70.2 LED has LM-80 data available immediately, reducing the time required to receive ENERGY STAR® and DesignLights Consortium® qualifications.

"Unlike some companies, Cree continues to invest in improving light output, efficacy and reliability of our Extreme High Power LEDs to enable our customers to quickly improve their existing designs and create innovative new products," said Dave Emerson, Cree LEDs senior vice president and general manager. "Our XHP LEDs highlight the unique advantages of Cree's ceramic high power LED technology in reducing the cost and improving the performance of systems where extreme light output is required."

Featuring Cree's EasyWhite® technology, which provides the industry's best color consistency, the XLamp XHP70.2 LEDs are available in 2700-6500 K with high CRI options. Product samples are available now, and production quantities are available with standard lead times. ■

New Luminus COB LEDs with Higher CRI and Gamut Options

Luminus Devices, Inc., a global manufacturer of high-performance LEDs and solid-state light sources, announced volume availability of its new Xtreme Sensus chip-on-board (COB) LED array. Xtreme Sensus gives retailers and visual merchandisers new options for illuminating displays or creating atmospheres that make people feel engaged and excited. Building on the success of Sensus, Xtreme Sensus is even further below the blackbody locus and delivers an even brighter, 'pure white' light that studies have shown is preferred by observers. Luminus engineered Xtreme Sensus with an extended gamut area, greater than 130, which means colors will be saturated and provide a sense of energy while remaining aligned with people's mental expectations for visual correctness.



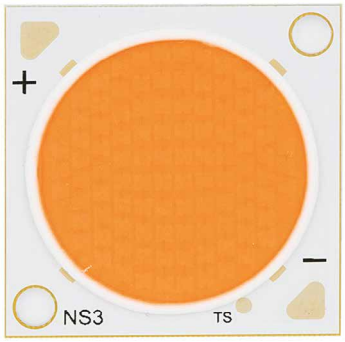
Luminus' Xtreme Sensus delivers bolder, brighter colors and contrast to meet retailer and visual merchandiser desires, with a color point for both 3000 K and 3500 K below the blackbody locus

"With Sensus, people simply see more colors, deeper colors, and greater contrast so that scenes and retail products are visually more dynamic and exciting," said Tom Jory, VP of Illumination Marketing. With Sensus and Xtreme Sensus, designers can more finely tune the experience they wish to create. Xtreme Sensus extends Luminus' Generation 3 platform that provides the industry's highest efficacy (170+ lm/W), output and selection of light emitting surface sizes from 6-32 mm.

Luminus continues to evolve and refine LED technology so that designers and visual merchandisers can replace conventional lamps with more efficient light sources that are better targeted to their needs and more cost-effective over time. ■

Seoul Semiconductor Introduces Acrich COB

Seoul Semiconductor presents the new Acrich COB family of products targeting the high-quality and high efficiency lighting market. "The Acrich COB family is an entirely new LED concept, adopting its proprietary Acrich MJT technology - multi-junction LED technology and direct AC technology on a COB platform," said Nam Ki-Bum, CTO of Seoul Semiconductor. "In addition to the MJT COB and AC COB line-ups, Furthermore, two enhanced COB products will be also launched this year."



Efficient, powerful and reliable; that's how SSC characterizes the new MJT COB and AC COB product lines

Overview:

- 17 new COB products adopting Seoul Semiconductor's Multi-Junction and Acrich technologies
- New COB products, yielding the best performance in the industry which can be applied to broadcast studio lighting in Japan
- A line-up of high-performance products was created using differentiated technologies which will lead the global COB market

The new products exhibited at the Lighting Fair are based on Acrich technology, which is Seoul Semiconductor's core LED technology for high efficiency direct AC driven LEDs. Acrich COB has two line-ups: MJT COB and AC COB. MJT COBs use integrated multi-junction technology chips and have the world's highest luminous efficacy of up to 168 lm/W. They come in standard form factors with a single power connection. AC COBs use direct AC driving technology, which combines four groups of LEDs in a unique, solderable design. This dramatically improves the simplicity in design and the lifetime of the product by eliminating the external AC-DC converter.

The line-up includes 11 different MJT COB products ranging from 6 W to 180 W and 6 Acrich COB products that operate off 120 V and 230 V AC. Seoul Semiconductor also provides various solutions such as optics and holders to help customers manufacture their lighting fixtures.

In addition, Seoul Semiconductor developed a high CRI COB for spot lighting for broadcasting studios. Seoul Semiconductor applied its MJT COB technology to this product, yielding the best performance in the industry.

MJT COB is a product combining multi-junction technology and chip-on-board technology, to which Seoul Semiconductor owns the corresponding patents. It uses the integrated multi-junction technology, and is characterized by the high light quality and reliability.

The high luminous efficacy of 168 lm/W, together with a CCT of 5000 K, a CRI of 80, a junction temperature of 85°C and 40 W of power, is about 6% higher than that of existing products This high performance is achieved by the MJT COB utilizing only 54 chips, compared to competing COB products requiring 144 chips. MJT COB is more reliable due to a significant reduction of wire bonds which is a leading cause of defects in COB products.

The AC COB product line is driven by an AC source. As it does not require a bulky and short-lived converter, the circuit cost can be reduced by about 25%, and it features good space utilization and a long lifetime.

Both product lines are suitable for a wide range of general lighting applications requiring high quality and high efficiency indoor and exterior lighting applications including shop lighting streetlights, industrial and commercial lighting.

Seoul Semiconductor, which has been developing the COB technology for the past 10 years, and now owns hundreds of COB-related patents. The company plans to continue to exercise its patent rights actively, when there are infringements of the patented rights to COB technologies. ■

Fulham Introduces New DirectAC LED Engines

Fulham, a leading supplier of lighting components and electronics for commercial and specialty applications, will be demonstrating its new DirectAC LED Engines at the Strategies in Light conference being held here this week. The new AC direct drive unit removes the need for a driver, resulting in a cost-efficient, reliable lighting solution that is ideal for wall sconces and ceiling luminaires.

Fulham's DirectAC LED Engines are designed with integrated circuitry to create a low-flicker, low-profile lighting component for surface mounted luminaires

Eliminating the need for a separate LED driver gives the DirectAC LED Engines an extremely low profile that simplifies installation. The units come in a full range of wattages, from 10 W to 34 W, making them ideal substitutes for fluorescent luminaires. They also feature extremely low flicker to achieve CEC Title 24 requirements, and offer smooth TRIAC/ELV dimming down to 10%.

"We are seeing increasing demand for versatile LED luminaires that can serve as fluorescent alternatives and retrofits," said Edwin Reyes, Product Director, LED Light Sources at Fulham. "Our new DirectAC LED Engines are designed as high-performance, low-energy units that are easy to install and offer a longer lifespan than fluorescents with a fraction of the power consumption. They are an ideal solid-state lighting alternative to fluorescent lighting."

In addition, the DirectAC LED Engines are available in a variety of color temperatures with a CRI up to 90. The units feature a high voltage barrier lens that meets the UL 5VA flame-rating, which allow them to be used with plastic diffusers in open or fully enclosed luminaires. In addition, they can be installed in both dry and damp locations.

The DirectAC units are available in three configurations: the engine only, the engine with lens, and the engine with lens and mounting plate. All units are UL and select models are ENERGY STAR® Luminaire 2.0 listed so they qualify for most rebate programs. ■

Greater Efficiency and New Light Color for Spotlight LED Modules

Tridonic has given its sixth generation SLE LED modules a chip upgrade and at the same time expanded its color palette. The ART, FOOD and FASHION colors, each optimized to a specific application, have now been joined by the TINGE light color which makes warm tones appear even more vibrant. All the versions benefit from greater efficiency in high-output mode and are now available with a 17 mm light emission surface.

Tridonic adds a new color to its improved 6th generation SLE LED modules with the SKE G6 TINGE

The dimmable LED modules for spotlights and downlights are impressive not only for their greater efficiency of up to 30 percent and better color rendering but also for their improved robust 50 mm package which is ZHAGA compliant. A more stable connection between the chip and the package is therefore achieved and the thermal conductivity is improved. New versions with

a 17 mm light-emitting surface (LES 17) close the gap between 15 mm (LES 15) and 19 mm (LES 19) modules so there is a choice of different emission angles for spotlights.

Variable, powerful and color stable:
Thanks to the greater energy efficiency of the modules a higher luminous flux can be achieved relative to the power consumption. Less power is needed to produce the same luminous flux as the predecessor modules. The LED modules are also compatible with all the drivers in the standard portfolio, resulting in numerous possible combinations tailored precisely to the specific applications.

The chip upgrade has also led to improvements in the color rendering of the modules and therefore their quality of the light without sacrificing energy efficiency. In particular, the Ri09 color rendering factor has been improved. The FASHION LED module now has a color rendering index of 95, and ART an even higher one at 98. Even saturated red tones can now be presented true to life. All the modules combine high quality of light with high color consistency corresponding to MacAdam 3, or MacAdam 2 in the case of the special ART color.

Application-specific colors at a glance:
LED modules in the FOOD series with their different spectrums (Gold, Gold+, Meat, Fresh Meat, and Fish) are tailored to different categories of food. Colors appear intense. Rich brown tones give bakery items a crustier look, warm shades of red give meat and sausages a fresh, succulent appearance and cold light tones emphasize the freshness of fish and seafood.

ART LED modules offer unprecedented quality of light and provide perfect lighting for even the most demanding exhibits in museums, art galleries and exhibitions. The full-spectrum technology used here provides the basis for excellent color rendering with an average value of all tones achieving a color rendering index of 98.

FASHION LED modules bring the colors on fashion garments to life. Every fashion show is a highlight. Everything from radiant white tones and brilliant colors with high color saturation to subtle pastel shades are presented true to life. The LED modules with a color rendering index CRI of 95 will not bleach the colors out of exhibits even after lengthy exposure.

The trendy TINGE color has been added to the FASHION palette. It lies just below the Planckian curve on the CIE chromaticity chart. Its slightly warmer color location makes fabrics and accessories appear more vibrant, especially multi-colored items. ■

Seoul Semiconductor Europe Introduces Reference Modules for its Wicop LEDs

Seoul Semiconductor Europe, a subsidiary of Seoul Semiconductor Co., Ltd., a world leader in LED-technology, announced the availability of reference modules based on its package-free Wicop LEDs. Marc Juarez,

Head of Technical Team at Seoul Semiconductor Europe, says about the new reference modules: “With these new modules, our customers can implement even faster our robust and efficient Wicop LEDs, which provide a market leading color uniformity combined with a high luminous efficiency. In addition, Seoul Semiconductor realized a very efficient and smooth process of delivering customized solutions, providing customers with the speed and flexibility needed in this rapidly changing environment.”

Seoul Semiconductor’s Wicop reference modules follow the outlines given in Zhaga Book 15 and are tailored to common customer needs

“We found that offering module solutions, based on our highly innovative technologies, will allow our customers to evaluate the technology and its benefits easily, enabling them to realize their solutions faster than by just using LED components”, Mr. Andreas Weisl, CEO Seoul Semiconductor Europe and Vice President Sales, explains. “Resources at our customers are often limited, so they need powerful, reliable and easy to handle solutions to meet their requirements. As a solution provider, we help them to be ahead of competition and to achieve a fast time-to-market,” he said.

This first release includes reference modules for the Wicop Y19, Y22 and Y22P LEDs. The Y19 module consists of four clusters of 2 x 2 LEDs with a combined typical flux of 4,650 lumens, while the Y22 and Y22P modules achieve 1,268 lumens with four single LEDs each. They all feature a Color Rendering Index (CRI) of 70 and a Correlated Color Temperature (CCT) of 4,000 K.

All modules announced are tailored to common customer needs and follow the outlines given in book 15 of the Zhaga specification, which defines the location and pitch of the LEDs and the position and size of the alignment holes for optical lenses. The boards feature standard power connectors and are easy to assemble and easy to use together with commercially available lenses, like the new Wilma lens-array from LEDiL.

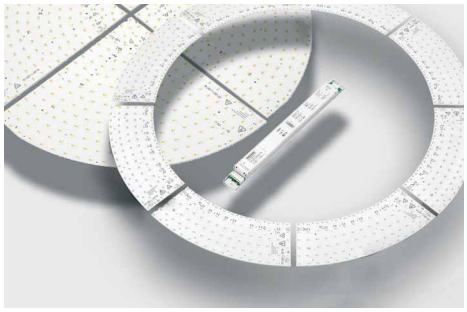
Wicop LEDs with their luminous efficiency of up to 210 lm/W at 350 mA are well suited as a light-source for applications such as wall washers or floodlights in the architectural space and lighting in warehouses or production sites in the industrial area. Outdoors they can be used, for example, for street lighting, in tunnels or for the illumination of stadiums, harbors, airports or railway stations, as well as for security applications.

Their compact footprint makes these LEDs several times smaller and much brighter than conventional LEDs, enabling cost savings at the system level. This is achieved through its state of the art chip design with the phosphor film directly attached to the chip surface, making the previously needed packaging with frames and gold wires obsolete. This way, Wicop LEDs are also suitable for applications, where a small form factor is needed.

The three reference modules introduced today are available from Seoul Semiconductor Europe. Production quantities can be provided on request. If necessary, they can also be customized by Seoul Semiconductor’s regional labs for special requirements. ■

Tridonic Introduces Tunable White Modules

With the new CLE Tunable White modules, Tridonic is adding components for round wall and ceiling luminaires to its tunable white portfolio. The color temperature can be set dynamically between 3000 K and 6000 K, with the luminous flux remaining constant.



Tridonic extends its range of tunable white portfolio with the CLE PREMIUM module series

Tridonic offers modules with an adjustable color temperature between 3000 K and 6000 K with the CLE Tunable White system. The CLE Premium modules are tailored to round wall and ceiling luminaires and are only available as pre-calibrated sets. In addition to four or eight LED modules, which lead to module diameters of 261 mm, 401 mm or 541 mm, the sets contain low-profile LED Drivers. The drivers provide various connection options via their digital interface: DALI Device Type 8, DSI, switchDIM and colourTEMPERATURE. This ensures a constant high quality of light with a CRI > 80 and small color tolerances corresponding to MacAdam 3 across the entire dimming range from 10 to 100 percent. The CCT remains constant during dimming.

Depending on the LED module used, the luminous flux is 4 x 1150 lm, 4 x 2450 lm or 8 x 900 lm. System efficiency is up to 166 lm/W depending on the module size. The CLE Tunable White system requires no additional cooling and has a life of 50,000 hours. The manufacturer offers a 5-year system guarantee.

Light that addresses the needs of people and mimics light over the course of a day with its white tones has a stimulating effect on people’s well-being and can help increase concentration and productivity. This is of great benefit not only in offices and educational establishments but also in retail and health care facilities. Current studies suggest that the right light can have a positive effect on disruptions in biorhythms and depressive moods. ■

LEDiL Introduces New LED Optics for Indoor and Outdoor

LEDiL OY, the market leading innovative company designing and manufacturing secondary optics for LEDs and COBs, announced the release of several new optics for indoor and outdoor applications. The new products cover applications from retail lighting to industrial lighting, area lighting, arena lighting and street lighting. The new offerings concern reflectors as well as single lens and lens array optics.

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LEDiL's Barbara-G2 70 mm reflector family is just one highlight out of six new products

In more detail, the new releases include both lenses and reflectors for COB LEDs. Molly represents a totally new product family while Barbara-G2 is a new revision. For the more traditional packet type LEDs we have new Strada and Stradella products available. Previous Stradella modules gave you 8 individual lenses packed in our standardized 50x50mm platform. Now we are pleased to introduce the same size module with 16 lenses. For the IP-2X6 series we have two new 90-degree rotated beam versions, and for more demanding - high temperature, high lumen - applications we have both 50x50 mm and 90x90 mm Strada modules made from silicone.

Barbara-G2 - 70 mm reflector family for midsized COBs:
LEDiL's new Barbara-G2 is compatible with HEKLA sockets and connectors with bayonet fastening mechanism for quick installations and replacements. Optimized performance for the latest midsized COBs and compatibility with LEDiL's RZ-sub lens allows it to be used in applications from retail to stage lighting with full RGB and tunable white color mixing.

Molly - indoor lighting optics for up to 19 mm COBs:
Molly is LEDiL's new cutting-edge optical lens design that benefits from bigger size COBs. The rugged PMMA construction locks straight into sockets and connectors with no need for extra holders. Uniform illuminance with flat top peak, no spill light and perfect design for cylinder type track lights makes Molly an excellent choice for professional indoor lighting.

Stradella - cost efficient street and highbay lighting:
The Stradella product family consists of dense lens arrays and tiny single lenses with high luminous performance. Beams are especially designed for street and highbay lighting and modules are also available with a 50x50 mm footprint similar to their big sister STRADA-2X2 optics. Optimized for mid-power and compatible with high-power and CSP LEDs.

Strada-2X2MXS - 90x90 mm platform now in silicone for up to IP67 and high temperature applications:
The Strada-2X2MX platform has now been made available in a more durable silicone. This brings natural resistance to high temperatures, UV radiation and impacts. Combined with LEDiL's efficient industry leading optical design and standardized modular footprint you can have a multipurposed luminaire design that not only fulfills all lighting requirements but is built to last - even in the most extreme environments.

Strada-2X2S-T3 - LEDiL standard 50x50 mm platform now in silicone for high temperature applications with universal IESNA Type III beam:
The Strada-2X2S is made from silicone to withstand extremely high temperatures and applications requiring high lumen outputs. The standardized 50x50 mm modular footprint and one screw fastening provides the flexibility to use the same luminaire design with silicone lenses as well.

Strada-IP-2X6 - Standardized 2X6 modules with integrated silicone gasket:
Strada-IP-2X6 are IP66 and IP67 tested lens modules with wide range of highly efficient street lighting beams. The integrated silicone gasket ensures ingress protection against water and dust allowing them to be used without protective covers. The lens modules are mounted with 8 screws and have enough reserved space to fit in needed luminaire components. ■

ams Launches AS7225 Tunable-White Lighting Smart System Sensor

ams AG, a leading provider of high performance sensor solutions, today announced the AS7225 tunable-white lighting smart system sensor, further broadening the solution set for sensor-integrated tunable-white lighting solutions. With the addition of the AS7225, OEM lighting manufacturers can access ams' closed-loop CCT tuning and daylight compensation, while retaining the existing host microprocessor architecture in their smart lighting design. The result is higher precision, more flexible LED binning, and lower system costs for tunable white lighting systems.

Sensor-driven system-on-a-chip lighting family expands to speed OEM and market adoption of variable-CCT and daylight-responsive LED lighting

Key features of the AS7225 include:
- "Calibrated for life" Tri-stimulus XYZ color sensor for direct mapping into the CIE color space
- Comprehensive register-driven command set enabling complete sensor control plus management of precision tuning directives
- Integrated support for tunable white, daylighting or combined functionality Outdoor LED Market

The AS7225 is equipped with the product family's industry-first embedded tri-stimulus CIE XYZ color sensor to enable precise color sensing with direct mapping to the International Commission on Illumination (CIE) 1931 color space which is recognized as the standard coordinate definition for human color perception. CCT and daylighting tuning directives are communicated to the host microprocessor via an industry-standard I2C interface, allowing IoT smart lighting manufacturers to avoid costly calibration and tuning algorithm development and reduce time to deployment.

"As the lighting industry moves to tunable solutions, the inclusion of closed loop sensor-driven integration not only increases white or daylighting tuning precision, it also loosens the required precision for both LED binning and system components. This results in cost reductions for both the overall bill of materials, as well as in time and cost savings

in the materials management and manufacturing processes", commented Tom Griffiths, Senior Marketing Manager at ams.

The AS7225 is an extension of ams' Cognitive Lighting™ smart lighting manager family. The efficient AS7225 is available in a 4.5 x 4.7 mm LGA package, for flexible integration into luminaires, light-engines and larger replacement lamps, such as LED linear T-LED products. The device provides precise CCT tuning direction between configured warm and cool white LED strings within a luminaire. In addition to the CCT- tuning functions, the AS7225 can additionally be used looking outward in luminaire designs to provide precise daylight management, or can deliver combined CCT-tuning and daylighting directives by the addition of ams' TSL4531 ambient light sensor.

Recent trends in LED device pricing show that chips have moved away from being the primary cost element in a typical commercial luminaire. This means that in just a few years, tunable lighting will become the standard for new commercial lighting installations. Comfort, productivity and health benefits of good lighting is becoming cost effective. Tunable lighting will be a key element in delivering those benefits from LED smart lighting platforms. ■

Swatch Group - World's Smallest BT Chip with Useful Lighting Features

Three world records in the "Swiss Silicon Valley". Swatch Group is proud to introduce a new Bluetooth chip with exceptional features unrivaled by any existing product. The new integrated circuit is designed 100% by EM Microelectronic, Swatch Group R&D and the Swiss Center for Electronics and Microtechnology (CSEM).

Swatch Group's new, smallest, feature-rich BT chip sets three records and also offers unique, useful features for lighting applications

The IC has already set the following records:

- It is - first and foremost - the smallest Bluetooth chip on the market. The ultra-miniaturization of electronic components is crucial for the densification of functions in portable electronic devices and for the Internet of Things
- It has the lowest energy consumption - compared to its competitors - for different scenarios of use, thus increasing the autonomy of connected objects, an essential factor in this field
- Its high-speed start-up capability is unparalleled, which makes it possible to improve the reactivity and the lifetime of, for example, electronic beacons

This technological marvel has already been officially qualified to meet the latest Bluetooth standard, version 5.0. Its prowess is masterful because the chip consists of more than 5 million transistors on a surface of about 5 mm^2. Designed for maximum flexibility, it can work alone or in conjunction with various sensors; system integrators can take advantage of a microcontroller with very low power consumption or can use the chip to add a Bluetooth communication function to any portable electronic device. ■

OEM Systems Group Expands the Intelligent Zitares Electronic Control Gear Range

OEM Systems Group is expanding the Zitares intelligent product family from the BAG brand with a further SELV control gear unit. The new single-channel LED ECG ICD1200-70FR-20 was specifically developed for higher power ranges up to 70 W.

OEM Systems Group's LED ECG ICD1200-70FR-20, the latest member of the Zitares Electronic Control Gear portfolio, was developed for a power range up to 70 W

The DALI-dimmable LED ECG is suitable for the constant current operation of LED modules and is ideal for assembly into linear luminaires due to its slim construction (360 x 30 x 21 mm). With a wide operation current range from 950 to 2000 mA and a maximum of 70 W this control gear unit can be used in highly diverse applications. SELV topology also enables simplified luminaire construction. A further advantage: the ICD 1200 functions with pure amplitude dimming for flicker-free light in the complete range of 1 to 100%, enabling camera-compliant illumination.

Diverse setting options and analysis of operating data is made possible in combination with the zitares360 software. With its intelligent functions the ICD1200 is capable of detecting various operating conditions and modifying output current to ensure that the reliability and performance of the system are optimized across the complete service life. ■

Lemonbeat Combines DALI, Ethernet and Its Own IoT Ecosystem

The Dortmund-based company Lemonbeat GmbH - the developer of the IoT infrastructure technology of the same name - is expanding its portfolio, adding interfaces for "DALI", the international standard for lighting controls in building automation, as well as cabled Ethernet technologies.

Lemonbeat's new LB to Dali/Ethernet adapter enables devices to be easily integrated into the Lemonbeat IoT ecosystem

With its software technology of the same name, Lemonbeat has developed a comprehensive construction kit for the Internet of Things that can bestow "intelligence" on even simple battery-powered devices. In this way, devices can interact with each other directly and independently off any central cloud-based or gateway control system via the "Lemonbeat smart Device Language" (LsDL). This makes IoT installations more reliable, and means that only data that are relevant for analysis or monitoring purposes are transmitted for

central processing. The patented, energy-saving “Lemonbeat Radio” wireless technology is typically used at sub-GHz frequencies to enable communication between devices. This technology makes large bandwidths possible, and is suitable for local networks that are operating at their limits under conventional standards. Lemonbeat technology uses proven Internet standards such as XML or IPv6, which means that it can be implemented flexibly.

Initial applications can be found in areas such as smart homes, smart gardens, and even in the professional automation of commercial buildings thanks to Lemonbeat’s cooperation with Phoenix Contact.

In order to add “Lemonbeat Intelligence” to the international “Digitally Addressable Lighting Interface” (DALI) standard that is used in building automation to control lighting equipment, the company now provides an adapter that straightforwardly integrates these devices into the Lemonbeat IoT ecosystem. An additional interface allows devices to be integrated into Lemonbeat networks via cables using Ethernet technology.

The new adapter enables devices to be easily integrated into the Lemonbeat IoT ecosystem using DALI or Ethernet.
The adapter acts as a translator, with further communication subsequently taking place via Lemonbeat Radio over sub-GHz frequencies. The prototype in the photo features both of these interfaces; however, just one of the two technologies will be offered in a standardized industrial housing, depending on the specific application. ■

Fulham Launches Lumoseries 150 W LED Driver

Designed for 230 V higher output luminaires such as high bays used in Europe, the Middle East and Asia, the new 150 W LumoSeries LED driver like others in the LumoSeries range, features the lowest in-rush current in the industry, which means that more drivers and luminaires can be operated on a single circuit, thus reducing the cost of installation with fewer circuit panels and less wire to run.

The lightweight plastic-cased LED driver has compact dimensions of just 212x76x46 mm for easy fit within luminaires. Its high specification includes a wide range of current settings from 700 mA to 4 A; output voltage 24 to 60 V DC; and has 0-10 V dimming which can be set for dimming to off at 1 V. It also features thermal overload protection with internal or external NTC and there is a 12 V fan power output also controlled by an NTC temperature sensor.

Fulham, the lighting components and electronics specialists, has launched a new 150 W LumoSeries LED driver

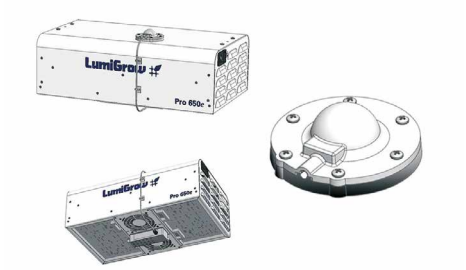
As with all LumoSeries drivers from Fulham, the 150 W LumoSeries LED driver comes with a five-year warranty so that the power supply matches the reliability of typical LED lifetimes of 50,000 hours.

Mark Needham, Fulham’s European Vice President for Sales commented, “This latest addition to our range of high specification drivers enables our customers to take all the benefits of a Fulham LumoSeries driver into their higher lumen package luminaires.
This higher power LED driver carries the long-life technology of all Fulham products, increasing the portfolio of high performance, highly reliable and worry free LED drivers to our customers.”

The engineering of Fulham LumoSeries LED drivers is second to none. All LumoSeries drivers are built on core engineering design principles for exceptional standards of performance and reliability in LED systems. Highest grade critical components together with design features for thermal management ensure excellent reliability. Low ripple designs create flicker-free lighting and perfectly smooth dimming. Simplicity of specification and installation is a key feature of all Fulham LumoSeries drivers which have wide voltage and current ranges as well as industry leading low in-rush current. As a result, the LumoSeries drivers have future-proof flexibility with their changeable voltage and current settings enabling seamless support of future LED generations and at the same time minimizing supply chain complexities. ■

LumiGrow - Sun Manages Lights with Grow Light Sensor

LumiGrow, a smart horticultural lighting company, announced today that they’ve begun a pilot program for the industry’s first dynamic horticultural grow light sensor. The grow light sensor works in tandem with LumiGrow LEDs to target the precise amount of light that a plant receives. By specifying precise light levels, greenhouse crops can experience perfect lighting conditions regardless of changes in weather or other light-limiting factors.



The LumiGrow Grow Light Sensor enables a precise automated management of light levels and spectrum inside a greenhouse. It can, for example, be used to target DLI levels over optimal photoperiod

Dr. Melanie Yelton, VP of Research at LumiGrow stated, “Our Plant Research Group has been working directly with major commercial growers and research institutions to discover new ways that light can be used to improve crop quality and production. It’s through these partnerships that we’ve come to understand how controlling light levels dynamically and specifying the length of time that crops receive illumination (known as photoperiod), can improve quality and biomass.”

The LumiGrow Grow Light Sensor works in conjunction with the LumiGrow SmartPARTM Wireless Control System, a cloud-based software that empowers growers to schedule changes in light intensity and spectrum by zone. The sensor measures how much of the sun’s light enters the greenhouse, then feeds this information into the SmartPARTM System to automatically adjust LumiGrow LEDs and manage precise light levels inside the greenhouse.

“Greenhouse lighting that adjusts with the sun’s intensity has potentially huge benefits towards increasing electrical efficiency and cost savings”, explains LumiGrow CEO,

Shami Patel. “The LumiGrow Grow Light Sensor is really the next logical step in smart horticultural lighting. The sensor makes our lighting even more dynamic and easier to use, because there’s really nothing easier than having the sun manage your lights.”

By having lights that ramp up or down due to outside conditions, LumiGrow is taking grow light technology further away from static full-power settings, a potentially wasteful and expensive strategy. Traditionally, High Pressure Sodium (HPS) lamps were an industry standard, but as with many older technologies there have been limitations. When creating a lighting strategy that optimizes growth while maximizing growers’ profits, HPS technology can’t adjust to changes in crop production requirements.

The LumiGrow Grow Light Sensor is a pilot product aimed at redefining how growers use and think about light. “LumiGrow was the first horticultural LED lighting company to introduce adjustable spectrum technology to the global market a decade ago.” explains Shami Patel. “As pioneers of smart greenhouse lighting we continue to explore the ways that light can be used to improve growth strategies from a comprehensive perspective. We really do see ourselves as more than a lighting company”.

Tridonic and EON Reality - Augmented Reality App to Control and Provision Lighting

Tridonic, a leading international supplier of integral lighting solutions and EON Reality Inc., the world leader in Virtual Reality based knowledge transfer for industry, education, and edutainment, have partnered to develop an Augmented Reality control and provisioning interface for Tridonic’s IoT enabled industrial lighting solution, net4more. The AR application will be announced and demoed at CeBIT as part of Tridonic’s keynote: “Lighting as the backbone for the Internet of Things”.

Augmented reality is used to simplify the provisioning process and ease control of lighting devices

By using Augmented Reality (AR), controlling and provisioning banks of LED lights becomes substantially easier. Lights can be identified and controlled visually through the Augmented Reality application which interfaces with the device over a sophisticated mesh network allowing users locally or from around the world to view device performance or control the light itself. net4more builds on IPv6 protocols allowing easy communication with third party services and devices, specifically in this case EON Reality’s AVR platform.

"Lighting will play a decisive role in the Internet of Things as it is everywhere, digital, and connected. It thus forms the ideal backbone for the IoT through which all the other devices can be connected. With our system net4more we will not only be able to connect luminaires, but offer value that goes beyond lighting" explains Mathias Burger, Director Product Management Controls, Tridonic. "Together with EON Reality, we are now exploring how lighting, IoT, and Augmented Reality can be combined to enable further services and make, for example, lighting control or maintenance easier for the user."

EON Reality's AVR platform interfaces with IoT data provided by the net4more solution in Augmented Reality, both for provisioning and control. The AVR Platform was purpose built to display real-time contextual data from the local environment as well as empower individuals with no programming experience to build an illuminated world with IoT data.

"We strongly believe that Augmented Reality will be the go to interface for the Internet of Things," said Mats Johansson, CEO of EON Reality. "AR allows humans to experience data visually and effectively bridges the man/machine divide. By moving data from computer screens to in the field of view, we are increasing efficiency and productivity for workers in a whole host of industries." ■

Casambi's Firmware Update Adds New Functionality to Smart Lighting Platforms

Casambi, a world's leading provider of smart wireless lighting control software technologies, has issued a new firmware update to its smart lighting platform to provide integrated support for users of EnOcean switches, Digital Addressable Lighting Interface (DALI) devices and movement sensors. A new control hierarchy has also been developed to make it easier for users to automate lighting operation across a wireless network and to allow manual overrides to be performed when required.

EnOcean switches can now be paired to a Casambi network and work seamlessly within its framework. With the support of NFC technology, system commissioning is rapid and settings are easy to configure. Within a Casambi lighting control solution, the EnOcean switches can control luminaires individually or in groups across a network and operate different programmable scenes and animation sequences.

Casambi's firmware update improves control of EnOcean, DALI and motion sensor devices

Casambi has integrated support for DALI devices within its smart lighting control platform to enable color temperature and color changes for device type 8 (DT8) fixtures and allow control of a linear DALI dimming curve for drivers that support device type 6 (DT6) extensions. When commissioning the DALI driver, the Casambi firmware now automatically assigns and reassigns DALI short addresses to DALI drivers. At each power-on, the platform verifies that all required addresses are available and short addressing is then only performed if needed.

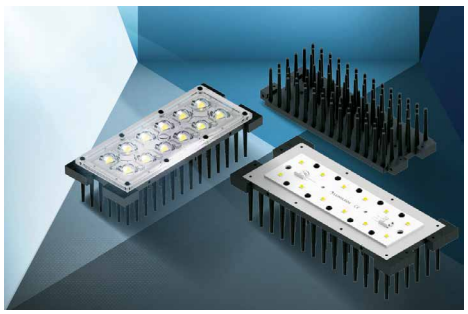
The Casambi lighting control system has further improved the use of motion sensors. Input sources can come from ordinary relay-based movement sensors turning a smart switch or mains-powered push button input of a Casambi-ready device, and from a movement sensor integrated with Casambi's CBM-001 module. It also provides an opportunity to track the data from individual sensors, and standalone sensor devices can now be quickly configured by simply navigating to the sensors menu tab within Casambi's software app for tablets and smartphones.

A new control hierarchy allows users more co-operative configuration across a network between automated lighting controls (presence sensors and timers) and manual lighting controls (the app, switches and push buttons). For example, the platform will enable a timer to switch lighting on or off within an office area at a designated time or when a person is detected by a motion sensor, but facility managers or staff can manually override this automation if lighting needs to change at other times or locations.

Casambi's latest system update also integrates improvements which offer greater functionality of the Xpress switch, enable Casambi units to be replaced without readdressing or commissioning, and extend the possibility for networks to have global fade times for starting up, toggling and dimming. A series of fine firmware adjustments also provides support for two mobile devices to simultaneously connect with each Casambi device without limiting control responsiveness. ■

MechaTronix Cooler Platform for the Outdoor LED Market

Just shortly after the launch of the 2x2MX, the next standardization in outdoor light engines is a fact. This time Lumileds, Ledil and MechaTronix joined forces to create a 2x6 emitter platform for outdoor use. The scope of this LED platform ranges from integration in street lights over high mast applications to industrial high bays. The heart is the Lumileds Luxeon XR-TX, sitting on the MechaTronix CoolBlock® 2x6 LX and covered by the Ledil Strada IP 2x6. The result is an ultra-compact waterproof LED engine, thermally validated, easy to assemble with off-the-shelf available components creating up to 4000 lumens.



MechaTronix's CoolBlock® LX 2x6 emitter platform makes use of LEDiL's Strada optics. Multiple elements can be combined using CoolConnect® Inter-01 as a connection bridge

MechaTronix has thrown in a few extra gimmicks this time. With a simple add-on, what they named the CoolConnect Inter, the LED engines can be stacked together to an endless power platform. The coolers are developed in this way so that after assembly there remains an air gap for optimized convection. Also, the water tightness of the cable feed-troughs has been taken into account, by development of a compact M6 gland which fits in the design. ■

GlacialTech Announces New 400W Igloo SS400 LED Flood Light Heatsink Kit

GlacialTech, the diversified LED technology provider, announces a new 400W heatsink for outdoor flood lights. The Igloo SS400 features an efficient heatsink with thermal resistance 0.1875 °C/W, preventing LEDs from overheating with large-surface area heatsinks. A waterproof glass cover is available for outdoor applications, with an IP65 rating for weather protection and adjustable stainless steel mounting rotation bracket and screws.

GlacialTech's Igloo SS400 is available in double unit configurations for up to 800 W of LED illumination

Features:

- Rated for 400 W CoB or MCPCB LEDs
- 0.1875°C/W thermal resistance.
- Adjustable stainless steel mounting bracket and screws.
- Available in single and double unit configurations up to 800W.
- IP65 rated, suitable for outdoor areas

Specifications:

Type: Igloo SS400
Part Number: CT-SS400000AK0001
Dimension: 400x270x110 mm
Weight: 5750 g
Material: AL1050
Color: Black
Surface Treatment: Black Anode
Crafts: Stamping + Bonding
Thermal resistance: 0.1875°C/W
Surface area: 3912600 mm^2
Reference design power: 350-400 W

Besides the default single unit kit, the Igloo SS400 also comes in double unit configurations for up to 800W of LED illumination, allowing easy installation of high output lighting for stadiums, parking lots, outdoor storage areas and industrial complexes.

High thermally efficient LED heatsink: GlacialTech's experience in thermal design allows the Igloo SS400 to create a heatsink boasting an excellent thermal resistance of 0.1875°C/W using stamping technology. The efficient thermal performance means high output CoB or MCPCB LEDs up to 400 W can be accommodated. Customers can easily use the Igloo SS400 to construct LED flood lights with high performance while using much less energy.

SKD package up to 800 W of LED lighting: The Igloo SS400 thermal module is available standalone, or as a semi-knockdown (SKD) kit that includes heatsink module, waterproof glass cover, and adjustable stainless steel mounting bracket and screws. The Igloo SS400 heatsink kit can be ordered in single and double unit options, each unit can be individually adjusted. SKD kit allows for up to 800 watts of energy efficient LED lighting for powerful outdoor application.

Rugged IP65 environmental protection: With an IP65 rugged design, LED flood lights built with the Igloo SS400 SKD kit are dustproof and waterproof against extreme weather and strong jets of water. Along with its adjustable stainless steel mounting bracket, users can create lighting for the harshest environments. Fixture designers can choose the appropriate LED lighting module and driver for their lighting needs and easily create high performance outdoor application with dependable GlacialTech thermal technology. ■

Fischer Offers New LED Heatsinks with Integrated Mounting Hole Pattern

Wrongly, the LED is often designated as a cold radiator and gives the impression that no further cooling is necessary. In reality only approx. 35 % of the used electrical energy is converted to light output according to the latest LED technology. The remaining amount of energy develops a heat loss in analogy to common semi-conductor elements which necessarily must be emitted to the ambient air by means of an effective thermal management. Specifically on that point, the company, Fischer Elektronik GmbH & Co. KG, extends a wide range of products on innovative LED heatsinks.

For improved versatility and convenient assembly, Fischer Elektronik's new heat sinks offer a mounting hole pattern for most recent LEDs

The round extruded heatsinks made of aluminum with part numbers SK 642 and SK 643 have an inner core of solid material for housing the LEDs. The outside diameter for both heatsinks is 100 mm. As a special feature, both heatsinks have integrated mounting holes made in the extrusion process which can be used for LED mounting and its bracket system with the help of self-tapping screws. Zhaga compliant LED modules with a mounting hole pattern of 35 mm can also be mounted as well as a majority of customary LED modules. As a standard, heatsinks in ten different lengths are offered whereas other lengths, additional mechanical treatments and surface coatings according to customer specific demands can also be realized. ■

New GL SPECTIS 1.0 Touch FLICKER Spectrometer

With new LED lighting applications, the problem of flicker in slow-motion video has resurfaced. There was a time when this was a very common phenomenon with fluorescent lighting, but as technical improvements were made to the ballasts, the problem was largely eliminated. Today the main source of such flicker is LED lighting with particular drivers supplying power to the lights. At sports facilities, having optimal illumination and minimal flicker in the lights are important factors to consider when installing LED lighting. The lighting at FC Chelsea's famous Stamford Bridge stadium (Fulham, London, England) was recently replaced with LED lighting that creates unique illumination effects and dazzling light displays.

GL SPECTIS 1.0 T Flicker measurements can help to assess light quality for a flicker-free slow-motion video in LED ambient lighting

Flicker-free lighting is extremely important for slow-motion replays that show home TV viewers exactly what happened, something which is now taken for granted in professional sports. At frame rates up to 480 fps for slow-motion sequences, modulation of the artificial light output can produce perceptible brightness variations. Normally, up to a certain frequency, our persistence of vision compensates for light modulation, which is why we generally do not notice fluctuations in light caused by the alternating current powering lights. During the planning and design phase, the use of professional light meters is essential to verify the proposed lighting system has minimal flicker.

GL Optic light measurement instruments were used during installation of the new LED playing field lighting at Stamford Bridge. Mike Simpsons, Director of Engineering & Design at Philips Lighting, stressed that "The GL Optic device allows us to rapidly and accurately assess the quality of LED-based lighting installations. The GL SPECTIS 1.0 touch is a very fast spectrometer and easy to use in the field".

The new mobile GL SPECTIS 1.0 T Flicker spectrometer from GL Optic is suitable for measuring flicker in the signal range 0.1 Hz to 12.5 kHz. The user can take measurements of light sources and LED floodlights. To fully characterize and compare light sources, the GL SPECTIS 1.0 T Flicker can process recognized flicker parameters such as flicker frequency, flicker index and flicker factor. The instrument can also be used to capture other photometric and colorimetric data such as illuminance, colorimetric locus and color rendering index, and displays the analysis results on the color touchscreen.

Due to the ever more demanding quality expectations and detrimental effects on video and film production, flicker has become a major issue at sports facilities. The GL SPECTIS 1.0 T Flicker from GL Optic can be used to detect, characterize and ultimately avoid flicker. ■

Instrument Systems Expands Series of Calibration Standards

Instrument Systems unveils a new calibration standard of the ACS-570 series. Together with the PSU 10 controller, the Munich-based manufacturer of light measurement technology offers its own all-in-one solution for the calibration of luminous flux and luminous intensity of measurement systems.

New calibration standard series ACS-570 for the calibration of luminous flux and intensity of LEDs with compact PSU 10 power and TEC control unit

The measurement systems supplied by Instrument Systems can be simply and reliably checked with the LED calibration standards of the ACS-570 series, and if necessary recalibrated in relation to the absolute photometric value. Luminous flux and averaged LED intensity are calibrated according to the CIE 127:2007 substitution method. The test labs of Instrument Systems, accredited to ISO 17025, guarantee a high degree of precision and direct traceability to the national reference standard of the German National Metrology Institute (PTB).

Thanks to its particularly fast operational readiness and long service life, the ACS-570 series is suitable for diverse laboratory uses and challenging demands in the production environment.

Optimized thermal management guarantees reproducibility and a permanently stable optical radiant flux of the LED calibration standard. The LED and temperature control system are housed in a casing with low thermal conductivity and thus insensitive to external temperature fluctuations.

Through the combination of the new calibration standard with the PSU 10 power and TEC control unit, Instrument Systems offers an all-in-one solution with fast temperature control and high stability of the operating current. Alternatively, the ACS-570 calibration standard can also be used with power sources and TEC controllers of other manufacturers. ■

TE Connectivity Introduces LUMAWISE Endurance S Module

Connectivity (TE), a world leader in connectivity and sensors, has introduced a new compact connectivity solution for street lighting with LED light sources. TE´s LUMAWISE Endurance S module consists of a standardized interface between the receptacle and module base or sealing cap, which uses an integrated single gasket that can accommodate and seal both luminaire and module using the same connection interface for either 40 mm or 80 mm diameter central management systems.

TE Connectivity's new LUMAWISE Endurance S Module has been developed to accommodate the requirements of smarter street lighting applications

Central management systems offer more control, better programming, and higher efficiencies for LED lighting systems. The LUMAWISE Endurance S module offers greater flexibility in luminaire design and street lighting architecture. The system is field upgradeable, making it possible to simply and quickly upgrade existing luminaires.

Stand-alone system or complementary to ANSI/NEMA solution:
Specifically for outdoor LED light sources and drivers, LUMAWISE Endurance S has been designed as a standalone system and can be used in a complementary function as an auxiliary sensor module when additional

functionality is required in ANSI/NEMA based fixtures. Installation is easy, due to its simple push-and-twist lock feature which does not require any tools and can be completed using one hand. The LUMAWISE Endurance S module can be mounted in any direction and offers improved sealing when compared to other systems. Modules can be exchanged and upgraded in only a few seconds without having to electrically isolate the lighting pole.

LUMAWISE Endurance S was co-developed with several partners to ensure a complete system is available, including application specific drivers and control nodes. TE also collaborated with the Zhaga Consortium, a global lighting-industry organization that standardizes components of LED luminaires.

“The standardized interface defined in Zhaga Book 18 enables the installation of future-proofed outdoor LED luminaires, which can be easily upgraded with smart communication and sensing capabilities,” said Dee Denteneer, Secretary General of Zhaga. “We are pleased to see that member companies including TE are already using the specification to develop products that will stimulate the market for smart outdoor LED luminaires.” ■

New Push Grip Wire Connectors for Lighting from TE Connectivity

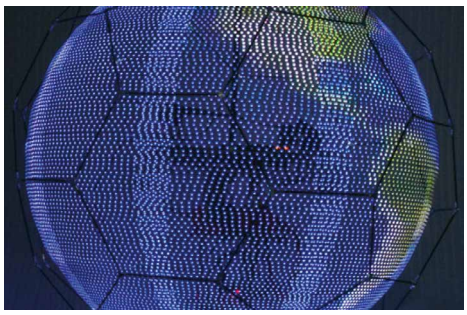
TE Connectivity (TE), a world leader in connectivity and sensors, has introduced the new Push Grip wire connectors for electrical installations. These tool-less, poke-in wire splice connectors provide visual termination of solid and stranded wires in gauges from 22 to 12 AWG (0.5 – 2.5 mm^2). The connectors are color-coded according to the number of positions for easy identification, and their compact size enables them to be used in tight spaces. A test slot incorporated into each connector allows for voltage testing.

TE Connectivity's new Push Grip wire connectors suit many electrical installations

TE’s Push Grip wire connectors are intended for a wide range of applications such as retrofit lighting, digital signage, light equipment in commercial buildings, and residential wiring systems. They can be used up to 600 V for building wiring and to 1000 V for lighting fixtures. The connectors have an operating temperature range of minus 40°C to 105°C and the clear housings are in UL 94V-0 flame retardant polycarbonate.

DOCOMO Develops World's First Spherical Drone Display

NTT DOCOMO, INC., in a continuing quest to create innovative new business, has developed a spherical drone display - an unmanned aerial vehicle that displays LED images on an omnidirectional spherical screen while in flight - which DOCOMO believes to be a world first.



Illuminated spherical drone display

The device comprises a spherical external frame, an internal LED frame consisting of a series of eight curved LED strips that extend from top to bottom, a drone fitted inside the sphere and legs protruding underneath. During flight, the LED frame spins on its axis in a rapid horizontal motion, forming an afterimage effect to create the illusion of a solid sphere of motionless LEDs. The highly maneuverable drone can be operated virtually anywhere, including venues such as concert halls or arenas where it can fly around as part of a performance or deliver advertising messages, event information, etc.

The maximum diameter of the spherical frame is about 88 cm and the entire device, including the drone, weighs just 3.4 kg. The display measures 144 pixels high and 136 pixels wide (horizontal circumference).

Equipping a drone with a spherical display had proved difficult until now due to challenges such as the display interfering with the airflow of the drone's propellers as well as the added weight of the display. However, DOCOMO's solution uses a largely hollow display that is exceptionally lightweight and allows air to flow through it, yet it still achieves the illusion of a solid display by creating an afterimage effect with rapidly spinning LEDs.

DOCOMO aims to commercialize its spherical drone display in the fiscal year ending in March 2019. Going forward, the company will explore potential entertainment and messaging solutions for event venues, including stadiums and concert halls.

DOCOMO will showcase its spherical drone display at NTT ULTRA FUTURE MUSEUM 2017 during the Niconico Chokaigi conference at Makuhari Messe, which will begin on Saturday, April 29. The exhibition will include a flight demonstration inside the event hall.

Under the "docomo Drone Project," DOCOMO is exploring ways to combine aerial mobility and communications mobility in innovative solutions for logistics, messaging, entertainment and other fields. ■

Philips Lighting - First-Ever Wireless Linear Retrofit Lamp

Philips Lighting, a global leader in lighting, introduced a simplified path to connected ready lighting with the introduction of Philips InstantFit LED T8 lamps with EasySmart technology. The first and only wireless, network-capable linear lamp retrofit, the Philips InstantFit LED enables intelligent control from the Leviton Wireless Room Controller System with the simplicity of a plug and play installation that reduces energy, effort and costs.

Philips InstantFit LED T8 lamps with integrated EasySmart technology make it simpler to save money, energy and time

Upgrading LED lighting can reduce energy consumption by up to 50% as compared to fluorescent lighting. When enhanced with controls such as dimming, sensor-based occupancy sensing and daylight harvesting, the upgraded lighting system can save an additional 20-40% in energy use.

"Philips Lighting's approach to smart innovation includes both advancing what is possible with LED lighting and making it easy to install and apply," said Bertrand Vandewiele, LED Product Marketing Head at Philips Lighting. "Our EasySmart technology is a perfect example to demonstrate that intelligent lighting and simple programming and installation do not have to be mutually exclusive."

An expansion of Philips Lighting's existing InstantFit LED platform, EasySmart LED T8 lamps simply install into existing fixtures without needing to be rewired since they operate on instant start ballasts. The addition and integration of flexible wireless controls from the Leviton Wireless Room Controller System provides dimming, occupancy or vacancy sensing, multi-zone daylight harvesting, manual control and scene control capabilities. These intelligent controls capabilities can adapt to different tasks and suit individual preferences, as well as help to promote productivity and comfort in the space.

The wireless technology is built on the ZigBee 3.0 open standard protocol, which allows easy integration of the LED T8's with

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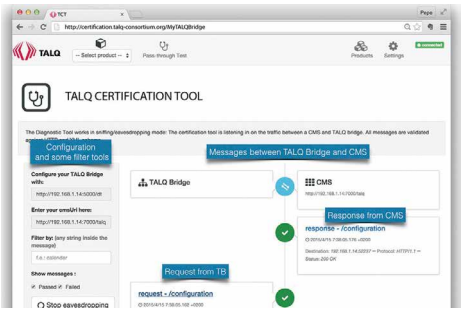
a wide variety of control devices and systems. Encrypted to protect against unwanted intrusion, the lamps can be provisioned for individual and group or zone lamp control based upon a customer's preferences or task-appropriate presets. The system can easily be programmed and customized to improve energy savings and simplify maintenance operations.

"Leviton is excited to offer the first wireless controls that are compatible with the Philips EasySmart technology," said Richard Westfall, Vice President and General Manager of Leviton Energy Management, Controls & Automation. "Together, Leviton and Philips Lighting are making product selection and installation simple for commercial users who want to retrofit their lighting system." ■

Smart Street Lighting Products Getting Ready for Global Standard

The TALQ Consortium, developers of the global standard interface for smart outdoor lighting networks, have just released the formal beta version of the entire TALQ Test Suite for its members. With this test tool companies can now start testing their smart lighting solutions for multi-vendor interoperability. The Test Suite will allow first products to be TALQ certified later this year – ensuring interoperability without the expense and delay of plug fests. Furthermore, the tool enables the Consortium to work on extending the TALQ Standard to other smart city applications.



TALQ Consortium releases beta version test tools to allow TALQ certification (Image credits: © TALQ Consortium)

Cities and municipalities, when planning long-term investments like street lighting, always try to choose future-proof and interoperable solutions that will not constrain their future investment decisions. That is why, in 2012, the TALQ Consortium was founded to develop a global interface standard to connect and manage heterogeneous street lighting networks from many different hardware and software vendors. The TALQ Specification focuses on the so-called 'application layer' of the interface protocol, allowing maximum freedom for outdoor lighting manufacturers to develop optimized solutions within an interoperable framework. The TALQ Interface is built on standard internet protocols and security standards, such as XML/HTTP and Transport Layer Security, and is independent of connectivity technology.

Test Suite to ensure interoperability of Outdoor Lighting Networks

In addition to the technical specifications, a rigorous test procedure and intelligent test tool have been developed to ensure TALQ-compliant products provide the highest level of interoperability. The beta version of this complete TALQ Test Suite is now available to all TALQ member companies. For the first time, lighting manufacturers have access to a tool allowing them to evaluate their own products for TALQ protocol compliance. The test tool supports the full TALQ protocol and can test both the TALQ bridge and Central Management System interfaces.

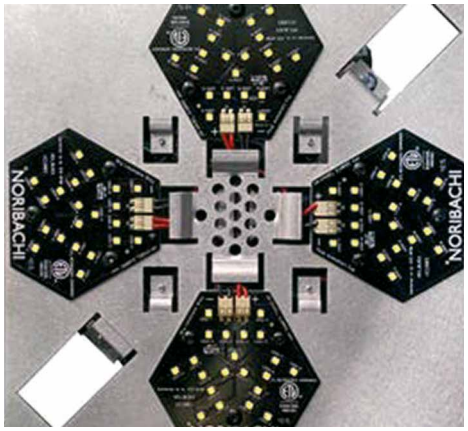
The beta version of the test tool allows real-time testing of the manufacturer's implementation of every feature for TALQ compatibility. First tests of existing products during an earlier plug fest have proven the added benefit of functionality and reliability testing using the test suite.

"The test tool is the fruit of constructive collaboration and detailed feedback from many experienced companies of the lighting industry. We are proud to release a tool that enables the industry to develop interoperable systems and ease investment decisions for cities." says Dr. Nick Hewish, facilitator of the TALQ Certification Working Group.

While the TALQ Consortium finalizes the rollout of the Smart Outdoor Lighting Standard, it can now concentrate on new topics such as opening the TALQ Specification to become a standard interface for other smart city applications. In this way TALQ will continue to enable cities to have more flexibility, reduce investment risks, become future-proof and achieve greater operational savings. ■

Noribachi Launches Full Spectrum LED Grow Lights

Noribachi, a leading U.S.-based technology company with a focus on lighting digitalization, announced the launch of its high-quality, full spectrum LED grow lights developed in its Northern California growlab.



Noribachi's full spectrum LED grow lights allow a flexibility in production by adapting the light to the requirements of different plants or seasons

"This is a very exciting time for us," said Russell Akiyama. "Using innovative and efficient LED lighting and technology to assist in the growth cycle of owners, trees, fruits, vegetables and more will allow a flexibility in production both in and out of season. We look forward to this capability enhancing our ability to service the many needs of our customers."

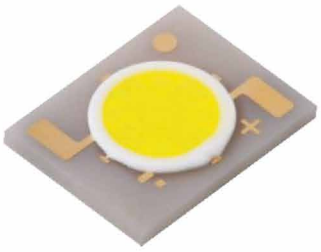
Noribachi's LED technology expertise allows the company to engineer a wide variety of energy efficient grow lights that maximize space and light output as well as lower energy costs for commercial growers, urban farmers and hobbyists. The initial product launch features a variety of warehouse grow lights as well as DIY grow light kits developed specifically in the company's grow lab.

Noribachi's Growlab (NGL) is testing ground for new products and smarter growing techniques. As part of NGL's vast testing environment, Noribachi has developed a "Customer Grow" program. This program invites customers to send plants with specific requirements to the NGL for testing. From the testing period, Noribachi will design a customized mixture to maximize light output for optimum growth for each specific plant.

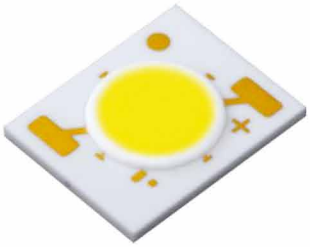
"We are already at the forefront of LED innovation, integration and optimal lighting,"

Lighting the World
ONE LED AT A TIME

COB Series



Z Series
High Density



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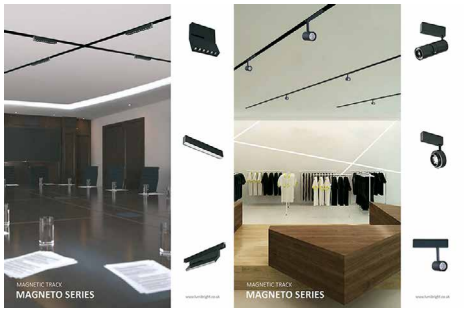
said Franklin Dibachi, Director of Engineering, Noribachi. “It is a natural step for us to bring that innovation to the farming and horticulture industries. As a showcase of our technology, we have started growing pumpkins in the lab that we will present at the Half Moon Bay Art & Pumpkin Festival in October.” Noribachi’s full spectrum LED grow lights can be purchased directly through Ledfullspectrum.com. All products are manufactured at Noribachi’s Los Angeles area facility and ship between 3 – 5 days from purchase. All LED grow lights carry a standard 5-year warranty with an optional 10-year warranty available.

Lumibright Introduces Versatile Magneto Combo Series

Lumibright's Magneto has revolutionized track systems providing flexibility to combine them in a variety of ways. Insets are installed using magnets on a patented slider enabling to adjust the beam angle to highlight desired objects in every detail with optimal light quality. Magneto track light has unique distribution technology with independent patented innovation design in strong magnetic adsorption installations and optical module cellular lighting functions.



Lumibright's Magneto - as the name suggests - uses magnets on a patented slider enabling adjustments of the lights

Combo track lighting is a versatile way to light any room with options of ambient overhead lighting, directional or spotlighting. Consider adding smaller track lights above a showcase or mannequin to add a bit more light. Longer, adjustable monorail lighting can be used to illuminate a hallway or a wall of art, highlighting your unique style aesthetic. The series are well-suited for retail stores, malls, art galleries, universities, supermarkets, offices, restaurants, villas etc.

The Magneto Combo Series offers a delicate subtle appearance with adjustable combination options to use cellular light modules for accent as well as general lighting. The embedded installation design, slim narrow edge on an optimized structure, this intelligent lighting system brings out the unique charm of fusion illumination to blend lamps with space perfectly.

Green Creative - Elevate Series Low Glare Panel LED Luminaires

Green Creative, the commercial grade LED lighting manufacturer, proudly announces the release of its Panel 2X4’ 38 W and Panel 2X2’ 30 W luminaires. Part of the Elevate Series, these new panels use the latest in edge-lighting technology to produce a smooth, uniform lighting effect. In addition, these fixtures feature SootheOptic low glare technology that minimizes visual glare, creates a comfortable lighting environment and offers more useful light than traditional panels. With a Unified Glare Rating <19, these panels are ideal for illuminating offices, classrooms, hospitals and retail spaces.

Green Creative's latest Panel LED Luminaires are characterized by a low glare rating below UGR 19

“The new SootheOptic diffuser eliminates the glare and discomfort associated with traditional panels,” says Green Creative’s Product Manager Victor Pellerin. “Our unique design provides comfortable light to the areas that need it most.”

Each panel comes standard for T-grid installation but can also be suspended or surface mounted. These luminaires are dimmable on 0-10 V circuits and have a 75,000-hr lifetime and 10-yr warranty. Each panel is available in 3000 K, 3500 K and 4000 K CCT.

These products are available through Green Creative distributors and are ready to ship from the company’s west coast, central and east coast distribution centers. For more information on where to purchase these products near you or how to become a distributor, please contact Green Creative.

Lumibright Introduces Nice Series Spotlights

The remarkable Nice Spotlight Series are an extensive selection of high performance optics to meet specific lighting solutions after months of engineering. Elegant, slim and sleek, the all new LED Nice Spotlights have been designed and developed for radiant lighting experience providing 50,000 hours of stylish lighting.

Some examples out of Lumibright's Nice spotlight series

The range of spotlight have an extra ordinary feature of being deep recessed with an accurate beam that provides smooth and clear brightness. Highly efficient and compact, they are deep settled with dark reflector housing, dispersing beam with no more glare in the eyes. Housing and cover ring are made of extruded aluminum body, strengthening its durability and lifespan to last for years. This addition brings you nano technology for color finish, available in black and white that are durably rust free. High light output and long-life make this range superior. Nice series is developed for ruling the industry with the most efficient light source and die casting aluminum housing for great heat dissipation.

Completely designed and built in the UK, Nice series is available in two different color-finishes white/ black with LED chip having three color temperatures: Bright /cool white, Soft /natural white and warm white. The LED provides a vast color profile. Being durable, reliable and long-lasting, LEDs can burn for a staggering 60,000 hours in which a consumer would have to buy from 10 to 20 halogen bulbs just for one socket.

Illumination - Innovation - Imagination

1% Xitanium Indoor Linear and Point Source Drivers

The Philips Advance Xitanium range of programmable LED drivers are perfectly suited for Linear & Downlight fittings in commercial applications. These models are compatible with standard 0-10V dimming systems to deliver reliably smooth dimming performance down to a minimum of 1%.

Linear LED Driver with 1% Dimming + SimpleSet

- 20W/40W/54W/75W Linear Mount
- 120-277V Main Input
- Class 2 Output
- 0-10V Dimming
- 1% Minimum Dimming Level
- Programmable Dimming Options
- UL/CSA/ETL
- Class P
- Compatibility with Fortimo Linear Modules
- 5 Year Warranty

Applications

Indoor Linear, Office and Retail Lighting

Point Source LED Drivers with 1% Dimming + SimpleSet

- 25W/36W/50W/75W J Box Mount (Bottom Entry)
- 25W/36W/50W/75W Surface Mount (Side Entry)
- 120-277V Main Input
- Class 2 Output
- 0-10V Dimming
- 1% Minimum Dimming Level
- Programmable Dimming Options
- UL/SREC
- UL/CSA/ETL
- Class P
- Compatibility with Fortimo Modules
- 5 Year Warranty

Applications

Indoor Downlights, Wall Sconce, Ceiling, Retail and Hospitality Lighting

For the latest information on Philips products contact your local FLS sales representative.

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TECHNICAL REGULATORY COMPLIANCE UPDATE

Segment	Product	Standard (Certification)	Region	Technical Regulatory Compliance Information
Lighting	Tubular LED Lamps	IEC 62931:2017	Int.	IEC has released IEC 62931:2017 on Feb 10, 2017. This document specifies the safety and interchangeability requirements together with the test methods and conditions required to show compliance of non-integrated tubular LED lamps, intended for general lighting purposes, having: • A rated wattage up to 70 W • A rated voltage up to 190 V ripple free DC • GX16t-5 cap The standard requires that tubular LED lamps shall use the new GX16t-5 cap exclusively for LED lamps to prevent users from improperly installing LED lamps into lighting equipment for fluorescent lamps. The GX16t-5 cap is characterized by the shape of a cap pin to prevent the lamps from falling, the one-side power supply to prevent the electrification of users, and the structures to keep hands away from a power-supply terminal. It comes in length of 600 to 2400 mm
Lighting	Lamps	Appliance Efficiency Regulation	California	California Energy Commission adopted new standards updating the 2015 Appliance Efficiency Regulations (Title 20) for lighting appliances. Updates will roll out in two tiers with Tier 1 effective January 1, 2018 and Tier 2 effective July 1, 2019. This update adds standards for small-diameter directional lamps. The updated regulations incorporate elements of lighting product quality for both general service LED lamps and small-diameter directional lamps in addition to the traditional lighting appliance efficiency standards previously included in the regulations. The addition of these new standards will require revisions to the California Appliance Efficiency Database product certification process, as well as updates to product labeling requirements for lamp marking, marketing material, and product packaging
Lighting	LED Lamps	Resolution No. 108-2017-MEM/DM	Peru	The Ministry of Mines and Energy has published Ministerial Resolution No. 108-2017-MEM/DM, which approves the 24 component type LED lamp Technology, whose characteristics are found in Appendice which is a part of this resolution Ministerial. The technical specifications for various LED lamps, including regular and globe LED lamps with built-in ballasts, and dichroic and tube types are approved. The Ministerial Resolution went into effect on March 16, 2017 following its publication in the Official Gazette
Lighting	Self Ballasted Lamps	TIS 2234-2557, 2017	Thailand	The Thai Industrial Standards Institute (TISI) has proposed to withdraw TIS 2234-2548(2005) Self-ballasted lamps for general lighting services: safety requirements, and replace it with TIS 2234-2557(2014) as a mandatory standard. This standard specifies the safety and interchangeability requirements to demonstrate usage for domestic and similar general lighting purposes. It comes in force on Feb 24, 2018 and states the requirements to control the start and stable operation of tubular fluorescent and other gas-discharge lamps. The discharge lamps that qualifies under this have: • Rated Power less than 60 W; • Rated voltage 100 V to 250 V; • Edison screw or bayonet caps. It includes photobiological safety and lower (below the level) blue light and infrared hazards needs to be marked and labelled
Regulations	Energy Labeling	2017/254	EU	Energy labeling in the EU has been updated by Commission Delegated Regulation (EU) 2017/254, with regard to the use of tolerances in verification procedures, will be effective from March 07, 2017. The verification tolerances are designed to allow for variations that emerge in the measurements taken during verification tests, which are due to the differences in the measurement equipment used by suppliers and surveillance authorities across the Union. It clarifies that these verification tolerances shall not be used by the manufacturer for compliance purpose

A free training can be arranged for a clear understanding of the upper stated standards.
For further information on the latest upgrades and testing standards and training, please contact cps@tuv-sud.com

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June 20th and 21st 2017 | Humboldt Carré Berlin

AGENDA – Design Day

June, 20th 2017 (Tue)	
08:00 - 08:30	**Registration**
08:30 - 09:00	**Opening Speech: EBV LightSpeed – Advanced Services and Experience Center** **Sebastian Hülck** Director Segment Lighting, EBV Elektronik, Poing, Germany
09:00 - 10:00	**Roadway Lighting – Visual Performance, Light Quality Parameters and CIE recommendations** **Prof. Wout van Bommel** Light Consultant, the Netherlands
10:00 - 11:00	**Flashnet LoRaWAN Street Lighting and Smart City controls** **Lorand Mozes** CEO Flashnet, Brasov, Romania
11:00 - 11:15	**Coffee Break**
11:15 - 12:15	**High-end Retail Lighting incl. high-density COBs as alternatives to CDM / CMH lamps** **Nicolas Johner** Lighting Director, Louis Vuitton Moët Hennessy (LVMH), Paris, France
12:15 - 13:15	**Lunch / Buffet**
13:15 - 14:15	**Residential, Commercial and Retail Lighting Design studies** **Arch. Paolo Giovane** Metis Lighting, Milan, Italy
14:15 - 15:15	**Architectural Lighting Design with LED** **Alexander Rotsch** Lighting Design Leader Germany Arup, Arup Deutschland GmbH, Berlin, Germany
15:15 - 15:30	**Coffee Break**
15:30 - 16:30	**Design considerations with LED Modules for Distributed Lighting Applications** **Henrik Clausen** Director Fagerhult Lighting Academy, Fagerhult, Habo, Sweden
16:30 - 17:30	**The Digitisation of Buildings** **Akshay Thakur** Business Development Manager IoT, Cisco, London, UK
17:30 - 18:00	**Osram Einstone BLE iBeacon Technology and Beaconsmind Implementation** **Rosanna Pierantognetti** Director Consulting & Sales, beaconsmind AG, Erlenbach-Zürich, Switzerland

AGENDA – Technology Day

June, 21st 2017 (Wed)	
Registration	
Opening Speech: EBV LightSpeed – Advanced Services and Experience Center **Sebastian Hülck** Director Segment Lighting, EBV Elektronik, Poing, Germany	
Tailored Light Applications on the nanoscale **Dr. Sönke Fündling** Head of Epitaxy Competence Center, TU Braunschweig, Braunschweig, Germany	
Flicker Parameters for Reducing Stroboscopic Effects from Solid-state Lighting Systems **Andrew Bierman** Senior Research Scientist, Adjunct Assistant Professor, Lighting Research Center (LRC), Troy, NY, USA	
Coffee Break	
Micro Optics for LED beam shaping **Dr. Peter Schreiber** Fraunhofer IOF (Institute for Applied Optics and Precision Engineering), Jena, Germany	
Lunch / Buffet	
LiFi - PTP and PTMP implementation for luminaires as Access Points **Dr. Frank Deicke** Head of BU Wireless Microsystems Fraunhofer IPMS (Institute for Photonic Microsystems), Dresden, Germany	
Thermal design optimization of LED Systems via CFD Methods **Thomas Buck,** Senior Account Manager, Mentor Graphics, Frankfurt, Germany	
Coffee Break	
TEN° binning – the new OSRAM Opto Semiconductors binning **Alexander Wilm** Senior Key Expert, Osram Opto Semiconductors, Regensburg, Germany	
Very High Frequency LED Drivers **Mickey Madsen** CEO, Nordic Power Converters, Herlve, Denmark	

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CIE Fosters Co-Ordination of Global Research and Standardization on Temporal Light Modulation

Dr. Jennifer Veitch, recently convened the CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems. Below is the exclusive report she provided on the workshop findings and the attitude of the CIE towards this important issue.

Everyone reading this magazine is aware of the profound technological changes in lighting equipment and systems over the past 15 years. Individual light-emitting diode (LED) packages, are moving close to what is thought to be the practical maximum efficacy of 300 lumens per watt (lm/W), and commercial luminaires are said to be aiming to deliver 200 lm/W by 2025 [1] – roughly 3-4 times more efficient than the fluorescent lighting systems they will replace. By comparison, if automotive fuel efficiency were to improve to the same degree, common gasoline-fuelled cars would consume 1.77 l/100 km in 2025, rather than their projected performance of 2.14 l/100 km in 2025 [2]. The lighting industry is contributing strongly to the achievement of international targets for energy efficiency and reduced greenhouse gas emissions.

However, success depends on the widespread adoption of new lighting technologies. The relatively low uptake of compact-fluorescent lamps offers lessons in how not to change the market. One important consideration is that the new product must at least maintain the performance levels of the one it replaces, and if possible there should be an improvement. New products that cause problems for users, particularly if they become associated with discomfort or health concerns, will not succeed in the long run.

Unlike the familiar incandescent, fluorescent, and discharge light sources that LEDs replace, the new lighting systems are diverse. LEDs are semiconductors that reproduce the current waveform faithfully with a very rapid response, and the electronics to drive the device vary from one device to another. Therefore, there is a wide variety of temporal patterns of light output. These temporal variations are known colloquially as flicker, and more precisely as temporal light modulation (TLM). In addition to the driver designs of the light source itself, dimming controls can add flicker even to light sources that do not exhibit flicker when operated at 100% output. Many systems use pulse-width modulation (PWM) dimming (100% modulation at one flicker frequency with varying duty cycles).

TLM needs attention from researchers, standards development organizations, industry, and regulators, because it can be a source of problems for viewers. The problems can include visual perceptions known collectively as temporal light artifacts (TLAs). TLAs include flicker (the perception that the light appears to vary in intensity), stroboscopic effect (the perception that a moving object looks still), and phantom array (pattern appears when eyes move). Other phenomena include effects on eye movements, visual performance, headaches, eyestrain, brain activity, and cognitive performance. Several factors influence whether or not these effects occur, including the frequency and amplitude of the modulation, the occurrence of spectral variations, the adaptation luminance, the contrast of the target, the size of the retinal area being stimulated, and the location of the source in the visual field. Moreover, individuals vary in their sensitivity to TLM. At the extreme, a small percentage of people can experience an epileptic seizure following a very short exposure to TLM. A larger percentage might experience mild discomfort, which is a less severe consequence but one that could adversely affect the uptake of new lighting technologies.

Recognizing these potential problems, many organizations have undertaken

activities to improve our understanding of TLM and its effects, and to develop recommendations and standards to limit the potential for those effects. One of the first publications was IEEE S1789-2015, which recommended practices to limit the potential for adverse effects. CIE formed a technical committee to develop a technical report to identify metrics for TLM that would predict whether or not viewers would experience TLA. The National Electrical Manufacturers' Association is developing a recommendation for TLM measurement and metrics. There are also activities under way in several other national, regional, and international bodies.

All of this activity is healthy, but we at CIE could see a danger of competing recommendations being produced by different bodies. There are only so many experts available to serve on these various committees. Unlike some topics, there is no reason to think that recommendations for TLM would need to be regionally specific, and therefore we all would be better served by a co-ordinated, harmonized approach to reduce duplication and to speed the development of a single set of documents covering metrics, measurement, and criteria for protecting public health. CIE took the lead in bringing together all of the interested parties to begin the process of working together: we convened the CIE Stakeholder Workshop for Temporal Light Modulation Standards for Lighting Systems, a 2-day workshop held in Ottawa, Canada from February 8-9, 2017. Financial support was provided by Natural Resources Canada – Office of Energy Efficiency; National Electrical Manufacturers' Association; Philips Lighting; BC Hydro, the IESO Conservation Fund (Province of Ontario), and the National Research Council of Canada.

The workshop brought together 30 experts from around the world, drawn from standards development

organizations, industry associations, research institutions, regulators, and certification laboratories. The photo adjacent was taken at the workshop. The objective of this meeting was to develop a roadmap of research, recommendations, and standards activities related to TLM from lighting systems. Although the participants represented the many stakeholders, we were not empowered to recommend the content of any of these documents: our focus was on developing the roadmap that will lead to the standards we agree are needed.

Over the two days, a professional facilitator guided our discussions as we came to agreement about broad areas where much is known and gaps in our understanding – suggesting directions where researchers could fruitfully advance knowledge that will support recommendations and standards. Among the big research challenges will be to move from laboratory studies of simple, controlled light exposures, to more naturalistic settings with multiple light sources. Participants also developed agreement about some urgent needs for immediate action, particularly to come to a shared practice of measurement so that research labs produce results that can be compared and, later, industry and regulators have reliable ways to determine whether or not products and systems comply with whatever standards may be set.

At the end of the two days, we had developed a roadmap, but perhaps most importantly we had developed rapport and willingness to work together. The roadmap will be published as a CIE Technical Note in summer 2017, which will be freely available. In the meantime, CIE will soon begin work on a measurement protocol, and will establish a Research Forum for continuing discussion; meanwhile, the existing work on metrics to predict TLA continues. Existing activities in our sister organizations also continue, but the intent is to develop joint activities where appropriate. Equally importantly, we will seek to work together to involve allied researchers from vision science, cognitive psychology, and physiology in developing the knowledge base, and will promote TLM to research funding bodies as an important topic needing their investment.

We at CIE are excited about the potential to work together with others to address this problem, so that we can harness the creative energy of technology developers both to reduce energy use and to create lit environments that serve all of us well. ■

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Tech-Talks BREGENZ - Philipp Henrici, President and Managing Director at BJB

Philipp Henrici

Dipl.-Jur. Philipp Henrici MBA is President and Managing Director at BJB GmbH & Co. KG in Arnsberg, Germany. He studied law at the Friedrich Schiller University Jena and Freie Universität Berlin, where he received his Dipl.-Jur. degree in 2002. In 2006 he received his MBA at University of St. Gallen, Switzerland. He started to work for BJB in 2007 taking over several management positions in USA, Hong Kong, Taiwan and Japan. In 2008 he became President/ Managing Director at the BJB headquarters in Arnsberg.

It's unusual for a lighting company to be older than electric lighting itself, but BJB in Arnsberg, Germany is celebrating their 150th anniversary this year. LED professional's Siegfried Luger and Dr. Günther Sejkora spoke with Philipp Henrici, the President and Managing Director at BJB about disruptive technology changes, starting from petroleum lamps to electric lighting as well as conventional lighting versus solid state lighting. They also touched on the subjects of chances and drawbacks of LED component standardization, modular systems and automated production processes.

LED professional: Thank you for finding the time to come to Bregenz for our Tech Talk. We know that you must be very busy this year because of BJB's 150 year anniversary. Perhaps you could tell us a little about the company?

Philipp Henrici: In the 150 years since it was founded, BJB has been occupied with the subject of light. We started out with oil lamps and changed over to petroleum lamps. We developed a special burner that was so good that we could sell it to our competition. It was at that point in time that BJB made the strategic decision to operate as a supplier because it was clear that we couldn't operate as a competitor and supplier at the same time.

At the beginning of the 20th century, the next innovation came along – namely, the electric light. BJB quickly started to concentrate on sockets and became the world leader with this product.

LED professional: Why didn't the big lamp and light manufacturers claim that business area for themselves?

Philipp Henrici: That's a good question. The answer is probably because the socket is purely an OEM business and lamps with lamp-exchange is more of an end user business. It was simply a good fit with lamp producers and BJB developing lamp socket systems together. BJB has become the first place to look when it comes to innovations for the lamp industry. From the 1970's onward, all lamp innovations on the socket side were made together with BJB. Over time, BJB didn't only concentrate on the socket. In the "old days" we tried to build up other mainstays and today BJB is still the world market leader for lighting solutions in ovens. If you have an oven at home, you can be almost sure that your lighting solution comes from BJB. In the 1990's, when automation technology gained increasing significance, we started working with automation technology. We were one of the first companies that was able to hardwire lights automatically. In this way we have continuously been able to improve the position of our products on the market.

LED professional: And how did the LED change your business model?

Philipp Henrici: LED technology naturally turned everything upside down. In the old days, one needed a socket based system. Unfortunately, in the LED world, that isn't really necessary. Because of that, the years from 2008 when LED technology was intensively establishing itself, BJB went through a difficult phase. We had to completely reorganize ourselves and even question parts of our own business model. This is how we developed from being a provider of interfaces in lighting technology, to a component and solution provider. Today our program not only includes sockets, that exist in LED technology even though they aren't really necessary, but also everything that you need for the conception of a luminaire. It has to do with optics, fastening technology, automation and the printed circuit board itself. Those are all the things you can purchase from us. On the other hand, the customer can choose the components that they need for their solution themselves. We want to keep the market open and offer the customer as much freedom as possible.

LED professional: You mentioned sockets before ...

Philipp Henrici: Our philosophy is that our clients should have the option to exchange certain components that we offer. For that you need the appropriate interface.
The client should have the freedom to use standardized solutions. A few years ago we brought the Linear Flat System on the market. This is a linear component that is equipped with a socket based interface. In the meantime, this solution has been standardized, the interface meets the IEC Norm and the lighting solution is in the Zhaga book 14.

Siegfried Luger, Philipp Henrici and Günther Sejkora talking at the famous Opera House in Bregenz

BJB's Linear Flat System became a Zhaga Standard in book 14. This approach combines easy application for linear systems, similar to FL tubes, without compromising LED technology requirements

LED professional: Is this system replaceable for the client; whether the luminaire manufacturer or the end user?

Philipp Henrici: It is replaceable for the end user as well. The LED assembly group can be exchanged without the use of tools, just like the traditional light bulb. It is standardized as an AC and a DC component.

LED professional: We are also interested in the market position of BJB. Does your business operate on a world-wide basis? Where are your main markets? And how is your turnover split in different product groups?

Philipp Henrici: Here you have to differentiate between the product groups. We have a market share of over 70% for lighting solutions for ovens. At the moment our turnover in the area of general lighting is a bit more. The turnover for household appliances is about 30 million Euros and for general lighting, which means conventional lighting and LED technology we make around 40 million. This year we are expecting 45 million in that category. Another 4 to 5 million comes in from automation solutions. But of course, the solutions help us to place our components more prominently on the market.

LED professional: Besides general lighting there are a number of other business portfolios that LED's reach today. Examples are the automotive industry and UV applications. What do you think about these fields and are you active in other business portfolios?

Philipp Henrici: At the moment we are focusing on household appliances and general lighting. I don't want to rule out other portfolios but at the moment they are not our focus.

LED professional: What does your market share look like divided up geographically?

Philipp Henrici: We sell about 80% of our products to foreign countries. This doesn't only include exports because we also manufacture some of our goods outside of Germany. About 80% of the value added is in Germany. Our biggest markets are Germany and the USA (about the same volume) followed by Italy, Spain, England, Japan, Poland and Turkey. Those are the 8 biggest markets.

LED professional: You mentioned before that BJB originally came from the non-electric lighting sector and then made big changes. And then there was the technology change from the conventional lamp to the LED. How did that change affect BJB?

Philipp Henrici: The technology change had a disruptive character. In the old days, when we used conventional lighting, you had to have a socket based interface, a light socket. In modern times, we don't need that, even if we are convinced that it still makes sense. The old socket business has been getting smaller by around 20% per year since 2008. And when that happens you have to come up with something to stay on the market.

LED professional: So the traditional sockets have had to be replaced by clamps.

Philipp Henrici: Well, in many cases it is a printed circuit board with an SMD clamp on it, which we also have in our program. But of course you can't compare it to the socket interface that we had in the past. Connecting terminals have always been in our program but we only developed the SMD clamp in connection with LED technology.

We have developed towards the module. And you have to differentiate here. On the one hand we have the standardized components, like our Linear Flat System, that we want to have as an open system. On the other hand, we offer our customers PCB solutions. With respect to standardized solutions, however, we can't compete with the giants in the industry. We are very responsive to the needs of our customers and do everything we can to make their special solutions possible. Right now we are the only company on the market that has active components, passive components, like fastening technology and optics, right up to automation, in one portfolio. In this way we can offer the client advantages with components that are aligned with each other, that others can't deliver.

LED professional: But those are customer specific solutions that can't be mass produced.

Philipp Henrici: When it comes to passive components, those are standard solutions or close to standard. For example, our COB-connectors are already aligned with the standard. We are also willing to find the required solution together with the client.

LED professional: You just mentioned the keyword "COB connectors". One might see the COB solution as a counterpart to the customer specific LED-board. At the beginning of LED technology, there were only customer specific solutions, and you were pushed right out of the business but you have found the way back into the business with standardized modules through your COB connectors. How do you see this development? Will there only be standardized solutions in a few years?

Philipp Henrici: I believe there will be both. LED technology offers completely different possibilities for the luminaire manufacturer when it comes to design. And if they want to implement a special design they probably don't want to use standards. On the other hand, if they want to offer solutions that are cost optimized, they won't be able to refrain from using standards.

There are standards in all branches of industry. The automobile industry is the big example that uses standardized modules that are equipped with standardized components. That is an economic necessity: if costs have to be reduced, you need standards. That is why I believe that when it comes to luminaires in big volume, standards will prevail.

LED professional: Are your COB connectors oriented on Zhaga standards or do you create your own standards?

Philipp Henrici: Both. Right now there are 6 Zhaga standards in regards to COB connectors and we offer connectors according to them. But these standards have only existed for the past one or two years. We have about 80 connectors in our program because there weren't any standards before. We will continue to offer what the market requires in the future as well. I can imagine that in the future, because of the Zhaga standards, our variations will decrease.

LED professional: Is Zhaga a standard that you absolutely need in your portfolio?

Philipp Henrici: Absolutely. We are also a member of Zhaga. We have always pushed the standards. The industry is always saying that it wants standards and there isn't any other committee that is engaged in them. If there ever is another committee, then we would be willing to work with them as well. But right now, Zhaga is the only committee that has set standards in motion.

LED professional: COB connectors can be seen as an evolutionary development of the socket.

Philipp Henrici: That was our idea, as well. We developed the idea, which we also patented, in order to not have to solder. When the first COB modules were developed, you still had to solder even though the lighting industry was used to working with plug contacts. We started to look for a solution and that's how the COB connector technology came into being.

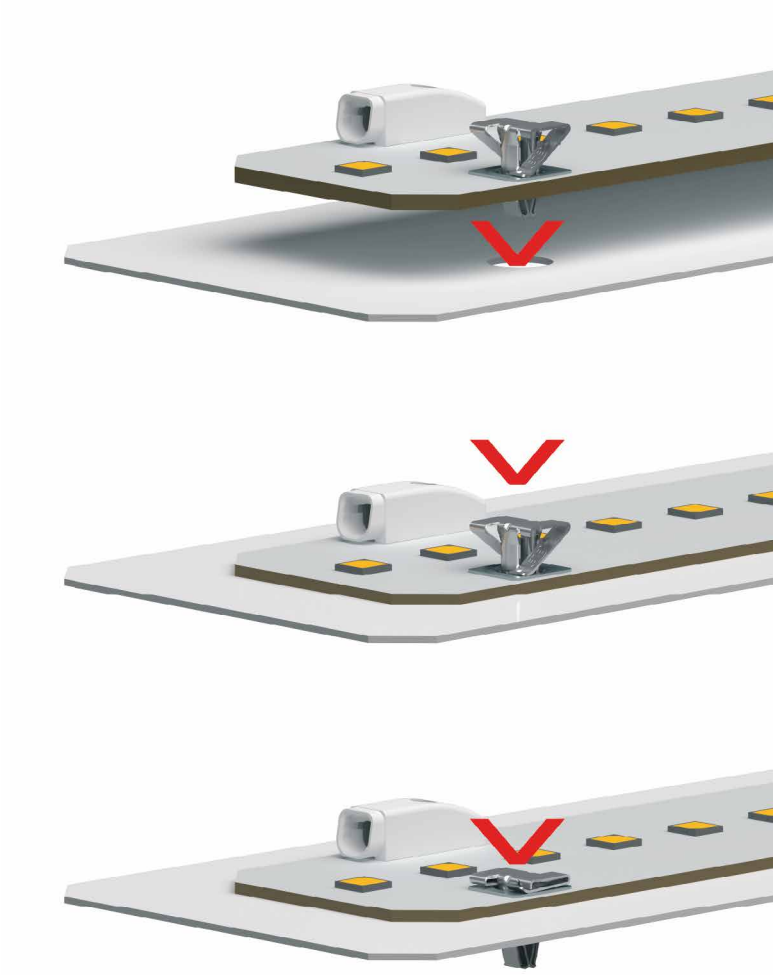
LED professional: On the other hand, you developed in the direction of LED modules, which was a new direction for your company. How much did it change your business in the areas of product development and/or production?

Philipp Henrici: A lot. First we had to make the decision to get involved with active components. It was clear to us in 2008, already, that we had to do something and further develop ourselves. The question we asked ourselves was: If the interface, meaning the socket, is discontinued, should we turn in the direction of luminaire development or illuminants? We decided to go with the illuminants because that would allow us to keep concentrating on our existing clientele, namely, luminaire manufacturers. We didn't want to become competition for our customers.

Since the established lamp manufacturers didn't want to work together to bring a socket based solution to the market, we decided to do it ourselves. Because of the amount of know-how required and the vertical range of manufacture it turned out to be quite a challenge. We had to start working with electronics and new production technologies and the supply chain. But when you are confronted with this type of disruptive technology, you always have to find new paths.

LED professional: You said that you didn't want to compete with your customers, but what happens if your customer wants to move in the direction of illuminants?

BJB offers various complete solutions for CoB including holders and optics



BJB's "push-to-fix" solution for the automatic assembly of printed circuit boards replaces the screw

Philipp Henrici: Our customers are free to do as they please. You don't have to buy the module from us, you can purchase individual components. We produce the end product. That is, at the most, a component, and the customer is still the luminaire manufacturer.

LED professional: What is integrated in your modules?

Philipp Henrici: There is the LED on the PCB, the plastic socket and the optic is also integrated. And if you take the AC option, the driver is also integrated. We have AC and DC solutions. The market demands both types. Some people say that the trend is heading towards AC solutions while others say we still need DC solutions because of the light quality. If we talk about the flicker index, I will need a DC solution to place the capacitors. I believe that there will be both in the future and we have to offer both types to our customers.

LED professional: The LED meant a complete shift for you in the area of components. How does the LED affect the area of automation?

Philipp Henrici: That hasn't been concluded yet. When the LED started it was a step back for production technology. In the old days, everything in a big company was automated. Housings, reflectors, assembly, wiring – everything was manufactured automatically. And then when the LED came along, we had to start soldering by hand again. We saw that as a step backwards and started to offer solutions that would allow for the automation of luminaire manufacturing also with LED's. We presented these solutions at the last light+building event.

The automation process will change in as much as the wiring complexity lessens compared to what it was like in the old days. There is also a lot of potential when it comes to assembling the components. Solutions have to be found where the printed circuit boards are not attached with screws any more, but rather, with appropriate fasteners. And that's what we've been working on during the past few years. There is a lot of potential, especially now that LED solutions are coming in quantities. But you have to be flexible as well, because the life time of a product is quite a bit shorter than it was before.

LED professional: Did expanding your product portfolio towards lamp manufacturers have an effect on your markets or did it remain the same since your customers are solely luminaire manufacturers?

Philipp Henrici: With regards to general lighting, our customers come exclusively from the area of luminaire manufacturing. But the value chain didn't only change for us, it also changed for the luminaire manufacturer. Our portfolio includes optics that we can offer which are lighting technology elements. In the past, reflectors were used and that was usually the domain of the luminaire manufacturer. Today lenses are used and the luminaire manufacturers lean towards buying the lenses from manufacturers like BJB. The value chain is altered everywhere.

LED professional: You have already integrated forward, will you keep moving in that direction? You integrated the AC driver so will you integrate a DC driver in the future?

Philipp Henrici: In regards to standard drivers, that won't be the direction we take. There are driver solutions that are especially adapted to our components so we are dependent on driving our own innovations forward. Take, for example, the Linear Flat System: It is available as an AC solution and therefore we have to integrate the innovation into the product ourselves. We presented a system at the Euroshop where we could click the Linear Flat Module onto a conductor rail. You can sink the

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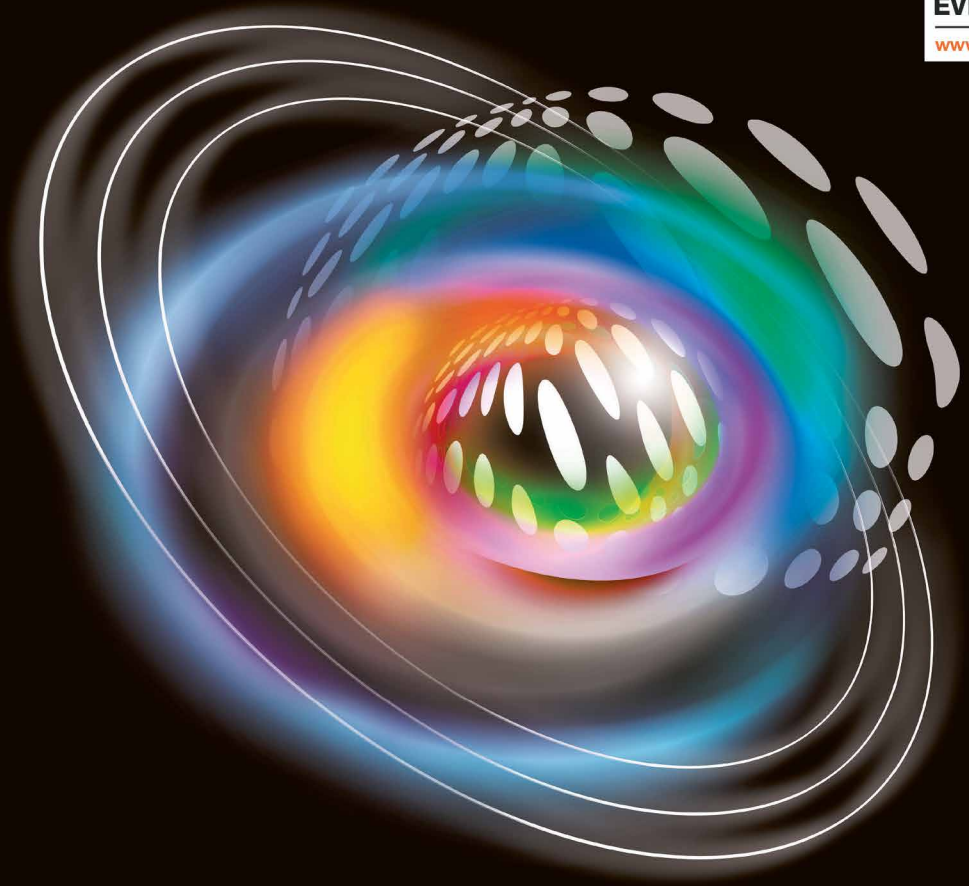

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driver into the conductor rail, which places high demands on the form factor of the driver. Since there wasn't anything like this on the market and we needed one, we developed this driver together with a partner.

LED professional: Are there other, innovative approaches that you can tell us about?

Philipp Henrici: We developed the "push-to-fix" developed for the automatic assembly of printed circuit boards which replaces the screw. Right now the printed circuit boards are mostly screwed into the luminaire and this is very time intensive. With the "push-to-fix" the printed circuit board is just pushed in. The SMD push-to-fix is an further development in which the element is set and soldered in the production process. The printed circuit board can be set and fixed automatically later.

LED professional: What research and development topics do you see as important in the mid and long term for your company? What key technologies does BJB need in order to stay successful?

Philipp Henrici: Optics is becoming increasingly important and reflector technology is used less and less. The direction we are going is new materials and new solutions, individual solutions for lighting guidance and dissemination. All these things have to be integrated in the automation process. Right now we have electronics, the LED and optics. If we want to integrate them into the automation process they will all have to be aligned with each other. The industry will develop in that direction and we will have to do a lot of research and development work.

LED professional: You used to develop systems together with the lamp manufacturer and then offer components from the system. In the meantime you are developing your own system solutions more and more and offering them. If I think about which systems will be relevant in the future, Smart Lighting comes to mind. Will you be moving in that direction as well?

Philipp Henrici: We will definitely have to engage in that. Digitalization is moving forward and the LED is also a type of digitalization. But the path goes on and you can see at every trade fair that the lighting industry is occupied by it. Personally, I still haven't seen "The Solution". I think that's because a standard hasn't been created yet. If we talk about IoT, all of the equipment has to communicate with each other and for that to be possible, they all have to speak the same language. But if everyone thinks they have to push their own standard through, it is going to be difficult. We'll see if the industry can agree to a standard.

It would be foolish, in today's world, where everyone is talking about this subject, for us not to concern ourselves with it. Last year, at the light+building, we showed a demonstrator that is based on the THREAD standard.

LED professional: I'd like to come back now to your 150 year jubilee: Does BJB have any special events planned to celebrate?

Philipp Henrici: We will have an Open House. We are very closely linked with the city of Arnsberg and we want to do something for our employees as well as for the citizens of the city. So we plan to combine the Open House with a corresponding event where we will erect stands with food and drinks. The stands will represent our international locations and the food will be specialties from the different regions, like Japan or Spain. I hope it will be are great time to everyone that attends.

LED professional: In that case we'd like to wish you a great event and success for the future. Thank you for taking the time to talk to us! ■

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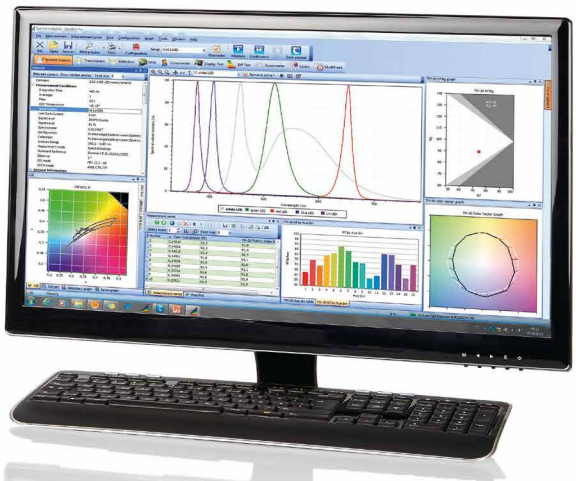

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New Glass-Based Phosphors for White Light-Emitting Diodes

Phosphors were always the key component of high quality white LED light. With the increased efficacy and the higher power capabilities of blue high power LEDs, the phosphors become even more important for reliability, color consistency and overall light quality. Franziska Steudel, Florian Wagner, A. Charlotte Rimbach, Bernd Ahrens, Peter W. Nolte and Stefan Schweizer, scientists at the Fraunhofer Application Center for Inorganic Phosphors, a Branch Lab of Fraunhofer Institute for Microstructure of Materials and Systems IMWS, investigated different glass and ceramics based phosphors for white LEDs.

Most white light-emitting diodes (LEDs) consist of a blue LED chip directly coated with an organic polymer containing a yellow phosphor. Heat-induced degradation of the polymer-based encapsulation results in an efficiency decrease and color temperature change of the LED. The growing heat generation results from increasing electrical currents used to drive the LEDs, thus making thermal management a key parameter for LEDs. Therefore, not only temperature-stable phosphors, but also phosphors having a good thermal diffusivity are required. Luminescent glasses or glass ceramics might represent an attractive alternative to LED phosphor due to their higher thermal and chemical stability. Within the framework of this research, luminescent properties and the thermal diffusivity of lanthanide single- and double-doped glasses and glass ceramics are investigated. The thermal diffusivity of the glass ceramics is one order of magnitude higher than that of the glasses, making the glass ceramics comparable to conventional Ce:YAG phosphors.

Introduction

The demand for high luminous flux of LEDs results in increasing operating currents and thus to a growth of the power density of the LED. Although current LEDs are highly efficient, the inevitable losses result in a heat up of the system, causing a spectral shift of the LED emission and a decrease in efficacy and reliability. In phosphor-based LEDs additional efficiency losses arise due to the heat generated from the Stokes shift. Thus, the efficacy of high power white LEDs strongly depends on the thermal management. There exist several methods to maintain a low junction temperature by active and/or passive cooling, but all of them are at the back of the blue emitting LED chip, which implies that the highest temperature within phosphor-converted LED packages is within the phosphor. Even in case the junction temperature of an LED chip is kept below 60°C, the polymer-based phosphor can reach temperatures of more than 80°C for an operating current of 1000 mA [1]. Hence, the LED phosphors do not only require high thermal stability, i.e. high quenching temperatures, but also high thermal diffusivity to efficiently dissipate the heat generated in the phosphor. Conventional polymer-based phosphors have a relatively low thermal diffusivity of approximately $0.2 \cdot 10^{-6}$ m²/s [2]. Higher thermal diffusivities, however, lead to a lower phosphor temperature [3].

Luminescent glasses represent an attractive alternative as LED phosphor. Tb3+ and Eu3+ doped borate glasses have a good thermal stability as well as quantum efficiency values higher than 85 % [4]. In addition, the color coordinates of double-doped glass can be varied over a broad spectral range. Within the framework of this paper, these glasses are thermally processed to glass ceramics. The luminescence properties of the glasses and glass ceramics are compared and the thermal diffusivity is analyzed.

Experimental Details

Borate glasses were prepared using lithium oxide (Li_2O) and aluminum oxide (Al_2O_3) as network modifier. A ratio of three moles of boron oxide (B_2O_3) to two moles of network modifier was used. The glasses were additionally doped with europium oxide (Eu_2O_3) and/or terbium oxide (Tb_4O_7). The nominal composition of the samples is as listed in Table 1. The chemicals were weighed in a platinum gold crucible

(Pt/Au 95/5) and melted at 1000°C for approximately 3 h. The melt was then poured onto a brass block at 400°C, which is below the glass transition temperature of undoped lithium borate glasses of T_g = 459°C (Section "Thermal properties"). The glass was kept at this temperature for 3 h to eliminate residual mechanical and thermal stress before allowing it to slowly cool to room temperature. The glass samples were then cut into squares of 15×15 mm with thicknesses varying between 1.0 mm and 1.8 mm and polished to optical quality (Figure 1, left). To initiate crystallization, the samples were annealed at a temperature of 530°C for 10 min. This is in analogy to the procedure reported by Appleby et al. [5]. The glass ceramics are shown in Figure 1, right.

Differential scanning calorimetry (DSC) was performed with a commercial system suited for temperatures up to 1700°C (Netzsch DSC 404 F1 Pegasus). The samples were cut into small pieces of about 25 mg, ground in a mortar to a fine powder, and then filled in a platinum rhodium crucible (Pt/Rh 80/20). An empty crucible was used as a reference. The temperature was increased with a heating rate of 10 K/min. The nitrogen flow was set to 20 ml/min during the measurements. The onset method was applied to obtain the characteristic temperatures summarized in Table 2, except for T_p. Here, the peak value is used.

The thermal diffusivity was analysed by means of lock-in infrared (IR) thermography. The IR camera (InfraTec ImageIR 8380S) comprises an indium antimonide (InSb) focal plane array (FPA) snapshot detector with a geometric resolution of 640×512 px and a spectral range for detection from 2.0 µm to 5.7 µm. The samples were periodically excited with a 980 nm laser diode (THORLABS L980P100) with a maximum power of 100 mW directly focused to the centre of the sample. The laser and the IR camera are connected to a lock-in box which synchronizes the image capturing with the laser pulses at a certain lock-in frequency, *f*. The entire setup is placed in a closed sample chamber, entirely in black, to screen it from external thermal radiation.

Photoluminescence (PL) measurements were performed with a commercial quantum yields measurement system (Hamamatsu C9920-02G) coupled to a 3.3 inch integrating sphere with a xenon lamp (150 W) as excitation source and a photonic multichannel analyser (Hamamatsu PMA 12) as detector.

Dopant	Composition / mol%					Ln^{3+} content / at.%
	B_2O_3	Li_2O	Al_2O_3	Tb_4O_7	Eu_2O_3	
–	60.0	33.3	6.7	–	–	–
Tb^{3+}	57.6	35.5	6.4	0.5	–	0.5
Eu^{3+}	59.3	33.1	6.6	–	1.0	0.5
Tb^{3+}/Eu^{3+}	57.4	35.6	6.4	0.5	0.1	0.5 / 0.05

Table 1:
Nominal composition of the investigated samples (lanthanide = Ln^{3+})

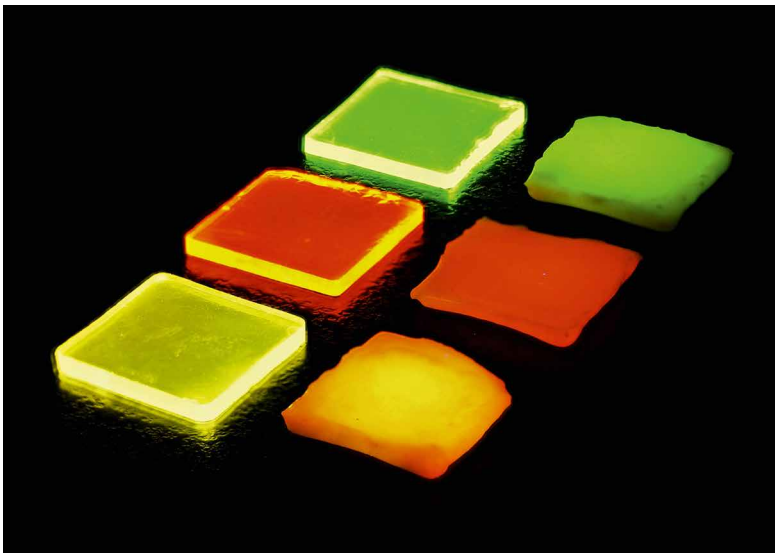


Figure 1:
Ln^{3+}-doped borate glasses (left) and glass ceramics (right): Tb^{3+} doped (top), Eu^{3+} doped (middle), and Tb^{3+}/Eu^{3+} double-doped (bottom) under ultraviolet irradiation

Results and Discussion

Thermal properties

The DSC curves of the glass samples are as shown in Figure 2.

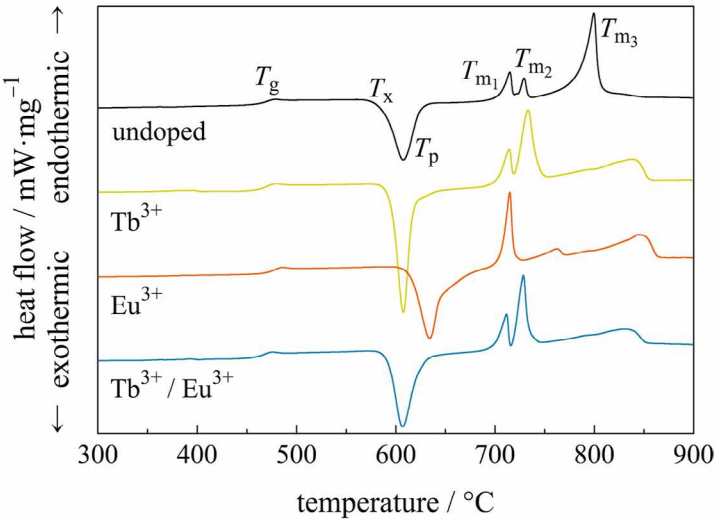


Figure 2:
DSC data of the undoped reference glass (black), Tb^{3+} doped (green), Eu^{3+} doped (orange), and Tb^{3+}/Eu^{3+} double-doped borate glass (blue)

Table 2:
Thermal properties of the investigated glasses: onset glass transition temperature (T_g), onset glass crystallization temperature (T_x), peak glass crystallization temperature (T_p), and the different onset glass melting temperatures (T_m). All values are given in °C

Dopant	T_g	T_x	T_p	T_{m1}	T_{m2}	T_{m3}
–	459	587	608	705	725	787
Tb^{3+}	459	595	608	702	719	–
Eu^{3+}	468	615	634	706	–	–
Tb^{3+}/Eu^{3+}	457	592	607	700	716	–

The obtained characteristic temperatures are summarized in Table 2. The undoped glass sample shows an increasing heat flow at approximately 460°C, which represents the glass transition temperature, Tg. At a temperature of $T_x = 587°C$, the onset of an exothermic peak is observed with its maximum at $Tp = 608°C$. This peak is due to glass crystallization. Between 700°C and 800°C, three endothermic peaks occur, which originate from the glass melting process.

Upon single-doping with Tb^{3+} or double-doping with Tb^{3+}/Eu^{3+} the glass transition temperature and the peak glass crystallization temperature do not show significant changes with respect to the undoped glass whereas for the Eu^{3+} single-doped glass the glass transition temperature and the peak glass crystallization temperature increase by approximately 10°C and 20°C, respectively. Note, that in the double-doped glass the Eu^{3+} concentration is lower than the Tb^{3+} concentration for color management reasons. The onset glass crystallization temperature and the melting behavior of the glasses are significantly affected by the lanthanide ions. The lowest T_x is obtained for the double-doped glass, closely followed by the Tb^{3+} single-doped glass. The Eu^{3+} single-doped glass has the highest onset glass crystallization temperature. The first glass melting peak, T_{m1}, is similar for all four glasses at approximately 705°C. The second glass melting peak at approximately 725°C increases in intensity for the Tb^{3+} single-doped and the Tb^{3+}/Eu^{3+} double-doped glass compared to the undoped glass. For the Eu^{3+} single-doped glass, this second melting peak is not observed. Either this phase does not exist as a result of crystallization in Eu^{3+} single-doped glass or the peak is shifted to lower temperatures and merged with the first peak. For both, the Eu^{3+} and the Tb^{3+} single-doped glass, broader endothermic peaks arise at 760°C and at 850°C, respectively. The broad shape of these peaks indicates evaporation of glass material [6, 7]; it is known that boron vaporizes at high temperatures [8].

The thermal diffusivity, σ, of the glasses and glass ceramics is analyzed by means of lock-in infrared thermography. The samples are periodically excited from the front side with a laser diode, which generates thermal waves in the material. The phase delay of the wave, ϕ, is recorded at the backside of the sample and can be expressed as [9, 10]:

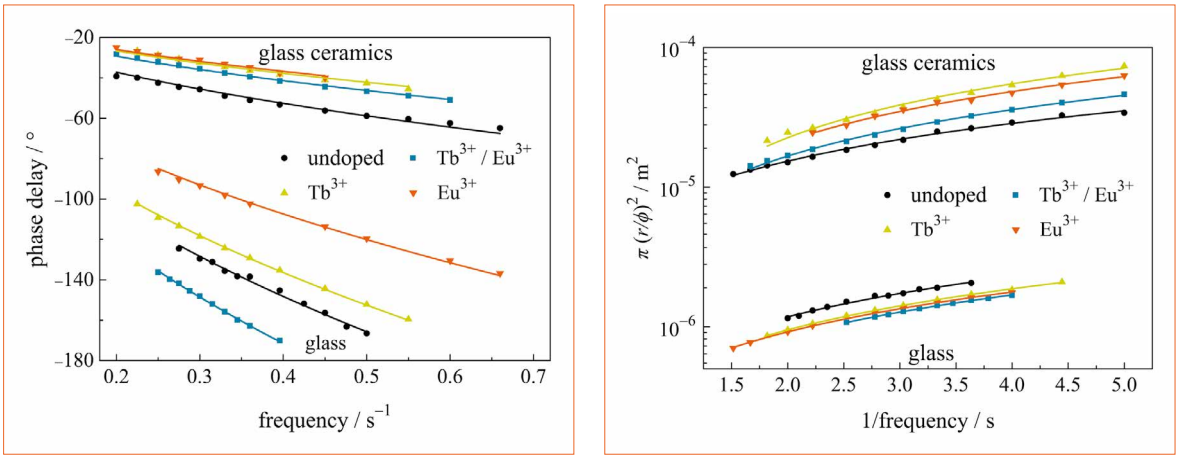
$$\Phi = \frac{r}{\sqrt{\sigma / (\pi \cdot f)}} \quad (1)$$

with r the thickness of the sample and f the (lock-in) frequency of the laser pulse. In Figure 3, left, the experimentally determined phase delays (symbols) and the corresponding fitting curves (solid lines) are shown. Due to the detection limit of the IR camera, only phase delays obtained for amplitude signals larger than 10 mK, can be precisely determined, resulting in different possible values for the lock-in frequency, f. The glasses have phase delays of approx. $\phi_{glass} \approx 70°$ to 180°, whereas the glass ceramics (GC) show phase delays of $\phi_{GC} \approx 20°$ to 60°. Note, that the phase delays in Figure 3, left, are not corrected for sample thickness. Re-arranging Equation 1 leads to a thickness-corrected phase delay, which is directly proportional to the thermal diffusivity, σ:

$$\pi \cdot \left(\frac{r}{\phi}\right)^2 = \frac{\sigma}{f} \quad (2)$$

This relationship is shown in Figure 3, right. Here, the thermal diffusivities can be directly obtained from the slopes, which coincide with the values obtained from the fit of Equation 1 within the fitting error. The thermal diffusivities for the glasses and the glass ceramics

Figures 3:
Measured (left) and thickness-corrected (right) phase delay of glasses and glass ceramics (symbols) as well as the corresponding fitting curves (solid lines)



obtained from the fits amount to $\sigma_{glass} \approx (0.4 \text{ to } 0.6) \cdot 10^{-6}$ m²/s and $\sigma_{GC} \approx (6 \text{ to } 16) \cdot 10^{-6}$ m²/s, respectively. Hence, the crystallization of borate glasses to borate glass ceramics increases the thermal diffusivity by more than one order of magnitude. Comparison of the results to literature values, reveals a higher thermal diffusivity of the glass ceramics than conventional Ce:YAG ($\sigma \approx 4 \cdot 10^{-6}$ m²/s [11]).

Luminescence properties

The normalized emission spectra for 376 nm excitation are shown in Figure 4. The energy levels involved are indicated. The Tb^{3+} doped glass (black curve) and glass ceramic (blue curve) show the characteristic Tb^{3+} emissions in the green spectral range, with peaks at 490 nm, 543 nm, 583 nm, and 622 nm, which can be assigned to transitions from the excited state $^5D_4$ to the ground state levels ^7F_J (J = 6, 5, 4, and 3), respectively. The typical Eu^{3+} emissions in the red spectral range are caused by transitions from the excited state $^5D_0$ to the ground state levels $^7F_0$ to $^7F_4$ (580 nm to 700 nm). The electric-dipole transition $^5D_0$ to $^7F_2$ at 613 nm is hypersensitive to variations in crystal symmetry [12]. The high intensity of this transition in borate glass indicates the amorphous nature of the matrix material with low inversion symmetry for the Eu^{3+} ion. Both emission spectra of the single-doped glass

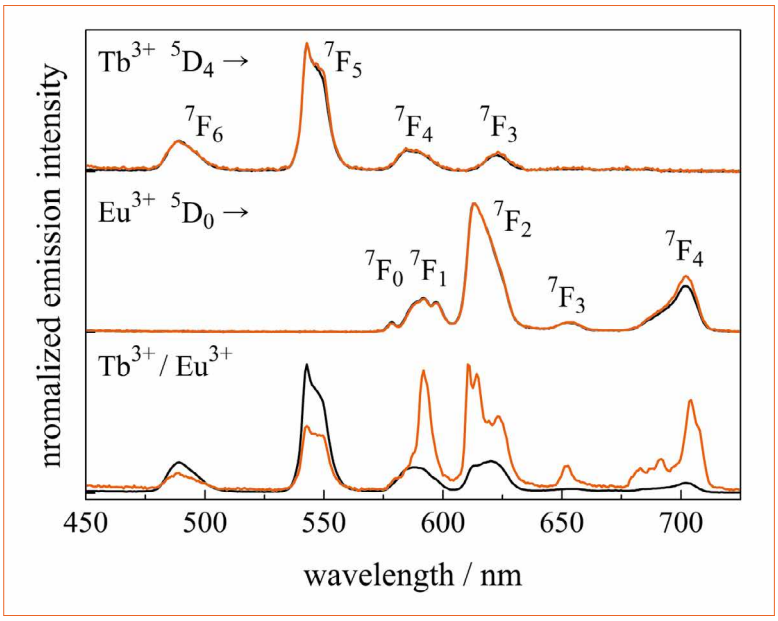
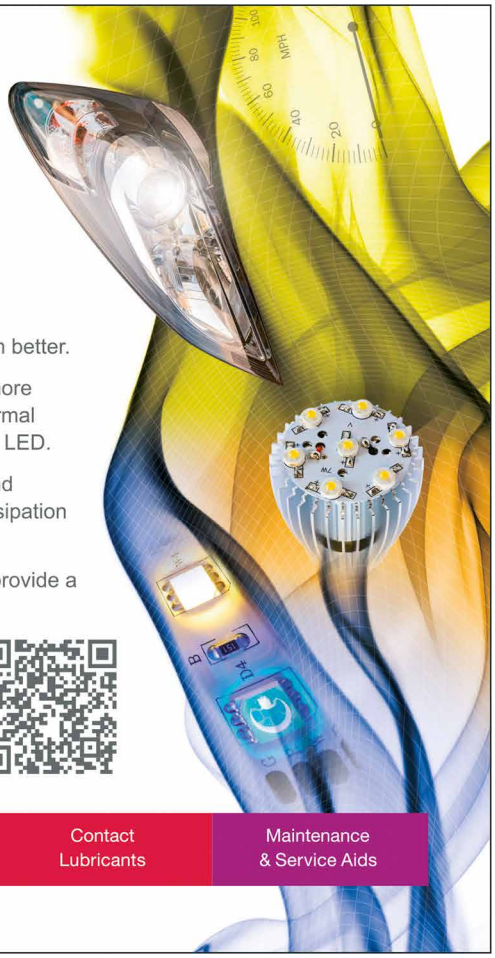


Figure 4: Emission spectra of glasses (black curve) and glass ceramics (orange curve) doped with Tb^{3+} (top), Eu^{3+} (middle), and Tb^{3+}/Eu^{3+} doped (bottom). All emission spectra are recorded under 376-nm excitation



and glass ceramic have the same spectral behavior. In contrast, the Tb^{3+}/Eu^{3+} double-doped glass shows a change in emission intensities upon crystallization. The intensity of the typical Tb^{3+} emissions is lower, while the intensity of the Eu^{3+} emissions is higher in the glass-ceramic sample, which results from an increased energy transfer from Tb^{3+} to Eu^{3+}. This red shift in the emission spectrum can clearly be seen in Figure 1: The double-doped glass has a yellow color impression, while the glass ceramic has an orange one. Additionally, in the double-doped glass ceramic the Eu^{3+} emission bands show Stark-splitting and the ratio between the transitions $^5D_0$ to $^7F_2$ (613 nm) and $^5D_0$ to $^7F_1$ (592 nm) decreases compared to the single-doped glass ceramic. Both effects originate from a change in the crystal field around the Eu^{3+} ions, i.e., a part of the Eu^{3+} ions is possibly incorporated into the crystals. For the double-doped glass ceramic, the degree of crystallization is probably higher than that for single-doped glass ceramics due to lower glass crystallization temperatures T_x and T_p.

Conclusion

The thermal diffusivity of Tb^{3+} and Eu^{3+} single-doped and Tb^{3+}/Eu^{3+} double-doped lithium borate glasses and glass ceramics was analyzed. Processing the glasses to glass ceramics increases the thermal diffusivity by more than one order of magnitude, i.e. from σ_{glass} = (0.4 to 0.6)·10^{-6} m^2/s for the glasses to σ_{GC} = (6 to 16)·10^{-6} m^2/s for the glass ceramics, making it comparable to the conventional Ce:YAG. The emission spectra of the single-doped glasses do not change upon crystallization, whereas the emission spectra of the double-doped glass ceramic reveal an increase in energy transfer from Tb^{3+} to Eu^{3+}. ■

Acknowledgement:
The authors thank the “Ministerium für Innovation, Wissenschaft und Forschung des Landes Nordrhein-Westfalen” for its financial support to the Fraunhofer Application Center for Inorganic Phosphors in Soest as well as to the South Westphalia University of Applied Sciences within the FH STRUKTUR 2014 project “LED-2020”.

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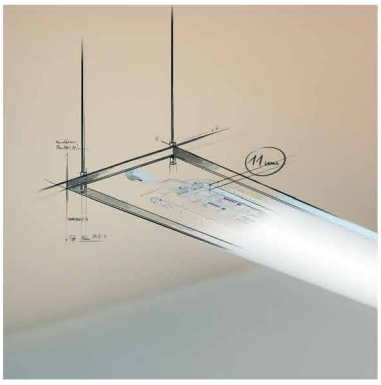
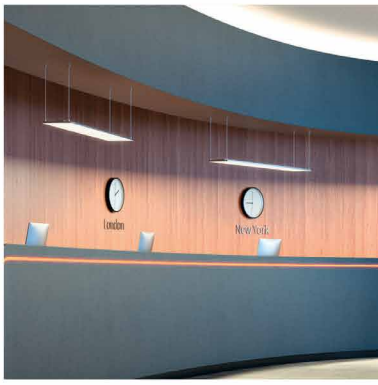
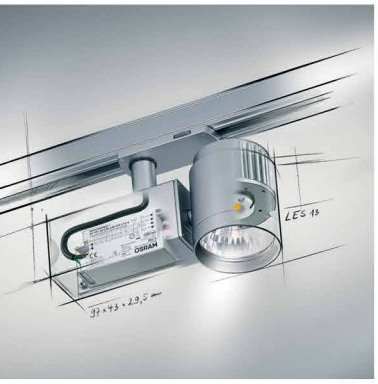






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Ultrathin Direct-Lit LED Module with Beam Shaping Thin-Film Optics

Thin, high quality, LED light panels are still a challenge. LED professional's scientific partner, CSEM, investigated and developed a new approach with its partners, GAIKER-IK4 and BASF-SE. The authors, Oscar Fernández and Rolando Ferrini, from CSEM, Leire Barruetabeña, from GAIKER-IK4, and Sorin Ivanovici from BASF SE, present a solution that uses low-cost and spectrally poor, ultra-cool white LEDs in conjunction with optical color conversion foils, to transform the output to a high-quality light. They also describe a combination with added lime and red LEDs for a color tunable solution.

A direct-lit LED-based lighting module is described that features an ultra-thin form factor and high-quality light both photometrical and spectrally.

Thanks to a smart integration of optical foils for efficient light management, a high luminance uniformity results for a total module thickness well below the LED pitch. In addition, such light management solution produces a directional glare-free photometric light pattern.

Using an appropriately engineered organic-based color conversion foil, CCF, and the characteristic broad emission of the organic phosphors inside, warm white light with excellent color rendering properties could be achieved from low-cost and spectrally poor ultra-cool white LEDs.

The flexibility of the light management foils and the CCF foils make their manufacturing compatible with cost-competitive roll-to-roll processes.

On the other hand, the incorporation of independently addressed colored LEDs into the module allows on-Planckian white point tuning, albeit with certain impact on the color rendering properties. Our light management solution performs acceptably in a wide range of color points thanks to its good color mixing capabilities. Suggestions are made to improve on both aspects.

The cost structure of the module, analyzed using life cycle cost analysis revealed that the addition of colored LEDs is, by and large, the main factor for the cost of the module.

LED Panels for High-Quality Lighting

Ultrathin Direct-Lit LED Module with Beam Shaping Thin-Film Optics

Thin high quality are light panels are still a design challenge with LEDs. LED professional's scientific partner CSEM has investigated and developed a new approach with its Partners GAIKER-IK4 and BASF SE. The authors Oscar Fernández and Rolando Ferrini from CSEM, Leire Barruetabeña from GAILER-IK4, and Sorin Ivanovici from BASF SE present a solution that uses low-cost and spectrally poor ultra-cool white LEDs in conjunction optical color conversion foils to transform the output to a high-quality light. They furthermore describe a combination with added lime and red LEDs for a color tunable solution.

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LED Panels for High-Quality Lighting

LEDs today can produce extremely high luminance levels (of several 10'000s cd/m2). However, due to their small size (≤ 1 mm^2), the total flux is typically not higher than a few tens of lumens, too low for most lighting applications that require two orders of magnitude larger values. Consequently, high flux LED-based lighting devices use LED arrays.

Very often, the light emitted by LEDs must be redistributed to meet the illumination specifications due to their (typically) Lambertian demission pattern. For example, unless fitted with appropriate secondary (and often tertiary) optics, LED arrays illuminate nearby targets non-uniformly and cause multi-shadows.

Lambertian light sources, such as LEDs, are suitable to illuminate flat (i.e. not susceptible to multi-shadow effects) surfaces in very close proximity, like in LCD displays and task lighting, but are nonetheless not useful for large distances unless appropriate optical solutions for beam shaping. [1/p.79]

On the other hand, the average human eye can see in a brightness range of ~9 orders of magnitude from 1/1,000 to 100,000 lux [2/p.102]. Several processes including changes in pupil size achieve such a large dynamic range. [3/p.40.3] The continuous adaptation required when exposed to very different light levels often results in eye fatigue. [4]

In addition, the highly (spatially) concentrated light emission and the concomitantly high (Lambertian) luminance levels produce glare and ultimately loss of visibility, discomfort and irritation. [5/p.553] This issue deserves particular attention in the Professional Lighting segment where highly specular surfaces such as computer screens are commonly found. Furthermore, when brightly illuminated, the perceived characteristics of displays suffer from degradation of the visible grey-level, from reduction of the visible contrast and from reduced peak perceived color gamut [6,7].

The development and implementation of efficient beam shaping solutions will, in addition, contribute to reduce the amount of wasted light (30% in outdoor lighting has been estimated [8]) hence reducing energy consumption and minimizing the potential negative impact on our health [5/p.553, 9].

A common way to alleviate these disadvantages is to use LED panels where the light emitted by a relatively numerous collection of LEDs is uniformly distributed into a large area (typically ~600×600mm^2).

In the so-called direct-lit configuration a collection of LEDs are distributed more or less regularly on the surface of a planar substrate. The LEDs illuminate a diffuser plate located at a certain distance, d, above them. In order to achieve a uniform luminance over the entire diffuser, it needs to be separated from the LEDs by a distance comparatively higher than that between adjacent LEDs, the so-called LED pitch, t. The ratio of these two quantities is often referred to as the distance-to-height ratio, DHR=t/d.

The advantages of direct-lit configuration compared to the alternative edge-lit approach have summarized elsewhere. [10]

The main building blocks of the LASSIE-FP7 module [l] are the LED foil with integrated heat management structures, the light management foils, the CCF foil and the intelligence system. Here we report on the light management and CCF components. Insights into the LED foil and the intelligence system technology can be found in [11] and [12] respectively.

Optical Solutions for Ultrathin LED-Based Panels

Slim panels (DHR >> 1) are advantageous not only from an aesthetic perspective but also because of the space/weight savings they offer for recessed/pendant installations. Both aspects are, in addition, advantageous for stock keeping, handling and transport.

From an aesthetic perspective, uniform luminance distribution across the complete (emitting) area of the module is highly desired for it places the focus on the light itself rather than on the light sources. The well-known fact that human vision is drawn to gradient rather than to absolute luminance levels [13,14/p.24] poses a real challenge for direct-lit panels with DHR >> 1.

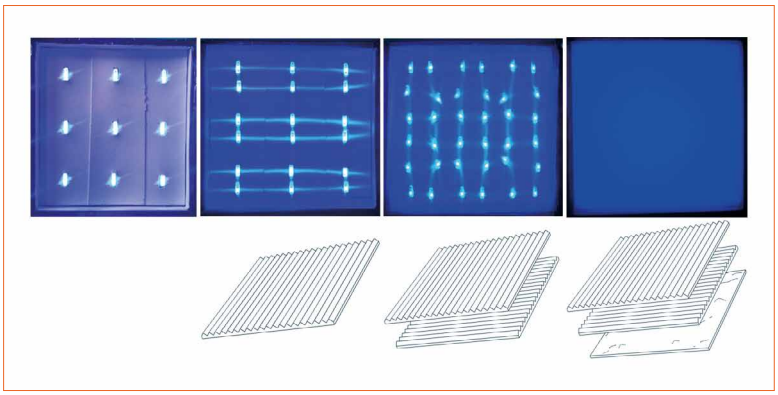


Figure 1:
Top view of a 50×50 mm², 3×3 LED array with the foil combinations shown below. A highly reflecting substrate (98% reflectance) was used. All foils are less than 200 microns thick

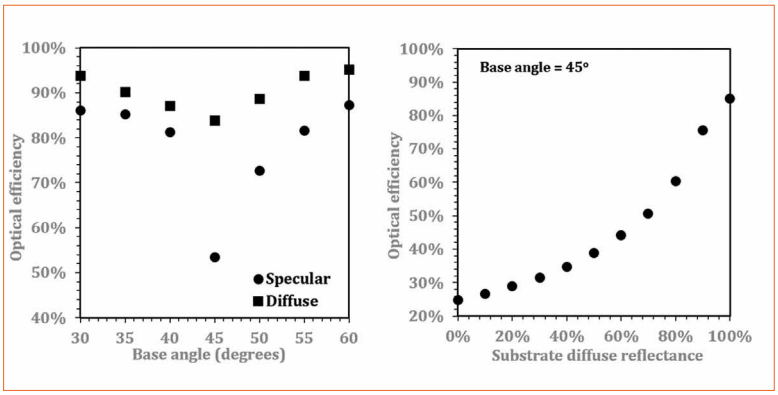


Figure 2:
Simulated optical efficiency of an LED array and two crossed prismatic foils as a function of the prism angle (left). Two cases are considered, 100% diffuse and 100% specular reflectance. The foils are located at 10 mm from the source. Simulated optical efficiency of the same module in the case of a 45 degree prism angle as a function of the module (diffuse) reflectance (right)

The DHR can be reduced by shaping the Lambertian into a batwing emission pattern using lenses, although at the expense of a substantial cost increase. Alternatively, micro structured pixels have also been proposed based on optical simulations [7]. Unfortunately, the experimental demonstration has, so far, proven elusive due to manufacturing constraints of the simulated optical microstructures.

In the LASSIE-FP7 project we have developed a solution based on the vertical stacking of optical thin films which produces highly uniform luminance levels (luminance uniformity ~86%) across the complete emitting whilst keeping a large DHR value of ~1.67 and an optical efficiency of ~70%. Remarkably, the principle of operation of this solution does not relay on the alignment of the foils with respect to the LEDs or with one another, which facilitates their integration into the module. See Spectral tuning with individually addressed colored LEDs section for the proposed solution of very good color mixing capabilities.

Figure 3:
Top view of the (20x20 cm²) LASSIE-FP7 module with (left) and without (right) a multilayer light management solution. The multilayer stack transforms the non-homogeneous light pattern produced by the point-like LED sources into a spatially uniform emitting surface

In addition to a thin-film diffuser, the optical stack contains two (similar) prismatic foils perpendicularly oriented with respect to each other in order to exploit the recursion mode [15/p.79] and doubling capabilities characteristics micro prisms [16] (Figure 1).

The optimum base angle of the micro prisms was investigated using ZEMAX Ray-Tracing optical simulation software. Figure 2 left shows the predicted efficiency of an LED array with two prismatic foils as a function of the prims base angle. Perfectly reflecting (specular and diffusive) LED substrate is assumed. The observed efficiency dip indicates the angle (45 degrees) where the recursion mode, i.e. light mixing, is at a maximum. Diffusive reflectors convert recursion into emission modes upon reflection on the substrate, thus achieving high efficiency and optimum light mixing.

Since light mixing is achieved mainly through light recycling of the recursion mode, highly reflective substrates are mandatory for acceptably low optical losses (Figure 2; right). We selected a white reflecting foil with 98% measured diffuse reflectance across the visible under normal incidence.

The capability of the developed solutions in homogenizing the LED light is shown in Figure 3. It is worth mentioning that, contrary to standard micro prismatic foils (such as, e.g., 3M brightness enhancement foils, BEF) those used in LASSIE-FP7 produce a nice diffusive and achromatic off-state appearance even under bright ambient light (not shown).

In addition to the light mixing and source doubling, the micro prismatic structures enhance on-axis

Figure 4:
Fully covered module observed off-axis. A small area has been purposely left uncovered to show the de-glaring properties of our light management solution

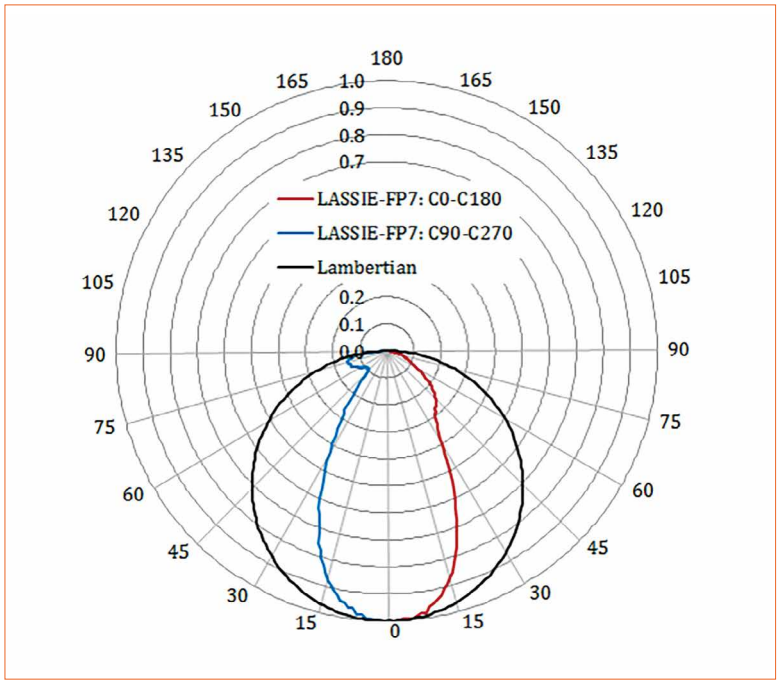


Figure 5:
Experimentally measured luminance intensity distributions with and without the light management solution

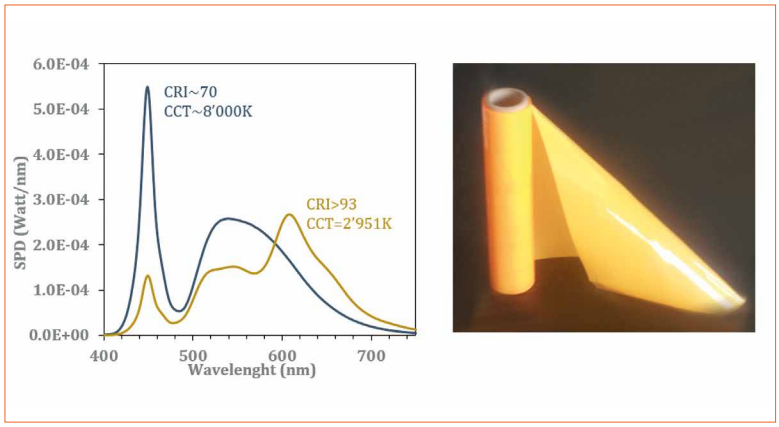


Figure 6:
Spectral power distribution, SPD (left), of the cool white (~8'000K) LEDs with (brown curve) and without (blue curve) BASF CCF. The CCT and CRI values are given in the inset. Picture of a BASF CCF roll (right)

emission at the expense of that emitted at high angles (Figures 4 and 5). The high directionality of the resulting beam is non-glaring and better suited to illumination of distant targets.

High-Quality Emission Spectrum

The human eye cannot easily discriminate between two metameric (same white point) visual stimuli. However, we see objects around us by the light they reflect and hence their appearance (particularly color) is determined by the objects' own nature as well as by the spectral distribution of the light source.

The capability of light to render natural colors, referred as color rendering, is defined in the CIE International Lighting Vocabulary as "the effect of an illuminant on the color appearance of objects by conscious or subconscious comparison with their color appearance under a reference illuminant". [17]

If a given color (wavelength) is missing or underrepresented in the emission spectrum of the light source, it will not be revealed in the reflected light. [18] Therefore, broadband spectral characteristics with no missing wavelengths render colors better.

High color-rendering LEDs are available commercially from the major LED manufacturers including OSRAM, CREE and Lumileds [19, 20, 21].

However, we know from the Life-cycle analysis (see Cost Analysis section below) that the largest contribution to the cost of the LASSIE-FP7 module corresponds, by far, to the cost of the LEDs themselves. The use of expensive high rendering LEDs will unavoidably result in an unacceptably high cost.

A proprietary technology, cost-competitive solution for high-quality light spectrum

BASF proprietary color changing foil, CCF, technology offers an excellent cost-competitive alternative to achieve high color rendering light. The flexible CCFs contain efficient organic phosphors embedded inside a thin polymer foil. The CCFs are produced entirely by roll-to-roll processes, which, together with the small phosphors quantities needed to have a substantial down-conversion, make these CCFs a cost-competitive solution.

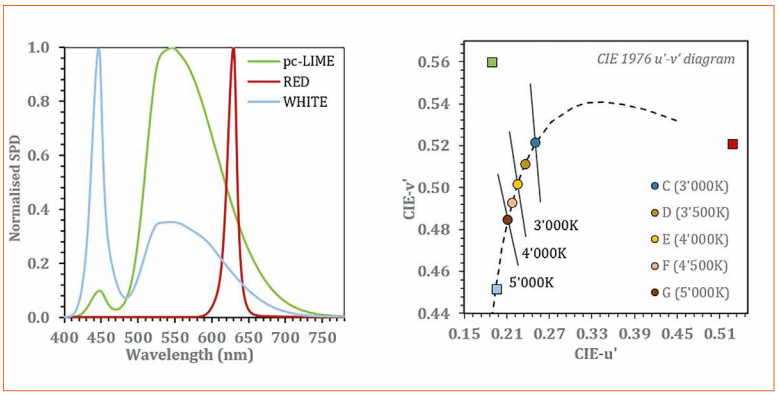


Figure 7:
Normalized SPD (left) and color coordinates (right) of the selected LEDs as provided by the suppliers in the datasheets

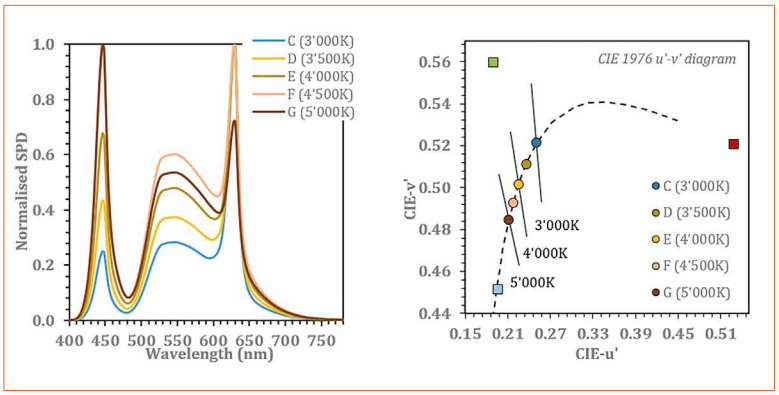


Figure 8:
Calculated emission spectra (left) expected for 3,000K (C), 3,500K (D), 4,000K (E), 4,500K (F) and 5,000K (G) obtained with 3014L and 3535L red and pc-lime LEDs at different relative radiant flux levels. The CIE u'v' coordinates (right)

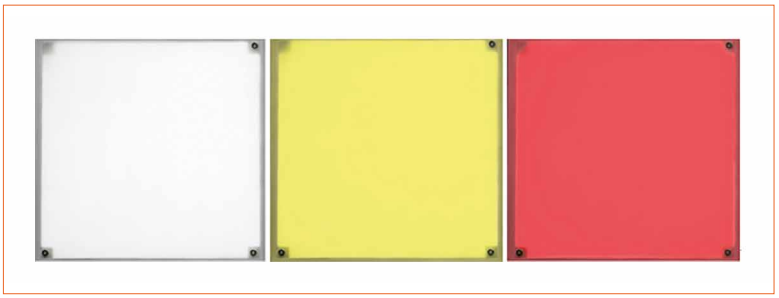


Figure 9:
Emitting surface of the LASSIE-FP7 module tuned to different colors that demonstrates that CSEM light management solution also offers excellent light mixing characteristics

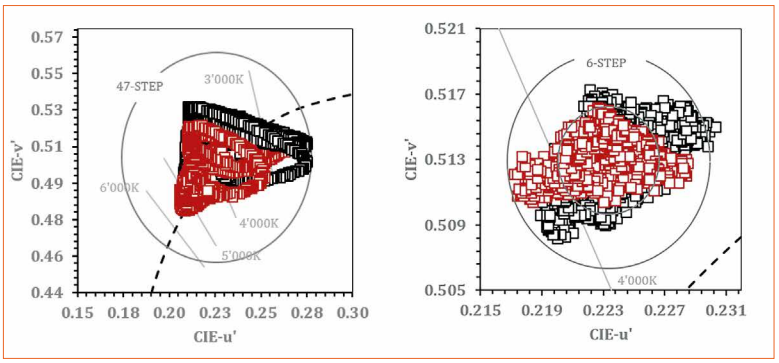


Figure 10:
CIE-u' and v' color coordinates measured over the emitting surface of the LASSIE-FP7 module with the diffuser (left) and with the complete 3-foil solution (right). The MacAdam circles [24] on the right figure correspond to 3, 4, 5 and 6-steps

High-quality spectral characteristics (column A in Table 1) have been experimentally recorded (Figure 6) using the CCF in combination with low-cost, LUXEON3014 cool white LEDs (CCT~8'000K) with poor spectral properties (CRI~70).

The luminous efficiency values of 102 and 87 lm/W were recorded with and without the CCF; the moderated optical losses associated to the Stokes-shift (7.7%) and the non-perfect quantum efficiency of the CCF (9%).

Spectral tuning with individually addressed colored LEDs

At the beginning of the century, the so-called Human Centric Lighting, HCL, appeared in the scene of lighting design. Among other features HCL exploits the variable spectra power distributions achievable with LED-based lighting modules that incorporate separately driven LED color channels. [22/p.336]

In LASSIE-FP7 we have investigated color tunable LED panels by introducing colored LEDs (LUXEON 3535L pc-lime and red) whose normalized SPDs and CIE-u'v' color coordinates are given in Figure 7. Since the color gamut defined by the LEDs contains all white points of interest, on-Planckian points in the (3'000-5'000 K) range can be achieved by selecting the adequate driving parameters on each channel (Figure 8).

The main properties of the SPDs are given in columns C-G in Table 1 where it can be seen that color rendering decreases with increasing light "coldness" especially in the TM-30-15 metrics. These results indicate that on-Planckian color tuning and high spectral quality requires additional color channels. Eventually, CCF technology may be used together with colored LEDs to alleviate the observed drop in quality for cool white.

Moreover, the addition of the colored LEDs brings about another interesting advantage, for they can, in combination with the intelligence system, compensate for the color drift of the white LEDs that will likely result following the phosphor degradation.

Finally, the thin-film light management stack described above demonstrated good color mixing properties (Figures 9 and 10). With color consistency below 3-step MacAdam across all viewing angles when measured at a fixed point of the module.

The spatial color variation is, to a large extent, a consequence of the LED layout (Figure 3) where LEDs of different colors are separated by a large distance. Arranging the LEDs into arrays of clusters is expected to render color constancy below 3-step MacAdam.

	A	C	D	E	F	G
CCT (K)	2'951	3'000	3'500	4'000	4'500	5'000
Δu'v'	0.0004	0.0001	-0.0001	0.0001	0.0000	0.0001
CRI	>93	87	87	85	82	79
R9	41	83	98	81	63	45
R_f (TM-30-15)	-	83	82	83	78	75
R_g (TM-30-15)	-	111	108	106	104	103

Table 1 (left): **Main characteristics of the relevant SPDSs shown in Figures 6 & 7**

Cost Analysis

Life cycle cost LCC, is a tool which takes into account all costs directly related to a product over its entire life cycle, from resource extraction over the supply chain to product operation and disposal phases. The continuous feedback provided by LCC has greatly supported us in the selection of the most adequate designs, materials and processes towards minimizing costs.

Life cycle Phase	Cost (EUR)
Production	320
Operation	37
Disposal	-0.26 (benefit)

Table 2: **Life-cycle cost of the LASSIE-FP7 module for the different phases**

The estimated cost of the LASSIE-FP7 module (Table 2) is higher than that of standard large-area LED-based modules for Professional Lighting. Nonetheless, our module offers features that are not available in standard products and make LASSIE-FP7 module unique for niche applications that prioritize light quality over cost. Color proof islands in clothing retail stores, with an estimated market size of 50,000 units per year, has been identified as the best fit for the LASSIE-FP7 module.

Production cost analysis

As indicated in Table 2 the production costs account for most of the total cost and hence will be discussed in more detail.

In the production phase, we used the MMM-cost model that stands for Man-Machine-Material, the three principal production costs, although additional elements such as overheads (15%) and margin (15%) have also been accounted for. Furthermore, our methodology for risk-profitability analysis uses the CAPM (Capital Asset Pricing Model) method.

The cost associated with the production of the LASSIE-FP7 module described in the preceding sections is dictated by the cost of each component and the cost of the assembly process and includes the contribution from labor, material, energy and machine costs under the conditions summarized in Table 3.

The module components are the LED foil (including heat management structures), the light and color management solutions and the intelligence.

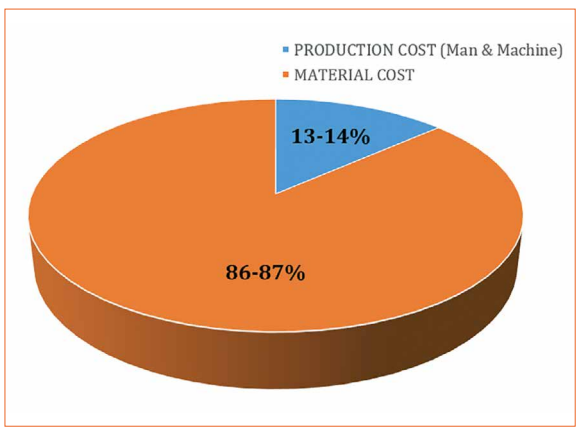
Market size	50,000 modules/year
Operation	5,520 hrs/year (3 shifts; 5 days per week)
Module size	600×600 mm²
Module assembly	25-35 EUR/unit - subcontract
Maintenance cost	5% of the investment
Stock	None
Luminous efficacy	90 lm/W
CCT	~ 3'000K
Colored LEDs (Luxeon 3535L)	882
White LEDs (Luxeon 3014)	441

Table 3: **Conditions used in the LCC analysis related to the production phase**

The largest part (86-87%) of the estimated cost of the LASSIE module corresponds to the cost of the materials (Figure 11).
In particular, the LED foil represents the largest contribution (67% - Figure 12), being the cost of the LEDs themselves and related processes (substrate, LED and resistor bonding, thermal management structures, etc.). Other components of the foil (substrate, conductive bus lines, and thermal resistors) play a much more minor role.

In particular, the LUXEON 3535L colored LEDs is ~6.5 times higher than that of the cool white LUXEON 3014 LEDs (0.13 vs. 0.017 EUR/LED for quantities above 1,000,000 units). This indicates that the color tuning/correction capabilities represent the main contribution to the total cost.

This result is in line with the trend observed in commercially available



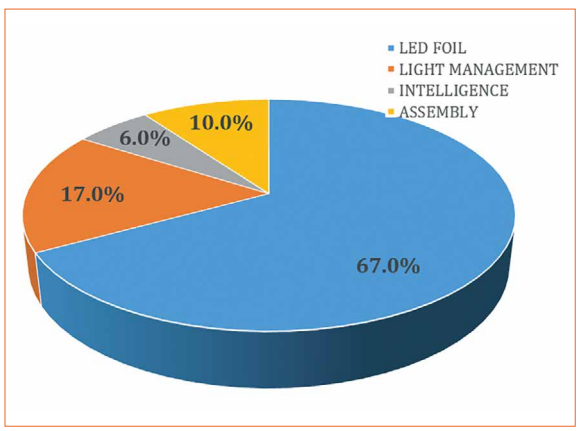


Figure 11 (left): **Relative cost contributions of the materials and production of the LASSIE-FP7 module**

Figure 12 (right): **Relative cost contributions of the components and assembly used in the LASSIE-FP7 module**

Table 4:
Technical specifications of MEXXOTECH LED panels with and without color tuning capabilities [23]

Model	X1-40K-HI	X3-30K-56K-HI
Luminous flux (lm)	6,900-7,300	6,700-7,500
Efficacy (lm/W)	92-98	90-100
CCT (K)	4,000	Tunable (3,000-5,600)
CRI	> 90	> 90
Dimensions (mm)	617 x 617 x 47.4	617 x 617 x 47.4
Lifetime (hours)	>60,000	>60,000
Retail price (CHF)	695	1,495 (excluding DALI)

color tunable LED panels.
For example, MEXXOTECH offers two similar modules (Table 4) with and without color tuning; the latter retailing at less than half the price [23].

Conclusions

The potential of thin-film optics has been demonstrated to improve photometrical as well as spectral properties of LED-based large-area panels.

The incorporation of the three-foil stack designed by CSEM has demonstrated an increase in luminance uniformity form nearly zero to 86% for a DHR value well above unit.

On the other hand, using the cost-competitive CCF technology from BASF, the low quality light emitted by low-cost bluish LEDs can be down-converted into a warm highly rendering white light.

On-Planckian color tuning using three independently addressed (color) channels is also demonstrated but a price in the rendering ability must be paid when cool white light is pursued. The observed depreciation of the rendering properties in the bluish part of the white zone can likely be solved by combining colored LEDs together with the CCF technology.

The addition to color tuning, colored LEDs permit color correction to counterbalance the degradation of the white LED phosphor and the concomitant white point drift hence maintaining a constant white point across the lifespan of the module.

The incorporation of color tunability has a substantial impact on the production cost of the module driven by the cost of the colored LEDs. For this reason such module fits niche applications (e.g. color proof islands in retail clothing shops) where the tunability represents a huge added value regardless the cost increase. ■

Acknowledgments

The authors would like to thank Gerhard Wagenblast at BASF (Ludwigshafen, Germany) for his support with the characterization of the Color Changing Films and Kimmo Keränen at VTT (Oulu, Finland) for the supply of the LED foils.
The research leading to these results has received funding from the European Union Seventh Framework Program [FP7/2007-2013] under grant agreement n°619556, project LASSIE-FP7 (http://lassie-fp7.eu/).

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Smart LED System in Package through Wafer Level Integration Approach

It is believed that LEDs will dominate all lighting applications in the near future. Integration and packaging are the two critical issues that, if resolved, will enable efficient and reliable solutions for lighting requirements. Z. Kolahdouz, H. van Zeijl, and G. Q. Zhang from the Institute of Microsystems and Nanoelectronics (DIMES) at the Delft University of Technology, and M. Kolahdouz from the Thin Film Laboratory and Nano-Electronics at the Department of Electrical and Computer Engineering of the University of Tehran show that wafer level packaging is a promising method to ensure lower cost, higher scale, and superior yield. A new integration approach of a smart unit of LED lighting is introduced: LED System in Package (SiP).

Emerging high power light emitting diodes (LEDs) was a key step for the development of new application areas in lighting [1-4]. The most common manufacturing approach for high power white LED source is the dichromatic method, which is also entitled as the phosphor-based white method. It is a combination of a short wavelength LED, such as blue or UV, and a phosphoric wavelength shifter. In the phosphor coating, a portion of photons are converted to yellow and the rest travel without any change. The light output is seen as a white light by human eyes [1-3]. This method shows good color rendering, long lifetime, and acceptable reliability over time. However, aging and high junction temperature affect the emitting wavelength and intensity [4-6]. This degradation may refer both to phosphor coating and LED chip performance over time. While the phosphor working mechanism is related to the manufacturing process [1], we can compensate LED aging and adjust its light intensity by controlling its driving current in a closed-loop system [7].

Silicon based Wafer Level Packaging (WLP) is the technology of choice for broad range of applications. This technology is a key in terms of cost and thermal design. It can provide batch fabrication and component integration, as it is compatible with CMOS technology and thus, can include microelectromechanical system (MEMS) components

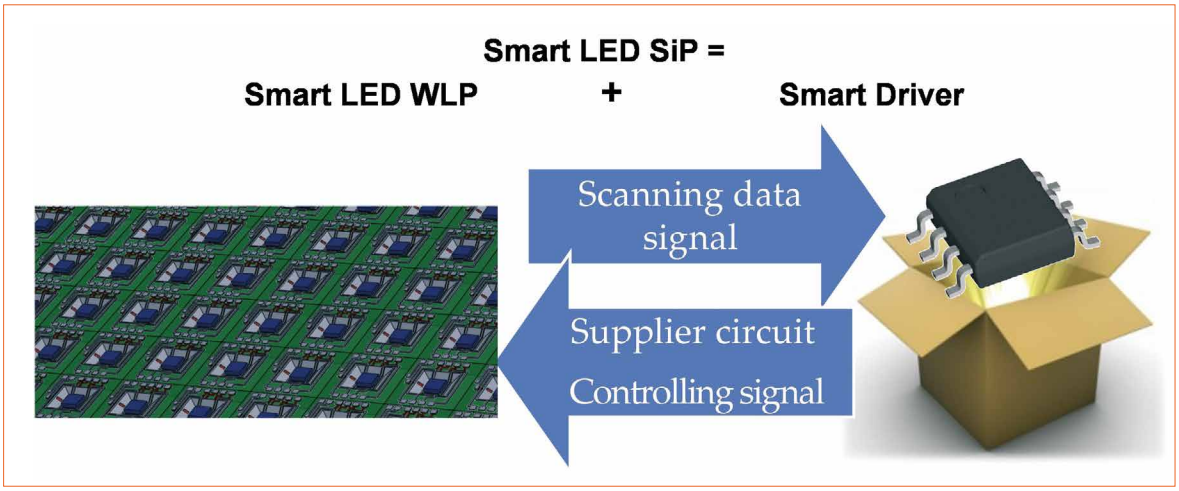


Figure 1:
A smart LED system comprising a smart LED WLP and a smart driver

as well [5, 6]. Applying these technologies, a smart LED package can be produced that resolves the brightness problems associated with LED intensity decay [6].
There are two categories of silicon-wafer-based WLP LEDs; the surface-mount type, in which electrodes are formed on a silicon wafer and then the LED chip is attached to the wafer; and the cavity type, in which cavities are formed prior to the electrodes [6].
Generally, the cavity is fabricated using KOH wet etching on a (100) silicon wafer. The cavity acts both as a reflector and a holder for filling phosphor and resin.

Another concern is large heat dissipation in such a high power package. Silicon wafer-level-package (WLP) can be a good solution for thermal management and a cost effective integration [6, 9, 10].
Using silicon-based infrastructures, IC technologies, and MEMS toolset and processes allow us to integrate different functional sub-blocks on the same die.

Monolithic integration of photonics and electronics in Si and other group IV elements was previously demonstrated [11-13]. Different groups reported integration of sensors and controlling blocks in Si-based LED WLP [6, 14-16]. However, developing a complete real-time light output controlling block in a low-cost process is still a point of interest.

In this article, a new integration approach of a smart unit of LED lighting is introduced: LED SiP. It comprises a smart LED wafer level package and a smart driver.
This concept is depicted in Figure 1. Smart LED WLP is used as a Si based interposer for LED chips. Firstly, it integrates the wafer level optics, related interconnections, monitoring devices and powering circuits. An LED chip would be mounted later. In addition, to make the package smart and leverage semiconductor process, as much controlling functions as possible would be integrated into the silicon interposer. Smart driver is the brain of the total system. It works both as a driver circuit to supply power and a controller. By getting real time sensing data of the package, it can have better control over electrical and thermal management. Also, wireless communication and remote control functions can be included. Due to the rather large nature of LED chips, the final Si utilization yield of the interposer cannot get that high, but simple low cost processing can compensate the total cost of the package.

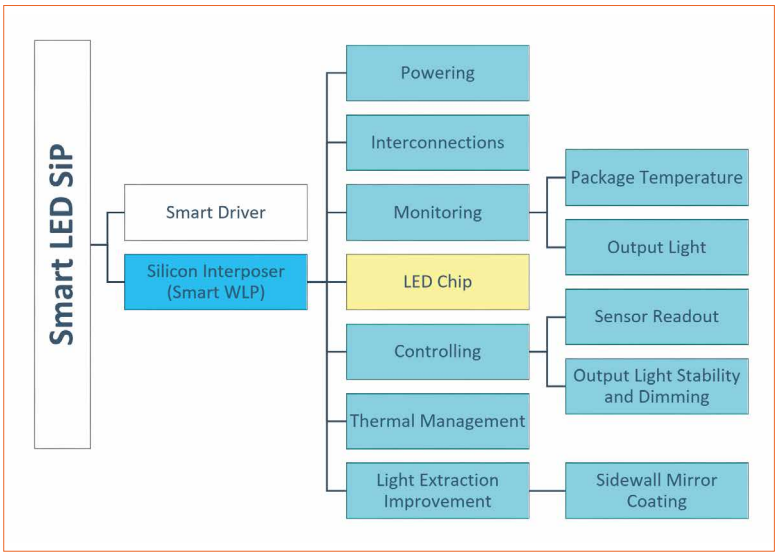


Figure 2:
Different functions in a smart LED SiP (scope of this article is shown in color)

Smart LED SiP

The main focus of this article is on the smart WLP part. The final smart WLP is a high lumen output lighting module. It includes high current blue LEDs and different sensors in a reflector cavity. In this Si interposer with a high topography, lithography defined wiring is used as a reliable interconnect solution. Additionally, the control circuit of the LED output light was integrated on the same die to reduce costs of any required external circuitry. In more detail, the interposer monolithically integrates on-chip reflector cavity, sensors, remote phosphor layer, litho-defined wiring, power switching transistors, digital sensor readout circuit, and analog light feedback circuit into one smart LED WLP [17].

Different functions and operation levels of this system are presented in Figure 2.

The advantages of such a LED SiP are:

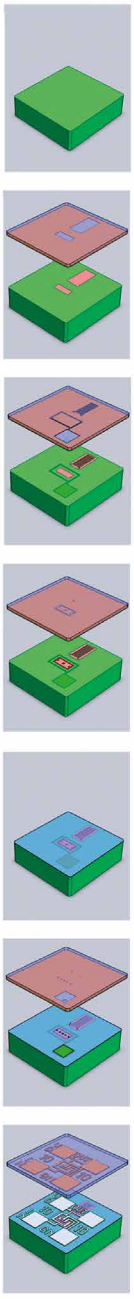
- Capability of wafer-level optics
- Capability of wafer-level phosphor remote coating for stable color uniformity
- Higher brightness efficiency: on-chip reflector cup (cavity with mirror coating) reflects the sidelight and improves light extraction efficiency up to 15%
- Better thermal management: high thermal conductivity of Si substrate
- Lifetime improvement: self-monitoring system
- High reliability: better interconnect reliability, closed-loop feedback circuit for stability and aging compensation

To do so, BiCMOS 5-7 process was employed. It is a straightforward process that by just using 5-7 masks (corresponding to 1-2 metal layers) can monolithically implement different devices such as MOSFETs, BJTs, diodes, and resistors.
The seven masks include N-well, N^+ area, P^+ area, contact opening, first metal, via opening, and second metal. Table 1 lists core of the process consists of 5-7 mask steps. A brief process overview is given in Figure 3. More details on BiCMOS process can be found in [7]. Due to large die size of LED chips, BiCMOS5/7 has a large potential to be utilized for WLP of smart LED systems [7, 18].

Table 1: Core process mask steps of the BICMOS5/7 process (the grey shaded ones are added for BiCOMS7)

Mask name	Main purpose
NW	• N-type area for the PMOS transistor (N-well) and for the collector of the bipolar transistor
SN	• N-type source-drain for the NMOS transistor and for the emitter of the bipolar transistor • Low resistance collector contact • N-type guard ring
SP	• P-type source-drain for the PMOS transistor and for the base of the bipolar transistor • P-type guard ring
CO	• Contact openings
IC	• Interconnect and gate material
VIA	• VIA openings
IC2	• Second interconnect layer

Figures 3 a-g: Process overview of the core steps in the BICMOS5 process



(a) Start material: p-type silicon.

(b) Mask 1 is used for patterning the phosphor implant and deep diffusion of n-well and n-type collector.

(c) Mask 2 is used for patterning the shallow boron implant for p-type source/drain and p-type base.

(d) Mask 3 is used for patterning the shallow arsenic implant for n-type source/drain and n-type emitter.

(e) The wafer is annealed and the surface is thermally oxidized (100 nm SiO_2).

(f) Mask 4 is used for contact opening and wet chemical etching.

(g) Mask 5 is used for interconnect metal. AlSi (1%) is deposited using PVD and patterned and etched with dry etching process.

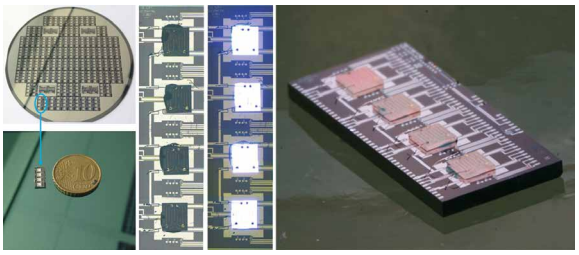


Figure 4: Monolithically integrated 2D LED SiP

Silicon-based WLP through low cost 7-mask BiCMOS process gives us the opportunity for integration of different passive and active components for a complete smart system. For sensing functions, thermal and optical sensors were implemented, characterized, and calibrated. Light measurement of the LED chip through the blue selective photodiode showed notable consistency to the LED datasheet values. Temperature sensors integrated just beneath LED chips, measuring the temperature in real time and the results were confirmed with IR photos. For controlling functions, a 4-bit flash ADC for reading out sensing output light, and a power switch for driving the LED current (up to 700 mA) were monolithically integrated. The reported components provides an essential platform for future work to have an analog or digital control system for any specific application. Furthermore, other technologies with large area demand such as Lab-on-Chip can benefit from this approach by utilizing smart silicon interposers. Figure 4 depicts some figures of 2D implementation of LED SiP.

A silicon stripe-shaped photodiode was designed and fabricated for sensing blue light in the LED wafer level package. The maximum responsivity was at 480 nm, which is matched with the blue LED's illumination. This IC technology compatible photodiode, with junction at 330 nm, demonstrated a very high selectivity to blue light. The fabricated device presented a two-fold increase in the responsivity and quantum efficiency for blue light spectra compared to similar devices published earlier [7, 19]. The 3D schematic and the measured responsivity vs. wavelength are given in Figure 5(a) and (b), respectively.

To guarantee a stable light output that is linearly controllable with a reference input voltage, a monolithic light output feedback control circuit was integrated. It is also an appropriate solution for packaging a phosphor-based white LED module. Si-based wafer level smart control unit was integrated through our low-cost 7-mask BiCMOS process. For sensing blue/UV light in the package, the photodiode with its peak responsivity at 480nm wavelength was used. For controlling functions, a feedback circuit with a power transistor for driving the LED current was monolithically integrated. The opamp functionality was successfully tested with having 47 dB gain. The whole feedback circuit could regulate light output based on a reference voltage with removing power supply ripples even at very high frequencies

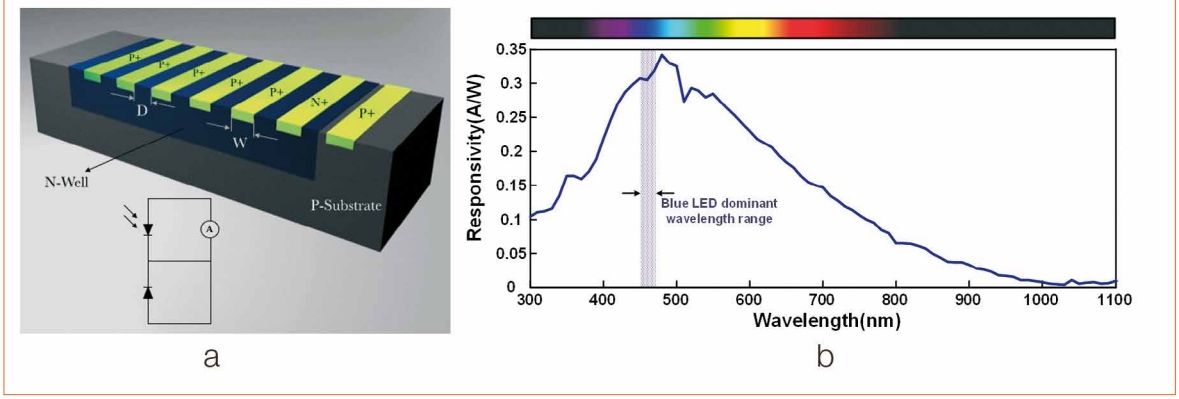


Figure 5a,b:
3D schematic of a blue selective photodiode (a), and responsivity vs. wavelength (b), measurement result (the patterned inset shows the dominant wavelength of the target LED)

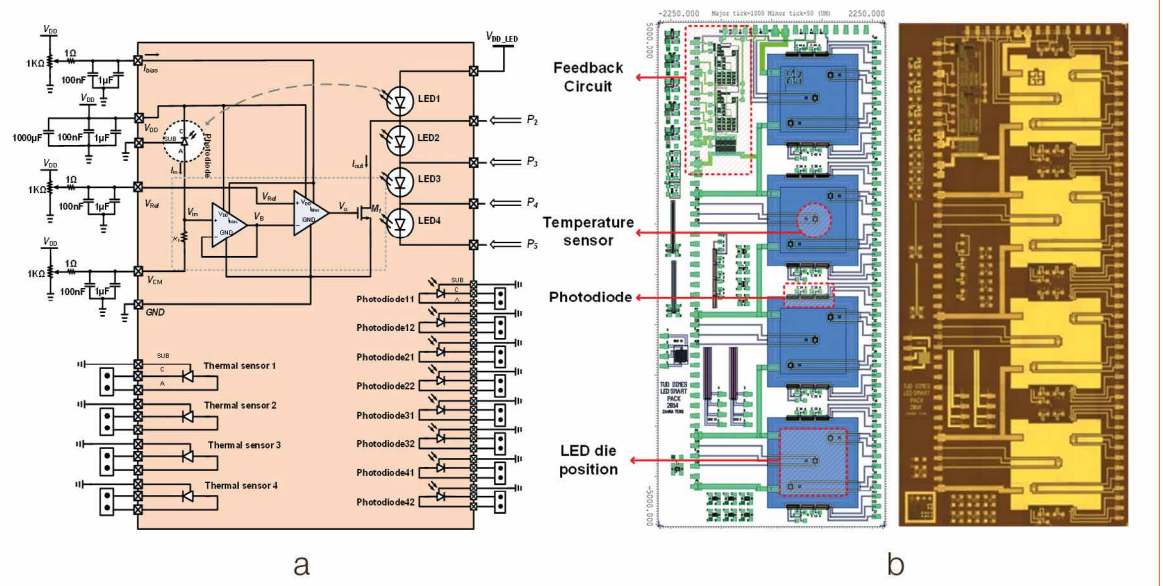


Figure 6:
Schematic of the package (a) and layout and chip micrograph (b) showing component positions in the package

(up to 680 kHz). Robustness of the feedback system was tested against changes in LED current/voltage to light intensity characteristics, which can be caused by aging or temperature changes. Considering a tight error tolerance of 1% for the light intensity, the system was able to handle up to 150 mA and 0.6 V change in current and voltage characteristic of the LED. Furthermore, it demonstrates the functionality of silicon based smart LED packaging with stable and regulated light output. This can also be applied to other smart systems like interposer for high-level electronics, MEMS, etc. Figure 6(a) illustrates complete schematic of the package with components used on its test board. The layout and chip micrograph is given in Figure 6(b).

New challenges were emerged by moving from 2D SiP to a 3D package. In this case, a KOH etched cavity in Si interposer makes a high topography that brings up new challenges. It acts as a precision cavity with aluminum coating in place of sidewall mirror. The main challenge is the lithography aspect-ration with steps over a few hundred micrometers topography.

To overcome the conventional lithography limitations over high topographies, a high aspect ratio (HAR) lithography approach was developed that can be used both for the 3D SiP and, in general, for litho-defined lateral wire bonding. Litho-defined wire bonding uses conventional CMOS interconnect toolset and processes in combination with multi-level lithography aiming for “wire bond like” interconnect structures and HAR interconnects. It also enables advanced heterogeneous integration of different components with less reliability issues and problems. This method consists of placing and attaching the chips on supporting substrate, passivation layer deposition, metal deposition and patterning through advanced high aspect ratio.

(3D) Lithography, which is the main key for such a method [20]. This method can be applied for heterogeneous integration areas, where a reliable and flexible interconnection method is critical.

Finally, a 3D silicon interposer was designed and fabricated for smart wafer level packaging of phosphor based white LED modules. It integrates different planar control blocks in addition to an on chip active reflector cup, which can improve light output efficiency of the package. The cup is implemented

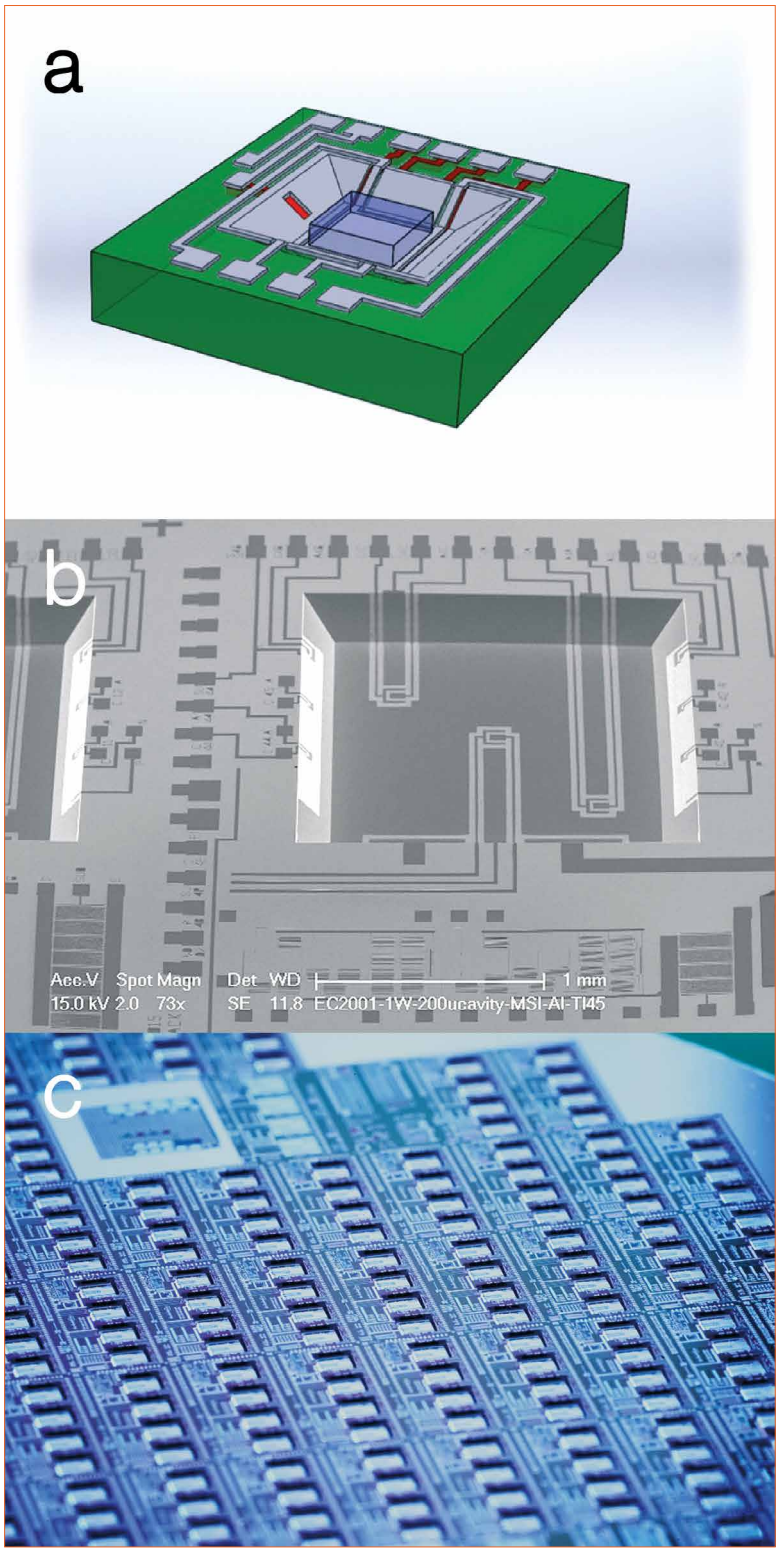


Figure 7:
Unit cell of a 3D LED WLP, LED chip is mounted on an active reflector cup including sidewall light sensor, bottom temperature sensor and high aspect ratio litho defined wiring lines (a), SEM image of an active cavity including bottom and sidewall sensors, controlling blocks on top and litho-defined wiring (b), and photograph of a wafer level integration of 3D Si based interposer for Smart LED SiP (c)

with a 200 µm KOH cavity coated later with a thin aluminum layer to form a mirroring sidewall. Furthermore, temperature and light sensors were fabricated on the cavity bottom and sidewall, respectively. The wires for LED driving current and sensor connections were patterned the whole way from top surface to cavity bottom. The fabrication process was the modified BiCMOS7 with 2 µm gate length. This new process enables to integrate different sensors and transistors on the top plane, cavity sidewall, and bottom. It also provides integration of large area LED chips with other functional devices. Different sensors were characterized. The bottom temperature sensor showed linear behavior of forward voltage versus package temperature at a constant forward bias current. The sidewall photodiodes with multi-stripe anode demonstrated a high responsivity to the emitted light. This is for the first time that a functional active device is fabricated on the sidewall of a silicon cavity.

The suggested smart Si-based interposer is not only applicable for LED WLP, but for a broad range of applications especially the ones with large area devices. It can monolithically integrate different performance monitoring and controlling blocks, in a low cost/area process line, which make a smart interface for the main device.

Conclusion

Taking part in this tremendous developing industry and market demands, wafer level packaging can be considered as a key processing point. At present, most LED components are made with single chip packaging technology. The main manufacturing processes follow conventional chip-based IC packaging. So there is a need for LEDs to migrate to wafer level packaging to use the same benefits as IC's. Hybrid integration of LED chips on a Si interposer can reduce the cost, and moreover, eases the integration of various functional devices. Using Si devices and capabilities makes it possible to design and fabricate a smart lighting module as a SiP for broad applications, especially in the Internet of Things (IoT) area. As IoT promises application diversification, the spotlight is now turned to advanced packages in order to answer market demands. ■

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Variability in LED Production and the Impact on Performance

LEDs are subject to manufacturing deviations, which have an impact on the end product. Benoit Bataillou and T. Merelle, guest authors from Pi Lighting, review the surprisingly large impact on LED performance and light quality. They used traditional as well as modern indicators like CRI and TM-30 as well as the latest circadian indices to measure. The results are explained by spectral modeling and a variability study. They show the large impact on CRI, even with small deviations inside the same bin.

One of the most known but least understood subjects is LED variability. Variability is, as Wikipedia defines it, how a distribution or series of data is stretched or squeezed. – But where does it come from?

A white LED is a little system. A semiconductor device (or several devices), is covered with an encapsulant and phosphorus connected inside a package, sometimes with an extra primary optics on top. For those who come from the "Silicon world", the first striking difference in the LED world is the material defects quantities- Without going in too many details, one can assume about 5 to 7 orders of magnitude between the density of crystalline defects within the grown LED material and a regular epiwafer for the silicon world [1].

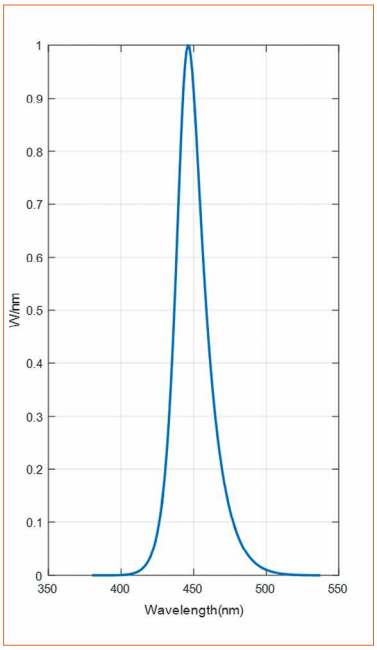


Figure 1:
Royal blue InGaN LED, also nicknamed a "pump"

The structure itself, the emissive part of the blue die, is a stack of layers of different composition, each of them of an average 2 to 3 nanometers thick [2]. This is a crystalline layer of 6 atoms thick, covering the area of the device (typically 0.5 to 1 square millimeter). In this structure called quantum wells, each variation of thickness leads to a different light emission. There is a batch effect (lot to lot), a tooling effect (tool to tool) and statistical effects (variation of well thicknesses).

Contributors to Variations

So first, the light emission of blue has intrinsically a large variability, and those large peaks a blue LED shows are well known. Showing those peaks to experts in II-VI semiconductors or GaAs epitaxy engineers, I overheard in the lab that those peaks were more "potatoes" than peaks. The position of the peak also moves with the content of the quantum wells and their average thickness.

Second, the rest of the LED also brings in variability. Phosphorus is a mix of several compounds, doped garnets embedded in a matrix. This material has the property to absorb (not equally) a set of wavelengths and convert them (not equally) to longer wavelengths.

Third, the package and reflections within the package cause another source of variability, slight misalignment of the die within the package can cause different light paths, and such different color shifts.

The result of this, and everything above depending on current and temperature, is white light that the eye (which is quite a nice color sensitive device) detects.

From this over-summarized view, LED production can be expected to be a fine cuisine (and cuisine is an

art where I come from), and will show consequent variability in the resulting color points.

What does it give us? A population of "identical" LEDs, which are actually far from identical, from which the manufacturer will select bins (color bins, Vf bins, CRI bins, etc.), to reduce variability. In the rest of the paper ANSI binning will be used as basis, as it's the most popular binning approach. But all apply to divide the color space.

Simulating Variability

The following example of simulation of variability demonstrates a simple case. Starting from measuring a single LED, from a manufacturer that was nice enough to participate in this study, a model was developed to fit it.

Starting from this "champion LED", the spectrum will slightly be modified to evaluate the consequences.

Being relatively satisfied with the fit quality, the two peaks (the blue peak and "yellow" peak) were extracted. Then, the position of the blue peak was slightly changed, and the resulting variations in the phosphorus composition were simulated by changing the height of the yellow peak.

A "virtual binning", will be done and the spectra chosen with color points staying inside the four "ANSI 4000 K" bins [3].

Of course, models must be validated. To do a quick check, two extra LEDs were measured, provided by the same manufacturer, located in different sub-bins of the same large bin (we are trying to obtain color points far away from the champion LED color point).

Those LEDs were measured looking in the large color cloud for two color points as close as possible. Then the spectra between the original simulation and a real LED located at same color point were compared. The result is shown in figures 4.

From the figures above can be recognized that there are some slight differences, so the validation of the model is not perfect, but overall the spectrum is well represented.

Now what? Assuming that a population of LEDs is adequately correct simulated, it is possible to have a look at the variability of the different colorimetry metrics.

Logically, CCT varies of 225 K (the size of the bin). More interesting is the variation of CRI within this color cloud.

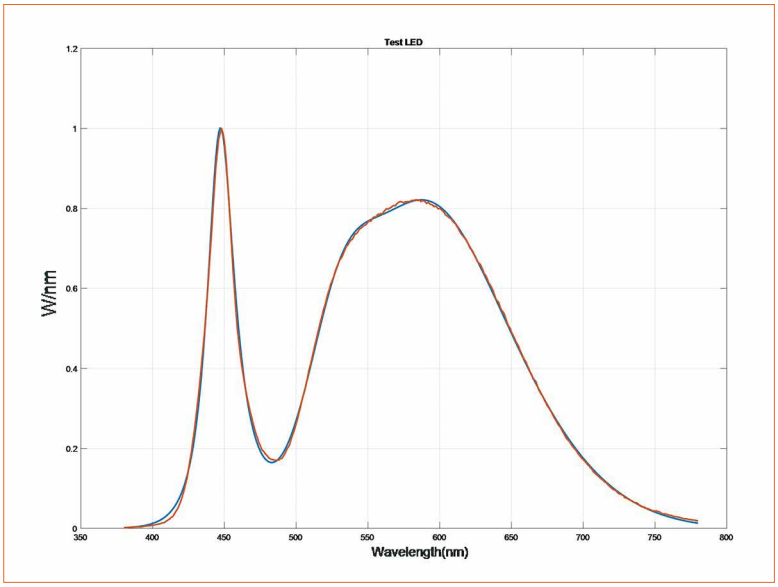


Figure 2:
The champion white LED spectrum(orange), and the model fit (blue)

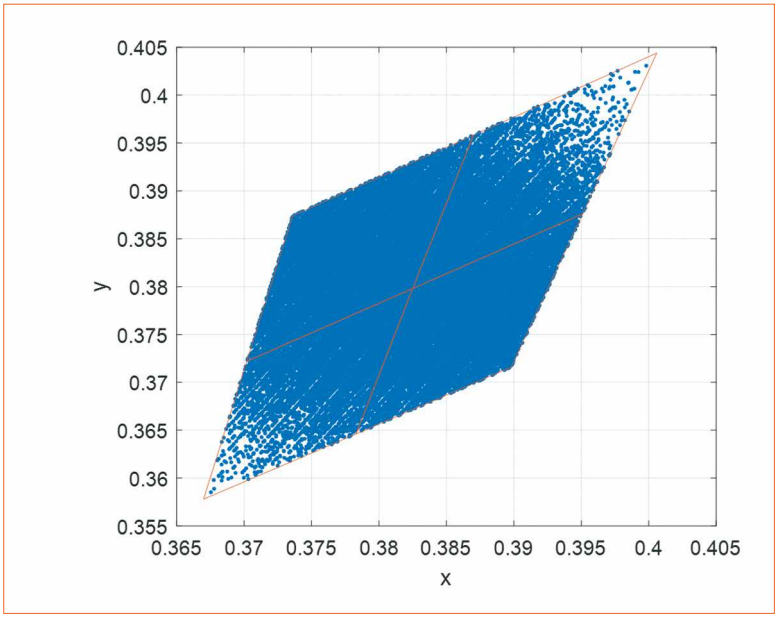
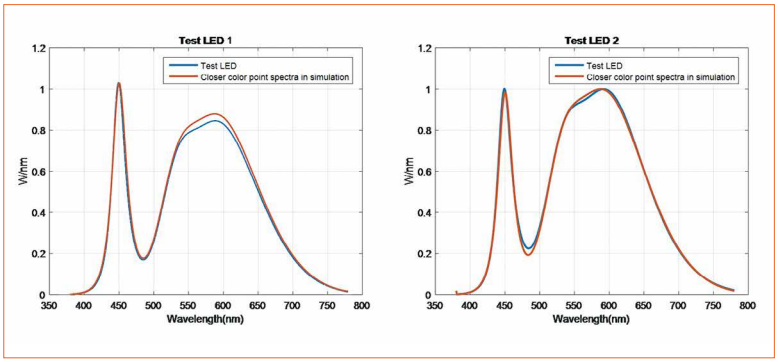


Figure 3:
4000 K ANSI bin LED divided into 4 sub-bins, and 85000 color points of virtual LEDs obtained by modifying the champion white LED



Figures 4:
Two new LEDs, measured and compared with spectra in cloud above where the color point is as close as possible

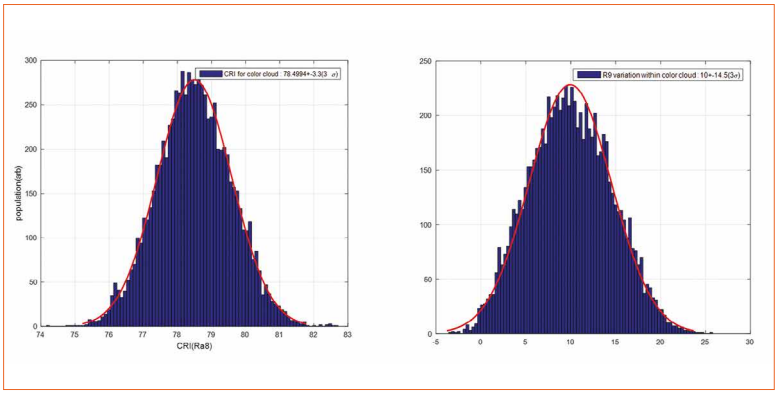


Figure 5:
CRI and R9 variations (and normal fits) due to the small spectral differences within ANSI 4000 K bin

There is a variation range of approximately 6 points of CRI, and 29 points of R9. In terms of percentages, R9 has variability close to 300% (3 standard deviations), ranging from negative values up to 25.

It is noteworthy to mention that the only cause of this variation is the small spectral changes from an LED to another within the same bin.

Figures 6a&b:
Equations to calculate CL_A (a) and CS (b)

a

$$CL_A = \begin{cases} 1622\left[\int Mc_\lambda E_\lambda d\lambda + \left(a_{b-y}\left(\int \frac{S_\lambda}{mp_\lambda} E_\lambda d\lambda - k\int \frac{V_\lambda}{mp_\lambda} E_\lambda d\lambda\right) - a_{rod}\left(1 - e^{\frac{-\int V'_\lambda E_\lambda d\lambda}{\text{RodSat}}}\right)\right)\right] \\ \qquad if \int \frac{S_\lambda}{mp_\lambda} E_\lambda d\lambda - k\int \frac{V_\lambda}{mp_\lambda} E_\lambda d\lambda \geq 0 \\ 1622\int Mc_\lambda E_\lambda d\lambda \quad if \int \frac{S_\lambda}{mp_\lambda} E_\lambda d\lambda - k\int \frac{V_\lambda}{mp_\lambda} E_\lambda d\lambda < 0 \end{cases}$$

b

$$CS = 0.75 - \frac{0.75}{1 + \left(\frac{CL_A}{215.75}\right)^{0.864}}$$

Circadian Indexes and MR Variability CS

Circadian index CS and MR (Melanopic ratio) represent the disturbance of the circadian clock by a given light. Circadian index follow a rather complex formula. Details of the calculations can be found in the publications from Lighting Research Center/RPI [4].

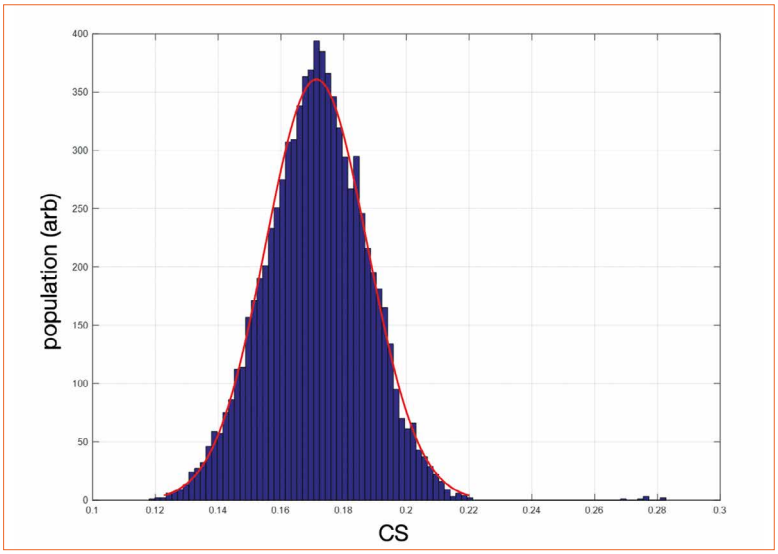


Figure 7:
CS@250lux distribution within 4000K ANSI bin

The CL_A is the complex basic formula needed to calculate CS, which is then calculated as using the CL_A [5], shown in figures 5a&b.

This metric is spectral AND illumination dependent, so the calculations are done at 250 lux. Looking at the cloud of LEDs, one will recognize a surprisingly large CS distribution within the 4000 K bin.

CS average is 0.17, with a variation (3 standard deviations) of 28%.

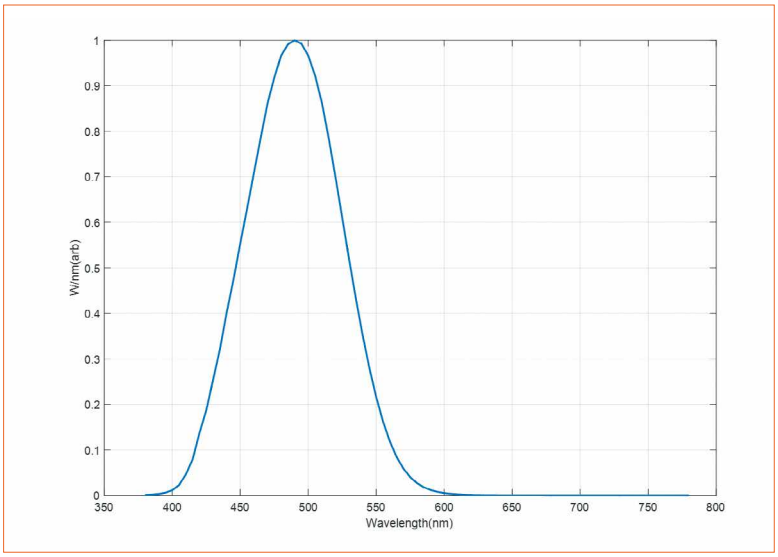


Figure 8:
MR calculation - the Melanopic curve above, times a spectrum, divided by flux, is the MR

MR

MR or Melanopic Ratio represents the quantity of light present under a specific curve (similar to the Mc quantity in the CL_A/CS equation), divided by the luminous flux. This gives a “circadian content” which is convenient to use practically. This quantity is only spectral dependent. The MR times the illumination gives the EML, Equivalent Melanopic Lux.

Applying this to the population of 4000 K LEDs, one will see that the distribution centered at MR=0.61 ±14% (3 standard deviations).

Conclusions

The investigation and simulation showed that within a single ANSI bin, the variability created a surprisingly large spread on all studied quantities. The CRI, R9, Cs, MR, had variations between 14% and 300%, for a single ANSI bin.

Going further, it can be seen that the specifications are intricate. The CRI specification a manufacturer will provide, or a user will ask of a manufacturer, is dependent on the provide or accept color spread.

The more and more popular circadian metrics will also depend on the other specifications.

As for the color cloud itself; conclusions on the impact of variability can be made by comparing two different spectra that look “similar” and their color shifts.

The color points of those two spectra, which look “similar”, are not in the same color bin. They are at 0.009 u’v’ distance, which is what is often assume to be about 9 SDCM or 9 MacAdam ellipses. They also have a difference of 283K and a difference in R9 of 150%. In practical use, one would consider those two LEDs to be very different one from each other, despite a very similar spectrum.

Color points, which are a simulation of how the human color perception works, are very sensitive to any spectral variation. This means LED users must be careful when specifying too narrowly.

And on the LED manufacturer side, offering very narrow color spreads is also a natural tendency, but variability can lead to large yield losses and unrealistic expectations from customers.

Finally, the model can be extended to individual phosphorus peaks, linked to more “physical” parameters (phosphorus thicknesses and content, etc.), as a basis for a more detailed study. ■

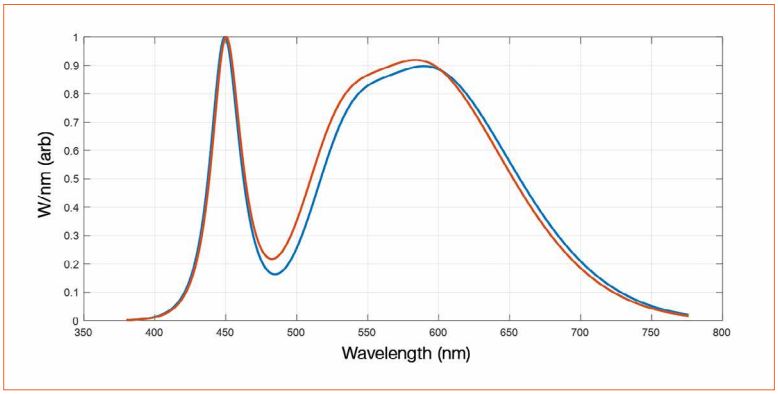


Figure 9:
Two “similar” spectra picked in the color cloud. Same blue pump, <5% difference in W/nm

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Technology Challenges in Professional Tunnel Lighting Applications

The guide for tunnel lighting CIE 088:2004 is the most established international standard for the illumination of road tunnels. However, Switzerland's ASTRA (Bundesamt für Strassen) and the ASFINAG in Austria both provide guidelines that go well beyond these requirements. Maximilian Herzig, Product and Key Account Manager Lighting at SWAREFLEX GmbH shows solutions to satisfy these requirements and explains why the commonly used value of "lumen per watt" is not a perfect method of evaluating system performance and efficiency.

The main purpose of general tunnel lighting is to prevent accidents and enhance safety and comfort for the drivers that drive through or enter a tunnel, by providing maximum visibility of any objects on the road surface.

The CIE 88 - Guide for the Lighting of Road Tunnels and Underpasses provides a guideline for tunnel lighting that serves as a basis for many national regulations. It divides the tunnel into different zones according to the specific requirements in each one of them. The threshold zone requires very high luminance values in order to facilitate the adaptation of the driver's eye to the darker lighting conditions in the tunnel compared to the higher outside lighting level. The length of the threshold zone is defined by the speed limit at the tunnel portal, as higher speed limits require a longer threshold zone. In the following transition zone, the luminance on the road surface is slowly reduced until it reaches the lighting level of the tunnel interior zone, offering a smooth adaptation from the entrance levels to the lower interior levels. Typical values, considering a maintenance factor of 0.67, in the first half of the threshold zone are around 150-300 cd/m², while the interior zone usually is limited to 2-6 cd/m².

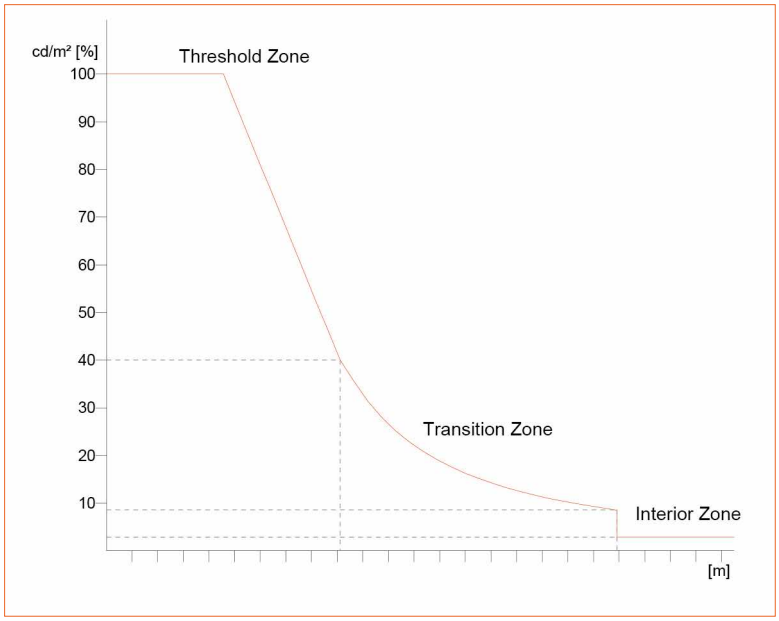

Figure 1:
Adaptation curve of the luminance in tunnels

Currently acknowledged parameters for the quality of lighting in road tunnels include total and longitudinal uniformity of the lighting on the road surface (ideally no flickering light / dark transitions), the lighting of the tunnel walls, avoidance of glare as well as color temperature and color rendering. As in recent years, semiconductor technology reached a state in which the LED became a more than feasible alternative to conventional tunnel luminaires with sodium vapor lamps. Many national standards shaped the requirements on the mentioned parameters into new forms.

New LED Tailored Standards

Besides regulations of, for example, Switzerland's ASTRA (Bundesamt für Straßen), the planning manual (PLaPB 800.562) of Austria's ASFINAG from 2016 is one of the first standards that is specifically tailored to the potential offered by LED tunnel lighting systems. While it introduced a clustering into different tunnel lighting classes, specifying not only different lighting requirements per cluster but also defining different distances between luminaires, from up to 18 m (cluster standard) to a continuous luminaire line (cluster premium), it also declared different demands on energy efficiency and lighting color as well as color rendering. Color rendering may not seem the most important topic in tunnel lighting, but given the increasing amount of different markings in signal colors inside road tunnels, it is important to quickly distinguish yellow from red, or blue from green. And still, the advantages of LED systems compared to conventional lighting systems go beyond true color lighting, high luminous efficacy and efficient light distributions via lenses. LED systems can offer analog dimming in the interior and also entrance zone, thereby eliminating problems regarding luminance uniformity on the road surface caused by switching off whole groups of luminaires. Current LED tunnel systems already turned into intelligent solutions that communicate the current state of the luminaire as well as the driver (temperature sensors, input voltage measuring, DALI communication). However, there are still discussions where the supply and control electronics have to be integrated. Some tunnel markets require intelligent drivers inside the luminaire while others demand all electronics to be installed in maintenance rooms inside the tunnels or control buildings at the portals.
Both solutions offer advantages with the latter minimizing maintenance works in the tunnel driving space.

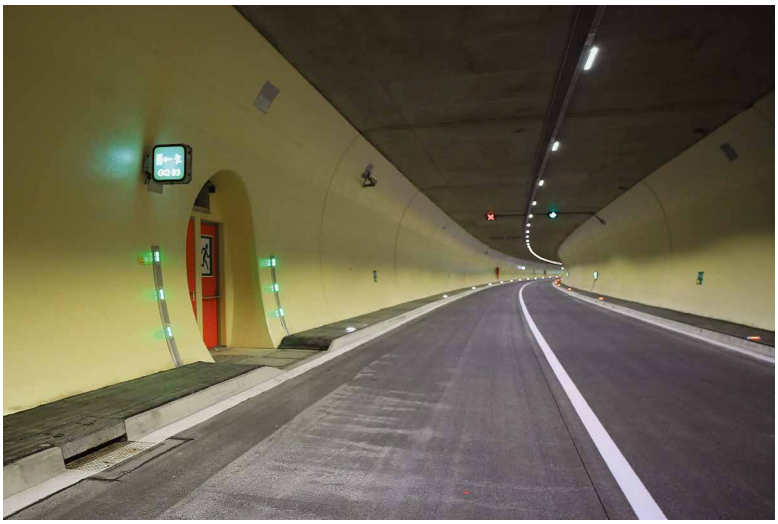

Figure 2:
Tunnel Lighting Cluster Comfort

Figure 3:
Tunnel Lighting Cluster Premium

Basically, the general properties and requirements of tunnel luminaires in D-A-CH countries shifted from orange light with CRI 20 - 30 (provided by sodium vapor lamps) to 4,000-4,500 K with a CRI of 70 or even 80 (with LED) and on top, some current projects require a system efficacy of even above 110 lm / W combined with a system lifetime of > 80,000 h (with less than 10% failures during this period).

Requirements Beyond the Pure Luminaire Specifications

But some requirements, as they are very important, cannot be fulfilled by the luminaire alone. Due to the fact that, especially early LED luminaires appeared more glaring than conventional luminaires, the avoidance of glare became more and more important. Some regulations already require a threshold increment of 8% or even only 6%, as a lower value means less glare. The threshold increment is defined by the relation of veiling luminance to the luminance on the road surface, with a lower veiling luminance or a higher road luminance reducing glare. The veiling luminance itself depends on the luminous flux of the luminaire and the light distribution. As it is possible to develop luminaires that maximize the road luminance and also offer a relatively low veiling luminance, there is one key factor that no luminaire manufacturer can control. The luminance coefficient q0 of the pavement which determines the relation between illuminance [lx] and luminance [cd/m^2] on the road surface. Depending on the pavement class, the luminance coefficient usually varies between 0.05 and 0.07. So, the q0 alone can change the luminance value on the road by approx. 30%.

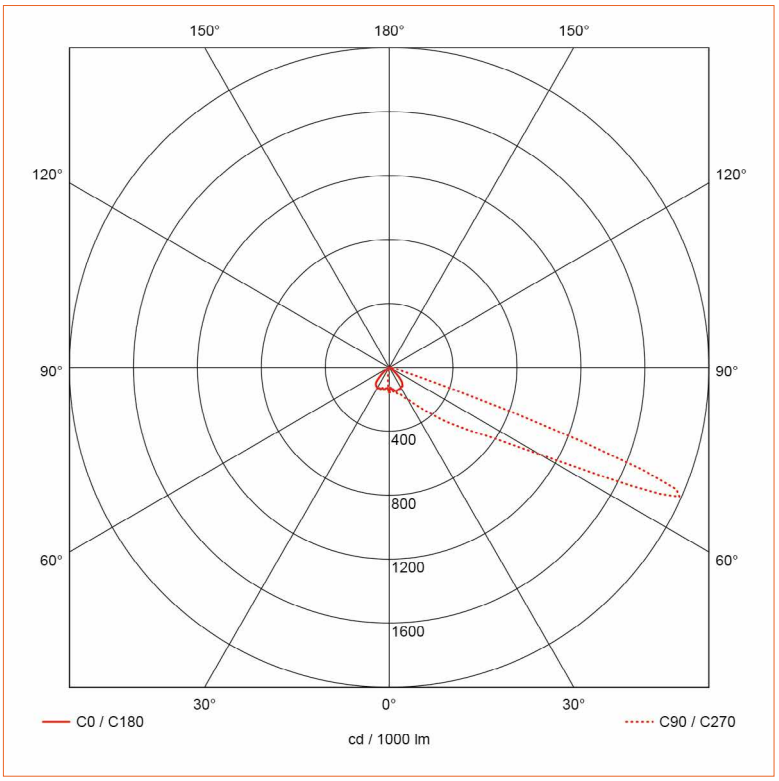

Figure 4:
Counter beam light distribution

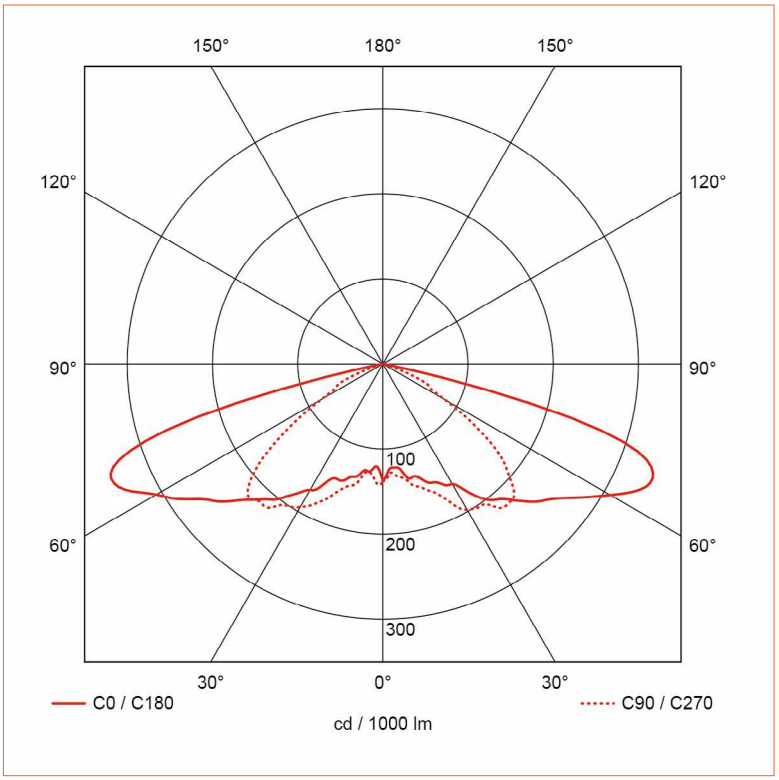

Figure 5:
Symmetrical light distribution

In turn, the luminous flux of the luminaire has to be increased by 30%, leading to a higher veiling luminance and a higher threshold increment.

Efficacy Requirements and How to Achieve Them

A requirement that makes sense but may not always lead to the intended results is the luminous efficacy, that is lm/W. This value perfectly describes the efficiency of a LED, with higher lm/W guaranteeing more energy efficiency. The same is mostly true for all tunnel luminaires with a symmetrical light distribution, which are almost exclusively used in the interior zone. As the transmission values of the different optics on the market are very comparable and almost always near 90% and the light distributions also provide similar road luminance values, luminous efficacy is here the right and easiest choice for determining the energy efficiency of the whole luminaire. But what about luminaires for the threshold and transition zone?

These luminaires are normally equipped with counter beam optics, which distribute the light at a very flat angle to the driver.

Due to their light distribution, counter beam optics provide superior luminance values compared to symmetrical optics. So, counter beam optics are, and also have been in the past, necessary for economic and efficient lighting in the tunnel entrance zones. However, they can only be used in the threshold and transition zone due to the smaller luminaire distance in these areas. Counter beam optics in the interior zone with a typical luminaire distance from 8 - 15 m would create too much glare and the lighting uniformity would not be comparable to the uniformity obtained with symmetrical optics at these luminaire distances. As shown in figure 4, the peak intensities of counter beam optics can be at a vertical angle of above 60° and, more importantly, the light is distributed almost exclusively in one direction. This kind of “light bending” leads to reflective losses and thereby lower transmission values of the optic, which results in less lm/W of the luminaire. What the lm/W value, in the case of threshold and transition luminaires, does not take into account is that - given the same lumen input – counter beam optics with peaks at above 60° will create reasonably higher luminance values on the road surface, than counter beam optics with an intensity peak at, for example, 55°, although the latter might have higher transmission values and therefore a higher luminous efficacy.

Here it is also important to note that the optics with intensity peaks at higher vertical angles do not necessarily produce more glare.

Therefore, a value that would be better suited to describe and require the energy efficiency of tunnel entrance lighting, would be a specific surface power density that takes into account the obtained luminance values, the length of the threshold and transition zone, and the power consumption of all installed entrance (counter beam) luminaires.

Conclusion

Almost all new standards that have been set considering the potential of LED luminaires are headed in the right direction and will lead to a steady increase of lighting quality, which will also result in more perceived and actual safety, higher energy efficiency and more sustainability of current and future tunnel lighting systems. System providers such as Swareflex offer and develop new solutions that fulfill current requirements and push the boundaries even further. Current state-of-the-art luminaires with optics made of top grade technical glass offer a longitudinal uniformity of more than 0.95 at a luminaire distance of 8 - 12 m. That means that the luminance value in the middle of the driving lane does almost not change at all over the course of the tunnel, thereby practically eliminating all flicker effects on the road surface. The latest generation of tube systems offer up to 125 lm/W and completely separate the luminaire in the driving area from the supply and control electronics in the maintenance rooms. But some requirements still have to be challenged as not only technology but also regulations have to be always evolving.

Enabling Total Control in the Next Generation of Outdoor Lighting

Outdoor lighting is certainly one of the applications with the greatest potential for energy saving. Although many approaches are discussed, they all end up with a smart lighting solution. In order to accommodate this, intelligent software and electronics are required as well as standardized, robust interfaces. Ronald Weber, Global Industry Manager, Building Automation and Benjamin Nelson, Business Development Manager, Intelligent Buildings, both from TE Connectivity, present a Zhaga compliant solution.

"One key area for investment in energy efficiency is street lighting, where there are not only major opportunities to significantly reduce electricity consumption, but also additional benefits associated with phasing out environmentally harmful technologies, reducing maintenance costs and achieving much better overall control of the street lighting environment." This is a quote from the European Public-Private Partnership Expertise Centre (EPEC) at the European Investment Bank.

Forecasters are predicting that by the end of next year, over half of all street lighting will be LEDs. In a report issued late last year, smart infrastructure market intelligence company Northeast Group predicted that, across 125 countries, over 280 million LED streetlights would be added over the next ten years, reaching a penetration rate of 89% by 2026.

The Trend to Smart Outdoor Lighting

Today, with the rapid advance of LED control technology, it is possible to tune outdoor lighting to take account, not only of the time of day and ambient light conditions, but also the weather, specific events and applications. And on top of that, extra functionality can be built into outdoor lighting to provide feedback to central control systems on the state of individual lights for enhanced and cost efficient maintenance.

Many luminaire operators are considering moving from streetlights with basic functionalities to more flexible Central Management Systems (CMS) that offer more control, better programming, and higher efficiencies. The city of Harrisburg, PA, provides a good example. The city engineer originally wanted LED lighting simply to save energy. Exchanging traditional lighting for LEDs could yield a reduction in the energy bill for lighting of 20-30%. But the engineer also found out that by using LED street lights with an integrated intelligent controls system, he could not only make a direct saving through reduced energy consumption, but his long-term maintenance costs would also come down, owing to the much greater level of efficiency in the maintenance system that the controls allowed.

Key components available to outdoor lighting fixture designers include items such as a family of versatile dimming receptacles; photo control base assembly and related dome covers that provide a complete power and signal interface between the intelligent photo control device and dimming receptacle; a lighting control enhanced base that mates to a standard dimming

Figure 1:
Enabling total control in the next generation of outdoor lighting

receptacle which provides AC power switching and multiple DC voltage sources necessary for complex control node solutions; easy-to-use LED holders that integrate thermal, electrical, optical and mechanical connections for leading edge luminaries, and a standardized platform of receptacles, caps and bases that reduce the complexity of data and sensor controls in street lighting architecture by providing a pluggable architecture for small sensors and controls.

A tier system is now developing in the lighting industry, not unlike that now operating in the automobile sector. OEMs concentrate on their core competencies and leave development of peripheral technologies to their suppliers. An example of this can be seen in the development of AC/DC converters to create a low voltage direct current for LED control systems. Until recently, most lighting companies were developing their own converters. Now, they can buy a dimming receptacle plug with the converter built directly into it. All the OEM needs to do now is develop its own control circuitry, which can then be connected to the module to form the final assembly. This gets the OEM to market quickly with a unique product developed with minimum engineering effort.

More Versatile Streetlight Controls

With LED lighting, we can now recreate and control light in a highly efficient and cost effective way. An example of this type of solution that enables new levels of control is the sensor ready (SR) platform a new connectivity standard for outdoor luminaires, designed to integrate sensors with LED light sources and drivers. The Endurance S platform reduces the complexity of street lighting architecture by removing the need for hard-wired auxiliary modules and the associated wiring and in its place provides a 100% pluggable solution. It comprises a receptacle, sealing cap, module plug bases, and associated dome covers. Used in conjunction with an SR driver, an SR pluggable sensor module can be plugged into a 4-pole twist-lock SR receptacle mounted on the fixture enabling a high degree of sensor control flexibility.

Some time ago, NEMA and ANSI together developed a standard around a receptacle that fits on top of every street light. This would normally just have a photo cell plugged into it, so the light would switch on and off according to ambient light conditions, but now, increasingly sophisticated receptacles are now being fitted. Some NEMA dimming receptacles provide a far greater level of functionality in the photo control module. The lighting can be dimmed, the color can be modified, and it can even be made to flash.

In advanced development at TE is the LUMAWISE Endurance N Enhanced Base, intended to create a platform for rapid development and manufacture of street and outdoor lighting control solutions that are compliant to standards developed by National Electrical Manufacturers Association (NEMA) in conjunction with the American National Standards Institute (ANSI). It provides AC power switching and DC power supplies necessary for complex control node solutions, allowing designers more time to focus on value-adding features. It incorporates an ANSI-compliant mechanical architecture that supports design reuse and modularity across lighting control products. Applications are in street and roadway lighting control, commercial & campus outdoor lighting management, smart city control networks, and in bridging smart grids to smart cities.

These and other developments are helping to vastly improve the control we have over our lighting systems. We can put light, not only exactly where we need it, but precisely when we need it. But there is so much more that can be done. In the smart city of the not-too-distant future, as an ambulance makes its way to the scene of an emergency, the street lights change in intensity or even in color to show the driver the quickest way. The limits of what can be done with light color and intensity are expanding all the time.

More Versatile COBs

Multi-functional chip-on-board (COB) holders now available can form the core of the fixture ecosystem by integrating LED electrical, mechanical, thermal, and optical interconnectivity. As well as solderlessly terminating to COB LEDs, they can incorporate some core control elements. As a result, they can accelerate time to market, minimize applied costs, facilitate easy integration, and improve assembly efficiency when compared to traditional methods of LED integration.

Extending LED Capabilities Beyond Simple Illumination

As we become more familiar with LEDs for lighting, and the possibilities that they open up in terms of design and functionality, we can start looking at how controls can further develop their potential. It is now possible, for example, to use LED lighting for highly secure line-of-sight data transmission.

Parking meters can communicate with nearby street lights, which, using very high speed modulation capability, can transmit information to meter attendants in the neighborhood – sorry folks – that a car has overstayed its allotted time. Or, on a more positive note, they could provide much more precise data than is usually available today on available parking spaces.

In fact, a form of “smart parking” has already been deployed in the largest parking monitoring system in the world – in Moscow, where congestion has been cut by over a quarter since installation. There are other significant deployments in major cities in Russia and China.

Figure 2 (left): Fully rotatable dimming receptacle, photo control base & cover

Figure 3 (right): Module for smarter street lighting applications

New Standards for LED Lighting

Over the past few years, engineers and system architects at leading component suppliers have been working with downstream partners to create a vision of a new street lighting architecture. A key consideration was the potential of new architecture and new functionalities to help create value for developers, installers and users of outdoor lighting, whilst making the move from individually programmed street lighting to CMS.

Until recently, designers have mostly only been able to select NEMA/ANSI standard product lines, simply because no specific alternative – or even European – standard existed. Now, there is a new connectivity solution for LED street lighting, and a new European standard for outdoor luminaires.

One compact connectivity solution for LED street lighting that offers greater flexibility in luminaire design and street lighting architecture is the LUMAWISE Endurance S. Because it is field upgradeable, it is possible to simply and quickly upgrade existing luminaires.

A standardized interface between the receptacle and module base or sealing cap uses an integrated single gasket that can accommodate and seal both luminaire and module using the same connection interface for either 40 mm or 80 mm diameter central management systems. This allows different modules to be exchanged and upgraded in only a few seconds, without having to electrically isolate the lighting pole.

The new product was co-developed with several partners to ensure a complete system is available, including application specific drivers and control nodes. The partnership also collaborated with the Zhaga Consortium, a global lighting-industry organization that is standardizing components of LED luminaires, including LED light engines, LED modules, LED arrays, holders, and electronic control gear (LED drivers) and connectivity fit systems.

Zhaga describes a connectivity fit system for smart outdoor luminaires in Book 18, currently in draft form, which defines a standardized interface between an outdoor LED luminaire and a sensing/communication module that sits on the outside of the luminaire. The module connects to the LED driver and control system, and typically can provide sensory inputs while also communicating with other luminaires in a network. The standardized interface defined in Zhaga Book 18 enables the installation of future-proofed outdoor LED luminaires, which can be easily upgraded with smart communication and sensing capabilities.

Visions and Conclusion

The limits to the functionality that can be built into outdoor LED lighting systems continue to expand. Radio transceivers enable individual lights to be integrated into a network. Sensors can monitor energy consumption and the general “health” of individual lights, with any problems then being flagged. Outdoor LED lighting can now even become part of a city-wide environmental control system.

There is so much more that can be done. In the smart city of the not-too-distant future, as an ambulance makes its way to the scene of an emergency, the street lights change in intensity or even in color to show the driver the quickest way. The limits of what can be done with light color and intensity are receding all the time. Street lights will no longer be just street lights. They will become nodes in a sensitive, intelligent city.

Wherever people live, work, and congregate, there is need for outdoor lighting. And so there is potential for sensing applications to make that lighting more appropriate and responsive to people’s needs. In tunnel lighting, sensors can monitor temperature and humidity, and can be used in closed-loop systems controlling air flow. It should even be possible to get early warnings of fires breaking out if spikes are registered.

Imagine an entire city with a networked lighting system enabled with temperature and humidity sensors. It will be possible to evaluate microclimates in local areas throughout the city and adapt accordingly.

So for example, sensors will be able to recognize areas of stagnant air flow, enabling city managers to put out environmental alerts much faster than ever before, and hopefully avoid a flood of health-related issues for city inhabitants. ■

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Cover-page

Artwork: Thomas Klobassa, ©LED professional 2017

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Pick-and-Place of CoBs

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COMPONENTS & TECHNOLOGIES
Issue 62 - July/Aug 2017

TECH-TALKS BREGENZ

Jamie Singerman - Worldwide Corporate Vice-President at Future Lighting Solutions

With so many new products and platforms being introduced, not only with respect to intelligent lighting, but in all product areas, the question of how distributors can stay up-to-date and how the can ensure that customers have current, up-to-date information about new products, is raised. Just one of many hot topics discussed in this TTB.

RESEARCH

"Best Papers" at LpS 2016: LED-Retrofit Based on AlGaN/GaN-on-Si FET Drivers

Different approaches of GaN-based FETs are becoming a popular research field because several advantages to their Si-based relatives are expected. The presented research demonstrates the suitability of an AlGaN/GaN-on-Si field effect transistors (FETs) for their use in LED drivers. The transistors are tested in an isolated buck converter for an LED-Retrofit lamp providing a total light output of 2676 lm at an efficacy level of 119 lm/W. The results compare favorably to state-of-the-art commercial solutions.

TECHNOLOGIES

Benefits of Higher Integration with SoCs

The discussion on the benefits of higher integration with SoCs is usually focused on wireles control. What is often overlooked is that SoCs enable a new approach to maintenance of commercial lighting systems. This article discusses how integration with SoCs can help keep lighting systems working at peak performance, what tools different stakeholders gain, how they can be used, and what technical challenges still need to be resolved.

APPLICATION TECHNOLOGY

Redefining Automotive Lighting with Groundbreaking Digital LED Technology

Current state-of-the-art LED technology still does not completely meet today's increasingly demanding requirements placed on lighting elements inside motor vehicles. Car manufacturers demand an array of new functionality; they require LEDs to be controlled individually, accurate brightness and color adjustment, compensation for temperature and ageing, and much more, all at very competitive cost. This article explains a new groundbreaking approach that provides the viable, easy-to-use solution.

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Imprint

LED professional Review (LpR), ISSN 1993-890X

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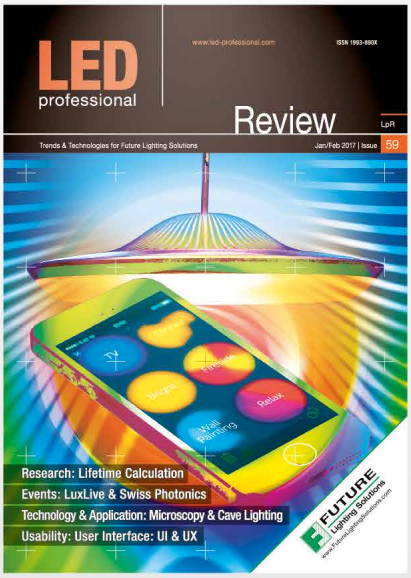

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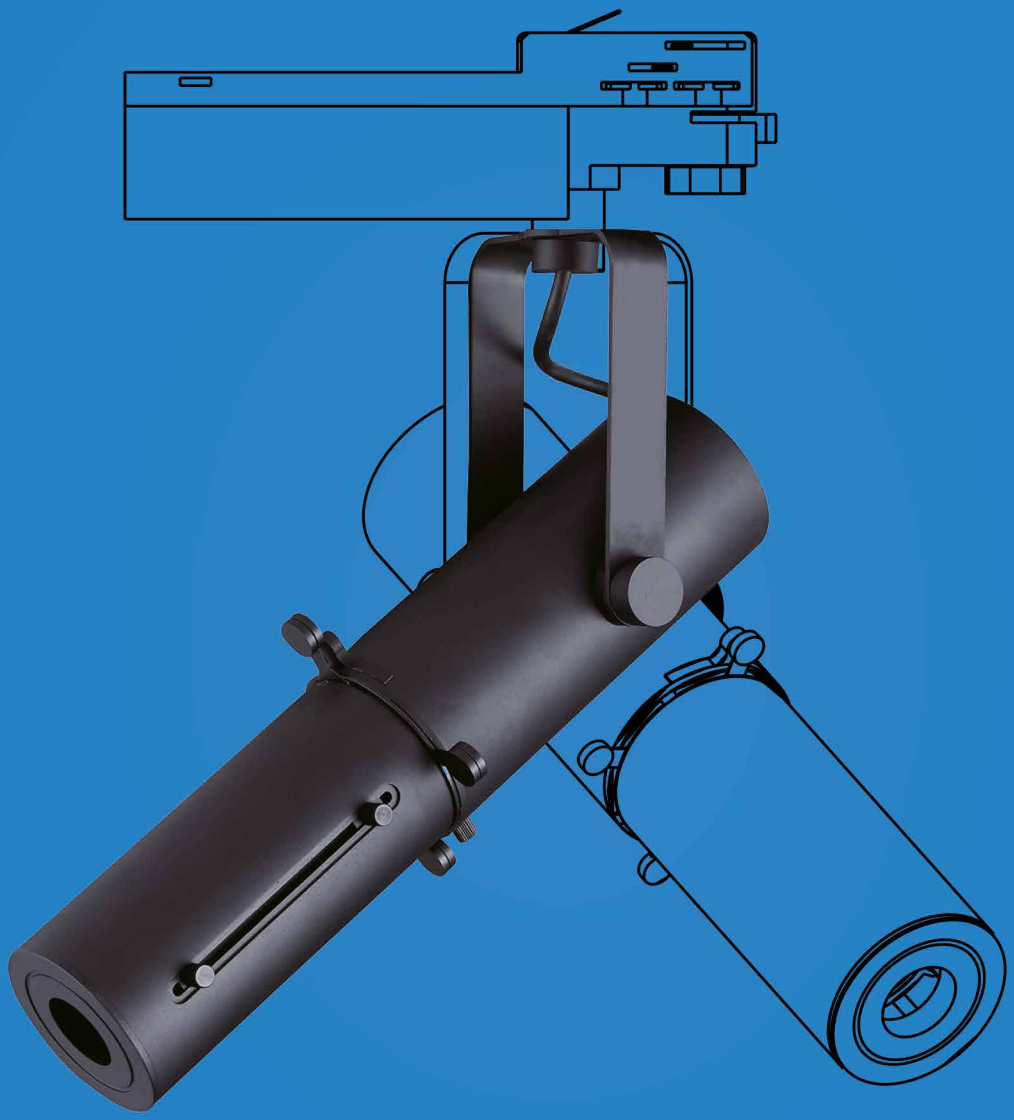

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