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LpR

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Tech-Talks Bregenz: Ken Munro

Research: Thermal Testing, Production

Manufacturing & Technology: Micro-Plants & IoT

Application: Aerospace Exterior Lights

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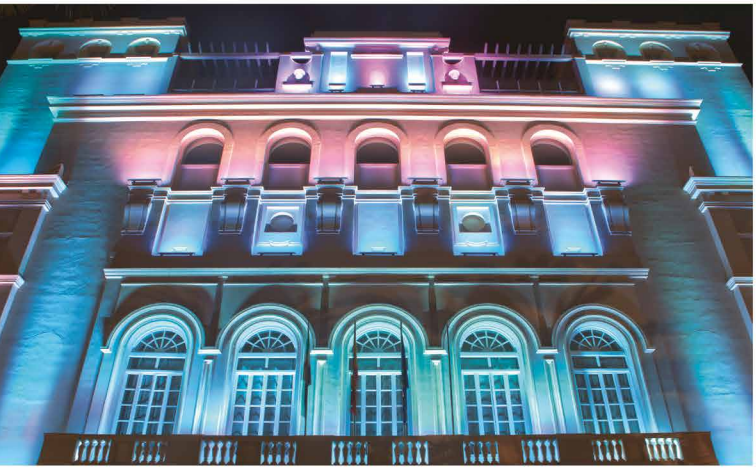

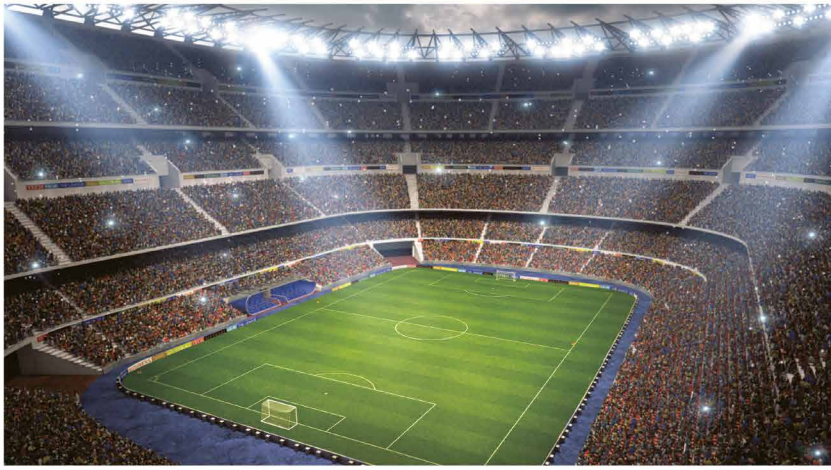

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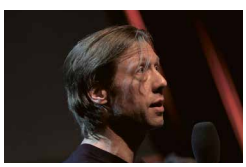

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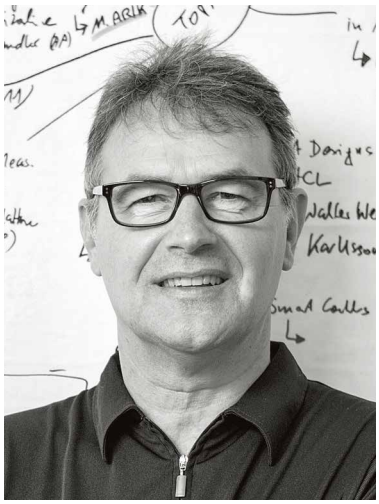

L+B 2018 - Connectivity & Services

At L+B 2018, the focus was on the topic of CONNECTIVITY with all kinds of forms and applications for many providers. In addition, it became apparent that more and more service providers were entering the market with concrete SERVICE solution packages. In the context of connectivity, we had an interesting conversation about current trends with Patrick Durand, Worldwide Technical Director, and Francois Mirand, Technical Director EMEA, from Future Lighting Solutions, which I would like to share with our readers. The high complexity of connected systems can pose a major challenge in projects. For this reason it is extremely important that connected lighting be based on two basic principles: Firstly, we need standards that are as widespread as possible. Secondly, the experts suggested that we need systems that are scalable and interoperable.

We agree with this opinion and see standardization as a key success factor for the market acceptance of smart systems. Service solutions are the second most important key for the implementation and application of modern lighting solutions. But which services are really required?

Here we certainly have to look at the entire value chain. From the assistance of distributors, such as the engineering tools from Future Lighting Solutions, to configurators of luminaires, such as the new Unico from XAL, to leasing models on sale – services; they all make a significant difference and form a unit together with standardized solutions.

The L+B 2018 showed the boundless directions the world of light is taking. Connectivity and services are the dominant topics facing the lighting industry on a broad scale. Of course, quality and safety play an important role. Particular mention should be made here of the new EU directives as was also well documented in the LightingEurope Forum. The world of light has opened up and has become enormously diverse and creative. However, the focus of all efforts is always to provide the right light for the respective application. Optimum lighting quality stays the primary goal above all else.

We hope you enjoy this issue of LpR. Please let us know how you experienced Light +Building 2018.

Yours Sincerely,

Siegfried Luger
Publisher, LED professional

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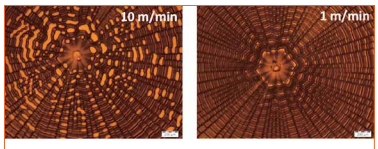

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Dr. Thomas Attenberger

Thomas Attenberger received his PhD in Physics from the University of Regensburg in 1992 for his work in the field of high-resolution spectroscopy with a thesis on “Persistent spectral hole burning”. He worked for several years as R&D project leader at a Munich high tech company, where one of his tasks was to establish a spectroscopy lab for performing basic research for optical sensor development. Attenberger joined Instrument Systems GmbH in 2001 as sales and product manager for LED test and measurement equipment. Since 2009 he has held the position of Vice President Sales at Instrument Systems GmbH, in which he is responsible for worldwide sales and marketing activities. This position brings him into close contact with other major players in the LED and SSL lighting industry.

BLUE LIGHT HAZARD - HOW DANGEROUS IS SSL LIGHTING?

Modern Solid State Lighting (SSL) technology has long since found its way into our normal working and living environments. In the early phases, consumers were most concerned with lifetime, pricing and light quality of the new LED-based light sources. Now they have become almost ubiquitous, a focus has been placed on safety. At the recent Light+Building exhibition topics such as photobiological safety and blue light hazard (BLH) were highly ranked among both visitors and exhibitors.

Photobiological safety is nothing exclusive to SSL sources, but must be evaluated for all light sources. Due to their similarity to laser diodes, LEDs were originally covered by the laser safety standard IEC 60825, which often led to an overestimation of the risks. Since 2009 LEDs and SSL sources have therefore been subject to IEC 62471 “Photobiological safety of lamps and lamp systems”. All lamp and luminaires brought onto the market must be classified according to this standard.

The standard identifies two health hazards that can be caused by visible light. Intense light may lead to retinal burns, a hazard that is easily avoided by normal aversive behavior. However, blue light between 400 nm and 500 nm may cause photochemical damage to the retina, a hazard that is difficult to assess by users. This so-called blue light hazard may lead to degeneration of the macula. The corresponding weighting function ranges from 300 nm to 700 nm with a maximum at 437 nm. In view of the distinctive blue peak of white LEDs, the question arises as to whether SSL sources are hazardous.

Depending on the radiance levels, BLH sensitivity and exposure times, IEC 62471 divides light sources into four risk groups ranging from 0 (no risk) to 3 (always dangerous). Risk groups 1 and 2 are sources that are not dangerous under normal behavior and aversion reactions. The standard also describes measurement equipment and procedures for the correct assessment of the risk classes of light sources. Additionally, IEC/TR 62778 explains how to apply IEC 62741 for simpler assessment of the BLH for lamps and luminaires.

Accurate risk assessment is a challenging task for the experimenter, and starts with the selection of the correct test equipment. Today’s measurement instrument of choice is often an array spectrometer instead of the hard-to-handle double monochromator suggested by the standard. But even high-end array spectrometers must offer advanced stray light correction methods to achieve the required high dynamic measuring range, especially in the less sensitive blue region. Carefully designed test adapters are necessary to ensure correct and reproducible test geometries. With such equipment, testing labs - which should be accredited to ISO17025 - can reliably assess the risk class of lighting products.

Several studies have evaluated the risk classes of various kinds of SSL sources, lamps and luminaires. In general, SSL sources were not found to pose a greater risk to the user than conventional sources. Most luminaires with non-directly visible LEDs were assigned to risk class 0. Only luminaires with directly visible LEDs ended up in risk class 1 or, in some cases, in class 2, which the standard still classifies as free of risk under normal use and aversion reaction - just like conventional sources.

I must emphasize that these positive results should not encourage manufacturers to underestimate the importance of safety assessment of light sources. Research on the safety aspects of lighting will continue, and only accredited labs using state-of-the-art test equipment will be able to ensure a reliable risk assessment. Consumers may rightfully expect lamps and luminaires providing light that is safe in every aspect. Otherwise, SSL lighting will not be able to assert itself in the long term. ■

T.A.

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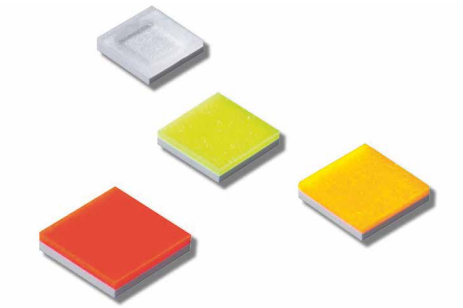
Nichia Introduces Direct Mountable Chips with Single Colors

Nichia Corporation is proud to introduce discrete color options in its Direct Mountable Chip series, a similar technology to the industry's Chip Scale Package (CSP). Nichia's Direct Mountable Chip color lineup, consisting of Royal Blue, Green, Amber and Red, along with its previously released white options, enables lighting customers to take advantage of Nichia's unique Direct Mountable Chip technology in a wide range of applications.



Nichia also offers color LEDs in Chip Scale Package (CSP) technology

With over 50 years of leadership in phosphors and 25 years of leadership in LEDs, Nichia has capitalized on its history to launch an innovative color solution which utilizes Nichia's own phosphor and blue die technology.

This approach brings numerous benefits to fixture manufacturers and designers. By using the same wavelength die in each color, Nichia has harmonized the Forward Voltage across the entire Direct Mountable Chip family, therefore simplifying electrical circuit designs. Additionally, unlike other discrete color technologies, the internal structure of each Direct Mountable Chip color is the same. Therefore, the directivity and height are also the same, thus making optical design much easier to manage. Finally, with the phosphor converted Red Direct Mountable Chip, the thermal droop characteristics are significantly improved from traditional Red AlInGaP LEDs. This allows for much better in-situ performance and overall color and stability.

Nichia's Direct Mountable Chip family was the first lighting CSP-type to incorporate unique technology, allowing for a single sided 120° Lambertian optical pattern, eliminating cross talk in lumen dense applications. By developing an innovative color lineup, Nichia's now expanded Direct Mountable Chip portfolio provides flexibility to all lighting applications, including color tuning, architectural lighting and other commercial and residential markets. ■

Osram Adds Six New High-Power IR LEDs to Its Oslon Black Family

Osram Opto Semiconductors is expanding its Oslon Black family for the infrared range with six new automotive IREDs. The 850 nm versions are intended for exterior applications such as night vision, pedestrian protection, pre-field recognition and lane detection. The new 940 nm versions are suitable above all for interior automotive applications such as driver monitoring, seat occupancy detection and gesture recognition. Thanks to different wavelengths and lenses these products cover a wide range of customer requirements and can be operated at up to 5 A in pulsed mode.

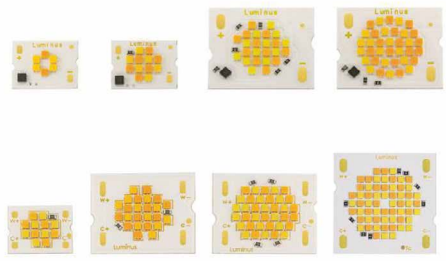
Osram's six new high-power infrared LEDs offer a very high pulse handling capability of up to 5 A for automotive applications like driver monitoring

The new products show a high maximum pulse current of up to 5 A, compared to 3 A previously. The IREDs are particularly bright, with an optical output of up to 2.0 W in continuous operation. The six new IRED versions are available in different wavelengths and beam angles. SFH 4715AS A01, SFH 4716AS A01 and SFH 4717AS A01 all have a wavelength of 850 nm and a beam angle of ±45°, ±75° and ±25° respectively. SFH 4725AS A01, SFH 4726 A01 and SFH 4727AS A01 all have a wavelength of 940 nm and a beam angle of ±45°, ±75° and ±25° respectively. A high refractive index silicone is used for the lens, giving it a particularly low profile so that only very little light is lost from the sides. The maximum operating temperature of the IREDs is 125°C. The high optical pulse outputs and the wide range of integrated lens options allow system designers to select the right IRED for virtually any application without having to install secondary optics. Infrared light sources in a wavelength range < 900 nm are perceived by the human eye as a red glow. This red glow is largely suppressed at 940 nm.

Like the rest of the Oslon Black family, the new IREDs offer outstanding performance, long lifetime and excellent thermal properties. ■

Luminus' Dynamic Modules for Dynamic CCT & Warm Dimming

Luminus Devices, Inc., has released its breakthrough warm dimming and dynamic tuning modules that deliver exceptionally uniform color and control across any environment and enable consistency from fixture-to-fixture and between linear, down, and directional luminaires that are used in the same space. Unique to the new modules are on-board IC chips that allow exceptional color quality and uniformity in hospitality, commercial and office environments.



An on-board IC on Luminus' Warm Dimming Modules (top) enables standard drivers and dimmers to deliver halogen-like illumination from 3000 to 1800 K with a typical CRI of 92 or 97 while CCT Tunable Modules (bottom) deliver a wider individual tuning range

The Warm Dimming module replicates the behavior of a halogen lamp and changes color from 3000 K to 1800 K as it dims. The very human-centric behavior is prized in restaurants, bars, and intimate environments.

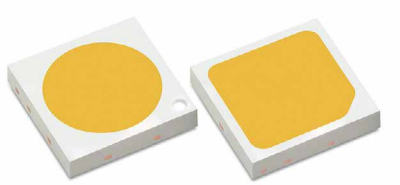
The CCT Tunable Module is a unique two-channel solution that allows for a broad range of color (6500 K to 2700 K or 4000 K to 1800 K) and output control over the lit environment with independent color and dimming management. Now it's possible to

change CCT while maintaining light levels or to dim the light level and precisely select the desired CCT. In an office or commercial environment this allows color tuning and light output that replicates changes in daylight from morning through evening or can be optimized based on human-centric parameters. ■

Lumileds - Highest Flux Two-Die Mid Power LED Luxeon 3030 2D

Lumileds introduced a new addition to its mid power family, the new Luxeon 3030 2D with a square LES, which is specifically optimized for high flux and maximum reliability in a variety of general lighting applications including downlights, high bay & low bay fixtures and outdoor lighting applications. “With the new Luxeon 3030 2D, we are able to offer the industry’s highest flux in a two-die mid power package, but also our hot-color targeted approach ensures superior color accuracy to that of other LED manufacturers,” said Mei Yi, Product Manager of Luxeon 3030 2D for Lumileds.

With hot-color targeting, components deliver specific chromaticity coordinates at the targeted operating temperature of 85C. This strategy results in minimal color shift in real-world operating conditions. Both LM-80 and TM-21 data are available for the new LED.



The new Luxeon 3030 2D mid power LED delivers outstanding flux exceeding 200 lm when driven at 240 mA and 6 V

The Luxeon 3030 2D uses two emitters in series to deliver over 110 lm at a warm white color temperature of 2700 K and 80 CRI (120 mA, 6 V). At a cool color temperature of 6500 K, the performance increases to over 120 lm at 80 CRI (max drive of 240 mA).

Offered over the full range of ANSI CCTs, the emitter is 1/9th ANSI micro-color binned for tight color control. Flux performance is significantly improved over the company’s existing Luxeon 3030 2D LED which has a round LES. Existing customers will still have access to the Luxeon 3030 2D with the round LES, which enjoys widespread adoption, especially for downlight, industrial and A lamp applications. ■

Osram's New CSP LED Takes Retail Lighting to another Level

Osram Opto Semiconductors has unveiled the prototype of the Oslon Pure 1010 at this year’s Light + Building in Frankfurt. Sized at 1x1 mm, the LED is destined to be used in spotlights for retail lighting where exceptionally compact LEDs with high light output are needed to bathe articles on display in a particularly attractive light.

The scalability of the chip scale package (CSP) LED gives customers outstanding flexibility in putting together their individual lighting solutions.

The prototype of the Oslon Pure 1010 stages not only jewelry on display. It delivers the highest flux density currently available on the market

The prototype of the new Oslon Pure 1010 with its typical luminous flux of 100 lm at 350 mA and a color temperature of 3,000 K almost perfectly follows Lambert's law and achieves a flux density of 237 lm/mm^2 when operating at 1,000 mA. The achieved luminance is then very much higher for the same component size. This property is useful particularly if the new LED is used for illuminating merchandise in retail outlets – diamond rings in a jeweler's shop, for example.

The Oslon Pure 1010 gives lighting designers a high degree of flexibility because of its extremely compact 1.0x1.0x 0.25 mm dimensions. The new LED comes without a primary lens. The reduction in height is thanks to the chip scale package (CSP). The light-emitting surface is contacted not in the usual way with a bond wire from above but within the component itself without the need for bond wires. These properties together with the small dimensions enable multiple LEDs to be placed very close together in a small space. Warm white and cold white LEDs can be combined – the number of individual LEDs, their arrangement and the relative proportions of warm white and cold white LEDs can be tailored to meet specific customer requirements.

If applications call for highly concentrated spotlighting, customers can simply add appropriate secondary optics. Thanks to the compact dimensions and directional emission of the Oslon Pure, the secondary optics can also be very small, which in turn means that the overall solution will save even more space and cost. The prototype of the Oslon Pure 1010 gives customers outstanding flexibility in putting together their individual lighting solutions. ■

Everlight Introduces High-Efficiency and Horticulture Lighting LEDs

Everlight Electronics demonstrated its 5630X-ELB LED series and horticulture fit LEDs as well as all lighting and lighting-related products, such as luminaires for horticulture and fish lighting, at Light + Building 2018 in Frankfurt, Germany.

With their new ELB series products, Everlight offers a cost effective solution for horticulture lighting applications and industrial applications as well

Everlight's 5630X-ELB series not only boasts 228 lm/W (@65 mA 5000 K CRI>80), but also meets DLC4.0 with light-on tests in the high temperature range (105°C), L90>36,000 hours and achieves/features a color tolerance less than 3SDCM. Thus, the 5630X-ELB series combines the advantages of luminous efficacy and stability to provide best lighting solutions for commercial, professional and industrial applications.

Monochromatic light LEDs are widely applied for horticulture lighting, by combining colors to effectively meet the requirements of specific spectra and optical functions. Everlight developed a special series of products based on monochromatic light wavelength to cover PAR 450-745 nm from high to low power with SHWO 3535-ELB, 3030-ELB and 2835-ELB.

The new 2835 PC Red-ELB with 5% blue intensity (CCT) can achieve a WPE of 35% (0.5W) to simultaneously replace Royal Blue & Deep Red with a luminous efficacy of 15 lm/W. The new 3535-ELB series owns the advantages of high luminous efficacy, price-performance ratio and a WPE of 65%. In all colors, the products are tested to meet LM80 and effectively guarantee to meet the customer's requirements.

Everlight also supplies various horticulture LEDs in all forms to meet the demands in different environments, with the goal of maximizing livestock and plant stock growth and achieve targeted energy-saving objectives. ■

Lumileds Improves "Punch" in Broadest Color Choices

Lumileds introduced the LUXEON CZ Color Line, a product line optimized to deliver maximum punch. "The LUXEON CZ features 20% higher punch than any other undomed color LED," said Jennifer Holland, Product Line Director of the LUXEON Color Family. The LUXEON CZ Color Line consists of 21 LED color options, which includes 13 color and 8 white emitters.

Lumileds' LUXEON CZ Color Line produces best punch compared to other undomed emitters and features maximum usable light for a variety of applications

In addition to industry leading punch, the LUXEON CZ Color Line makes fixture designs with narrow beam angles possible. "It is easier for optics to pick up all the light because the emitters cast minimal light below the horizon, unlike comparative products on the market," said Holland.

The product line eliminates crosstalk, ensuring a true color point when LEDs are packed closely together. The LUXEON CZ Color Line ensures a true color point in compact designs and is especially suited to architectural lighting, entertainment lighting, dimmable lamps and fixtures and emergency vehicle lighting applications.

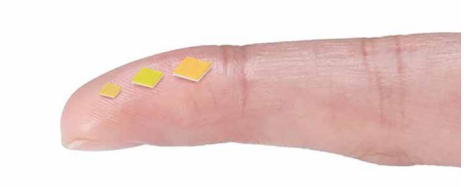
In addition, LUXEON CZ consists of the same robust buildings blocks as the award-winning LUXEON C Color Line. All LUXEON CZ and LUXEON C LEDs feature identical focal length in an undomed design, an approach that leads to superior color mixing in all applications.

To accelerate time to market and simplify designs, LUXEON CZ and LUXEON C are designed in the same footprint and are also hot tested at 85°C to ensure excellent performance at real world conditions. The industry's lowest thermal resistance (2.8°C/W) helps reduce the size of optics and heat sinks for the most compact lamps or fixtures.

Leveraging the features and reliability of the well-known LUXEON C, Lumileds has extended these benefits to LUXEON CZ, giving lighting manufacturers the confidence and flexibility to use them individually or even together. ■

Samsung Enhances CSP LEDs' Luminous Efficacies

Samsung Electronics announced that it has achieved the industry's highest light efficacies for its fillet-enhanced chip-scale package (FEC) LED lineup – LM101B, LH181B and LH231B.



Samsung updates its tiny CSP LEDs and improves efficacy again

Initially chip-scale package (CSP) LEDs had not been widely used in mainstream LED lighting markets due to relatively lower efficacy levels compared to conventional LED packages. However, the newly upgraded, efficacy-leading FECs can be applied to most mainstream LED lighting environments, including ambient, downlight, spotlight, high bay, canopy and street lighting applications.

The enhanced FEC LEDs are based on Samsung's most up-to-date CSP technology which builds TiO2 (Titanium dioxide) walls around the side surfaces of the chip to direct light output upwards. The technology provides considerably higher light efficacy than conventional CSP LEDs while offering greater flexibility for luminaire designers. Moreover, dramatically reduced cross-talk between neighboring packages allows each package to be placed in close proximity to one another.

Building on these advancements, the revamped FEC LED packages achieve the industry's highest light efficacy levels, to suit an even wider range of lighting applications. The mid-power CSP, LM101B, features an increased efficacy of 205 lm/W (65 mA, CRI 80+, 5000 K), which is the highest among 1W-class, mid-power CSP LEDs. The 3W-class LH181B provides 190 lm/W (350 mA, CRI 70+, 5000 K), which represents a more than 10-percent enhancement over the previous version. The LH231B package continues to offer 170 lm/W (700 mA, CRI 70+, 5000 K).

With Samsung FEC's small form factor and reduced cross-talk, the LM101B is particularly well suited for spotlighting applications where packages can be densely placed within a small light-emitting surface area. Samsung also made the LM101B much simpler to mount compared to other mid-power CSP LEDs, by modifying the electrode pad.

In addition, the LH181B operates at a maximum current of 1.4 A (Amps), making it an ideal component for high-power LED luminaires requiring superior lumen density.

The Samsung FEC lineup, now in mass production, is available in a full range of color temperature (CCT) and color rendering index (CRI) options.

Lumileds Introduces Next Generation CoB LEDs

Lumileds introduced its fourth generation of chip-on-board (CoB) LEDs, the Luxeon CoB Core Range, which leads the market in efficacy and quality of light. With the new Luxeon CoB Core Range, Lumileds sets a new standard with 5% greater efficacy than the nearest competitors.

Most impressively, Gen4 of the Luxeon CoB Core Range leads the industry in 90CRI with a 12% increase over the previous generation

The goal of Lumileds is to address the industry-wide issue of the efficiency gap between 80 and 90CRI CoBs. With this new generation, Lumileds has limited this gap tremendously by increasing the 90CRI performance by 12% over the previous generation. In the past, there was a tradeoff between light quality and efficiency, but customers no longer need to make that sacrifice with these products.

Lumileds ability to deliver outstanding efficacy exceeding 130 lm/W in 90CRI is largely the result of Lumileds own phosphor development and engineering coupled with precise process and manufacturing controls at the company's manufacturing facilities. Due to these improvements, Lumileds also improved the thermal resistance of the CoBs by 25%, further reducing the burden on heat sinks and shrinking the size of optics at the system level. The result is exceptional fixture efficacy and smaller fixtures. ■

LG Innotek Introduces UV LED Module with Perfect Waterproof

LG Innotek announced that it has supplied UV LED module for water purifiers to the famous Japanese purifier manufacturer for the past year and achieved the perfect quality of zero defect rate. The Japanese market is known to have very strict quality standards, but it has proved its great performance and quality by supplying about 50,000 modules without a single defect.

LG Innotek's UV LED Module for water purifiers

UV LED is the advanced semiconductor light source that emits ultraviolet light with a short wavelength of 200 to 400 nanometers (nm). It eliminates germs and viruses and chemically reacts with special substances to be used for the surface, water, and air disinfection, healthcare, medical care, biotechnology, and curing and exposure equipment.

The LG Innotek's UV LED module with waterproof feature emits ultraviolet rays to directly remove 99.9% of various germs and viruses while immersed in the water of the water tank of a water purifier. It is a waterproof product specialized in water purifiers with a water tank and installed in the inner bottom or sides of the water tank.

Especially, this product boasts the complete waterproof performance of IPX8 level that is the highest level among international waterproof standards. It is safe to operate for a long time at a water depth of 1 meter.

LG Innotek's UV LED is also harmless to human body since it uses only ultraviolet rays for sterilization without any chemicals or heavy metals. Unlike conventional mercury UV lamps, it is safe from breaking.

The product is convenient to use as it allows you to control sterilizing ultraviolet rays quickly and precisely. The mercury UV lamp requires about two minutes of preheating, while LG Innotek's UV LED module does not require preheating by using an advanced semiconductor light source. ■

SABIC - LEXAN™ DLCW Light Diffusing Technology

SABIC, a global leader in the chemical industry presented the latest addition to its LEXAN™ sheet sign portfolio, LEXAN™ DLCW (Diffused Light Cool White), an advanced light diffusing polycarbonate sheet, at the International Sign Expo.

The innovative technology behind the LEXAN™ DLCW sheet delivers exceptional light transmission. Inset: The LEXAN™ DLCW sheet allows placement of LEDs closer to the diffuser, saving valuable design space

Featuring a special combination of high light diffusion and high transmission via an optimized surface texture and advanced diffuser technology, the extruded polycarbonate sheet delivers considerable advantages over traditional materials in terms of bright, uniform illumination, impact resistance, attractiveness and design freedom.

The LEXAN™ DLCW sheet has demonstrated to be 30 times stronger than typical acrylic LED diffusers, making it an ideal choice for applications where safety and security are paramount - particularly in high-traffic, damage prone areas, such as schools, commuter transport stations and detention facilities. In addition to providing greater safety, superior durability results in minimizing replacement costs.

The innovative technology behind the LEXAN™ DLCW sheet allows placement of LEDs closer to the diffuser, saving valuable design space and delivering exceptional light transmission resulting in fewer overall LEDs being required. The sheet also has excellent cold bending and thermos-formability features as compared to acrylic allowing designers to be more creative. These innovative features have considerable benefits for project owners and installers by reducing construction, installation and operating costs and making installation and sustainability efforts easier.

The unique surface texture and state-of-the-art diffuser technology ensures light is projected uniformly across the lens and provides hiding power for LED hot spots while maintaining light transmission as high as 85 percent.

LEXAN™ DLCW sheet is suited for applications including indoor skylights, privacy partitions and windows, lighted display shelving, menu boards, formed production and flat signs. ■

Electrolube - First Clear UL94 V-0 Flame Retardant PU Resin

The global electro-chemicals manufacturer, Electrolube, has frequently been approached regarding the prospect of an optically clear, flame retardant resin. As the demand for LED encapsulation ever increases, particularly for hazardous areas, Electrolube has developed the long-awaited new UR5641 encapsulation resin.

There is a great demand for flame retardant materials for LED lighting applications. Electrolube is the first company, worldwide, to offer a clear UL94 V-0 flame retardant PU resin for LED applications

Technically, UR5641 almost defies convention and is very different from other resins that claim to be flame retardant and transparent. Traditionally, in order to obtain the desired flame retardancy resin manufacturers have used solid fillers to achieve flame retardancy but such fillers simply do not permit a transparent resin when cured. Traditional liquid flame retardants tend to be halogenated, whereas Electrolube's UR5641 does not contain any filler and has the additional benefit of being halogen free.

Conventional resins that claim to be flame retardant and optically clear are actually pale amber when cured. Many of these resins are most likely to be based on epoxy technologies which are prone to yellowing. Electrolube's UR5641 is based upon aliphatic urethane chemistry, which is naturally resistant to the yellowing effects of natural light, making it useful for both exterior as well as interior applications.

UR5641 cures to provide a flexible, protective and aesthetically pleasing covering over the luminaire elements. The resin also offers high resistance to weather, acids and alkalis, water and mold growth. UR5641 is a two-part, semi-rigid, optically clear, flame retardant polyurethane resin that meets the UL94 V-0 standard. Due to a carefully selected blend of components, UR5641 is an extremely durable, low viscosity system that can be used for a wide variety of applications. The new resin is eminently suitable for the protection of LED luminaires exposed to hazardous atmospheres, such as emergency lighting, or lighting intended for installation in ATEX rated/zoned environments.

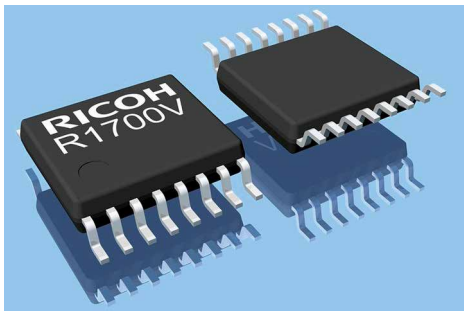
The UR5641 resin demonstrates high dielectric strength at 11 kV/mm, excellent thermal conductivity of 0.35 W/mK and

provides a wide operating temperature range between -40 to +120°C. The RoHS-2 compliant resin also provides a cure time within 24 hours at 23°C or 4 hours at 60°C. ■

Ricoh Launches a LED Driver IC with PFC and low EMI Emission

Ricoh Electronic Devices Co., Ltd. in Japan has launched the versatile R1700 LED driver controller. Designed to use in LED lighting applications and including features such as power factor correction, the controller boasts low EMI emission by zero voltage switching and various safety protection circuits.

Ricoh expands its portfolio of ICs targeted for LED lighting applications, the R1700 is a brand new product which is powered directly from mains and converts its primary power source into a voltage suitable to drive LEDs. The IC is optimized for non-isolated LED driver circuits and has a wide input voltage range up to 650V to tolerate peaks in the supply voltage caused by switching inductive loads and to have enough safety margin.



Ricoh's LED driver IC solution uses a unique one stage switching conversion with an advanced buck-boost (inverting) topology

A conventional LED driver circuit usually consists of two switching DC/DC Converters whilst Ricoh's solution uses a unique one stage switching conversion with an advanced buck-boost (inverting) topology. Additionally, an edge resonance controlled Zero Voltage Switching (ZVS) circuit allows a high operating frequency. These two features accept the use of smaller and less bulky components which makes the application suitable for integration in regular but also small and thin sized lighting fixtures. Compared to conventional circuits, a board-space reduction of 70% and height reduction of 50% can be achieved. A second significant advantage of Ricoh's approach is that the electronic circuit emits considerable less EMI noise.

Ricoh's R1700 is a high efficient Power Factor Correction (PFC) controller with ZVS, which significantly reduces the switching loss and switching noise generated by synchronous rectification. The PFC circuit improves the ratio between active and apparent power resulting in a lower load current from the source (energy supplier).

The LED brightness level can be dimmed from 100% to 5% by connecting a PWM signal to the DIM input. As an alternative option one could consider adding the R1580 constant current driver into the circuit. This IC converts a PWM signal into a linear dimming signal, the main advantages of this

method is that the LED driver MOSFET is not continuously switching, which suppresses the harmonic current and EMI emission and results in a flicker-free LED operation. Especially when the light source is used for recording photos and videos, the resulting footage quality may be affected by flickering illumination. Striking effects are areas or lines on the footage with a different exposure. Another advantage of the R1580 is its wide dimming range; it extends the standard range from a minimum setting of 5% to 0.5%. In particular for RGB LED configurations, the extended dimming range ensures a wide control of the color temperature settings.

Diodes' AL8862 Buck Driver Adds Dimming to Commercial Applications

A wide input voltage range and integrated power MOSFET make the AL8862 buck LED driver a solution well-suited for developers of LED lighting drive circuits looking to minimize board space and r educe BoM cost with excellent analog and PWM dimming functions.

Diodes' new AL8862 helps to minimize board space while providing a typical output current accuracy of 5% at up to 1 A and 97% efficiency

With a typical output current accuracy of 5% at up to 1 A and 97% efficiency, the AL8862 can operate from an input voltage range between 5 V and 60 V, making it suitable for commercial, industrial, or architectural lighting. Its small profile means it can also be used in appliances of all sizes.

An external control pin accepts either an analog or PWM signal to add dimming capabilities, which brings an additional dimension to connected lighting, such as color mixing. The integrated MOSFET is rated at 60 V, making the AL8862 a viable solution for higher power output applications.

Leveraging Diodes Incorporated's proprietary technology, the MOSFET also has an ultra-low Rds(on) of just 0.4 Ω, which delivers high efficiency while minimizing the need for external components. Comprehensive protection against possible fault conditions caused by short or open circuits is also included, along with over-temperature protection.

New High Efficiency LED Lighting Controller from ON Semiconductor

ON Semiconductor, driving energy efficient innovations, has announced two new QR PSR PWM controllers for LED lighting with Power Factor Control (PFC) function. The dimmable NCL30386 and the non-dimmable NCL30388 provide market-leading options for designers of LED lighting units such as luminaires used in office and industrial building applications.

ON Semiconductor's new NCL3038x constant current and constant voltage IC solution allows precise wide range dimming in modern LED lighting applications

Both devices are high power factor (PF), single stage, constant current (CC) and constant voltage (CV) primary side regulated (PSR) pulse width modulation (PWM) controllers for Flyback, Buck-Boost or Sepic power topologies. They operate in Quasi-Resonant (QR) mode to achieve efficiency levels that exceed those stipulated in power standards such as the EU's Ecodesign as well as Energy Star® and the NEMA SSL regulations.

The integrated digital power factor correction (PFC) algorithm ensures a market-leading PF of greater than 0.95 and total harmonic distortion (THD) of less than 10% across a universal input voltage range. Integrated high voltage startup current source ensures fast startup, low standby power and wide range operation at the output. Current and voltage are regulated via a digital PSR CC/CV loop control, typically achieving in the region of ±2%, to give highly uniform lighting brightness under all conditions.

The devices are simple to use and operate from a wide VCC range of 9.2-26 VDC, with valley lockout and frequency foldback ensuring high efficiency across the entire voltage range. Design is further simplified by the inclusion of safety features such as brown-out and overvoltage protection plus the ability to detect short circuits in the output, winding and diode.

Neither the NCL30386 nor the NCL30388 require many external components to complete the design, reducing time-to-market, BoM cost and the space required to realize a complete lighting solution.

Additionally, the NCL30386 offers excellent dimming features, including the option for either linear or quadratic dimming curves. The wide analog dimming range is controlled by two dedicated analog / PWM control pins that allow for precise dimming with a 0.5% minimum dimming ratio - and no audible noise present.

PI's New LYTSwitch-6 LED Drivers - Efficient & Low Standby Power

Power Integrations, the leader in high-efficiency, high-reliability LED-driver ICs, announced the LYTSwitch™-6 family of safety-isolated LED-driver ICs for smart lighting applications. The new ICs deliver flicker-free output up to 65 W, and feature up to 94% efficiency and as little as 15 mW standby power, with configuration options for two-stage or single-stage PFC support.

LYTSwitch-6 LED drivers from Power Integrations feature high efficiency and very low standby power; ideal for smart lighting and ballast applications

Targeting smart residential and commercial fixtures and low-profile ceiling troffers, LYTSwitch-6 ICs also exhibit fast transient response, which facilitates excellent cross regulation performance of parallel LED strings without additional regulator hardware, and allows easy-implementation of a pulse-width-modulation (PWM) dimming interface. LYTSwitch-6 ICs include both constant-voltage (CV) and constant-current (CC) operation, enabling lighting manufacturers to reduce the number of product variants, resulting in manufacturing and logistics savings.
The new ICs are protected by an advanced thermal foldback system which prevents overheating while delivering as much light as thermally possible in any circumstance or installation.

LYTSwitch-6 ICs feature a built-in 650 V or 725 V MOSFET and secondary-side FluxLink™ control which eliminates the need for an optocoupler and provides highly accurate output with better than 3% CV and CC over line, load and temperature. Power conversion for the flyback stage is more than 94% efficient, achieved by using synchronous rectification and quasi-resonant switching which enables high power output without a heatsink. For example, a 35 W, 12 V, 2.92 A design with an additional PFC circuit has been demonstrated to be over 89% efficient. Devices offer low standby power - less than 15 mW in universal AC input conditions – even with line voltage sensing, which allows the IC to protect itself from mains voltage surges and swells.

Comments Hubie Notohamiprodjo, director of product marketing for LED lighting at Power Integrations: “LYTSwitch-6 ICs are ideally suited to smart lighting applications with multiple outputs.
By eliminating heatsinks and optocouplers and reducing the size of the output capacitor by as much as 30%, component count and system size are also reduced.”

LYTSwitch-6 LED-driver ICs are available now, priced at $0.84 in 10,000 quantities. A reference design (DER-637) describing a 35 W PWM-dimmable LED power supply with efficiency over 89% and a power factor greater than 0.9 is available for download from the Power Integrations website. ■

Most Thermally Efficient & Cost-Effective MCPCB

LED thermal management innovator Cambridge Nanotherm launches Nanotherm MCPCB — the lighting industry’s most thermally-efficient and most cost-effective metal-clad PCB. Thanks to a recent technological breakthrough regarding the company’s patented electro-chemical process, which creates a 20µ-thick dielectric layer of alumina atomically bonded to the aluminum board, Cambridge Nanotherm has been able to radically drive down the cost of Nanotherm MCPCB, which is now available to customers at a lower cost but better efficiency than even the best MCPCBs on the market. Samples are available immediately.

Technological breakthrough ensures Nanotherm MCPCB is the most cost-effective and most thermally efficient MCPCB for the general LED lighting applications developer

Nanotherm MCPCB offers an industry-leading thermal efficiency of 120 W/mK, offering electronics designers better than 56% of the thermal conductivity of an aluminum plate. Nanotherm MCPCB also offers a robust stability at an operating temperature of 130°C, and is lead-free solder compatible and ROHS and UL recognized.

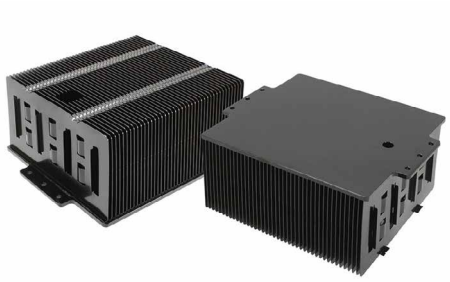
This price reduction brings Cambridge Nanotherm’s revolutionary ceramicised aluminum boards, which used to be only affordable for high-power applications, solidly within the price range of all general lighting applications for the first time.

Cambridge Nanotherm sales and marketing director Mike Edwards said: “The fact that our Nanotherm MCPCB is now available to the general lighting market is testament to the hard work and research our scientists have put in over the past three years. One of our greatest strengths at Cambridge Nanotherm is that we can easily ‘swap in’ our thermal management technology to customers’ existing MCPCB machining processes, but we are particularly dominant when it comes to integrating CSP designs into tunable white solutions. Where a company may have previously used a traditional MCPCB, now they can use Cambridge Nanotherm’s technology, gaining greater thermal efficiency at a lower price, with no costly retooling and minimum integration effort.”

Nanotherm MCPCB is now available for prototyping and mass production orders. Industry-standard copper finishes, solder mask and feature sizes are all available - as are double-sided substrates containing a dielectric surface and wiring traces on both sides of the MCPCB. ■

GlacialTech Announces New Igloo SS150-V2 LED Flood Light SKD Kit

GlacialTech, the diversified LED technology provider, announces a new 150 W heatsink for outdoor flood light and available for single CoB or Multi-chip LEDs. The Igloo SS150-V2 features an efficient heat sink with thermal resistance 0.358°C/W for Multi-chip LEDs and 0.451°C/W for single CoB. The Igloo SS150-V2 with heat pipes design for single CoB to enhance the heat dissipation quickly.



GlacialTech’s new Igloo SS150-V2 heat sinks are designed for multi-chip LED or single CoB based lights

Features:

- Rated for 150 to 180W single CoB or Multi-chip LEDs
- Thermal resistance 0.451°C/W for single CoB and 0.358°C/W for Multi-chip LEDs
- Adjustable stainless steel mounting bracket and screws
- IP65 rated, suitable for outdoor applications

GlacialTech’s experience in thermal design allows the Igloo SS150-V2 to create a heat sink boasting an excellent thermal resistance

using stamping technology. The efficient thermal performance means high output single CoB or Multi-chip LEDs up to 180 W can be accommodated. Customers can easily use the Igloo SS150-V2 to construct LED flood lights and make sure LED will not be overheated and keep long life.

The Igloo SS150-V2 thermal module is available standalone, or as a semi-knockdown (SKD) kit that includes heat sink module, adjustable stainless steel mounting bracket and screws. Also offers the waterproof bridging connector which can easily install the power cables between LEDs and drivers. The SKD kit allows use in high output lighting for stadiums, parking lots, and outdoor storage areas.

With an IP65 rugged design, LED flood lights built with the Igloo SS150-V2 SKD kit are dust proof and waterproof against extreme weather and strong jets of water. Fixture designers can choose the appropriate LED module and driver for their lighting needs and easily create high performance outdoor application with dependable GlacialTech thermal technology. ■

Lextar Announced ADB Automotive Headlight Module

LED vertical integration manufacturer Lextar Electronics released its adaptive driving beam (ADB) LED headlight module system. In coordination with CCD module, it can detect oncoming cars and dynamically adjust the beam pattern, creating a future new trend for LED automotive headlights.

Besides a headlight module, Lextar announced a whole series of automotive LED components and modules for the Auto Lamp Exhibition

The series products of automotive LED packaging, LED module, light engine and others were displayed at the Auto Lamp Exhibition Shanghai (ALE) end of March to demonstrate the vertical integrated LED product capacity of Lextar.

Market research points out that the current market occupancy of ADB headlights will increase rapidly from current less than 1% in the global vehicle market to 15% in 2025. Lextar takes the initiative in smart headlights by investing in technological R&D and will demonstrate its achievement to the public. Lextar's ADB smart headlight module is equipped with 64 matrix arranged in-house chip scale package (CSP). It utilizes self-manufactured hi-power chips in coordination with optical design and CCD lens module, enabling it to detect oncoming and preceding cars and dynamically adjust the range of high beam and low beam, to prevent oncoming car drivers from being interfered by the light. This can highly enhance driving safety and eliminate the need to manually switch from high to low beams when driving at night.

In addition, Lextar also displayed a series of LED components and modules applied to car headlights, rear lights, interior lights, display panel backlight, IR sensors and other products. The whole series of LED packaging components have passed the quality certification of AEC-Q102 and use Sulphur-resistant materials in order to provide customers with high quality and reliability. Module series can be customized according to customer's demand and customized shaped light boards and optical lens can be made according to different cars. Moreover, the application of LED is further expanded to display panel and sensor applications besides vehicle lighting. Among them, Lextar's VCSEL sensor module demonstrates anti-doze application, in which the camera and software can conduct 3D detection when drivers close their eyes, nod, yawn and other actions. ■

Fulham Announces Numerous New Products and Solutions

At Light + Building, Fulham Co., Inc., a leading supplier of lighting components and electronics for commercial and specialty applications, demonstrated several new products and solutions for lighting applications. Fulham will demonstrate the new universal voltage versions of its DirectAC direct-drive LED Engines and its new line of LinearHO high-output LED modules to European OEMs and distributors. Furthermore Fulham demonstrates Bluetooth Mesh and PoE technology for LED lighting control.

Fulham's highlights at Light + Building 2018 were their new universal voltage versions of its DirectAC LED Engines, the new LinearHO modules, and their new wireless and wired lighting control technology

Universal Voltage Integrated DirectAC LED Engine and Retrofit Kit:
Fulham's latest DirectAC LED Engines are low profile, self-contained units with an integrated driver that can support power ratings from 120 to 277 volts.

Integrating the driver on the circuit board makes the DirectAC LED engine more versatile and cost-efficient. Since this newest DirectAC LED Engine supports universal voltage, it is ideal for retrofits as well as new installations. The LED engine is ideal for application such as wall sconces and ceiling luminaires, but it can be installed in virtually any setting. The integrated driver design also makes Fulham's Universal DirectAC LED Engine suitable for open and enclosed luminaires, and luminaires with plastic and glass lenses.

"More of our European OEMs and distributors are delivering luminaires for large construction projects as well as retrofits, so we wanted to offer a one-size-fits-all LED light kit that could be installed anywhere," said Edwin Reyes, Product Director, LED Light Sources, for Fulham. "Adding the driver circuitry to the board reduces the size of the LED engine as well as the cost of manufacturing, and universal voltage support means customers can stock one unit for more applications. We also expect the DirectAC LED Engine to gain popularity with installers since it can be fitted in five to 10 minutes."

The DirectAC LED Engines are available in 10 W, 15 W, 23 W, and 34 W round

configurations as well as a 15W, 4 by 7-inch rectangular configuration. They offer a lumen maintenance of L70>54,000 hours, with a color consistency of 3 SDCM and a variety of color temperatures with an 80 CRI up to 90 CRI, making them ideal for replacing fluorescents, and the units are leading/trailing edge dimmable from 100 to 10 percent. To reduce flicker, the DirectAC Engines have additional circuitry for use with 50/60 Hz power lines; flicker is below 30 percent when operated at line voltage which meets most standards requirements for low flicker. All units are suitable for installation in dry and damp locations, indoor or outdoor.

Newest High Output LinearHO LED Modules:

Fulham's new LinearHO modules have been designed for use with high bay, waterproof/non-corrosive and recessed modular luminaires, along with other luminaires where high-output lighting is needed. The LinearHO modules are also suitable for use within damp environments.

The LinearHO DC LED modules are high-lumen, high-efficacy units designed to replace and enhance where traditional linear lamps would have previously been used. The LED modules are compatible with constant current drivers including most of Fulham's LED drivers and emergency lighting systems.

The variants of LinearHO modules available include 560mm delivering >7,100 lumens and 1120 mm or 1475mm delivering >13,600; available in 3000 K, 4000 K and 5000 K color temperatures, with 80CRI or 90CRI options. All variants have pre-mounted magnets and push-in connectors for easiest installation and are self thermally managed due to their extruded aluminum design.

"We are seeing more demand for high-output linear LED modules for outdoor applications and harsher environments, such as linear highbay applications, so we designed our LinearHO LED modules for both new installations and retrofits," said Mark Needham, Vice President of European Sales for Fulham. "These new high-output modules will be popular with installers as well since they can be installed in minutes. Our goal is to provide OEMs and installers with LED modules that are more versatile, standards compliant, and easy to customize and install."

Fulham's LinearHO DC LED modules are ideal replacements for Fluorescent T5HO, which were typically used in high bay, recessed modular and within single or twin waterproof/non-corrosive linear. Each variant of the LinearHO LED modules can be used with their optional diffused lens accessory optic that can be simply clicked-on without the need for any tools or additional components. The LinearHO LED modules are fully compliant with all associated European specifications requirements and are fully available now.

Bluetooth Mesh and PoE Technology for LED Lighting Control:

The new wireless lighting control technology uses the Bluetooth mesh control stack from

Silvair to provide two-way communication to smart light fixtures. The new Power over Ethernet (PoE) LED Linear Engine technology combines DC power and smart lighting control.

Fulham's Light + Building Bluetooth mesh demonstration included a Bluetooth to 0-10 V LED controller and a 40 W LED driver with add-on Bluetooth connectivity via a Fulham Intelligent Wireless Module. Both products will be used to control third-party sensors and wall switches, showing the promise of Bluetooth Mesh compatibility. These are some of the very first wireless LED controllers to provide two-way Bluetooth communications, enabling control commands and commissioning as well as data gathering for performance monitoring and analytics.

Bluetooth mesh can be used to enable a wireless lighting management ecosystem that can quickly pay for itself, as well as laying the foundation for centralized lighting controls as the foundation for IoT (the Internet of Things). ABI Research predicts there will be 48 billion Internet-enabled devices installed by 2021, including smart luminaires, and open standards such as Bluetooth mesh will make it possible to consolidate these devices into an IoT infrastructure. Fulham is demonstrating a prototype app that shows how sensors in luminaires can be used for additional IoT functions such as managing HVAC, alarm systems, emergency exit signs, and smart door lock controls.

Adopting Bluetooth mesh for wireless lighting controls offers a number of advantages since Bluetooth is a well-defined, open standard that promises fast, reliable performance and scalability. Mesh networking was designed for applications such as building automation, supporting many-to-many communications, and it is ideally suited for connected lighting since it can simultaneously connect sensors in hundreds to thousands of luminaires.

Fulham also displayed a new PoE Linear LED Engine technology, which can be integrated into a variety of form-factors. Unlike previous generations of PoE products that can only issue commands via a 0-10 V interface, the PoE LED Engine connects directly to the LED light module, providing complete two-way communication with the fixture to gather data about luminaire performance, power consumption, and operating temperature, as well as issuing commands such as on/off, dimming, color tuning and timed scheduling.

Using PoE to power LED luminaires simplifies installation, since only one cable is needed for both power and controls. PoE provides the LED luminaries with a low-voltage DC power source providing up to 52 W of power. This makes the luminaire more energy efficient and less costly since no conversion drivers are required.

PoE also allows makes it easier to accommodate high bandwidth sensors such as IP cameras in the same network infrastructure used to power and control lighting. With PoE, each LED luminaire has a unique IP address, making it easy to add lighting to an IoT infrastructure, including remote management over the Internet.

"We have been developing clever LED products with integrated programmability for some time. The next step toward smart lighting is to add communications to programmability, and our technology demonstrations at Light +Building highlighted some of the possibilities offered networked lighting ecosystems," said Russ Sharer, Vice President of Global Marketing and Business Development for Fulham. "In addition to providing two-way communications for both control and data gathering, using open standards such as Bluetooth Mesh and Power over Ethernet to connect luminaires paves the way for IoT integration. LED lighting with built-in sensors creates an ideal framework for IoT infrastructure. These technologies have been requested many times by our OEMs, and we are excited to share their status." ■

A Quantum Leap in the Quality of Tunable White Systems

Second generation Tunable White systems consist of two to six linear or area LED modules and corresponding DALI DT8 LED drivers. They cover the entire color temperature spectrum from 2,700 to 6,500 K, have an extended dimming range down to 3 percent and, together with appropriate control components, provide the hardware basis for human centric lighting.

Tridonic's new Tunable White systems offer even better quality of light, high visual comfort and unprecedented color consistency

The new Tunable White systems (SELV) fit in first-generation non-SELV housings but offer even better quality of light, high visual comfort and unprecedented color consistency. This combination is of great benefit for offices, shops, educational establishments and medical facilities because the right light can be produced for any particular lighting application. Preconfigured kits are available comprising two to six LLE or QLE Premium LED modules and associated low-profile DALI DT8 drivers in 50 or 100 W versions.

The color temperature can be infinitely adjusted between 2,700 and 6,500 K via a sophisticated calibration algorithm in all the possible combinations. This means that the natural changes in daylight can be simulated and matched precisely to the lighting task. The luminous flux remains constant at all times. The system can also be dimmed from 100 to 3 percent, exclusively via amplitude modulation. There is therefore no dimming flicker. The color location that has been precisely defined in the kits is retained at all dimming levels. Even if there are a large number of luminaires in a room the light will have a homogeneous appearance. The high quality of light is reflected in the high color rendering index of Ra > 90 and color consistency corresponding to MacAdam 3.

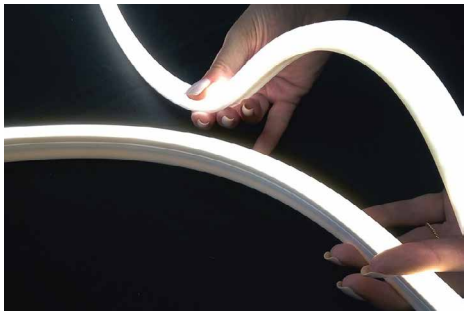
Simple operation and control:
The driver is equipped with colourSWITCH and switchDIM so the color temperature and dimming level can be easily changed using two buttons. This is also possible from a momentary-action switch or smartphone via basicDIM Wireless. A selection of predefined color temperatures and dimming levels are available at the touch of a button. The kit can also be operated from a touch panel. The integrated DALI interface enables the kit to be easily connected to central light management systems.

Depending on the version, Tunable White modules LLE G2 PRE (24 x 280 mm) deliver a luminous flux per module of 700 or 1,500 lm, and tunable white modules QLE G2 PRE (270 x 270 mm) a luminous flux per module of 1,250 lm. While LLE modules have an efficiency of up to 112 lm/W, QLE modules achieve up to 136 lm/W.

With their improved technical specifications, carefully designed control technology and impressive flexibility, the Tunable White systems meet the growing demands for lighting that can be tailored precisely to the requirements of different situations to enhance the well-being of users. The manufacturer specifies a life of 50,000 hrs and provides a five-year guarantee. ■

Bilton Realizes a Fully Encapsulated LED Module

With the new Bilton AIR series, Bilton is presenting innovative and avant-garde ideas that will revolutionize the future of LED lighting. This is achieved through a progressive hybrid solution. The new Bilton LED module series Bilton AIR is a highly flexible silicone hose and, in addition to protection class IP67, guarantees top light quality, effective heat dissipation and is resistant to external influences (UV, salt, chlorine, etc.).



Bilton's new LED strip light is flexibly shapeable

Top features:

- IP protection IP67
- Flexibly shapeable
- Lighting upwards or sideward
- Max. module length up to 5 meters
- Luminous flux up to 1,000 lm/m
- Voltage 24 VDC
- CRI >80
- Light color available in 2,700, 3,200 and 4,000 K

The LED strip light is flexibly shapeable. There are two versions of the Bilton AIR SIDE - with lighting from the side, and the Bilton AIR TOP - with lighting facing up. Both model versions are available in 3 different light colors. Bilton AIR bends in every direction, making the LED strip light perfect for any application – indoors and outdoors!

We showcased real innovation at Light and Building 2018. The hybrid solution of the Bilton AIR series realizes the novel design of a completely encapsulated LED strip light. Many came and saw the innovations for your. We want you to go beyond the limits of feasibility and, under our motto “The Art of Linear Lighting” we showed inspired and versatile works of lighting art that can be achieved with LED modules. ■

Two Drivers in One Housing for Direct and Indirect Lighting

The dimmable two-channel DALI DT6 constant current LED driver is the latest addition to the Premium SELV series and is already DALI-2 certified. It will typically be used in linear and panel luminaires in offices and healthcare facilities for direct and indirect lighting applications. Simple tunable white solutions are also possible.

The main application for Tridonic's new 2-channel LED driver is direct/indirect lighting. For even more flexibility, a 4-channel version is also available

The LCA 50W 350–1050mA 2xCH lp PRE LED driver has an output of 50 W and accommodates two channels in its housing. For each channel the output currents can be set separately between 350 and 1,050 mA, either via I-select 2 plugs or DALI. The integrated one4all interface supports DALI DT6, DSI, switchDIM and corridorFUNCTION V2. The driver is also equipped with a proportionSwitch interface. While preset dimming levels for the connected luminaires can be easily selected with a pushbutton via switchDIM, different predefined dimming levels are available for each channel via proportionSwitch. Dimming in this case has a contrary effect: increasing the brightness on one channel reduces the brightness on the other channel. This means, for example, that different brightness levels can be set for direct and indirect light in pendant and floor-standing luminaire or simple tunable white applications can be realized.

High efficiency, low standby losses

Measuring only 350x30x21 mm, the driver can be easily integrated in existing or new luminaires. It achieves an efficiency of up to 90 percent and has a wide dimming range of 1 to 100 percent. Thanks to low standby losses of less than 0.25 W, the driver is an impressive energy saver. It is suitable for luminaires of protection classes I and II and is also designed for emergency operation. With a life of up to 100,000 hours the driver is also extremely durable. The manufacturer offers a 5-year guarantee. ■

MOSO High Reliable & Flexible Programmable Outdoor LED Driver

MOSO, one of the most influential and well-known new energy enterprises in China, is dedicated to providing efficient, intelligent and safe outdoor LED power supply solutions by introducing its programmable LDP series worldwide.

Mosos's new outdoor LED driver is characterized by its high surge immunity and great flexibility due to the implemented programming option

Applications:

- LED street lighting
- Industrial lighting
- Landscape lighting

DM-5KV & CM-10KV surge immunity, fully glue-potted IP67 for -40 to +60°C dry/wet/damp conditions, supporting universal 90-305 Vac input, CE, ENEC certified by TUV lab, LDP series is configurable constant current LED driver with high reliability. The rated power range is from 42 W to 320 W.

Monitored by an infrared-based programming device, the fully programmed drivers offer all dimming options and a wide range of output current in a single driver, which deliver maximum flexibility with customized operating settings and intelligent control options for manufacturers, as one driver can be programmed for many different luminaire designs. LDP provides built-in timer dimming function, further increasing the energy savings and CO_2 reductions achieved with LED lighting. It also helps clients to largely improve the management of logistics and inventory. ■

Inventronics Introduces New Surge Protection Devices

Inventronics has announced the release of a new surge protection device family designed to be used in conjunction with any of their LED driver families. Inventronics LED drivers offer industry-leading protection already but recognize some customers desire external protection for applications in hostile grid environments. These applications can include high bay, high mast, arena, roadway, industrial zones and open parking lot lighting.

Inventronics' new surge protection device family is designed to be used in conjunction with any of their LED driver families

The PU-20KS10KHT and PS-20KS10KHT is designed according to UL 1449 Type 5 and IEEE C62.41.2 specifications. They have a maximum discharge current (Imax) of 20 kA, 8/20 µs and a normal discharge current (In) of 10 kA, 8/20 µs. The PU-20KS10KHT operates from 90-305 Vac while the PS-20KS10KHT operates from 249-528 Vac.

Their robust surge protection enables them to significantly improve the reliability and extend the lifetime of connected LED fixtures. They use a Gas Discharge Tube (GDT) to disconnect the MOVs and prevent catastrophic failure and risk of fire. They are both IP20 rated with UL certification. ■

Acclaim Lighting - New Wireless Universal Dimming Module

Acclaim Lighting, a leader in innovative and advanced lighting technology, introduces its new wireless Universal Dimming Module (UDM-W). UDM-W is a multi-protocol driver designed to allow conversions between popular control systems, and allow for maximum control flexibility and integration with fixtures. UDM-W gives users a choice between a wireless and wired DMX input, by natively adding Acclaim's Aria Wireless DMX technology.

Wireless Universal Dimming Module complements Acclaim Lighting's wired UDM and features DMX, 0-10 V and line voltage dimming ability for a wide range of applications

Both the wireless and wired UDM units support DMX / RDM and 0-10 V inputs, while its outputs are DMX / RDM, 0-10 V and IGBT digital line voltage dimming (compatible with forward and reverse phase fixtures). Operating with 0-10 V Sink Power, the unit can deliver an output up to 25 mA drive current. Adjustments in mode settings can be achieved by utilizing the on-board dip switches or RDM.

The brand new UDM-W, with Aria Wireless DMX, has a 2,600-foot, line of sight wireless reception range with a 300-foot range between obstructions and walls. The UDM can take a power of 1000 watt at 100-277 VAC, while outputting 100-277 VAC or 50/60 Hz via IGBT. AC options include 90-277 AC pass through while using DMX, to allow power output to fixtures.

The unit hosts one input and one output via ½-inch conduit nipples. IP64-rated for damp locations, UDM operates in temperatures ranging from -35°C to 50°C. In addition, the UDM has transient voltage protection, DMX isolation, and comes with a 5 year limited warranty. ■

Inventronics New 1200 W LED Drivers

Inventronics has announced the release of a new series of ultra-high-powered LED drivers designed to solve many issues OEMs face in high-powered applications such as horticulture, high mast, airport and stadium lighting. By using one EFD Series LED driver instead of multiple lower-wattage drivers it eliminates the extra costs of mounting gear, junction boxes and complex wiring while providing more flexibility in the lighting fixture design. They also simplify the luminaire design by providing easier thermal management, lowering fixture weight and a stress-free installation.

Inventronics' new outdoor LED driver series offers a broad input voltage range of 180-528 Vac and a programmable output current as well as a number of features that help reduce inventory

The new series offers three models supplying 1200 W and operates over a 180-528 Vac input voltage range for single and three phase applications. They provide a high-level of design flexibility with programmable full-power output currents from 3.36-7.4 A and multiple dimming options including Isolated 0-10 V, PWM and 3 timer options. This helps to reduce inventory even more and removes the need to design in separate LED drivers for multiple configurations.

In addition to their flexibility and their robust thermal design, the EFD-1K2SxxxDT/DV is IP67 (DT is also TYPE HL), which is ideal for

environmentally harsh indoor and outdoor conditions typical of high-powered applications. The EFD series also features over-voltage, over-temperature and short-circuit protection, plus a higher level of built-in surge protection: 6kV line-to-line and 10kV line-to-earth. These drivers implement the new external over-temperature protection for LED modules, another key factor in significantly improving reliability and extending lifetime.

The EFD series is optimal for building lighting systems. These products supply a low output ripple ideal for HDTV broadcasting and are Controls-Ready. They work with a wide variety of sensors and controls since the drivers are equipped with dim-to-off capabilities and an always-on 12 V auxiliary supply sourcing up to 200 mA. This allows the EFD series to power Inventronics controls modules directly, bypassing the power and voltage restraints associated with power packs and AC relays.

The new series is approved to UL, FCC, and CE standards. Production quantities of the EFD-12KSxxxDT series suitable for North American use are available now. The EFD-12KSxxxDV suitable for use in Europe and other regions are also available now.

ULT's Everline PA LED Drivers with 1-10 V Auxiliary Output Power

Universal Lighting Technologies, a global leader in lighting and a member of the Panasonic Group, recently introduced its PA Series of LED drivers. Designed for the smart fixture, PA drivers eliminate the need for a separate power supply for sensors by providing 12 Volts DC (12 Vdc) or 24 Vdc auxiliary output power.

ULT's latest Everline® PA LED Drivers add auxiliary output to 0-10 V outdoor and industrial applications

These drivers are compatible with any standard 0-10V analog dimming control signal. They can be programmed down to a minimum dimming level of 5 percent using the popular EVERset tuning software. The software allows designers to customize PA driver parameters, such as minimum and maximum output currents, dimming curves, dimming control voltages and a dim-to-off command. Specific configurations can then be saved for production use.

“Universal has always focused extensively on providing our customers with the right driver for the right application, which is why we developed a family of programmable drivers with auxiliary output power for outdoor and industrial luminaires,” said Kevin Boyce, director of product management at Universal Lighting Technologies. “PA drivers have been engineered to support the emerging Internet of Things (IoT) transformation by providing power directly to sensors and reducing the number of components inside luminaires.”

PA drivers are well suited for industrial and outdoor applications with Class 2 output, Type HL rating and 6 kV surge protection for extreme environments. The LED drivers are available in 55 W and 95 W.

ULT Adds Everline Emergency Drivers

Universal Lighting Technologies has expanded its comprehensive line of lighting solutions with Everline® Emergency LED Drivers for offices, classrooms, warehouses and other commercial applications.

Universal Lighting Technologies' new drivers were designed to meet North America's emergency lighting requirements

Available in four models (ELD10UNVL, ELD10UNVLPL, ELD7UNVCL, and ELD20UNVL), the new drivers were designed to meet North American buildings’ strict emergency lighting requirements. Rather than installing separate emergency lighting fixtures, OEMs and contractors can specify Everline Emergency LED Drivers to be installed in LED luminaires that require emergency battery back-up systems.

Individual product benefits include:

- Targeted for downlight applications, model ELD7UNVCL provides 7 W of emergency power and an output voltage range of 15-50 Vdc and provides lead within flexible conduit for connections
- Targeted for linear fixtures, model ELD10UNVL provides 10 W of emergency power and an output voltage range of 15-50 Vdc
- Targeted for architectural fixtures, model ELD10UNVLPL also provides 10 W of emergency power and an output voltage range of 15-52 Vdc while featuring a low profile (1.18” h x 1.18” w)
- Targeted for high bay applications, model ELD20UNVL provides 20 W of emergency power, an output voltage range of 20-50 Vdc and offers lead within flexible conduit for connections

“With the addition of emergency LED drivers to our product portfolio, Universal can provide a single source for our existing LED driver customers to now buy both pieces of equipment,” said Kevin Boyce, product manager for Universal Lighting Technologies. “This offering will be beneficial for fixture OEMs needing to specify emergency solutions and for contractors looking to save time and money by installing emergency drivers in conjunction with standard LED drivers.”

Compatible with Universal’s Everline LED drivers, the emergency drivers offer 90-minute illumination time, an integrated NiCad Battery and a wide operating voltage range.

LIFUD High Bay LED Driver & Smart Sensor

LIFUD just launched her second generation of high bay driver, LF-FHB series. It can be completely turned OFF even without cutting off the AC power. When the second generation of LF-FHB series works with a smart sensor (= microwave sensor + light sensor) which was developed by LIFUD R&D, the light turns on/off automatically.

LIFUD's second generation of LF-FHB series works with a smart sensor

If the users want to set the reaction of the sensor and the light according to their preference, we can offer a remote control to help them with it. Besides the on/off function and 4 default scenes, the remote control can help to set the brightness level, the light-on time, the induction zone and how the brightness changes according to different daylight levels.

The LF-FHB series is of IP65 for indoor application. The high efficiency up to 95% and low stand-by power less than 1 W help to improve the light efficacy and save energy.

Super high efficiency and great thermolysis property expand the product lifetime. Meanwhile, the driver is with high power factor and low harmonic interference. In addition, all-round protection, including surge protection, over voltage protection, short circuit protection and over-temperature protection, greatly improve product stability.

The top of this product is equipped with a potentiometer which helps to adjust the output current/power of the product. The lighting fixture can be hung by a hanging ring or a bracket. Various installation options for the lighting fixture meet diverse needs. ■

Espen Technology - Innovative Powerline Dimming For 0-10 V

Espen Technology announced that it is offering the VersaDim System, an innovative, comprehensive dimming and control system using PCLC powerline communication technology. Espen demonstrated the new system at LightFair International.

VersaDim is an easy and secure power line communication dimming system comprised of a controller and a receiver. In a typical installation, one controlled fixture needs one receiver. One controller can control many receivers on the same branch circuit. No separate signal wires are required, there are no compatibility issues common to standard wall dimmers, and the system is plug-and-play. VersaDim eliminates wireless security concerns; does not adversely affect power line quality (PF/THD); handles heavy loads up to 2,000 W without derating; and is capable of zone control.

Espen Technology's VersaDim is a PCLC (Powerline Communicated Load Control) solution with comparable functionality like wireless controls, only cheaper and without their drawbacks

PCLC (Powerline Communicated Load Control) is an emerging control technology that provides the important capability of wireless controls (avoiding separate signal wires) while eliminating the drawbacks of wireless - extra cost in commissioning, maintenance, and security issues.

According to John Clancy, SVP of Sales & Marketing at Espen, “The VersaDim system stands out as an innovative new smart lighting technology because it’s an elegant and simple approach in a world of rapidly increasing complexity. It combines the best benefits of wired and wireless dimming approaches.” ■

Redesign of Gigahertz-Optik's BTS256-EF Light, PAR and Flicker Meter

The lighting industry requires high accuracy spectral light meters that can handle complex measurements. These include measurement of pulse width modulated light sources and the ability to measure both indoor and outdoor lighting, determination of thermal transient behavior of lamps, their flicker properties and so on. The primary criterion that such meters must always meet is the quality of their photometric features.

The redesigned BTS256-EF is able to fulfill an even broader range of requirements than ever before

With the BTS256-EF, Gigahertz-Optik GmbH, a renowned measuring device manufacturer, offers a universal measuring device for the determination of all relevant light parameters in general lighting. The new device has been updated which includes a redesign of some of its features. Changes include the enhancement of the wavelength range from 360 nm to 830 nm and the implementation of all functions of the BTS256-E, BTS256-EF and BTS256-PAR meter.

Due to its redesign, the BTS256-EF is able to fulfill an even broader range of requirements. Its measurement features include photometric and colorimetric parameters, Photosynthetically Active Radiation (PAR) of plant grow lights, Human Centric Lighting (1), Stroboscopic Visibility Measure SVM (2), Short-Term Flicker Pst (2), and ASSIST Flicker Perception Metric Mp.

The BTS256-EF is also available with an optional Wi-Fi function. ■

Photobiological Safety Measurement System from GL Optic

The photobiological safety measurement system from GL Optic – in short: GL PSM System 200-800 nm is the world's first mobile and preconfigured measurement system for monitoring and assessing the blue light hazard of all types of lamps.

Blue light hazard (photoretinitis) is defined as the potential risk for a photochemically-induced retinal injury resulting from electromagnetic radiation exposure at blue wavelengths of 400-500 nm.

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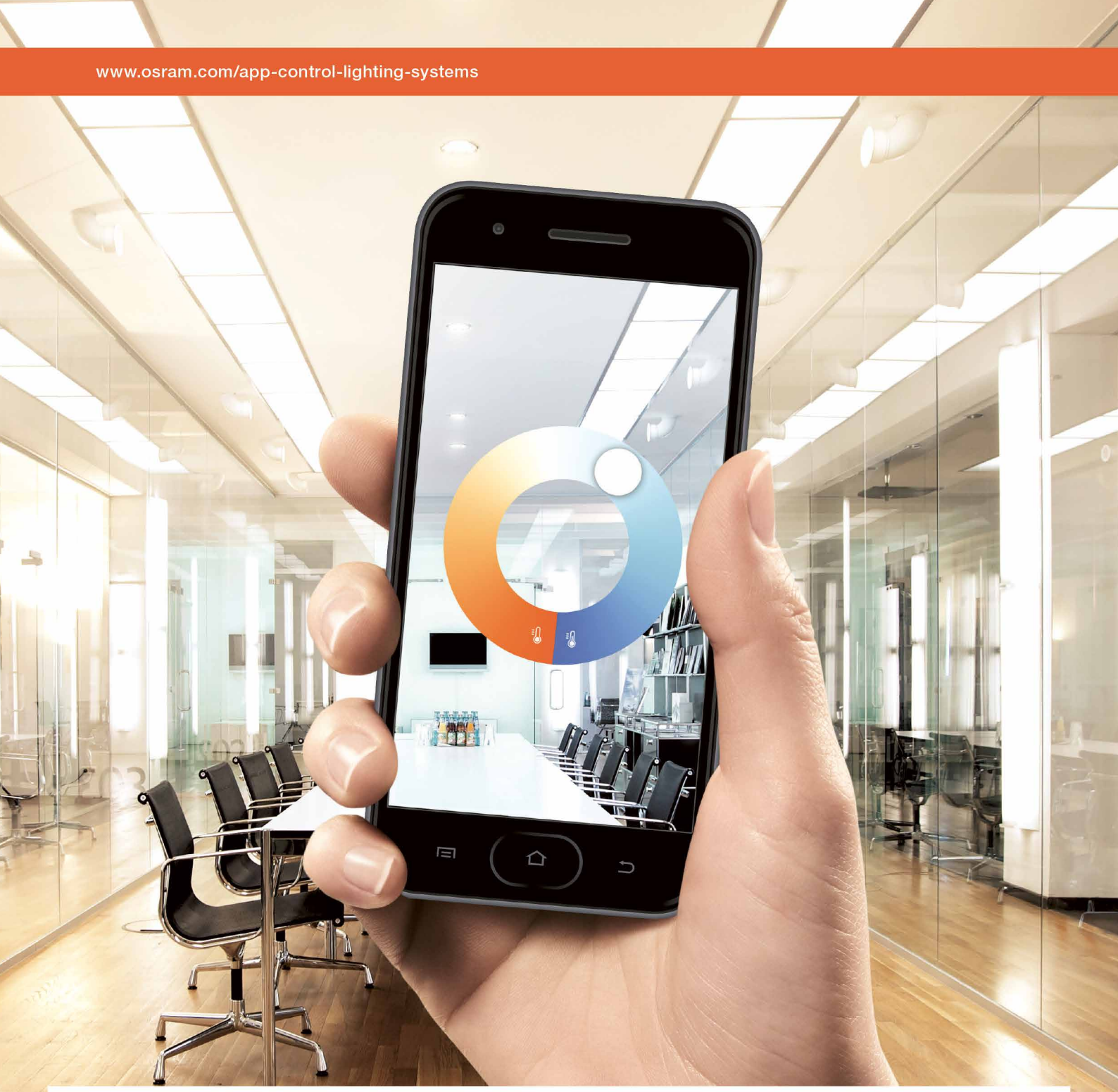


Light is yours to command

Functional intelligence for smart lighting with mobile apps

OSRAM is innovating commercial lighting with mobile apps designed for lighting professionals and end-users. Easy configuration means you spend less time installing. OSRAM'S user-friendly mobile apps empower end-users with switching, brightness adjustments and the ability to change color temperature from their smartphone.

Light is OSRAM

OSRAM

GL Optic's GL PSM System 200-800 nm is the world's first mobile and preconfigured measurement system by GL Optic for the evaluation of the blue light hazard

Today, a great proportion of our lives take place in artificially designed spaces and under artificial light, whether indoors or outdoors. In addition, we use PCs, tablets, and smartphones with illuminated displays on a daily basis. As a result, contrary to our natural circadian rhythm, we are often exposed to artificial light until late in the evening, which is produced by light sources with a distinct blue component. Several studies have shown that the blue light contained in LED lights has a negative effect on the sleep rhythm of humans. In addition, influences on visual performance are also confirmed as even the retina can be damaged by permanent exposure to visible blue light.

Up to now, it has been quite complicated and associated with extensive measurement configurations such as the use of a double monochromator to measure and evaluate the blue light hazard of lamps and luminaires. The new GL PSM system from GL Optic simplifies such measurements by pre-configuring the system for hazardous radiation measurements and risk assessment. Due to the plug-and-play concept, enabling the spectrometer and software to automatically detect accessory equipment, precise measurements can be performed within minutes.

The user is supported by a tool used for the first time for photobiological measurements: a software assistant that guides the user step-by-step through the individual measurement process. Inaccuracies caused by faulty measurement setups or incorrect configurations can be avoided and accurate measurements can be achieved.

The GL PSM system performs measurements according to the standards IEC (EN) 62471 (Photobiological safety of lamps and lamp systems) and EN 14255-1 (Measurement and assessment of personal exposures to incoherent optical radiation). The system consists of a high-resolution, factory-calibrated grade spectrometer, the GL SPECTIS 5.0 Touch (UV-VIS) 200-800 nm, a specially designed irradiance probe and a radiance telescope that recreates the properties of the human eye according to the above mentioned standards. The system also includes the GL SPECTROSOFT light measurement software for extensive light analyses and evaluations.

Precise and simplified light measurements even without the use of complex measurement setups with double monochromators are now available with the GL PSM system from GL Optic. For applications that require an extended spectral range, a 2-channel measurement system covering a range of 200-2500 nm is available. ■

Casambi Introduced New Class 2 Embedded Bluetooth 4.0 Module

Casambi, the world's leading provider of smart wireless lighting control technologies, presented the ecosystem of its rapidly-expanding Casambi Ready product portfolio at Light + Building 2018. On display was an extensive range of partner products, drivers, dimmers, switches, and control modules all working harmoniously with Casambi's native products.

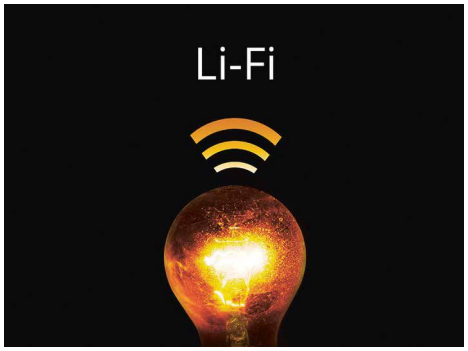
Casambi showcased the fast-growing wireless lighting control ecosystem with new hardware and software at Light + Building

At the show, Casambi presented its new Class 2 embedded Bluetooth 4.0 module, which provides integration possibilities to LED drivers, different lighting control applications, light fixtures and LED bulbs. The CBM-002A/B has a powerful 32-bit ARM® Cortex™-M4 CPU and a 2.4 GHz transceiver and two antenna options. The company also revealed a new hardware solution that enables the use of DALI sensors for presence detection or daylight harvesting as well as the control of DALI drivers that have an integrated DALI bus power supply.

Casambi also demonstrated the benefits users will gain from the latest release of the company's lighting control app for smartphones, smart watches and tablets. The Bluetooth-based software enables easier commissioning and improved functionality to access multiple wireless networks in larger buildings, better management of daylight harvesting, and improved tools for creating changing lighting. ■

Philips Lighting LiFi: Broadband Data Through Light

Philips Lighting, the world leader in lighting, is now offering Light Fidelity (LiFi), a technology in which high quality LED lighting provides a broadband Internet connection through light waves. As the lighting company for the Internet of Things, Philips Lighting is the first global lighting company to offer LiFi-enabled luminaires from its existing office lighting portfolio.



Philips Lighting introduces LiFi. Paving the way to mass adoption of this exciting technology

- French company Icade pilots Philips LiFi-enabled luminaires at its smart office in Paris
- Secure and highly stable high-speed Internet connection without compromising light quality
- First major lighting company to LiFi-enable regular office luminaires

"LiFi has enormous potential for today's digital age and as the world's leading lighting company we are proud to pioneer new and innovative services for our customers," said Olivia Qiu, Chief Innovation Officer, Philips Lighting.

"While radio frequencies are becoming congested, the visible light spectrum is an untapped resource with a large bandwidth suitable for the stable simultaneous connection of a vast array of Internet of Things devices. Being a lighting company, we ensure that our customers benefit from the finest quality energy efficient light along with state-of-the-art connectivity," she added.

Broadband Internet connection and quality illumination at the same time

LiFi is a two-way, high-speed wireless technology similar to WiFi but uses light waves instead of radio waves to transmit data. Philips Lighting's office luminaires enabled with LiFi technology provide broadband connection with a speed of 30 Mb per second (Mb/s) without compromising lighting quality. With 30Mb/s a user can stream simultaneously several HD quality videos while having video calls.

Icade, the French real estate investment company, is piloting the ground-breaking technology in its smart office in La Defense, Paris. "LiFi has the potential to be a real game changer in offices. As the leader in our market we wanted to explore the possibilities of this technology for existing and future clients. We plan to showcase the technology in our smart office in La Defense, so aside from stable connectivity, light quality is crucial to us," said Emmanuelle Baboulin, Head of the Commercial Property Investment Division at Icade.

Benefits of LiFi

LiFi offers benefits over WiFi as it can be used in places where radio frequencies may interfere with equipment, such as in hospitals, or where WiFi signals cannot reach or are weak, such as underground. Other user cases include environments demanding high security; for example, the back office of a financial institution or government service. LiFi adds an extra layer of security as light cannot pass through solid walls and a line-of-sight to the light is needed to access the network.

How does LiFi work?

Each luminaire is equipped with a built-in modem that modulates the light at speeds imperceptible to the human eye. The light is detected by a LiFi USB key/dongle plugged into the socket of a laptop or tablet (in the future such technology will be built into laptops and devices). The LiFi USB dongle returns data to the luminaire through an infrared link. With Philips LiFi-enabled luminaires, customers get the double benefit of quality, energy-efficient LED light and a highly secure, stable and robust connection as LiFi has 10,000 times the spectrum of WiFi.

Why LiFi from Philips Lighting?

Philips Lighting leads the way in offering seamless hand-over between light points; meaning that as a user moves from one side of a large office to another, they maintain their connection as one light point hands off to another. The coverage-zone provided by Philips LiFi-enabled luminaires is also believed to be the widest in the market.

The company has LiFi-enabled normal office luminaires that provide quality energy-efficient light. ■

Litetronics Introduces Family of Easy-to-Install LED Strip RetroFit Fixtures

Litetronics proudly introduces its new LED Strip RetroFit family of adjustable, easy-to-install, 4-foot LED strips that can upgrade linear fluorescent fixtures from 2.75 to 5 inches wide to energy-saving LED technology in minutes. Utilizing the existing building wiring and fixture base frame, Litetronics' LED Strip RetroFits represent the industry's easiest and quickest way to convert floor, corridor, area, and aisle lighting within a broad range of retail, commercial, and institutional applications to the comprehensive benefits of LED lighting.

Offered in 24 and 30-Watt versions that deliver 3,120 and 3,900 lumens respectively, the one-piece LED Strip RetroFit kits come complete with the accessories needed to quickly convert from fluorescent to LED technology without tedious rewiring or fixture realignment to the ceiling. With two hinged latches to hang the RetroFit from the fixture in an open position, both of the installer's hands are free to complete installation, making assembly uniquely simple. LED Strip Retrofits further require no paint touch-ups or post-installation work and instantly offer an even surface of illumination as well as the polished look of a new diffuser lens.

Litetronics' new retrofit products are intended to upgrade linear fluorescent fixtures from 2.75 to 5 inches wide utilizing the existing fixture base frame

Sporting an attractive 100,000-hour life and 10-year warranty, Litetronics' LED Strip RetroFits feature 0-10 V dimming and are available in 3500 K, 4000 K, and 5000 K versions. Ideal for single or continuous row mounting, they operate in universal 120-277 V settings and are also safe for food service applications. In addition, the RetroFits' edge-to-edge flanged design ensures a clean aesthetic even when two 4' RetroFits are installed end-to-end in an 8' fluorescent fixture frame. LED Strip RetroFits are also DLC premium-listed, reflecting their outstanding performance characteristics and eligibility for utility rebates nationwide.

"Our new LED Strip RetroFits represent another way in which Litetronics provides an easy choice for professional lighting users looking to upgrade their fluorescent fixtures to the benefits of LED technology," said Robert Sorensen, CEO of Litetronics. "Eliminating the costs, maintenance concerns, and disposal issues associated with fluorescent lamps and ballasts, LED Strip RetroFits can reduce energy consumption and costs by 70% compared to existing fluorescent fixtures and offer the utmost in 'innovation simplified' for the market's broad range of applications." ■

Fraunhofer IAP Develops Power Generating Films and Luminescent Glass

New inks for inkjet printers make it possible to print organic displays or solar cells on film and glass for the use in architecture, the textile industry and many other industries.

Flexible photovoltaic elements, manufactured at the pilot plant of the Fraunhofer IAP

They turn light into electricity or vice versa: the inkjet inks developed by researchers at the Fraunhofer IAP can be printed on solid substrates as well as on flexible foils. In effect, solar cells and organic displays can be produced fast and cost-effectively.

Together with research partners, the Fraunhofer scientists have developed methods to print organic photovoltaic elements for use in architecture and for the textile industry on film.

Printed displays rolled up?

Also for displays, printing processes are utilized at the Fraunhofer IAP. Using specially developed inks from organic light sources and quantum dots, the researchers print, for example, organic light-emitting diodes (OLEDs) and quantum dot-based LEDs (QLEDs). The displays can also be printed on different materials. Printing on film makes them flexible to some degree. "Until we can flexibly roll up our televisions, we still have a little research to do", explains Dr. Armin Wedel, head of the research division Functional Polymer Systems at the Fraunhofer IAP. "Although there are already curved and even scrollable displays, they still have to be rolled up on rigid rolls with a defined diameter," says the OLED specialist.

ESJET printing for high-resolution OLEDs

New perspectives for the production of printed displays result from the use of ESJET printing (electrostatic printing). The scientists at the Fraunhofer IAP are working on this procedure together with twelve other partners within the project Hi-Response, which is funded by the European Union.

The ESJET printing process allows the use of a wider range of inks, as even very viscous inks can be processed. The drop-on-demand system also makes it possible to set the thickness of the printed layer very precisely. The printed structures can be as small as 1 micron. In the future, the printing of high-resolution, active-matrix-driven OLEDs should be possible.

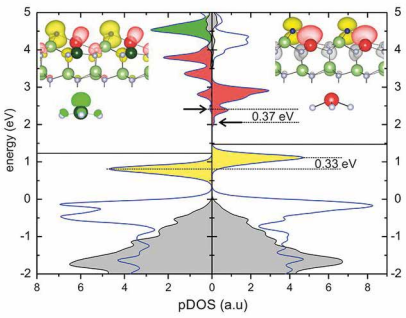
Quantum materials for the display industry

In addition to OLEDs, the IAP scientists are also researching QLEDs based on indium phosphide quantum dots. They are free of conventionally used toxic cadmium. The results so far are groundbreaking for the industry. Indium phosphide-based QLEDs are gradually catching up on the performance advantage of cadmium-based systems in many areas. Regarding luminance, they are already outperforming cadmium-based QLEDs. ■

Fundamental Limitation of In Concentration in InGaN Solid-State Devices

For the first time an international research group has revealed the core mechanism that limits the indium (In) content in indium gallium nitride ((In, Ga)N) thin films - the key material for blue light emitting diodes (LED). Increasing the In content in InGaN quantum wells is the common approach to shift the emission of III-Nitride based LEDs towards the green and, in particular, red part of the optical spectrum, necessary for the modern RGB devices. The new findings answer the long-standing research question: why does this classical approach fail, when we try to obtain efficient InGaN-based green and red LEDs?

Despite the progress in the field of green LEDs and lasers, the researchers could not overcome the limit of 30% of indium content in the films. The reason for that was unclear up to now: is it a problem of finding the right growth conditions or rather a fundamental effect that cannot be overcome? Now, an international team from Germany, Poland and China has shed new light on this question and revealed the mechanism responsible for that limitation.



On-site projected density of states (pDOS) of a 2×2 N adatom (0001) GaN surface with 25% InN at the topmost surface layer. For a detailed explanation, please refer to the content (Credit: IKZ Berlin)

The figure shows the on-site projected density of states (pDOS) of a 2 ×2 N adatom (0001) GaN surface with 25% InN at the topmost surface layer. The In atom sits at a fourfold/triply coordinated site, respectively. The blue curves indicate the pDOS on the N adatom and on the first surface layer atoms. The gray shaded area denotes the pDOS from the fourth surface layer and the yellow shaded area the highest occupied surface state. The arrows indicate the onset of the lowest unoccupied surface states and the horizontal solid lines the position of the highest occupied states. (Insets) Yellow, red, and green colored density plots indicate the partial charge density of the states in the energy range shaded in yellow, red, and green in the pDOS, respectively. (Insets bottom) Schematic representation of the tetrahedra formed by the triply coordinated metal atoms and the three N atoms bound to them. The red/green isocontour surface shows the corresponding dangling bond state. Dark/light small balls denote the N adatom/atoms, respectively. Red/green balls are the In/Ga atoms, respectively. The dark green in the left inset denote the triply coordinated Ga atom.

In their work the scientists tried to push the indium content to the limit by growing single atomic layers of InN on GaN. However, independent on growth conditions, indium concentrations have never exceeded 25% - 30% - a clear sign of a fundamentally limiting mechanism. The researchers used advanced characterization methods, such as atomic resolution transmission electron microscope (TEM) and in-situ reflection high-energy electron diffraction (RHEED),

and discovered that, as soon as the indium content reaches around 25 %, the atoms within the (In, Ga)N monolayer arrange in a regular pattern - single atomic column of In alternates with two atomic columns of Ga atoms. Comprehensive theoretical calculations revealed that the atomic ordering is induced by a particular surface reconstruction: indium atoms are bonded with four neighboring atoms, instead of the expected three. This creates stronger bonds between indium and nitrogen atoms, which, on the one hand, allows the use of higher temperatures during growth and provides material with better quality. On the other hand, the ordering sets the limit of the In content of 25%, which cannot be overcome under realistic growth conditions.

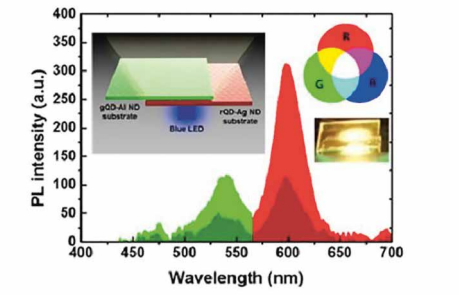
"Apparently, a technological bottleneck hampers all the attempts to shift the emission from the green towards the yellow and the red regions of the spectra. Therefore, new original pathways are urgently required to overcome these fundamental limitations," states Dr. Tobias Schulz, scientist at the Leibniz-Institut fuer Kristallzuechtung; "for example, growth of InGaN films on high quality InGaN pseudo-substrates that would reduce the strain in the growing layer."

However, the discovery of ordering may help to overcome well known limitations of the InGaN material system: localization of charge carriers due to fluctuations in the chemical composition of the alloy. Growing stable ordered (In, Ga)N alloys with the fixed composition at high temperatures could thus improve the optical properties of devices.

Acknowledgements:
The work is a result of a collaboration between Leibniz-Institut fuer Kristallzuechtung (Berlin, Germany), Max-Planck-Institut fuer Eisenforschung (Duesseldorf, Germany), Paul-Drude Institut fuer Festkoerperelektronik (Berlin, Germany), Institute of High-Pressure Physics (Warsaw, Poland), and State Key Laboratory of Artificial Microstructure and Mesoscopic Physics (Beijing, China).

Highly Efficient Low Cost QD LEDs with Metallic Nanostructures

The Korea Advanced Institute of Science and Technology (KAIST) announced that a team of their researchers have discovered a technology that enhances the efficiency of Quantum Dot LEDs. Professor Yong-Hoon Cho from the Department of Physics and his team succeeded in improving the efficiency of Quantum Dot (QD) Light-Emitting Diodes (LEDs) by designing metallic nanostructure substrates.



This is a spectrum showing different fluorescence with and without metallic nanostructure (Credit: KAIST)

QD LEDs possess very small semiconductor light sources and are considered to be the new rising technology for high performance full-color display. However, it is expensive to manufacture displays with QD LED only.

Existing QD-based displays use blue LEDs as a source of light, and they employ a method of color conversion through excitation of green and red QDs. There are two inconveniences with the existing QD-based displays. As mentioned previously, QD LED is costly; hence the unit price of QD-based displays is higher. Also, the efficiency of a liquid type of QD is drastically lowered after contact with air.

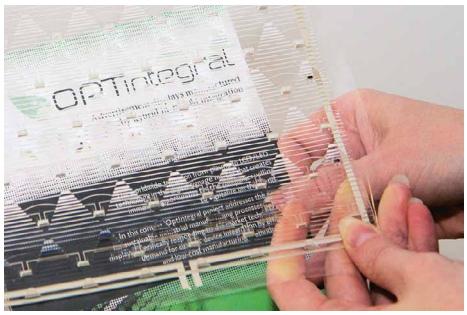
Professor Cho found the solution in a metallic nanostructure for lowering the production cost while improving the efficiency of QD LEDs. The team exploited the phenomenon of so-called surface plasmonic resonances when nanoscale metallic structures are exposed to light. Depending on the metal, the size, and the shape, the properties of metallic structures vary. The team used different metallic nanostructures for each QD LED - silver nanodisks for Red QDs and aluminum nanodisks for Green GDs - to make them more fluorescent.

With brighter QDs, it requires fewer QDs to manufacture QD LEDs, contributing to a lower unit price. The team used silver and aluminum in this research, but metallic nanostructures can be redesigned according to the desired purposes. Professor Cho said, "Implementing metallic nanostructures into QD LEDs in a proper manner can reduce the quantity of the QDs required for the system, leading to lower unit prices."

Acknowledgements:
This research, led by PhD candidate Hyun Chul Park, was chosen as the cover of the international journal, Small, on December 27, 2017.

VTT: Light, Flexible and Energy-Efficient LED Advertising Boards

Through a European project, VTT Technical Research Centre of Finland and Neonelektro have developed new types of LED displays that combine the flexibility, low cost and high technical performance enabled by roll-to-roll mass manufacturing technology.



In the Optintegral project, a flexible, thin and transparent light panel was developed by integrating a flexible LED foil with a plastic, overmolded structure. Optical features were added to the panel surface

"Flexible, light weight, and of an easily customizable size, the LED advertising panel enables the creation of a dynamic look for large area applications, or those that require a 3D shape, such as vehicles," says Project Manager Eveliina Juntunen of VTT.

The OptIntegral project, which was completed at the end of January, used a hybrid integration manufacturing process (combining injection molding and printed electronics), in which the flexible electronics substrate was immersed in an overmolded polymer. Overmolding protects the components and enables additional features, such as optical and mechanical structures to be integrated during a single processing step.

This technology was applied to the production of large area LED displays during the project. Overmolding was used to add optical structures to the display elements, improving the visual appearance of the product. In addition, VTT's measurements indicate that overmolding lowers the temperature of the LEDs by around 20%, which is significant in terms of the reliability and efficiency of LEDs. This makes the displays energy-efficient, lightweight, flexible and even three-dimensional.

VTT Technical Research Centre of Finland (VTT) used a roll-to-roll process to make flexible LED substrates for the displays, refining the process to make it more productive. Neonelektro Oy developed an overmolded RGB display element manufactured using the roll-to-roll technique.

"Interest in dynamic backlighting has grown dramatically during the project, and we have developed a new product family based on it. Developing a technology to meet such demand has opened up new markets for us," says Matti Koponen, who is in charge of product development at Neonelektro.

The project was coordinated by the Spanish organization Eurecat, The Technology Centre of Catalonia. In addition to the Finnish partners, the consortium included the Spanish firm SnellOptics and the Spanish Association for Standardization (UNE), LumyComp and Megatex from Bulgaria, Holografika from Hungary, and the University of Bath from the United Kingdom. The project was funded by the European Commission's Horizon 2020 program.

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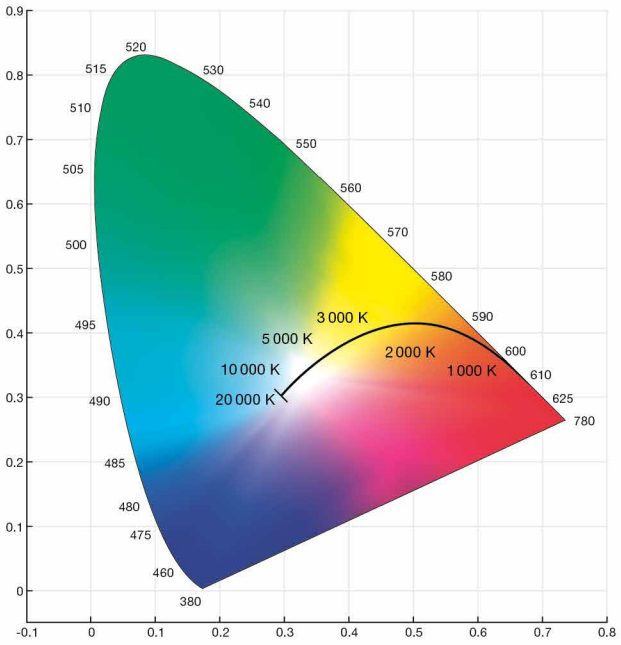

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TECHNICAL REGULATORY COMPLIANCE UPDATE

Segment	Product	Standard (Certification)	Region	Technical Regulatory Compliance Information
Regulations	Luminaires	IEC TR 61547-1:2017	Int.	This second edition which covers an objective light flickermeter and voltage fluctuation immunity test method cancels and replaces the first edition published in 2015. This edition constitutes of below technical revisions: • Update of scope to reflect the more general application of the objective flickermeter; • Describing the light flickermeter and voltage fluctuation immunity • The specific voltage fluctuation immunity test method extended for lighting equipment rated for 120 V AC and 230 V AC, 50 Hz and 60 Hz • More detailed description of the test set-up and environment
Regulations	Luminaires	IEC 61347-1:2015/ AMD1:2017	Int.	This third edition specifies general and safety requirements for lamp controlgear for use on d.c. supplies. It cancels and replaces the second edition published in 2007. Few significant technical revisions are: • Marking requirements like Marking of SELV circuits with: 'SELV' • Additional requirements for creepage distances and clearances and working voltages • Test of terminals other than integral terminals • Clarification of the rated voltage of insulation bridging components • Creepage between accessible part and circuits shall be considered acc. to 15.4 • Modification of schematic drawing figure 4 & 6
Regulations	Luminaires	IEC 60598-2-22:2014/ AMD1:2017	Int.	This fourth edition cancels and replaces the third edition published in 2008 and specifies requirements for emergency luminaires for use with electrical lamps on emergency power supplies not exceeding 1 000 V. Few significant technical changes with respect to the previous edition are: • Photometric testing is modified • Addition of definitions for Practical emergency light source flux • Additional requirement for products with automatic test system
Regulations	Luminaires	IS 2418 (Part I and II)	India	On March, the Indian Bureau of Energy Efficiency (BEE) published the regulation on mandatory energy star labelling program of tubular fluorescent lamps for general lighting services. The regulation covers all wattages with dimension between 1100-1500 mm of which colour temperature is 6500K for halo-phosphate category, and 2700 K, 4000 K and 6500 K for tri-phosphate categories. The covered lamps shall be affixed such particulars on labels which is indicated in the Bureau of Energy Efficiency (Particulars and Manner of their Display on Labels of Tubular Fluorescent Lamps) Regulations, 2018. The date of enforcement of this regulation is 1st July 2018 while the compliance date of new requirements is proposed on 1st Jan 2019.
Lighting	Luminaires	Order No. 18-02	Philippines	In Administrative Order No. 18-02, 2018 on this February, Philippines National Standard (PNS) is adopted for mandatory implementation: PNS IEC 62560:2012 - Self-Ballasted LED Lamps for General Lighting Services by Voltage > 50 V – Safety Requirements All manufacturers, distributors, importers, and retailers of said product shall comply with the requirements of this standard. To demonstrate the compliance, the products must secure a Philippines Standard (PS) License and an Import Commodity Clearance (ICC) prior to its distribution and sale

A free training can be arranged for a clear understanding of the upper stated standards.
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The LUXEON SunPlus Series is purpose-built to enable ease of system design for Horticulture applications. The LUXEON SunPlus Series offers the only LEDs available today that are binned and tested based on Photosynthetic Photon Flux (PPF). The LUXEON SunPlus Series includes three different packages: LUXEON SunPlus 20 Line, which is 2.0mm x 2.0mm, LUXEON SunPlus 35 Line, which is 3.5mm x 3.5mm and LUXEON SunPlus CoB Line. The LUXEON SunPlus Series includes options for single driver solutions and multi-channel, color tunable solutions.

Features and Benefits

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- Dramatically reduced time to market

Primary Applications

- Horticulture

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LUMILEDS

CIE Research Strategy in Metrology for Advanced Photometric and Radiometric Devices

Photometric devices are devices that measure optical radiation and which are designed with a very specific spectral response. Most commonly, illuminance meters and luminance meters are used to measure the illuminance and luminance distributions in the field. These are relatively simple devices, characterized by a specific input optics according to the required task and a filter to make the spectral response of the instrument match the spectral luminous efficiency function of the human eye (typically V(λ) for photopic vision). In testing laboratories, integrating spheres are used to measure the total luminous flux of a light source and goniophotometers are used to measure luminous intensity distributions, total luminous flux and partial luminous flux. These devices are all well understood, and several CIE technical reports are available that give guidance on their characterization and calibration [1][2][3][4].

Due to technological progress new types of photometric and radiometric measurement devices have recently appeared on the market and are used in many applications. Additionally, new types of instrumentation are currently under development in response to new CIE publications and new lighting technologies emerge onto the market.

Examples of New Types of Instrumentation and Applications

Imaging luminance measurement devices (ILMDs)

Analogous to using a digital camera for photography, ILMDs combine an array detector (typically a CCD or CMOS sensor) and a specially designed filter to measure a luminance distribution in a "single shot". They can be used to evaluate complex scenes much more rapidly and with greater resolution than traditional spot luminance meters. As a result, ILMDs are becoming very popular in many areas of applications, for example glare evaluations in indoor lighting, street and tunnel lighting measurements, and light emission measurements.

Hyperspectral imaging devices.

These devices allow direct measurement of spectral and spatial distributions, i.e. each pixel of an image also contains spectral information. This can be used to identify materials (i.e. mineralogy), to measure the stages of development of vegetation, to identify skin anomalies and even for surveillance purposes.

Imaging luminance-based near-field goniophotometers

Combining ILMDs with a goniophotometer allows the measurement of spatially- and angularly-resolved luminance distribution of light sources in the near-field. The collected data can be used to improve the performance of luminaires through optical raytracing methods and allow users to evaluate illuminance distributions in virtual measurement planes at any distance from the source. Additionally, far field data (i.e. luminous intensity distributions) can be determined using quite compact measurement devices.

Measurement devices for quantifying photochemical and photobiological effects

It is well known that intrinsically photosensitive retinal ganglion cells (ipRGCs) in the human retina have an impact for various non-visual effects, including synchronizing circadian rhythms, pupillary control and conscious visual perception. CIE joint technical committee JTC 9 has recently defined a metric, and in particular several action spectra, to quantify such effects. New measurement devices will soon appear on the market that perform measurements according to the new metric and the defined action spectra. These instruments will need to be characterized and calibrated.

High-speed measurement systems to quantify fast-varying (pulsing, modulating, flickering) optical signals

Temporal light modulations (TLM) are known to affect human visual perception and performance. The freely available CIE technical note TN 006 [5] gives new definitions for the perceptual effects modulated light can produce. Measurements are usually performed using high-speed acquisition systems. Several types of measurement devices (including "flickermeter") can be found on the market but there is currently no harmonized way of characterizing these instruments, leading to an inability to compare measurement results between different instruments and different laboratories.

Hybrid measurement devices using spectroradiometers and broadband measurement devices

One of the challenges for manufacturers and users of photometric devices is the match of the spectral responsivity of the instrument to the required spectral luminous efficiency function. This match can never be perfect, resulting in measurement errors. This is especially apparent for spectrally narrow sources, such as coloured LEDs. Some devices available on the market now are using a built-in spectroradiometer to correct spectral mismatch of a photometric device in real-time. In addition, colorimetric data (i.e. chromaticity coordinates, correlated colour temperature, colour rendering and colour fidelity indices) can also be obtained as a part of the measurement.

CIE Activities

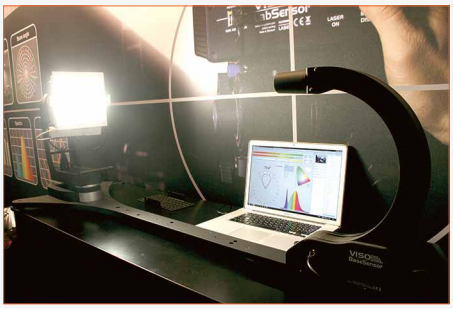
New CIE technical committees have been established and are currently writing technical reports to provide guidance on the characterisation and calibration of some of these devices. Further, it is anticipated that other new technical committees will follow in the near future. However, in most cases additional research is still necessary, and the period of time allowed to finalize a technical report or standard is often too short. In spite of this, there is an immediate need to define quality criteria and calibration procedures for devices such as near-field goniophotometers and high-speed measurement systems to quantify fast-varying (pulsing, modulating, flickering) optical signals, as such devices are becoming more widely used in practice. Hence, CIE is calling for new contributors not only to participate in the technical committees, but also to offer practical research on the open topics to feed into the technical committees. Having more research groups operating in parallel can enable a technical committee to perform its work more efficiently.

The key research questions are:

- What are the relevant quality indices needed to characterize advanced photometric and radiometric devices? How do these indices relate to the measurement uncertainty encountered in typical lighting measurement situations?
- How to describe the mathematical models and equations describing the measurement procedure?
- What would a typical measurement uncertainty budget look like for measurements on particular types of equipment and for measurement of different types of light sources?
- How to calibrate these new types of devices? What are the best artefacts to transfer the photometric and radiometric quantities to the measurement devices?

On a wider scale, an additional motivation for this research topic is that new challenges like "smart lighting" (i.e. adaptive and sensor-based lighting) and the implementation of the other research topics within the CIE Research Strategy priority list imply on the one hand the need to completely characterize a given lighting situation, including daylight and artificial light from various sources, and on the other hand to thoroughly characterize the light sources with respect to spectral and spatial properties.

As with all physical metrology, traceability of measurement results to the International System of Units (SI) is often mandatory. New knowledge is required to combine source-based and detector-based



measurements under various environmental conditions. New devices and measurement systems such as those described above are needed to meet these challenges. The outcomes of this research topic will increase the quality of photometric and radiometric measurements in general and therefore increase confidence in lighting products. The availability of reliable and traceable measurements is also a prerequisite to develop and verify intelligent sensor systems used to enable smart and adaptive lighting.

The key questions and topics described above are defined in the CIE research strategy, available at the CIE website (http://www.cie.co.at/research-strategy). This particular aspect of the CIE research strategy is managed by CIE Division 2. Division 2 deals with the physical measurement of light and radiation, which includes studying procedures for the metrological evaluation of ultraviolet, visible and infrared radiation, and studying the optical properties and performance of physical detectors and other devices required for their evaluation. ■

References:

[1] CIE 070:1987 The Measurement of Absolute Luminous Intensity Distributions
[2] CIE 084:1989 Measurement of Luminous Flux
[3] CIE 121:1996 The Photometry and Goniophotometry of Luminaires
[4] CIE 210:2014 Photometry Using V(λ)-Corrected Detectors as Reference and Transfer Standards
[5] CIE TN 006:2016 Visual Aspects of Time-Modulated Lighting Systems – Definitions and Measurement Models

Tech-Talks BREGENZ - Ken Munro, Partner & Founder, Pen Test Partners

Ken Munro

Ken Munro is a regular speaker at the ISSA Dragon's Den, (ISC)2 Chapter events and CREST events, where he sits on the board. He's also an Executive Member of the Internet of Things Security Forum and spoke out on IoT security design flaws at the forum's inaugural event. He's also not averse to getting deeply techie either, regularly participating in hacking challenges and demos at Black Hat, 44CON, DefCon and Bsides amongst others. Ken and his team at Pen Test Partners have hacked everything from keyless cars and a range of IoT devices, from wearable tech to children's toys and smart home control systems. This has gained him notoriety among the national press, leading to regular appearances on BBC TV and BBC News online as well as the broadsheet press. He's also a regular contributor to industry magazines, penning articles for the legal, security, insurance, oil and gas, and manufacturing press.

KEN MUNRO

Besides "his electrical IoT kettle", the doll, Cayle, is one of Ken Munro's preferred examples of vulnerable products. In the meantime Germany has stopped importing her

Today, hardly a day goes by that we don't hear about security breaches, hacker attacks or comprimized data; often as a result of insufficient security measures. IoT does not really improve this situation and it is therefore necessary for the industry to take this threat seriously. This is especially true for the lighting industry, whose aim is to become the IoT enabler. Ken Munro, founder and partner at Pen Test Partners, is an ethical hacker whose passion is to hack any technical product he can get his hands on. Unfortunately, he succeeds way to often. LED professional talked with him about ethical hacking, where he sees the risks in various products, where the risks are hidden and what can be done to minimize them.

LED professional: Thank you for coming to the Tech Talk Bregenz. We're really interested to hear more about network security and data privacy in the context of the Internet of Things (IoT). We're seeing nodes on the network proliferate and - from what we saw in your presentation - those networks are being exposed to attack through our failure to configure these devices correctly or deploy them securely. But before we go into details, can you tell us a little about yourself and your company?

Ken Munro: I work for a company called Pen Test Partners and we specialise in the security of the IoT. That grew out of our extensive experience in working on embedded control systems found in industrial utilities like electrical companies and water companies, where these systems are used to manage production processes to control supply. These are very important systems: if they go wrong, the power goes out. Over time, these systems were connected to allow utility providers to control their production facilities from the other side of the country or the other side of the world resulting in sensor-based networks. Now we're seeing the replication of that in the IoT.

Just to be clear, the IoT by itself is fine. The technology offers us unprecedented convenience and control. We can warm our house or our car when we need to. Monitor the safety of our homes and provide access remotely. And in the medical arena we can better manage patients with long-range diagnostics to check on pace makers or blood pressure monitors.

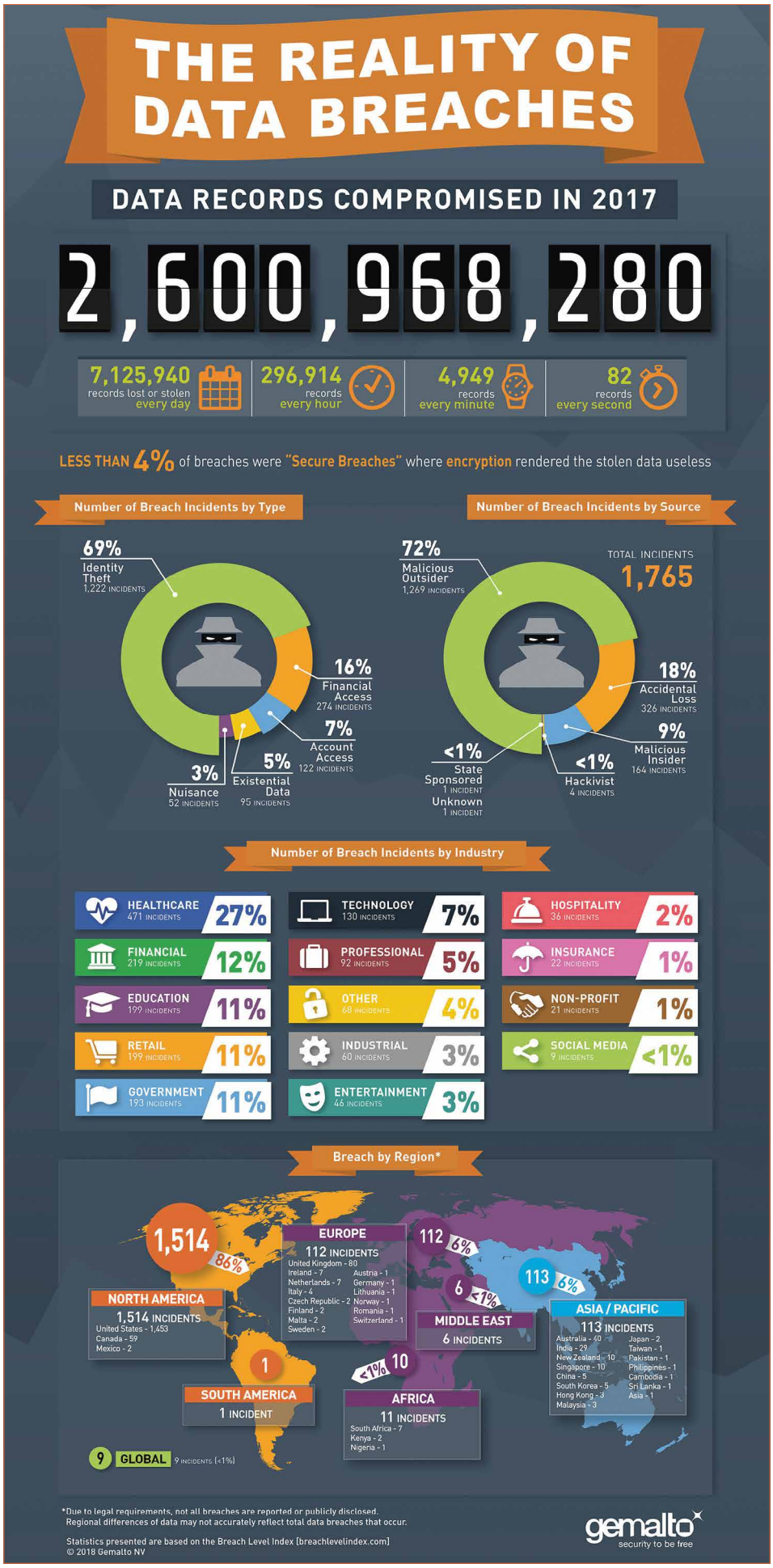
It's when we connect these insecure devices to the Internet that we can run into problems with hackers quick to exploit vulnerabilities. Fortunately there are many companies, like ourselves, who are researching, disclosing and publishing issues. Sometimes the manufacturer listens and sometimes they don't. In fact, more often than not - they don't. And then we have to talk about it to the public - because if we don't, the problem doesn't change.

The flaws we find vary. It could be that the manufacturer forgot to implement encryption so there is no SSL or TLS so it's easy to intercept the traffic. Or maybe it's problems with the API which determines how you control the device from your smart phone or via the cloud and that can see you able to control all those devices. Or a hacker may seek to seize control of a bed of devices, to steal personal data or to cause havoc through maliciously switching off services.

One that we spend a lot of time investigating is firmware security on the IoT hardware. If this hasn't been written securely and the chip hasn't been secured either, the hacker can extract the firmware and reverse engineer that. Often we discover that we can hack every component of the system through to the device, the manufacturer, the hosting company of the API, you, your customer - everything - because the firmware is not written properly.

LED professional: I'd just like to clarify one point: In general we are always talking about hacking. But hacking, per se, is not the criminal act of corrupting or damaging something. Could you just explain exactly what hacking is?

Ken Munro: The term hacking doesn't apply to what many people think. Hacking is playing around or tinkering. The term comes from years ago when people would hack a device to make it do something different or hack together technology. It's only recently that it's been associated with malicious



activity over computer systems. What we provide is ethical hacking: a hacking service that is done in a controlled manner where the intent is "good". So you could say that the crux of the matter is the intent. If hackers have the wrong intent and try to damage you, they are the people you should be worried about. But there are many ethical - or "White Hat Hackers" - out there whose aim is to improve security by spreading awareness. As a company, you can engage them to test and evaluate your security. Some will find flaws and tell you about it for free. Sometimes they'll want a reward - we call it a bug bounty - but by and large, they are motivated to do the right thing.

LED professional: And to really get an idea of the importance of the safety and security issues: Could you give us a short history of how it has changed over the years?

Ken Munro: The biggest step change has been the connection of very sensitive systems, or lots of less important systems, to the Internet. Initially, the Internet was just a lot of connected computers. Sensitive systems were all safely tucked away on protected networks. Take, for example, the control system of a nuclear power plant. This would have been isolated on a dedicated network which may have used obscure protocols as opposed to HTML. Nowadays, even highly specialised organisations want to connect their systems to the Internet to gain the advantages of remote access and they think setting them up privately so they can only connect from the power plant to the control room, to the corporate HQ is sufficiently secure. But along the way, mistakes can be made. Imagine if the telemetry system governing a nuclear power station were to be interrupted, threatening control of the system. That is as bad as it gets and this genuinely happens.

There is an excellent search engine called Shodan (shodanhq.com) for Internet connected devices where you can locate industrial controllers for hydroelectric power stations, electricity generating plants, production systems control for production lines: they're all on the Internet and are discoverable when they shouldn't be!

Encryption and data security companies monitor data breaches and publish their findings on a regular basis. The info-graphics (Credits: Gemalto [1]), speaks for itself and leads to the conclusion that making IoT devices as secure as possible is paramount

The compromise of these devices can lead to devastating consequences. If you were to lose access to the Industrial Control System of a nuclear power station, there could be severe consequences. But few people realise that, collectively, the compromise of millions of IoT devices can also power large scale attacks. Imagine if I had control of one million smart thermostats or ten million smart light bulbs or a thousand smart vehicles. What if I could make all of those IoT devices start making requests against one system? If they're instructed to simultaneously "Connect to google" or "Connect to a DNS provider" or "Connect to a social network" that can create a denial of service attack. We caught a distributor denial of service attack or a "DDoS" last year and it took FaceBook and various other social networks off the Internet. And that is the risk of not getting IoT right.
You might think "It's just my light bulb" or "It's just my thermostat" but when in their millions, those devices can cause a huge amount of damage.

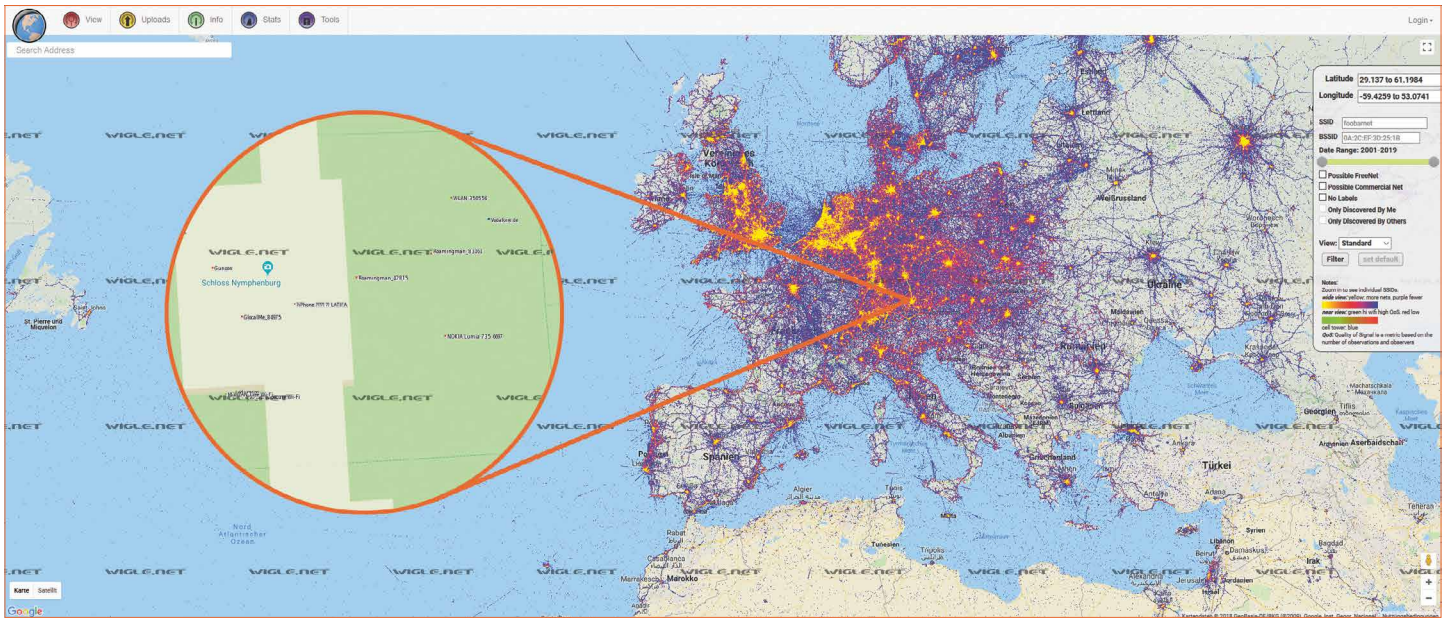
LED professional: Is it always the device itself or can it also be caused by the implementation? For example, if I have my light bulb in my system connected to my private network with Internet access, am I personally accountable because my Internet connection is not secure?

Ken Munro: Some responsibility does rest with the user. So it's very important to make sure that your password is secure. The Wi-Fi key should be changed so that it's different to the original one shown on the back of the router.
The mobile app you use to control your smart lightbulb needs to be unique and set by you. If it's too simple or it's a password you use somewhere else you'll be easier to hack. It has to be strong, by which I mean long and complicated.
A password manager can help generate and store these passwords for you and you never have to remember it. It's a little app that runs on your phone or your computer and all you have to do is copy and paste your password or auto-populate the password on that app.

LED professional: That's a good tip for everyone! But tell me, what can a hacker do once he has control of your device? Yes they can switch it on or off or locking and unlock your door, observe your habits or steal your personal data and post it online or attack a system. But are there other ways that the devices can be misused?

Ken Munro: Yes, very much so. But let's start with the first one. What's the consequence? It's a light bulb. I can turn your light on and off - but so what? It's annoying but I can unplug it and call the company who installed it to have them fix it.
But that very smart device may be the step that the hacker takes to get into your home. So maybe it's a smart light bulb that uses Bluetooth or Wi-Fi or ZigBee or Z-Wave and someone outside can connect directly to your light bulb and can use that as a step to your light controller and then from your light controller to your Wi-Fi router.
And once they have that, they have everything. Once I have your router I can intercept all of your traffic.

At LpS 2017 Ken's enthusiasm for his work shone through in a talk that was both informative and fun to watch



A lot of information about accessible networks can be found easily on the internet. For instance, wigle.net shows wireless hotspots that make people aware of the need for security when running a wireless network. With a little detailed knowledge the information can be used for hacking unsecured hotspots or products

Everything. Your banking details, your passwords. So the risk is not to the device, be it a light bulb or a thermostat, it's the systems that it can lead to. If that device is insecure, that's the way in to the rich pickings on your network.

LED professional: Since they can take over your equipment and everything on your network, is it possible for them to mimic you by stealing your identity to harm others?

Ken Munro: Potentially, yes. Your light bulb might be the way into the hub that controls it. One hub could then be used to attack other hubs in different houses around the world. So actually, you become the source of the vulnerability even though it's the manufacturer's fault for not writing the software properly. So the police officer then knocks on your door because it was traced back to your IP address. And what's your defense against that? How do you prove it wasn't you given the log on your Wi-Fi router says it was you.

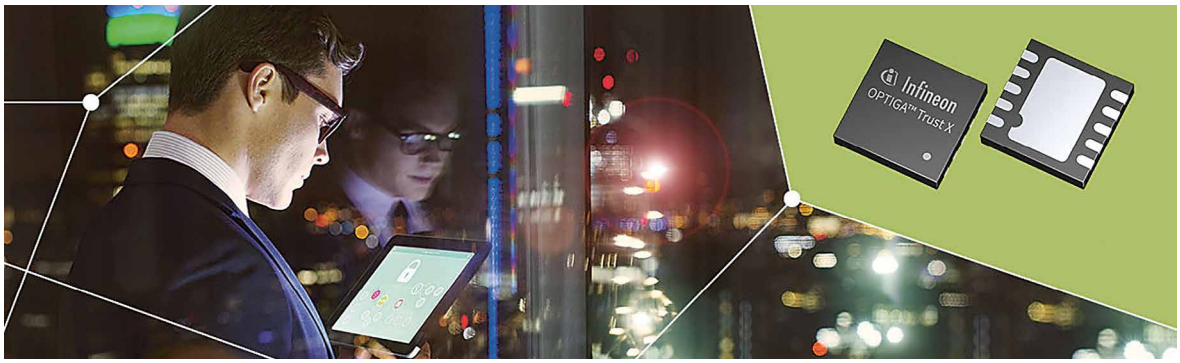
The next point I want to make is about installers. The product may well be secure and the manufacturer will issue a guide to ensure correct installation. The instructions for the installer might provide a process to follow together with a caveat from the manufacturer that states if this advice is not followed, it renders the product insecure. We often find instances where installers have failed to follow that advice with IoT equipment resulting in a vulnerable device that is then just waiting to be compromised. So I strongly advise everyone, whether they are an installer or a manufacturer, to make sure installers are trained. Make sure you have a verification system to ensure the product is securely installed because otherwise it will be the manufacturer's reputation and/or the installer's reputation placed on the line and the consumer's data that will be exposed.

LED professional: During your career, have you recognized similarities between product groups? Are there product groups that are more secure than others?

Ken Munro: It depends on the history of the device and where you find it in its life cycle. Some products, such as industrial controllers, started becoming more secure, ten to fifteen years ago, when the audit process gained momentum, so in many areas security has improved. But each time a new product group comes to market, we see a new set of security flaws. We did a lot of work on smart TV's and discovered they were listening to you speak but now audio controls are vastly improved. But there are inevitably exceptions to the rule. If you look at Building Management Systems (BMS), we continue to find security flaws there. The last few years has seen innovation in smart lighting take off and it's this drive to be first to market that can see security sacrificed. For that reason, it's very important that you can fix your product when it is on the market using Over the Air (OTA) updates.

LED professional: Is there a relationship between the price of a product and how secure it is?

Ken Munro: We carried out extensive research last year to see if there was a relationship between an expensive product and good security. Perhaps surprisingly we found it was random. So you can buy an expensive product with terrible security or a very cheap Chinese copy that has better security. Generally speaking you'd make the assumption that an expensive product with a high build quality or used for industrial purposes would be good but actually there is no correlation between price and security which makes it impossible to tell without testing. That's why industry regulators are now looking to push Kitemarks [I] to incentivize manufacturers to invest in security and to help users differentiate and flex their buying muscle.



There are a number of security solutions available on the market now. Consequent use of them can significantly reduce the risk of being hacked (Credits: Infineon [2])

LED professional: Are there differences in the security levels when it comes to Bluetooth, ZigBee, etc.?

Ken Munro: All the ones we've mentioned: Wi-Fi, Bluetooth, BLE, ZigBee, Z-Wave - they all have good support for security. The problem is that often the manufacturer doesn't implement the security. We have just finished some research around Bluetooth Low Energy (BLE) and one of the most common problems is not setting up the connection securely. BLE has support for strong pairing and strong cryptography and bonding. It's very secure and very difficult to crack. But most manufacturers simply offer a connection with no security at all. No PIN, no encryption, nothing! In all the products that we have tested, we've never seen BLE used to create a bond. Even though the functionality is there, manufacturers don't use it.

LED professional: One of the new systems is LiFi. Do you have any experience with it?

Ken Munro: We haven't looked at LiFi yet. That's next. But Wi-Fi, for example, has fantastic support for security and encryption and everyone uses WPA, WPA2. But there is a fundamental flaw in use and that is that everyone leaves their Wi-Fi chip set on their mobile phone "on".

I did a survey in London for Sky News last week and we showed this problem is endemic. The London Underground is doing a trial right now to gather useful data from travelers to establish how they should schedule their trains and how they should direct people but if they wished, they could also track individuals. So I could tell you exactly where you were at any point in time just by virtue of your mobile phone Wi-Fi.

LED professional: So in the end, everybody is responsible for his or her own security?

Ken Munro: Yes, make sure you set strong passwords, use a password manager if you're a consumer or you're working in business, and if you use social networks, use Two-Factor Authentication (2FA - that's where an SMS message is sent to your phone to check it is you logging in). Even better, use a source called "Authenticator App" which sends a message to an app on your phone which only you can verify.

LED professional: So if you have one insecure device it can be like an open door and lead the way to other connected devices? Is every device in the house a threat?

Ken Munro: That should not be the case if these devices are configured by the user or installed by a technician correctly. Yes it takes a little bit longer to do but it will then prevent the type of scenario you're describing. Unfortunately, the tendency is to just plug-and-play. As users we assume that if it works, it's fine. But one device can compromise others. Voice control is a good example of that in the form of Voice Activated Assistants such as Alexa.

LED professional: Can we talk about Alexa?

Ken Munro: Alexa itself is fairly secure. It's always listening, of course, but is fairly secure. The problem is that many people then integrate Alexa with their products either wrongly or without considering the security implications. It's one thing to say "Alexa, turn on the lights" but it's another thing to say "Alexa, unlock my door." What's to stop a criminal outside your house shouting through your window and walking in? There are other silly consequences - the radio show that saw residences up and down the country ordering a doll's house springs to mind - so it's very important that manufacturers think about the potential negative impact of using voice control.

LED professional: There is an old story about a company that made classic mechanical locks which then they hired a former criminal to open the doors to test the locks.

Ken Munro: That's exactly how ethical hacking works. We will reverse engineer your technology, take the chips apart, inspect the contents of the chips, find the firmware running on the chip and establish all the ways a hacker could potentially compromise your system.

LED professional: I remember that you said there are a lot of opportunities on the hardware level, not just the software level?

Ken Munro: Yes, this is the game changer with IoT devices. In the past, when we were just focused on mobile apps it was fine. You owned the server. It was your data center and you had control. But now with

the IoT, you're putting your hardware in the hands of not just the consumer but also the hacker. You're giving them time to explore and dismantle that product to establish its vulnerabilities. To survive that, your hardware security has to be excellent and robust, using obfuscation to fool the hacker or tamper-proof components. Sadly, that's rare. We use logic probes and analyzers and find weaknesses in the chip, the firmware and the software and, if we extract your firmware, we gain access to your secret keys and your passwords.

LED professional: Is there a difference between products in the private and professional sectors?

Ken Munro: It's random, again. Of course, there are many more products on the market for the consumer than there are in the business area. But what we find so often is that when you buy a corporate product, industrial grade and you plug it into your network for your elevators, your lights or your ventilation, that creates a back door.

LED professional: What can the consumer do? I know that you said we need strong passwords, etc. but if I buy a light bulb, I don't usually need a password.

Ken Munro: There is nothing you can do as there are no standards although we are starting to see regulations emerge. The U.S. senate has drafted an IoT security bill and the EU is doing some work at the moment but there's still a long way to go. In the UK, we've seen the DCMS (Department for Digital, Culture, Media and Sport) release its Secure by Design guidelines which are a first draft. In principle, this is to be welcomed and it does allude to a Kitemark called Trustmark for home-based devices. But there's a lack of teeth to the standard with no talk of enforcement.

LED professional: What future developments do you see and what general advice do you have for the industry?

Ken Munro: Manufacturers and installers need to ask questions about security. So often, a manufacturer will have an idea, they'll make a product, they'll send it to manufacturing and then it will go to market. No-one during the process has stopped to ask about security. If the question was asked early on in the development process we'd see manufacturers look for advice, seek assistance in secure app design, ask the hosting company about how data is protected, and the hardware manufacturer about physical security. But if it's asked too late, everyone is caught on the backfoot. Manufacturer's turn a deaf ear to disclosure. Consumers are the last to know they've been exposed. So the one piece of advice I'd give the installer is ask your manufacturer about security. Ask their specification. Ask for their installer security guide. And to the manufacturer ask the security question early and anticipate how you will support that product. Ask your suppliers about security. Do that and you'll have a secure product and I won't be hacking it.

LED professional: Do you have any idea about security costs? If you develop a bulb with IoT capabilities and you do all the things you just suggested, how much of the development costs will go towards security?

Ken Munro: It shouldn't be significant because when you specify your development, you should be asking the security question and stating the device should comply with standards X,Y, Z. OWASP (The Open Web Application Security Project) has some great standards for mobile apps, web apps and API's. And if you have it in your contract that the product should comply with these standards and then it doesn't you just say "I'm not paying you" so maybe it's cheaper!

The cost for security should be marginal if you ask the question about security early enough. Research from Gemalto [1] suggests that 9 percent of IoT vendor budgets are spent on security. Security gets expensive when you try to do it at the last minute. Trying to retrofit security is very difficult and very expensive. I would also seriously think about what the impact is on your brand if your product is hacked. What if my product is the source of a Denial of Service attack? What about the liability of my product? Think about bad exposure, bad public relations, bad marketing, and think about lack of sales. Remember that security is a bit of an insurance policy. It's making sure you are not an Equifax, for example.

LED professional: So every development company should add it to their project management guidelines?

Ken Munro: Absolutely.

LED professional: Thank you very much for your time.

Ken Munro: Thank you. ■

Notes:

[I] The Kitemark is a UK product and service quality certification mark which is owned and operated by The British Standards Institution (BSI Group). The Kitemark is most frequently used to identify products where safety is paramount, such as crash helmets, smoke alarms and flood defenses.

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Automatic Panel Level Transient Thermal Tester

The thermal resistance junction in case is an important parameter for the reliability of LEDs because degradation of the LED is temperature driven. Simulation and testing has advanced over the past few years but transient thermal analysis (TTA), which is required to understand the thermal transfer path, is especially work and time consuming - and not automated. Gordon Elger, Professor for Electronic Manufacturing Technologies, Technische Hochschule Ingolstadt, and his co-authors, Maximilian Schmidt, Alexander Hans, and Dominik Müller, present and discuss an automatic panel level TTA tester. They explain the challenges and the solution and demonstrate the applicability of using LED test board-panels.

Today, LED systems can be differentiated not only by high power, mid power and low power application, but also concerning reliability, i.e. high reliability and low reliability. On the one side, low cost LED consumer goods and, unfortunately, partly also replacement LED bulbs are located at the low reliability side of the lighting applications. On the other side, reliability and long lifetime determines the economic and ecological success of high-end LED illumination systems, e.g. outdoor illumination, signaling, agricultural LED systems and automotive lighting. LED lighting systems can, in general, reach very long lifetime of up to 100,000 h when appropriate designed and business models are based on the failure free operation of the light sources. Junction temperature and drive current are the key parameters that determine lumen degradation. In addition to the slow lumen degradation also catastrophic failures of the LED can occur. For eliminating these failures not only die and package design but also process and material control in manufacturing is important. Finally, the environmental conditions during operation like humidity, corrosive atmosphere and thermo- mechanical stress are fundamental for the lifetime of the LED systems.

Because many failures are driven by the junction temperature T_j of an LED, thermal management is essential to realize cost competitive but reliable LED systems. Transient thermal analysis (TTA) is a powerful approach to measure the junction temperature of the LEDs in a system and the thermal resistance R_{th_el} of the LED module [2-4]. A method for the automation of this measurement process will be demonstrated in this paper.

How Transient Thermal Analysis Works

After switching a heat load, i.e. switching the LED drive current from high heating current to low sense current, the forward voltage *Vf(t)* is measured time resolved. The thermal path from the die through the LED package to the heat sink can be resolved. TTA has become a common method and it is standardized in the MIL-STD-750F (3100 Series) [5]. Also the Solid State Technology Association (JEDEC) published valuable standards and thermal characterization test methods [6] in their JESD51 series. They are applicable to a wide variety of semiconductor packages under different mountings and usages conditions and underpin the thermal specifications of the manufacturer. TTA can also be applied for reliability testing. The location of failures can be identified. For example, it is possible to distinguish between failures such as delamination of the LED die or cracking of solder interconnect from the LED package to the printed circuit board (PCB) [7]. However, the TTA measurements are often considered as complicated and time consuming. The thermal load which is switched, i.e. the electrical energy minus the optical energy, and the proportional factor

between temperature and forward voltage have to be measured to calculate the real thermal resistance R_{th_real} (Symbols used as defined in JEDEC51-51: R_{th_el}: electrical-thermal resistance using as thermal load the electrical power, R_{th_real}: real thermal resistance using the real thermal load). To reduce the measurement effort, the relative thermal resistance method was introduced [1].
By relative thermal resistance measurement the k-factor and thermal load are not measured, but obtained by thermal path normalization to reference samples, i.e. known good samples, for which thermal load and the k-factor are known, i.e. precisely measured.
To obtain the R_{th} the thermal response need to be measured as early as possible after switching the heat load, in especially to resolve the thermal resistance between die and first heat spreader or substrate (first level interconnect). The measurement dead time and resolution depends on the electrical response of the equipment and the sample itself, i.e. parasitic capacity of the LED and parasitic inductance of the equipment. Typical well-designed and maintained equipment reaches 20 µs dead time. Signal cable length and electromagnetic noise influence the switching time and the stabilization of the detection current and therefore the measurement signal. Often every individual set-up in a lab, even from the same supplier, can behave differently. The errors influence the data evaluation and results. Especially in the structure-function, the dominating approach to analyze the transient temperature data, is influenced by the dead time and the method how to extrapolate the very early $V_f(t)$ data. It plots the cumulative thermal capacitance C_{th} in dependence of the cumulative thermal resistance R_{th} alongside the heat flow path (one dimensional approximation). Most of the artifacts which influence the structure function are visible in the time domain, i.e. visible in the time derived $V_f(t)$ curve and could be detected before further data processing.

Today, TTA equipment migrates from lab equipment to automatic inline inspection for quality control and reliability analysis. However, high time resolution and dead time to access the first level die contact is not yet commercially available as an automatic in-line tester. Here, the performance of the electronic hardware, the automation approach, the automatic data evaluation and test report generation for an automatic panel level LED tester with the focus on reliability testing of LED on wafer or panel level is developed and described.

Transient Thermal Analysis

Method based on JEDEC 51-14 and JEDEC 51-51

To determine the R_{th} junction to case, the temperature gradient within a LED system has to be measured. The forward voltage V_f of the junction can be used as a temperature probe due to its quasi linear temperature dependence. Actually, the dependence is non-linear and can be derived from semiconductor theory by the Shockley equation. However, in an adequate small temperature range (within 30°-50°C) it can be linearly approximated for a defined drive current (EQ1).

Approximation of V_f for a limited temperature range:

$$V_f = -\frac{1}{k} \cdot T + U_{con} = s \cdot T + U_{con} \qquad (1)$$

The constant factor k, called the k-factor (sensitivity s = 1/k) defines the relation of $V_f(t)$ from temperature T. The sensitivity s is in the range of 2 mV. The constant Ucon is due to contact resistance of the probing system and the inner serial resistance of the LED. The k-factor depends on the energy bands and the effective electronic state densities of the junction and, therefore, also from internal and packaging induced stress in the junction. The sensitivity s may vary for a single LED from wafer to wafer batch between 1 mV and 3 mV.

After determination of the k-factor for a specific drive current, the forward voltage can be used to calculate the temperature change in the LED junction when the specific current is applied. However, the k-factor can change during reliability testing in dependence of the device and epitaxial design of modern LEDs. The same holds for the LED efficiency. The lumen flux as well as the thermal load, change during accelerated testing of the LEDs. Therefore, to obtain the accurate thermal resistance R_{th_real} the k-factor and the lumen flux need to be measured again after every interval of accelerated lifetime testing. This causes a significant amount of experimental effort and is not adequate for large volume reliability testing or in-line inspection.

As discussed in the introduction, the transient thermal analysis is a common method to measure the thermal resistance of microelectronic packages that contain active semiconductor devices. The thermal response of a system like an LED package on a printed circuit board is measured time resolved after switching a heat load as shown in figure 1. Initially a constant heat flux is applied by a large drive current (I_{heat}) until the thermal equilibrium is reached. The thermal equilibrium is then changed by switching off the heat flux. The forward voltage $V_f(t)$ is measured time resolved applying a small sensing current I_{Sense} while the system transfers into its new thermal equilibrium. The temperature $T(t)$ is obtained from $V_f(t)$ by equation (1). For accurate absolute temperature measurements U_{con}, i.e. the contact resistance, in equation (1) needs to be small or very reproducible. Transient testing determines the difference $\Delta V_f = V_{f(junction\ hot)} - V_{f(junction\ cold)}$ and is independent from U_{con} and by that independent from the contact resistance. However, one needs to measure the V_f for hot condition, i.e. heat flux switched on for a sufficiently long time so that the thermal equilibrium is reached, and Vf for cold condition (heat flux switched off for a sufficiently long time so that the thermal equilibrium

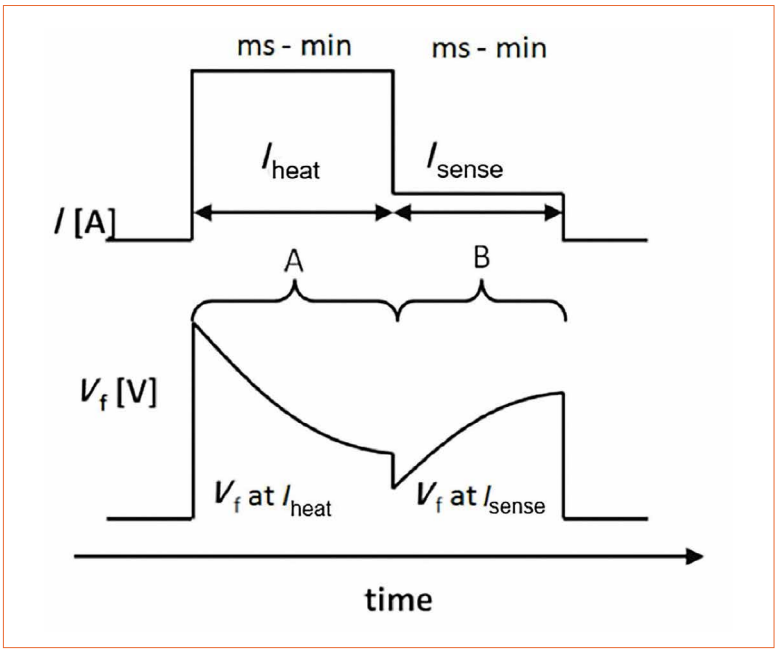


Figure 1:
The heat load is switched using the drive current of the LED. During heating up under high drive current V_f decreases from the initial large value because the junction heats up. Due to switching from large heating to small sensing current V_f is initially reduced because the required V_f at lower current is smaller *(V(I)* characteristic curve) and rises afterwards while the junction cools down

is reached) for the same drive current I_{Sense}. After switching off the drive current from I_{Heat} to I_{Sense} a delay time, i.e. dead time, is required until the system has stabilized after current switching before accurate V_f data can be obtained. The dead time is discussed in more detail in section 3, below. The same holds true when measuring the heating up of the device and besides that, under high current conditions noise is increased. In addition, while heating up the thermal load changes due to change of WPE in dependence of the temperature. Cooling down measurements are therefore preferred. However, for in-line measurements also heating up data are useful and utilized.

Based on the transient $V_f(t)$ measurement the transient thermal impedance $Z_{th}(t)$ is calculated:

$$Z_{th}(t) = \frac{\Delta T(t)}{P_{th}} = \frac{k}{P_{th}}(V_f(t) - V_f(t=0)) \quad (2)$$

Following the JEDEC51-14 (app. B), the logarithmic time derivation of $Z_{th}(t)$ is calculated. First the time is substituted by the logarithmic time z = ln(t):

$$a(z) = Z_{th}\,(t = exp(z)) \quad (3)$$

Afterwards the logarithmic time derivation is obtained.

$$b(z) = \frac{d}{dz}\,a(z) \quad (4)$$

The approach for dead time correction is described in JEDEC51-14 in section 4.3 (offset correction). The widely spread approach is the square root correction. However, the time interval for which the square root correction is performed is not generally defined in the standard. From a practical point of view the shortest possible time interval is used. However, it depends on the dead time of the experimental equipment. In most papers published on TTA, the dead time correction is not described appropriately. To compare TTA measurement performed with different equipment the square root correction intervals have to be defined equally. The structure function is obtained after the calculation of the time constant spectrum $R(z)$ for the Foster-Representation and afterward by Foster-Cauer transformation. However, in this paper the structure-function is not used for automatic TTA analysis. Automatic TTA analysis is based on the transient time data to filter out measurement errors that are better visible on the time domain. The relative thermal resistance method utilizes solely the $b(z)$ curve for thermal path analysis. Later on, the structure function can be calculated in addition.

Relative R_{th} Measurement

As discussed in the previous section, for determination of the real thermal resistance R_{th_real} in addition to the transient $V_f(t)$ curve, the k-factor and the thermal load have to be measured. The relative thermal resistance method avoids this by relative measurement. Using calibrated known good samples the R_{th_real} is calculated. In the following, the concept of the relative thermal resistance measurement for reliability testing will be explained. The concept is rather straight forward and nothing more than a normalization after the logarithm of $b(z)$ is calculated in EQ 5 below.

The effect of the logarithm is straightforward. Linear factors are transferred to an axis offset. The efficiency of the method is depicted in figure 2. When measuring an LED at different current slight changes in the efficiency changes the $Z_{th}(t)$ curve. This is also visible in the b(z) curve and the structure function. However, in the $B(z)$ curve it can be noticed that the heat path doesn't change: all $B(z)$ curves are solely moved perpendicular to the time axis. In the following, normalization will be called the process "moving the $B(z)$ curves perpendicular to the time axis" to match the $B(z)$ curve on a known good sample. After normalization the index N is added, i.e. $B_N(z)$ are the normalized $B(z)$ curves. The normalization is performed by a least square root fit of an axis offset.

$$B(z) = log(b(z)) = log\left(\frac{k}{P_{th}}\,\frac{d}{dz}\,(V_f\,(t=ln(z)) - V_f\,(z=1))\right) = log\,\frac{k}{P_{th}} + log\,\frac{d}{dz}\,(V_f\,(t=ln(z)) - V_f\,(z=1)) \quad (5)$$

For in-line testing the approach is the following: The sample under test is normalized onto a known good sample. As long as the least square root fit is below a defined limit, the sample under test passes. Clearly, signal to noise of the sample under test needs to be under a defined limit as well. Very good signal to noise is anyway crucial for TTA measurement. Therefore, the requirements for the measurement equipment are very important and discussed in the next section. In addition, for failure identification more detailed data evaluation need to be performed. The data evaluation approach developed for the automatic tester is described in section 4.

Hardware

To realize fast TTA equipment, two main technical features need to be realized: Fast switching-off of the heating current and fast regulation of the sense current. The general electric circuit diagram used for fast TTA equipment is displayed in figure 3 (top). For fast switching of the heating current it is bypassed from the device under test (DUT) using switch S1. The sense current is continually applied. However, after switching off the heating current the forward voltage jumps from roughly over 0,5 V within the switching time. Due to the large *dI/dt* parasitic inductances need to be avoided and the diffusion capacity of the diode need to be discharged. The switching of the heating current is displayed in figure 4. In addition, the regulation of the sense current has to respond within a short time. A forward voltage measurement when switching the heating current is depicted in figure 5. The oscillation due to parasite inductances and the regulation of the sense current are visible. After 2 µs the sense current is stabilized and the measurement data can be used for thermal analysis. To observe the thermal resistance as close to the die as possible fast detection is required. With a targeted dead time of 1 µs an appropriate bandwidth needs to be used. The sampling rate used in figure 5 is 20 MHz. With an

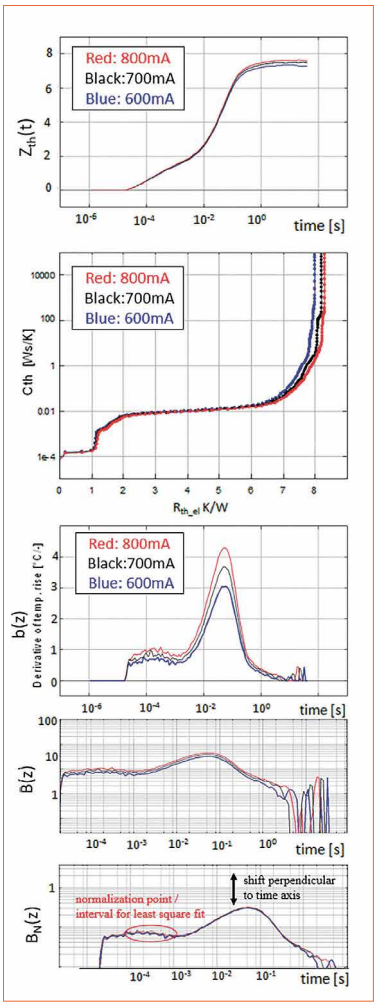
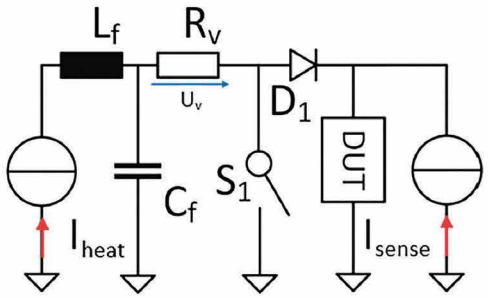


Figure 2: General description of the relative R_{th} method: The heating current is varied in the measurement. The dead time in this example is 20 µs. Time data before 20 µs are eliminated, i.e. the square root extrapolation is not used. The optical efficiency changes with the heating current, therefore the R_{the_el} changes. The optical efficiency has to be measured to obtain R_{th_real}. However, the thermal path of the diode doesn't change with the heating current. After calculation of the logarithmic time derivation *b(z)* the logarithm of *b(z)* is displayed, i.e. *B(z)*. The curves can be moved on top of each other: The thermal path is identical. The factor $f = k/P_{th}$ can be obtained from normalization



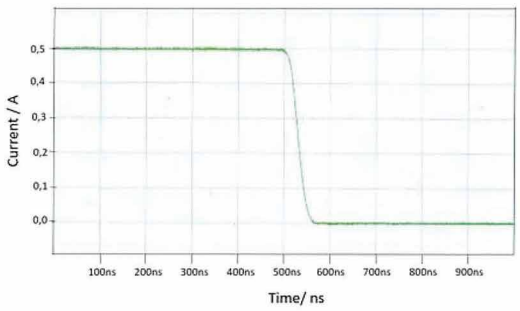


Figure 3: Concept for fast switching of the heating current. On the left side a simplified (schematic) circuit diagram of fast TTA equipment is depicted and on the right side the measured switching time for the heating current (100 ns). The Diode D1 is used to separate the sense current source from the heating current source

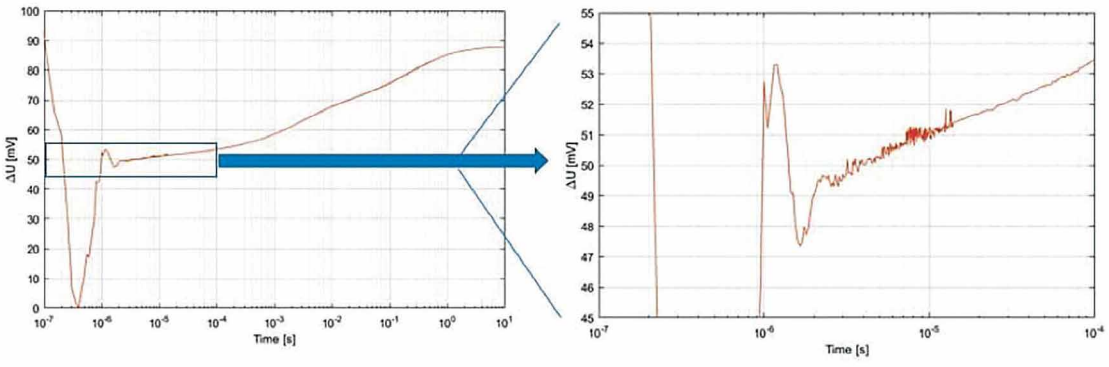


Figure 4: Measurement of the forward voltage of a diode by a 20 mA sense current after switching the thermal load. Sample rate of AD-converter is 20 MHz and bandwidth of anti alias filter 5 MHz. After 15 µs the bandwidth is reduced by digital filtering to reduce noise and data size. Afterwards, reduction of bandwidth is done in steps

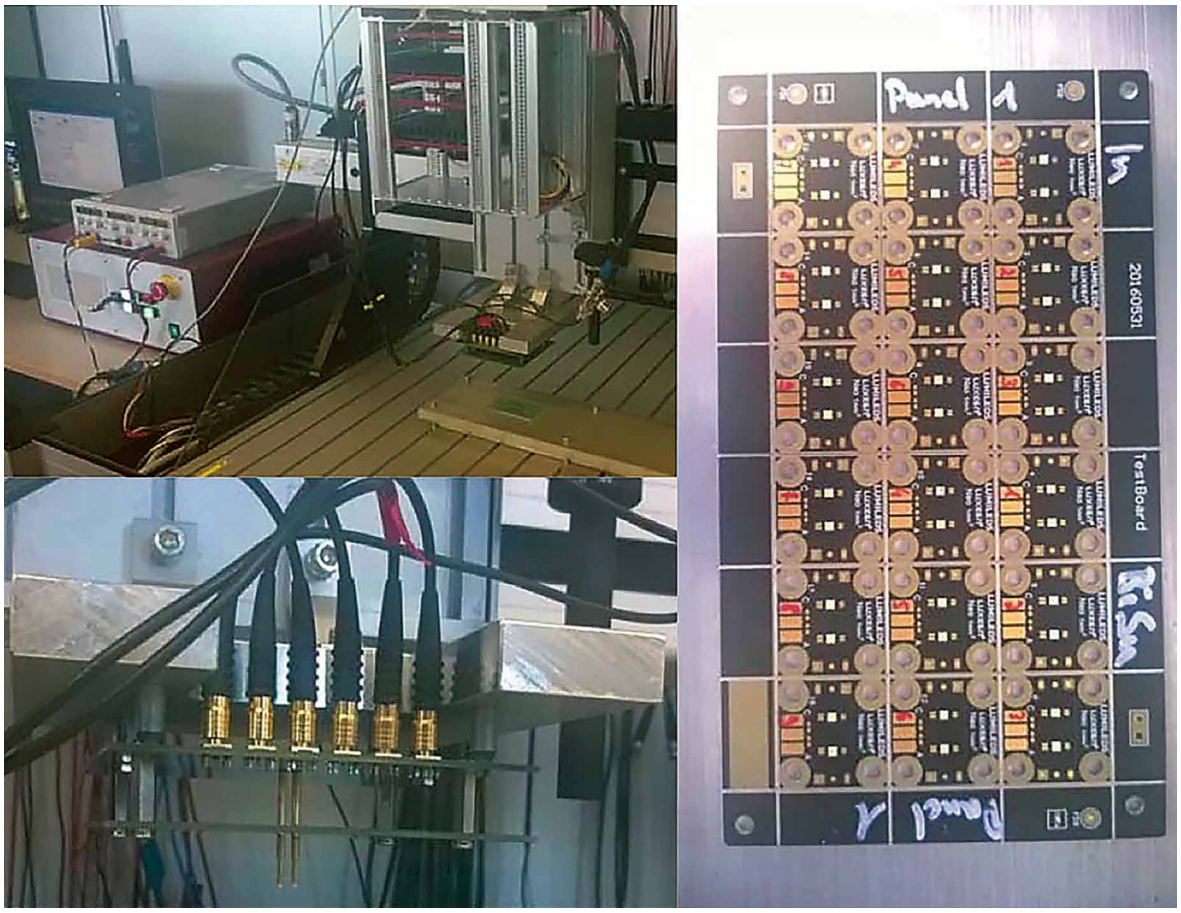


Figure 5:
The automatic tester is displayed on the top left and the probing system on the bottom left. An LED panel is on the right

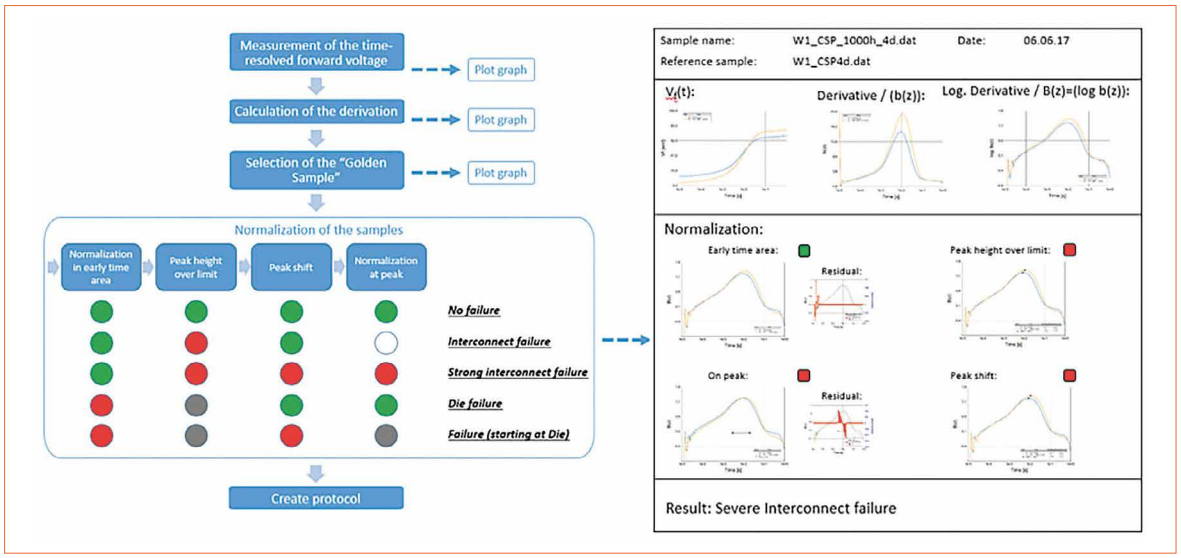


Figure 6:
Data processing procedure as described in the text

anti-aliasing filter of 5 MHz a time resolution of 200 ns is reached, well below 1 µs. The time data are required on a logarithmic time scale and the high bandwidth is solely useful within the first 10 µs. Afterwards it can be reduced stepwise. In figure 5, the filtering can be recognized at 15 µs. In the example it is reduced to 500 kHz, which causes the significant reduction of signal to noise.

The automatic tester is displayed in figure 5. It is based on a xyz-probing system. The electronic is mounted on the probing arm to keep the electronic connection as short as possible. Four point probing pins are used for electrical connection of heating/sense current and voltage measurement. For recognition of the alignment marks and test pads, a camera is mounted close to the probing pins.

Data Processing

First of all, the measurement capability of the equipment has to be tested using calibration samples. After measuring of the $V_f(t)$ of the sample under test, the data are filtered and the time derivation $b(z)$ is calculated. Appropriate filtering is required. The quality of the data, i.e. signal to noise and dead time are evaluated using $V_f(t)$ and $b(z)$, i.e. limited noise in the range 1-50 µs and no deviation from the theoretical

curves (including potential failures). Potential theoretical curves are obtained by measurements and by FE simulation supported failure mode analysis [7, 8]. Afterwards, the *B(z)* curve is calculated. All curves can be displayed in the protocol including the preselected reference curve, i.e. the known good sample. The curves are normalized using the known good reference sample. Because the normalization is a least square fit of the axis offset it delivers a residuum plot and value, i.e. the sum of the square root deviation of the measurement curve from the reference curve in the selected time range. The residuum is evaluated: total residuum and behavior of the residuum, i.e. the residuum should be solely arbitrary noise if the thermal path of the sample under test is identical in the selected time interval. Normalization is performed at two time intervals: early normalization (die domain) and at the maximum peak position (interconnect to board domain). If the normalization in the die-domain is residual free, the die interconnect is without failure. If in addition in the interconnect to board domain the normalization succeeds and *B(z)* peak position and peak value are within a defined range the sample under test passes. The k-factor and the thermal load are calculated from the normalization and the R_{th_real} is calculated. If the peak value of *B(z)* is increased or shifted significantly the sample is considered as failed. Also for the failed samples the R_{th_real} can be calculated as long as the die-domain normalization succeeded. If the die-domain normalization is not residual free an early normalization failure is displayed. If, in addition, the normalization is possible at the maximum, a die failure is defined. Following this general approach the failure modes are defined for the different LED packages.

Conclusions

An automatic transient thermal impedance tester is realized. Automatic measurement and data evaluation is implemented based on the relative thermal resistance method. Based on calibrated known good samples, also the absolute R_{th_real} can be calculated. Pass and fail criteria can be defined based on the LED package and application. Also failure mode analysis based on the TTA measurement can be implemented. In addition, the common structure function can be calculated using the numerical procedure described in the JEDEC51-14 standard. ■

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Roll-to-Roll UV Nanoimprint Lithography for Large-Area Nano- and Micro-Structuring of Flexible Substrates

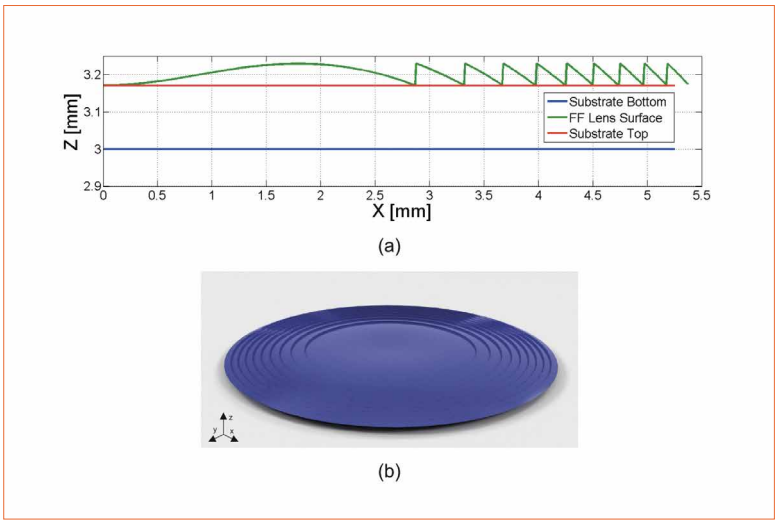
Cost and time-efficient methods for the fabrication of optical elements are highly desirable in the field of lighting. Imprinting optical structures in combination with large area fabrication turns out to become an effective approach in this regard. In particular roll-to-roll UV nanoimprint lithography (R2R-UV-NIL) has a large potential to set new benchmarks for the fabrication of miniaturized, low-cost and low-weight optics that can be applied in many fields of applications. In the following, the Joanneum Research Forschungsgesellschaft m.b.H team, Claude Leiner, Stephan Ruttloff, Dieter Nees, Anja Haase, Ladislav Kuna, Wolfgang Nemitz, Franz-Peter Wenzl, Christian Sommer, Barbara Stadlober and Ursula Palfinger, led by Paul Hartmann, demonstrates the maturity of the related process chain, combining optical design, direct laser lithography, step&repeat imprinting for shim fabrication and R2R reproduction.

During the last few years, light emitting diodes (LEDs) have conquered almost all segments of the lighting market as a consequence of the manifold of advantages they provide, ranging from long lifetime, reliability, energy saving, light and color control to new possibilities for system integration. Their compact size also allows the use of tailored primary and secondary optical elements to generate arbitrary radiation patterns, in particular in case of freeform (FF) optical elements, or to couple and to guide the light in accordance with demands. These optical elements may have dimensions of centimeters down to millimeters and a variety of methods for their fabrication are applied owing to the complexity of the optical elements and the required precision. Examples in this regard range from injection molding to ultra precision diamond machining. However, a lot of these methods are comparably expensive and suchlike fabricated optical elements account for a notable percentage to the costs of a luminaire. Therefore, more cost and time-efficient methods for the fabrication of such optical elements are highly desirable. One such fabrication method could be imprinting of optical structures, ideally using roll-to-roll (R2R) processes for large-scale fabrication. However, imprinting is limited to fabrication of optical elements with much smaller sizes than the ones typically used for lighting. On the other hand such ultrathin, foil-based optical elements also offer, besides their low height, additional benefits, including ease of system integration and reduced weight.

The Fabrication Procedure

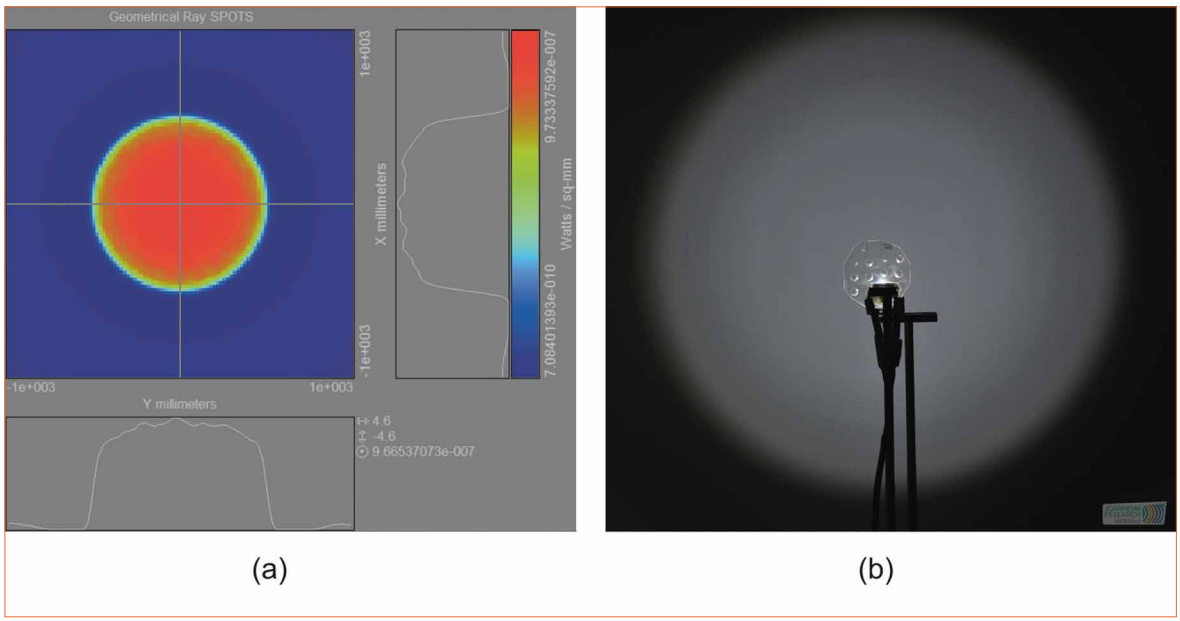
The process described below allows for the fabrication of tailored optical structures cost and time-efficiently by an approach that is based on master fabrication by mask-less gray scale laser lithography and the replication from these masters using step&repeat imprinting for shim fabrication. This shim can then be used as a stamp for R2R reproduction. Exemplarily, the fabrication of ultrathin freeform micro-optical elements on foils will be shown. Such foils can be directly integrated into the light sources or they can be laminated, e.g., on optically transparent plates.

The design procedure for the ultrathin FF micro-optical elements has been published in more detail elsewhere [1, 2]. It enables realization of (freeform micro-) optical elements with heights of several 10 µm that provide radiation patterns on a target plane as desired. In order to generate such ultrathin FF lenses a sophisticated algorithm for calculating the freeform surface was implemented, including the introduction of minimal and maximal thresholds of the freeform. Figure 1 shows a cross-section along one half of the diameter of such an FF micro-optical element that was designed to provide a rotationally symmetric radiation pattern. Also the 3D model of the FF micro-optical element is shown in the figure.

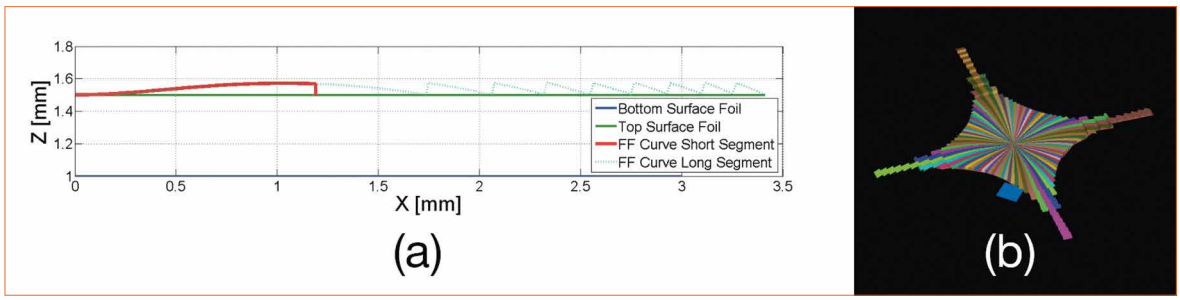


Figures 1a&b: Cross-section along one half of the diameter of the FF micro-optical element (a), and 3D model of the FF micro-optical element (b)

Figure 2 shows the predicted light intensity distribution on a target plane using the FF micro-optical element of figure 1 in combination with an LED light source as well as an image showing a wall that is illuminated by an LED through the FF micro-optical element. The latter one was fabricated in a batch process [3]. The sag height of the FF micro-optical element is about 60 µm and the diameter of the element is about 10.75 mm.



Figures 2a&b: Light intensity distribution on the target plane using the FF micro-optical element in combination with an LED light source, simulation (a), experiment with a wall representing the target plane (b)



Figures 3a&b: Cross-sections along one half of the diameters of a FF micro-optical element (a) and a (98 segments) 3D Model (b) designed for generating a uniform irradiance distribution with a square shape on a target plane.

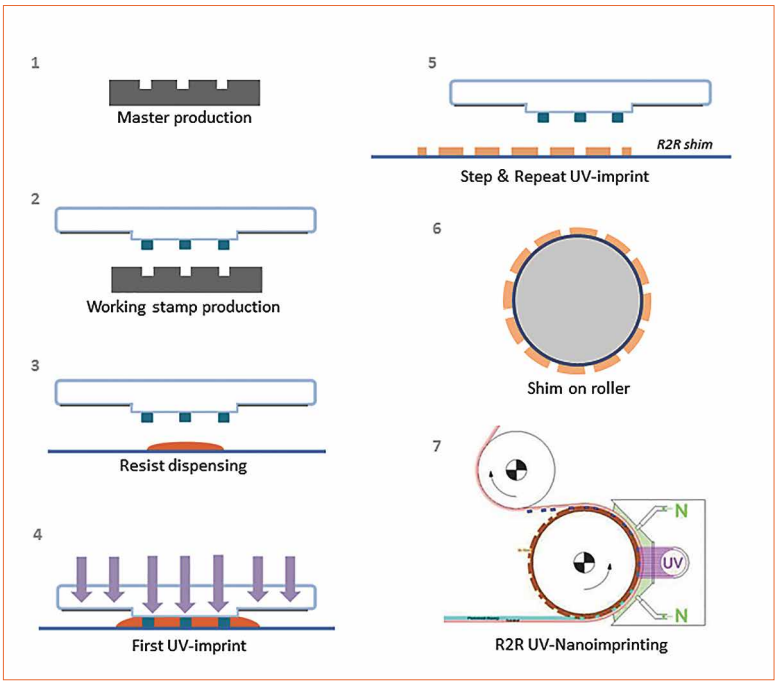


Figure 4:
Process chain for the R2R-UV-NIL based fabrication of optical structures. The main steps are master fabrication (1), step&repeat (2-5) and R2R-UV-NIL (6-7)

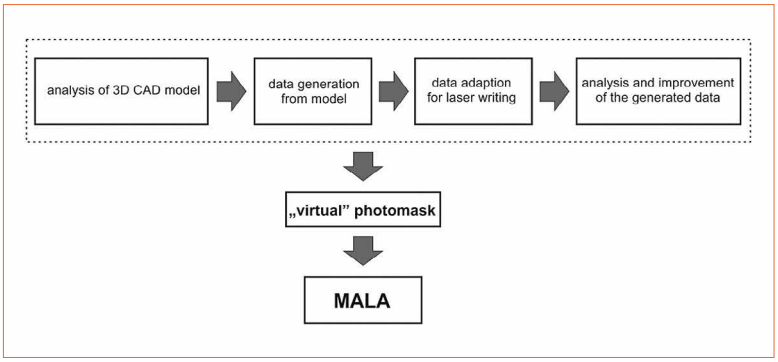


Figure 5:
Schematic of the fabrication of the master by mask-less laser direct write lithography (MALA)

Still, the procedure can also be extended to design non-rotationally symmetric irradiance distributions with, e.g., an irradiance distribution having a square shape. In this case the FF object has to be "segmented" into different slices with a constant azimuth step size, as shown in figure 3 and discussed in detail in [2].

The R2R-UV-NIL Process

Besides their compactness and low weight, the main benefit of such structures is the possibility to fabricate them on a large scale in an R2R process. In this regard R2R-UV-NIL is one of the most promising high-resolution patterning techniques that can account for cost-effective large-scale production on flexible substrates [4]. Initially demonstrated for thermal imprinting in 1998 by Tan et al. [5], Ahn et al. [6] extended its potentials to R2R-UV-NIL. While for thermal imprinting a thermoplastic material is embossed at temperatures above its glass transition and hardened by subsequent cooling, in UV-NIL the desired structure is transferred by a stamp into an imprint resist and fixed simultaneously by UV-curing.

With R2R-NIL the flat and rigid stamps that are used for a lot of other imprinting processes are replaced by roller stamps. This has the advantages that the imprinting is done continuously, which allows for a more homogeneous and conformal pressure application, improved resist displacement, seamless pattern transfer and high throughput. Such roller stamps can be either patterned rolling cylinders with either a metallic or silicone surface, or bendable patterned stamps that are wrapped around a metal roller [4]. Such flexible stamps, named "shims" can be easily attached on and detached from the roller.

The whole process chain for R2R fabrication of micro-scaled optical structures therefore comprises the aforementioned optical simulations, the fabrication of a master in accordance with the optical design, up-scaling of the master for the fabrication of a polymer shim and finally roll-to-roll fabrication. From a viewpoint of optical design and the complexity of the optical structures, larger heights would be preferable. On the other hand, from the viewpoints of laser lithography and R2R-NIL fabrication, smaller heights are preferable. Therefore, in dependence of the complexity of the structures a certain compromise with respect to the final height have to be made for which the aforementioned implementation of an additional algorithm in the design process that allows to define arbitrarily threshold values for the final height of a specific structure, is an essential step to align simulation and fabrication.

The process chain for the fabrication of the simulated structures is shown in figure 4.

Process chain for the R2R-UV-NIL based fabrication

An effective method for the fabrication of masters for suchlike structures ((1) in Figure 4) is a mask-less laser direct write lithography (MALA) approach, which is based on gray-scale direct laser lithography [3].

Besides the laser writing process itself, the most relevant part of master fabrication is the generation of a "virtual" photomask. The virtual photomask, which is directly generated from the 3D model of the FF micro-optical element, specifies the respective light dosage that is applied at a given XY-position of a stage on which the sample is placed. This light dosage can be varied while scanning the laser beam across the sample in accordance with the desired structure to be fabricated.

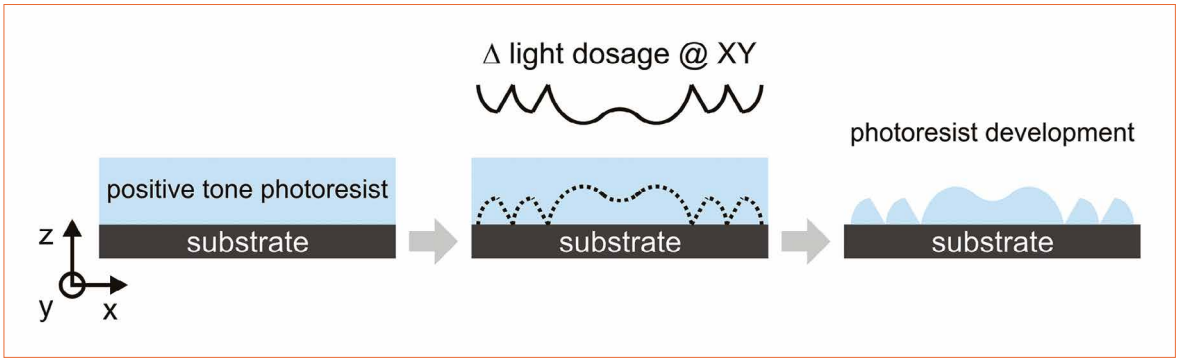


Figure 6:
Scheme of the operating mode of the MALA process

The whole process is schematically illustrated in figure 5, the operating mode of the MALA process in figure 6.

The next step ((2-5) in Figure 4) is the up-scaling of the master to a shim by step&repeat equipment. This tool allows very fast up-scaling of the written structures to larger sized masters and shims for R2R processes by highly precise stitching of the pattern elements of the master structure. For this, the master template is replicated by imprinting its pattern to a working stamp, which is used for the actual step and repeat processing ((2) in Figure 4). Using such an approach, the lifetime of the master template can be largely prolonged. In the step&repeat process a UV curable resist is applied to the substrate (3). The transparent working stamp then comes into contact with the substrate. In a subsequent step the resist is cured with UV light (4). Finally, the working stamp is released (5) and reused for the next print, close to the previously set structure.

Figure 7 shows an image of the step&repeat equipment. Figure 8 is an image of a shim that was fabricated from the master template of free-form micro-optical elements, after metallization. Once the shim is fabricated the shim can be used for large-scale replication by R2R-UV-NIL (6-7 in Figure 4).

Proof of Concept in the Pilot Plant

Figure 9 shows an image of the R2R-UV-NIL pilot plant. For R2R fabrication a liquid UV-curable imprint resist is coated on a floating foil on a 250 mm wide web.
The requirements on the specific imprinting resist used are many-fold ranging from good substrate adhesion over a high curing rate and low surface energy to sufficiently

Figure 7:
Image of the step&repeat equipment

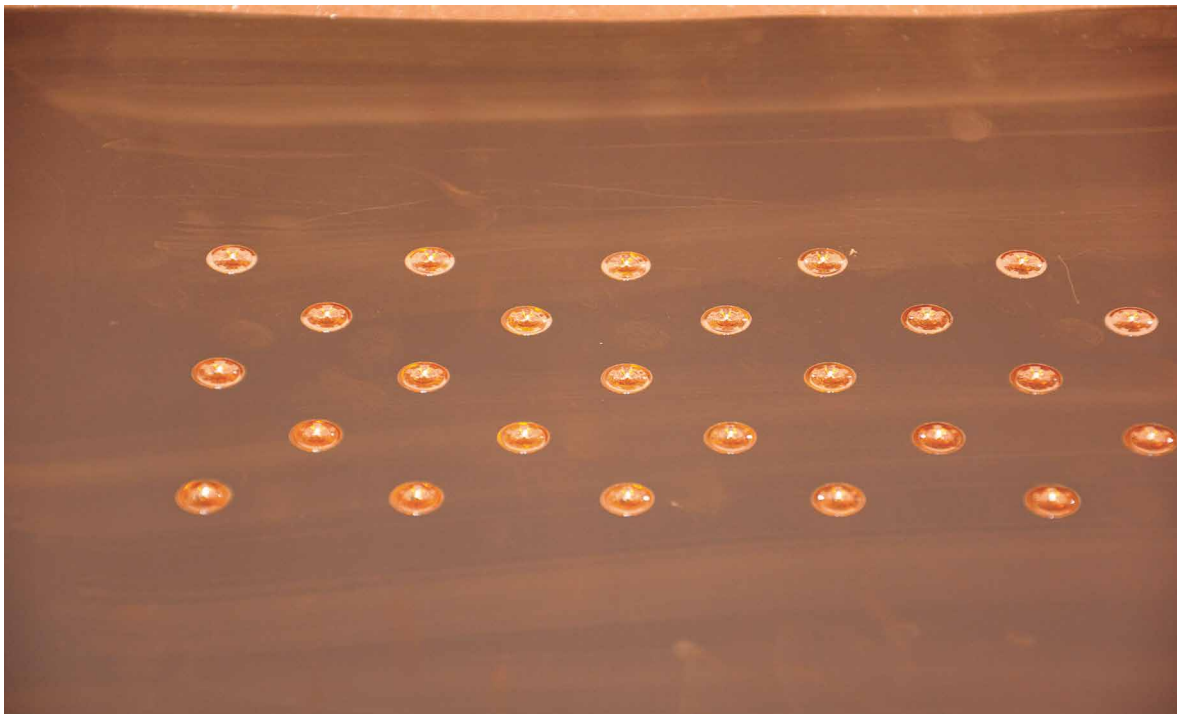


Figure 8:
Image of the shim fabricated by step&repeat with the free-form micro-optical elements after metallization

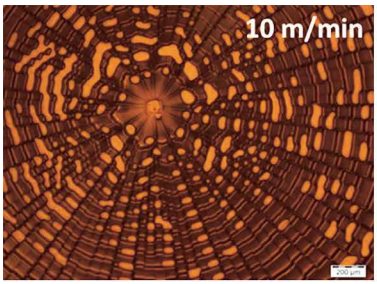
low viscosity for fast spreading and filling of stamp cavities [4]. Still, a clear benefit is also that the resin composition can be varied and/or additives can be added to the resin, which allows for the modification of the refractive index of the structured layer. This allows much higher flexibility in exploiting all potential optical effects compared to thermal imprinting into a single polymer foil material.

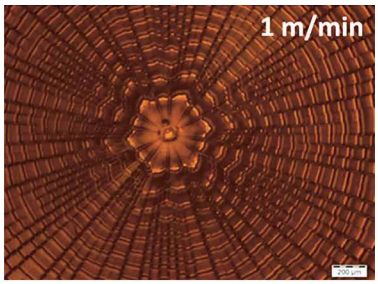
On its way through the R2R machine, the coated foil passes the imprinting unit which contains the shim that is mounted on a steel roller. The pressure that is needed to transfer the topographic shim pattern into the resist is applied by a soft rubber-coated counter roller pressing the substrate against the shim ((7) in Figure 4).

Figure 9:
R2R-UV-NIL pilot plant at Joanneum Research in Weiz, Austria

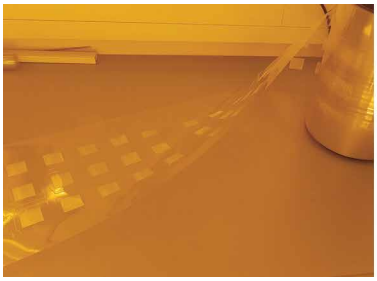
Still, the alignment of structure design, resist parameters and process parameters is quite a complex process with a lot of mutual interferences that have to be aligned precisely to one another in order to allow for structures with high quality and precision. Improvements in this regard are ongoing; in particular with respect to the process speed for fabricating high quality R2R-UV-NIL imprinted free-form micro-optical elements. Figure 9 shows the current status, which allows the R2R fabrication of defect free structures with a process speed in the low m/min range, while structures fabricated at around 10 m/min still suffer from imperfections and embedded air bubbles.

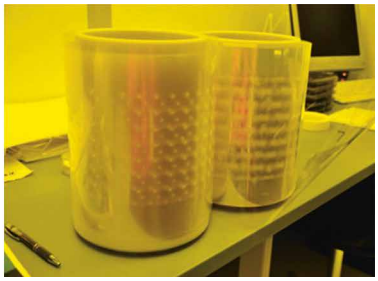
Figures 10 show the free-form micro-optical elements fabricated by R2R-UV-NIL at different speeds, and finally, figures 11 shows a final roll with free-form micro-optical elements as well as a further example with light-coupling structures.





Figures 10:
Free-form micro-optical elements fabricated by R2R-UV-NIL at different speeds(left: 10 m/min| right: 1 m/min)





Figures 11:
Final rolls with (left) light coupling structures and (right) free-form micro optical elements fabricated by R2R-UV-NIL

Conclusions

Still a young technology, all these examples demonstrate that owing to the progress over the last years R2R-UV-NIL and the related process chain has become a mature technology for cost- and time-effective large scale fabrication of optical elements. Such miniaturized, low-cost and low-weight optics will have a huge impact in the coming years not only for lighting, but also for a lot of other applications in that optical structures are core elements. ■

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A New Approach for Manufacturing LED Advertising Boards Backlighting

Today's displays and advertising boards should be flexible, lightweight, and of an easily customizable size, which makes them relatively expensive. Simplification and/or new approaches and production technologies are required. In a European project called OptIntegral, researchers have developed new types of LED displays that combine the flexibility, low cost and high technical performance enabled by roll-to-roll mass manufacturing technology. Dr. Eveliina Juntunen, Senior Scientist at the VTT Technical Research Centre of Finland, and her team, Vishal Gandhi, Satu Ylimaula and Arttu Huttunen, also from VTT, Samuli Leivo and Matti Koponen from Neonelektro Oy, Dr. Robert Heath and Dr. Haiming Hang from the University of Bath School of Management, with Encarna Escudero and Enric Pascual from Eurecat - The Technology Centre of Catalonia, demonstrate the results of this project.

Modern manufacturing technologies of flexible electronics and in-mould integration could realize all features that are requested from state-of-the-art displays and advertising boards but adaptation to new approaches and production technologies is required. In this article, two different solutions for advertising boards backlighting based on advanced in-mould integration are introduced. In in-mould integration, flexible electronics is overmoulded with plastics providing additional features to the backlight. Measurements done on different tests structures show benefit in both optical and thermal performance, and the pilot manufacturing of an advertising board RGB backlight demonstrates high yield of the full roll-to-roll manufacturing process. The user evaluation done in a public test installation concludes that curved shaped advertising board with RGB backlight gained significantly more attention and was significantly more effective on both communication and metacommunication than the standard display with the identical advertisement design used as a reference.

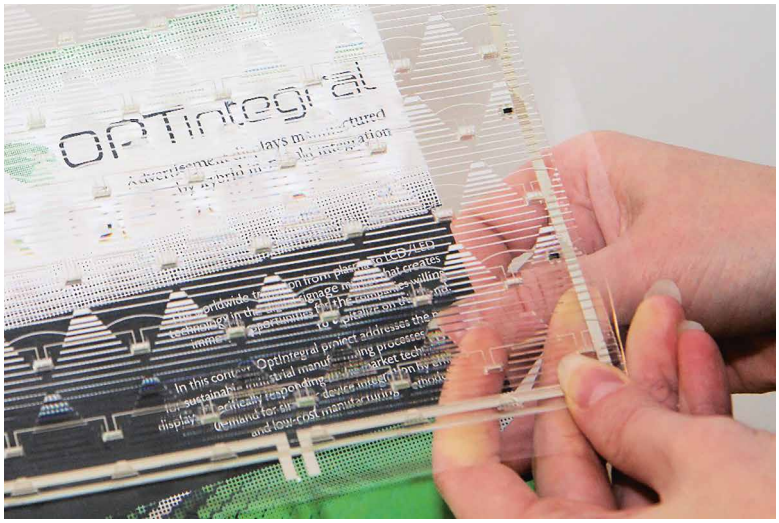


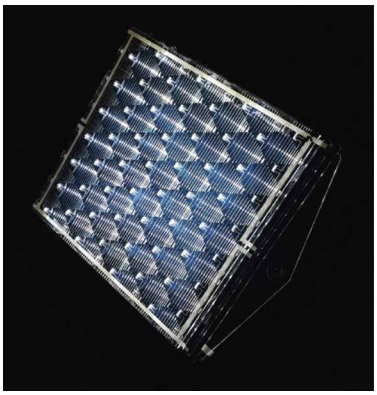
Figure 1: In the Optintegral project, a flexible, thin, and transparent light panel was developed by integrating a flexible LED foil with thermoplastics overmoulding realizing optical features on panel surface

Increasing the Performance of Printed Electronics

The device functionality of printed electronics can be increased by assembling discrete components like LEDs to the flexible foils making it possible to create hybrid integrated structures with higher complexity [1]. Such combinations are thin, large area, and lightweight elements that can be cut and bent into desired shape [2]. This is an attractive feature for advertising boards backlighting in vehicle applications for example. Hybrid systems built on flexible foils are also compatible with thermoplastics overmoulding that enables fully integrated and sealed manufacturing of additional features such as optical and mechanical functions at low cost [3].
In OptIntegral-project, this technology was applied to the production of large area LED displays. Overmoulding of flexible electronics was used to add optical features to the display elements, improving the visual appearance and thermal management of the product.

In-Mould Integrated Optical Features on a Light Guide

A light guide functionality was designed for an advertising board backlight to spread the light emitting from the LEDs to a wider surface area. Using such approach, evenly illuminated advertising boards could be realized with reduced number of LEDs and with thinner structures both having positive influence on production cost. In-mould integration enables optics to be realized on LED backlighting module in one process step. Overmoulding occurs when the flexible electronics foil is placed inside the mould cavity. During the moulding, the thermoplastic material is injected with heat and pressure into this cavity where it cools and solidifies to the shape of the cavity [4]. Here, the LED backlight was built on flexible electronics foil that was over-moulded with plastics to create a light guide. The optical structures designed to direct the light from the LEDs to the light guide and then from the light guide out from the front surface were integrated on the backlighting element using mould inserts allowing different optical features to be manufactured with the same mould. Two versions of the same backlighting element with and without optical structures on the front surface are shown in figure 2. It can be seen that developed optical features reduce the optical hot spots on the module surface and distribute the light out from the light guide more evenly giving the appearance of more evenly illuminated top surface.



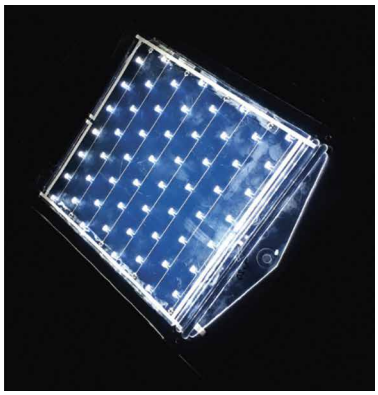


Figure 2:
In-mould integrated optical features on the light-guide module surface reduce the optical hot spots and distribute the light more evenly. Light-guide display in the left and reference sample without optical features on right

The optical features integrated on the backlighting element turn the light along the structure causing the light to travel inside the light guide longer. This cumulates more absorption to occur in the moulding material due to longer travelling distance. The backlighting element with and without in-mould integrated optical features on the front surface were studied with integrating sphere as 4pi-measurement giving the total light output. When measured with 100% drive current (20 mA per LED) 4% loss in total light output due to optical absorption was shown. The direction of the luminous flux emitting from the backlighting element was studied with goniometer. The measurements confirm that the in-mould integrated optical features on the front surface turn the light more along the light guide where as in the backlighting element without optical features more light escapes from the backside of the panel. The benefit of the developed optical features was 17% due to the increased light output from the front and side surfaces.

Embedding Reduces the LED Temperatures

Heat management is a key factor dictating the performance and reliability of LED solutions. The flexible foils are made of plastics and consequently are poor thermal conductors. Also, the embedding material is typically plastic. Metallic conductors printed on the foils improve the thermal performance, but are often minimized to reduce material consumption, cost and to provide maximum transparency. This contradicts thermal management of the in-mould integrated device [5]. Here, temperature of the LEDs was studied with thermal transient tester (T3Ster) in different thermal environments, such as with and without in-mould integration, and with two different drive currents. The T3Ster records the junction temperature of the LED as a function of time and calculates the thermal transient response of the structure. From this response, the cumulative structure function is processed giving a one dimensional description of the thermal path from the heat source to surrounding ambient that was 22ºC free air in this case. [6, 7]. The same samples of LED foils were measured before and after the overmoulding with identical measurement procedures. Each sample consisted of seven LEDs connected in series (illustrated as one row of LEDs in Figure 2) that was considered as one heat source. Average values are summarized in the (Table 1). On average embedding reduced LED temperatures by 20%. When measured on foil, most of the

cooling occurs via thermal convection and thermal radiation in air as convection towards the foil is limited due to small contact area and low thermal conductivity of the foil. The overmoulding replaces the air from the direct vicinity of the LED and increases the cooling via thermal conduction through plastics.

Roll-to-Roll Manufacturing of Dynamic RGB Backlight

During OptIntegral project, increasing interest for low cost, dynamic displays was detected, and low pixel resolution, dynamic RGB backlight based on full roll-to-roll (R2R) manufacturing was developed for this demand. The basis of the solution is flexible foil having continuous layout pattern on which the digitally controllable RGB LEDs are assembled. The overmoulding is carried out sequentially over the LED matrix enabling LED foil to remain flexible and in roll format also after the overmoulding. As such, different backlighting solutions can be realized with the same solution simply by cutting and bending correct size of the illuminating element out from the roll. The process steps are illustrated in figure 3. Commonly, the foil is inserted into the mould as a sheet like it was done with the light-guide demonstration introduced above. However, by using roll-to-roll (R2R) processing through all the manufacturing steps from printing to electronics over-moulding the separate sheet cutting step is avoided that increases the throughput and cost efficiency. The R2R over-moulding also benefits from less complex foil inserting in the moulding tool enabling better possibilities to fully automate the process as well as simplified component handling when the components can be kept in roll format.

Table 1:
LED temperature comparison on foil and in in-mould integrated structure - Ambient (air) = 22°C

Heating current through LEDs	Average T LED (C) on foil	Average T LED (C) embedded	Change in T LED (C) when embedded
10mA	95.0	75,6	-20 %
15mA	127.4	102,6	-19 %

Figure 3:
Manufacturing steps of full roll-to-roll processing

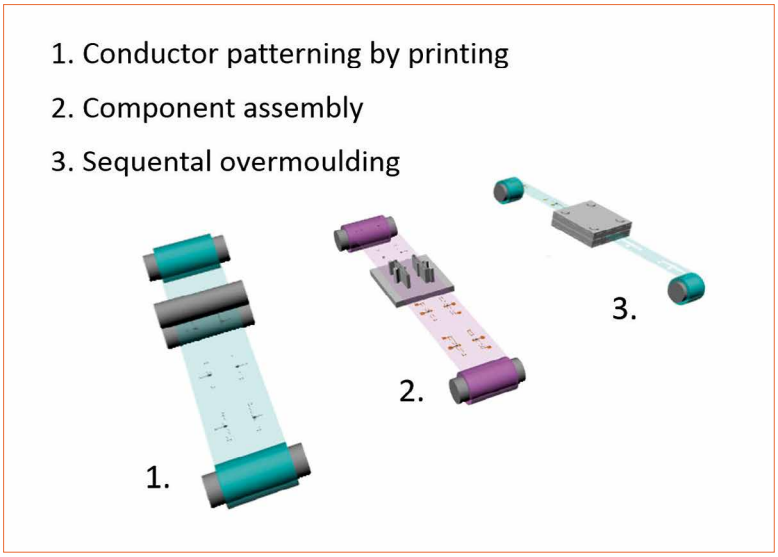


Figure 4:
Flexible, R2R overmoulded RGB LED foil was used to build dynamic, large area, and curved advertisement display

Curved, large area project demonstrator was manufactured using the developed RGB display concept. In the R2R manufacturing trial, 20 meters long RGB LED foil having 175 LEDs/ meter was overmoulded with over 99% yield. Large, circular advertisement board with printed canvas surface was built using the over-moulded RGB LED foil. The cylinder had identical print and RGB LED foil assembly on opposite sides. The diameter of the cylinder was 183 cm, height 57 cm and thickness 3 cm. Circular shape was produced to emphasize the flexibility of the developed LED backlight element, where as thin structure demonstrates the reduced thickness achieved by optical features of the in-mould integration. Arduino MEGA microcontroller board was used to vary the backlight colour smoothly from cold white to warm white and to few reddish hues. In addition, in certain occasions local effects took place to highlight the icons with different colours and paint the tires of the race car red. The measured total electric power draw of the RGB backlight was between 85-121 W depending on the dynamic features used.

Effect of In-Mould Integration on the RGB Backlight Performance

Combined power consumption and optical measurement using integrating sphere was carried out to investigate the effect of plastics embedding of developed RGB LED backlight. In these measurements, two types of the same backlight LED foils were compared that means that the LED configuration in both types was identical. The first overmoulding type (called partial moulding) had a slightly diffusing optics covering LEDs and conductor tracks while leaving the other parts of the foil not covered. The second overmoulding type (called overall moulding) covered the entire foil surface with thin, clear plastic.
In addition, there was a simple lens shape on top of the LED. The optics is shown in figure 5. Bare foil with no overmoulding at all was used as a reference

The light measurement was done as 2pi-measurement by inserting the samples on the side entrance of the integrating sphere. The sample placed on the entrance of the sphere is shown in figure 6.
Each RGB colour was measured separately and the reported value is an average of 10 repeated measurements. The used measurement set up records the light coming out from the front (primary) surface. The light escaping from the back surface and the sides is neglected. Simultaneously to the light measurement, current and voltage were recorded with multi-meters giving the electrical power. Current was set to half of the maximum current of the LEDs.
The results listed in (Table 2) show that the sample with partial overmoulding (A in Figure 5) performs with higher efficiency than the bare foil although some light absorption must occur in the slightly diffusing optical element covering the LEDs. The benefit is 2-4 % depending on the colour and is assumed to be caused by improved thermal performance of the overmoulded sample. The result is opposite when considering the overall moulded sample (B in Figure 5) in which the efficiency reduction is 10-20% compared to bare foil. The overall moulded sample should experience the same thermal management benefit as the partially overmoulded sample. So, the decrease in performance is due to the change in optical structure.
The overmoulding covering the entire front surface could act as a light guide directing the light more sideways and away from the measurement sensors detecting only the light that comes out from the front surface.

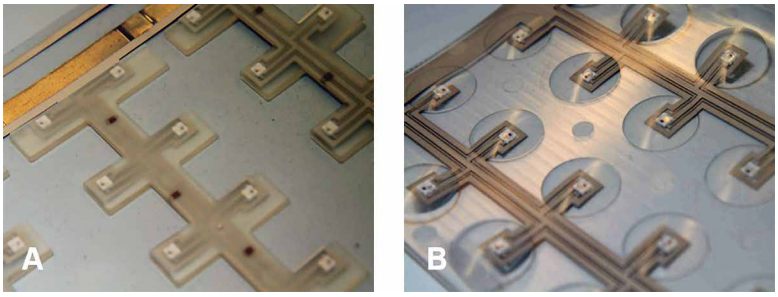


Figure 5:
Partial overmoulding (A) with slightly diffusing optics in-mould integrated over the LEDs and conductors and overall moulding (B) with in-mould integrated lens on the LED. Both backlight elements are made on the same RGB LED foil

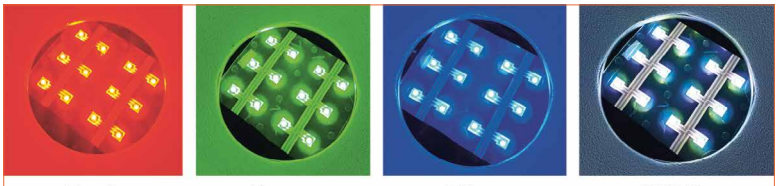


Figure 6:
RGB display sample placed on the entrance of the sphere for light measurements

Sample	Color	Electric power (W)	Radiant power 10^{-2} (W)	Efficiency (%)
Bare foil (no optics)	Red	0.53	3.3	6.2
	Green	0.53	3.2	6.0
	Blue	0.54	4.7	8.7
	White	1.23	10.4	8.5
Partial overmoulding A (diffusing optics)	Red	0.50	3.1	6.3
	Green	0.50	3.1	6.2
	Blue	0.50	4.6	9.1
	White	1.20	10.5	8.7
Overall moulding B (lens optics)	Red	0.50	2.5	4.9
	Green	0.50	2.7	5.4
	Blue	0.50	3.9	7.8
	White	1.19	8.7	7.3

Table 2:
Measured optical and electrical performance of the RGB LED backlight elements. The measurement includes 12 LEDs. Only the light leaving from the front (primary) surface is recorded

Impact on Advertisement Effectiveness

The evaluation of the performance of the developed curved, large area, RGB advertising board was carried out as a public installation and user study involving 30 test subjects in the Sports Training Village of University of Bath. The testing approach utilized a state-of-the-art glasses-based eye camera to measure the actual attention paid towards advertising. The evaluation also included an assessment of the performance of the display on both communication and metacommunication.
The methodology envisaged students being asked to walk freely along a prescribed route in which both the developed curved RGB display and the selected competitive display would be mounted.
The competitor display was a standard two-sided flat rectangular backlit display. The advertisement

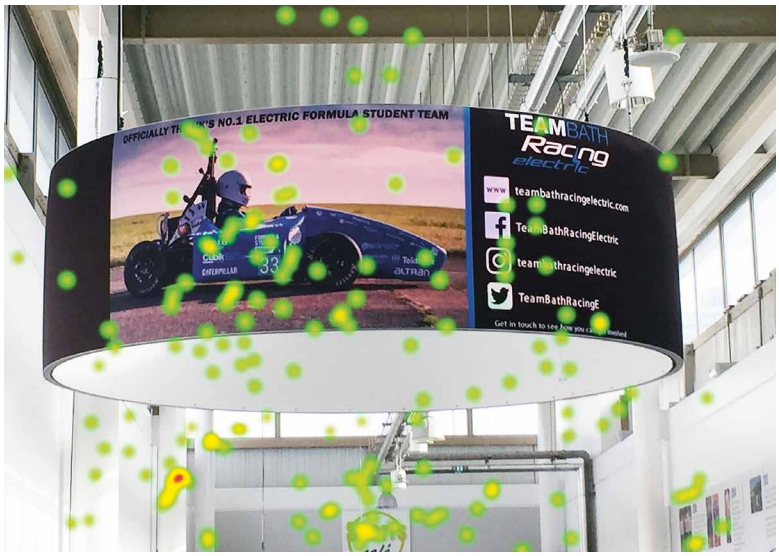


Figure 7:
Fixation map on curved, large area RGB advertisement board

design on each display was identical. Both displays were hung just above head height in a well-trafficked 4-metre-wide corridor leading to the Sports Training Village Café. Test subjects were equipped with lightweight portable glasses-based eye cameras, and were given no instructions other than to walk the prescribed route behaving as they would normally do. The dwell time spent looking at each display would enable the directional attention generated to be assessed, and the speed of eye-movement (fixations per second) would indicate the level of attention generated by each display. After subjects had walked past the displays, a short questionnaire was administered, asking questions concerning communication and metacommunication about one of the two displays. The questionnaire also asked how much attention the ad was perceived to be able to get. To obviate order effects the direction of the route would be reversed for half the subjects, such that the order of encountering the two test displays (Optintegral and Competitor) would be reversed.

Summary of all subjects viewing the test display through the eye-camera glasses is shown in figure 7. The findings of the eye-camera concluded that the directional attention and the level of attention towards the test display (RGB cylinder) was not significantly greater than towards the standard display. However, the findings of the questionnaire show that the test display is significantly more effective than the standard display on both communication and metacommunication. The test display (RGB cylinder) was also perceived to be significantly more attention-getting than the standard display. The reason it was perceived to be more attention-getting was concluded to be more due to its shape than the RGB colour effect.

Conclusions

Manufacturing and performance of innovative advertising board backlights is reported in this article. The manufacturing is based on in-mould integration in which the flexible electronics is overmoulded with plastics providing additional features to the product.
Full roll-to-roll manufacturing process is introduced and piloted with good yield in RGB LED backlight manufacturing. Measurements done on tests structures show benefit in both optical and thermal performance by in-mould integration. The user evaluation done in a public test installation concluded that curved shaped advertising board with RGB backlight gained significantly more attention and was significantly more effective on both communication and metacommunication than the standard display. ■

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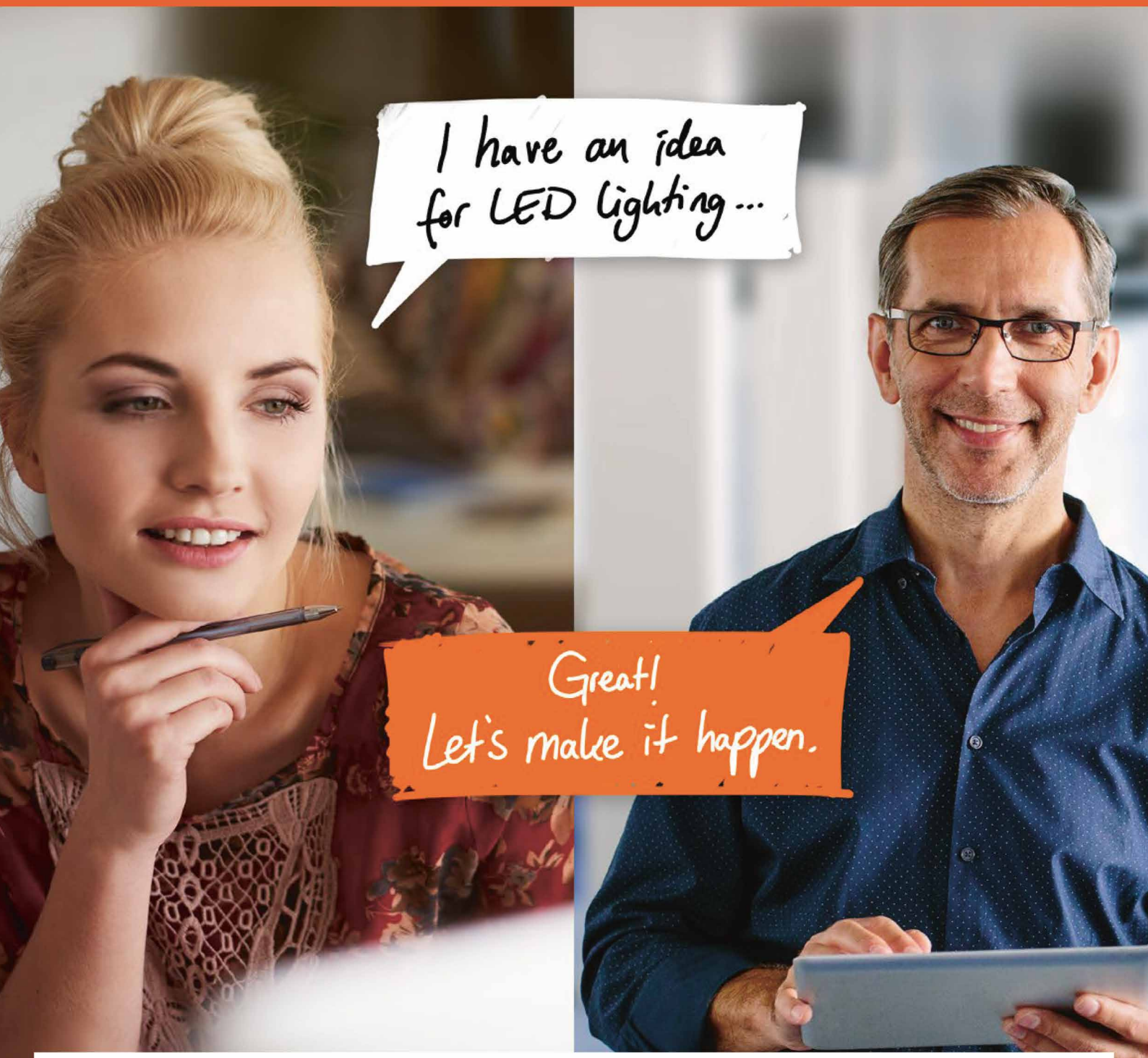

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Lighting Industry Quo Vadis - Impressions from Light + Building 2018

Messe Frankfurt recently announced a new record for Light + Building 2018: “A total of 2,714 exhibitors (2016: 2,626) from 55 countries launched their latest products onto the world market. Altogether, more than 220,000 trade visitors (2016: 216,610) from 177 countries made their way to Frankfurt and around 240,000 visitors were thrilled by the Luminale in Frankfurt and Offenbach.” These figures explain why, even if you were well prepared and spending the entire week at the event, a complete picture just cannot be given. Arno Grabher-Meyer, Editor in Chief of LED professional and Technology Manager at Luger Research, collected and analyzed as much information as possible, condensed it to his personal list of highlights, and wrote a summary.

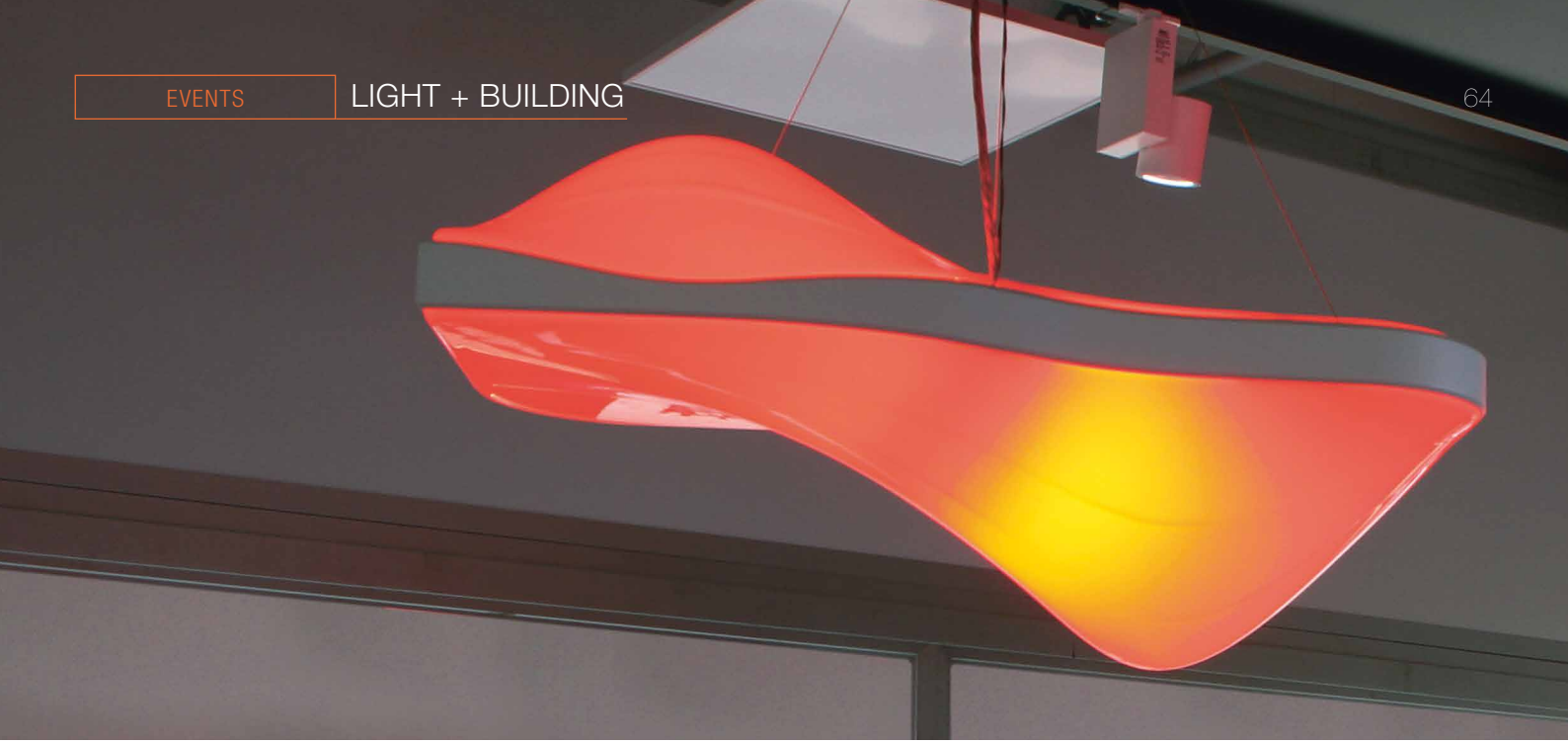
Light + Building is traditionally the lighting event where companies from all over the world introduce their newest, top innovations. Some companies even invite a selected group of people to a private demonstration of new concepts and prototypes. Occasionally, members of the press are allowed in and receive a rough forecast of upcoming trends, but unfortunately, taking pictures is strictly forbidden. LED professional was one of the lucky few that was invited to look behind some of these curtains.

Newcomers to the market also prefer Light + Building for presenting their products for the first time because of the size of the audience. The term “newcomer” doesn’t necessarily refer to a new, young and small business. Oftentimes the newcomer is a company with a long tradition in other technology fields that has realized that their competencies would be beneficial to the lighting industry. These types of companies are probably the most interesting from a technological point of view because they bring genuine innovations to the lighting market.

Light + Building is not only a revered place to present technical innovations but it is also the place to present new designs. Interesting approaches could be seen at the booths of small and large companies alike. While some attempts were, like in the fashion industry, just meaningless remakes in a new technology and therefore not very impressive, there were, at the other end of the scale, new designs that were inspired by the possibilities of new technologies. Finding these highlights within the enormous number of exhibits was a feat in itself. Therefore, I apologize in advance if I missed any - and I am sure, I did! (In this case, please feel free to send me your personal favorite.)

Last, but not least, Light + Building is the event where industry giants demonstrate their power and their visions. They are often technically interesting and sometimes hard to understand. At first glance, they might seem insignificant but these companies have the potential to define the direction in which the whole industry will need to develop, and their ideas should therefore, be observed carefully.

About 240,000 people called on 2,714 exhibitors who showcased products that they felt would initiate lucrative business deals. TRILUX demonstrated their vision of future light systems - cue modularity and advanced HCL features - to selected clients and partners at the back of their booth while the front was crowded with interested visitors



▲ **Fully color tunable luminaires with soft organic shapes at the Lumitech booth**

Designs & Applications Are Driving the Industry

Despite the fact that LED professional has a strong affinity to technology and components, it was imperative for me to peek beyond those boundaries especially because of the influence applications and designs are starting to have on technology again. Although it is interesting to see how designers and lighting designers have adopted LED and OLED technology, what is even more interesting is the way these creative people are challenging limitations and signaling what they expect from component manufacturers in the future.
In this respect, what struck me most were: Soft shapes using fabrics; Building integration and reductionism; mimicking natural illumination. Some approaches are diametrically opposed in their aims by hiding the light source and the luminaires that focus on the light itself. At the other end, the luminaire is portrayed as a piece of art without compromising the purpose of creating light. And between these two extremes, anything is possible.

There were certainly other interesting attempts but they were mostly the result of improving and developing

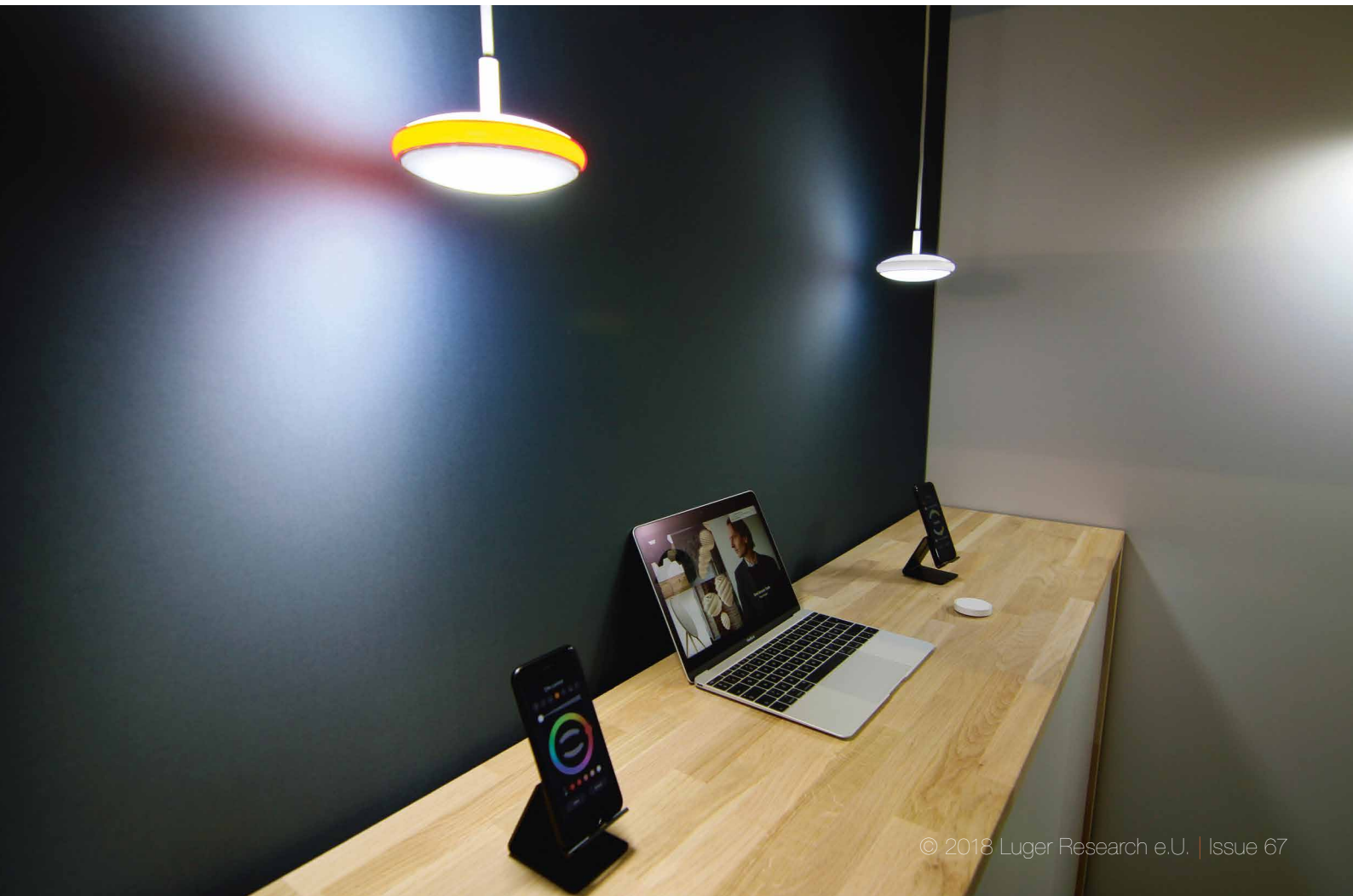
▼ **Vanory combines glass, fabrics and fully tunable RGB LEDsto create a unique ambiance**

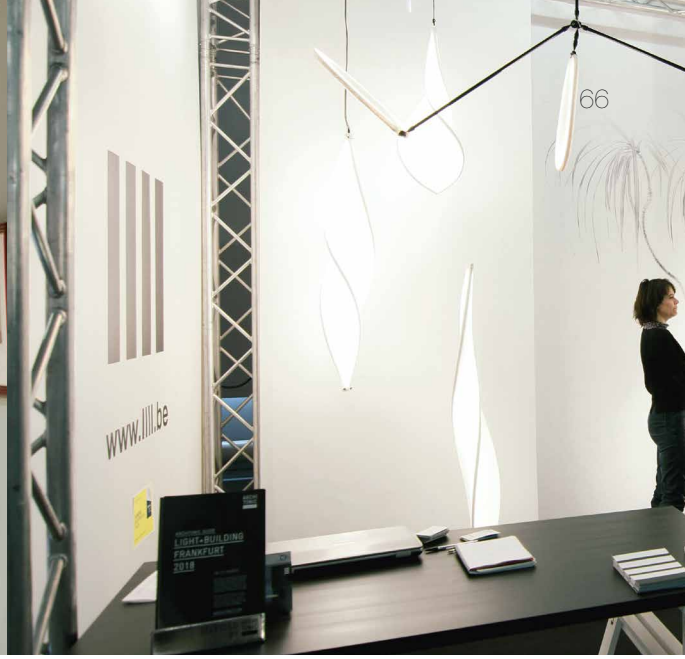
existing luminaire designs, which were rarely new or substantially different from their predecessors.

Cautious use of sensual fabrics and their ability to shape light into unique patterns at Light + Building 2016 was continued this year. The applications included combinations of glass and other materials for mood lighting and visual diversification as well as material for lampshades in organic, soft shapes. The materials used are often unlike the lampshade materials used in the incandescent era, and are used in diverse ways because LEDs and OLEDs don't get nearly as hot as halogen or incandescent lamps did, giving designers more freedom in their choice of materials. Slowly but surely this development is being adopted by more and more companies. A positive aspect of this trend is that many of the designs can't be used for an Edison socket, resulting in products that are true LED luminaires that can use the potential of this technology more fully.

Early visions of LED lighting were building integration and building luminaire construction elements visions but we are still waiting for the

▼ **A simple, soft design with fully controllable light output, paired with the unique Eclipse wireless controls. This is Shade's Orb**





▲ **Georg Bechter Licht's award winning system is characterized by maximal integration and miniaturization possibilities**

▶ **llll makes hovering lighting objects from fabrics and LEDs**

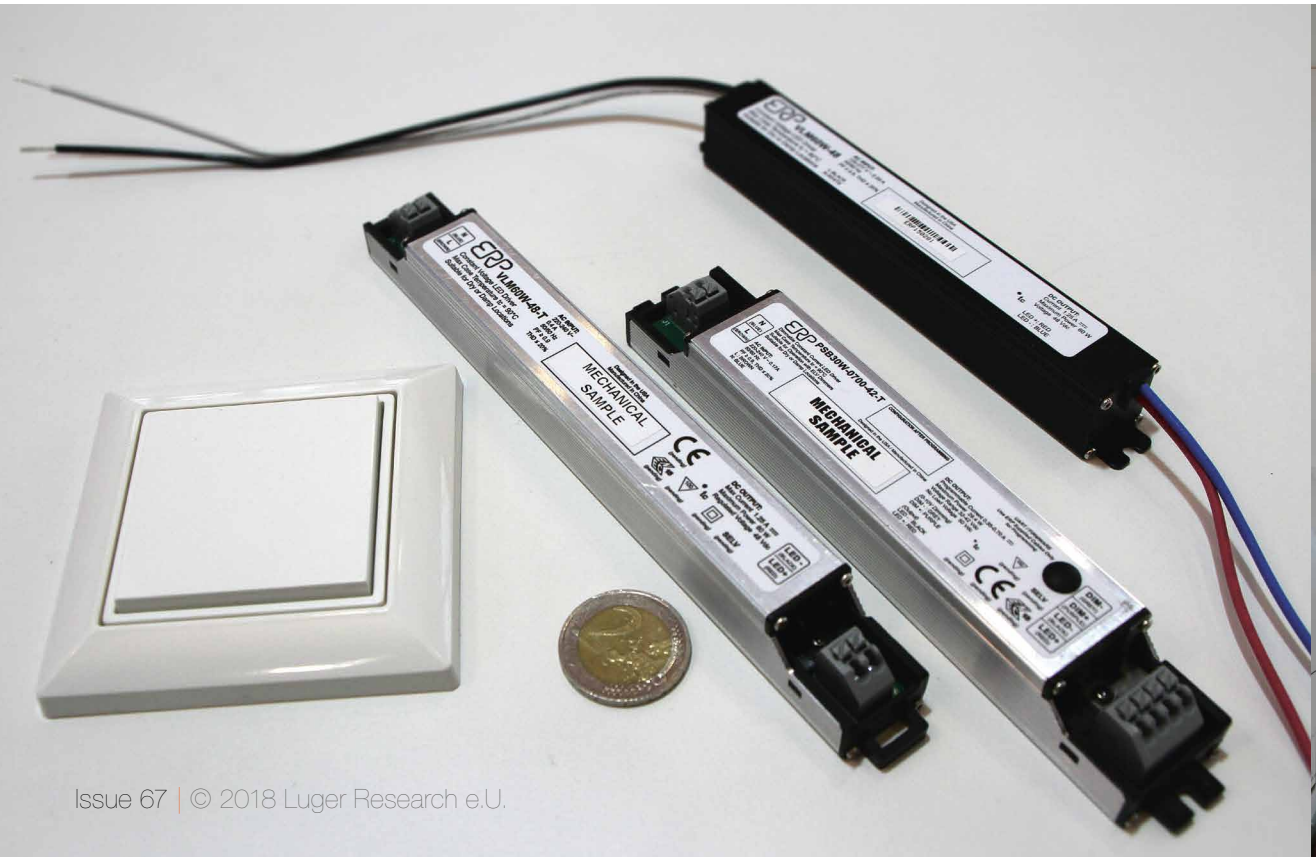
mass adoption. But still, the vision is slowly becoming a reality because of the enormous ingenuity and creativity of small companies; some of which are already making use of the latest communication and controls technologies with unique and advanced operation concepts. Although the ultimate building integration hasn't been realized yet, the success of these businesses and their crowded booths at the L+B might animate established lighting corporations to investigate these approaches or invest in some of these innovative companies.

In some respects, requirements have been recognized by the electronics industry and the first actions to accommodate them have been set: Drivers with integrated controls are now slimmer and smaller in volume. Several companies have started to shrink the dimensions of their drivers; mostly staying within certain limits and just reducing the height to allow slimmer form factors, but keeping a standard length. For most of the current applications this is fine but for some, this type of standardization is a disadvantage. Luckily, there are some companies that are starting to provide proprietary dimensioned, even smaller, drivers.

The pressure on components from the application, especially electronics, continues in driver ICs and concepts. Simplification - including miniaturization of the electronics circuits - has become an important issue. While some IC manufacturers have already found the answer, there are still a huge number of parameters that have to be considered. Some of those parameters are flicker suppression, exact control of the output current or equal power distribution over the whole length of a several meters long linear strip module, to name just a few.

Three other developments in electronics that came about because of user requirements and applications could also become game-changers. The first one is the realization by all the important companies that commissioning can be a critical, limiting factor for the

▼ **ERP proudly demonstrated the most compact LED drivers of their class, available with different controls options**



broad adoption of smart and truly human centric light installations because each and every light is a node that needs to be addressed individually. In many cases it is no longer sufficient to group various luminaires together and many well-known companies are working hard to find solutions for simplifying the process. The second one is lowering dimming levels down to 0.1%, which is provided by some manufacturers. The difference to the prevalent 1% is striking and the question of whether it is reasonable (use/application area) is easy to answer: Primarily dimming using systems with color or CCT tunable systems. The third game-changer is the NFC programming of drivers. This is probably the biggest adopted innovation for projects and mass applications and will soon become a Zhaga certified standard. This would allow for the programming and parameterization of drivers in bulk to the exact requirements needed in a project just before shipping them. Should there be changes or in case of a replacement, they can be easily re-programmed on location.

For years, psychologists and ethnologists have known that natural light conditions like the slow fluctuations under a shady tree have positive effects on the wellbeing and cognition of people. And even though it is no simple task, mimicking natural illumination seems to be the logical goal. Two companies have, at least in part, accepted the challenge. The two proposals have very different technical levels and price ranges and although they haven't yet fully achieved the feeling described above, their attempts are very impressive. Even though some people think that we should just spend more time outside and refer to human centric lighting as a gimmick, the approaches should not be ignored. A lot of effort and money has been spent on less important issues and product development with a successful return on investment. Further investigations and improvements could lead to a paradigm change in some applications so it is well worth it to keep an eye on these technologies.

▲ **Lextar's design includes gesture control for dimming this dim-to-warm capable luminaire**

◀ **Ewinlight Tech's design for Human Centric Lighting allows for the simulation of different outdoor situations from overcast to sunset or sunrise to a bright, sunny day**

▼ **CoeLux's Sun&Moon attracted a lot of attention. Shown here in sun mode, the moon setting was even more amazing - but hard to capture on film**

▲ **Lensvector demonstrated how to alter light distribution in a range between about 5° to 50° using a 2mm thin LCD lens, by altering the electrical field**

▼ **The sophisticated IQ Structures optics manufacturing method allows for the production of slimmer luminaires with well-defined, efficient light distribution**

Research and Development Is Ongoing and the Innovative Power Is Still Alive

I don't think that I'm the only editor of a technology focused magazine who has noticed that big news in respect to technologies on a component level have become scarce. This is because the technologies have matured and are no longer the driving force. Applications are the new innovation drivers with a few exceptions in the cases where companies focused on other technologies realized that their knowledge might be interesting for LED and/or OLED lighting. I'm not saying that there isn't any innovation anymore, but rather that the innovations are subtler or have switched to other technology fields. Besides the omnipresent topics of IoT and controls, the most visible innovations concern optics and the application of optics. Here, I should also mention electronics as well as laser lights, daylight using solutions and LiFi as discernable innovations.

Although LiFi is an ongoing topic, up until now the technology has only been used in a small number of projects. Although, I feel that this might change. Signify's (formerly Philips) presentation of broadband LiFi to a selected audience at Light + Building may trigger the broader adoption of this technology but it remains to be seen how fast it will make its way into the mass market.

Noteworthy optics are, for instance, zoom optics for spotlights with reasonable efficiency. While zoom lenses are basically nothing new, in comparison to their predecessors, this generation has two convincing attributes: They are quite efficient over the whole zoom range, and they are by far, not as bulky as they were before - allowing for slim, modern designs. While one solution is based on conventional technologies changing the angle by changing the distance between the LED and the lens by a few millimeters, the second solution is based on LCD technology and uses the principle that refraction index in an LCD changes with the applied electrical field. While this is certainly the most advanced technology, the liquid lens technology that was introduced a few years ago must also be mentioned. Unfortunately, the latter two technologies still have one significant disadvantage compared to conventional zoom lenses: They are currently much too costly for many applications and will very likely only be applied in the high-end segment or if dynamic zooms are required.

The new, approximately 2 mm thin optical devices, based on principles of diffraction applied in a novel way to achieve improved performance of white light illumination systems, were absolutely striking. This unique solution is based on full control over the modulation of material and geometric properties of the optical elements at a nano-level. A combination of complex transmission diffractive elements, with specially designed systems of micro-reflectors

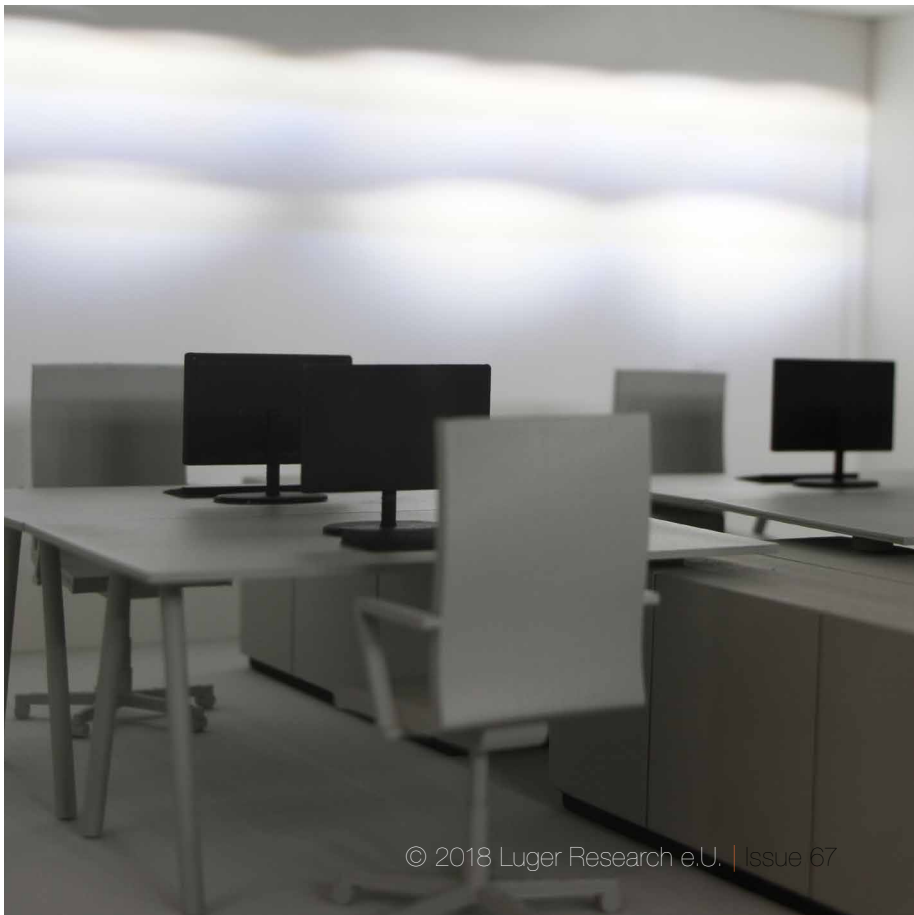
is a promising flexible unit for the construction of a new generation of luminaires. The knowledge for manufacturing these innovative optics comes with a long history and experience in producing recording anti-counterfeiting features and micro- and nanostructured materials for fuel cells.

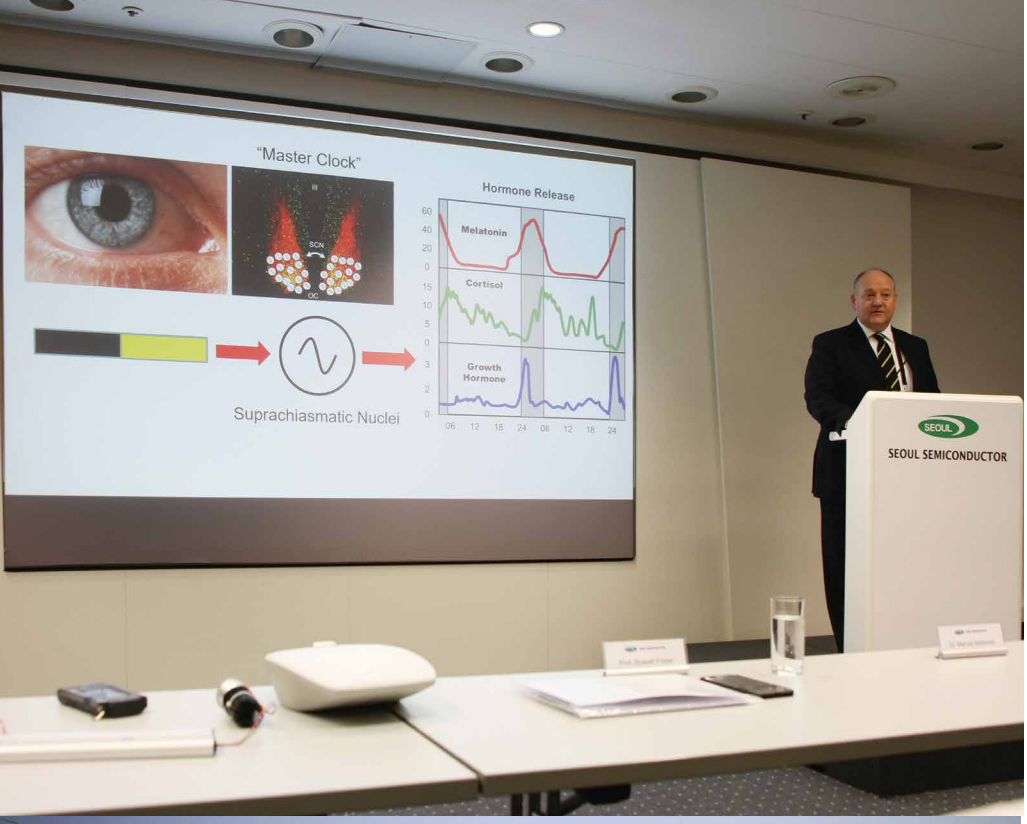
It has already been predicted that laser lighting will be the next lighting revolution but the high costs have limited the application to headlights in a few luxury cars. Two approaches that were demonstrated at Light + Building were aimed to change that. First, a cost reduction by about a factor of 5 within the last two years and then an expected significant further cost reduction speaks for a bright future in appropriate applications. While the full advantage seems to lie in very compact modules for narrow angle spotlights like searchlights, the presented solutions for other lighting applications are also very promising. High CRI can be achieved and unmatched contrast with razor sharp shadows can be attained that are not possible with any other artificial light source. LED professional will be carefully watching future developments of this technology and keeping you up-to-date.

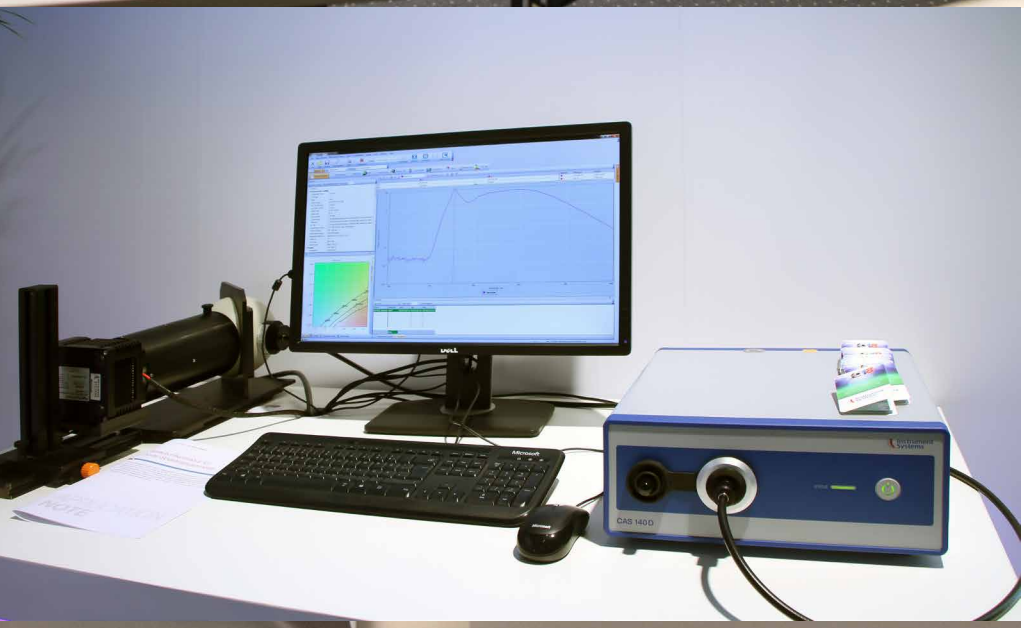
There were also interesting solutions that go beyond LEDs, OLEDs and lasers. While the use of daylight is definitely no new idea, it could be brought to a new level with improved materials. Technical progress might open new doors and the affirmation towards human centric lighting may support the adoption of this technology. With increased reflectivity of materials from the commonly 90%-95% up to 98%, new daylight systems might make sense. Some might ask what difference 3% would make, but in this application every percentage point counts. The idea of transporting sunlight from a roof or façade to the center of a building is as old as architecture itself. There are old buildings that used the method but with an incredible amount of space being used and high losses. Today, such solutions are ineffective and much too costly. With increased reflectivity of reflectors, an appropriate solution seems to be possible, and each percentage point - even a tenth of a percentage point - counts - as a simple calculation proves. A reflectivity comparison of a low-cost material (90%) with a high quality standard material (95%), a world leading material (98%) and a currently still fictive 99% reflectivity material used in a system which requires 25 reflections shows the following result: The light levels at the outlet of the system are 7%, 28%, 60% and 78%, respectively. The more reflections that are required, the more the gap opens. If the idea to install such solutions in a standard dimension in parallel to climatization channels can succeed, strongly depends on the material properties and perfect planning of the light channel. In any case, this approach might, in combination with intelligent controls of LED lights, further reduce energy consumption of buildings and offer another type of human centric lighting approach.

▲ **Parhelion proved that laser based modules can easily replace MR16 LEDs or halogen lamps with lower energy consumption and equal or better light quality**

▼ **In a research project with BASF, Bartenbach is working on the development of a new daylight control system for windowless rooms. While in their headquarters a life-size setup allows measurement and testing, at the show a model demonstrated the concept**







Trends and Topics with a Huge Potential to Influence the Market

Trends are not necessarily always positive, nor do they always provide extraordinary value. They can be artificially generated with clever marketing and they can disappear just as fast as they appeared. The problem for companies is that it can mean disaster if they don't follow a trend and it can also mean disaster if they do follow it. The one thing that all trends (good or bad) have in common is that the drive business and they line the pockets of the winners.

At Light + Building we saw several trends being pushed. Some were old and continuing and some were new. A few may peter out and die while some may be sustainable. Even though there still doesn't seem to be a common understanding of what human centric lighting really means, this, and IoT, are two of the long running trends. Providing a dedicated CCT and customized spectra for different applications is also a continuing and expanding trend. Tunable light and its more affordable sibling, dim-to-warm, were also shown a lot. Product versatility and flexibility are other noteworthy attributes. Automatizing to speed up production and lower costs, featuring modularity and standardization are other current trends. But the one topic that seemed to be most important for many companies and some business branches was: Blue light risks and blue light hazard.

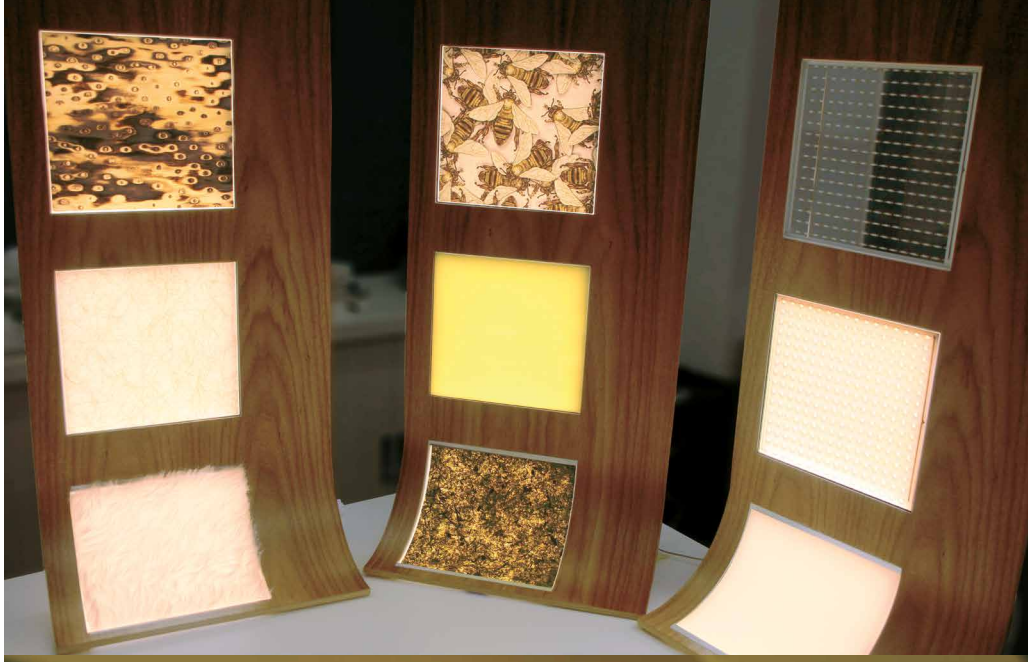
The term blue light hazard might be overly stressed and often used in an ambiguous manner, but it is important, and shouldn't be taken lightly. The safety standards gained center stage during the last few years and manufacturers have been urged to classify their products accordingly. Even though this means extra effort on their part, it can also be an advantage because a better rating may be a valuable marketing argument, a factor that was demonstrated at the show.
Another trend - not directly related to lighting - should also be mentioned: Companies have started to invite scientists and specialists to hold lectures on topics that they can provide solutions for and they invite their clients and journalists to attend. It's not surprising that in

◀ Many companies invited researchers to present their findings. Dr. Russel (top) was invited by Seoul Semiconductor and Prof. Sangchul Yoon (bottom) by Luflex (former LG Display). Manufacturers of measurement equipment like Instrument Systems (center) introduced products for better and simpler IEC 62471 and IEC 62778 conformity testing

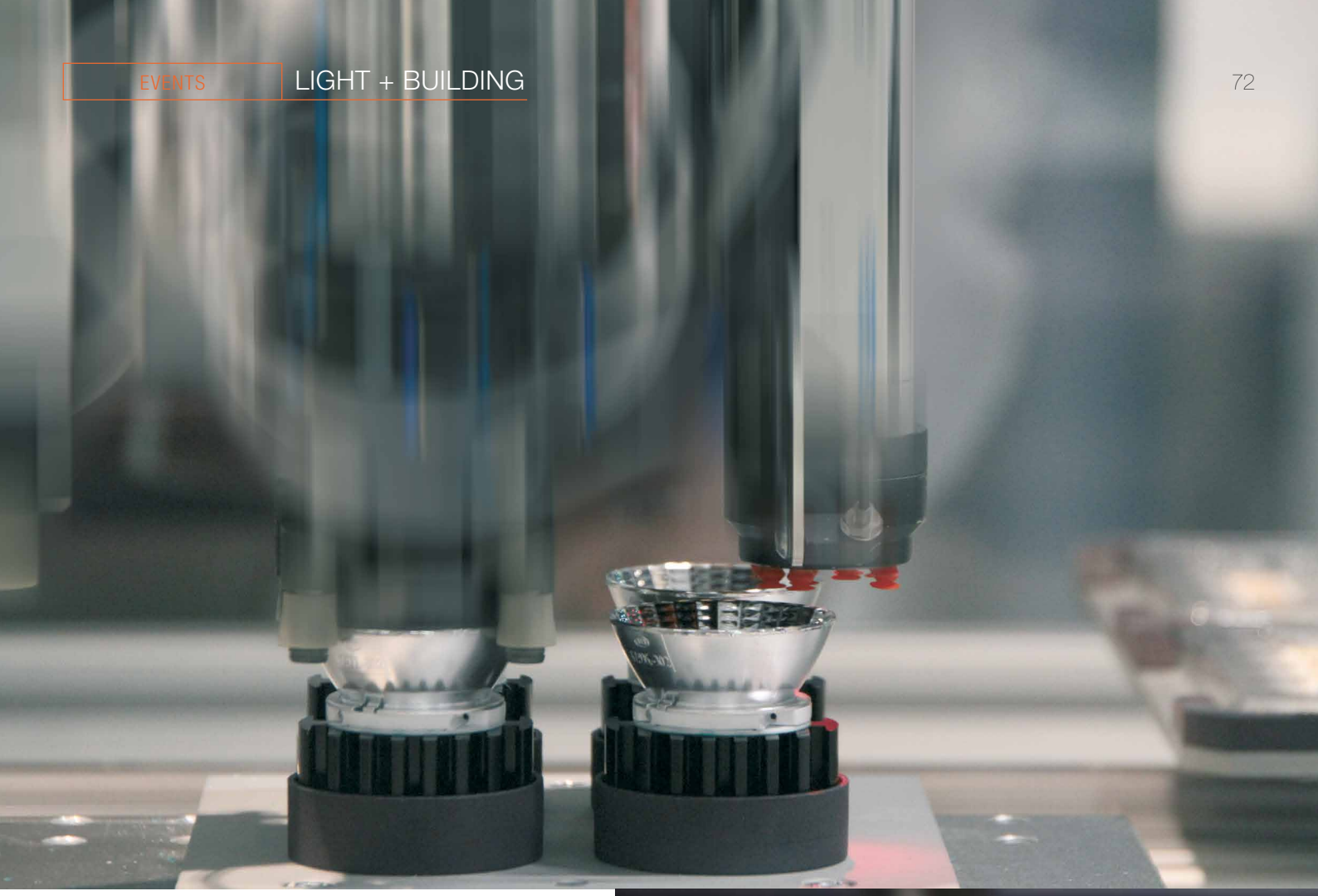
many cases blue light issues were the topic of discussion and this fact underlines the relevance and potential of the topic. Without going into detail about the substance of the lectures it should be recognized that clients are more sensitive now to the subject and IEC 62471 and IEC 62778 conformity has become more important than ever before. It was therefore not a surprise that much of the new measurement equipment was also focused on this topic. The range of products involved both hardware and software. Some hardware, like integrating spheres or spectrometers, may need to be adapted because the regulations not only concerns blue light, but also UV and IR and the resulting health risks are addressed in the regulation. In most cases new software was developed that simplifies the measurement task.

The trend of striving for flexible area lights is ongoing. New developments and improvements in OLEDs were presented and even if only gradually, companies that had abandoned their OLED development projects years ago are starting to revive their applications. On the other side, LED based, flexible modules that are much thinner than ever before and which have been significantly improved were on display. While the OLED manufacturers argued that their products only had minor or even no blue light hazard, the manufacturers of LED based systems argued that they had better light shaping options and larger formats.

The continuing human centric lighting trend with its requirement for increased controllability also supports the trend towards IoT. The philosophies of the different companies in this segment are conflicting. Some want to become the provider of data and data analysis that can be obtained by the IoT connected lighting equipment while the others want to be enablers, providing the basic hardware to anybody who wants to connect their sensors to the IoT environment. And still others want to equip their nodes with the required sensors to provide raw data to any other intelligent node within the system. It remains to be seen which concept and philosophy will prove to be the best approach. One general trend that may make the end-user happy, because it is more



▶ Like the new OLEDworks module (center), flexible OLEDs are still popular, but the are becoming challenged by a new generation of thinner, flexible LED based products, e.g. by the products from DesignLED (top). Already, the trend to smart lighting is slowly followed by smart controls concepts beyond mobile devices, even without batteries (bottom)

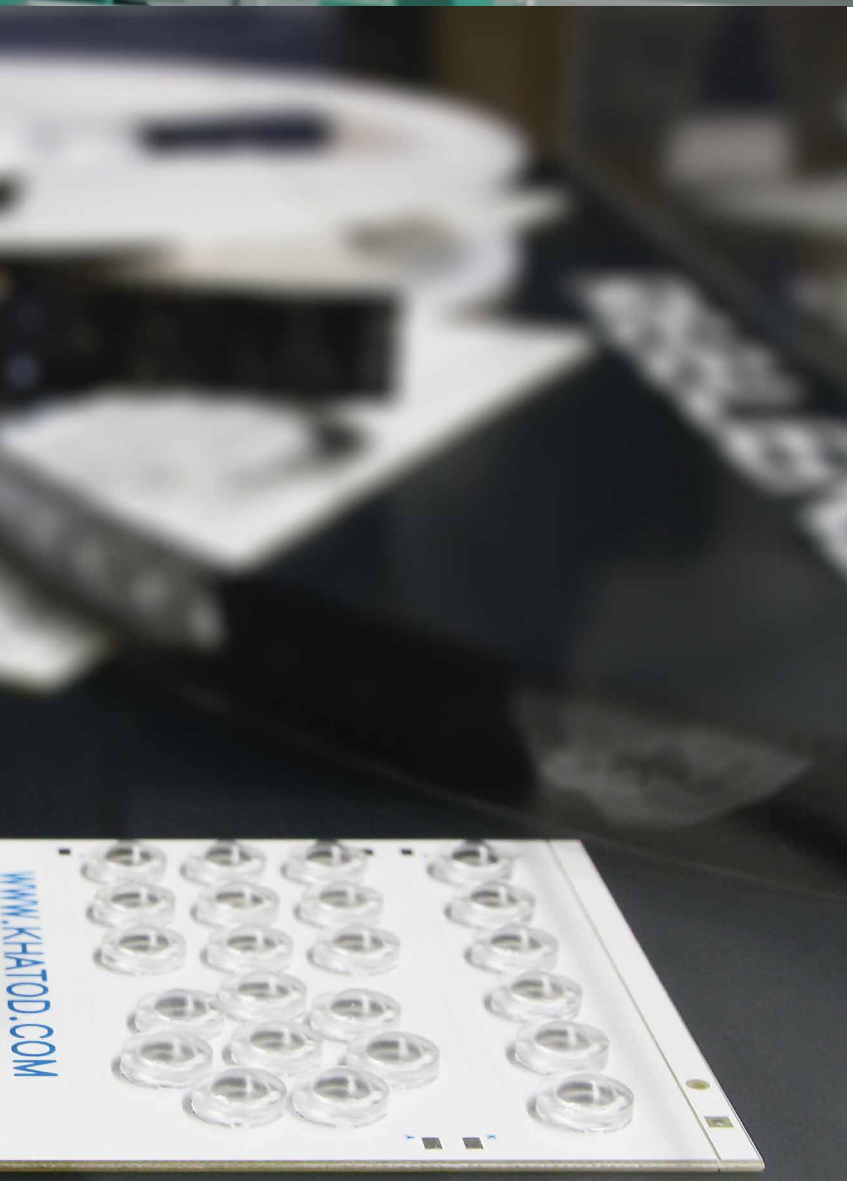


▲ **BJB's automation machine for linear lights assembles a luminaire in just 68 seconds with unparalleled accuracy. Even faster, assembly of spotlights or downlights (image) with the most advanced lighting technologies just takes nine seconds**

▶ **Component manufacturers also recognized the need for more automation. Kathod, for example, introduced the world's first reel lenses**

substantial for the average person: It took a while for companies to realize that instead of an app, a simpler control solution is required that can perform 90% of the tasks, giving the mobile device and its app the job of configuring the system and scenes and solving complex settings. In the meantime programmable, wireless switches and controls are available for virtually any system. In many cases there is no need for a power source and sometimes they are based on interesting, new, innovative and unconventional operation concepts. Many of these wireless controls devices are available for the most relevant wireless solutions. This is especially relevant as competition between the different systems is ongoing.

A longer lasting trend with new technologies and concepts that have been pushed forward is the trend towards automation of production. Increasingly, powerful robots and sophisticated software combined with cameras and other sensors allow for a fully automated production line for various lamp and luminaire types. The latest trend in this



▲ **EID Tech promoted their fully automated micro-plant production concept - manufacturing local, closer to the places where the product should be sold**

respect are the “micro factories” that allow for a local creation of value on a 10x10 meter facility. This could make high-wage countries more competitive and more independent from East Asia. These trends play into the hands of product modularization and standardization, which touches on another, upcoming trend.

For a long time, modularization was banished from the lighting industry because it seemed too costly and inefficient. Simplified, a luminaire consisted of a few components/ modules: Housing, a light source, a driver with controls (if any), and an optical system. However, the increasing system complexity, with the digitalization of light and the request for customization and flexibility demanded that the industry rethink their point of view. First we had some clever examples of modular luminaires, some of which were ready to be sold to the public, and then we had others that were far-reaching and just behind the curtain. You don’t need a crystal ball to know that the number of these types of concepts will increase by the next Light + Building event.

Final Thoughts

What are the lessons to be drawn from Light + Building 2018? What is new or what are the consequences? Was it worth spending a week at Light + Building and should I go again in 2020? For me the answer is simple: Even though it was sometimes hard to find eye-catching, noteworthy innovations, there were many interesting new products that could be experienced firsthand. There are only a few places that one can go to exchange views with so many influential people or company representatives in this business like Nichia's COO, Hiroyoshi Ogawa, and Light + Building is one of them. It is probably the most important place for a business to go to adapt its future roadmap or garner ideas for future projects or developments. It is a great place to learn what drives the business, which trends are fading and which are on the rise. It may be exhausting to walk miles and miles at this huge fair and talk for a full week at meetings and appointments, running from booth to booth, but it is totally worth every second. Light + Building is the must-visit event in 2020. ■

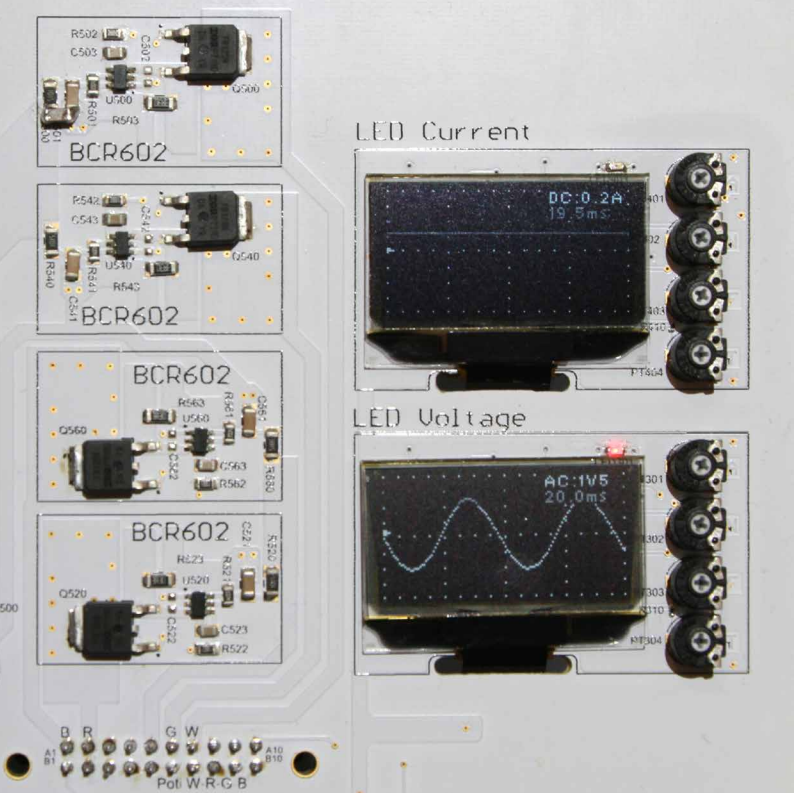
◀ **In cooperation with Bartenbach, XAL designed a clever, new modular concept. The two Austrian companies developed Unico, a powerful downlight with up to nine individually controllable 38x38 mm optical modules. Each can have its own very different photometrics, brightness and, if a color tunable version is chosen, CCT setting**

▼ **Special colors for various applications, from automotive to effect lighting and to horticulture were presented by Lumileds**

▲ The combination of design and intelligent controls, as presented by volatiles, drew a lot of attention

▶ Light quality, and mainly providing a spectrum closer to that of sunlight, like Luminus Devices (right) and Nichia (below). While the applied technology might be completely different, filling the missing spectral range of conventional High CRI LEDs, like cyan, improves whites and color fidelity

▼ Miniaturization and simplification of driver circuits must not compromize the output signal quality. For instance, Infineon demonstrated that current ripple suppression for non-flickering light can still be provided through innovative driver concepts



A Manufacturing Revolution for the LED Lighting Industry

Western business investments in local manufacturing facilities have been declining since the 1980s due to partnering with contract manufacturers in Asia. But with increasing and hidden costs in Asia, companies are now seeking to bring manufacturing back home. A recent innovation, microfactories, could be the solution. Paavo Käkelä, Chairman and VP at EID Tech in Finland, presents the microfactory called Ant PlantTM. He explains this new, flexible manufacturing concept, shows how it works and how it is set up, and analyzes the benefits of local, automated production of LED lighting products as an alternative to contract manufacturing in Asia.

Companies have been in search for better profits and lower labor costs through contract manufacturing in Asia. During the last decade, however, Chinese labor cost has risen with an increase of 64% since 2011 [1]. Due to this trend, some companies are now taking their business elsewhere with lower wages, or considering automation, to secure competitive production cost. When also considering all hidden costs of overseas contract manufacturing, including the import taxes, customs fees and freight expenses, many companies have realized that it is more reasonable to bring the manufacturing back home to automated factories, instead of searching for another low-cost labor country.

New Unpredictable Risks Emerging in Global Markets

US Manufacturers are voicing concerns about the downside of the import tariffs the Trump administration is slapping on $50 billion worth of Chinese products. At the same time, there are talks about potential changes in NAFTA. And who knows, maybe even EU relations will become volatile if the worst-case trade-war scenarios play out.

Many of the manufacturing business leaders have no way of predicting how all this will impact their business in the long term. Political risks, corruption, changes to the tariffs, supply chain costs, changing exchange rates, a need for big committed capital for the advance payments for outsourcing partners, long lead times, quality risks, etc. Nobody can accurately forecast the global market behavior and its impact on one single business.

It's like driving in fog down a busy highway with no headlights. At the same time, manufacturing CEOs need to continue developing their strategy and make sound investment decisions.

Automation is Here to Help

One way to reduce the risk of unpredictable global markets, is to bring manufacturing back home. With today's automated production line solutions, it is becoming a real option to run a successful and profitable manufacturing business without outsourcing it to Asia.

EID Tech, a manufacturing automation company, has spent the last four years in developing the entirely new concept called Ant Plant™ Microfactory. It is an example of the new trend, where the local manufacturing operations are made profitable again, thanks to a new reasonably priced automation and robotic production solutions.

The microfactory concept has the potential to change the way the LED lighting industry is manufacturing its products. The field-data from the first LED Lighting microfactory owners demonstrate that it can reduce the local manufacturing cost to a competitive level vs. Asian imports. It also makes manufacturing more flexible, with faster lead times and rapid small batch product runs. By using fully automated manufacturing with automated burn-in and testing, the microfactory also substantially increases the quality of the LED

lighting products, as all the products are 100% tested and human errors are eliminated.

Factory as a Service Brings Additional Benefits

Companies investing in production line automaton are often worried about their long term operations. What happens, for example, if they suddenly have to modify or change the product design?

By using a well modularized system, updates are easy to make when product modifications require changes in the assembly setup. Fully automated microfactory operations are controlled from the cloud and field engineers can be supported remotely to make any changes at customer premises with minimum downtime to the operation.

When new updated parts or components are needed, and if they are different size or form factor, vision-guided general feeders enable quick and easy changes to new parts.

Most of the updates can be done remotely from the microfactory service center with the help of customer's engineers. To secure optimized and uninterrupted operation, the product line data is continuously collected and analyzed in the cloud. If any deviations appear in the process, corrective actions are prepared remotely and the required service can be often done even without stopping the production.

Brief Description of a Modularized Microfactory

A fully automated microfactory line, for example for LED Tube production, has six main modules (Figure 1).

The six main modules for an LED Tube production:

- Loading (1)
- Assembly1 (2)
- Assembly2 (3)
- Aging (4)
- Testing & laser marking (5)
- Individual / serial packaging (6)

Customers can choose a combination of these modules that will best fit their manufacturing needs.
For example, if the setup only calls for sample-based offline testing, and there is already an offline packing line in the factory, the assembly and the laser marking functions may be all that is needed. In that case, only the first three microfactory modules and the laser marking and unloading modules are required (Figure 2). Additional modules can be added later, if aging, testing and packaging need to be added. The set-up time for installing new modules to the line is on average only two hours until production is running again. The modular design also makes it possible to make the investment in the microfactory in smaller installments.

Installation of the complete microfactory line at customer premises can be done in only eight hours because the interface between the modules is just connecting the power lines and communication network. During the installation the robot picking and

Figure 1:
Microfactory with the complete line using all 6 modules

Figure 2:
Simpler example of the microfactory, just using the loading, assembly and laser marking+ unloading modules

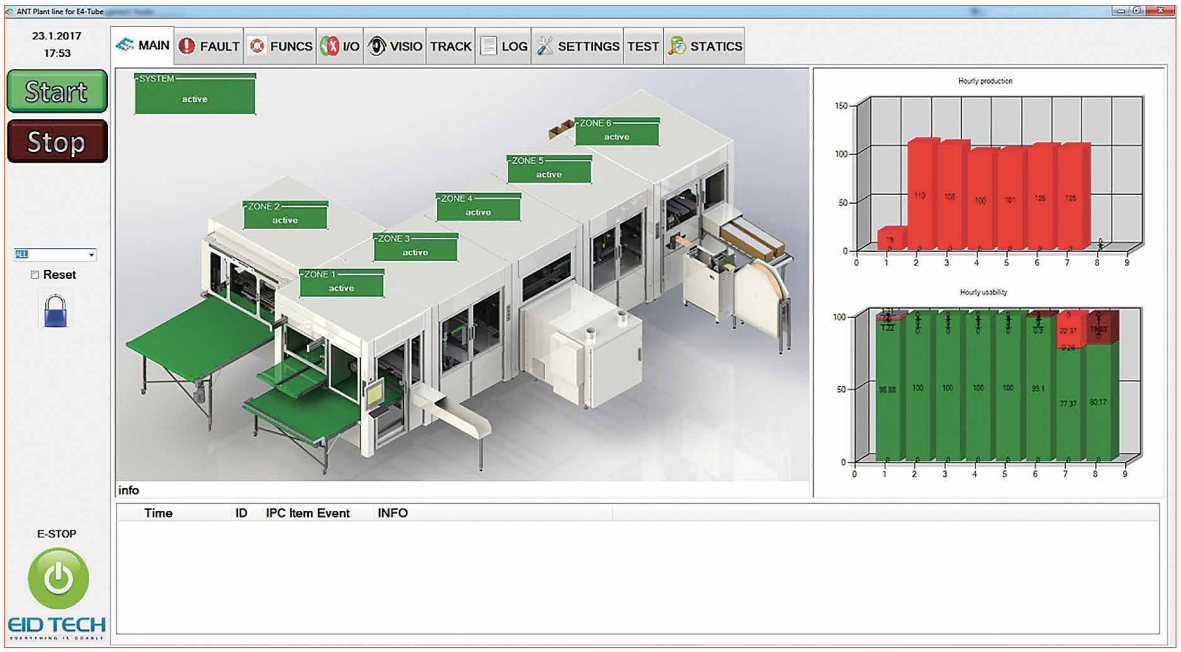


Figure 1:
A Graphical User Interface simplifies monitoring, controlling and operating of the plant

placing points will be prepared and tested, and then the production can start running.

With the best microfactory setup, not only the production line is modularized. All the applications inside the cell are also their own individual modules. The line also has its own communication network with one secured external connection point for remote control and data collection. All the applications have their own I/O modules and are connected with Fieldbus, so they are easy to change when required due to product design changes. Robots are placed on the cell ceiling, which allows maximum space for applications working area inside the cell. The application and control software is also modularized to each function and application.

The microfactory line is controlled from Graphical User Interface (GUI) (Figure 3). The GUI has different user access levels, which are defined together with the customer. The operator can run the line and monitor the cell states, yield and output. Any changes to settings, when product type is changed, can be done by advanced user. Production engineers can also easily change settings and make service and maintenance actions when needed.

Quality Improvements that Only Robots Can Guarantee

Quality of a product has three critical components: Product design, used materials and manufacturing process. To make sure that the automated production can run efficiently in most of the cases DFA (Design For Automation) work is needed.

During the DFA planning the critical points in the product architecture are defined to ensure the best possible manufacturability and production output, with minimum compromises in product design. DFA work connects the manufacturing process and product together.

When the product design and manufacturing process are properly prepared and designed, when the needed test points are defined, possible human errors are minimized, and only the validated material suppliers are used, it is possible to achieve an extremely high level of product quality. And that quality is made possible by preparing the process and product design before manufacturing, with full automated production and tests, and not by quality monitoring later on by the operators during the process.

Logistics and Supply Chain - Automated

Offering a centralized regional hub that will feed product parts and materials to remote microfactories, will help to secure larger purchasing volumes and cost reduction for product parts. That benefit is then shared with all the microfactory users that are using the service. The regional hub concept makes the short lead times to parts possible and reduces manufacturer's inventory cost. Compare that to an outsourced Asian operation, that may require large quantity orders, with pre-payment and long lead times.

Microfactory Has Its First Focus on the LED Lighting Industry

While the same microfactory concept can be applied to any high volume production of small size merchandize that requires assembly, it is planned first to serve the LED lighting markets. Manufacturing LED tubes, fixtures and panels, seems to be ideally fitted for gaining the benefits of the microfactory operation, and the feedback from the first customers has been encouraging.

As LED lighting products continue becoming more standardized and price competition intensifies,

the pressure to lower manufacturing costs continue to increase. Microfactory technology offers the local based LED lighting companies a new flexibility, better customer response-times, the quality and cost that will help them to stay competitive for the long- term future. With fully automated microfactory solution, today, even smaller western LED lighting companies can run profitable and flexible manufacturing at home, closer to their own market and customers.

Local Wellbeing

Even if microfactory operations are 100% automated, they always provide people with work – for instance, to support the manufacturing and handle human–robot collaboration. While a fully automated and intelligent microfactory doesn't need people to assemble or package the products, someone still has to do specialist work or work which is needed for production support functions. Technological advances in tools for engineering already make it necessary to have a college degree in many types of manufacturing jobs. This development brings new possibilities for millions of workers with skills in advanced machinery in the near future.

Conclusions

LED lighting manufacturers can gain several benefits by using the micro-factory concept. Micro-factories offer both business and national economic benefits due to several reasons.

Benefits of micro-factories:

- Flexible manufacturing:
  Full control over local production line enables rapid response to customer demand, and optimized end-product inventory with lower working capital need
- Competitive cost:
  With a fully-automated micro-factory, operated by one person, the product cost is competitive with Asian imports
- Superior quality:
  With micro-factory's automated product burn-in and testing capabilities, the human error factor is minimized. Micro-factory users have reported 3x lower field failure rate and 3x longer product life vs. Asian contract manufacturing
- Local and green:
  Local manufacturing supports vibrant local partner ecosystem development around the micro-factory operations and enables building a local brand, for example "Made-in-USA"

Using microfactories like Ant Plant™ may not be the only required action to keep and improve competitiveness of our western industry, but it can be a significant contribution to it. Furthermore, this concept allows smaller companies and start-ups to set up their own production with relatively little cost, and by that may enable new creativity and new ideas. ■

References:

[1] Euromonitor: https://www.cnbc.com/2017/02/27/chinese-wages-rise-made-in-china-isnt-so-cheap-anymore.html

Integrating Lighting in the Internet of Things

Following the rapid penetration of LEDs, lighting now becomes integrated into the Internet of Things. Over the past three years a consortium of leading European companies worked on the OpenAIS project, partly funded by the EU within the Horizon 2020 program. Now showing the results, the consortium is working on a full size demonstrator. Ben Pronk, System Architect at Philips Lighting Research, and Frank van Tuijl, Project Manager at Philips Lighting show how OpenAIS creates an open ecosystem to enable a wider community to deliver the smartness of light and they explain how it is possible to adapt the system to cater to the diversity of people and demands.

The Internet of Things (IoT) extends the Internet Protocol (IP) communication beyond its established markets in computers and mobile phones to billions of resource-constrained endpoints ("things"). In the lighting domain these "things" will comprise physical devices as intelligent luminaires and sensors as well as infrastructural elements as gateways. IoT opens these "things" to regular Internet services and fast networks allowing (remote) control and data collection from these devices. The introduction of IoT as the backbone for connected lighting systems enables seamless communication, contextual services and data sharing between devices ("things") and is bringing radical changes to the industries by converging multitudes of vertical markets.

The lighting industry has been going through a transformation to Solid State Lighting for some years. The introduction of LED-based systems enables increased control capabilities (e.g., switching and dimming) and reduced operational costs and energy consumption. Incorporating IoT and connectivity in lighting systems now creates yet another revolution and opens a plethora of new opportunities and value propositions. IoT-technology is maturing quickly, which makes it economically feasible to connect each luminaire to the Internet. Hence, it is an excellent opportunity to establish the Internet of Lights, i.e., an advanced lighting system with IoT at its core.

Benefits of the Internet of Lights

Converting to IoT based systems will introduce mainstream digital and communication technologies in the lighting domain. As in other digitized domains, this transformation is expected to come with advantages in (product) costs, development efficiency and availability of solutions and vendors. This will provide opportunities for the lighting industry to decrease both CapEx and OpEx costs by leveraging on commodity hardware, network and other software stacks.

A transition towards IoT is not merely a cost reduction effort, it brings several additional benefits: It enables using the network infrastructure in the building for controlling and powering the lighting systems rather than using a dedicated lighting network. Having IP connectivity to all light points also enables flexibility and interoperability with other systems such as Building Management Systems (BMS), smart grids and cloud services. It provides flexibility to seamlessly combine multiple connectivity technologies, for example, in both wired and wireless solutions and eliminates the need for expensive gateways for

doing application layer translations. Finally, it enables a large variety of new services. For example, sharing occupancy data collected by presence detectors used for lighting controls with BMS for air conditioning or with cloud for data analytics opens up new possibilities and services.

Overall, it can increase the comfort and well-being of the people in a building, lead to more efficient use of the building and even help to achieve certifications such as BREEAM or LEED by increasing the building performance rating and reducing the carbon footprint.

User Scenarios of the 2020's

The project researched the requirements for the office environments of 2020 and beyond. The information obtained in structured interviews with industry experts across the value chain, were analyzed, distilled and grouped into three main "super" scenarios.

The three "super" scenarios:

- *Easy Life* "…a solution that is easy to specify, design, install, commission, operate and maintain without making compromises on the ease of use…"
- *Increase Building Value* "…in the changing world of office space, provision owners will need to make their properties more attractive for businesses to lease or rent……..."trophy workplaces" making visits to the office a luxury and a rewarding experience…"
- *Building Wide Ecosystem* "….in the future, systems in a building will be expected to share sensors and seamlessly interoperate to the benefit of the building and their stakeholders"

These scenarios form the cornerstone motivations behind the design work and value proposition.

The Architectural Challenges

Existing IoT architectures do not fully meet the requirements from the lighting industry and other stakeholders. Every IoT framework investigated was missing features for application in lighting control systems.

The most important features:

- Low-latency group communication: Most IoT frameworks are very much focussed on connecting field devices to the cloud. For many IoT applications like vending machines this is a suitable set-up. However, lighting has the unique property of intensive real-time local coordination and communication between many nodes. Therefore, efficient and secured n:m communication between the nodes in a system is a prerequisite
- Operation not dependent of central cloud server: lighting functions must be available always, therefore local communication and control has to be available also when a central server or a cloud connection is absent, be it temporarily or permanently. This again requires an independent, network-based communication amongst nodes
- For the application layer a dedicated Object Model was developed, as evaluation showed that public models like IPSO were much too limited for advanced high quality lighting control and simple integration into BMS's. Existing application models like ZigBee or KNX were not taken into account by the consortium as they did not support IP natively (yet)

The OpenAIS Solution

We will now detail the architectural solution as proposed by the consortium. We will start with a discussion on the selection of a suitable IoT-framework to build the Internet of Lights on. This paragraph will be followed by a description of the network stack build-up. After that, we will focus on the two main topics identified above, the OpenAIS Group Communication and Object Model. Finally, we will explain how commercially differentiating features can be created.

THE OpenAIS CONSORTIUM & THE OpenAIS PROJECT

OpenAIS is a pre-competitive R&D project that runs from 2015 to mid-2018 and is coordinated by Philips Lighting. The project is supported and partially funded by the Horizon 2020 program of the European Union.

The OpenAIS consortium includes partners from all segments of the Lighting vertical: facility management, installation, lighting manufacturing, technology suppliers and academic partners. Application focus and carrier case is Professional Indoor Office (Europe).

The OpenAIS consortium

The OpenAIS partners are Philips Lighting B.V., Zumtobel Lighting GmbH, Tridonic GmbH & Co KG, Johnson Controls Systems and Service Italy SRL, Dynniq Belgium N.V., NXP, ARM Ltd, Technische Universität Eindhoven and TNO-ESI.

The OpenAIS project that started from the presumptions that connected lighting solutions will constitute a significant part of the (future) Internet of Things (IoT) infrastructure.

The project vision included that:

- Lighting will offer the infrastructure to integrate devices and deliver additional functionality beyond lighting
- IoT will use existing ecosystems and standards to create commercially differentiated solutions and finally
- In a landscape of mainly proprietary solutions, as of today, an IoT-based Lighting system for professional environments in the near future demands openness and interoperability, as many professional customers want to avoid vendor lock-in

Consequently, the goals of the project were defined as:

- Create an open architecture (standard) for lighting control systems, allowing multi-vendor systems, based on (emerging) IoT-standards and ecosystems, and
- Validate this approach by a large-scale pilot in an actual office environment, demonstrating the promises of interoperability, third party mix and match.

IoT-framework

During the state-of-the-art research phase in 2015, various existing and upcoming IoT standards offering lightweight IP-based management and control were investigated.
One of these standards is Lightweight M2M defined by the Open Mobile Alliance (OMA), abbreviated "LWM2M". The public Version 1.0 of the LWM2M standard has been chosen as the basis for the OpenAIS architecture.

LWM2M is a framework for device management and service enablement that defines the LWM2M protocol between a LWM2M Client (i.e. a resource-constrained M2M field device) and a LWM2M Server (which is the configuring entity and typically not resource-constrained). The protocol was developed for use over cellular M2M connections with potentially very low bandwidth and a non-negligible communication cost per kilobyte, but the standard is also applicable when used over any other IP-based network technology.

The protocol is optimized for resource constrained field devices, that is, devices with limited RAM, limited flash memory, low-bandwidth connectivity and/or limited CPU resources. LWM2M uses the Constrained Application Protocol CoAP as a transport mechanism. It also supports data payloads in multiple data format standards: industry-standard JSON, compact TLV and plain text/numbers.

A key advantage of LWM2M compared to other IoT initiatives at the moment of selection was that it had a released specification and implementations already on the market.

Network stack

In the choices made for the network stack the project objectives are clearly visible.

Project objectives:

- IPv6-based communication with UDP as the transport layer. IPv6 multicast and 6LoWPAN compression will be supported
- Support any (future) physical medium that is IPv6 capable and is able to deliver a defined minimum transport capacity. Typical larger systems will have a LAN backbone with IP routers or Border Routers to integrate different local IoT networks (using e.g. BT, BLE, 6LoWPAN, Wi-Fi, PLC, VLC, PoE, etc.)
- All communication uses the well-standardized CoAP protocol, defined by the IETF especially for use in the domain of constrained embedded devices. CoAP implements the REST communication paradigm that powers today's web services
- Security and privacy of data communication are achieved by using a combination of transport layer (DTLS) and application layer (OSCORE) based encryption
- On top of these layers, LWM2M and other services run. Finally an application layer has been specified, which is elaborated in the Object Model paragraph

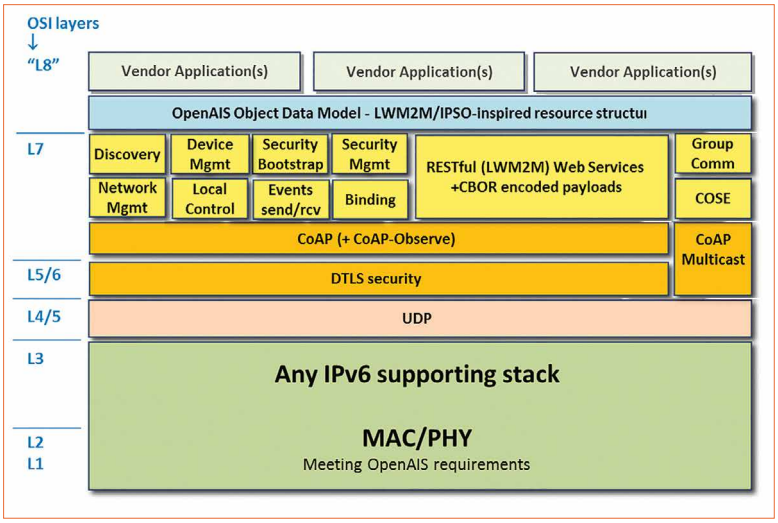


Figure 1:
Network stack

Open (Secure) Group Communication (OGC)

The consortium developed a group communication mechanism that operates in parallel to LWM2M device control to provide low latency and controlled bandwidth communication links, needed in lighting controls for professional buildings. Secure OpenAIS Group Communication enables the operative lighting use cases, supports local (node to node) control and event handling and ensures interoperability across vendors. Setup of groups is secured through commissioning.

Important characteristics and design choices for the mechanism are:

- CoAP Multicast [RFC7252] [RFC7390] protocol over IPv6 multicast.
- Support for multiple Application Groups re-using an IPv6 Multicast Group, to obtain efficiency in the usage of IPv6 multicast addresses.
- Multicast security model, offering authentication and authorization for multicast group commands or requests that is fast enough for lighting control.
- Multiple instances of a particular object type at a single node are reachable with a single group request, even if the object instances have different instance identifiers across different devices. Multiple object instances at a single node may be associated with different groups to support lighting application best.
- Multiple IPv6 Multicast Groups (destinations) supported per OpenAIS device, supporting complex device and controls structures.
- Support of multiple IPv6 (multicast and unicast) destination addresses per group to allow for situations where multicast reachability of (some) devices is hampered by router settings or firewalls.

The Group Communication is used in parallel with LWM2M.

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Future systems may, if needed, use other IoT frameworks and still stay interoperable through use of the OpenAIS Group Communication (OGC). OGC can be applied across diverse IoT frameworks, enabling interoperability for lighting controls.

In our view, OGC is a non-differentiating middleware stack that enables differentiated commercial solutions and is a prerequisite for interoperability between vendors on device level.

Object model

This application layer is completely based on a Sensor-Control-Actuator model to which the project added a datacollect object that simplifies the data acquisition in lighting networks. The OpenAIS Object Model is structured as a RESTful architecture. In the implementation CoAP and JSON have been used to implement a versatile RESTful communication. In the object model we identify next to common functionality for presence, buttons, on, off, dim and color control a number of new concepts.

New concepts:

- Data Collect Object: A data object allows the collection of all status/event information as transmitted by actuators, sensors and groups in the system. It offers functionality for (pre)processing data (grouping, trending, compressing, and data reduction), intermediate storage and buffering, e.g. when the connection to the back-end/cloud is limited or interrupted.
- The common API for group communication is represented by a unified logical object (per application), that hands over the data and requests to the (fully vendor specific) physical objects. This structural approach also helps to arbitrate conflicting requests to a single actuator.
- Layered architecture: Contrary to ZigBee, that has the concept of direct links between sensors and actuators, in the OpenAIS architecture control objects sit "in between" sensors and actuators. These contain the logic that determines the actions to be taken on events, and may be physically placed at any place (sensor, actuator, server or cloud "devices").
- Stacking of control objects: The architecture allows the stacking of control objects, i.e. Superior Control Objects can control groups of control objects and base their behaviour on the combined sensors settings of these groups. Simple examples of this behaviour are open plan behaviour or corridor linking. Note that this hierarchical model can be more than one deep. There may be floor and building control objects to represent even higher levels of control, e.g. scheduled control for an entire building. Stacking is organized to provide local control if superior control fails or becomes (temporarily) not available
- Redundancy: The architecture also includes mechanisms to define redundant control behaviour, where secondary or ghost control objects can serve as a fall back in case of communication interruptions or software/node crashes
- Legacy systems are incorporated using (application-layer) gateways that talk "OpenAIS" on the IPv6 interface. The level of legacy integration is up to the designers of the gateways and not limited by OpenAIS
- OpenAIS provides out-of-the-box functionality, which delivers (non-secured) basic operation to ease installation and installation-testing for luminaires, switches, presence detectors and light sensors
- Mobile devices like tablets and phones provide user control of this system with fine-grained access control and authentication. User access may include functions like selection of control algorithms/modes, as well as direct on-demand (lighting) group control. This is achieved without the need to commission the mobile device as a part of the system. Access control (AA/AAA) can be executed on a building server or in the cloud using standard IT solutions
- Cloud services benefit also from the data collector objects that also provides extended authentication and encryption before sending data to the cloud

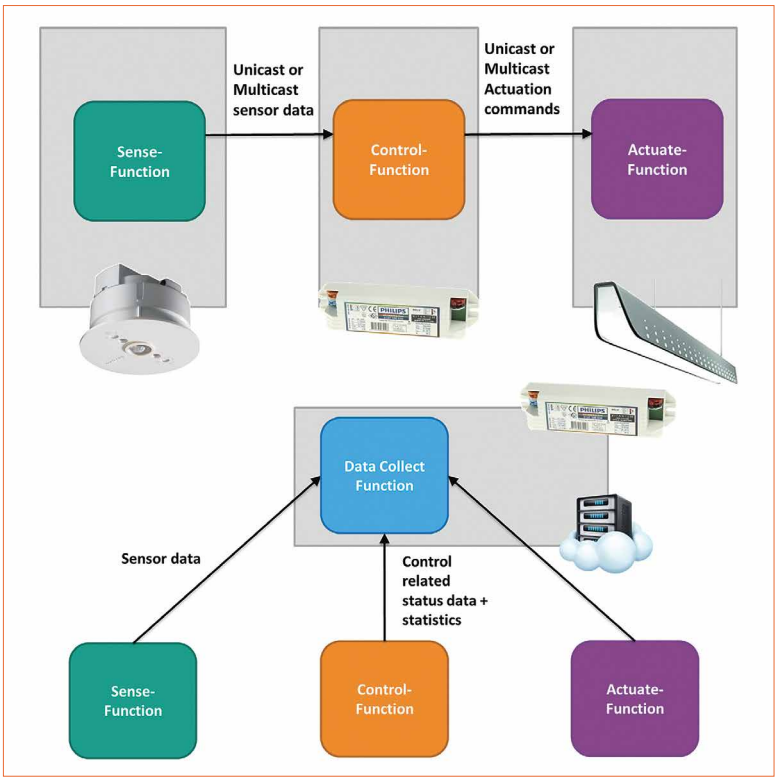


Figure 2:
OpenAIS Object Model examples

In figure 2, some standard examples of instances of the object model are given. The Reference Architecture has been published including the object model [1]

Support for commercially differentiated solutions

The Architecture supports the stacking of control functions, which means that a new control function can be added to a system. This function can extend the already existing functionality by "controlling or overriding the control function", without the need to physically replace it or take the existing one out.

Multiple object instances relating to one physical object can be used with a specific binding for each object instance. This mechanism can be used to extend the system behavior by configuration/ commissioning only. It can be used in a way that the basic behavior of the already commissioned system is maintained and used as fallback.

Additional or derived object (classes) may be added to the device, providing additional features. Such objects may also be created in a way that additional communication (frameworks) and properties are used, to support specific IoT data protocols, or even add in parallel future communication protocols like KNX/IoT, BACnet/IoT.

The basic security mechanisms and keys as implemented in OGC can also be used to protect commercial extensions and options in the field.

Large Scale Pilot

The consortium has chosen to validate and demonstrate the system in a real- life pilot, as this yields superior feedback and pushes the partners to deliver an implementation close to production quality. In this pilot, a lighting system prototype at scale of 400 luminiares - mixed vendor, mixed wired and wireless and mixed mains and UPoE devices - has been deployed successfully.

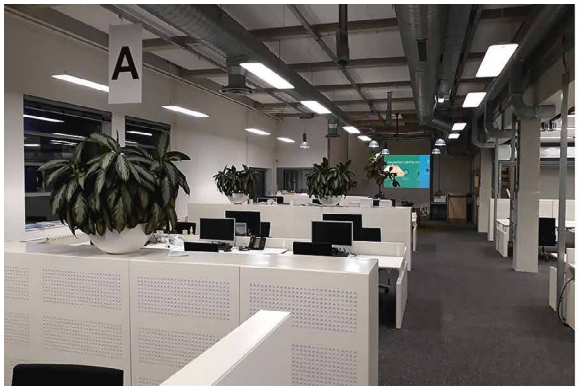
For the Pilot location, the "White Lady" building in Eindhoven has been selected. The building itself is a former Philips factory built in 1930 where light bulbs were made. Renovated by the city of Eindhoven it is now a national monument and in daily use as offices. Architects from all over the world study and visit the building for its remarkable design. It is therefore ideal to demonstrate the new OpenAIS architecture for lighting controls. The 5th floor tenant, GGD-BZO (municipal health service), has embarked on a renovation journey to update to LED using the latest controls architecture for lights.

For the pilot, the consortium did a complete light, control and network design as well as the installation, commissioning and operation of the building.

Philips provided SmartBalance and PowerBalance luminaires, with adapted UPoE LED-drivers. For wireless, a module was implemented using NXP MCU and RF chips to design Thread connected luminaires. These wireless modules were used to control desk lights. A full non-differentiating software control and communication stack was implemented based upon the LWM2M and ARM Mbed embedded software platform and extended with the lighting specific and/or vendor specific additions. All luminiares are equipped with embedded PIR and lightlevel sensors.

Zumtobel contributed luminaires from their Mirel and Glacier series, equipped with Tridonics' Net4more (ethernet and Thread) communication modules, LED-drivers and embedded occupancy and lightlevel sensors. Power is supplied via conventional mains cables or via PoE for stand-alone sensors. The common control and communication stack is used also with ARM's Mbed embedded software platform.

Figure 3:
The White Lady building with the OpenAIS pilot on the 5th floor



Figures 4:
Impressions of the pilot office space in the White Lady building. Luminaires from Philips (left) and Zumtobel (right)

Dynniq provided the IT infrastucture based on Cisco's UPoE switches for the wired backbone and developed a commissioning tool. ARM and NXP provided the Thread border routers as the backbone of the wireless network. ARM provided Mbed as the common software development platform.

Johnson Controls integrated their Metasys BMS system into the system, collecting the data from the lighting system, e.g. energy consumption and occupancy data, and visualizes this data for workflow and process optimizations.
They also implemented direct control of the lighting control strategy, operating with scenes and schedules.

Figure 5: User control app by TU/e

TU/e provided mobile apps for personal control of light settings at the individual workplaces and for scene settings in the meeting rooms.

Advanced lighting control strategies have been deployed including granular sensing and control strategies (local dimming) using local occupancy and light level sensing per luminaire. Personal control is achieved via Office Mobile app.

Figure 6:
OpenAIS light show during the Eindhoven Glow Light Festival

Validation and Demonstration

At the time of writing, the pilot has been successfully launched and the building is in full operational use by the tenant. The validation of the OpenAIS architecture is in progress through an extensive program that includes checking of the user requirements as collected for the 3 main 2020 "super"scenario's described above. Furthermore there is a more specific Pilot specification that describes the details of the White Lady Installation and control, that will be validated together with the pilot design, the system, the Lighting, the network, the controls aspects and the user satisfaction. Naturally some aspects of the solution are not directly part of the pilot specification, but extremely important to assess, for example, the responsiveness and synchronisation reliability etc. Yet as these are essential aspects of the architecture, they will also be validated using the White Lady prototype.

The most visible public result until now is shown in the picture below. During the 2017 Eindhoven Glow Light festival the installation was used to play patterns visible from the façade of the building, showing the flexibility and performance of the control solution.

Conclusion

OpenAIS has designed and implemented a fully functional (and stable) multi-vendor lighting control system based on IoT-standards and frameworks, with the IPv6 protocol to all end nodes, in a hybrid system of mixed wired and wireless networks. By using standard IP communication, translating gateways and proprietary protocols have been completely avoided.

At the same time, the consortium has proposed and validated a middleware solution to address the lighting specific digital era challenges in professional spaces of secure low latency group communication, central server independence and support for commercially differentiated solutions. It also defined and validated an object model for interoperable high quality office lighting and seamless integration into (future) BMS. The system specification and API's are open available, enabling interoperability between the participating lighting vendors, as well as independent 3rd party developers of value added software.

The system offers a flexible lighting control mechanism allowing the fast implementation of many advanced and challenging use cases as will be demanded by the office workers and building owners of the 2020's. OpenAIS has addressed the challenges of extending the Internet Protocol application to resource constrained IoT end nodes for professional lighting. ■

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[1] (http://www.openais.eu/en/results/)

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LED Lighting Requires New Approaches in Optics

Even though LED technology has been established LEDs still need new approaches in electronics, thermal management or optics to make complete use of their advantages. Marek Škereň, Chief Technology Officer of IQ Structures, explains how new optical devices, with the trade name Nanoptiqs, based on principles of diffraction are applied to achieve improved performance of white light illumination systems. This unique solution is based on full control over the modulation of material and geometric properties of the optical elements at a nano-level. A combination of complex transmission diffractive elements, with specially designed systems of micro-reflectors (produced using an innovative mass-production technique) is also presented as a promising flexible building unit for the construction of new generation luminaires.

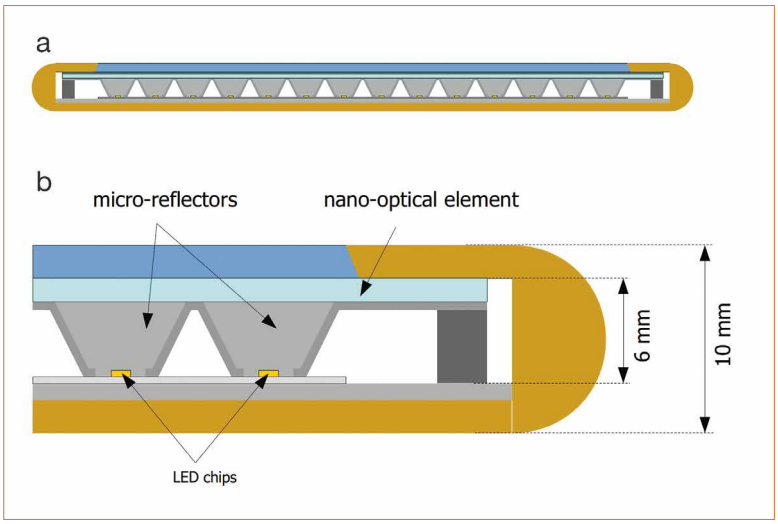
For a long period of time light from lighting systems was managed using conventional optical elements based on reflection or refraction. Large light sources required bulky optical systems, however, the beam shaping capabilities were rather low. It was almost impossible to achieve complicated light distribution curves (LDC), even for complex configurations of optical elements. An invention of LED based solutions for lighting applications introduced new degrees of freedom to the design of luminaires. The most important parameter from this point of view is the size of an LED chip, which is significantly smaller than the typical dimensions of conventional light sources. Generally, a small light-emitting volume enables miniaturization of optics and complete luminaires. However, the highest potential follows from a significant increase of spatial coherence of the emitted light. New approaches based on diffraction of light from micro and nano-structured materials can now be used for extended shaping of light distribution curves. Application of diffractive elements dramatically increases flexibility of the beam shaping process and enables precise illumination of areas with complicated shapes and requirements with a spatial distribution of energy. Such capability results are not only a significant improvement in the quality of illumination, but it can also lead to an important increase in overall efficiency of illumination systems and reduction of energy consumption. Moreover, in most cases the systems based on diffractive elements are lightweight, convenient for mass production and have lower environmental impact following from their production and disposal. The presented approach opens new interesting possibilities also for visual design of future light fixtures. The designers benefit from significantly higher flexibility of shapes of optical components. The complexity of the optical function is not any more closely connected with the complex geometry of the optical elements. Thus, smooth designs with simple geometric shapes can be used in combination with the sophisticated optical performance of the luminaire. Also, the geometric dimensions of light fixtures are positively influenced, extremely thin or narrow bodies can be constructed (Figure 1).

Physical Principles and Design Approaches

Application of principles of diffraction for managing light from illumination systems requires several important issues to be addressed. The most critical one is the strong dispersive behavior of diffractive structures under polychromatic illumination. The diffractive dispersion is naturally much stronger than the dispersion of refractive systems. There are several approaches to the suppression of coloring effects; some with stronger emphasis on color properties and others oriented more on diffraction efficiency of the elements.

The new solution is based on sophisticated calculation of three-dimensional nano-structured elements with high resolution. The design and optimization is performed by polychromatic light using in-house developed numerical tools. Due to the high amount of processed data and large number of parameters the calculation is extremely computationally intensive. On the other hand, it is possible to tune the behavior of the system for polychromatic light exactly according to the needs of a particular application. Manufacturing of the designed micro/nano-structures is also highly demanding due to the complex nature and modulation of the material properties. Especially important is the orientation of micro/nano-structures with such a geometry, which already fully suppresses the unwanted dispersion, but, simultaneously, it is still applicable for effective mass-replication processes. Similar structures are still used more and more, not only in lighting applications, but also in other optical systems. However, these microstructures are usually one-dimensional and the shaping functionality is rather limited. To achieve full flexibility in operation it is essential to use full three-dimensional micro/nano-structures. Such elements are still, in general, highly demanding from a point of view of design and mastering processes.

Figure 1:
The picture of a luminaire based on the new technology approach demonstrates the wall-washing effect of a surface-emitting, ultra-thin, low-glare luminaire with visually homogeneous luminous surface



Figures 2a&b:
Schematic illustration of the luminaire from figure 1 (a). The active part of the system, as thin as 6 mm, consists of a combination of circuit board with LED chips, specially designed micro-reflectors, and nano-optical element (b)

Higher complexity of the micro/nano-structure induces volume behavior of the diffractive element also for relief-type structures. Thus more rigorous modeling approaches must be used to simulate the interaction of light with optical elements instead of simple ray-tracing techniques. The numerical tools have been developed to simulate light interaction with structured matter in a fully vectorial form. These tools in combination with commonly available ray-tracing software packages are integrated within the design and simulation of the systems. The micro/nano-structure is calculated point-by-point with resolution better than 100 nm, very often reaching values down to 10 nm. Thus, the design process is extremely computationally intensive and requires state-of-the art computer hardware.

Complex Hybrid Optical Systems

Although the diffractive structures are very flexible and capable of sophisticated operation, it is often difficult to achieve required functionality just by using a simple micro/nano-structure. In such cases, more complex nano-optical elements can be used with general three-dimensional modulation of material parameters. The described complexity has significant impact on the design and modeling processes, thus special tools have been developed to cover such needs.

To achieve maximum flexibility of the systems, it is necessary to handle one more important issue connected with the widespread application of wide-angled LED chips with Lambertian emission. To collect as much light as possible from the chip, a type of reflection barrier or micro-reflector could be

used. The complete assembly can be constructed according to the drawing displayed in figure 2. The system of micro-reflectors performs pre-processing of the light incident in the transmission optical element. The reflected light, together with the direct beam from the LED source, is further managed by a transmission optical micro/nano-structured element. Because of high demands on spatial coherence of light at the plane of the optical element, the whole system must be designed, simulated, and optimized within a single loop within the same design environment. The developed design packages take into account all of these aspects.

When multiple LED chips are used on a single circuit board, the described combination of reflectors and sophisticated transmission elements can serve as a building unit for larger luminaries. Particular functionality (LDC) of each such unit can be tuned separately from the neighboring cells without visible changes to visual appearance of the unit. The change itself can be realized through replacing only some of the components in the optical system. Such a level of flexibility is extremely important from a commercial point of view as the chance to tune the LDC without replacing the complete optical system is highly interesting in many applications.

Manufacturing, Mass-Replication and Commercial Application

Apart from the improved functionality, this approach is distinguished by a significant increase in efficiency of mass production. The micro/nano-structured reliefs can be effectively mass-replicated using various types of embossing processes. Very often, a roll-to-roll technology can be used with large widths and high throughputs. On the other hand, mastering of the tool for mass-replication is a tricky task with high demands on precision and elementary feature size. Manufacturing of three-dimensional optical nano-structures requires application of state-of-the-art mastering techniques with extreme spatial resolution.

In many cases, micro-reflectors represent important parts of the solutions, which improve efficiency, and overall performance of the system. On the other hand, application of precise miniaturized systems of reflectors based on extruded aluminum or injection-molded plastics are questionable because of high costs, low throughputs or limited precision of shapes. Therefore, a completely new technology has been developed, which is based on the shaping of thin plates from a wide variety of plastic materials. The invented technique features high throughputs, high efficiency of manufacturing process and excellent fidelity of created shapes. Simultaneously, thin plastic carrier material ensures low weight and high resistance against environmental influences. Altogether, the described properties promise excellent applicability of the micro-reflectors in a wide variety of applications.

An example of the luminaire based on the new solution is presented in figures 1 & 2. The photo of the luminaire of figure 1 demonstrates the wall-washing effect of a surface-emitting, ultra-thin, low-glare luminaire with visually homogeneous luminous surface. Such a performance cannot be virtually achieved using conventional manufactured optics components.

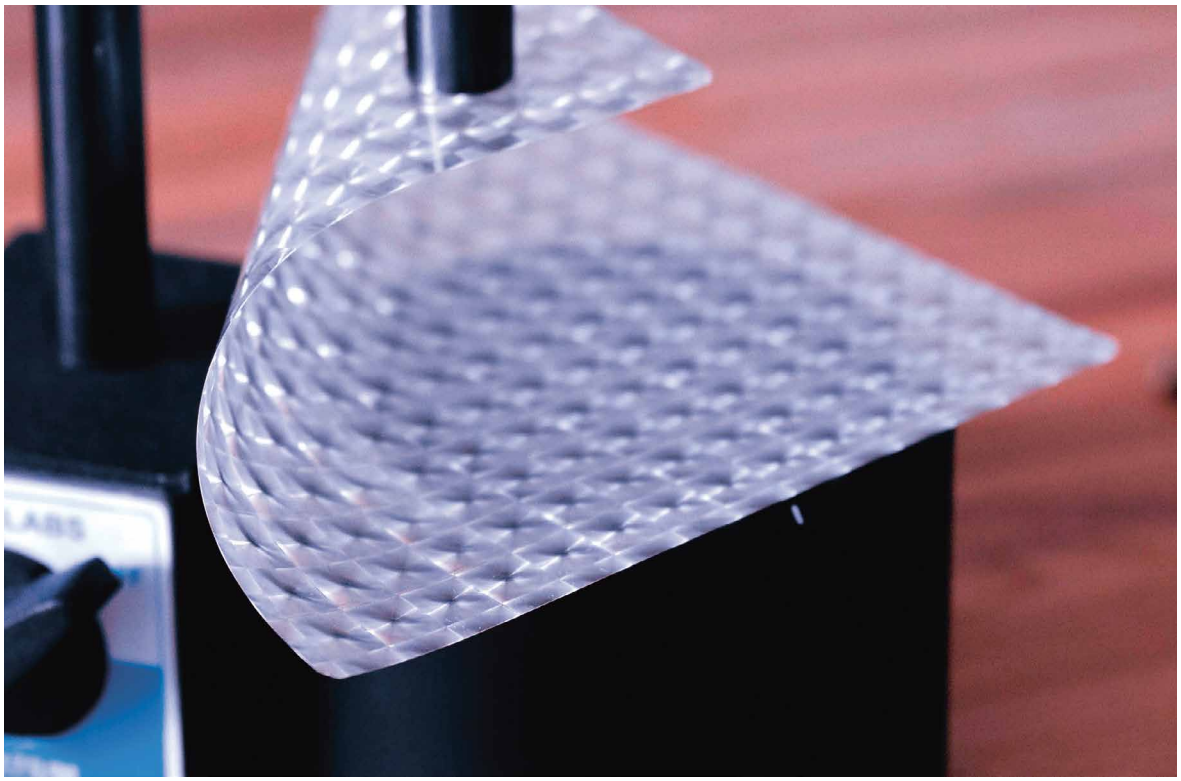


Figure 3:
Only an optical foil like this, based on the presented new technology, allows the luminaire design and light distribution shown in figures 1&2

Conclusion

The presented approach to design and manufacturing of optical systems for lighting applications is distinguished by a significantly improved optical performance and completely new parameters for manufacturing processes. It was demonstrated that new complex functionalities could be achieved without decreasing the efficiency of manufacturing. On the contrary, in most cases the mass-production of these components is more effective and robust when compared to manufacturing of conventional optical systems. Although mastering of the production tools is often demanding and can require the application of the latest state-of-the-art technologies, the mass-replication step is very efficient. Altogether, the proposed solution represents a promising direction, not only in general lighting applications, but also in the fields of light management for automotive industry, optical sensors, traffic and pedestrian lights, and many more. ■

Figures 4a&b: **Both figures demonstrate the advantage in size for the new optical approach compared to a reflector (a) in diameter, and to a conventional lens (b) in thickness**

Abrasion in Transparent Lens Materials for Exterior Aircraft Lighting

For aircraft manufacturers and operators, LED technology promises to keep planes operating longer with reduced maintenance costs and lower power consumption. As the need to frequently replace burned-out incandescent bulbs is eliminated, the importance of constructing a reliable exterior lighting system capable of maintaining safe levels of light output despite continual exposure to particulate abrasion, thermal, and chemical stresses is crucial for operators to realize the benefits of LED technology. In this study, Adam Willsey, Manager of Research, Engineering, and Quality Assurance at Kopp Glass, reports how Taber abrasion and high-velocity particulate testing was performed on three different jet aircraft lens materials, including: heat strengthened borosilicate glass (Kopp 9000), hard-coated polycarbonate, and aviation grade acrylic (Makrolon AR and Plexiglas II UVA).

The ability of pilots to see and be seen in poor weather conditions, especially on and near busy airfields, is critical to ensuring the safety of the public. Exterior aircraft lighting is a critical component that helps provide necessary visibility. Aircraft lighting has followed general conventions used in marine applications to help identify positioning between aircraft, and have several individual lighting systems to help this identification process including position and anti-collision lights and in some cases icing, landing, and taxi lights [1,2,3,4] The light output requirements for anti-collision and position lights are clearly identified in several SAE standards [3,4,5].

In order ensure a long lifetime and reliable performance, the lens covers used in aircraft lighting applications must provide consistent transmission of light, with minimal material degradation after exposure to harsh conditions. In this study, abrasion testing was performed on three different jet aircraft lens materials, a heat strengthened borosilicate glass (Kopp 9000), a hard-coated polycarbonate (Makrolon AR), and an aviation grade acrylic (Plexiglas II UVA), to demonstrate suitability for the extreme aerospace environment. Taber abrasion and high-velocity particulate testing results demonstrated a significant abrasion resistance advantage for glass compared to the plastic. Severe transmission loss was observed in the polycarbonate compared to the glass and far exceeded the transmission losses (theorized or deemed acceptable) by industry sources [6]. Abrasion resistance, the ability of exterior lenses to stand up to these harsh environments, must be a high priority during the lighting fixture design and maintenance processes otherwise the potential cost savings of LED technology cannot be achieved in application.

Figure 1:
Aeronautics is one of the most challenging applications as stresses and strains for all materials are extremely high

Table 1:
Comparative properties of materials tested

		Borosilicate Glass (Kopp 9000)	Poly-carbonate Makrolon AR	Acrylic Plexiglas II UVA
Optical Properties	Transmission	UV-nIR	Vis-nIR	UVA-nIR
	Refractive Index	1.49	1.58	1.49
	Density (g/cm^3)	2.33	1.20	1.20
	UV Resistance	High	Low	Med
Mechanical Properties	Tensile Strength (MPa)	60	75	70
	Hardness (Moh's)	5.5	3	3
	Brittleness	Yes	No	No
	Young's Modulus (Gpa)	65	2	3
	Abrasion Resistance	High	Med	Med
	Chemical Resistance	High	Low	Low
Thermal Properties	CTE (E-7/°C)	43	650	720
	Operating Temperature (°C)	410	130	70

Lens Materials

Exterior aircraft lighting fixtures use a transparent lens to cover and protect the light source, with the most common lens materials being glass or plastic. Glass lenses are usually made from borosilicate or soda lime silicate compositions and can be provided in annealed or heat strengthened (tempered) states. Plastic lenses are most commonly made of polycarbonate or acrylic, with or without a hard coating applied to improve durability [6]. Table 1 provides a summary comparison of these three materials.

Borosilicate glass offers excellent optical performance, durability when exposed to the airstream, and the ability to withstand high operating temperatures. It is resistant against mechanical and chemical abrasion and maintains high levels of light transmission in application.

Plastic lenses provide a reduction in lens weight and good impact resistance, but they can be highly sensitive to chemical and mechanical degradation. Intense and prolonged exposure to UV light, such as from solar radiation, has no effect on glass but can cause plastics to become brittle and discolored. Both materials can be molded into a shape or contour [6].

Performance in Application

Light covers or lenses are critical to protecting light sources, like incandescent bulbs or LEDs, from the harsh environment of the airstream, while transmitting as much light as possible, in order to create an efficient and effective system. According to SAE AS8037C, "the light covers or color filters used shall not readily support combustion and shall be constructed so that they will not change shape or permanently change color or shape or suffer any appreciable loss of light transmission during normal use."[3]

In the harsh and demanding environments experienced by exterior commercial and military jet aircraft lenses, it is necessary to select materials that can provide consistent performance.

Figure 2 shows an example of the light intensity loss of a polycarbonate lens for a wing tip light assembly. SAE guidelines and supporting literature confirm the loss of light output with plastic covers and recommend light fixtures be designed with the presumption of degraded lens output [6]. Fixtures designed with plastic lenses must allow for 20-40% loss in transmission, either by compensating with higher wattage incandescent lamps, more LEDs, LEDs of higher intensity, or driving lower intensity LEDs to higher brightness using more electrical power. In addition, SAE has recommended guidelines on anticipating and engineering around LED reduced light output over the service life of the fixture, furthering the need for careful consideration of lighting design [7]. All of these compensating design solutions tend to increase the total cost of owning and maintaining a light fixture with plastic lenses to maintain the required light output. Generally speaking, the loss in transmission will negatively affect the required photometric light output of the lens, which could result in a safety hazard as the light then becomes scattered.

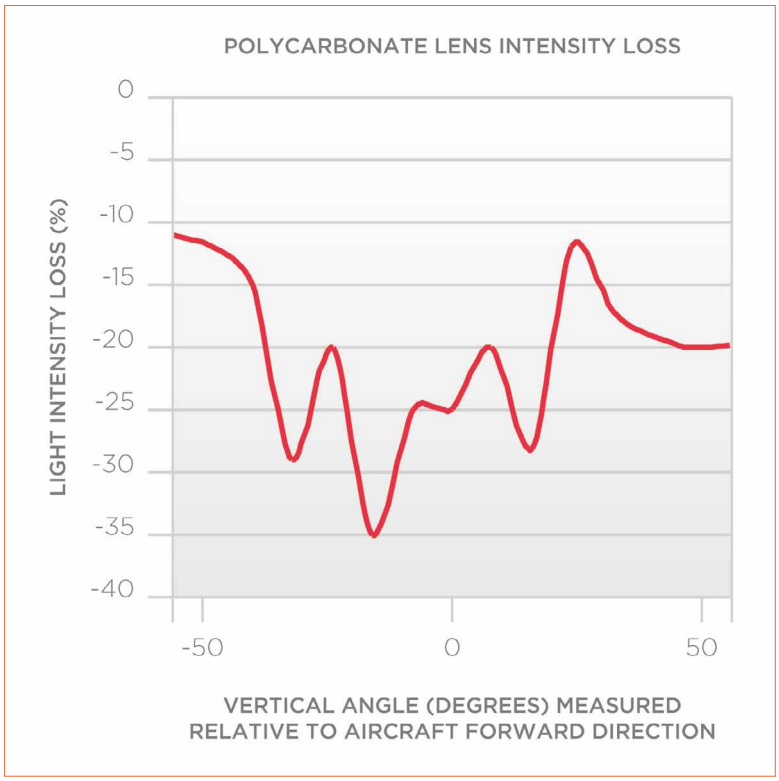


Figure 2:
Plastic lens light intensity loss experienced for a sample wing tip exterior light assembly. Data reproduced from SAE ARP5637 [6]

Experimental Procedure

Two different testing methods were used to assess the abrasion resistance of borosilicate glass and plastics. The Taber Abrasion test method is an industry standard testing protocol used to illustrate abrasion resistance of materials ranging from plastics to glasses to ceramics [8]. A high-velocity particulate impact test designed to simulate erosion effects on aircraft surfaces in flight was used to illustrate the abrasion resistance of glass and polycarbonate in a more application-like environment.

Taber abrasion method

The Taber Abrasion test method was developed and used based on the ASTM D1044 guidelines [8]. A Taber Abrasion Model 174 was used to abrade the samples. The Taber Test experimental procedure followed ASTM D1044 guidelines with the three exceptions.

Test setup variation to ASTM D1044 guidelines:

- The vacuum nozzle had an 8 mm diameter opening in place of the recommended 11 mm diameter
- A spectrophotometer was used to measure transmission in place of a haze
- Samples were run up to 2,000 cycles beyond the recommended 100 cycles to help simulate abrasion resistance between materials over a longer time frame

Abrasion in this method is simulated by the rub-wear action that is produced by contact of the test specimen against the sliding rotation of the abrasive wheel. As the turntable rotates, the wheels are driven by the sample in opposite directions along a horizontal axis displaced tangentially from the axis of the sample. One abrading wheel rubs the specimen outward toward the periphery and the other,

inward toward the center.
The wheels traverse a complete circle on the specimen surface, revealing abrasion resistance at all angles relative to the weave or grain of the material [8].

High-velocity particulate abrasion test

A high-velocity particulate abrasion test was performed on September 27, 2017, at the US Air Force Particle Erosion Test Facility at Wright-Patterson AFB, maintained and operated by the University of Dayton Research Institute (UDRI) to serve the international aerospace community. Access is provided for both military and commercial testing. The particle erosion test apparatus, or "dust-rig," was designed and built in 1983 to simulate erosion effects on aircraft surfaces subjected in flight to dust-laden environments [9].
A schematic of the testing apparatus is provided n figure 4.

The test was conducted on six specimens of both glass and hard-coated polycarbonate.
Each sample was 4.75" diameter (x3), 3.75" square (x3), and the test setup consisted of five independent variable parameters that define the exposure environment during the test provided in Table 2.

Samples of both glass and hard-coated polycarbonate were exposed to periodic and increasing levels of particulate (sand) at the prescribed impact angle to simulate aircraft lighting lens applications.
The erosion and impact of the sand on the samples were controlled by a rostering system to ensure even and consistent abrasion across the defined test sample area.

Results and Discussion

Taber abrasion results

The Taber abrasion results for the borosilicate glass, hard-coated polycarbonate, and acrylic (Plexiglas II UVA) samples are shown in Figure 5.

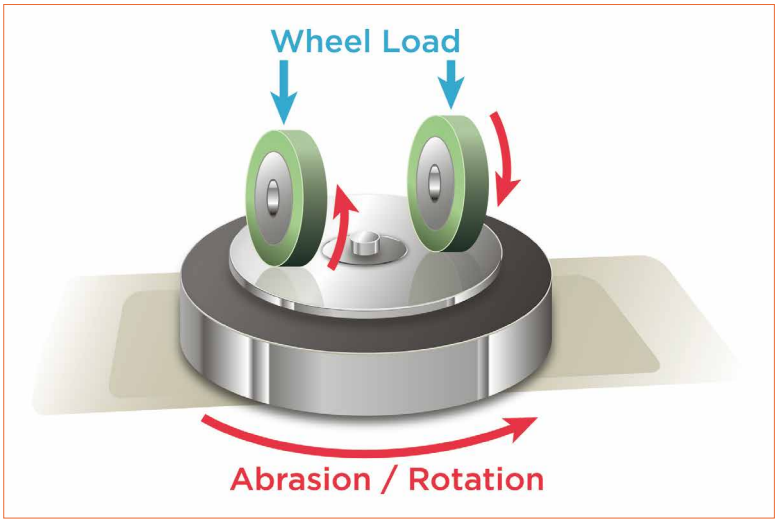


Figure 3:
Schematic of the Taber abrasion test method and testing equipment

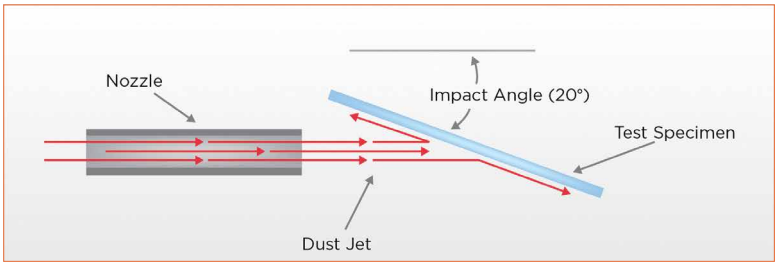


Figure 4:
Schematic of the high-velocity particulate impact abrasion test method and equipment

Particle Type	Foundry sand - 100% quartz sand
Size of Particle media	177-240 µm Foundry
Velocity	420 MPH
Impact Angle	20°
Mass Loading	0.14 gm/cm^2

Table 2:
High-velocity particulate impact abrasion test variable parameters

THE SOCIETY OF AUTOMOTIVE

Engineers (SAE) formed appropriate committees to create many of the standards, recommended practices, and aerospace circulars used for guidance in the aerospace industry. These standards and guidelines are necessary to ensure that each aircraft maintain visibility and awareness when in operation, thereby helping to prevent accidents through well-known and consistent visual clues [3, 4, 5].

SAE ARP 5637 STATEMENTS:

"The most significant shortcoming of plastic lenses is optical performance. When plastic lenses are exposed to the airstream, particulate (ice and rain) and abrasives in the airstream damage the lenses' exposed surfaces. This is referred to as "lens erosion" damage and it appears as cloudy or opaque areas on the lenses much like sandblasting would produce. The effect of this degradation is reduced light transmission and light being scattered in unwanted directions. The light reduction can be significant." [6]

"Careful consideration must be given to the total cost of ownership of both types of materials over the life of the aircraft, which is a key consideration for the owners of commercial and military aircraft." [6]

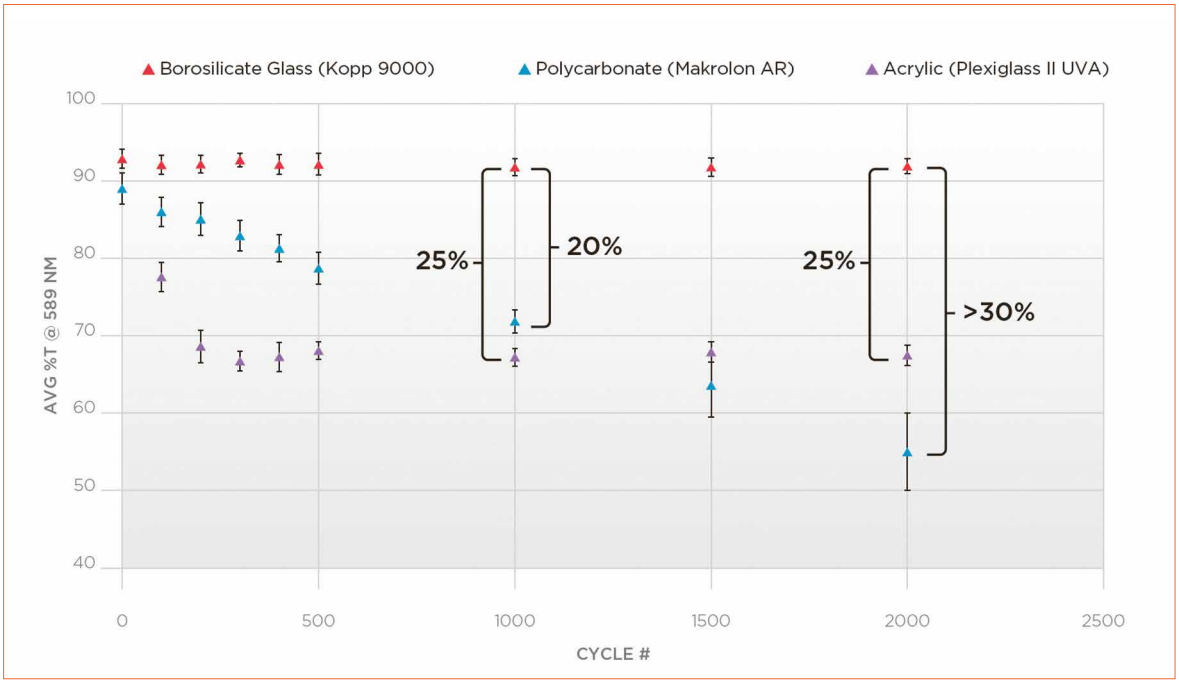


Figure 5:
Photopic transmission of glass and polymer samples following increased cycles (exposure) on the Taber Abrasion test

The transmission of these materials is plotted against increasing number of cycles on the test equipment. The samples demonstrated degradation in transmission as the number of cycles increased. The borosilicate glass displayed significantly less transmission loss as compared to the hard-coated plastic samples.

The results illustrate the significant difference in abrasion resistance of the borosilicate glass compared to hard-coated polycarbonate and acrylic. At 1000 cycles, the glass displayed greater than 20% more light transmission than both polycarbonate and acrylic. The glass continues to separate itself from the polycarbonate at even higher cycle counts maintaining over 90% transmission, with the polycarbonate exhibiting only about 65% transmission at 1500 cycles and only 55% transmission at 2000 cycles. In addition, the glass transmission remains significantly higher (approx. 25%) than the acrylic transmission level even as the acrylic transmission levels off after 500 cycles.

High-velocity particulate testing results

The high-velocity particulate test results are shown in Table 3. The sample transmission decreases with increasing exposure to simulated atmospheric particulate matter (sand). Intuitively, we can equate an increased amount of sand exposure to more accumulated flight hours. Therefore, the design goal for a lens material is to keep light transmission as high as possible.

Table 3:
The test results - high-velocity particulate abrasion test

Sand Exposure (g/cm²)	Photopic Transmission (%) Borosilicate Glass (Kopp 9000)	Photopic Transmission (%) Polycarbonate (Makrolon AR)
0.000	91.5	88.7
0.033	78.2	68.6
0.060	69	49.5

The transmission levels start similarly high between the two materials but diverge with increasing exposure. The borosilicate glass samples exhibit consistently higher abrasion resistance to the particles, providing for longer periods of high transmission. Table 3 demonstrates that glass requires nearly double the amount of sand exposure to drop below 70% transmission compared to the hard-coated polycarbonate. Also, at the exposure level where the transmission loss of polycarbonate has reached approximately 50%, the transmission loss for glass is only at approximately 70%. The glass significantly outperforms the plastic in this testing and correlates well with the results of the Taber abrasion tests.

Another critical result from the high-velocity particulate impact testing is the potential level of severity in the degradation of transmission in the plastic material. SAE guidelines for designing excess light output into a fixture only indicate potential transmission losses of nearly 35% for polycarbonate, as shown in figure 2 [6]. This testing showed even more significant light loss, nearly 40%, was possible. The additional transmission loss of plastic could be much more significant and may require light fixtures to be designed with an even greater loss taken into consideration in order to meet the prescribed SAE light output levels. Alternatively, plastic lenses will need to be repaired or replaced more frequently before unsafe significant transmission loss occurs to maintain required light output levels, with the related escalation in the total cost of ownership.

Conclusions

The critical function of lenses in exterior aircraft lighting applications is to maintain a consistent transmission of light to ensure the highest level of safety. The Taber abrasion and high-velocity particulate impact testing provide an effective means for comparing current aircraft lens materials to determine suitability. At increasing cycles and exposures, the glass continued to maintain significantly higher levels of transmission than plastic. The tests indicate that the abrasion resistance of glass will significantly outperform that of plastic in exterior jet aircraft lighting applications.

As airframes are pressed into nearly continuous service across varying environments, using materials that can withstand particulate abrasion, thermal, and chemical stresses will reduce the total cost of ownership of an exterior light fixture. When margins of safety, reliability, and maintenance protocols are considered, glass is the superior choice for exterior light fixtures on commercial and military jet aircraft. The testing is clear in showing glass lenses can withstand the harsh operating environment of aerospace for more significant periods of time than their plastic counterparts, helping to provide a consistent, reliable, and safe flying environment. ■

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LMT's large gonimeter exhibited at Light + Building 2018

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SMART ELECTRONICS & COMPONENTS
Issue 68 - July/Aug 2018

TECH-TALKS BREGENZ

Rico Kramer - CEO and Founder of eSave

Rico Kramer launched his company just 7 years ago, but the story started much earlier. In 2008 he travelled to Taiwan looking for warm white LED lamps that he could'nt find in Europe at the time. In the end he returned with a powerful 140 W streetlight in his baggage that led to the development of the e-Save wireless control system. He talks about the history, the technology and the different product requirements in different regions, and much more.

RESEARCH

"Best Papers" at LpS 2017: Aerosol Jet Printing: A Promising Technology for LED Packaging

Modern LED packaging technologies have to satisfy the demand for integrating an ever increasing number of components into a module. Therefore, there is a clear need for alternative packaging processes. A promising technology in this regard is additive manufacturing. Recently, aerosol-jet printing has demonstrated many advantages. The article shows the potential of aerosol-jet printing in various aspects of LED module packaging based on test samples and test structures.

TECHNOLOGIES

Intelligent Lighting - A Case of Diminishing Returns?

The ongoing second transition phase of "LEDification" will be characterized by an increased use of smart lighting controls. But this causes additional power consumption for their operation. The amount of needed power may typically vary between some milliwatts and several watts. Thus, the central idea of more controls being equivalent with less power does not seem logical anymore. In a number of typical use cases the substance of this conclusion will be reviewed and the impact and real benefits of lighting controls will be analyzed.

APPLICATIONS

Emerging Applications for UV LEDs in Agriculture

The Ultraviolet (UV) LED market has expanded five-fold in the past decade and is projected to still grow fast. A key trend expected to influenstillce the market is the ability to expand into new applications, including agriculture. UV light, at proper frequency and dose, can increase the production of active substances in plants and it can also help maintain a healthy growing environment. But to fully take advantage of UV LEDs, some re-design considerations are required. The author will explain which considerations these are; for instance, why it is crucial to incorporate the appropriate lens materiall.

subject to change

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