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LpR

The Global Information Hub for Lighting Technologies

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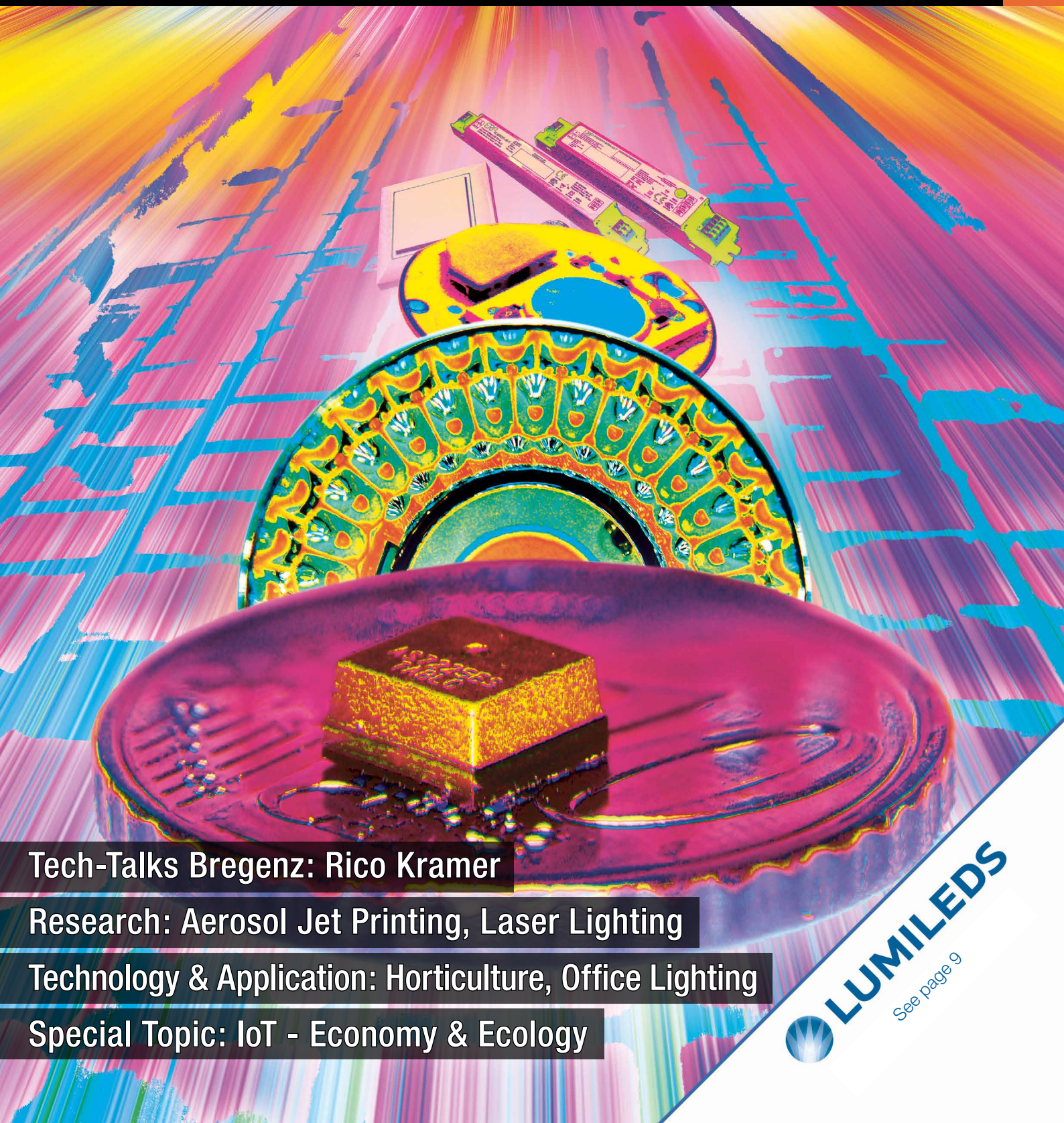

Tech-Talks Bregenz: Rico Kramer

Research: Aerosol Jet Printing, Laser Lighting

Technology & Application: Horticulture, Office Lighting

Special Topic: IoT - Economy & Ecology

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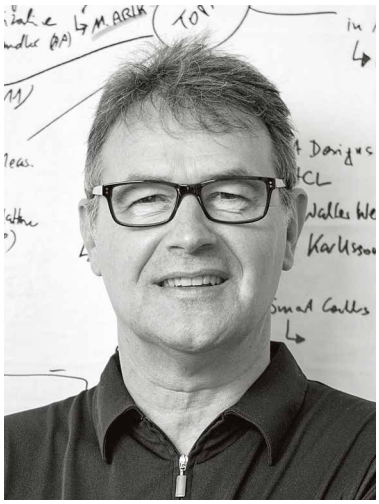

Smart Electronics & Components

Digitalization is taking big steps forward and will definitely not stop just before it gets to light. On the contrary, there is every reason to believe that after the LEDification phase, the digitization phase will fully cover the lighting sectors.

The integration capability - especially in the digital area - allows for further miniaturization and transforms lighting systems from hardware-driven architectures to software-based and intelligent structures. This achieves optimized form factors for designs and can pack more and more functionality into ever-smaller structures.

Analogous to the developments of smart phones and computers, packing densities are getting higher and higher with simultaneous functional extensions. This change to software-driven, smart and modular approaches is the key to new lighting concepts.

Like all innovations, there are also secondary effects in this change, which in turn, must be addressed and resolved. Security, quality, timeliness, serviceability, and many more, are all topics we have to deal with intensively in order to be able to implement this change. If this is not done correctly, smart systems can very quickly become killer products.

We are faced with the exciting, challenging and inspiring task of making the transition to the digital world of light without losing sight of the quality and demands from the user's point of view.

This issue is dedicated to the topic of digitization with many of the articles offering solution contributions to help and inspire you along the way.

Yours Sincerely,

Siegfried Luger
Publisher, LED professional

Almost too beautiful just for the road – lighting design with PLEXIGLAS®.

What does a leading specialty chemicals group have to do with car design? For over 60 years, Evonik, with its PLEXIGLAS® molding compounds, has been a driving force behind the auto industry. Why? Because the multifaceted ways in which PLEXIGLAS® can be formed open up virtually endless possibilities for design. One shining example is crystal-clear or colored PLEXIGLAS® whose top light-guiding properties and color stability make for innovative automotive lighting systems. For more inspirational PLEXIGLAS® products, go to **www.plexiglas-polymers.com.**

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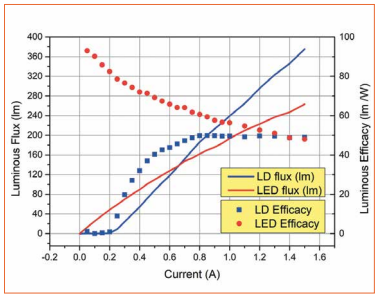

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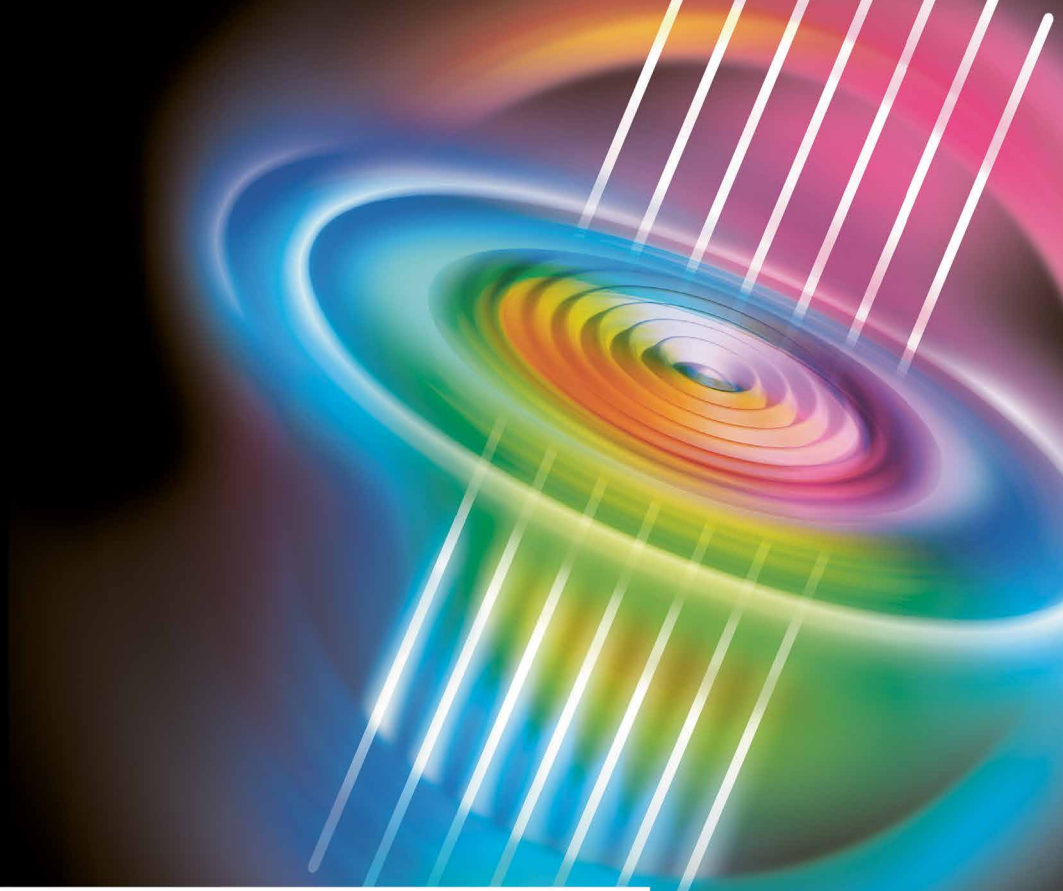

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Marvin Boell

Marvin Boell researched the topic of „Prediction and description of color perception of light spectra using modified color matching functions“ while studying for his PhD at the Technische Universität Darmstadt. He worked as an R&D engineer and product manager for a lighting manufacturer in Singapore where his job was to develop lamps and luminaires. Mr. Boell joined TUV SUD in 2016 as a project manager. His job there is to develop testing methodologies for grow lights, a.k.a. plant or horticulture lights. This position brings him into close contact with other major players in the LED lighting and vertical farming industry.

UV-LIGHT FOR PLANT DEVELOPMENT

Since the development of the incandescent lamp, greenhouse farmers have been using electric light sources as a supplement to natural sunlight. Initially, light intensity was the major concern. Later, growers learned to manipulate plant development by altering the power distribution of the light spectrum for added value such as taste and appearance.

In recent years, the idea of using UV light became more prominent. The UV range (UV-C range in particular) can damage and disrupt the DNA of biological organisms such as bacteria. As such, it is well known for its use to sterilize and purify medical equipment. In plants, UV light can induce stress. However, creative growers managed to take advantage of a plant's countermeasures to induce "favorable" plant responses such as increased polyphenol production and flavonoid biosynthesis. With the emergence of LEDs this targeted approach has become easier.

According to Dr. Mandar Godge, Research Scientist at Temasek Polytechnic Singapore, "LEDs enable a targeted physiological manipulation of a plant's properties such as the photosynthesis and photomorphogenesis by selecting specific wavelengths of the electromagnetic spectrum. These manipulations bring in enhanced yields, higher nutritional value and pest disease resistance in plants, making them versatile for urban farming. UV - LED in particular, will gain in importance since the focus is already moving away from providing sufficient intensity for optimal photosynthesis to the usage of customized light spectra for added value." This shift becomes even more relevant with the recent discovery of UV-B specific photoreceptor UVR8 which will open the door for new ways to influence plant development. The UVR8 serves as a plant's regulatory signal as opposed to a frequently injurious source of stress, and UV-LEDs can be used to specifically target these receptors.

"In the right dosage, UV light can be beneficial to plant growth and development. The increased understanding of the role of UV light on plants' responses will lead to a revolution in artificial lighting for indoor farming," said Dr. Mandar.

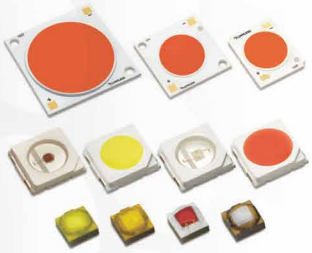
While the usage of UV light in horticulture offers huge potential, the electrical components still have some challenges to overcome. One of these challenges is the usage of the "correct" material; UV LEDs (UV-C in particular) need different materials in their semiconductor makeup to "get the wavelength right". Additionally, since UV wavelengths tend to damage or degrade organic material, the choice of materials that can be used for LED components are limited to inorganic materials. Ceramics such as aluminum oxide can also be used, but this will present the LED designers with a different set of problems, as ceramic tends to be brittle and prone to cracking.

As with conventional LED lighting, thermal management offers challenges. As a rule of thumb, up to half of the energy used for a white LED is converted to light; the remaining half is lost as heat. In the case of UV-A LEDs, the efficiency can drop to 40% and the efficiency of UV-C LEDs can be as low as 5%, leading to 60% and 95% heat loss respectively. The emitted heat must be conducted away to avoid overheating which can potentially lead to the destruction of the LED die.

The usage of UV LED in horticulture offers huge potential and benefits, but as with the more established plant lights, there will be no "one size fits all" solution and it remains to be seen, to what extent the added value will justify the added cost due the higher complexity of the components and systems used. ■

M.B.

LUXEON SunPlus Series for Horticulture



LEDs engineered to deliver the precise wavelengths of light needed to improve crop yield

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

- Three package options: 2.0mm x 2.0mm, 3.5mm x 3.5mm and CoB for design freedom
- Colors specifically targeted for the wavelengths where plants absorb light
- Higher crop yield, uniformity of the crop growth and/or enhanced nutritional content
- Dramatically reduced time to market

Primary Applications

- Horticulture

To find out how LUXEON SunPlus Series is pushing the boundaries of light, visit **FutureLightingSolutions.com** or contact your local FLS representative.

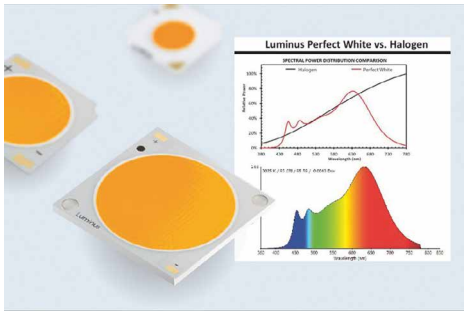
FUTURE Lighting Solutions

www.FutureLightingSolutions.com

LUMILEDS

3rd Gen Luminus Spectrally Tuned LED Light Sources

Luminus Devices, Inc. has released its third proprietary spectral technology, PerfectWhite™, which closely replicates the visual characteristics of halogen lamps. When compared to halogen, PerfectWhite was preferred by lighting designers in testing at both Light + Building and Lightfair.



Spectrally tuned sources are the essential components of human-centric lighting

Though the spectrums are a virtual match - Luminus filled the cyan gap - PerfectWhite's color point is slightly below the black body locus and as a result, there's no green/yellow tint that is common to halogen. A better halogen has long been a wish of the lighting design community and PerfectWhite delivers without infra-red, without green/yellow tint, and without ultraviolet radiation.

AccuWhite is spectrally engineered to maximize CRI performance, and it delivers the company's highest color rendering products with a guaranteed CRI minimum of 95 and a typical CRI of 98. Lighting designers and visual display managers continue to seek the very highest CRI and TM-30-15 ratings for the most demanding interior lighting applications. AccuWhite LEDs offer TM-30-15 values as high as 95 for Rf (fidelity) and 100 for Rg (gamut), while still achieving as high as 125 lumens per watt efficacy at a case temperature of 85°C.

Sensus™ spectral technology addresses demands in retail shops to inspire shoppers with light that creates more dramatic, vibrant and exciting environments where whites are whiter, and saturated colors like blue and red are richer and more vibrant. Sensus' engineered spectrums in 3000 K and 3500 K produce a large gamut area index (GAI BB15 as high as 120) and chromaticity below the black body curve, thus allowing people to see pure, bright whites and deeper colors with greater contrast. While other LEDs might also produce pure whites, Luminus' Sensus achieves this without sacrificing efficacy, as demonstrated with up to 148 lumens per watt at 85°C. ■

Everlight Showcased new Signage LEDs at InfoComm 2018

Everlight Electronics Co. Ltd., a leading player in the global LED and optoelectronics industry, attended InfoComm US for the first time to demonstrate the indoor and outdoor components for LED signage, including all types of dimension, package, viewing angle and performance.

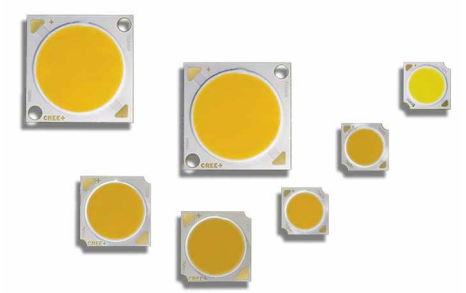
Everlight extended the range of their already broad signage LED portfolio

The new EAPL1010xx-ELB for indoor applications is designed with 4 pins and a dimension of 1.0x1.0x0.65 mm, excellent color and contrast as well as high reliability, effectively protecting damages from transportation, installation or artificial collision and conforming to the indoor panels with P1.6-P2.5 mm. The EAPL1515xx-ELB series with a dimension of 1.5x1.6x1.65 mm conforms to the panel with a pitch of P2-P5 mm. Our PLCC series are RGB LEDs with a strengthened structure and brush-ink/dark support, effectively promoting the screen consistency, zero seam and contrast. The relevant modules were especially demonstrated at our booth.

We have led the market of signage screen with small pitch since 2010, continuously promoting the stability of LED, signage effect and bonding convenience. EAST0707xx-ELB series can achieve P0.7 mm to implement seamless connection, natural color and high definition signage. Our products with small pitch must pass 13 reliability tests and optical decay less than 5%. We are the earliest enterprise to own 8000-hour reliability test. Our outdoor products not only pass 3000-hour reliability test, optical decay less than 10%, and obtain IPX8, but also provide UV, vulcanization resistance and wide view angle to present the highest resolution signage. ■

Cree Expands Metal COB LED Offering

Cree announces an expansion of the XLamp® High Current LED Array family with new CMT LEDs that extend Cree's latest metal-based chip-on-board (COB) LED technology to the most prevalent COB form factors. In addition to providing up to 45% more lumen density and up to 17% higher efficacy, all Cree® XLamp High Current LED Arrays feature an innovative metal substrate technology that delivers higher reliability than competing metal COBs.



Cree's new XLamp CMT LEDs deliver up to 45% higher lumen density than the direct competition

With more than 6,000 hours of LM-80 data available, the expanded family of LEDs enables lighting manufacturers to immediately upgrade their designs for DesignLights Consortium® and ENERGY STAR® eligible applications, such as track, downlight and outdoor lighting.

The CMT LEDs and the recently announced High Current CMA LEDs make Cree's new metal-based COB technology available in form factors that are compatible with most commercially available holders and optics in the market. The newly expanded High Current LED Array family (CMA and CMT) join Cree's industry-leading Standard Density and High-Density families (CXA and CXA2), which creates the industry's broadest portfolio of COB LEDs. COB LEDs mount directly to a heat sink without a separate circuit board, simplifying the luminaire manufacturing process and reducing system cost.

The CMT LED family includes 10 LEDs across three (9.8 mm, 14.5 mm and 22 mm) light emitting surface (LES) sizes to address a wide variety of applications. Featuring Cree's EasyWhite® bins, the XLamp CMT LED arrays are available in 2700-6500 K CCTs with standard color options of 70, 80 and 90 CRI and premium color options that include high fidelity (98 CRI) and specialty color points.

Luminus 280 nm UV-C LEDs for Disinfection

Luminus Devices, Inc., has expanded its ultraviolet (UV) LED portfolio with two new 280 nm devices intended for the medical and health and well-being product segments. The standard footprint 3535 surface mount emitter is a 350 mA device with peak output up to 60 mW. The second ultra-compact emitter is 1.3 mm by 1.3 mm and only 0.85 mm tall; it delivers 3 mW at 20 mA and peak output of 11 mW at 100 mA.

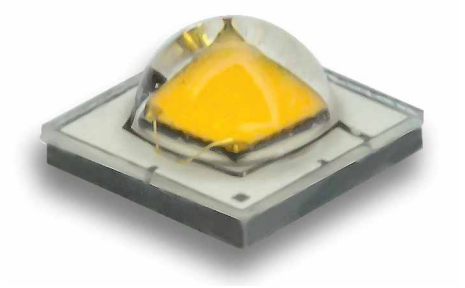
Luminus' new 3535 and 1313 UV-C LEDs provide 280 nm light for disinfection and sterilization applications

"Air, surface and water disinfection markets will see a significant number of new products and new product categories over the next 36 months," said Stephane Bellosguardo, VP of Specialty Lighting Marketing.

The new UV-C devices are just the latest additions to an already robust ultraviolet portfolio from Luminus. It offers both surface mount devices and modules in the UV-A spectrum that are designed for horticulture, curing, additive manufacturing, and medical instrumentation.

Luminus Introduces "Horticulture White" LEDs

Luminus Devices, Inc., a global manufacturer of high-performance LEDs and solid-state light sources, has expanded its horticulture LED portfolio with new SST-20 series white LEDs to complement the extensive range of discrete wavelengths from UVA (365nm) to Far Red (730nm).



The new SST-20-W Series for Horticulture helps growers check for diseases

Incorporating white light in horticulture fixtures provide illumination in the greenhouse and make it easier to

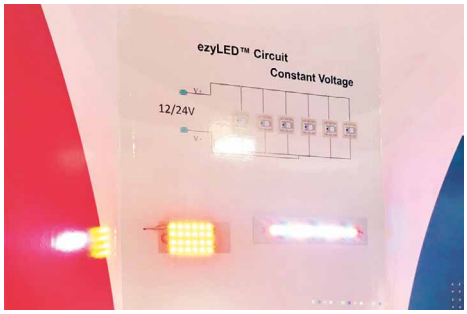
observe crops for signs of disease and, in many cases, white LEDs can replace blue LEDs as they provide similar PPF, and thereby potentially reduce production costs. With a flexible offering spanning 2700 to 7000 K, customers can now select the light most appropriate to their needs.

The need for improved crop yields and more sustainable food supplies is more important than ever and our horticulture LED advances enable innovative luminaires that directly address the market's needs.

As the horticulture and farming research community discover productivity and crop quality gains through wavelength and spectrum engineering, Luminus continues to expand its offering by adding new wavelengths to its current portfolio so that growers and farmers can maximize production yields, become more sustainable and reduce costs. ■

American Bright Introduces NEW 12V/24V DC EzyLED

American Bright, a global LED lighting solutions manufacturer, announced a new series of EzyLED 3030. EzyLEDs are connected in parallel, and directly driven by a conventional 12V /24V DC source. For this series of low-to-medium powered LEDs, the IC is built into the LED chip design which dramatically reduces the additional circuitry and eliminates the need for on-the board IC driver and other passive components. Without the need for extra resistors, bridge rectifiers and current regulative diode, inventory management is dramatically reduced making this an ideal solution due to its simplicity and ease of use.



EzyLED 3030 devices operate over a wide voltage range while the luminous intensity remains constant for 10.4V < Vin < 24V, making them perfect for automotive applications

Features and Benefits:

- Patented LED chip design with built-in IC
- Uses conventional 12 V /24 V DC voltage sources
- EzyLEDs connected in parallel
- Luminance and Correlated color temperature (CCT) remains
- Built-in rectification for non-polar applications
- Active thermal management
- Wide Voltage input range for easy adoption
- 12 V AC/DC: 10.5 - 24V
- 24 V AC/DC: 22.5 - 36V

Applications:

- Automotive: side marks, rear lamps, interior lighting
- Indoor: Linear Lamps, down light, spot light, advertising
- Outdoor: Architectural and General lighting

The EzyLED 3030 devices operate over a wide voltage range while the luminous intensity remains constant for 10.4V < Vin < 24V, and maintains approximately 50% of its nominal value when input voltage drops. These devices can actively modulate the power usage by decreasing the input current to avoid overheating. The input current, light output, and color temperature can stay consistent despite the exterior voltage changes or fluctuations. ■

Samsung Offers LED Component Solutions for Horticulture Lighting

Samsung Electronics announced that it is now offering LED component solutions that have been optimized for horticulture lighting. The company's new horticulture LED lineup features a newly developed "red LED" package, as well as additions to key existing Samsung "white LED" package and module families to include horticulture lighting specifications.

Samsung introduces a high-power horticulture package and adds horticulture lighting specifications to several existing lineups

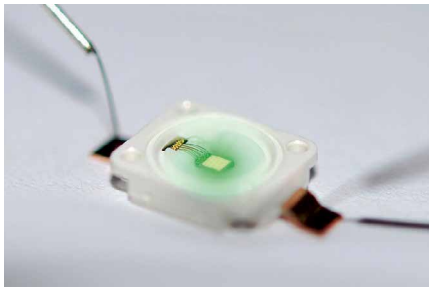
Samsung's new horticultural LED - the LH351B Red - is a high-power package providing a wavelength of 660 nanometers (nm) with a photosynthetic photon flux (PPF) value of 2.15 micromoles per second (µmol/s) (350 mA), making it optimal for most types of horticulture lighting. The 660-nm wavelength helps to accelerate the growing of plants including their photosynthesis, as well as enrich the blooming of flowers. The package also features a very low thermal resistance of 2.0 kelvins per watt (K/W), allowing for easier heat dissipation within LED luminaires. Moreover, the LH351B Red uses the same electrode pad design as its LH351 series counterparts, enabling greater PCB design flexibility in luminaire manufacturing.

Beyond its new LH351B Red offering, Samsung has added horticulture specifications to its mid-power packages - LM301B; LM561C, and two linear modules - Q-series and H inFlux. These LED component families now include PPF values of 0.52 µmol/s (65 mA), 0.49 µmol/s (65 mA), 24 µmol/s (0.45 A, 21.9 V) and 114 µmol/s (1.38 A, 46.9 V), respectively.

In addition, the white LED packages and modules feature extremely high light efficacy of 2.92 micromoles per joule (µmol/J) (65 mA), 2.72 µmol/J (65 mA), 2.43 µmol/J (0.45 A, 21.9 V) and 1.76 µmol/J (1.38 A, 46.9 V), respectively, while the LH351B Red delivers 3.13 µmol/J (350 mA). These high efficacy levels minimize the impact of lighting on ambient temperatures, allowing growers to better control temperatures in almost any greenhouse environment and save on energy costs. ■

Osram - 40% Increased Efficiency of Green LEDs

The significant drop in light output (green gap phenomenon) exhibited by green LEDs has often been the cause of efficiency problems and high costs in customer applications. For its indium gallium nitride (InGaN)-based green LEDs, Osram Opto Semiconductors has now succeeded in drastically reducing the typical forward voltages by around 600 mV. With a simultaneous increase in optical output power, customers instantly benefit from improvements in efficiency of up to 40% compared to predecessor products across the entire UX:3 portfolio from Osram.



Osram Opto Semiconductors has now succeeded in reducing the typical forward voltages of green LEDs

Developers at Osram Opto Semiconductors have managed to reduce the typical forward voltages of green direct emitting InGaN LEDs by 600 mV to 2.6 V at power densities of 45 A/cm^2. The benefits are considerable, particularly for applications in which red, blue and green LEDs are used in combination. Because all three colors now have a voltage of less than 3 V the drivers, which were previously designed for higher maximum voltages, can now be dimensioned smaller. This in turn reduces both dissipative power loss and costs. The crucial factors in increasing efficiency were improved charge carrier transport and optimized material quality in the epitaxial layers.

At 350 mA, 1 mm^2 UX:3 chips achieve efficiencies of 175 lm/W and higher at wavelengths around 530 nm with the new technology. Absolute light output in excess of 300 lm at a pumping current of 1 A opens up new applications for customers.

“Until recently, these efficiency values seemed unattainable for green direct emitting InGaN LEDs. We are now moving into areas that up to now have been achievable only with phosphor conversion emitters but with significantly reduced spectral quality. Thanks to the success of our development team we have been able to drastically reduce the green gap phenomenon for our customers,” said project manager Adam Bauer from Osram Opto Semiconductors.

The team is currently working on further improvements that offer potential which has become evident as a result of the recent findings.

Matrix Platform with Integrated Light Guides

Lumileds announced that its Matrix Platform light engines can achieve breakthrough lumen outputs and efficiencies, using its next generation integrated light guide technology. The revolutionary technology provides non-pixelated illumination for visual comfort and the flexibility to select tailored light distribution patterns in the design of indoor and outdoor luminaires.

Lumileds ultrathin Integrated Light Guide plates deliver diffuse, non-pixilated lighting with >25,000 lumens and 128 lm/W system efficiency, meeting DLC Premium V4.2 qualifications for outdoor fixtures

The integrated light guide plates can be combined with other Matrix Platform advanced technologies such as integrated driver technology, connectivity and control and/or dimming electronics, to accelerate time-to-market of fixtures while meeting Design Light Consortium (DLC) Premium qualifications.

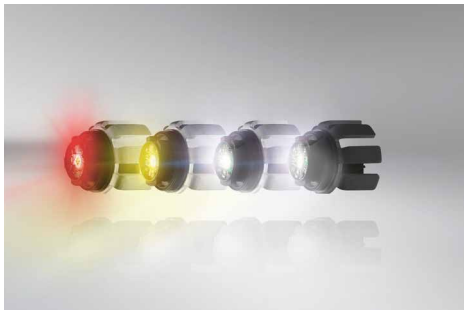
Controlling the light distribution is just as important as how much light is generated and at what efficacy. Lumileds integrated light guide technology provides the ability to control the beam and provides an integrated optical solution that enables superior visual comfort at desired light distributions (Lambertian, Type 3, 4, 5, Asymmetrical, Batwing).

The integrated light guide solutions can use high power or mid power Luxeon LEDs in a variety of color temperatures and CRI to achieve DLC Premium-qualified fixtures. Initial designs for outdoor fixtures have demonstrated 25,000 lm output at 128 lm/W system efficacy, surpassing the requirements of the DLC Premium specifications for outdoor lighting. For indoor area lighting, the integrated light guide technology is also attractive for its uniform distribution, visual comfort and high efficiency.

The Advanced Technologies of the Matrix Platform enable manufacturers to simplify and better manage the supply chain and accelerate time-to-market of luminaires to capture higher market share. Other Matrix Platform Advanced Technologies include the Oberon Intelligent Assembly pick-and-place system, which eliminates binning and allows Luxeon LED selection by parameters such as flux, Vf and/or flux. The Integrated Driver allows the best utilization of space for system optimization and slim, compact fixtures. The Matrix Platform's Connectivity and Controls solutions allow rapid implementation of wireless controls to enable smart lighting with IoT solutions. ■

Innovative XLS Product Family from Osram

Osram is launching XLS (exchangable LED Signal), standardized LED light sources for signal light applications in the automotive industry. By combining standardized light sources and LED technology they will fundamentally change the automotive signal lamp sector. The LED-based signal lamps are scheduled to appear on the roads from the fall of 2018.



Osram is convinced that standardized signal lamps are paving the way for the widespread use of LEDs in high-volume vehicle segments

Over the past few years, LED technology has brought many benefits in terms of design and has led to greater energy efficiency. As a consequence, however, a bewildering array of vehicle-specific solutions has been created. To reduce this complexity, Osram has developed an innovative standardized LED light source for signal light applications. With the XLS product family Osram is launching a signal light portfolio that offers all the innovative benefits of LED technology while offering the proven benefits of traditional lamps such as standardization and exchangeability.

A single platform for all LED signal light sources

The UN/ECE (R128) standardized lamps will be available in four types for different signal applications in yellow (LY5), white (LW5, L1) and red (LR5). The yellow LY5 with 280 lm and a life of up to 4,000 hours is used for turn indicators. LW5 is a white signal lamp for reversing and DLR lights with 350 lm and a life of up to 5,000 hours. The two other members of the XLS product family currently in planning are a red brake, rear and fog light (LR5), which provides up to 4,000 hours of light with a luminous flux of 120 lm, and a white high-precision fog light (L1) with up to 350 lm and a life of up to 5,000 hours. With protection against electrostatic discharge, polarity reversal and overvoltage the Osram XLS products comply with all standard requirements for modern vehicle electronics. Osram uses chip-on-board technology for its XLS light sources. This enables the LED chips to be spaced very close to one another with common optics.

Innovative exchangeable light sources setting new standards

The XLS product family delivers a wide range of benefits for consumers, headlight manufacturers and car manufacturers. A standardized platform for LED signal lamps reduces the number of individual solutions for vehicle models. Integrating the heat sink and electronics in the light source eliminates the costs for their design and approval for each individual solution. All this considerably reduces overall costs for car manufacturers across the various areas - such as the supply chain and quality control. The reuse of design modules and the same platforms also cuts down on the time, effort and costs of development. For car workshops and car owners a standardized solution means the light sources can be directly replaced in the event of a fault, which in turn means lower repair costs and greater road safety. Long-term availability of the lamps will encourage the establishment of the XLS product family.

Series production of the lamps in the automotive plant in Herbrechtingen, Germany guarantees premium quality and is an important milestone in the further development of standardized automotive light sources. Customers of XLS products benefit from the many years of experience in manufacturing car lamps, at this plant.

The standardized XLS product family enables design cycles to be shorter and complexity to be reduced, making it a pioneer for the widespread penetration of LED technology in high-volume vehicle segments. Osram's launch of LY5 and LW5 in yellow and white means that for the first time users (Tier1/OEMs) can equip vehicles with standardized exchangeable LED signal light sources in all signal applications. The first Osram XLS products are scheduled to appear on the roads from the fall of 2018.

For the first time, the uniform XLS platform with four different light sources can cover all the important signal applications. ■

Elmos' LIN Controller for Flicker-Free RGB LED Applications in Vehicles

The Elmos IC E521.36 enables a variable, cost-efficient and very space-saving design of RGB LED modules for the connection to a LIN bus. The device includes a powerful 16-bit microcontroller with 32 kbyte NVM, 128-byte EEPROM and a LIN transceiver that meets the requirements up to LIN 2.2. The integrated microcontroller can be programmed with IAR's widely used software development environment. The addressing in the network takes place with the integrated BSM auto-addressing (bus shunt method).

The Elmos IC E521.36 provides flicker-free RGB LED light in vehicle interior applications

Furthermore, the device has three current sources, each with up to 40 mA and three 16-bit PWM generators. The 48MHz PWM clock ensures full 16-bit color resolution at a 732 Hz repetition rate, enabling flicker-free applications and meeting all known OEM requirements.

Possible application is the ambient lighting in the vehicle interior.

For power management and temperature compensation, the IC has an integrated temperature sensor. In addition, a differential measurement of the LED voltage can be performed with the ADC and thus effective temperature compensation can be achieved.

Auto addressing is a robust and well-proven method of addressing applications in a LIN bus system. All the necessary development and diagnostic tools are already in the field for this process. The method used is based on passive components in the LIN line and offers very good fault tolerance, e.g. at "Loss of Ground", as well as the possibility of "mixed" installation with standard LIN bus applications. This allows bus applications that do not know the BSM procedure to be integrated into a system. Each bus application is also reachable during the addressing of the participants. Broadcasts can be sent to all applications at any time. Through a simple software implementation in the slave, the master can make the address assignment plausible. This unique feature even allows addressing to be diagnosed.

ERP Power Introduces Computer Controlled Dimming

ERP Power LLC (ERP), a leading provider of small, smart and connected LED drivers for the lighting industry, announced the world's smallest programmable drivers with innovative and disruptive Computer Controlled Dimming™ technology.

ERP's world's smallest LED drivers deliver processor-controlled, programmable dimming to optimize dimmer compatibility and deliver desired lighting project ambiance

The patent-pending Computer Controlled Dimming technology means ERP Power PHB Series TRIAC dimmer compatibility scores improve from 90% to 98+%, dramatically reducing any flicker, shimmer, and ripple issues. Typical LED drivers deliver relatively constrained dimming performance at 20/40/60/80/100% output. The new PHB Series delivers programmable 1% TRIAC dimming granularity with startup and sustained operation at 1% to ensure architects and lighting designers have precise scene control. Linear and logarithmic dimming profiles are fully programmable.

The patent-pending power electronics design includes 30/40/50 W models in an aluminum housing to improve thermal performance while offering side lead, bottom lead or European terminal block configurations. The PHB Series drivers help LED lighting fixture manufacturers meet the technical requirements of ENERGY STAR®, California Title 24 and the DesignLights Consortium (DLC) specifications.

The UL Class P next generation PHB Series driver is one-fifth smaller than similar

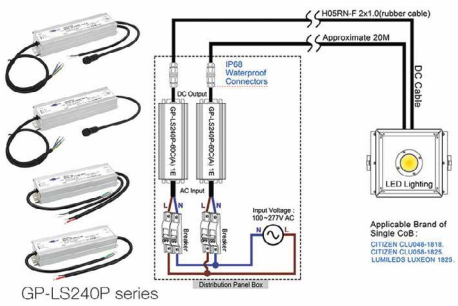
capacity drivers in the industry; programmable for flexible deployment in a broad range of constant current applications; connected with wired and wireless controls; and high efficiency to reduce electricity consumption. As with previous generations of ERP Power LED drivers, the PHB Series delivers Tri-Mode Dimming™ compatibility with 0-10 V, TRIAC and ELV dimmers.
A unique 0-10 V dimming profile programming feature offers 5 pre-programmed choices or a custom 0-10 V dimming profile to be created.

Programmable Output:
Customers can deploy a single driver across multiple lighting fixtures if the power output is programmable. This lowers inventory costs and provides LED supplier flexibility in the customer's supply chain while enabling adjustment of current and lumen output for specific lighting project installation requirements. The ERP next generation driver output is high efficiency and fully programmable in a wide range of output currents while maintaining efficiency of 90% from 50-100% of load with power factor greater than 0.9 and THD less than 20%.

ERP Power's introduction of Computer Controlled Dimming is empowering architects and lighting designers to create the most interactive LED lighting experiences with the precision ambiance and scene control of an incandescent or halogen environment for high-end residential, retail, museum and hospitality applications.
The next generation PHB Series will be available for sampling in Q4 2018 and from ERP Power distributors in volume quantities in Q1 2019. The new ERP drivers are designed in California and built to last with a 5-year limited warranty. ■

GlacialPower's New GP-LS240P LED Drivers offer 3-in-1 Dimming

GlacialPower, the power division of the LED technology manufacturer GlacialTech Inc, announces the new GP-LS240P LED driver series. The driver provides a wide range of input voltage from 90 to 305 Vac, as well as offers constant current and constant voltage operating modes. The active power factor correction driver delivers the excellent efficiency up to 93% at 230 Vac.



In addition to a wide voltage input range and excellent active PFC, GlacialPower's GP-LS240P provides 3-in-1 optional dimming control modes

Features:
- Universal AC input from 90 to 305 VAC
- Constant current and constant voltage
- High Efficiency up to 93%
- Built-in Active PFC function
- 3-in-1 dimming functions available
- Compact size design
- Safety protections include OVP, OCP, SCP, and OTP
- IP67 rated enclosure, for protection from water and dust
- IP68 waterproof connectors, for convenient maintenance

The tough and dependable GP-LS240P series incorporate features to ensure safe operation and long lifespan. These include over current protection (OCP), short circuit protection (SCP), over temperature protection (OTP) and over voltage protection (OVP).

The GP-LS240P protected against environmental threats by its waterproof and dustproof IP67 rated enclosure, the LED driver handles challenging indoor and outdoor lighting tasks in extreme weather and environments. To save maintenance time and costs, the IP68 rated power connectors can be connected without opening the housing.

In order to support a wide variety of lighting scenarios and LED modules, the GP-LS240P with 3-in-1 optional dimming control modes. It provides analog DC dimming controlled by an external voltage from 0 to 10 V, and offers PWM dimming, as well as resistance dimming mode controlled by resistance ranging from 0 to 100 KΩ.

The GP-LS240P-60C 1E (non-dimming) and the GP-LS240P-60CA 1E (3-in-1 dimming) are the drivers with IP68 power connector can support several high power single CoB include Citizen CLU048-1818, Citizen CLU058-1825 and Lumileds Luxeon 1825.

The output DC cable with IP68 power connector and other optional accessories which provide the flexibility of assemble and disassemble driver with CoB, and separate driver from luminaires for future maintenance easily. High integration components can shorten the development schedule of LED luminaires and quickly launch the product in the market. ■

ULT's Everline PW Linear LED Drivers Offer Wireless Programming

Universal Lighting Technologies, Inc., a global leader in lighting and a member of the Panasonic Group, recently introduced its PW Series of wirelessly programmable Everline LED drivers for indoor linear lighting applications.

ULT's new PW Linear LED Drivers introduce wireless programming functionality to the LED lighting market

The PW Series of programmable LED drivers are available in 20, 30, 55 and 80 Watt power levels. They feature programmable output current and relative 1 percent dimming with optional dim-to-off functionality. Notable programmable features include output current, dimming level, dimming curves and dimming set points. OEM partners can use Universal's EVERset software and tuning wand to quickly program the drivers, providing greater functionality and flexibility for fixture design-ins.

"Universal Lighting Technologies continues to lead the lighting industry with an innovative line of LED drivers that represent the best in flexibility and functionality in today's marketplace," said Kevin Boyce, Director of Product Management for LED Drivers at Universal Lighting Technologies.
"PW Drivers are specifically designed for linear troffers in open office spaces, conference rooms, suspended luminaires and low ambient industrial luminaires."

With easy programmability and read back functionality, OEM partners can configure customized lumen levels and dimming curves for their specific customers' needs. PW Series LED drivers are UL Class P listed and are rated for Class 1 and Class 2 control wiring. ■

EFORE New Drivers - IP66/67/68 Protected

EFORE Plc is pleased to announce the immediate availability of the new DDP/MDP600 SC Sealed Power supply series, designed to withstand extreme environmental conditions, including submersion to 1 m for up to 40 days.

EFORE's new DDP600 SC Series of sealed LED lighting grade AC/DC power supplies are available in 24 and 48 VDC versions

The DDP/MDP600 SC series delivers 600 W of rated power up to 55°C ambient with natural convection cooling, especially desirable for high power demand, fan-free applications.
The 800 W peak power capability (up to 10s) ensures the required power is there when needed, such as MRI and CT scanner systems, for short time frames. Available in single 24 and 48 VDC standard output voltages, the series operates from a universal input voltage range of 85 - 305 VAC, enabling worldwide deployment. The unit's very low stand-by power consumption of <0.3 W means higher available stand-by power is available to end system components in equipment subject to energy consumption limit regulations (normally 500mW). Active PFC, EN61000-3-2 compliant (Class C, >25% load) combined with UL8750 approval makes it particularly well suited for large indoor/outdoor LED Lighting and horticultural lighting systems.

Additional features include high efficiency to 94%, low earth/touch leakage current, +5 V 1.5 A stand-by output, remote On/Off signal and 5000 m altitude operation.

Units are approved to the latest IEC/EN/UL 60950-1 safety standards for industrial and IT applications, UL8750 for LED lighting, and IEC 60601-1 3rd edition for Medical applications, including 2xMoPP, BF compatibility and IEC 60601-1-2 4th edition EMC compliance, a strict requirement by the latest medical standards for immunity. These medical safety standards ease medical equipment integration, eliminating the need for an additional isolation barrier.

These rugged and efficient power supplies are suitable for use in Industrial Laser systems, automation and process controls, harsh/polluted environments, telecom antenna and base station systems and high-power LED lighting applications. ■

Douglas Lighting Controls Introduces LitePak™ 2

Douglas Lighting Controls, a member of the Panasonic family of companies, today announced the introduction of its next generation LitePak™, a cost-effective, fully digital and dimmable lighting control solution designed for use in a variety of retail and commercial spaces, including gas stations, convenience stores, warehouses and auto dealerships.

LitePak™ 2 is a cost-effective, fully digital and dimmable lighting control solution for commercial applications

With its 0-10 V dimming control, LitePak 2 enables daylight harvesting and dimming functionality to automatically provide the right amount of light when needed, reducing energy consumption.

LitePak 2 is available in 8 and 16 relay, dimming or non-dimming, central and

expansion panels that can be combined to support up to 48 light circuits. The central enclosure includes a Lighting Control Unit (LCU) with touchscreen interface to group relays, set schedules and create automated functionality. Each steel panel is ordered with a locking surface mount or flush mount cover. NEMA Type 4 enclosures are also available for harsh environments.

Digital peripheral devices from Douglas Lighting Controls—occupancy sensors, wall station switches, indoor and outdoor daylight sensors—are easily connected to the panel using readily available #18/2 AWG to create a robust and reliable dialog low-voltage, polarity neutral, power and data network.

Contractors and engineers can expedite project approvals and turn-around by using LitePak 2 in its standard configurations. LitePak 2 is designed to meet ASHRAE and Title 24 project requirements.

TE's New LED Holders - Compatible With Most COB-LEDs

TE Connectivity (TE) has added the LUMAWISE Z45 LED Holder to its range of holders for chip-on-board (COB) LEDs. The new second-generation LED holder from TE is made in a high-strength, highly reflective halogen-free flame retardant thermoplastic (PBT). The Z45 LED holder is 5 mm smaller in diameter compared to TE's Z50 holder and uses adhesive for fast and easy assembly of the COB LEDs in the luminaire.

TE Connectivity offers new LED holders that are compatible with most COB-LED lighting components

The LUMAWISE Z45 LED Holder provides a quick and easy solderless connection to COB-LED arrays, thanks to the use of poke-in contacts and adhesive bonding. It conforms to Zhaga standards for LED modules, making it compatible with other LED lighting components. The standard screw pitch of 35 mm enables the use of standard heatsink drilling and mounting procedures. The 120-degree optic angle of the LED holder keeps light loss to a minimum and the use of adhesive for LED assembly allows for high COB-board size tolerance, without the need for a clamping system. The design of the holder ensures even distribution of pressure from the LED across the heatsink.

The low profile of the new LUMAWISE Z45 LED Holder means that reflectors and lenses can be placed close to the light emitting surface. "At TE one of our goals is to design products that make the design process easier for engineers. This product, with a platform design that ensure optics are always at the same distance from the light emitting surface, makes it simple and easy to change LED package sizes without any redesign," notes Jeroen Iedema, product manager at TE Connectivity.

ELT Presents eLED RKIT for Outdoor Applications

ELT, leading manufacturer of lighting components, launches eLED RKIT, a complete unit comprising a high output 24 LED module and eSMART constant current driver which is 100% programmable, enabling a high level of flexibility and variability to adapt to any classical lighting fixture application (Villa, Fernandina,…), industrial lighting or other types of luminaires.

ELT's latest product combines a versatile driver with an LED module for outdoor applications

The new eLED RKIT from ELT is a reliable and versatile solution, which, together with support and service from the lighting project assessment department, makes a complex and demanding project a success.

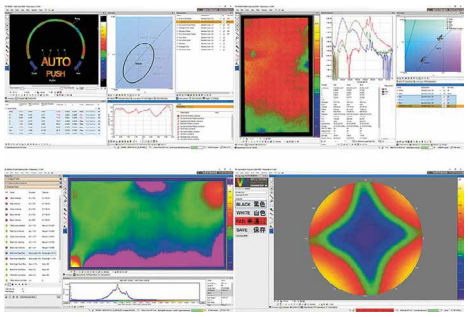
This 100% programmable driver, which integrates eSMART technology, allows a wide range of programmable options and numerous dimming modes: ON/OFF, DALI, 0-10 V, 1-10 V, ActiDIM (autonomous and dynamic regulation that adapts to night hours), ActiDIM Parking (combining autonomous regulation and presence detectors), MainsDIM (head-end regulation to vary the grid voltage), Line Switch (line switch regulation), and Parking (light regulation via presence detectors).

The 24 high output LED module is mounted on an aluminum heat sink. It combines PMMA lenses that guarantee a high level of protection - IP67, high optical efficiency and highly efficient light distribution.

The new eLED RKIT offers a flicker-free light quality and is available in different color temperatures and light distributions to adapt to the most demanding lighting requirements.

Westboro Photonics - Photometrica® V7.5

Westboro Photonics, a leading manufacturer of imaging colorimeters and photometers for the analysis of displays and lighting and the publisher of the Photometrica measurement and analysis software, announces the release of Photometrica version 7.5.



Photometrica 7.5 with the WP690E(S) and optional accessory is the optimal tool for testing automotive instrument panels, flat panel display uniformity, flat panel analysis or viewing angle contrast ratio measurement

Photometrica 7.5 further enhances the most powerful and sophisticated measurement analysis software by providing easier methods to focus, preview and analyze measurements. The revised electronic lens control improves the speed and accuracy of setting the lens focus and iris.

Some of the New Features & Enhancements in Photometrica 7.5:

- Electronic control of lens focus and iris
- Measurements can now be taken at any working distance, even for virtual images in
  - headsup displays
  - AR displays
  - VR displays
- Users can set the focus through the software, and accurately have the distance to the virtual image reported
- New defect characterization tools to detect mura, Black Mura and light leakage in displays
- Faster measurement and computational algorithms
- More analysis tools including automated character and symbol detection

The software's extensive and powerful tool set identifies and quantifies the amounts of light and the color of objects using spatial and data driven techniques. These methods are used by leading laboratories and manufacturers to analyze AR, VR, flat and curved information displays of all types including automotive and avionic cockpit instruments; backlit keyboards; lamp beam patterns and visual scenes.

Unique to Photometrica is a multi-measurement architecture that enables convenient display and comparison between measurements of objects under different conditions. For example, a measurement document may contain display measurements at multiple gray levels, or different temperatures of a room at different times of the day.

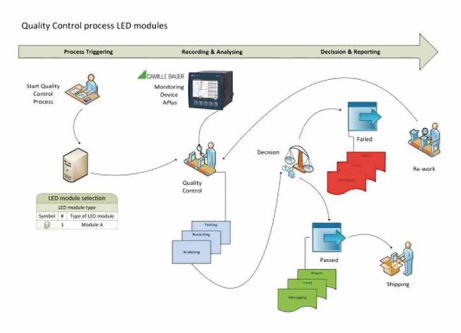
Customization and Automation

For most measurement applications, Photometrica provides all the control and analysis capabilities required in the lab. For partly or fully automated applications, the Photometrica SDK provides scripting and customization capabilities as well as an interface to core processing functionality for equipment and measurement control (using Python, LabVIEW, MATLAB, C#, C++, and more).

Customization can include user-defined windows employing any number of controls, such as labels, number edit boxes, sliders, drop-down menus, buttons, graphs and tables. Each control can be associated with scripts to perform a set of actions in the software. ■

Quality Inspection for LED Module Manufacturing

In terms of energy savings and energy efficiency, LED (light-emitting diode) is dominating private as well as industrial illumination more and more. LED is used to illuminate offices and private living areas, vehicle lightning, advertisings, street lighting, etc. In addition, LED technologies have conquered already into technology fields as entertainment electronics, aerospace, fiber optic based communication, medical areas, optical inspections, etc. With low weight, variable light colors, long-life at lower cost, etc., LED will remain as a future based technology.



Example of electrical testing process of LED module before further use according CIE S025/E:2015, including EMC, flicker and Harmonics

The challenge:
As LED these days is categorized as a bulk product, costs of production and related productivity are mandatory. Even for those bulk items, quality is required, especially for the area where safety and reputation plays an essential part. To perform reproducible photometric and colorimetric measurements the International Commission on Illumination (CIE) provided requirements defined in the standard of CIE S 025/E:2015. The standard aims in particular to cover measurement methods for testing the compliance of LED devices with the photometric and colorimetric requirements of LED performance standards issued by IEC/TC 34. And here the particular challenge occurs: Testing of LED modules as an extra quality process, influences the costs directly.

The solution:
To remain marketable, testing of LED modules shall be efficient, unsophisticated and reliable as well as extremely cost optimized. The APLUS of Camille Bauer perfectly fits to all requirements.
APLUS is designed in the way to measure over 3 phases - even with different loads on each phase. Instead of using one costly power meter for qualifying one LED module in a test stage, with APLUS three LED modules can be tested simultaneously. This reduces investment cost as well the demand of space down to one-third against single-phase devices.

While the accuracy corresponds to the requirements, APLUS often is much less cost intensive than other used measurement devices in such specific application, and this in addition to an excellent durability. Reducing complexity, besides its three-phase measurement capability, can further be enhanced by means of individual parameter settings. Measurement data can be captured in a straightforward manner during the various production phases, and can be sent to analyzing and re-cording software. ■

New LED Vapor Tight Slim Strip Lights from Litetronics Support

Litetronics proudly announces the introduction of its new LED Vapor Tight Slim Strip Lights, a family of uniquely rugged and low profile fixtures that are ideal for space-constrained industrial applications requiring a durable and energy-efficient solution. Available in 4' and 8' versions that consume 30 and 55 Watts respectively and deliver a powerful 130 lumens per watt, the line of fixtures optimally supports commercial, industrial, and institutional lighting needs within corridors/hallways, storage areas, stairways, parking lots, gas stations, car wash/auto body operations, and a broad range of other applications subject to harsh, wet, or otherwise challenging conditions.

The attributes of Litetronics' new strip light are that it is DLC Premium-certified, slim, vapor tight, and it is easy to mount and connect

Measuring just 1.5 inches in diameter, the DLC Premium-certified fixtures' slim IP67-rated design - ensuring protection against dust, water, and other liquids - is both impact- and corrosion-resistant. Rated for both indoor and outdoor use, the fixtures' highly transparent UV-protected polycarbonate lens combined with rust-resistant mounting brackets ensures the delivery of bright, reliable, and uniform light output in some of the market's most demanding environments, from car washes and factories to construction sites, outdoor installations with compromised air quality, and more.

Fully-sealed with an extruded housing and tightly-fitted end caps, the Vapor Tight fixtures' lightweight design - the 4' version weighs only 1.8 pounds and the 8' version weighs just 2.6 pounds - helps simplify installation on a wall or ceiling in just minutes. Among other user-friendly design features, the fixtures' connection cable is pre-assembled to the housing with a water-tight PG cable screw; the fixture is subsequently installed by securing the mounting brackets to the wall or ceiling, then snapping the fixture into the brackets and tightening the brackets to the fixture's aluminum base. From there, installation is easily completed by connecting the far end of the cable to the power; an optional suspension kit facilitates use in applications where a directly-attached fixture isn't needed.

Supporting 100-270 Volt applications and available in both 4000 K and 5000 K versions, Litetronics' Vapor Tight Slim Strip Lights promote a clean aesthetic and feature a long 50,000-hour life and five-year warranty. In addition to standard wall and ceiling mount accessories, suspended-mount accessories are also available. ■

Oreon Introduces Oreon Grow Light Extended Voltage

Oreon, Dutch manufacturer of high quality LED fixtures for greenhouse horticulture, presented their Oreon Grow Light Extended Voltage fixture during GreenTech2018 in Amsterdam's RAI. The new water-cooled LED grow light can be connected to a 220-480 V power supply in a greenhouse.

The extended voltage range of Oreon's grow lights makes them more universally applicable

Extended voltage
With its higher voltage the new LED fixture can be used in an existing 400 VAC installation (480 VAC in North America).

Growers will benefit from the lower installation costs achieved by switching from HPS lighting to sustainable LED lighting. The new lamp has been produced in close collaboration with driver manufacturers Mean Well.

Increased light output

The light output from each fixtures rises to 1790 uMol/s with the introduction of this new lamp, while efficiency remains as high as before, making the Oreon Grow Light 2.2 EV a worthy replacement for the 1000W HPS lamp. The lamp can be supplied with 2 different lenses, a specially developed "batwing" wide angle lens which helps achieve crop uniformity even at shorter distances and a narrow-angled "deep beamer".

Water-cooled lamps

All Oreon's LED fixtures are water cooled, delivering highly efficient illumination without heating up the greenhouse. Water-cooling provides growers with complete control of the climate in the greenhouse as well as the cultivation strategy. This means that the lamps can be used throughout the year. Less cooling and ventilation is required, resulting in improved CO2 values and other benefits. High output from a compact fixture means fewer lamps are required and there is less shading. The end result is high quality yields right through the year, with reduced energy costs. ■

MaxLite Presents LiteBars™ - Limitless Design Possibilities

Compact, linkable and easy to mount, LiteBars are the perfect solution for under cabinet, toe kick, cove, display, wall washing and other accent and indirect lighting applications. LiteBars can be linked for continuous runs of light up to 40 feet long, with near-imperceptible breaks in light. The ENERGY STAR certified bars are designed with a patent-pending, integrated connector that results in a separation of just 1/8-inch between linked bars. New-generation driver technology delivers smooth and even dimming performance across the entire connected run.

MaxLite introduces LED LiteBars™ as high-performing, continuous lighting for commercial and residential interiors

LiteBars are available in assorted lengths (6, 12, 24, 36 and 48 inches), CRI (80 or 90) and color temperatures (2700 K, 3500 K, 5000 K) to meet virtually any design requirement. A slim, 3/4-inch profile enables the bars to navigate the smallest spaces with ease. Accessories include 90-degree and flexible connectors that can be used to create hard or soft corners and shift between horizontal and vertical layouts. Bracket, pivot and magnetic mounting options facilitate quick and easy installation, with flexibility for applications in which shelving heights may change. LiteBars are damp rated and National Sanitation Foundation (NSF) certified, enabling the bars to be used in food preparation and refrigerated display cases.

Depending on configuration, outputs in the series range from 148 to 1,330 lumens, with dimming down to 10 percent of full light output. An architectural-grade diffuser eliminates hot spots and ensures eye-pleasing distribution of high quality light on any surface. LiteBars deliver a long lumen maintenance lifetime of 50,000 hours, and come supported with a five-year limited warranty. ■

Fulham Introduces EZ Exit Emergency Pathway Lighting Kit

Fulham Co. Inc. is expanding its HotSpot line with a new category of value-added emergency lighting products that extend building safety lighting. The new EZ Exit Lighting Kit is being offered as an add-on to conventional exit signs, lighting a path to safety using add-on linear LEDs lights integrated into existing T-grid ceilings.

Fulham extends commitment to safety with a new category of emergency lighting for new construction or retrofits that lights the path to a safe exit

The new HotSpot EZ Exit EM T-grid kits are available in 24-inch (FHEZ10A24) and 48-inch (FHEZ17A48) form factors. The EZ Exit kits are designed to fit into any conventional T-grid ceilings, either as a retrofit or part of new construction. Both LED units are equipped with a HotSpot constant power driver that delivers 90 minutes of emergency power after a 24-hour charge time. The EZ Exit 24-inch unit has 10.7 W of emergency output, delivering 1,480 lumens, and the 48-inch unit has a 17 W output in emergency mode with 2,485 lumens.

The EZ Exit units have universal mounting that is compatible with any type of T-grid fixture and both offer a universal input of 120-277VAC.. The EZ Exit seamlessly fits into any T-Grid ceiling attractively providing the customer with plenty of emergency light in a very sleek hidden design. The EZ Exit units come with an integrated test switch and carry a five-year manufacturer warranty. ■

LG Electronics Unveiled Blue Light Reducing Technology at LFI

LG Electronics USA is introducing energy-efficient LED lighting troffers with new LG “Safe Blue” technology, a first-of-its-kind innovation designed to help reduce light sensitivity, eyestrain and fatigue. Demonstrated at 2018 LIGHTFAIR International industry trade show, this new technology reduces the amount of blue light wavelengths that are common in conventional LED and standard lighting options. This cutting-edge solution can help improve occupant comfort in various commercial settings such as schools, hospitals and office buildings.

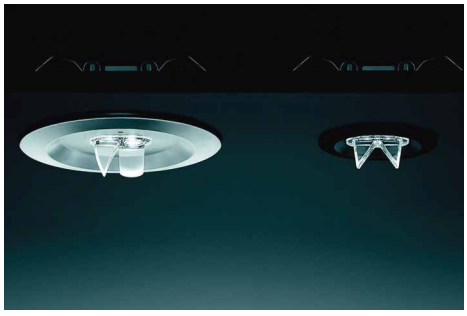
LG “Safe Blue” technology is designed to help reduce light sensitivity, eyestrain and fatigue

With The integral ZigBee® wireless capability makes connectivity easier than ever. The troffers with Safe Blue technology can also be programmed to customizable light levels, allowing for increased energy savings and to set the ideal light levels.

Installers can use LG’s mobile Android application to group, dim, schedule and manage features with the touch of a button, allowing rapid payback with energy savings from daylight harvesting, light-level optimization, and automatic occupancy or vacancy modes with this cutting-edge lighting solution. ■

Resclite PRO – Flexible, Programmable, Efficient Emergency Lighting

The new Resclite PRO LED solution from Zumtobel adds an extra dimension to emergency lighting. This smart emergency luminaire utilizes new lenses to provide enhanced flexibility and combines an unobtrusive look with the highest function-driven performance. A subtle design and the addition of a new mini version means that the fitting almost seems to disappear into the ceiling.



Resclite PRO continues the outstanding success story of the Resclite emergency portfolio. The small, energy-efficient LED spot with optimised optics is now even more flexible, even more powerful and even more intelligent

Facts and Figures:

- Light distribution (optics): escape, escape 90°, escape Wall, escape HC, anti-panic, anti-panic HC, Spot
- Power consumption: max. 5W
- Innovative NFC interface enables quick and easy control, configuration and maintenance via PROset Pen or PROset APP
- Long-life batteries
- Material: die-cast aluminum (cover)
- Mounting versions:
  - MRCR (ceiling recessed): IP 40
  - MRCR mini (ceiling recessed): IP 40
  - MSC (ceiling surface-mounted): IP 40 / IP 65
  - MRWR (wall recessed): IP 40
  - MSW (wall surface-mounted): IP 40 / IP 65
  - TECTON: IP 20
  - TRINOS: IP 65
- Power supply options:
- TRINOS: IP 65
  - Self-contained battery systems: E1D / E3D (DALI 1- or 3-hour emergency power supply)
  - Central battery: ECD (DALI) / ECP (POWERLINE) / ECC (circuit monitoring)

Modern emergency lighting has to guide people quickly, logically and reliably in the event of an emergency. Resclite PRO from Zumtobel continues the outstanding success story of the Resclite emergency portfolio. The small, energy-efficient LED spot with finely optimized optics is now even more flexible, even more powerful and even more intelligent. This emergency solution can be perfectly adapted to suit the requirements of different spatial environments and trusted to maintain maximum safety in a long list of applications – from offices and art and culture to industry. The new compact Resclite mini broadens the scope of the range even further. Thanks to its unobtrusive design, the mini version blends seamlessly into the structure of the building, making it the ideal choice for architectural projects.

The ideal light distribution for every application

A series of precisely optimized lenses ensures the best possible solution for a diverse range of locations. While the escape lens fully illuminates long escape routes, Resclite PRO can now also light up corners with a new escape 90° optic that covers two corridors at the same time, such as lateral passageways and shelf aisles in shops. The escape wall lens is the perfect option for mounting on vertical surfaces in stairwells and buildings with high ceilings. Large-area rooms like offices and conference rooms can

call on the services of the anti-panic lens, which helps reduce concern and confusion in the event of an evacuation by using a square distribution to push the light into every corner. In addition, the spot optics provides clear vertical illumination of fire extinguishers and first-aid equipment.
The range is completed by two more variants of the escape and anti-panic lens. The high-performance (HP) version provides increased illuminance levels or wider spacing of up to 35 meters between the individual luminaires, offering the perfect product for large industrial sites and logistics halls.
The high-ceilings (HC) variant is planned for mounting heights of between 7 and 30 meters, guaranteeing effective emergency lighting in buildings such as production facilities and DIY stores.

Intelligent lighting for maximum safety

Thanks to the new PROset technology from ZGS (Zumtobel Group Services), Resclite PRO can be quickly and directly addressed and configured using the dedicated PROset smartphone app.
The NFC (Near Field Communication) interface offers the chance to easily program various switching methods, including permanent light, non-maintained mode and specific dim values. The emergency light is also serviced via the interface. Parameters such as temperature and voltage are constantly monitored and recorded in a black box. All the information is stored permanently and can be accessed immediately.
The configuration of Resclite PRO is also possible in projects without a central controller.

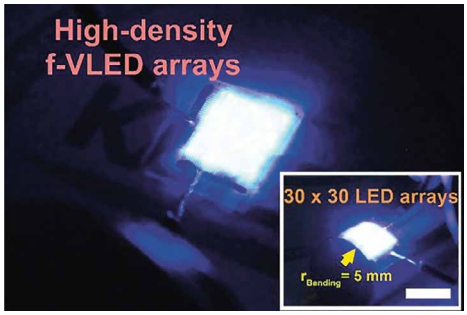
Simple and versatile installation

The flexible Resclite PRO range can be installed in various different ways to suit the conditions of individual applications. When it comes to ceilings, the standard and mini luminaires are available as recessed or surface-mounted versions. Alongside the IP40 version, the model with an IP65 housing ensures added protection against the dust and water that often prove a challenge for solutions in industrial buildings.
Discrete integration into the TECTON and TRINOS continuous-row lighting systems from Zumtobel is also an option.
The rotatable luminaire module means that the light distribution can be adapted to suit the respective building situation in just a few seconds, ensuring safe and accurate emergency lighting in every project.
Resclite PRO – your guide in case of an emergency. ■

KAIST Team Develops Flexible Blue Vertical Micro LEDs

In CES 2018, micro LED TV was spotlighted as a strong candidate for replacing the AMOLED display. Micro LED is a sub-100 um-light source for red, green and blue light, which has advantages of outstanding optical output, ultra-low power consumption, fast response speed, and excellent flexibility. Professor Keon Jae Lee from the Dept. of Materials Science and Engineering and his team have developed a low cost production technology for thin-film blue flexible vertical micro LEDs (f-VLEDs).

However, the current display industry has utilized the individual chip transfer of millions of LED pixels, causing high production cost. Therefore, the initial market of micro LED TV will be estimated to ~ a hundred thousand dollars for global premium market. To widely commercialize micro LEDs for mobile and TV displays, the transfer method of thin film micro LEDs requires a one-time transfer of one million LEDs. In addition, highly efficient thin-film blue micro LED is crucial for a full-color display.



A KAIST research team developed a crucial source technology that will advance the commercialization of micro LEDs. High performance and high density blue f-VLED arrays

The team developed thin-film red f-VLED in previous projects, and now has realized thousands of thin-film blue vertical micro LEDs (thickness < 2 μm) on plastics using a one-time transfer.

The blue GaN f-VLEDs achieved optical power density (~30 mW/mm^2) three times higher than that of lateral micro LEDs, and a device lifetime of 100,000 hours by reducing heat generation. These blue f-VLEDs could be conformally attached to the curved skin and brains for wearable devices, and stably operated by wirelessly transferred electrical energy.

Professor Lee said, “For future micro LEDs, the innovative technology of thin-film transfer, efficient devices, and interconnection is necessary. We plan to demonstrate a full-color micro LED display in smart watch sizes by the end of this year.”

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This news was provided by The Korea Advanced Institute of Science and Technology (KAIST). - Note: Content may be edited for style and length.

This research “Monolithic Flexible Vertical GaN Light Emitting Diodes for a Transparent Wireless Brain Optical Stimulator” led by a PhD candidate Han Eol Lee was published in the June 2018 issue of Advanced Materials.

Authors: Han Eol Lee, JeHyuk Choi, Seung Hyun Lee, Minju Jeong, Jung Ho Shin, Daniel J. Joe, DoHyun Kim, Chang Wan Kim, Jung Hwan Park, Jae Hee Lee, Daesoo Kim, Chan-Soo Shin, Keon Jae Lee. ■

CIE Considers the "Good and Bad" of Light

Light, and the wider optical radiation spectrum (ultraviolet and infrared radiation), provides us with many benefits. However, too much may be harmful and too little may mean we cannot carry out our daily activities, or may indeed compromise our well-being. Division 6 of CIE, Photobiology and Photochemistry, is responsible for developing action spectra for the effects of optical radiation on people, as well as flora and fauna. John O'Hagan, Luke Price and Luc Schlangen, respectively, Division 6 director, Division 6 secretary and chair of the Joint Technical Committee (JTC) 9, explain the work done to determine the balance between risk and benefit from exposure to optical radiation.

The risks of being exposed to too much optical radiation from the sun have been known for thousands of years. People who stared at the sun suffered eye injuries. We also have natural aversion responses to very bright light. However, we need sufficient light to carry out our daily activities, ultraviolet radiation to enable our bodies to produce vitamin D and infrared radiation for warmth. Common sense has served us well for most of our evolution.

Until relatively recently, our daily lives were driven by the availability of optical radiation from the sun. We rose when sunlight appeared and sought shelter and sleep as the sun set, probably spending much of the day outdoors. The availability of artificial sources of light (and heat) allowed our ancestors to extend their activities into the evening. However, such light sources were not without risk. Flames, in their many forms, resulted in burns, fires and exposure to noxious fumes. These risks persist for significant numbers of people across the less-developed world.

The incandescent light bulb provided the first really reliable and lower risk source of light, but some risk remained - with up to 95% of the electrical energy being converted to heat instead of light. LED technology has provided a more energy-efficient solution to our lighting needs. However, many health concerns continue to be raised.

CIE JTC 5 is currently revising the standard for the photobiological safety of lamps and lamp systems, and this work is nearing completion. The original standard (CIE S009/IEC 62471) defined risk groups and included short descriptors, which were open to misinterpretation. Most lamps and lamp systems are very unlikely to be harmful to people under reasonably foreseeable use. The exceptions are those that emit large amounts of ultraviolet radiation or which are primarily blue-light emitters. LED light sources that use a blue LED and a yellow phosphor will not exceed the blue light exposure limit under normal use exposure conditions. The revised standard is likely to emphasize that only Risk Group 3 lamps and lamp systems are of real concern. It is important that the harmful effects of a small number of optical radiation sources are addressed: this standard requires manufacturers to identify such sources to ensure that users are not at risk.

About the Role of Light for Biological Effects

Light has a significant role in determining our circadian rhythm, and achieves important biological effects that are distinct from perceptual vision. These effects are often referred to as non-image forming or non-visual effects of light. Many non-visual effects of light are mediated via the eyes and are highly relevant for human health, performance and wellbeing.

These effects are:

- Each morning, light resets our biological clock, thus regulating the 24 hour patterns in our hormones and behavior, our sleep-wake cycle and our circadian rhythm
- Light can improve alertness, alleviate seasonal and non-seasonal depression and elicit fast responses in the pupillary reflex or in brain activity
- Too much light at night can disturb sleep and circadian rhythms, but sufficient daytime light exposure can make us less vulnerable to the adverse effects of light at night

The stimulation of ocular photoreceptors is essential to elicit the above-mentioned effects of light. The classic receptors for vision, the rods and cones, are relatively well understood and characterised. However, pioneering work over the last 25 years revealed that the eye has another kind of photoreceptor [1]. This photoreceptor has a peak sensitivity in the shorter wavelength part of the visible spectrum and plays an important role in non-visual effects of light. The photoreceptor is known as the ipRGC (intrinsically-photosensitive retinal ganglion cell), and its intrinsic photosensitivity is based

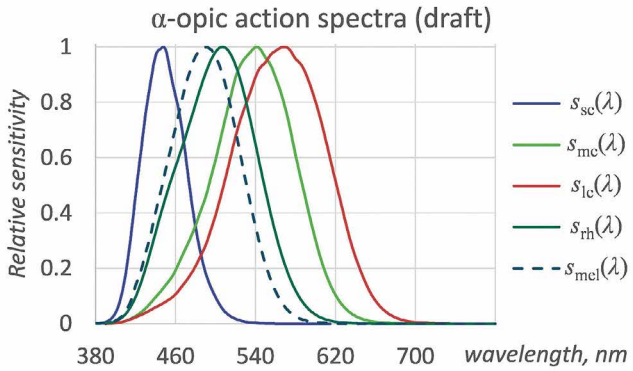

Figure 1: The five sensitivity curves, or α-opic action spectra, define spectral-weightings for radiometric quantities related to ipRGC-influenced responses to light

Quantity	Formula	Meaning	Unit
α-opic radiant flux	$\Phi_\alpha = \int \Phi_{e,\lambda}(\lambda)\, s_\alpha(\lambda)\, d\lambda$	weighted spectral flux integrated over wavelength	W
α-opic irradiance	$E_\alpha = \int E_{e,\lambda}(\lambda)\, s_\alpha(\lambda)\, d\lambda$	weighted spectral irradiance integrated over wavelength	W / m²
α-opic radiance	$L_\alpha = \int L_{e,\lambda}(\lambda)\, s_\alpha(\lambda)\, d\lambda$	weighted spectral radiance integrated over wavelength	W / (m²·sr)
α-opic efficacy of luminous radiation	$K_{\alpha,v} = \Phi_\alpha / \Phi_V$	quotient of α-opic radiant flux, Φ_α, and luminous flux, Φ_v	W / lm
α-opic equivalent daylight (D65) illuminance	$E_{v,\alpha}^{D65} = \frac{E_\alpha}{K_{\alpha,v}^{D65}}$	Illuminance level of daylight D65, producing an equal α-opic irradiance as the test source	lx

Figure 2: Example of α-opic quantities in the draft CIE S026 (α-opic can be: S-cone-opic; M-cone-opic; L-cone-opic; Rhodopic; Melanopic)

on the photopigment melanopsin that is contained within these cells. Apart from their melanopsin-based photoreception, iPRGCs also receive input from the classic photoreceptors (i.e. rods and thee types of cone). In principle, all five photoreceptor types can contribute to non-visual responses to light, where the relative contribution of a single photoreceptor can vary depending on exposure properties such as the (retinal) irradiance, subjective time, light history, light adaptation or sleep pressure.

In 2013, CIE together with ZVEI supported a workshop, which brought together the world experts in the field and resulted in a paper [2], a CIE Technical Note [3] and has also been reflected in CEN/TR 16791:2017 [4].
The experts recognised that the sensors in the eye - the cones, rods and the newly discovered intrinsically-photosensitive retinal ganglion cells, all had a role in circadian rhythm entrainment, and possibly other wellbeing parameter.

About the JTC9 Draft Standard

In 2016, CIE published its Research Strategy, including "Recommendations for Healthful Lighting and Non-Visual Effects of Light " and a more detailed roadmap for the necessary research [5]. In the same year, CIE formed a Joint Technical Committee (JTC 9) to produce a Standard on the CIE System for Metrology of ipRGC Influenced Light Response, as part of that Strategy. The JTC concentrated on the new insights on melanopsin-based photoreception and ipRGC-influenced responses to light and how to incorporate them into the methods that we use to quantify and assess light and lighting. In February 2018 the JTC9 draft standard passed its first CIE ballot and the comments are currently being addressed to finalise the draft international standard (DIS) that is expected to be published this summer. The JTC9 draft standard defines metrics, quantities and spectral sensitivity functions to describe optical radiation/light for its ability to stimulate each of the five photoreceptor classes (rod-, L cone-, M cone-, S cone- and melanopsin-based) that can contribute to retina-mediated non-visual effects of light in humans.

Each photoreceptor input is characterized by its own alpha opic radiance or irradiance, where alpha stands for one of the five photoreceptor classes (Figure 1).
Each alpha-opic photoreceptor input can also be expressed in terms of an alpha-opic equivalent daylight (D65) luminance or illuminance. This specifies the amount of daylight (D65) that is needed to achieve the corresponding alpha-opic radiance or irradiance. With these definitions (Figure 2), the standard will facilitate the development and testing of more advanced models, in which photoreceptor inputs are combined and used to predict how to achieve (or avoid) a specific non-visual effect.
There are important limitations: the standard will only provide tools to quantify the optical radiation received, and cannot on its own define which daytime and night time light exposures are beneficial, or counter-productive for health and well-being. It is necessary to take into account interactions between exposure duration, intensity, spectrum, timing and prior light history. However, it is intended that the standard will ensure that researchers report their exposure metrics in a common format so that studies can be compared. In time, it is hoped that the relative importance of the five photoreceptors can be quantified for specific positive and negative effects of light exposure on health and well-being.

Next Steps

During the upcoming 12-week ballot period on this draft international standard (DIS) "CIE system for metrology of optical radiation for ipRGC-influenced Responses to Light", the CIE welcomes any feedback through your CIE National Committee. An expert tutorial is planned to take place after publication.

CIE Division 6 also has the remit for developing action spectra for non-human exposure to optical radiation. Of particular interest is the development of internationally agreed action spectra for food production under artificial light. CIE is hoping to launch a new Technical Committee to undertake this work and welcomes expressions of interest (via ciecb@cie.co.at).

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Introducing the NEW Zhaga: Smart Standards. Smarter Lighting

During the 8 years of its successful existence, the lighting industry has changed. The Zhaga Consortium has evaluated these changes and their impact on Zhaga. As a result, the consortium has recently widened its scope to increase value for its members and the lighting market. Zhaga, with this widened scope, is currently referred to as the NEW Zhaga and is properly characterized through its new slogan: "Zhaga: Smart standards. Smarter lighting." Dee Denteneer, Zhaga Secretary General reviewed the vision and the mission of the new Zhaga and takes a deep dive into the key concepts that define the newness in the new Zhaga: interoperability, connectability and serviceability.

Vision and Mission

Benchmarking against the "current Zhaga", there is a lot of continuity: the new Zhaga remains true to its original calling to "specify interfaces of components in LED luminaires". Also, it will keep the specifications as thin as possible to maintain design freedom and scope for differentiation.

At the same time, the new Zhaga will be better positioned to address growth areas in lighting. In a nutshell, the newness in the new Zhaga stems from its ability to comprehensively address any interfaces for smart components, such as sensors and connectivity modules, its support of emerging business propositions from IoT and service economy, as well as its commitment to interoperability.

For an unabridged version of the vision and mission of the new Zhaga, please consult the Zhaga website [1].

Interoperability

Interoperability is a key concept for the new Zhaga. In its use of interoperability, Zhaga is fully consistent with common usage, as e.g. in the Cambridge dictionary: "if two products, programs, etc. are interoperable, they can be used together". Yet, the concept is subtle, as the "can" in the definition has an implicit reference to a user competence. Firstly, it refers to an element of information and requires an ability of a user to verify that products can work together and that there are no incompatibilities. Secondly, it refers to an element of operation and requires an ability to actually make things work together.

Zhaga has sofar focused on specifications that serve very advanced users; another set of specifications was developed for end-users through LED light engines integrating both modules and drivers. The new Zhaga includes use cases, such as late stage configuration and upgrade in the field, that involve installers and luminaire architectures with separate modules and drivers. This will require a different elaboration of interoperability.

In pursuing its vision of interoperability, the NEW Zhaga may:

- Specify Interface restrictions - to ease verification
- Prescribe connectors and fit systems to ease installation
- Consider all aspects of the interface

The availability of a testing and logo program is a key asset to demonstrate interoperability, certainly for specifications targeting non-lighting specialists.

Connectability

Connectability is pursued through connectivity interfaces that make it easy to configure and to upgrade LED fixtures, just by mounting or changing modules that provide sensing and communication capabilities. The interface allows for a separation of concerns between lighting and IT, and future proofs fixtures against the rapid innovation cycles in the IT industry. It also provides great efficiencies for luminaire manufacturers, as one luminaire may be configured at a late stage with one of the many different connectivity or sensing technologies.

To be economically viable, it is essential that this interface is developed as a standard. A large installed base of luminaires with this interface will drive a large ecosystem of sensors and connectivity modules, which will in turn add value for the luminaires and drive growth of the installed base of luminaires. It is not likely to get these reinforcing trends going in a fragmented industry with proprietary interfaces.

Book 18 Ed 1.0 is a good example for the extended vision of the NEW Zhaga. Currently it describes the mechanical properties of the Connectivity Interface. The control and power aspects will follow soon

ABOUT ZHAGA:

Zhaga has been an open industry consortium with some 100 members from the lighting industry developing interface specifications for LED luminaire components since 2010. Zhaga also manages a certification and logo program to indicate compliance to specificatons. The key idea behind Zhaga is as exemplary as the socket interface to the incandescent light bulb: Standardizing sockets and avoiding proliferation of proprietary form factors while reserving a large amount of room for specialization and differentiations is of great benefit to manufacturers and customers alike. Zhaga has shifted this insight to bring these benefits to LED lighting as well.

Zhaga has connectivity interfaces as a core standardization topic. It is well on its way to finalizing the specification for outdoor luminaires, securing a central place for lighting in the smart city. Book 18 Ed 1.0 describes the mechanical interface.
The control and power aspects of the interface will be completed in the new Zhaga. In combination, they yield a true plug-and-play interoperable solution. As a next step, the new Zhaga will develop a connectivity interface for indoors with similar plug-and- play properties.

Serviceable Luminaires

The ability to change or reconfigure parts of an LED system - such as a module or a driver - to accommodate changes in performance, appearance, functionality, building layout or utilization, or latest technology advancements is of great benefit to end customers. There are many business drivers for this ability, such as repair, upgrade, innovation to market, late stage configuration, circular economy possibly in combination with regulation.

Zhaga has ample experience with serviceable luminaires through its specifications of interfaces for LED light engines, e.g. modules with integrated control gear. However, it seems that the architecture with module and separate control gear is currently favored in the market. To also support serviceability for this luminaire architecture is still a considerable challenge.

Two aspects of a successful NEW Zhaga:
Firstly, that well-defined and standardized component interfaces are essential to develop the service business.
Secondly, that the new Zhaga Consortium is fully prepared, as well as has the right membership composition, to come up with solid solutions for serviceability.
The developed eco-system for spot modules, comprising COBs, holders, coolers, and optics, may serve to indicate the direction. More examples are developing within Zhaga.

Teaming Up

The new Zhaga operates in an environment with many other organizations devoted to LED lighting. The new Zhaga continues its course to keep an open eye on external developments and will not develop specifications that are available (or are better developed) elsewhere. To note are here the collaborations with the DiiA and the IEC. Close collaboration with DiiA is essential to guarantee full interoperability between luminaires and connectivity/sensor modules, as per Section 5. IEC is the perfect organization for maintenance of mature and successful Zhaga standards; a task overviewed by TC34 AG13.

As another perspective on teaming up, the new Zhaga develops a membership class called “Community Membership”. Community Membership is arranged via a formal contract, but at zero fees. It enables Zhaga to better interact with e.g. specifiers, installers and professional end users, and get their feedback on proposed initiatives and application requirements.

The Way Forward

Visions and missions are abstract expressions of high intentions and need to materialize through interface specifications that create value for the lighting industry. The outdoor connectivity interface, as well as the upcoming indoor interface, is concrete proof points already of the value of new Zhaga. Specifications are in the making to also implement our vision for other components in the luminaire.

In the end, a standards-setting organization is only as relevant as its support in the industry. Zhaga was and remains an open industry consortium and invites all companies from the lighting value chain to join and to jointly live the vision and mission in pursuit of value for the whole of the lighting industry. ■

References:

[1] www. zhagastandard.org

LpS Aims to Prepare Its Delegates for the Digital Future

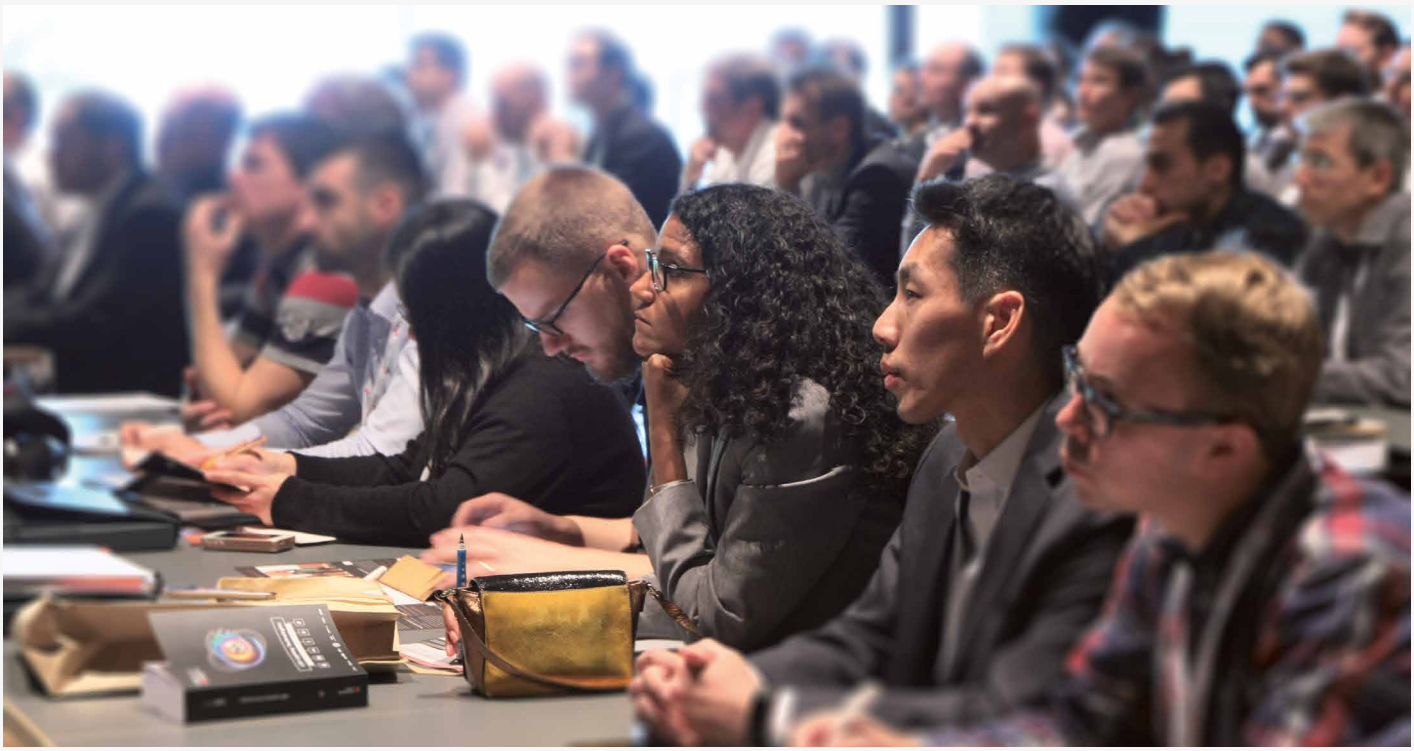
LEDification shook the world of lighting to its core, transforming how we engineer, innovate, design and even live. Today, in lighting, we know the next huge revolution is upon us, but unlike LEDification, this next phase is not really clear enough to define, predict or plan for. Siegfried Luger, Director of LpS, shares his thoughts on what we need to still focus on in engineering, what changes we need to make, and how he hopes LpS can guide attendees to building a secure, relevant and valuable future in lighting.

Core-focus updates:

It has often been said that you have to know where you are coming from to know where you are going. I think this rings true in lighting technology today. We have to be ready for the new digital future, but we have to make sure we never forget what we have built to date and what still requires our attention. The expert speaker sessions we have curated for LpS this year cover a new digital future, however, they also continue the essential continued discussions needed to build and shape the technologies we all develop and design today. LEDification is almost at full maturity, but now there are LED's for new applications and more niche functions with detailed specifications that require all our attention. The spectrum of the LED also needs more focus from us to activate the full spectrum of light we all desire and know is achievable. Testing, quality and reliability can never be forgotten, nor can standardization and its role in our combined future. Alongside the major topic of LED's we also have OLEDs and Laser Light that need to be explored. This year we want to share these core topic updates and impart the latest news to the delegates so the foundations of lighting technology are stronger for the future.

Beyond lighting technologies:

After working in lighting technology for most of my career, I have seen first-hand the many phases the industry has gone



through. I have been fortunate to have ridden the wave of change brought about by the invention of the LED, seen the first example of laser lights and now be a witness to the rapid transformative pace brought about by digitization. In the past, one thing remained constant and that was that lighting technology was designed essentially to illuminate. That is no longer the case; now light needs to be able to, for example, heal human skin, guarantee harvest yield, secure our homes, and enable data communication. This year's LpS will still bring the attendees sessions on core updates that have to be addressed in lighting, but it will also encourage attendees to broaden their horizons to include the multiple applications of light and the varied applications and users.

The bigger picture:

The challenges faced by connected luminaires, and their ability to communicate correctly are so pivotal to our future that we have created a track dedicated to this topic. In the past you only had to look at the luminaire and the light source; it was a focused and fixed developmental space. This has all changed now. Yes, you have to understand how your core technologies are evolving but you also have to recognize all the trends around you, your sector, and field of expertise to maintain the relevance of your products and work. These days it is far bigger than a single point of development. It is much more complex now to develop a human centric, user-focused luminaire that is agile and whose application functions correctly. To be the best engineer you can be, you have to understand the complete environment of the luminaire, its application and the user. We have seen a clear pattern emerging in engineering; there is a demand to understand more from the application point of view from designers, engineers and developers who want to develop systems in the correct way, to make them future proof. Our publications and symposium have always been dedicated to supporting lighting technologies and we continue to do so with our co-hosted event, Trends in Lighting. We will be combining the two areas of in-depth technology and the need to embrace innovations, applications and user approaches.

The future leaders in light:

LEDification was a revolution we all experienced over 8 years ago and it changed the entire landscape of lighting technology. Digitization is comparable to the LED revolution but what it will really look like is still uncertain. We had far more clarity with LEDification about the impact and the best paths to take. Digitization is an unknown. Since we can't predict the future, we should at least be prepared for it. We are seeing global giants like Google, Facebook and IBM joining the light communication space. New stakeholders with new ambitions, such as Microsoft and CISCO are ready to take on light and lighting. But how does this affect us and what can we do to be part of it? It's a whole new motion and phase in lighting and we want you to be better equipped to take part in it. This world of communicating light will change and transform over the coming years and it's those who are best prepared that will be able to remain agile in the future of light and lighting technologies. To be prepared you have to have a wide perspective, be open to collaboration, be up to date on developments and you must also be engaged. We don't think any of us need to compete with the global tech giants, but we should be ready to work with them and help guide them. An event like LpS is the perfect training ground for you to begin collaborative relationships, create open innovation and also keep up to date with all existing and real topics in lighting, rendering strong foundations on which to build your future. ■

Tech-Talks BREGENZ - Rico Kramer, Inventor, Founder & CEO, esave ag

Rico Kramer

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In recent years there has been a strong focus on safe communication and controls in the lighting industry. The success story of esave ag, however, started much earlier, when Rico Kramer, the founder and CEO of esave, travelled to Taiwan due to his dissatisfaction with the quality of early LED replacement bulbs. What the former Apple employee learned there led to the development of the esave concept and its technology. In the interview he talks about his intentions, the beginning of esave, wireless technologies in general, system security, commissioning, system incompatibilities, markets and their peculiarities.

LED professional: Thank you for coming to Bregenz for the TechTalk.

Rico Kramer: Thank you for inviting me!

LED professional: The first thing I'd like to ask you is to tell us a little bit about the company esave.

Rico Kramer: esave is about 9 years old now. The idea came around 2009 when I traveled to Asia for an event. I was very interested in LED lighting, especially lights with a warm color because at that time you couldn't find warm LED lights in Europe that could be put in existing holders. I went to an exhibition in Taiwan and I was shocked. They had all kinds of warm lights there and I also saw high-power LED streetlights for the first time. That meant that the streetlights had 140 Watt. I had never seen anything like that in Europe and I realized that it was a very good idea. I wanted to take the streetlight back to Switzerland with me and start selling LED streetlights even though I had no idea about lights. At the time I was working for Apple. So I went to the local government and asked them if they would like to test LED streetlights on the road and they thought it was a great idea even though the only advantage I could tell them at the time was the extremely long lifetime.

So we installed the light on a street for testing. The owner of the street and I were there on the first night and we were shocked when we turned the light on for the first time. It was so bright that we thought we would only need one luminaire for the whole city! It was so bright because although the original had 125 watts I thought that I would need more in Switzerland and installed 140 watts - not realizing the higher efficiency the LED would have. And that was the beginning of the idea for esave.

So we turned off the light and I went to see a friend of mine who is an engineer and told him that I had a problem. I told him that I had done an experiment with a streetlight but that it was much too bright. I needed someone to help me change the light level without changing the wiring and asked him if he had any ideas. He came up with the idea of trying to change it to wireless, which I thought was a great idea. We decided to work on the project together and it turned out to be the first esave controller.

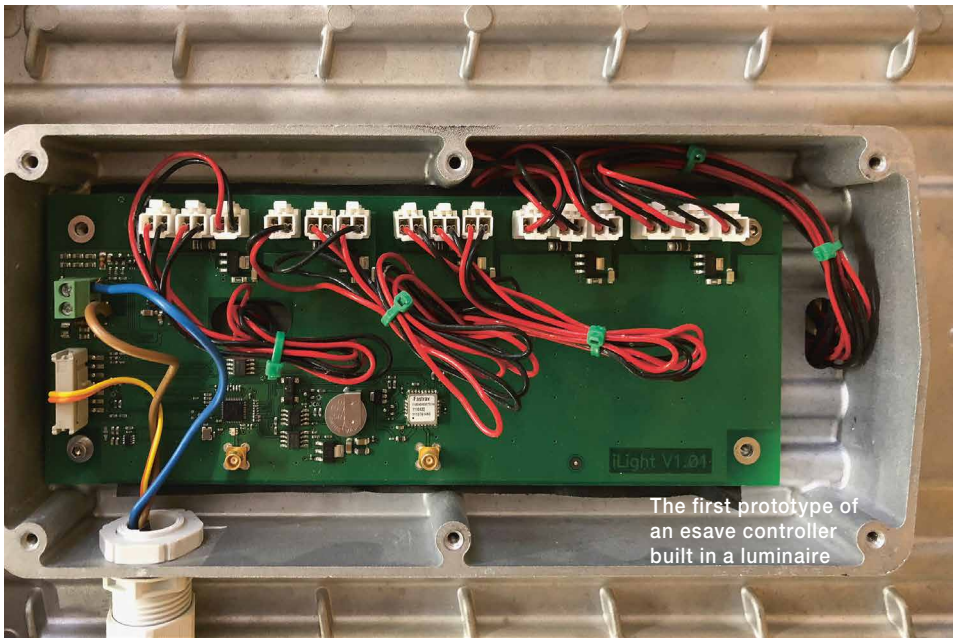
A couple of months later another friend of mine, a software engineer, developed the first software to control the luminaire. And so, in 2009 we had the first wireless controller using PC software. In 2011 we registered the name "esave", internationally, and opened an office. We started to visit luminaire manufacturers to present and to sell our controller.

LED professional: The name "esave" suggests that the main purpose of your products is to save energy. Is that accurate?

Rico Kramer: At the beginning the idea was to save energy but we soon learned that this wasn't the only thing that the market wanted. The market wanted other functions as well. And I thought energy saving could be the way for us to enter the market because everyone was familiar with that. If I went to someone and said, "I have an IoT luminaire" they didn't know what I was talking about. But if I explained that we have a "smart light" that dims when there is no one on the street and therefore you can save energy and also make your city safer because the light recognizes when there are pedestrians as well, they understood that this is what esave means.

LED professional: I think that saving energy is a good door opener in Switzerland but you are also in other markets - like the Middle and Far East. Is energy saving also a good door opener for those markets?

Rico Kramer: The Middle East, Far East and even Russia aren't focused on saving energy. Their main focus is people control. For example, in Singapore you have a small area with a high population made up of many different cultures. And their interest lies in knowing, not only about automobile traffic, but also pedestrian traffic. For them it is much more important to make the right bus stop in the right area and to know where there are pedestrian traffic jams on the sidewalks.



The first prototype of an esave controller built in a luminaire

Rico Kramer candidly talked about IoT and LED lighting technologies and his business

In Russia, on the other hand, they have many traffic jams with cars and they need to know if they should change the lines on the roads - like to make a truck lane or something similar. And this is what we can determine with an intelligent sensor. Here you're not saving energy - but you save resources.

LED professional: That means that, especially in this market, the step that is pushed by a lot of luminaire manufacturers to provide other data is already required.

Rico Kramer: Yes. They need this data. For example, in Singapore they have a lot of rain during the summer. If the rain is really heavy you cannot drive your car. But it's just a small area where this problem arises. If we can detect how much rain is coming, you can put up signs that say, "Please drive slowly because heavy rain is expected". This is the type of information that is important. In Germany, to give you another example, the dust resulting from cars is a big problem inside the cities. And now you can have sensors that measure that dust.

LED professional: Are these sensors yours or do you provide an interface to use other sensors?

Rico Kramer: At the moment we have a deal with Theben. They are a really big sensor technologies company and we now have a weather station ready that measures rain, temperature and the light level, so we can detect what level of light is needed on the road depending on the conditions. If it's wet, you need a little more light. We have an interface that is open for various sensors from different companies. But we also have our own sensors, like the new radar sensor where we measure the exact amount of traffic on the road and what type of traffic it is: cars, pedestrians, bicycles, etc. When we measure that, we can make the correct level of light. It doesn't make sense to have following lights on the big highways. But this new sensor will allow you to see if you have the right light level in respect to the amount of traffic on the road. We can measure the traffic per minute or up to an hour and then we bring the whole road up to the correct light level.

For example: We are in Bregenz now. Let's say the festival is finished and a lot of cars are leaving Bregenz. The sensor can measure the amount of traffic and bring the light level to a higher value to make the road safe for drivers and pedestrians, alike.

LED professional: Where did you get the know-how to find the right algorithm to do that? Do you work together with specialists in that field?

Rico Kramer: We follow the European norm that tells you exactly what light levels you need at a certain amount of traffic. We leave the system open because what is good for Europe is not good for Asia. In Asia we have ten or twenty traffic levels that we can set up. In Europe you can only move three steps up and down but in Asia you can move up to twenty steps up and down.

LED professional: Coming back to your company, you said you started the company about 9 years ago on your own and that the company grew very slowly. But what is the current state of esave? How big is it?

Rico Kramer: esave has grown a lot in the past year, mostly because we have joined more markets. We have 10 people now working at esave Switzerland and we have around 15 handicapped people, not from esave, but working for us, doing easy jobs in the production like packaging. Integration is very important to us. We have a franchise company in Russia.

It is very important to have local staff because Russia isn't a very easy market to penetrate. All production happens in Switzerland and we ship the products to our offices in the different countries. Then we have a sister company in Dubai. It's called esave Middle East. There is also esave Singapore, which is also a franchise. They also have a light designer working for them.

LED professional: So you have centralized development and production and have local distribution or sales offices.

Rico Kramer: Correct. We need the local people to work the markets. When you go to Asia as a European you have many handicaps - starting with the language and going on to the food. The locals know the market; they know the people, and the language. If I go there and speak English they just say, "See you next time."

LED professional: So your markets are Europe, Middle East and Far East, is that correct?

Rico Kramer: Yes - and Russia. The fastest growing market for us is the Russian market. I think it will become the biggest market for lighting in the near future.

LED professional: When we met in Basel I believe you said that you have two options: The first option is to provide the complete system, which consists of the luminaire, including your controls, the driver, and so on. The second option is to work together with other companies and only provide the controls and the driver. The real core - or the heart - of your system is the intelligence. Is that correct?

Rico Kramer: At the beginning we had the controller. And we had no chance to join the market. That is why it took a while to expand. Then I had the idea of integrating a luminary. So we started design luminaries here in Switzerland and we came up with "Stillness". But it was extremely expensive. And then we won a tender in Bern (the capital of Switzerland) for 1,000 luminaires. And that's when the name esave was born for luminaires as well. But we can't go out in the market and sell lots of luminaires. So we have to be open to give other companies the chance to join the tender with esave. And that's what happened. The next 3,000 luminaires were from Asetronics, a Swiss company. They joined in and we also won a second tender, which made it possible to open the market much faster.

In the meantime esave luminaires are being sold all over the world for any type of infrastructure. Here they are being used at a train station in the Pinzgau in Salzburg, Austria

Anyway - esave now produces the first intelligent LED modules. We have matched core chips with LED technologies where you only need new housing for a luminaire and everything is inside - in the LED module.

There are many standards, like Zhaga, but products aren't compatible with each other. In the future, this will be a big problem. How will you manage a city? You have various manufacturers for LED streetlights each one needs a certain sized LED module. Lifetime of a luminary is very long, but design lifetime is only around 3 years. They don't have the PCB boards in stock. So if something breaks, you have a big problem. It's not like before when all you had to do is to change the light bulb. Now you have to change the whole luminaire. So my idea is to match everything together, make one luminaire design and one light source design and plug it in and it's ready to go. This is what esave produces, but we don't sell it. We have licensed companies that go onto the market with this type of luminaire. So we are focused on the intelligent parts and the partners will sell it.

It was presented at light + building as the first intelligent LED module with multi-lenses, sensor technologies ready and water proofed.

LED professional: So what's the strategy of esave?

Rico Kramer: If I think about it - esave didn't really have a clear strategy as it grew. The first idea was to save energy - but the big players closed us out of the market. So then we started to make luminaires with controllers so we could get into the market and now we are a player. But the new market with IoT and intelligent parts, sensors and matched technology and everything that is coming in the future, it isn't that easy. My opinion is that we need standards.

LED professional: Let's talk about standards: There is an ongoing discussion about communication protocols. Most bigger companies want to have their own protocol - not open to other companies. For indoor lighting, we now have - after years - the DALI standard. It's now the common standard. I think you have your own protocol now - so in which direction would you like to go? Do you want to open it for other companies for the development of sensors, for example?

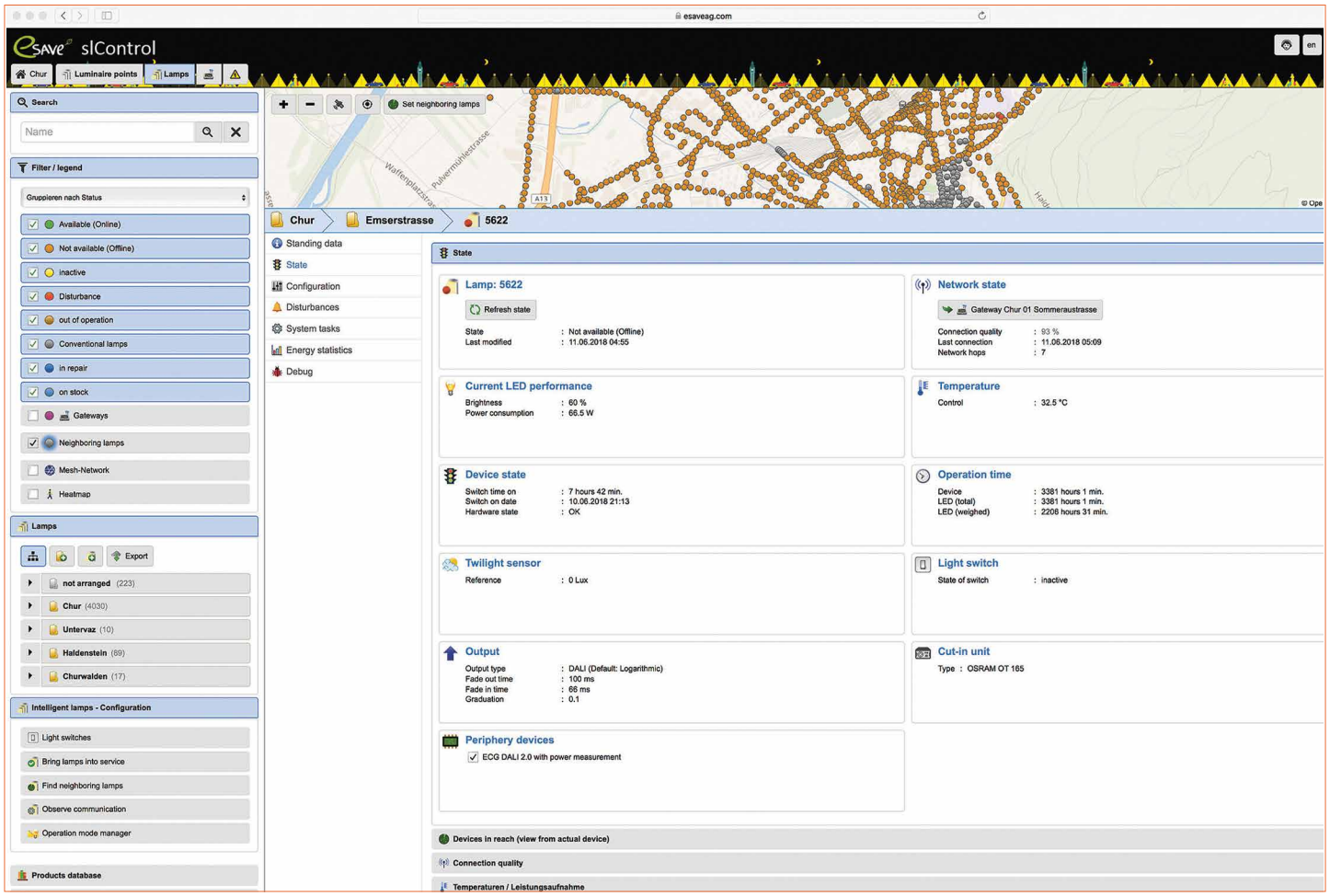
Rico Kramer: Yes, we've been thinking about what we should do about the standard for a very long time. We have seen that if we open the protocol we could have problems with hacking and those sorts of things. So it's more a question of safety. All the big standards have the potential to be hacked. This is why we leave the protocol closed, but we distribute the chips that have esave protocol included. That means the sensor manufacturers can make their sensors and put our core chip on it and it is compatible with our product. This is the best way for us to do it. It's like Lego blocks: You can make your own design and put the Lego communication inside and you'll be compatible with us.

LED professional: You opened the market for the communication module but you haven't opened the protocol.

Rico Kramer: That's correct. It doesn't make sense to open it now. We want to go forward - we want to be on the market. What we see today is the new Bluetooth 5 protocol. It is very interesting to us but it isn't ready. In future, when we have Bluetooth 5 on our controllers we can let standard controllers and standard sensors in that communicate via Bluetooth 5 with the esave network. I think that could be the first opener for others to join the esave standard. So we would have bridges that bring Bluetooth 5 to the esave 2.5 protocol.

LED professional: You are not only working on hardware innovations. What I saw at the Light + Building in Frankfurt was a very interesting Software management system for Smart Lighting.

Rico Kramer: That's correct. We have two products: We have the control software that runs on a Windows based computer that can manage up to 250 devices. It's a stand-alone - so you can set up your devices, you have no maintenance costs. You communicate with the lighting system via a USB stick. The system does exactly what you have set up. We also have the cloud version sl control. It is based on connected gateways. Each gateway can control up to 250 devices. If you look at



the city of Chur - where we are based - we have 4,000 luminaires and we installed 26 gateways.
So with this platform you have the chance to get a lot of information from your city. You can make heat maps - for example, to find crowded areas during the night. You can see traffic jams and where the most visitors are. On a Saturday, for example, you can see how many people go to a bar. We also have radar sensors installed that show us exactly what is happening. Is it a traffic jam or is it people walking? Your navigation system may tell you there's a traffic jam but it's possible that it's only a bus.
Our sensor technologies will be able to tell you if it is really a traffic jam or pedestrians or a bus.
To analyze the information we need a web platform. In big cities they want to have only one platform to control everything. So we don't only have the light function in this platform, but we have now also added water, gas, and district heating for Russia is also integrated.

We have different log-ins.This means that the people from the water can log in and enter their changes or their services by word code or by QR code. They can check, for example, if a pipeline is broken and exactly where it is broken.
We see this as the new future. It's a web platform, it's cheap and it's easy to handle. It doesn't matter whether you use android or apple. This is what we are working on right now.

LED professional: You said you're able to manage 250 luminaires with one gateway. Other systems claim to be able to manage many more. Is this a limitation for your system?

Rico Kramer: No, it's a hardware problem that limits the number of devices you can manage.
They don't have enough RAM to manage more controllers. But every problem can also be a solution!
If we have a number of gateways in a city and one breaks down - the luminaires will automatically go to the next gateway. So you have a redundant system. We have been observing this in Chur. Also when we have heavy snow, if you use LoRa, your antenna is down and you have no communication.
But esave uses a Mesh network. Every luminaire searches for another way and if one way is not available, maybe there is another. So this is good if you have more gateways.

LED professional: So the network is able to communicate with all streetlamps using this redundant network?

Rico Kramer: Not only streetlamps. Chur has started to build a new school building and we are managing the luminaires outside and inside. The system can control the light level by sharing the information about the level of brightness outside and the temperature and inside we can make the level of light right for the students. If the people move from inside to outside we can turn the lights on outside.

An important item in any lighting company's toolbox for operators is the software. esave's software is available as a standalone as well as in a cloud version

The latest member of the growing esave family is a Zhaga Book 18 socket based luminaire controller that transforms any conventional street light with this socket into a smart IoT capable street light

We don't say 'OK, here you have DALI standards' because DALI is a good idea but it's not a standard. Everybody has their own standard included in the DALI protocol. And that's a big problem. For example: If I want to use a Dali driver from A, I can't have the same protocol to read out the driver if it's from B. You need a different protocol to read out every driver.

LED professional: With Dali we have the standard and we also have several standardized extensions and non-standardized extensions.

Rico Kramer: Exactly - that's what I mean. And it's a big problem at the moment.

LED professional: You were saying before that you can communicate with the house and with the infrastructure within the house. Could this be a step in the direction of using your esave protocol not just for outside and streetlight systems but for indoor lighting as well?

Rico Kramer: That's correct. We are working very hard with our engineers to move indoors as well. But we are looking only at public housing - not residential housing. Residential housing is not the right market for esave.

LED professional: If you set up a system that is based on lighting, at the moment outdoor lighting, a problem may occur due to hot or cold temperatures. Some of the electronics fail and then some of the luminaires fail. What happens with your communication system if some of the electronics fail?

Rico Kramer: esave is designed for very hot and very cold temperatures. Our range is from -35°C up to 82°C. The problem usually comes from the driver. If the temperature is minus 5°C, 10°C or 15°C they don't produce any energy. It's a big problem because the streetlight is not running and esave is not running because we need the power from the power supply. But we have a reaction time on the software. This means that the luminaire must be offline more than seven hours in order to send an alert. And this gives us time to find the problem. But this shows the government that certain luminaires are making problems and they can have it checked. On our side, esave controllers are ready for high and low temperatures. We do our testing in St. Moritz, Switzerland where the night temperatures often go down to minus 35°C and the system runs very well.

LED professional: If you set up a system on the basis of esave how much effort is involved in installation and commissioning?

Rico Kramer: There is an easy way and a complicated way. So it mainly depends on how much the client invests at the beginning. If we talk about the standard installation (the not so easy way) is where you have a luminary with an esave controller inside. The installer just has to switch out the old luminaires for the new ones. He only has to set up the power. There is no need to install additional cables. The new luminaire identifies itself by flashing; you walk with your tablet to the luminaire and store the GPS coordinates from the tablet as an address for the luminaire. You can do this luminaire by luminaire. This only needs a few minutes to walk to the luminaire and then a second or two to set up the luminaire.

LED professional: Do you need addresses for the luminaires?

Rico Kramer: No, they are identified by flashing.

The easiest way is with the gateways. For the gateways we deliver three QR codes with every luminaire. One is in the luminary, one is outside the luminary and one is to put on the pole for maintenance and service later. Now the city will send the luminaire positions in an excel sheet to esave, so we can import the existing luminaire points from the old luminaires. Now every luminaire point is inside the gateways. The next step is the installation. The installer goes to the luminaire, scans the QR code - the luminaire needs not to be online. He now can match the QR code and the already stored position of the luminaire. At night, when the light turns on, the gateway searches for the new luminaires and automatically sets it

to the right light level that has been predefined in the system. The installer just uses the profile that was set up in the beginning for that particular road. You only need one or two seconds to install an intelligent luminary. Right now, there are 4,000 luminaires in Chur. They installed 100 luminaires a week and they just don't have the time to spend five minutes on each luminaire. It has to be a system where everything sets up automatically.

LED professional: We talked about going from lighting to urban infrastructure. You mentioned things like water and gas. But there are other urban infrastructures like parking systems. Do you see these systems joining in the future? Which one will be the leading system that the communication is based on?

Rico Kramer: Everybody would like to believe that they will be the main system. It's hard to predict what will happen. I can only tell you that we are working very diligently on our system but we have a communications standard - IoP - and we've opened it this month. So other systems can read the esave data from the server if they have a license. We can also read in data from other systems. With the new communication API we are open for the future.

We have two link points: We can bring other systems or other sensors into our network via the esave core chips or we have the API, which enables us to speak with other servers. I think that it is very important for the customer that we aren't too closed.

LED professional: You mentioned that you didn't want to open your protocol due to safety issues. Privacy and safety are very critical - especially in Europe. It's always critical, but I think that Europe is very careful when it comes to privacy and safety concerns. You said that the advantage of esave is that everything is on the chip and that makes it difficult to hack. Can you go into detail about that? Do you have safety measures on your chip or in your protocol?

Rico Kramer: We have many safety features inside. One is that the communication is not based on a normal protocol. We use our own protocol so you can't find our network. It's hidden. It's an industrial standard and not the 2.4-gigahertz network that you use for Internet. We also have IES encrypted technology. Every communication from chip to chip is encrypted. And we have also encrypted the software inside the chip. And if - somehow, someone is able to hack that, we also have the possibility to find that particular controller through the gateways. Every gateway must register automatically through the mesh network and if we did not produce the serial number we will find the controller.

The next question is about privacy. What is accepted as privacy? We have our server in Switzerland. Russia wants its server in Russia, the Chinese want the server in China and in Dubai, they want the server in the Emirates or Dubai.

In Russia they don't have the Swiss standard of privacy. Some of the links have to be opened so the government can see things. The same things happen in Asia and other countries. So we are hosting it in Switzerland.

LED professional: What's about compatibility over time?

Rico Kramer: Some of our competitors work with SIM cards. This can be a compatibility problem. So now we have 2G networks and we're moving to 4G and next year we'll be going to 5G. And when the next generation comes along all of the luminaires that were installed with a 2G SIM card won't run. On the esave side - we are very happy to have our own standard. Over the past 9 years we've had the same protocol. So the people that started 9 years ago with esave still have the same functionality on their controller as they did back then. We give them the firmware updates and they know that this is something special. We might have a change in hardware design but generally the functionality stayed the same. We believe that this makes us trustworthy in the eyes of our clients.

LED professional: In closing would you like to tell us a little about your plans for the future?

Rico Kramer: I can tell you that we are joining the Zhaga consortium. We have engineered a Zhaga controller. This means that the Zhaga socket - they come from Tyco - can be used to install the controller or sensor for a luminaire. For example, right now we need smoke detectors but why not use the Zhaga socket for something like that? In the future the buildings may change. Where there was a coffee-break room there might be a meeting room. So you need a different set of sensors. Why not just unplug it and plug it in where you need it - it meshes automatically. These kinds of ideas make the future very interesting for me.

LED professional: Thank you very much for your time.

Rico Kramer: Thank you. ■

A Study on Aerosol Jet Printing in LED Module Manufacturing

LED module manufacturing technologies have certainly improved over the last few years but the requirements have also increased. More components are packed on today's modules causing additional thermal stress, and, at the same time, the demand for lower cost challenges module manufacturers. So the (re-) search for new materials and new manufacturing processes and manufacturing technologies is still on. Paul Hartmann, Director of the Institute of Surface Technologies and Photonics at the Joanneum Research Forschungsgesellschaft m.b.H., and his team, Andreas Rudorfer, Martin Tscherner, Christian Palfinger, Frank Reil, Franz P. Wenzl with Ioannis E. Seferis, Eugeniusz Zych from the Faculty of Chemistry of the University of Wroclaw investigated the opportunities of aerosol jet printing and proved the applicability for alternative ways of phosphor deposition and integration and to replace wire bonding of dies.

Modern LED packaging technologies have to satisfy the demand for integrating an ever increasing number of components into a module to achieve high light intensity, dynamic color temperature- and light intensity control and high product reliability, while targeting low production costs. State-of-the-art LED dice packaging based on Chip-on-Board (CoB) technology comprises some shortcomings both of the manufacturing process and tolerances but also with regard to potential sources of failures. The extreme thermal conditions LEDs experience in particular in general lighting applications lead to heavy stress of the bonded wires exerted by surrounding silicone due to different thermal expansion coefficients.

Therefore, there is a clear need for alternative packaging processes. A promising technology in this regard is additive manufacturing. While ink-jet printing has gained some attention during the last years due to its material and cost saving potential, aerosol-jet printing has recently demonstrated many advantages. With the latter technology it is possible to print highly viscous inks containing particles up to a diameter of 1 µm and to deposit more material during a single printing step. Based on these technological advantages circuits with a higher ampacity can be realized.

Based on test samples and test structures, in this contribution the potential of aerosol-jet printing in various aspects of LED module packaging will be discussed, ranging from the deposition of the die-attach material, wire bond replacement by printed electrical interconnects to aspects and new concepts for phosphor deposition and integration.

Introduction

Light-emitting diodes (LEDs) are currently conquering the market for general lighting [1, 2]. However, there are still many challenges ahead before LED based luminaires will realize their full potential in terms of energy efficiency and white light quality [3]. Besides these quality features, which are directly related to comfort and well-being, also the reliability of the luminaires is of particular relevance for convincing people to abandon traditional lighting sources and to replace them by those based on LED technology.

With respect to reliability, state of the art fabrication of LED modules based on chip-on-board (COB) technology comprises some shortcomings both with respect to the manufacturing process itself but also with regard to potential sources of failures and manufacturing impreciseness. For instance, the electrical contacting of LED chips with surface-mounted contact pads is based on wire bonding, with the wire bonds encapsulated

in a silicone layer for mechanical protection. For white light generation, phosphor particles are added to this silicone layer, forming the so-called color conversion element (CCE).
The extreme thermal conditions LEDs experience in particular in general lighting applications, lead to heavy stress between the bonded wires [4, 5] and the surrounding silicone, because of their different thermal expansion coefficients. In particular, despite the overall thermal load, one also needs to consider the differences in temperature, which may occur within this silicone layer.

As a result of the low thermal conductivity of silicone and the heat induced in the phosphor particles upon the color conversion process (Stokes shift, quantum efficiency lower than unity), the highest module temperatures are often located inside the CCE, in particular nearby its top surface. Depending on parameters like the drive current, the quantum efficiency of the phosphor and the thermal conductivity of the matrix material, the temperature differences between the bottom part and the top part of the CCE may reach values in the range of more than 100 K [6]. As a result, the wires may break, resulting in an imminent failure of the module.

Also state of the art manufacturing technologies for the CCE itself comprise some shortcomings with regard to the fabrication of CCE architectures that support superior white light quality and good heat dissipation. For example, dispensing, the most common method for phosphor deposition, suffers from low accuracy. In addition, wire bonds may also negatively affect the geometry of a CCE [7].

Therefore, there is a clear need for alternative fabrication processes. A promising technology in this regard, which offers the potential for a more proper system configuration and integration in many aspects of module manufacturing, is additive manufacturing, a technology which has gained a lot of attention during the last years due to its materials and cost saving capabilities.

Additive printing technologies caused a paradigm shift in various technological sectors [8]. An increasing demand for new innovative, functionalized materials and corresponding process technologies, especially in the field of printed electronics, currently gives rise to an enormous number of academic and industrial research activities. Additive manufacturing is also suitable for direct fabrication of electrical interconnects on nearly any rigid and flexible substrate. According to market research companies such as IdTechEx this market will grow dramatically within the next 10 to 15 years.

For some time conductive and insulating structures on various substrates were mostly fabricated by ink jet printing. First attempts of fabricating LED modules by electrical interconnects made by ink jet printing have already been reported [9, 10]. But the use of ink jet printing is limited due to the need for high currents and low resistivity of electrical interconnects in LED operation. Other disadvantages of ink jet printing are: low viscosity of the ink, low solid contents and a limited particle size due to the nozzles geometry as well as the need for a low standoff distance to the substrate. Therefore, a mounted die may obstruct the nozzle, which runs counter to the demand for integrating an ever increasing number of components (photo diodes, sensors, etc.) into a module to comply with the customers' expectations, such as high light intensity, dynamical color temperature- and light intensity control, and so forth.

In comparison with ink jet printing, aerosol jet printing has demonstrated many advantages when printing high precision electronic circuits on 3D substrates. Using aerosol jet printing it is possible to print highly viscous inks containing particles up to a diameter of 1 µm and to deposit more material during a printing step. Based on these technological advantages circuits with a higher ampacity can be realized. A higher ampacity is an essential requirement for a better device performance. Due to the fact that aerosol jet printing allows for a much larger distance between the nozzle and the substrate surface, it is also possible to manufacture modules with a much higher dice integration density.

In order to exploit these advantages, the applicability of aerosol jet printing is investigated in many fields of application. Several scientific publications discuss the use of aerosol jet printing for organic solar cells [11], thin film transistors [12], the fabrication of ring oscillators [13] or the development of novel fuel cells [14]. Nonetheless, with the exception of some patent applications, publications dealing with the application of aerosol jet printing for the fabrication of LED modules are rare.

In the following, we address some of the challenges with respect to the module fabrication outlined above and discuss the potentials of aerosol jet printing in this regard. Within this work, the die-attach material, the electrical interconnects to the LED dice and the phosphor materials are applied by aerosol jet printing in order to fabricate a white light emitting LED module.

Experimental Methods

For aerosol jet printing (Figure 1 - scheme of the process), the ink is placed into a pneumatic or ultrasonic atomizer that creates a dense aerosol of droplets (1) with diameters ranging from 1-5 microns (2). The aerosol jet printing process with the pneumatic atomizer is influenced by a number of (adjustable) parameters, including ink temperature, carrier gas flow rate, exhaust gas flow rate sheath gas flow rate, nozzle diameter, tube heater temperature, working distance, stage speed, and stage

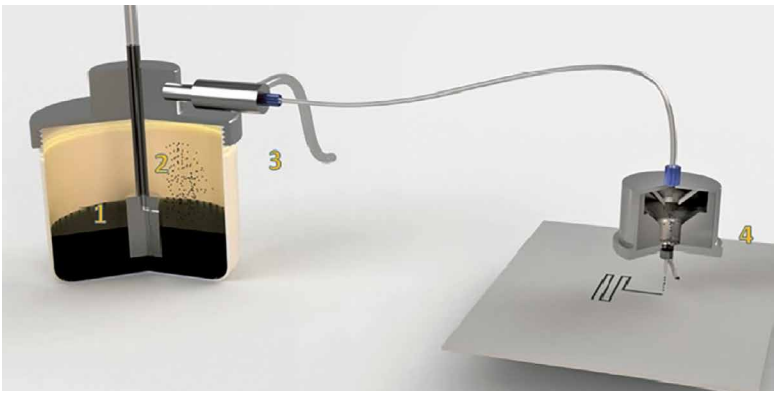


Figure 1:
The heat load is Principle of Aerosol jet® printing

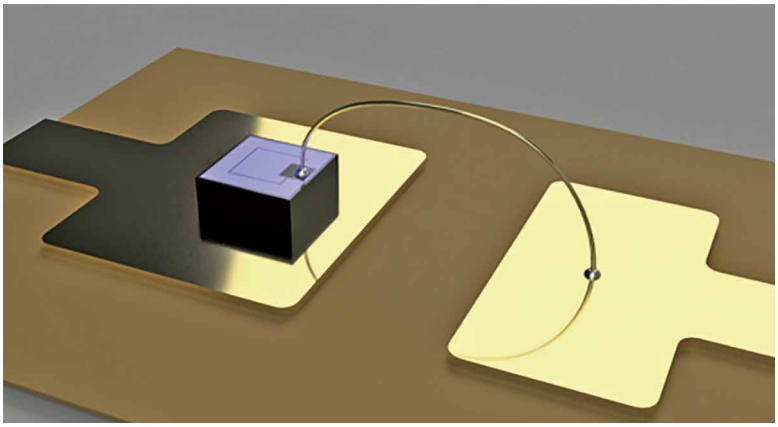


Figure 2:
Schematic of replacing the wire bond for contacting the top contact pad of an LED module by printed electrical interconnects. Firstly an insulation layer is printed on top of the bottom contact pad and the sidewalls of the LED die, subsequently an electrically conductive material is printed on the top of the insulation layer to form the electrical interconnect. To electrically interconnect the bottom contact pad and the LED die an electrically conductive die-attach material is used, which is also deposited by Aerosol jet printing

temperature. Subsequently the generated aerosol is carried by a gas (N2) flow to the deposition head (3). Within the deposition head (4) the aerosol is focused by a second gas flow (sheath gas). The resulting, high velocity converging particle stream is deposited onto the substrate creating fine features with line widths down to 10 µm. The line shapes and/or the written patterns can be designed using CAD. During the deposition process there is no physical contact between the material being printed and the nozzle. This allows keeping the critical areas of the print system clean and free of material build up preventing nozzle clogging and particle stream interruption.

The process has a natural standoff distance of 1- 5 mm or more between the nozzle and the substrate. Therefore conformal writing on 2D or 3D surfaces can be performed without changing the z-position of the nozzle within a range of a few millimeters.

In this study, the following printing system and materials were employed. For aerosol jet printing an Aerosol jet 300CE Deposition System from Optomec Inc. was used. For the die-attach material a silver nanoparticle filled epoxy, ACURA E8074 from Resin Designs LLC, designed for dispensing through an Optomec Aerosol jet system was used. For the isolation layer a polyimide (Sigma Aldrich) diluted with n-Methyl-2-pyrrolidon (NMP), ratio 1:2, was the material of choice and the electrical interconnects were fabricated from a conductive ink based on silver nanoparticles for aerosol jet printing, PG-007 from PARU. For the phosphors either a Yttrium aluminium garnet activated by cerium (Ce:YAG, with the phosphor particles milled in-house with a ball mill to smaller, printable particle sizes of 1 µm and below as will be discussed elsewhere in detail) or a fine powder of Lutetium aluminium garnet activated by cerium (Ce:LuAG) [15] was used. Besides the Ce:LuAG phosphor, the related ink was fabricated from Disperbyk D-142, AZ125-NXT, PGMEA and Veratrol. The LED-dice used are dice in vertical thin film configuration (with one contact on the top and the other at the bottom of the die). In particular, Cree EZ 500 Gen II and Cree EZ 900 Gen II (in case of printing the “LED” symbol on top of the die) dice were used.

Figure 2 shows a schematic of an LED die mounted on a printed circuit board (PCB) for which the wire bond (left side) for connecting the top contact is replaced by a printed interconnect (right side). For electrical insulation in case of the printed interconnect, first an insulation layer (covering the bottom contact pad and the sidewalls of the LED die) is printed and the electrically conductive interconnect is printed on top of it. In this work the print head was mounted in a 45° angle using a special tilt fixture.

Generally, printing over chip sidewalls and contact pads requires either tilting of the substrate or the print head in order to achieve sufficient surface coverage. In addition, due to shadowing effects it is not always possible to print the whole interconnect from the same position of the print head. For instance, as shown in figure 3, from printing position 1 it is possible to print the isolation layer and the electrical interconnect on the sidewalls of the die as well as on

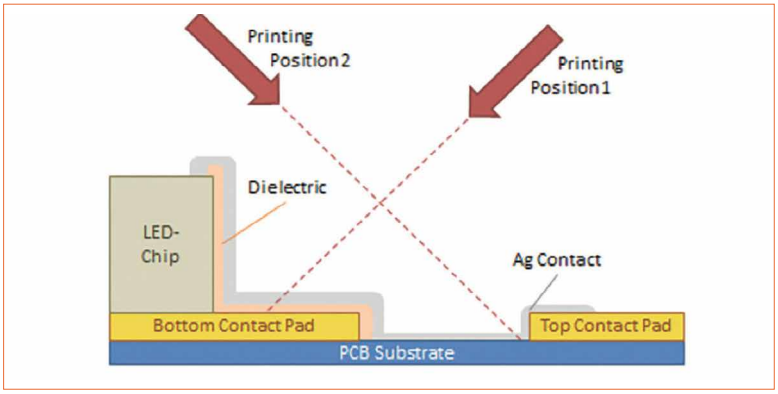
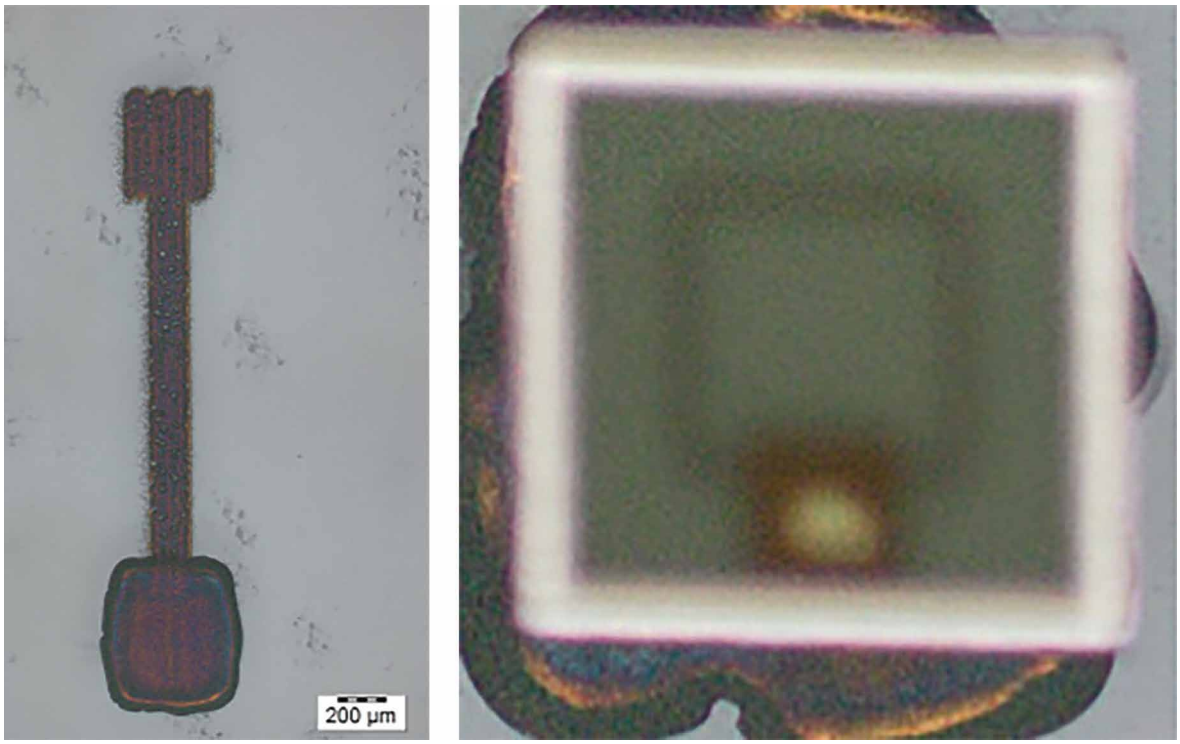


Figure 3:
Printing scheme: On the bottom contact pad and on the sidewall of the LED die the insulation layer and the electrical interconnect on top of it are printed from printing position 1. Since for this configuration some parts of the top contact pad are shadowed, the printing head is brought into printing position 2, from which the electrical interconnect on the top contact pad is printed



Figures 4:
Printed contact pad and interconnect, both printed from the die-attach material on a glass substrate (left). Subsequently, an LED die is placed on the die-attach material (right)

the bottom contact pad, however, some parts of the top contact pad are shadowed for printing position 1. Therefore, for printing the whole electrical interconnect (connection to the top contact pad) the nozzle arrangement (printing position 2) was changed (Figure 3).

Results and Discussion

Die-attach material

As a first step in the fabrication process of a white light emitting LED module the die-attach material is printed onto the bottom contact pad. Using aerosol jet printing, the required amount of material can be precisely controlled and tuned e.g., to the chip size. Too little or too much of the die-attach materials might lead to either an open contact between the die and the contact pad (which also impedes heat transfer) or a short circuit in case the die-attach material climbs up the sidewalls of the die. To demonstrate the flexibility of materials deposition, in the left image of figure 4 both a contact pad and an electrical interconnect were printed from the die-attach material on a glass substrate. Subsequently, a chip was mounted by applying an appropriate amount of die-attach material.

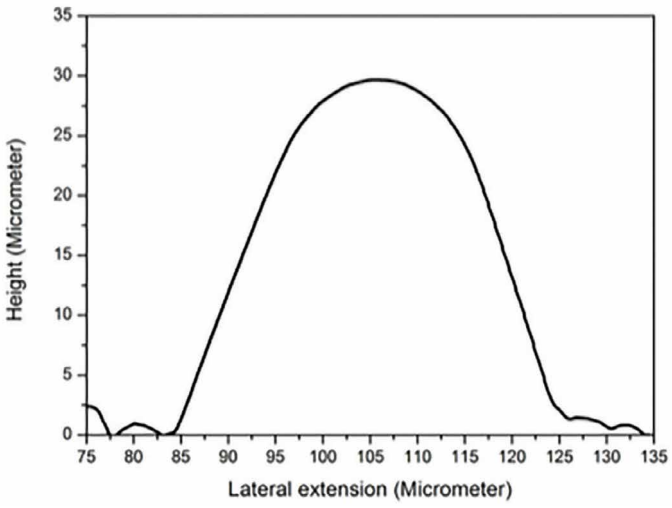


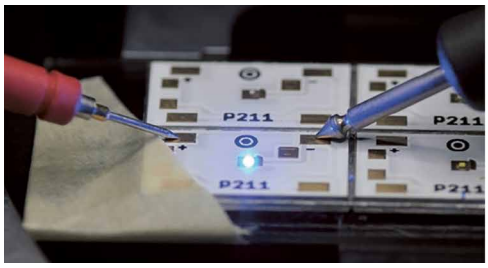
Figure 5:
Profilometer scan of the electrical interconnect on the polyimide layer

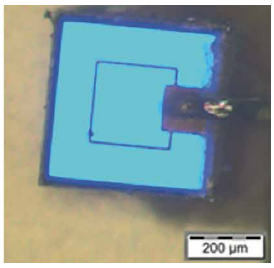
This process is used in the following to deposit the die-attach material on the bottom contact pad of the PCB.

Electrical interconnect

In the first step of the electrical interconnect formation procedure a polyimide layer was deposited on a sidewall of the LED die and on the bottom contact pad serving as an insulator as well as a smoothing layer (for the electrical interconnect layer). The thickness of the insulation layer can be tuned by printing several layers on top of each other. Albeit thicker layers are in advantage to lower the risk of short circuits, they might pose the problem of (micro) cracks during curing. Therefore, the height of the insulation layer was selected in the lower 10 µm range.

Subsequently, PG-007 was printed onto the insulation layer to form an electrical interconnect with a width of 40 µm and a height of about 30 µm. Figure 5 shows the profile of the electrical interconnect on the polyimide layer as determined with a profilometer, figure 6 images of the resulting LED module under operation.





Figures 6:
LED module with a blue emitting LED die (left) the LED die under operation (right). Both the die-attach material and the electrical interconnect were deposited by Aerosol jet printing

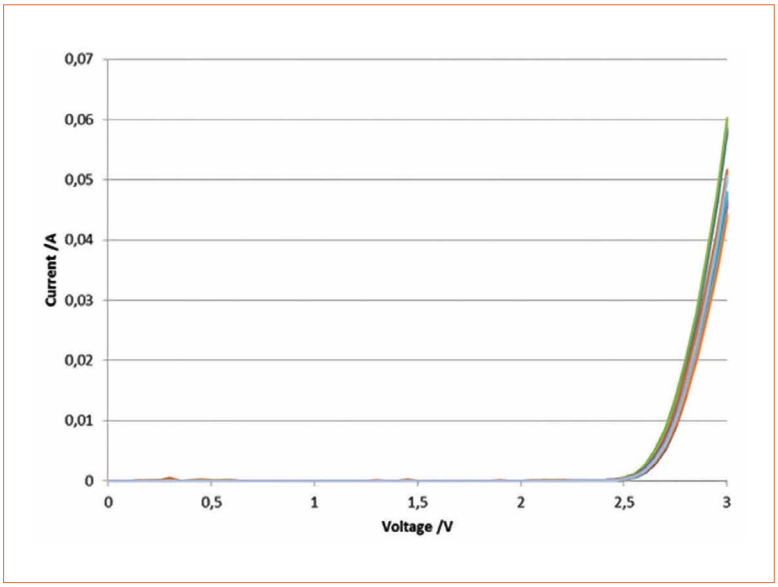
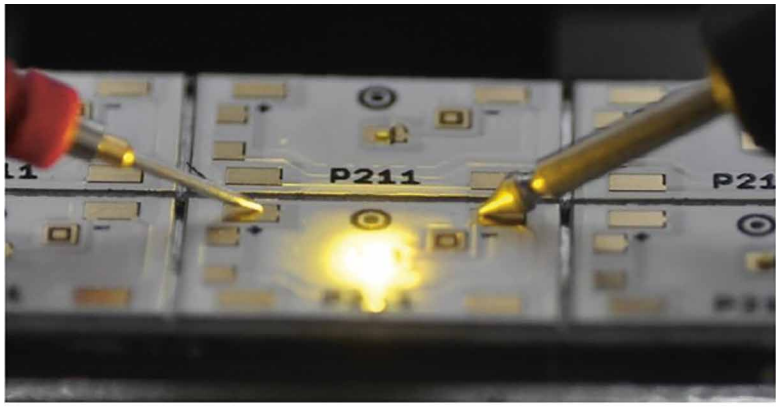
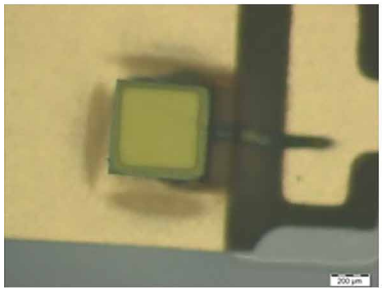
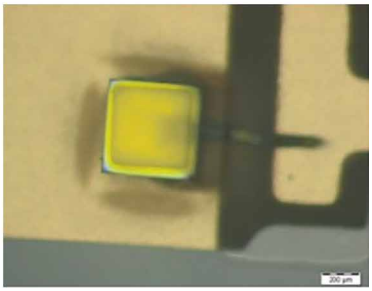


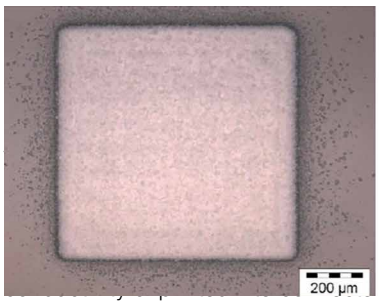
Figure 7:
Onset behavior of the I/U characteristics of 13 LED modules with the die-attach material and the electrical interconnects deposited by Aerosol jet printing. The onset behavior is in good accordance with the data sheet

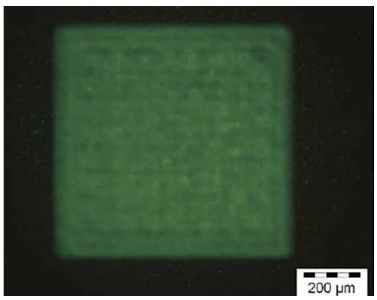






Figures 8:
LED with the printed die-attach, printed electrical interconnects and a printed phosphor layer on the top of it in the off-state (bottom left) and under low-current operation (top and bottom right). The phosphor is a conventional Ce:YAG phosphor that was milled with a ball mill down to particles sizes of 1 µm and below





Figures 9:
Optical (left) and fluorescence (right) microscope images of a square printed from the nanosized Ce:LuAG phosphor

Phosphor deposition

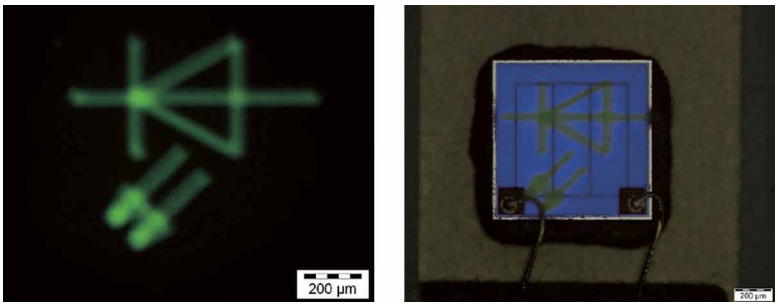
In the final step of the fabrication of a white light emitting LED module, the phosphor layer is printed on top of the LED die. Figure 8 shows an LED module, on which in addition to the fabrication steps shown in figure 5 also the phosphor layer (Ce:YAG) was deposited by aerosol jet printing.

It is still more convenient for aerosol jet applications to use phosphors synthesized with small particle sizes than to mill down conventional 10 µm phosphors. Therefore, in particular nano-sized phosphors are very promising for aerosol jet printing of a phosphor layer. In order to highlight the achievable preciseness, experiments were also performed with a Ce:LuAG phosphor with particle sizes in the nanometer range. Figure 9 shows an optical microscope image of a printed square (4 printed layers one above the other) from such a phosphor on a glass substrate as well as a fluorescence microscope.

Still, in order to demonstrate the high precision in the deposition of the phosphor layer that can be achieved by aerosol jet printing, a “LED symbol” was printed (5 layers) on a glass substrate using the Ce:LuAG phosphor. Figure 10 shows a fluorescence microscope image of this LED symbol on the glass substrate as well as an optical microscope image of an LED under operation on which the same LED symbol was printed (Cree EZ 900, Gen II with conventional electrical interconnects by wire bonding). The precision and the flexibility of aerosol jet printing for CCE deposition and shaping are therefore clear advantages, considering the importance of the geometry of a CCE and its exactness with respect to the white light quality of an LED [17] as well as the need for some specific shapes (e.g., with respect to efficacy, alternating areas of two phosphors in horizontal direction are preferable in comparison with two phosphor layers on top of each other [18]).

Conclusions

Additive manufacturing using aerosol jet printing technology was shown to offer a great potential as an alternative technology for the deposition of the die-attach material and the electrical interconnects of an LED module, for nowadays at least in low power devices. In addition, high precision deposition of the phosphor layers for color conversion was demonstrated, which can be employed even in high power applications. ■



Figures 10: **Fluorescence microscope image of an LED symbol printed from the Ce:LuAG phosphor on a glass substrate(left). LED with an LED symbol printed from the Ce:LuAG phosphor on top of it under operation (right)**

Acknowledgements:

Financial support from the Austrian bmvit, Project AeroPack, is gratefully acknowledged. The authors also thank C. Auer for performing the profilometer measurements and Tridonic Jennersdorf GmbH for providing the PCBs.

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Laser Technology for Lighting Applications: A Review and Analysis of a Promising Technology

LEDs are currently the dominating light source: efficient and cost effective. But LEDs also have some drawbacks. Another interesting technology developed slowly in the shadow of LEDs and has become an interesting solution for some specific applications: GaN based blue solid state laser devices. Although this technology offers some very interesting advantages, it also has challenges. Nicola Trivellin, Matteo Buffolo, Carlo De Santi, Gaudenzio Meneghesso, Enrico Zanoni and Matteo Meneghini from the University of Padova and its spin-off LightCube have been working toward the development of experimental systems and demonstrators and disclose their findings of the comparison between LED and LD systems.

In the last two decades the technology at the basis of the lighting field has seen a profound renovation: Light Emitting Diodes evolved from technological exotics to well-established products allowing for high efficiency, reliable and digital capabilities light sources. With the advent of luminous efficiencies up to 300 lm/W, mechanical standardization and reduced costs, Gallium Nitride based LEDs are now the standard light sources for home, industrial and automotive applications. Several research groups have been working toward the identification and the improvement of some still-present limitations of the LED technology, the most famous is known as efficiency droop, which causes a gradual decrease of light emission efficiency as the operating current density of the device increases. Efficiency droop not only has an effect on the maximum achievable efficiency at higher currents, but strongly affects the maximum light density that can be emitted from an LED chip. The direct effect of this limitation is the intrinsic need of larger optics, or multiple packages to control big Light Emitting surfaces in order to achieve high lumen output solutions. Several solutions have been proposed to improve the performance of Light Emitting Diodes, in particular semi-polar and non-polar crystal growth directions are the most promising, but faces difficulties in growth stability and yield. Another emerging technology to achieve high flux density and to solve the droop issue is based on semiconductor laser light. T his technology approach shall here be reviewed.

Introduction and the Current Status of Laser Lighting Technology

The development of high power GaN based blue laser devices [1] allows the development of remote phosphor converted laser based light source, where blue radiation emitted from a laser diode (or laser diodes array) is optically collimated (or focused according to the specific application) and excites a phosphor layer deposited over a transparent or reflective substrate, these systems are also known as LARP (Laser Activated Remote Phosphors). The combination of visible blue (450nm) light and remote phosphor is a technology well known for LEDs, but finds application also for laser diodes lighting systems.

In the latter case, the radiation is generated from the laser facet with a size of approximately a few hundredths of μm^2, while for an LED similar optical power is generated

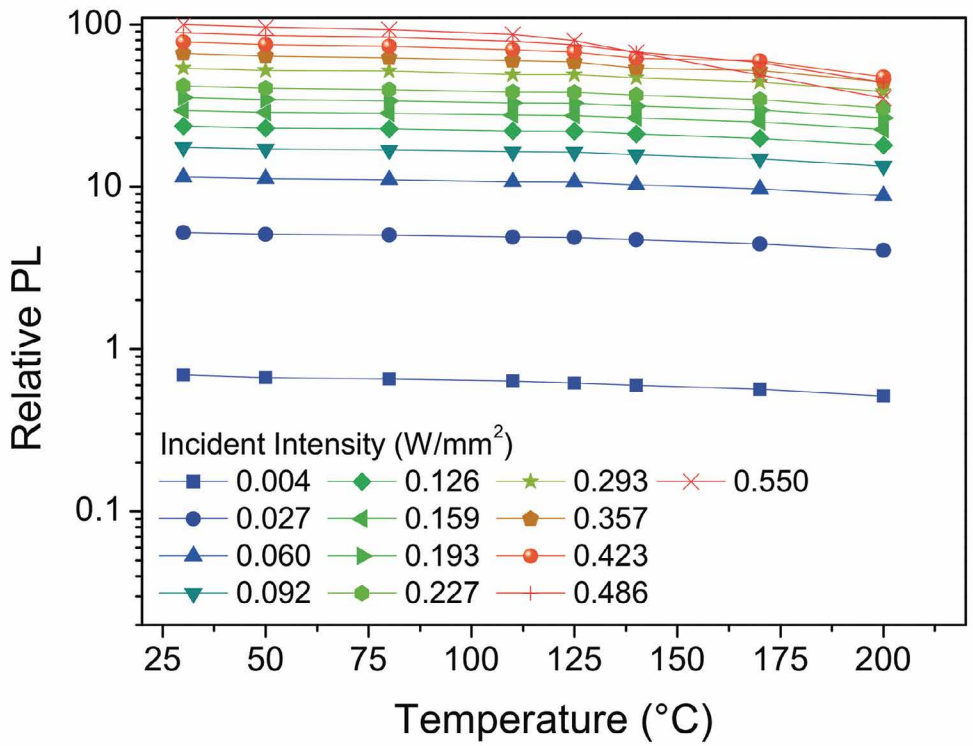


Figure 1:
Commercial binder-free Phosphor Photoluminescence as a function of irradiance and temperature[I]

typically from an active region of 1 mm². Moreover, the stimulated emission, typical of a Laser Diode, makes it possible to instantly recombine all the charges injected into the quantum region, thus not suffering from droop effects.

The laser radiation then hits the phosphor with a much higher irradiance, thus allowing much higher luminance, but also locally increasing the temperature of the phosphor due to Stokes shift losses, resulting in less than unity efficiency. The structure of a laser lighting system is dependent on whether the radiation passes through the phosphor deposited on a transparent substrate (similar to LED mixing chamber solution) or is reflected from the phosphor itself deposited into a mirrored substrate.

Experimental systems and demonstrators were developed [2] to analyze the state of the art technology and to study the advantages and limitation of LARP systems in comparison to standard LED based solutions. In the following, the major results of this work will be summarized and the characterization will be reported.

The comparison concerns:

- Binder-free Phosphors,
- Diffusive LARP based setups,
- Transmissive narrow beam LARP setups,
- Reflective narrow beam LARP setups

Diffusive LARP Based Setup

To characterize the efficiency of laser based white light systems, the luminous and chromatic performances of two identical prototypes with different light sources were compared.

The compared prototypes are:

- A commercially available GaN royal blue (455 nm) LED with an active area of 1 mm² and a maximum driving current of 1 A (typical emitted power of 550 mW at 350 mA, 25°C)
- A high power GaN multimode Laser Diode in TO56 package with a maximum optical output power of 1.6 W at a maximum drive current of 1.5 A, 25°C

The prototypes were completed by a 3D formed commercial remote phosphor candle shaped structure (nominal CCT= 3000 K, CRI = 90, diameter 16.9 mm, height 21.2 mm). The output light source is of the diffused type, since the 3-D phosphor act as a light diffuser.

Results from the comparison of the absolute lumen output of the LED and LARP systems are reported in figure 2. Results indicate that, once the Laser diode has overcome its threshold current, the LARP system is able to achieve a flux in excess of 360 lm at 1.5 A, as opposed to a flux of approximately 260 lm at the same current for the LED based system. This behavior is opposed to the efficiency/current characteristic of the LED based system that, although higher at lower currents, drastically decreases when the driving current is increased, due to efficiency droop. The efficiency of the laser system overcomes that of the LED system at a current of 1.4 A for the tested devices. This comparison has been specifically designed to study the droop behavior and the LED is driven above its maximum absolute current. The low efficiencies are caused by the choice of a high CRI phosphor material and a

Figure 2:
Comparison of luminous flux and efficacy of LD vs. LED

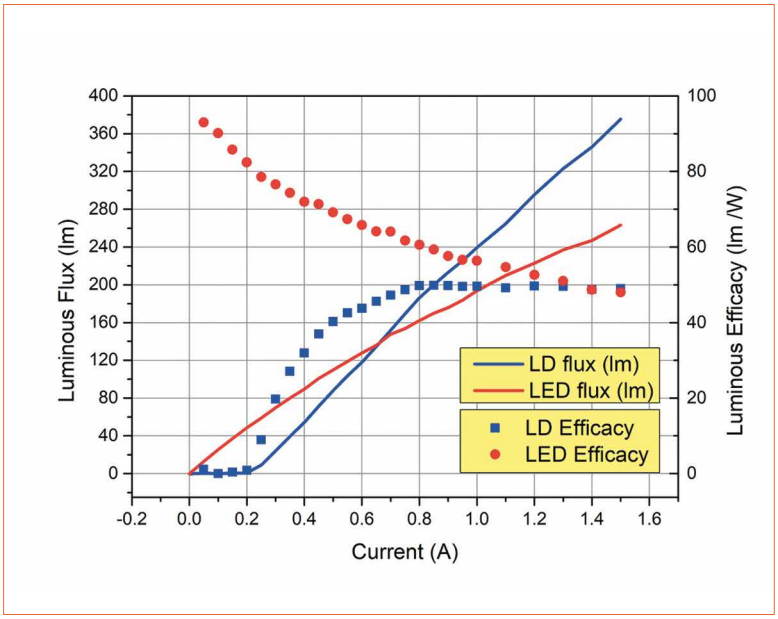


Figure 3:
Comparison of the spectra of LD vs. LED

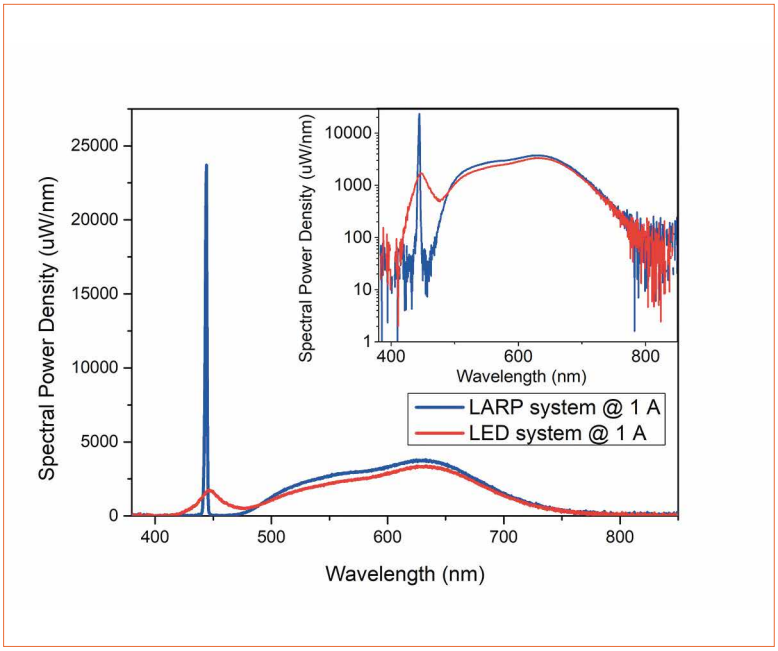
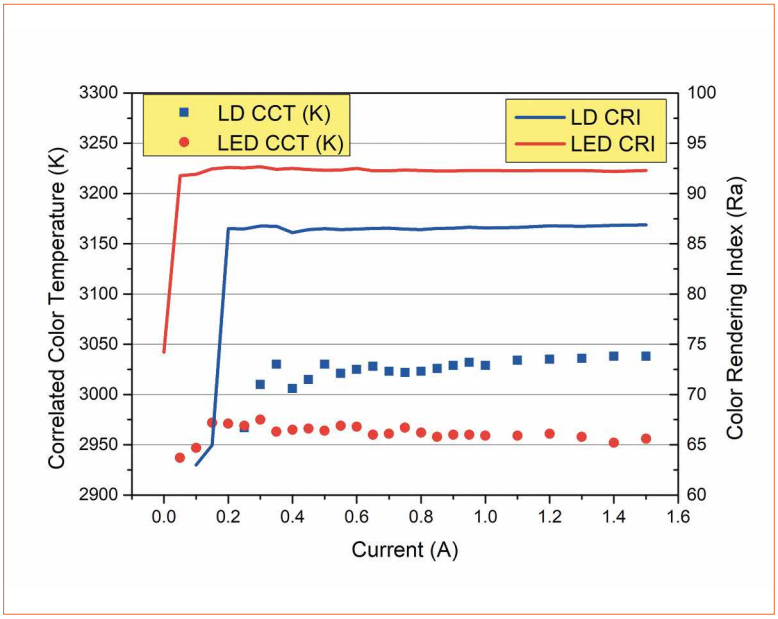


Figure 4:
Comparison of CCT and CRI of LD vs. LED



sub-optimal mixing chamber for the setup, which is identical between the LED and the laser source and therefore far from ideal.

The spectrum (Figure 3) of the blue peak of the LARP prototype is much narrower and thus much more intense as opposed to the LED prototype. The blue peak for the LARP setup is approximately one order of magnitude above the blue LED emission peak. Correlated color temperature (CCT) has a value of 3025 and 2950 K for the LARP system and LED prototype respectively; Color Rendering Index has an average value of 86 and 92 respectively. CCT and CRI do not show any significant variation with the driving current as presented in figure 4, thus indicating a good stability of the light chromaticity at different driving conditions.

Transmissive Narrow Beam LARP Setup

The first iteration of the study for a focalized LARP solution is based on a transmissive structure. The laser is collimated on the phosphor template, which is a structured glass substrate with the phosphor material encapsulated onto a silicone layer. This commercial phosphor structure allows an optimal uniformity, but the thermal resistance is limited by the conductivity of the glass thus only sustaining reduced laser irradiance. The setup structure, reported in figure 5, is composed by the laser diode positioned over a heatsink, a double lens condenser, a phosphor template and a focalizing lens; all the optical elements of the system are 1" spherical lenses with different focal distances. The emitted beam from the optical transmissive structure has been projected over a white reference screen, placed at 1320 mm from the focalizing lens, where the intensity has been measured by means of a calibrated CCD camera. The total flux of the light source has been measured by enclosing the entire structure into a Labsphere LMS-650 sphere.

The system optical performance analysis indicates that upon an accurate focalization the source is able to achieve a narrow emitted beam by means of small size optics. Figure 6 demonstrate a 2° average divergence is achievable with 1 inch optics, with average color uniformity over the projected image, since some yellow ghosting is visible on the minor axis of the beam.

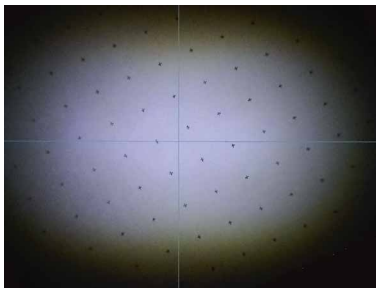


Figure 6: **Projected beam**

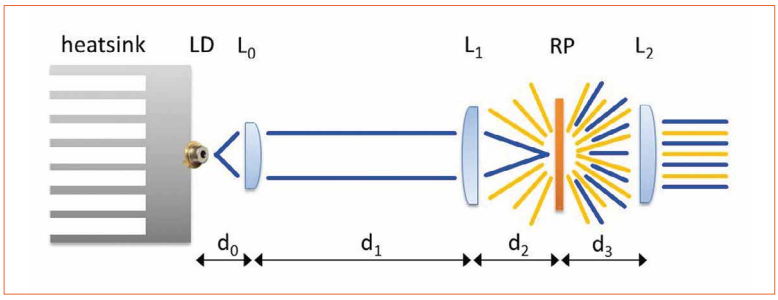


Figure 5: **Sketch of the laser transmissive setup [I]**

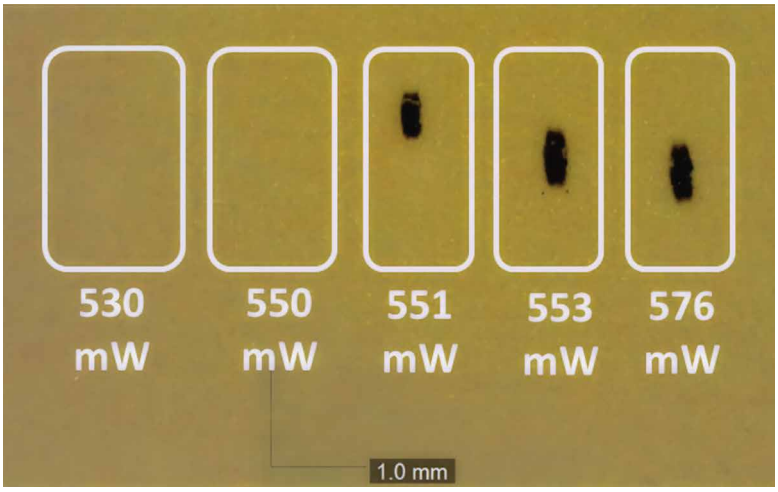


Figure 7: **Burning marks on silicone encapsulated phosphors over glass substrate when excited by a too high laser irradiance [I]**

The clear drawbacks of the transmissive system are:

- Low efficiency due to high optical losses and bidirectional emission of the phosphor template
- Limited maximum irradiance over the phosphor template due to low thermal conductivity of the transparent substrate

Figure 9 shows the feed forward effects of efficiency reduction with self-heating temperature increase. The two drawbacks can be reduced by implementing a reflective phosphor structure described in the following.

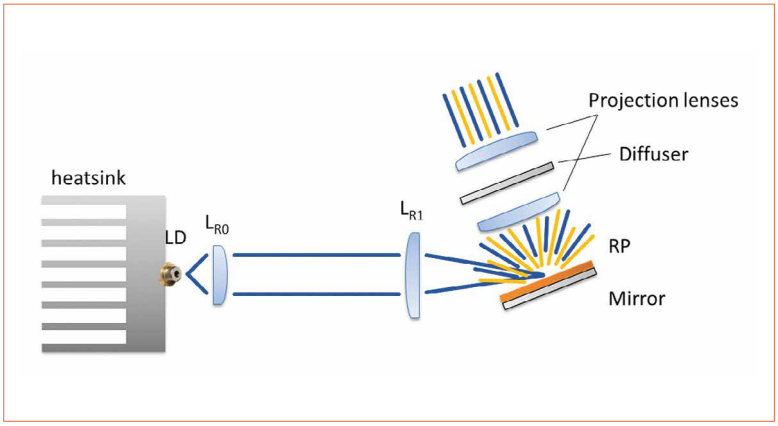


Figure 8: **Sketch of the lens based reflective setup [I]**

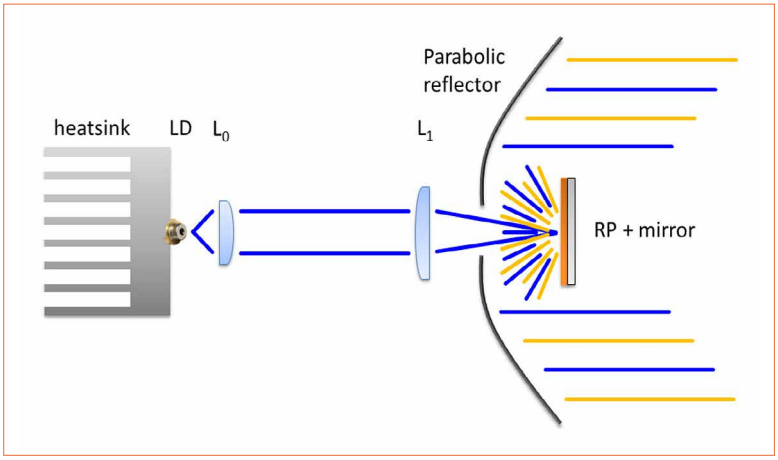


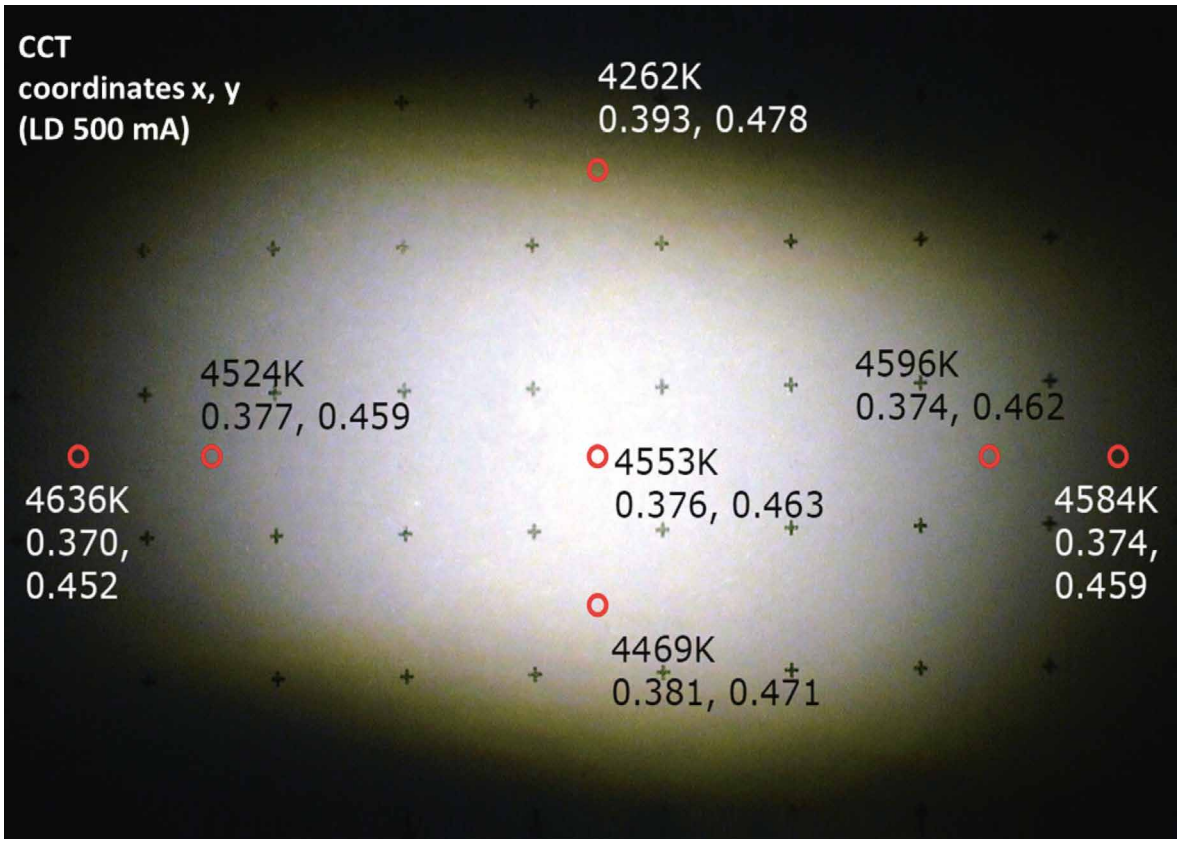
Figure 9: **Sketch of the parabolic reflector based reflective setup [I]**

Reflective Narrow Beam LARP Setups

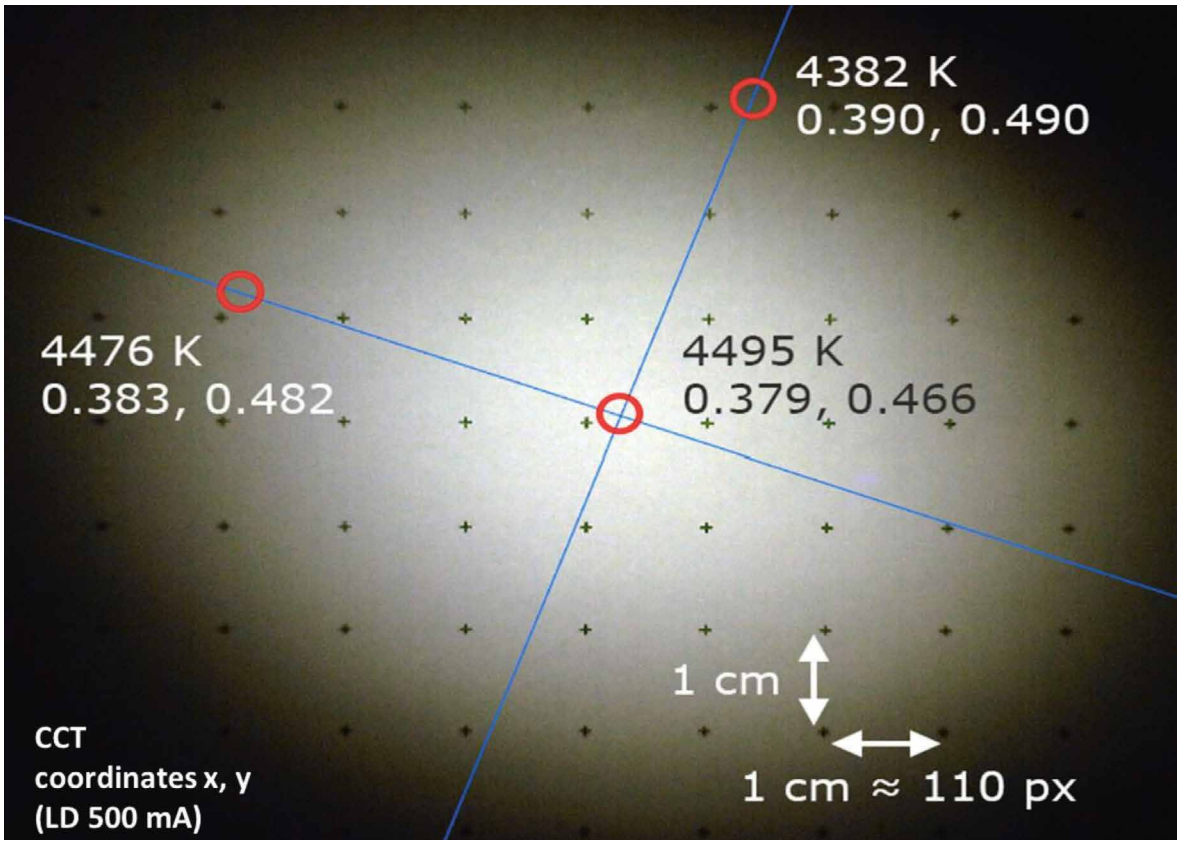
As previously described a different approach with respect to the transmissive structure is related to the possibility of layering the phosphor over a reflective surface. As presented in figures 8 and 9, reflective phosphor surfaces have the clear advantage of (nearly) doubling the amount of light collected by the optical setup. Prototypes of reflective structures are built around a binder-free phosphor layer deposited over a glass based optical mirror (based on dielectric reflector).

Figure 8 reports on a setup based on a tilted phosphor template that is excited by a collimated laser beam. The emitted white light is then focalized by an optical structure based on two 2” spherical lenses and an engineered symmetrical glass diffuser to homogenize the emitted beam. Figure 10 reports on the shape, size and chromatic

Figures 10:
Beam of the lens based reflective setup [I]



Figures 11:
Beam of the parabolic reflector based reflective setup [I]



properties of the emitted beam at a distance of 330 mm from the last focalization lens. Results report good color uniformity over a beam of 6° divergence, although quite far from the ideal white spot.

An alternative structure can be manufactured and based on a parabolic reflector presented in figure 9, where the laser beam is focalized through a hole in the reflector and thus exciting the phosphor template placed at the focal point of the parabolic reflector. The resulting beam size (Figure 11) has an average divergence of 8.5° and a good color uniformity.

Structure	Average beam divergence	Color uniformity over beam area	Efficacy	Diameter of the optical element
Reflective	2 °	Average	6 lm/W	25 mm
Lens reflective	6 °	Good	12 lm/W	50 mm
Parabolic reflector reflective	8.5 °	Good	18.7 lm/W	90 mm

Summary and Conclusions

The summarizing table 1 reports the major results of the three narrow beam laser tested solutions, where care should be taken of the fact that the phosphors are of different origins between the transmissive setup (commercial silicone encapsulated on glass) and reflective setup (custom drop casted on mirror). It is interesting to note that efficiency strongly improves on reflective setups, but also the divergence of the emitted beam. Of course, efficacies are still relatively low, but a significant improvement can be reached through laser diode and phosphor optimization.

In conclusion, the research shows that laser-based lighting, although still a growing technology, can push the limits of solid-state lighting in terms of efficiency at high currents thanks to low droop and optical management of the emitted light. The technological limits are still related to the laser diode performance and costs and the development of efficient cooling structures for the phosphor template.

Will LEDs or lasers win in the long run? It is very likely that both technologies will find wide application and create a real change in the lighting paradigm. The real winners will be the end users who will have access to two flexible and different technologies for lighting: LEDs and lasers. This will increase the degrees of freedom for designers, leading to an even bigger penetration of solid-state lighting in the application market. ■

Credits:

[I] Image/graph courtesy of MDPI Materials

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Challenges of the Integration of Lighting Systems and Components in IoT

Following the rapid penetration of LEDs, lighting is now becoming integrated into the Internet of Things. Over the past three years a consortium of leading European companies worked on the OpenAIS project, which was partly funded by the EU within the Horizon 2020 program, and now showing the results working at a full size demonstrator. In this follow up article to the introduction article of LpR 67, Ben Pronk, System Architect at Signify, and Stefan Verbrugh, Project Manager at Signify and Work Package leader in OpenAIS give deeper insight into the project. They explain the lighting specific challenges, describe the generic challenges for IP controlled lighting and present the approach to these challenges. They conclude by summarizing the findings from the pilot.

Over the past 3 years the OpenAIS project has worked on use cases, requirements and an architecture exploiting emerging IoT-technologies and IP to the end node for lighting. The defined architecture was implemented and evaluated in a real operational office environment by the installation of 400 luminaires in the White Lady building in Eindhoven (Figure 1). The installed system comprises wired and wireless luminaires from two different vendors: Philips and Zumtobel, seamlessly operating as one system. Use cases exploiting the advantages of this new lighting control system, for example: app-based personal light control, BMS integration and daylight control have been demonstrated.

Figure 1:
The White Lady pilot site

During the creation and evaluation of this pilot, the team had to overcome several challenges that result from applying not yet mature or “fit for purpose” IoT-technologies in this first of a kind lighting control system. This article describes the solutions to these challenges composed by the project team and the lessons derived for future IoT-based Lighting Control Systems.

The Move To IoT

The move to IoT fits in the overall picture of four decades of digitization. Where the digital changeover first happened in the domains of complex and large equipment like manufacturing lines and medical devices, it gradually came down, driven by the relentless Moore's law, via CE and telecommunication devices to finally reach even the smallest devices like door locks, luminaires and lamps. In all the affected domains this transformation has come with significant benefits in (product) costs and development efficiency by leveraging hardware, network and software stacks from a rapidly expanding ecosystem offering standardized solutions. The evolving and expanding ecosystems, often driven by de-facto (not formal) standardization, truly changed the way of working in entire industries.

The digital transformation in lighting does not only offer cost reduction, it also brings several additional benefits. Lighting systems can now utilize the network infrastructure in the building for control (and sometimes power) instead of using dedicated (and often costly) lighting solutions. Off the shelf protocols are supported by transparent gateways without (application) protocol translations and related development effort. Standard IP connectivity for lighting also enables much easier interoperability with other systems, such as Building Automation Systems (BAS), smart grids and cloud services that all are moving or have moved away from dedicated connection and protocols towards IP-backbones.

The interoperability, the IP-standardization, the network openness and growing ecosystem, together, enable a growing offering of services that are now unavailable or often nearly (economically) impossible. A simple example of such service can be found in the well-known occupancy detection function, applied in lighting systems for energy reduction purposes and ease of use already for decades. Sharing the available occupancy data collected by presence detectors of the lighting control system with HVAC, opens up advanced control and increased energy saving opportunities.

Many have therefore predicted the approaching end of controls systems and protocols that are intended to control lighting only. The project is first to fulfill this promise of an open IP-based system for professional indoor lighting controls.

Overview of Lighting Specific Challenges for the Project

Despite the fact that lighting does follow the general historic trends in digitization, the research revealed several lighting systems specifics that prevent a simple, one to one application of these in the lighting domain. The following points require specific attention when introducing standard IoT-technology for lighting control systems.

Duration of deployment

Lighting systems are normally deployed in a building for at least 20 years of continuous operation, the major maintenance activity over that period being the replacement of lamps/ILEDs reaching their designated end of life. However, digital systems, in general, have a much shorter (economic) lifetime. Network protocols, cpu's and software standards tend to be replaced at a frequency of just a few years. Various strategies to deal with this discrepancy have been applied in different industries with the "throw away after two years" of the early PC and mobile phone markets as the extreme variant of upgrade strategy. As replacing the entire luminaire after a few years is not a viable approach in the lighting industry (the cost of installation of the same order of magnitude the cost of the luminaires) other options need to be explored.

THE OpenAIS CONSORTIUM & THE OpenAIS PROJECT

The OpenAIS project started in 2015 as a response to the emergence of IoT as a leading force in the digitalization of buildings and homes. OpenAIS is a European Community supported project that is partially funded through the Horizon2020 program. The project team started from the assumption that further developments in IoT-infrastructure would drive a revolution in connected lighting solutions, moving these to open (IoT) standards and off the shelf Internet technology. Additionally, the project definition included the vision that the ubiquitous lighting infrastructure would be an ideal platform to integrate multiple IoT-devices and deliver additional functionality beyond lighting. Such a development would revolutionize the lighting business, moving it away from vertical silos and proprietary (and closed) solutions towards the use of (open) IoT- ecosystems and standards. As has happened in many "digitized" domains, this transition would, in the view of the project consortium members, also greatly shake up the entire value chain and stimulate demands for openness and interoperability by professional customers keen to avoid lock-in.

The OpenAIS project runs from 2015 to mid-2018 and is coordinated by Signify (formerly known as Philips Lighting). The OpenAIS consortium includes partners from all segments of the lighting industry and its adjacencies: facility management, installation, lighting manufacturing, technology suppliers and two academic partners. As a carrier case for the project Professional Indoor Office lighting in Europe has been chosen.

The OpenAIS consortium

The OpenAIS partners are Signify (formerly known as 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, Eindhoven University of Technology and TNO-ESI.

Short response delay

Where most IoT-applications focus on connecting (distributed) sensors and equipment to the internet sec, the lighting application stands out from the pack, as it requires, in office environments, extensive local communication between end nodes for, e.g. group behaviour and immediate and deterministic reaction to user requests. Also synchronization of multiple devices, like a group of luminaires has requirements in the 100 milliseconds second range that can not be guarenteed by a fully internet/cloud based control solution.

Local Operation and Availability

Despite its "ubiquity" and "normality" the presence of lighting often gets unnoticed and we tend to forget that lighting is actually a mission critical application in many "daily" circumstances, being a condition for productivity inside buildings and during certain periods of the year/day. In many circumstances the availability of lighting is directly related to safety. Development and even education is greatly boosted in countries where electrical lighting is introduced. This position demands availability of lighting; always, everywhere and with a fast reaction to lighting demands. Currently, internet connectivity and responsiveness have not yet reached the service levels of, for example, power networks in most countries. This requires the architecture to foresee local operation and availability even in situations with loss of connectivity towards central servers or the Internet.

The above lighting specific characteristics should be carefully considered when designing a lighting control system based on IoT-technologies. In the next paragraph we will list further challenges that will include more "standard" issues that come with digitization as well as those that are the consequence of being very early in the adaptation of IP-technology in this domain.

Overview of Generic Challenges for IP Controlled Lighting

The challenges that the project faced during its three and a half year itinerary into IoT-based lighting fall into several categories:

Early adopter effects

OpenAIS is designing and implementing a new lighting controls architecture fully based on IP to the end node and on IoT-platforms. Although all partners agree on this direction and share the belief that the final stage of lighting controls will be its full absorption into the IoT-infrastructure in buildings, it is still early days for an actual implementation. Many required technologies, both hardware and software, were available in prototype form only and still are maturing, leading to regular releases of improved versions. As a research project for the participating companies many of the developments have been prototypes only. Also, the architecture had to be based upon roadmaps and projections in many areas, where actual implementations were not yet available. Consequently, the implementation had to deal with the immaturity of the field, which led to major challenges. Main points here:

Overall silicon roadmaps

Cost and availability of processors with sufficient storage capacity and computing power. Although Moore's law and the progress of the silicon roadmap is the driving force that has opened up the vision of IoT-based lighting in the first place, reality is lagging here. Designing architecture for 2020 and beyond is reasonable and feasible based on the overall silicon roadmaps and the insights of the silicon partners in the project. However, the prototype implementation for the White Lady pilot, had to be based on existing silicon and CPU's, which were restricted in price and performance vs. the long-time expectations for the project.

IoT-frameworks & stacks:

Applying a standard IoT-framework to implement all basic connectivity and functionality is at the core of the OpenAIS philosophy and goals. However, at the start of the project most of the IoT-frameworks, if even announced, were paper ware at best. Even the IoT-framework selected (LWM2M) and its ARM-MBED implementation as main carrier were in an early phase of their development. During the project the stacks were continuously being extended, improved and matured by their suppliers. It is expected that this process will continue for some years, while IoT is maturing. Also, many more IoT-stacks have emerged over the duration of the project and any project starting such an endeavor now should perform a new state-of-the-art investigation to select the appropriate one.

Integration in the IT domain

Integrating lighting in the IT-infrastructure using open standards has been ongoing since the introduction of techniques like Power over Ethernet (POE), but is still relatively new for lighting suppliers, who previously relied on fully proprietary and separated busses and infrastructure. This brings a whole new viewpoint to the lighting design phase, including performance guarantees (and demands), throughput and reachability for lighting control and data reporting. Entering the IT-world also drives a whole new set of requirements, especially around security (and privacy) because now lighting will be prone to attacks, viruses and hacking as well. Hence, there is an increasing challenge to implement security in resource-constrained devices.

Interoperability and standardization

Customers in the 2020's will require that luminaires from multiple vendors can be mixed and controlled with the same system. At least the key functions such as

switching on and off and dimming must be fully interoperable. More advanced features like, for instance, following circadian rhythms in an optimized way, can still be proprietary and offer competing companies an opportunity to differentiate. In addition, interfaces with BIM and the BMS must work seamlessly across vendors. This requires an unambiguously agreed upon standard.

Shifts in the value chain

A final aspect and important challenge recognized by the consortium from the beginning was the impact the proposed changes, with lighting becoming an integral element of the building wide IoT-network, would have on the value chain and the roles of various parties therein. It is clear that with lighting and IT-infrastructure merging responsibilities and dependencies in the chain necessarily change. Installers may move more to IT-responsibilities or IT-installers may pick up the installation of the lighting network. Also, the business models for IP-points may change drastically. Now significant yearly charges for a single IP-point are the commercial standard. However, with hundreds or thousands of additional lighting points these kind of cost levels will no longer hold - and they will not be necessary. The number of nodes will be an order of magnitude higher, yet the data rate requirement will be low. This will result in a cost structure that is intrinsically different from current IP points for standard computing infrastructure. With open standards, interfaces and networks also the position of the classical lighting manufacturers will change, open standards will increase competition and allow entrants with standard software or package to enter the market. On the other hand, opportunities to add value by advanced control features and light effect will increase and lead to additional revenues [1].

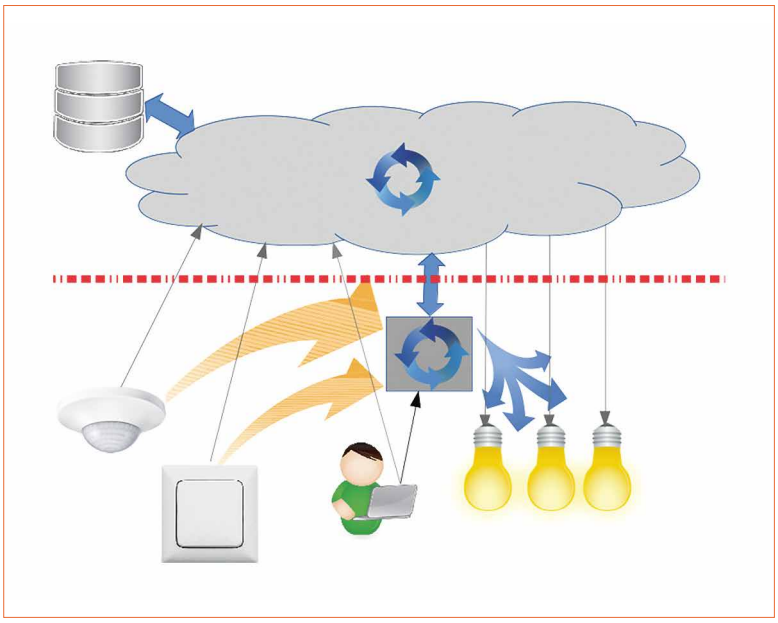

Figure 2:
Independence of central server. Low latency group control

While this part has been recognized and analyzed, the implementation of these changes in the market is beyond the project scope.

The Approach and Solutions to the Challenges

In this section we will discuss how the project tackled the challenges described in the previous two sections and simultaneously indicate which of these are “persistent” and will have to be solved/incorporated in any commercial implementation/ deployment of the architecture and which are temporary and related to the early adopter characteristics and first of a kind effect. Finally, a number of challenges have not been fully addressed due to their commercial nature. These can only be solved in a true business context and are beyond the scope of the project.

Group behavior, local communication and synchronization

To deal with the specific requirements of a lighting controls system, a group communication mechanism was developed that operates independently of the main IoT-framework (LWM2M in the case of the pilot implementation). This mechanism, based on CoAP Multicast over IPv6, supports a multicast model, offering authentication and authorization for group communication. For technical details refer to [2], a graphical illustration for the solution is shown in figure 2.

This mechanism is one of the cornerstones, as it does not rely on a central server or Internet connection to be present. As such it allows independent “always on” communication for the vital lighting functions. Its lightweight multicast operation supports the performance and synchronicity requirements of lighting, especially in a constrained wireless environment.

Early adopter effects

The project had the challenge that both the architecture and the applied technologies and concepts were new and, hence, not yet mature. During the project, we, over time converged on a practical best way to manage this situation.

The keywords in this are:
Plan for change and updates until the end of project and work incrementally. The latter is a standard project management wisdom firmly embedded in agile methods. The second one, however, is more counter-intuitive from a normal product development perspective.

In some detail:

- Assume in the planning a very frequent update of all (experimental/prototype) components, as they will mature over time. This even applies to components very recently commercially released.
- Guarantee that OtA (Over the Air) SW upgrade works flawlessly. This is the most important function on any feature list for a connected IoT-system! In the pilot many SW updates were applied after installation of the luminaires and this was absolutely necessary to cope with updates of the IoT frameworks, Mbed and Thread.
- Start with the implementation of a (very) reduced system and work incrementally thereafter. Start with one room approach and then scale up to the size of the real pilot installation
- Carefully consider the complexity and flexibility allocated to components in the system. Don't be afraid to fix variation points and reduce implementation efforts for the first release.

Standardization and interoperability

The consortium has standardized the Object Model as an extension to LWM2M at IPSO/OMA.
This Object Model, including all API's needed for an advanced lighting control system [3] was developed within the project to optimally serve the scenarios and use cases of the 2020's [4, 5] and provide full interoperability between the devices of various suppliers in the project. Within the pilot, devices of various suppliers were mixed and matched and full interoperability of (group) control over various vendors and wired/wireless was demonstrated.

Agreements across the industry to develop luminaires and controllers according to the same standard are among the major challenges for the near future.

IT-integration

Standard network components and topologies were used to build up the network for the system.
The backbone network consists of a number of interconnected rings using the Cisco® Catalyst® Digital Building Series Switch in a decentralized configuration for the ring which could also be used for powering the POE devices. A single connection between the network and the existing office network was established. The back-end applications like the BMS, Commissioning Tool, etc. were hosted on a (standard) server.
User apps were connected and directed to the already existing wireless-network of the office and connected to the access server.

Only Thread, a relatively new standard, still needed some specific implementations.
The partners in the consortium developed Thread border routers.
It is important to note that nothing in these border routers was actually OpenAIS specific and it is expected that commercial, off the shelf routers, when available, can be deployed in the system without any modifications. During the pilot, the quantity of Thread border routers was over-dimensioned to avoid any risks with the wireless performance of the still new Thread implementation. In practice, a single hop configuration was created to each end node. Results from the pilot give confidence that with ongoing deployment of Thread and the availability of commercial components the Thread network will also become part of the standard building infrastructure.

Duration of deployment

The software update mechanism has already been described as the most important function in any connected lighting control system that is based on IoT-technologies.
It is very similar to the PC and mobile device market, already familiar with a high frequency of updates and never-ending maintenance, especially for security aspects. This mechanism has been extensively used in the project to cope with incremental development and continuous framework improvement by the suppliers. The fact remains that existing CPU's will probably no longer be capable of executing the standard software stacks a decade from now. This topic has not been addressed in the project and remains to be solved. In various industries, solutions have been developed to cope with similar issues. Full replacement (mobile phone), addition of external memories and other components (PC) and full replacement of the digital part of the system (e.g. large medical equipment) are amongst the strategies applied. A future commercial implementation will have to give further thought to this issue and define a suitable strategy.

Conclusions

Despite the many challenges encountered in the realization phase, OpenAIS succeeded in implementing a fully operational multi-vendor lighting control system based on IoT-standards and frameworks, with IP connection to the end node, in a commercial setting. This system combined wired and wireless devices from multiple vendors in a single system connected through a standard IT-network with commercial components. The openness of the system was validated by the implementation of several additional components, commissioning tooling and user applications, by parties outside the main lighting manufacturers from the consortium.
Figure 3 shows one room in the White Lady office building with the pilot installation.

The major lighting specific challenges, secure: fast and reliable group communication and server-less (no-internet) operation have been solved in the architecture.
The consortium also standardized and proved the interoperability between lighting controls components from various vendors,

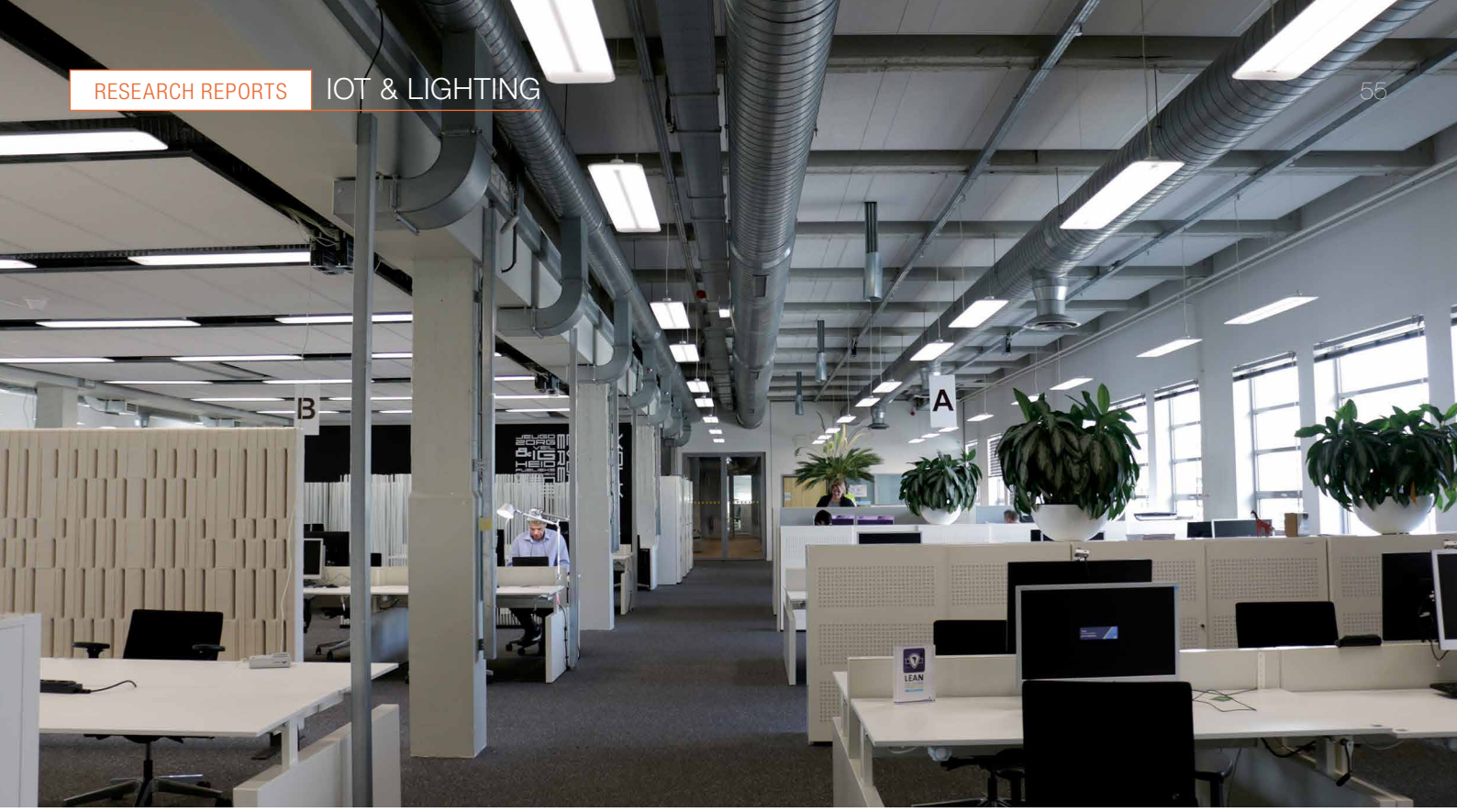

Figure 3:
Room in the White Lady pilot site

as such, opening the route to a complete ecosystem of lighting controls

Due to the timeframe of this project, the early adopter problem caused huge challenges during the implementation of the large-scale prototype. While, at this moment, there is still some IoT-ecosystem super fluidity, there is clear evidence that the mainstream developments are solving this problem. Over the lifetime of the project the number of ecosystems and their stability has been growing exponentially. This is not an uncommon phenomenon in digital transformations and it is to be expected that soon the market will settle, and a number of de-facto standard frameworks will emerge, allowing the system of the future to be built on. Furthermore, extending the Internet Protocol to very restricted end nodes has been sufficiently proven to assume current commercial issues will be resolved by the processor roadmaps of the mainstream silicon vendors.

Yet still some challenges remain to be solved at the actual introduction of OpenAIS based systems in a commercial release. Value chain adaptations are required and still form a risk for a successful introduction of IoT-based lighting systems, while lifecycle management still needs attention as well. Software upgrade mechanisms have been sufficiently proven, however, a clear and simple (controls) hardware upgrade strategy is still to be defined. ■

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UV LED Technology for Emerging Applications in Agriculture

The Ultraviolet (UV) LED market has expanded five-fold in the past decade and is projected to grow to over $1 billion by 2025. A key trend expected to influence 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 medicinal and traditional plants and it can also help maintain a healthy growing environment. But to fully take advantage of UV LEDs, some major re-design considerations are required. Terrance Berland, CEO of the Violet Defense Group, the parent company of Violet Gro, will explain which considerations these are; for instance, why it is crucial to incorporate the appropriate lens material.

With the explosion occurring in indoor and urban farming, not only are the energy savings of LEDs appealing, but the advancements made in UV LEDs are making it possible to bring the additional benefits of ultraviolet light, particularly UV-A and UV-B, to indoor agriculture. UV light has been shown to drive increases in the plant production of active substances in medicinal plants, including antioxidant benefits of numerous plants or THC levels in cannabis. UV light can also help maintain a healthy growing environment by reducing mold, mildew, and certain plant pests - all of which need alternatives to chemicals due to increasing fungicidal resistance.

While many of the leading fixtures used in indoor agriculture produce some level of UV spectrum (however small), their outer lens materials block most, if not all, of that UV light from actually reaching the plants. As the price of UV LEDs continues to decline, the ability to cost effectively incorporate targeted UV into the growing process with the right wavelengths, the right dosage, and at the right time in the life cycle of specific plant species will improve. However, UV LEDs will still need to be combined with the appropriate lens that enables transmission of the UV light without risking degradation or destruction of the lens and/or the LED itself.

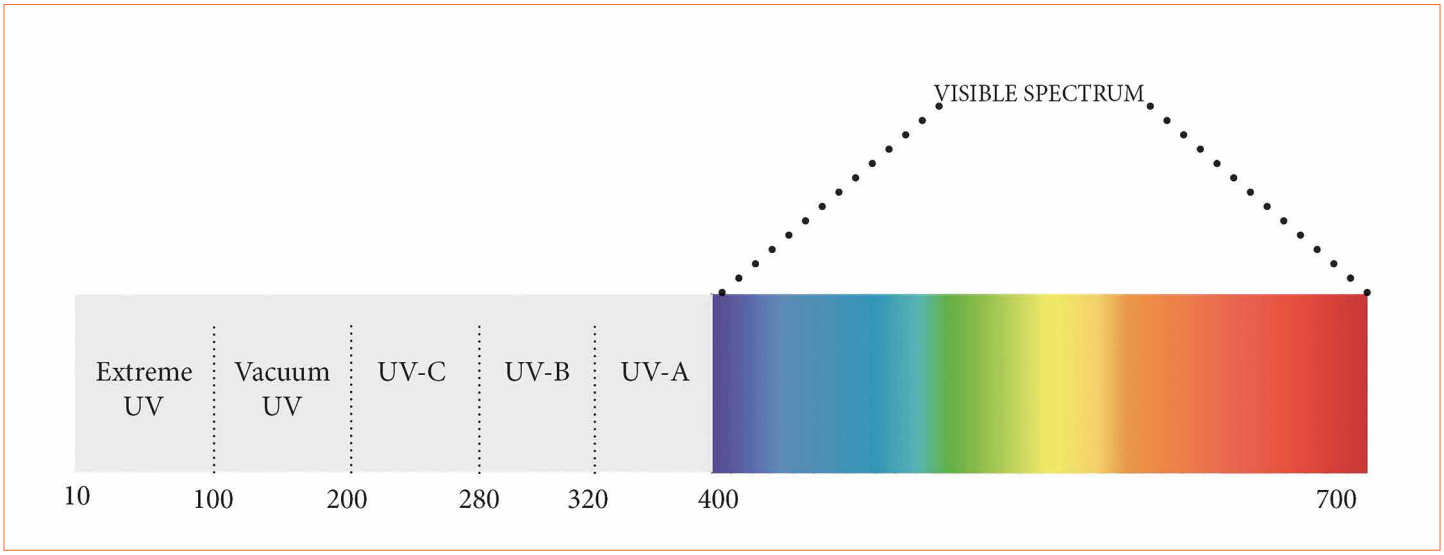

Figure 1:
UV and visible light spectrum with UV classifications

Introduction

History & wavelengths

Ultraviolet (UV) light is a key part of the electromagnetic spectrum with wavelengths ranging from 10 nm to 400 nm. This portion of the spectrum lies outside of the visible range for the human eye, though some portions of UV light are perceivable by insects and birds [1]. Much of the UV spectrum, including all the Extreme Ultraviolet (10-100 nm) and most of the spectrum below 280 nm is absorbed by the atmosphere. However, it's still important to understand the benefits of each part of the UV spectrum given our ability to artificially produce these wavelengths.

UV spectra classifications, their use and benefits:

- UV-C (200-280 nm): Almost completely absorbed by Earth's atmosphere, UV-C is commonly used for its germicidal effects
- UV-B (280-320 nm): Approximately 95% of UV-B is absorbed by the Earth's atmosphere and is frequently known for its association with increased risk of skin cancer, however, it has also been shown to have antimicrobial effects including dealing with agricultural infections and pests, such as powdery mildew or spider mites; as well as triggering plant responses that increase flavonoids and cannabinoids
- UV-A (320-400 nm): Often referred to as "black light," UV-A light has the longest wavelength in the UV spectrum and is considered the least harmful; it is most known for applications in UV curing, counterfeit detection, and forensics, but also has applications for agriculture given its ability to trigger desired plant responses as well

Recent advancements

Much of the UV lighting industry has been dominated by sources other than LEDs, particularly mercury bulbs. However, UV LEDs have made significant progress in recent years, not only due to advances in the manufacturing of solid state UV devices, but also as a result of increased pressure to find more environmentally-friendly and energy-friendly options of producing UV light.

However, LEDs have only recently been able to meaningfully accommodate all the UV ranges. LEDs transmitting UV light in the upper portion of UV-A (390-420 nm) range have been available since the late 1990s, typically being used for counterfeit detection or validation of driver's licenses or documents, as well as in forensics [2]. In fact, a large portion of the UV LED market is dominated by industrial and commercial applications for curing, such as inks, coatings or adhesives, typically done by UV-A light in the wavelength of 350-390 nm [3].

As you proceed into the shorter wavelengths of UV-B and UV-C, applications turn to disinfection for food, air, water, and surfaces. These are some of the newest wavelengths to be available in LEDs (the first commercial UV-C LED-based water disinfection system was introduced in 2012 [4]), although UV light has a long, well-established history of germicidal effects. Not only are the energy savings of LEDs appealing to many industries, such as water purification, but their extremely small sizes make them a very flexible option, including the ability to create portable disinfection systems.

Given these advancements, the UV LED market has expanded five-fold in the past decade and is expected to grow to $1.3 billion by 2025. A key trend expected to influence the market is the ability to further expand into new applications, including solar products, food and beverage industry, and agriculture [5]. However, additional advancements are still needed, particularly as it relates to the lens component of these products, to ensure that the technology can achieve desired outcomes for each industry in a cost-effective manner.

Benefits of UV to Horticulture

With the explosion occurring in indoor and urban farming, there has been an increasing desire to continue to refine the growing process in a cost-effective manner that will still yield positive results for the targeted plants. Much of the existing research on the use of LEDs in agriculture has focused on the wavelengths of visible light and the spectrum that plants need for various processes. During extensive research, "NASA determined that LED lights are the best single source lights for growing plants on Earth as well as in space [6]." In fact, there have been many studies conducted to identify the relationship between various wavelengths and their impact on plant growth. This information will allow for the further development of customized spectrum lighting that produces greater results for the plant at lower energy costs. For example, the red-light spectrum (630-660 nm) has been determined to be essential for stem growth and expansion of leaves. It is also the wavelength that regulates flowering and dormancy periods.

While early LEDs left most plants (and growers) wanting more, the latest state-of-the-art LEDs provide more viable options for indoor growing that will yield substantial cost savings (if paired with the right lens material), especially compared to traditional lighting options such as High Pressure Sodium (HPS).

Now, further advancements in UV LEDs are making it possible to bring the additional benefits of ultraviolet light, particularly UV-A and UV-B, to the indoor grow process in a very targeted way. Researchers found that in the absence of UV light, certain plant breeds may "develop callus-like intumescence growth on leaves and shoot tissues [7]." Ordinary glass, for example, blocks over 90% of UV-B radiation [8], therefore, plants grown in greenhouses or other similar environments, without supplemental lighting may experience adverse effects.

Figure 2:
UV light can enhance the amount of active substances in medicinal plants, such as antioxidant benefits of rosemary or THC levels in cannabis

UV light has also been shown to drive increases in the plant production of active substances in medicinal plants, including antioxidant benefits of numerous plants or THC levels in cannabis. Plants have chemical processes which enable them to identify the different wavelengths of light that trigger certain responses, including reactions to UV light that can alter plant shape and change chemical make-up [9]. This area of photonics, however, still needs a lot more research focus to truly understand all of the impacts, including the best methods for deployment.

One of the most common ways plants respond to UV light is the synthesis and accumulation of UV absorbing compounds. These compounds, including phenolic substances, act like a form of sunscreen for the plants to prevent damage that excessive exposure to UV light can cause. However, the benefits of phenolic compounds not only help protect the plants but have been shown to have significant human health benefits too, including antioxidant benefits and prevention of various chronic diseases, including certain cancers and cardiovascular diseases. Resveratrol, found in grapes and red wine, has been studied for its health effects on the heart, immune system, and even brain functions [10]. A study of rosemary demonstrated that its total phenolics approximately doubled when grown using UV-B radiation. Similar results were found for increased production of essential oils for Mentha spicata (spearmint) [11].

Another plant species known for its increase in production of medicinal compounds under UV radiation is Cannabis sativa. Research has found that higher levels of cannabinoids are found from plants at the lowest equatorial latitudes and higher altitudes (32% greater at 3350 m than 1500 m). The association was made that these areas of the world had higher levels of UV-B. Subsequent studies have shown that exposing plants to UV-B can cause Δ9-tetrahydrocannabinol (Δ9-THC) levels, which have extensive medicinal benefits, to increase by up to 48% in leaf tissues and 32% in flower tissues [12].

UV light can also help maintain a healthy growing environment by reducing mold, mildew, and certain plant pests - all of which need alternatives to chemicals due to increasing fungicidal resistance. The UV-absorbing compounds produced by plants to protect them from receiving too much UV radiation can also aid in defending plants against infection, injury, and certain plant pests. It's as if these compounds change the "attractiveness" of the plants to these pests.

One major threat to indoor growers is powdery mildew. However, UV light has been demonstrated to significantly reduce mildew in plants ranging from grapes, rose plants, cucumber, rosemary and strawberries. Researchers have successfully reduced the severity of powdery mildew by 90-99% using proper doses of UV-B [13].

UV-B light has also been proven effective at reducing survivorship

Figure 3:
Powdery mildew and mites pose a significant threat to many crops but can be substantially reduced with the use of UV light.

and production of eggs of spider mites, pests that have been known to destroy entire crops. In a study by Ohtsuka and Osakabe, less than 6% of larvae exposed to UV-B doses survived by the second day, and all larvae died by the 3rd day of their experiment [14].

A third major threat is Botrytis cinerea, a type of gray mold or often called gray rot that can target about 200 different species, typically with fruits or flowers, including strawberries, grapes, and cannabis. This pest is typically brought in from outdoors and then spread into an indoor grow room via air or by shoes and clothing. Therefore, handling this pest may involve whole room air disinfection and/or floor disinfection systems. Studies have shown that Botrytis cinerea spores are most effectively treated by using UV-C irradiation. Mercier et. al (2001) achieved disinfection rates of greater than 90% with UV-C dosages of 440-2200 J/m^2 [15].

Over the past several decades, the evidence supporting the benefits of UV light for protecting crops from mold, mildew, and other plant pests, along with the ability to enhance medicinal benefits of plants has grown tremendously. However, there are still significant challenges for how to successfully incorporate UV into an indoor grow facility.

Considerations for Integrating UV into Indoor Ag Lighting

When thinking about UV LEDs, you can't stop at just the LED. A UV LED System must think about the specific LEDs based on UV dose required, wavelength needed for the application, and the layout of the lighting relative to the plant canopy. However, you must then also add in thermal management, optical design, the power supply and driver [16], and most importantly, the lens material.

Determine dosage & wavelength needed for application

With indoor growing, it is critical to identify the spectrum that will best meet the needs of your plants, as the impact of different wavelengths depends on where you are in the grow cycle and on the specific plant species. For example, in the visible spectrum, a small percentage of green light (up to 24% for specific species) can be beneficial to support plant growth, but research has shown that it is species-specific and that more than 50% can have detrimental effects [17]. The same is true when incorporating UV light into agricultural lighting - you must be clear on what you are trying to accomplish for your plants.

Several scenarios may call for integrating UV into the primary lighting source for an indoor grow facility. For instance, Resveratrol, a medicinal substance produced by plants in response to stress, is formed by a chemical reaction that requires UV-A radiation with a wavelength below 360 nm. Growers interested in increasing levels of specific flavonoids or cannabinoids will likely want to target UV-A, UV-B or a combination of both to achieve their target effect.

If a grower is interested in preventing infestation with specific plant pests, such as powdery mildew, spider mites, supplemental lighting designed to deliver specific dosages of UV-B light are critical to helping control these plant pests. To treat Botrytis cinerea, UV light can be integrated in methods designed for whole room air disinfection or as a targeted supplemental lighting that could be used to deliver the right dosage of UV-C light on a regular treatment cycle. Given the varying needs and applications for UV into agriculture, it is important to partner with a lighting company that understands the applications of UV for both enhanced growth as well as disinfection/pest control.

Measuring light output

Whether evaluating a lighting fixture or individual LED components, a common methodology involves comparing the light output measurements advertised by various manufacturers. However, one must use extreme caution to ensure you are actually comparing the same measurement across the various options and be aware that many of the products/companies out there do not adequately disclose the parameters of their testing, including a critical dimension called distance. Without controlling for differences in these parameters, the comparison of numbers is meaningless.

Furthermore, many of the sensors on the market are designed to only measure specific parts of the electromagnetic spectrum and may not properly capture select portions, often including the far-red end of the visible spectrum and the UV end of the non-visible spectrum. For example, when specifically evaluating lighting options using Photosynthetic Photon Flux Density (PPFD), it is important to understand that the sensor will capture any energy in the wavelengths to which the sensor is calibrated. However, not all wavelengths carry the same energy, nor are all wavelengths equally valuable or attractive to the plant, and many of the key wavelengths could be excluded due to limitations on the measurement capabilities of the sensor.

The energy of each photon is inversely proportional to the wavelength of the associated electromagnetic wave. The shorter the wavelength, the more energetic the photon, the longer the wavelength, the less energetic is the photon. Therefore, red light has less energy than yellow or green light, even though red light is more desirable for plants in terms of photosynthesis and other plant chemical processes. In other words, lights producing high amounts of yellow and green light may produce higher PPFD readings but may not be producing the light needed by the plants.

If exclusively evaluating UV lighting options, it is noteworthy to mention that while there are a wide range of UV radiometers designed to measure UV generated by traditional broadband mercury arc systems that primarily produce UV-C, they will not properly measure the UV output generated by UV-LEDs, particularly if your light design includes multiple UV peaks that don't specifically line up with the target spectrum of the sensor being used. Many manufacturers of UV-LED chips will measure the UV output of their LEDs in an integrating sphere, also known as Ulbricht sphere [18] which may or may not be a good proxy for what the plant will actually experience.

Even if proper caution is taken using appropriate sensors to measure light output, the plants themselves are ultimately the best judge of the performance of your lights and the ability to achieve your desired outcomes, and you should seriously consider in-environment testing to help validate the claims from the product manufacturers.

The impact of the lens

When selecting LED lighting for plants, it's critically important to remember that while plants may not be able to get too much light, they most certainly can get too much heat. While LEDs are more efficient than mercury lamps, research suggests that UV LEDs only transfer about 15-25% [19] of received input power into light. The remaining is transferred as heat, so thermal management must be a critical part of the system.

In addition, when lights produce wavelengths in areas of the spectrum not needed by plants, the photons not absorbed by the plant, will ultimately translate to heat in the environment requiring more extensive cooling costs - both in terms of ongoing electrical needs, but also upfront infrastructure costs.

Similar to the coverings on greenhouses, certain types of lenses, such as the outer glass jacket from HPS lighting actually blocks much of the UV light from reaching the plants, translating that light into heat.

Another factor in the use of UV, or even deep blue LEDs is that most lens materials will experience significant degradation over time resulting in decreased efficiency, and it may even cause enough heat to remain trapped to ultimately destroy the LED itself.

However, new advances such as the patented technology from Violet Gro enable the combination of a UV light source with a special class of ultraviolet transmissive lens material, in direct and immediate contact, without producing these detrimental effects. This unique lens, and the associated direct contact with the UV LEDs, allows more of the UV light to be transmitted and projected through the lens to its intended source, thereby further increasing efficiency and decreasing heat output. This is beneficial to both the lifetime of the LEDs, and to substantially reducing the cooling requirements in the indoor grow facility.

What's Next

As UV LEDs continue to come down in price, the ability to effectively incorporate UV into the growing process with the right wavelengths, the right dosage, and at the right time in the life cycle of specific plant species will dramatically increase. This reality will allow for further research and development of UV solutions, including identifying the optimal combinations of UV wavelengths and dosages to achieve the desired effects for specific plant species.

Regardless of the desired plant growth or pest control outcomes, for effectiveness and longevity of the lights, UV LEDs will still need to be combined with an appropriate ultraviolet transmissive lens that enables transmission of the UV light without risking degradation or destruction of the lens and/or the LED itself. ■

Figure 4:
Example of an LED destroyed by heat trapped within the lens

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Smart Lighting and HCL in Office Applications

Wireless control makes it easy for office workers to customize their lighting conditions. And the more satisfied people are with their lighting, the better they work. Timo Pakkala, CEO of Casambi explains how office lights can become smart and fit for human centric lighting (HCL) and which benefits workers and companies may expect. He compares wired and wireless approaches and underlines the benefits of smart HCL lighting with several practical examples based on Casambi's solution.

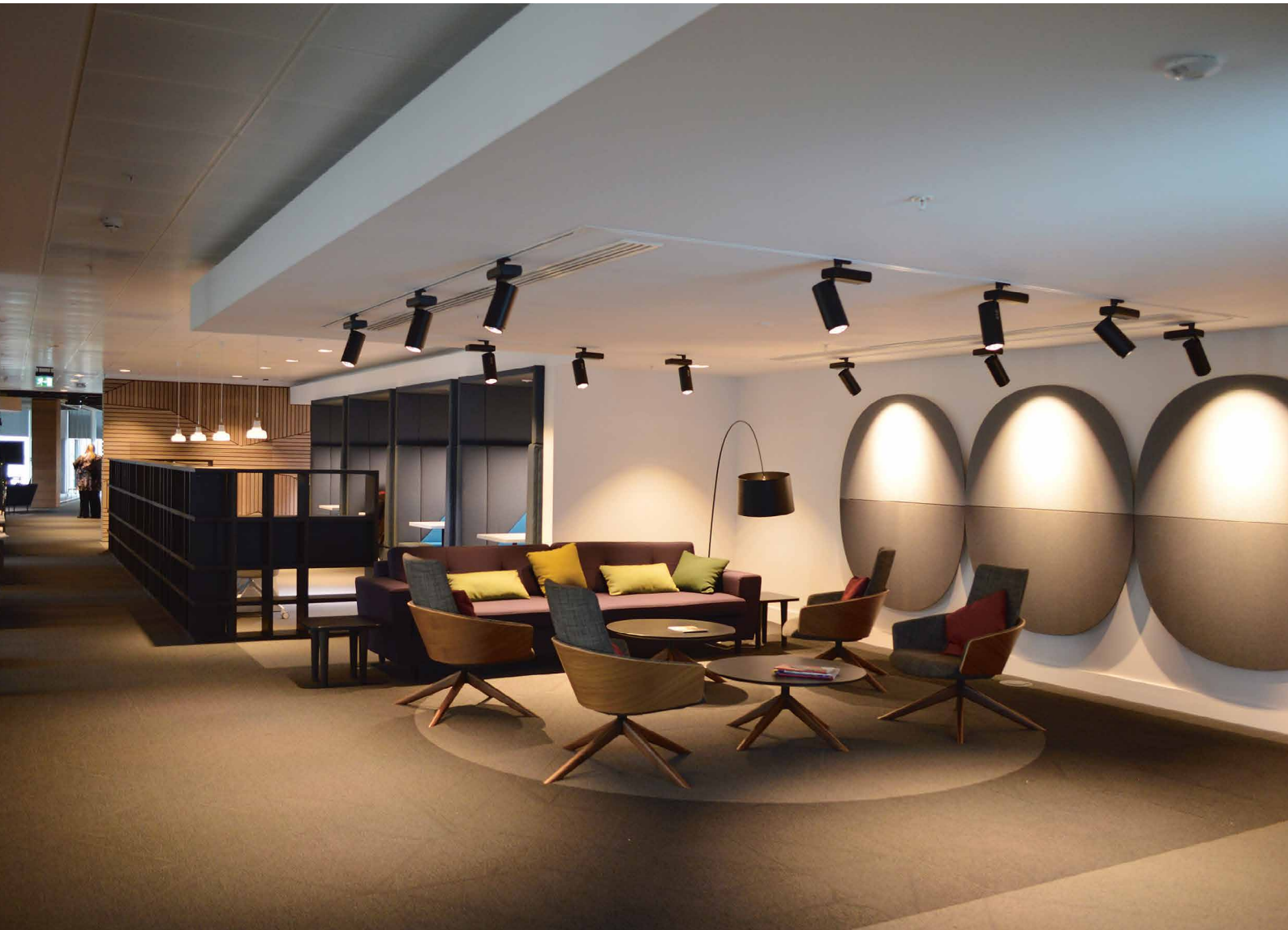
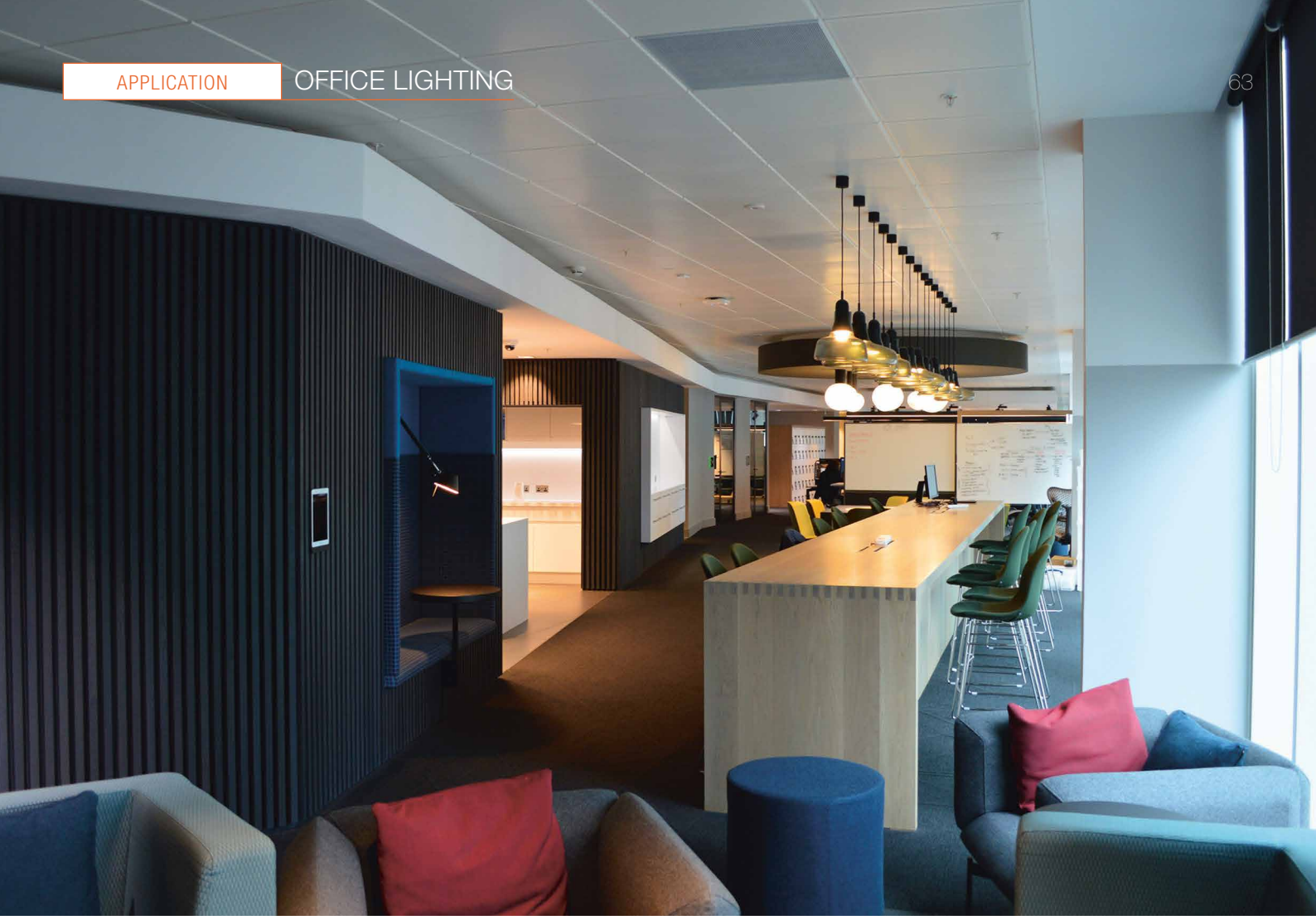


Figure 1:
The lighting at the large, Registers of Scotland office building now adjusts to support wellbeing and productivity of staff

Office lighting isn't something most people think about much, even though we typically spend around a third of our lives at work. However, I'm certain that most lighting professionals reading this article are already aware that illumination has a significant impact on how we feel at work, and how well we perform.

Traditionally, the main purpose of office lighting has been to provide enough light for the task at hand. But that's changing, as our understanding of how light affects workers continues to advance.



Why and How to Make Better Office Lights

The key thing to understand is that when working indoors, the wrong kind of light at the wrong time can leave us feeling drowsy, unfocused and uncomfortable. It can even contribute to health issues. This is because the human body is designed to respond to the changing light of the sun, to tell us when we need to be alert, and when we need to be at rest. But most indoor lighting doesn't behave that way, so the cues our body clock gets are not necessarily the ones it expects. This takes a toll on our ability to concentrate and do our best work.

The latest lighting control technology offers a solution. Thanks to LEDs, digital communication technology and the Internet of Things (IoT), lights can now become connected and intelligent, creating what is known as smart lighting.

This in turn enables "human-centric" or "circadian" lighting, which shifts subtly in colour and brightness throughout the day to mimic natural light, supporting our natural circadian rhythms - also known as our body clock.

Offices are one of the key settings where smart lighting can make a major difference. Enhancements in the comfort and wellbeing of office workers aren't just soft benefits. They have the potential to improve performance, and therefore productivity and profit.

The emergence of smart and human-centric lighting technology couldn't come at a better time for offices, which are already moving away from the familiar image of a uniform, grey expanse of cubicles and workstations. All over the world, offices are become more informal, more focused on comfort and wellbeing, and more attuned to mobile and flexible working. Employers, property companies, architects and industry bodies are all recognising the opportunity of investing to improve the environments in which people work.

Lots of today's lighting systems call themselves 'smart', but in reality, some are smarter than others. Truly smart lighting incorporates connectivity and intelligence. It should allow us to control the lights - usually wirelessly - and to take cues from ambient light levels and the number of people around, to decide whether lights need to turn on or off, or dim up or down.

Smart lighting can also harness the IoT to track data on things like air quality and temperature, or incorporate cameras for security purposes, enabling brand new services to help workplaces become more effective and more efficient.

Not all of this is new. Systems for controlling lights have been around for decades. The most commonly used protocol is DALI - a digital system for enabling lighting control. DALI systems need their own dedicated wiring, and need to be commissioned by an expert.

Other systems work using wireless technologies such as Wi-Fi and

Figure 2:
To support well-being and productivity of staff at the large Registers of Scotland office, a wireless controls solution is used

Figure 3:
Example of a Bluetooth two channel 0-10 V controller for dimmable LED loads and luminaires

ZigBee (or sometimes both), but these introduce challenges with coverage, reliability and security. Any lighting controls are only as reliable as the Wi-Fi signal.

Then there's the user interfaces. If we're being honest, this is not an area where lighting controls have typically excelled in the past. Control systems have often relied on clunky dedicated controllers that were hard for users to get used to.

Now, it's possible to control lights through an app installed on any wireless device such as a mobile phone, tablet or even a smart watch, and make the most of the intuitive user interfaces and touchscreen technology that we have all become accustomed to in the age of the smartphone. And today's systems can be completely independent of Wi-Fi networks, building on technology that is inherently more robust.

Smart Lighting in Action

So what does smart lighting look like in action? In Glasgow, a smart lighting control system is helping staff at Registers of Scotland to stay healthy and productive, by tuning light to work with their circadian rhythms.

The organisation, which manages vital public records, installed the system at its brand new,

BREEAM “Excellent” rated offices, which house 200 staff over 1700 m^2 of floor space.

Registers of Scotland chose to use the system based on Bluetooth Low Energy - the cutting-edge radio communication technology that’s built into every modern smartphone, tablet and even smart watch. It uses mesh networking to create a robust, self-organising and self-healing wireless network. Users control luminaires directly from a mobile device - with no need to rely on a router or gateway device.

The mobile app is designed to be simple and intuitive, so anyone can use it without specialist expertise. The app updates itself automatically when required, and delivers firmware updates wirelessly to the luminaires, making the whole system futureproof.

The control system at Registers of Scotland is used to manage around 450 tuneable white luminaires. The luminaires deliver human-centric lighting, while also dimming to save energy when there is sufficient natural light coming through the windows, or when an area is not being used.

Staff control the lights using a number of iPads equipped with the app, which are placed throughout the office space. These can be used to control lights in groups, and to create scenes. To locate and control a particular luminaire, staff use the app’s “Gallery” feature, which lets users upload their own photos or plans of a space, mark the positions of the luminaires, and then use this to select and control them.

The system also supports Philips Hue fittings, allowing Registers of Scotland to control these additional luminaires seamlessly through the same interface.

Kevin Stewart, facilities manager at Registers of Scotland, said: ‘The whole system is programmed so it works with circadian rhythms, so it changes all day long, but it’s very subtle. The feedback we’re getting is that the whole lighting system works really well. Staff are glad they’re able to change the level of lighting, so they’re happy, and we get better productivity out of them.’

The benefits don’t end there. The energy savings enabled by the lighting control system, which ensures lights are only on when they’re needed, has contributed to a massive 90% cut in the office’s carbon footprint since the move to the new premises.

Figure 4:
Staff control the lights using a number of mobile devices equipped with the app. The app is regularly updated, and unlike some other smart lighting solutions, the firmware is effortlessly updated wirelessly, making sure you always have the latest functionality and security

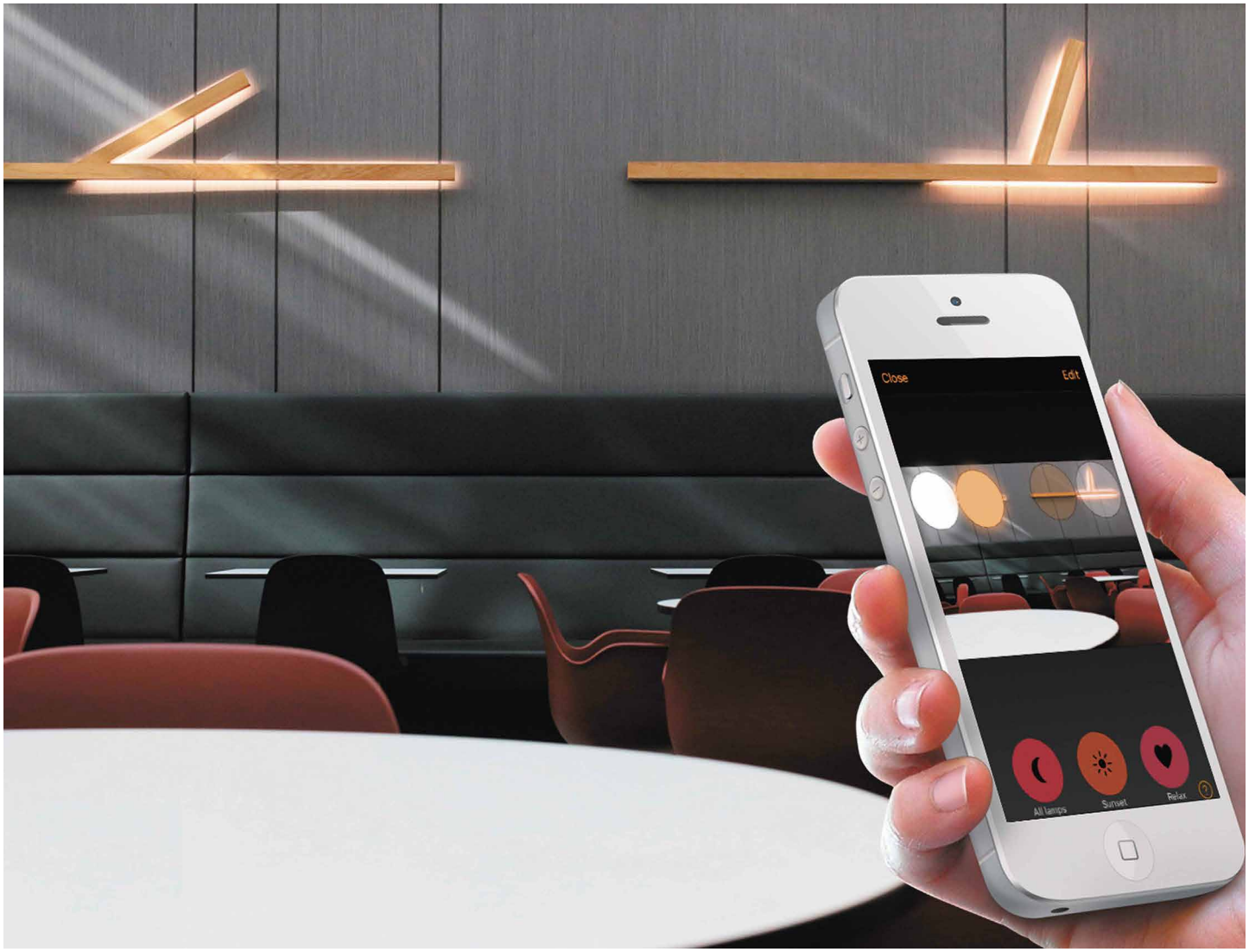


Figure 5:
Another key element of the system is the network of control features or customers to tap into professional office lighting applications. - Designers can control luminaires individually or in groups, precision-tuning brightness and color, and creating scenes and animations that can be programmed to respond to occupancy, ambient light levels or timers

Another key benefit of smart lighting is the ability to give people individual control. The more control people have over their workplace lighting, the more satisfied they are, and the higher they rate their wellbeing, according to one study undertaken by German research institute Fraunhofer IAO and lighting supplier Zumtobel. In spite of this, 81% of employees have little or no control over the lighting where they work, showing how putting control in the hands of employees remains uncommon sense.

Swedish private equity firm Ratos recently updated the lighting at its Stockholm headquarters, giving staff the power to personalise their lighting conditions using their smartphones and tablets, or with wireless wall-mounted switches. Pre-set scenes are also available to make it even easier to select the most commonly used settings. Staff have more control over their light, and the whole space feels more comfortable.

Similarly, at Abertay University in Dundee, Scotland, smart lighting has recently been introduced to the library building, as part of a major refurbishment. The installation includes around 20 wall-mounted wireless switches in rooms used for meetings, private study, group work and presentations. Thanks to the new technology, the university also has the option of giving students a degree of control over the lighting in breakout study rooms.

Wireless solutions obviously have particular appeal for retrofit lighting projects, because they allow adding controls without having to put in any new wiring. For this system, all that's needed are dedicated luminaires, and an iOS or Android mobile device with the free app.

This means smart lighting systems can be installed even in the most sensitive of historic buildings, as in Duke Humfrey's Library at the University of Oxford - a medieval reading room that was used to film scenes for the Harry Potter films. Here, the system wirelessly controls dozens of bespoke fittings that were specially created to match the feel of the 500-year-old setting.

The offices of Team Finland in the city of Espoo are another example of a workplace that benefits from light that adjusts in line with circadian rhythms. And the offices' minimalist, bespoke fittings are controlled without the need for any additional wires.

No one knows better the importance of good workplace lighting than lighting companies themselves. Smart lighting has been put to use in the offices and showrooms of a number of prominent European architectural lighting companies.

For its 120 m^2 showroom in Milan, Macrolux needed a control system that could change just as often as it changes the range of products it has on display. Smart lighting makes this easy. Because the system is based on a self-healing mesh network, and because commissioning is simple and intuitive, it's easy to add, remove and rearrange luminaires at any time. There is even no need to be on site to do it.

Conclusion

To truly put the value of smart office lighting in context, we should take a step back and consider the big picture of how offices work. When we think of offices, we might think of desks, computers, cubicles, water coolers and light fittings. But the thing that really makes an office tick is the people. It is they who represent by far the greatest cost to a business of running an office, and at the same time, they are the most important asset.

With that in mind, the job of lighting is clear: to make sure that people can give their best every day. And with everything we're learning about how good light affects the body, it's becoming more and more clear that smart lighting is a big step in that direction.

Human-centric lighting remains a relatively young technology, and although it is accepted that light can have a big impact on the human body, there is still a need for more best practice guidance on how employers can make the most of this in workplaces. Even so, smart lighting is an opportunity to get the basics right, and to make sure that the lighting installations of today are ready for tomorrow.

The list of workplaces using smart lighting is growing by the day, as more employers open their eyes to the benefits in terms of employee satisfaction and productivity. If you think your office can't afford smart lighting, you might want to consider whether you can afford to do without it. ■

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 a few milliwatts and several watts. Thus, the central idea of more controls being equivalent with less power does not seem logical. Matthias Kassner, VP of Product Marketing at EnOcean GmbH, reviewed the substance of this conclusion in a number of typical use cases and analyzed the impact and real benefits of lighting controls.

Unquestionably, LED lighting is revolutionizing the lighting industry and creating completely new market conditions. With LEDs replacing old lighting technologies, for example, new control capabilities enable building owners to achieve increased comfort and higher energy efficiency rates. But is intelligent lighting a case of diminishing returns?

From Lighting Control to the Internet of Things

The transition from existing lighting solutions towards LED lighting is occurring in three distinct phases, each with its own unique characteristics.

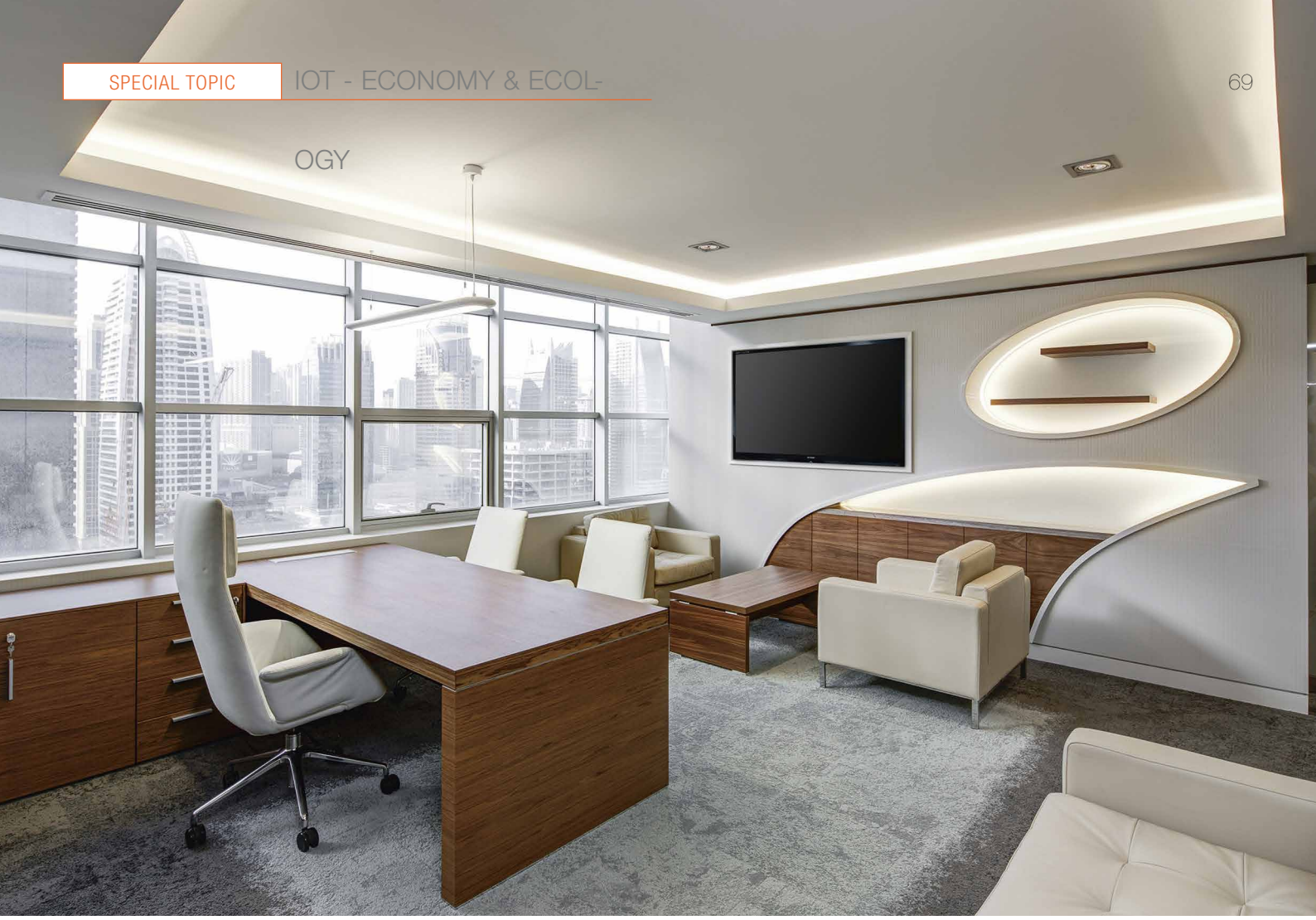
The first phase is characterized by replacing traditional light sources, such as incandescent light bulbs or fluorescent light tubes, with LED-based solutions. The key goal was to reduce the operational cost by means of lower power consumption and longer life time of LED light sources compared to their traditional counterparts.

LED-based lighting uses approximately 75% less energy and lasts 25 times longer than traditional incandescent lighting. The US Department of Energy estimated that the full transition to LED lighting could save about 348 TWh of electricity in the United States alone. This is the equivalent of the annual electrical output of 44 electric power plants (1000 MW each) and represents cost savings of more than 30 billion US Dollars at today's electricity prices [1].

Common expectation is that a second phase of this transition will focus on the combination of LED lighting with sensors and controls to create smart lighting systems which further optimize energy efficiency and user convenience. Looking at market drivers, it is clear that energy efficiency (and thereby cost reduction) would have to be a major selling point even for that second phase. It is therefore necessary to verify the underlying assumption that an increase in the usage of lighting controls will necessarily result in reduced energy consumption.

One key side effect of using smart lighting controls is the additional power consumption required for their operation. This power consumption will be contributed both by the input devices (sensors, switches, gateways) and the receiver/control logic within the light source itself. Smart lighting systems will require energy themselves to send, receive and analyze data and to control their connected drivers and luminaires. This power consumption is not insignificant considering the amount of sensor and controller nodes in a smart lighting system. It is therefore important to assess if the central idea of more controls being equivalent to less power does indeed hold for dense lighting control networks.

The increasing influence of the Internet of Things (IoT) also shows impact on lighting systems, enabling



them to become a data backbone for IoT applications. This is the third phase, where the lighting system continues to provide traditional lighting; in parallel it also generates and transports a wide variety of sensor data to the cloud. Taking the example of a lighting system with occupancy sensors, the basic functionality continues to be controlling the light. In addition however, the occupancy sensor data can be used to determine the space utilization of the office. Furthermore, the wireless network established between the light sources can be used to transport sensor data which is not directly related to lighting control, e.g. temperature, humidity or air quality sensors.

The analysis of this data offers huge benefits by, for example, using insights to make smart lighting respond to ambient light, humidity or CO2 levels. Additionally, this would open up new possibilities and applications such as people counting or providing additional information based on people´s presence. As a result, this third phase enables additional increase in efficiency, enabling smart lighting to play its full disruptive potential.

In this article, the case of office lighting will be used to quantify both the incremental power consumption from smart lighting controls and the savings that can be achieved by them. Additionally, key obstacles to the deployment of such solutions will be discussed and options on how to minimize them will be analyzed.

Approach

To quantify possible savings from lighting controls in offices, a baseline of minimum energy consumption required to light a workplace needs to be established. Afterwards, this baseline will be taken to estimate possible savings from different control schemes. The result of this will be put in relation to the power consumption of the control network to determine the overall benefit of smart lighting schemes. Conservative (low) estimates will be used both for the amount of energy required and for achievable savings to ensure valid conclusions.

Office Space Lighting

Lighting of offices can be implemented by a wide variety of light sources. Commonly used are ceiling lighting solutions such as troffers (rectangular light fixtures fitting into modular dropped ceiling grids) and suspended linear lights.

The size of work places within an office naturally varies in size with a minimum recommended size per workplace [2] in Germany ranges from 8 square meters (single office) to 15 square meters (open office). The minimum required illumination of workplaces based on work site policy [3] is 300 to 500 lux depending on the type of work.

Taking the minima of the above, one can see that the required minimum illumination of one workplace equates to 300 lux x 8 square meter = 2400 lumen. Assuming a luminous

Figure 1:
Whether in the office building or in retail stores, lighting shows significant impact on energy efficiency and comfort (Credits: pexels.com - CC0 License)

efficacy of 100 lumens per watt this means that a minimum of 24 W of electrical power are required to light an individual work place. The above figure is the absolute minimum based on a small office space illuminated with high efficiency LED lighting. Actual numbers will usually be significantly higher.

Lighting Control Mechanisms

There are four main control mechanisms which are commonly employed for reducing the energy consumption of lighting systems.

Four energy consumption reducing mechanisms:

- Occupancy sensors allow turning off the light automatically if it is not needed. This is especially beneficial for larger office spaces where individual areas might not be used all the time
- Defining times during which the lighting is turned on / off (scheduling). This approach is suitable for areas with a time-defined lighting pattern (e.g. reducing light level in shopping malls when closed, turning off outdoor lighting during the day)
- Ambient light level sensors can adjust the brightness of the indoor lighting based on the amount of available ambient light (so-called daylighting). This is especially beneficial for buildings with large glass fronts where lots of ambient light is available
- Defining maximum brightness settings for dimmable lights (so-called task tuning or institutional tuning) avoids overly lit areas and optimizes the light level for individual areas

Energy Savings from Smart Lighting Controls

The energy savings that can be realized with smart lighting controls have been extensively studied both on an individual level (specific buildings / installations) and on a high level across a wide range of different installations.

Those studies clearly demonstrate that all four lighting control mechanisms are well defined and have proven to significantly reduce energy consumption. Quoted energy savings range from 10% to more than 50% depending on the specific usage situation.

The US Department of Energy published a study [4] in 2017 determining the following typical savings for occupancy sensors depending on the room type:

Location	Typical Savings
Breakroom	29%
Classroom	40-46%
Conference Room	45%
Corridor	30-80%
Private Office	13-50%
Open Office	10%
Rest Room	30-90%
Storage Area	45-80%
Warehouse	35-54%

Table 1: Typical savings for occupancy sensors depending on the room type [5]

During a Meta study [6] of available savings data performed by Lawrence Berkeley National Laboratory in 2012, savings were determined to be 24% for occupancy-based control, 28% for daylighting control, 31% for personal tuning, 36% for institutional tuning and 38% for the combination of several approaches.

Assuming a basic lighting control system consisting of an occupancy sensor and a dimmer switch, it therefore is conservative to estimate that at least 30% savings in energy cost can be achieved. In terms of the office use case baseline, this means that at least 8 Watts of energy for lighting would be saved per work place.

Power Consumption of Lighting Controls

The power consumption that can be attributed directly to lighting controls is mainly determined by two device classes.

The device classes:

- Power consumption for input devices (sensors / switches). The amount of power consumed by devices that provide input data to regulate the light level, e.g. occupancy sensors, daylight sensors or dimmer switches
- Power consumption for output devices (controller)

The controller receives input from connected sensors (wired or wireless), calculates the corresponding light level and communicates it to the driver via a suitable interface (e.g. DALI).

These two device classes might be implemented separately (e.g. one central occupancy sensor providing input to several controllers) or together (as controller with integrated sensors). One example for such sensors is the Philips Easysense family [7].
The consumption of sensors is typically less than 0.1 W and that of controllers typically less than 0.2 W.

In addition to the consumption of sensors and controllers, one has to account for the standby consumption of the connected driver. This is typically less than 0.5 W. With these numbers it is possible to estimate that a complex control system (one controller, one sensor, one switch, one driver) will usually not consume more than 1 W of power. Putting this figure in relation to the realized savings it becomes immediately clear that the realized energy savings (8 Watts) strongly outweigh the additional power required for the operation of the smart lighting controls (1 Watt) in the case of an office environment.

This comparatively straightforward conclusion begs the question why smart lighting controls are not

universally adopted already today. Therefore, the state of adoption and potential hurdles will be discussed in the following.

Adoption of Lighting Control

The adoption of smart lighting controls or even the transition to LED lighting is still in the very early phase. The latest estimate [8] from the US Department of Energy puts the adoption of LED lighting within the Unites States in 2017 at 12.7%. The same report estimates that the share of connected lighting controls currently is well below 1% of the total installed base.

Lighting controls are increasingly becoming standard in new construction of office buildings, but this accounts only for a small fraction of the total number of buildings.

Europe contains some 160 million buildings as estimated by experts of the ECTP (European Construction Technology Platform). More than 80% of these buildings are older than 30 years and only approximately 1% are newly built each year.

From these numbers it is clear that major lighting energy savings can only be realized by retrofitting the existing building stock.
To successfully address this market, lighting controls must present a positive ratio between the cost spent for the upgrade of the lighting system and the realized gains.

The main factors affecting cost are the cost of the products themselves, the cost of installation and the cost of operation (including maintenance). The latter two factors can be significantly lowered by the use of a wireless control system (providing quick installation with minimal disruption) in conjunction with energy harvesting sensors.

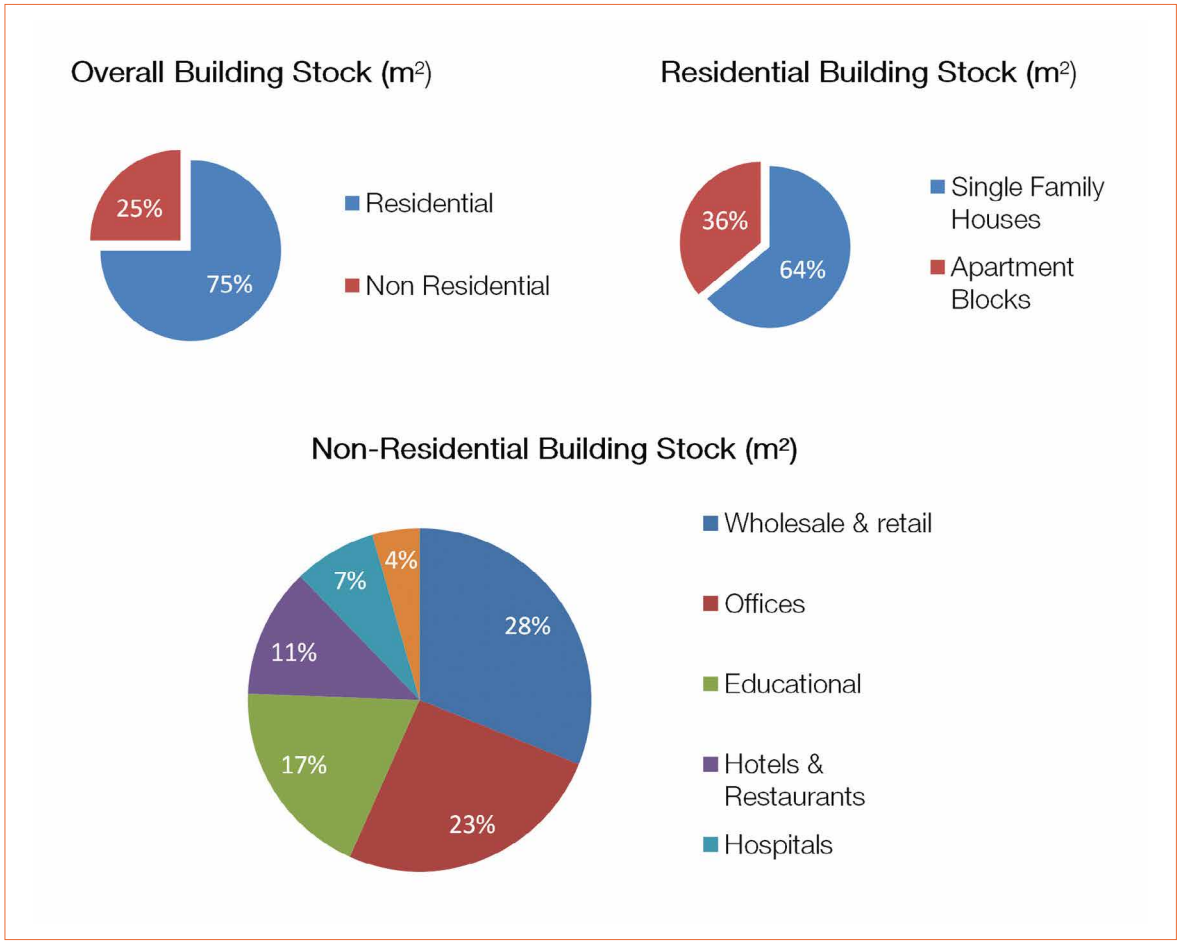


Figure 2:
European buildings at a glance [8]

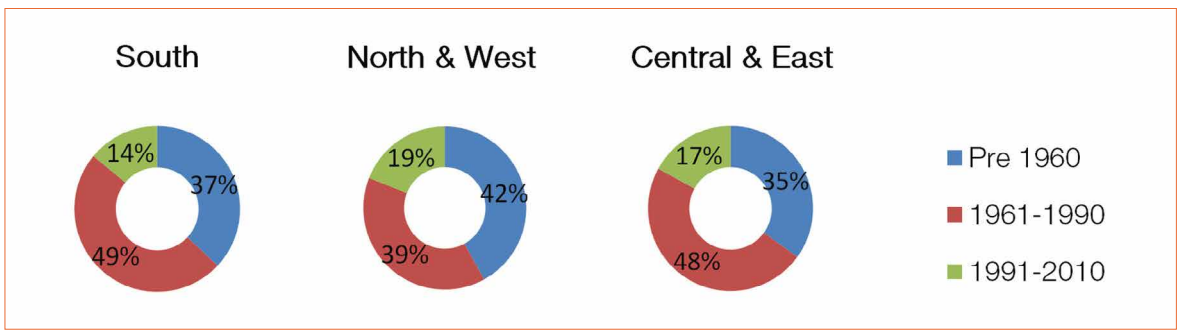


Figure 3:
Age categorization of housing stock in Europe, divided into three regions [9]

Expected Impact on GHG Emissions

GHG emission reduction associated with these energy savings depends on the energy source mix chosen. Considering the EU-27 average mix then the relationship is some 443 g of CO_2 per kWh saved. Thus the 180 thousand apartment's impact of 1600 million KWh energy savings would deliver a reduction of CO_2 emissions of some 700 million kg (or 700.000 tons) of CO_2.

According to the U.S. Environmental Protection Agency, an astonishing 30% of the average energy used in commercial buildings is wasted. Heating, ventilation, air conditioning systems and lighting typically account for more than three quarters of a building's energy use. The case might be less clear in home environments where lighting controls are typically integrated into devices such as Amazon Alexa or Apple Home requiring their own (less energy optimal) hardware for operation.

Amazon Echo for instance consumes between 2 and 3 Watt of standby power depending on the device used. According to a survey [10], with 31 million units sold as of January 2018, this equates to more than 500 GWh of energy per year creating an environmental impact of more than 200,000 tons of CO_2.

Global Energy Impact of Lighting

According to a study [11] of the international energy agency (IEA), lighting today accounts for approximately 19% (~3000 TWh) of the global electric energy consumption. The energy consumption for lighting is predicted to grow despite significant and rapid technical improvements like solid-state lighting, new façade and light management techniques.

Improving energy efficiency in lighting has therefore become a key focus of energy conservation activities and the use of lighting controls seems to be the most promising way to achieve this goal. Deployment of these controls will occur predominantly during retrofits and upgrades due to the low rate of new buildings.
The total energy consumption of buildings is estimated by the European Commission [12] to be approximately 40% of the total energy used in Europe.
Leveraging the sensor data generated by smart lighting systems to optimize, for instance, the operation of the heating and cooling system can therefore significantly add to the overall energy savings. ■

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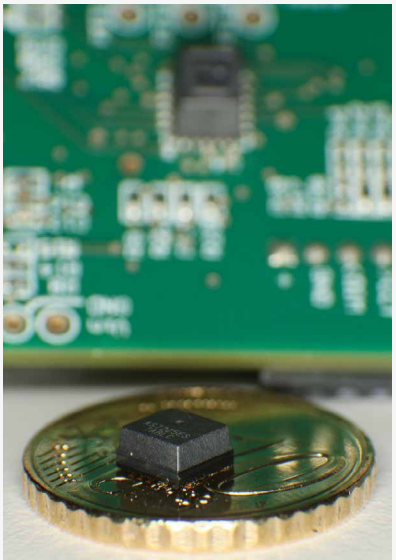

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Next LpR

SMART DESIGNS & APPLICATIONS
Issue 69 - Sept/Oct 2018

TECH-TALKS BREGENZ

Guido van Tartwijk - CEO of Tridonic

Many traditional luminaire manufacturers are currently facing difficult times. LED professional discusses how this situation affects an electronics manufacturer. The company's approaches to the hot topics of IoT, Smart Lighting, Human Centric Lighting, and Artificial Intelligence are addressed, including the underlying technologies. Light quality, health and well-being are covered as well as the future prospects of the company.

RESEARCH

"Best Papers" at LpS 2017: Smart Design of Freeform Micro-Optical Elements for Thin Direct-Lit Luminaires

Direct-lit LED luminaires consist of LED arrays. To achieve homogenous light distribution a diffuser sheet is placed at a certain height above the LED array. Usually the distance between the LEDs and the diffuser has to be bigger than the distance between the LEDs on the array. To overcome this limitation, additional optical elements like freeform lenses are necessary. A smart design concept for an extremely flat, direct-lit lighting system is discussed. The concept emphasizes the use of mask-less laser direct write lithography for the cost-effective fabrication of the thin freeform micro-lens array.

ENGINEERING

Evaluating Performance of LED Based Luminaires

Widespread performance data supplied by manufacturers make it difficult for the professional user to use an "apple-to-apple" comparison, especially if the data is not based on standardized metrics. This is, however, critical for the preparation of lighting projects or tender specifications. Experts from LightingEurope have therefore developed a guidance document that recommends a fixed set of performance data for LED based luminaires with particular emphasis on the useful life and data that is necessary for lighting application design.

APPLICATIONS

Interactive Lighting Control is Opening New Doors for LED Applications

Interactivity has been a growing feature of consumable technology for a number of years. Advancements in lighting control technology are allowing for sophisticated interactivity in LED mapping. These new technologies are bridging the gap between lighting control and AI, with the ability to analyze and map data input (such as audio) in real-time. Installations driven by interactive LED control technologies have their place in a variety of application spaces. The authors explain how this new technology works, what its applications are, and what the future of interactive lighting control looks like - not only for end-users, but also for lighting designers and technician.

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