LED professional Review

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LpR

The Global Information Hub for Lighting Technologies

May/Jun 2020 | Issue 79

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Future Proofed Lighting Systems

In this issue of the LED professional Review (LpR) we would like to take a closer look at the topic of ”Future Proofed Lighting Systems”.

At its core, the requirement is that lighting investments should be sustainable. There are various topics that should be examined in this context. Firstly, it’s the issue of the circular economy, the need of making products long-lasting on the one hand, and making them reusable and recyclable, on the other. Longevity depends on the original design per se, but modularity and upgradeability through connected devices are key functionalities to acieve long-lasting systems.

The use of sustainable materials, careful use of resources and the avoidance of waste or non-recyclable materials are essential here. Future Proof also means, however, that the functionality can be adapted in such a way that the lighting technology can meet the requirements of the visual tasks of the future. Human Centric Lighting, adaptive systems and dynamic, intelligent lighting solutions play a particularly important role here.

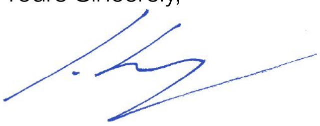
Future-oriented lighting solutions are therefore highly efficient, save resources and, via networking, offer the possibility of functional changes so that new lighting solutions can be flexibly adapted.

Secondly, future proof also means safeguarding current international standards, because this is a preferred way to guarantee future expansions and adaptations of lighting solutions. The topic of Light as a Service (LaaS), where lighting systems are “rented” from the provider, can secure Future Proof by having the manufacturer take care of the safeguards.

In this issue you will find articles provided by experts that delve deeper into the subject of Future Proof. In this phase of transformation, where the lighting industry now finds itself, the topic of future proof is especially important.

We’d love to hear what your definition of future proof is. Let us know your thoughts by leaving your feedback on one of our social media channels.

Yours Sincerely,



Siegfried Luger

Luger Research e.U., Founder & CEO
LED professional, Trends in Lighting, LpS Digital & Global Lighting Directory
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ADVERTISING INDEX

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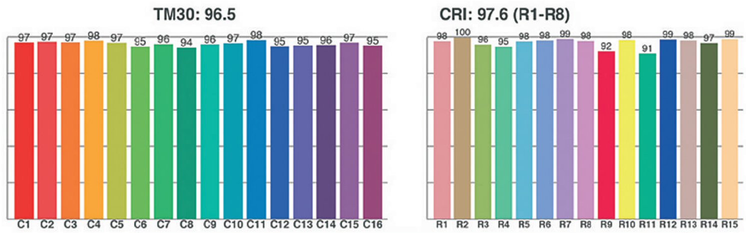

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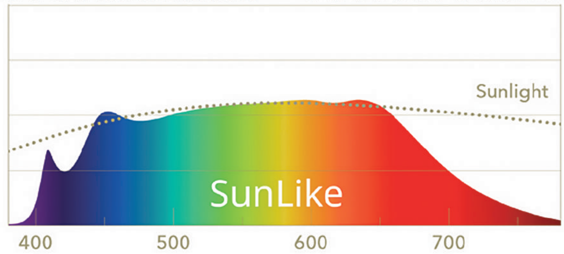
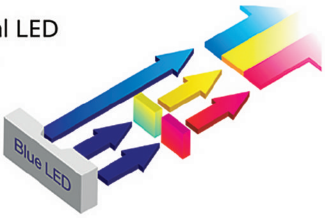
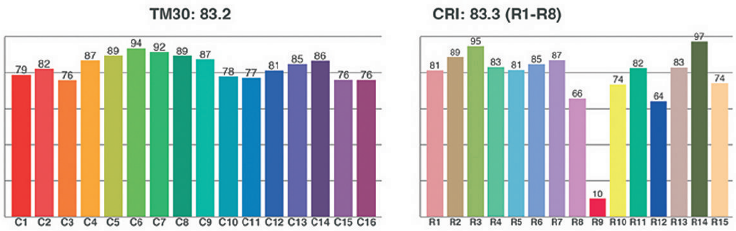
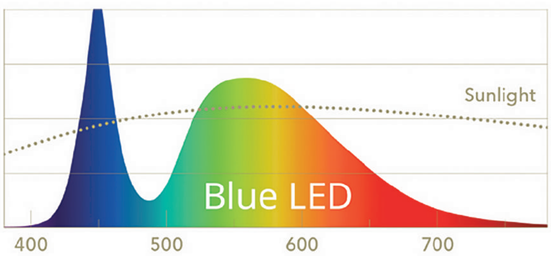


Traditional LED
Blue chip





Big Blue Peak
Very Low M-EDI (490nm)
Low color rendering
No natural spectrum



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Daniel Neves PIMENTA, Architect & Researcher

Educated as a carpenter and interior architect, Daniel Neves Pimenta gained experience at Behnisch Architekten with sophisticated architectural projects, including the "Haus im Haus", the world's first LED illuminated office building. Fascinated by the potential of LED, he worked for Nimbus as a designer, and subsequently as head of the design team until he took the lead of the product development team at XAL in Graz for three years. After a brief stop at Georg Bechter Licht in Vorarlberg, the Stuttgart born Portuguese returned to his Swabian roots to research the future of the lighting industry and Mass Personalization at the Fraunhofer Institute for Building Physics.

'Future-Proofing' - An Illusion in Lighting?

For a long time, the lighting business was a typical example of the manufacturing industry, with high quantities of standard components developed and provided by industrial giants. Even before the lightbulb was developed, lighting manufacturers standardized candles and candleholders to fit together properly. "Future-Proofing" was part of the business. Standardization, norms, industrialization, new production methods, and the reconstruction of the modern world paved the way to a smooth and stable market, which reduced innovation and creativity down to simple ploys of marketing and design. The real drivers for innovation were lying in the hands of a very small group of huge companies. This was the working culture that bound many of the luminaire manufacturers, with reducing costs, minimizing complaints and reducing communication efforts being their sole focus. Due to the fact that the lighting emitters were standardized, manufacturers could also optimize reflectors, lenses and housings to a maximum. Complex tools could be amortized as the number of light sources was limited and investments in the future proofing was easy. Those who had the power and means could increase influence and certainty by establishing patents and other intellectual property rights. Typically, wholesalers or professional retailers who distributed products had their own established customer base. The customers' needs were described to the manufacturers in detail by them, providing insightful exchange. Their influence was high, and the margin the retailers and wholesalers made, was even higher. At that time, concerning sales, the best "future proof" was to have a good channel of business to the customer.

With the introduction of the first SMD LEDs around 2004, the possibilities in terms of creating light sources increased in a way never seen before. The saturated market asked for distinctive features: The political ban of the classic incandescent lightbulb and the insufficient quality of the compact fluorescent lamp provided by the "giants" all led to an unknown change in the lighting business. All of a sudden, the influence of the top dogs dropped. Early adopters created fixtures with new form factors, efficacies and functions. Low-voltage allowed for a more playful relation between the designers, installers and the users of the lighting. The "old economy" patents and standards were untouched, and expensive tooling was avoided by using craft and manufacturing methods. Abruptly, even major luminaire producers were pressured to provide LED fixtures. The big industries weren't able to raise new standards and technical solutions like Zhaga in an appropriate time. The new technology offered an unknown quantity of possibilities that even changed the traditional distribution channel situation for both wholsalers and retailers. More and more, the distributors were left out of the process when defining new projects. The luminaire producers had to increase not only their skills in electronics and optics, but also in communication and distribution.

How can lighting be "future proof" when the market is changing faster and faster? Customers have growing expectations which need to be met, all while production is getting more competitive: Lot sizes are getting smaller, production costs and globalization are leading to price battles, sustainability goals are becoming more important and regulations are increasing. And all the while, the next big game changer, digitalization, has been knocking at the front door. I am sure that contrary to the methods described above, creativity and collaboration platforms will be keys to the future, not only in lighting business. It is necessary for companies to set up an environment where new ideas are not blighted but supported, where ideas are fostered in a surrounding which allows for failure, and where failures can be fixed in processes together with comprehensive and confident partners. The future will be much more complex than today, but there will be more experts to cooperate with, better tools to use, and new roads to navigate – we have to choose them wisely in order to make sure that lighting companies are relevant in the future. It´s not only about technology or IP, it is about a state of mind. ■

D.N.P.

APPOINTMENTS

New Date: Light + Building Will Be Held Again in Its Normal Sequence in 2022

In view of the world-wide situation caused by the Corona pandemic, and the prohibitions on events and travel restrictions associated with it, Messe Frankfurt has decided, jointly with its partners – ZVEI and ZVEH – and with the Trade Fair Advisory Council, to defer the eleventh Light + Building and to hold it, in accordance with its normal sequence, from 13 to 18 March 2022. Due to the present Corona

Light + Building has been cancelled in 2020

crisis it had already not been possible to hold Light + Building 2020, originally scheduled for March, for which reason the decision was reached to postpone the world's leading trade fair for lighting and building services technology to the later date of 27 September to 2 October 2020. Messe Frankfurt, together with its partners, then initiated appropriate measures to carry out the event postponement as well as possible. Having considered the current situation again, and ten weeks after the initial postponement, in view of the joint decision by the Federal German Government and German States that major events cannot be held in Germany until at least the end of August, no properly scheduled preparation and holding of the event can be guaranteed. When holding events of all kinds, travel conditions and regulations prohibiting assembly play a central role. It is the aim of the industry, and of business in general, to hold Light + Building, as a leading world trade fair, in conformity with its customers' expectations and in accordance with its conception and service commitment. At the moment Messe Frankfurt cannot guarantee that this aim can be assuredly achieved.

”The current regulations, combined with continued global travel restrictions and the potential threat to individual health, make it impossible to hold Light + Building in 2020”, states Wolfgang Marzin. ”At the same time, in the interests of exhibitors and visitors, we must avoid unnecessary costs in good time. The decision has not been easy for any of us, but now we shall be directing our energies to holding the next Light + Building in its accustomed sequence in 2022.” The decision likewise affects Intersec Building. Now, as a platform for connected security technology, the format will celebrate its premiere as an integral part of Light + Building in 2022.

”Light + Building is of quite particular importance for companies engaged in lighting and building services technology – it is here that industries with the latest technologies look far into the future. However much we regret the cancellation, we are also in favor of it. Given the manifold uncertainties and challenges, it was right to make this decision now, jointly and in a dialogue between partners”, is how ZVEI President Michael Ziesemer puts it.

The chairman of the ZVEI Association for Electrical Installation Systems, Daniel Hager, adds: ”In the present situation we would not have been able to experience the positive, cooperative and innovative spirit which Light + Building has embodied from its very start. Everybody's mind is elsewhere and social distancing is not suitable for a trade fair. So we should all look forward: the fair will continue to exist, as a beacon for the industry and as a platform rich in the exchange of ideas. I am sure: in March 2022, with new energy, we shall have a better starting point for the fair.”

Manfred Diez provides the following analysis from the perspective of the ZVEI Association for Light: ”The light industry is a very innovative sector, with many new products and technologies. To show these to a broad public, Light + Building is one of our most important tools. To make sure it stays so”, continues the Association's chairman, ”we must all pull together.”

At the same time ZVEH President Lothar Hellmann emphasized: ”Over the past 20 years Light + Building has developed into 'the' information and technology platform for the industry. What makes this leading international trade fair so vital is the intensive exchange which takes place between its participants. That there is nothing to replace the personal meeting, despite all modern communication, has been a major experience during the Corona crisis. I am therefore looking forward with pleasurable anticipation to Light + Building 2022, at which climate protection, electromobility and digitalization will provide a major focus.”

Holger Heckler also had some words to say on the matter. The chairman of the VEG (German Electrical Wholesalers' Association) said: ”We can perfectly understand this decision. It is really unfortunate for the electrical industry that Light + Building cannot be held in 2020 and we must manage as best we can without our most important trade fair. But health comes first.”

So for 2020 the task for the whole industry is to catch our breath, to come back all the stronger – at Light + Building 2022.

About Messe Frankfurt:
Messe Frankfurt is the world's largest trade fair, congress and event organiser with its own exhibition grounds. With more than 2,600* employees at 30 locations, the company generates annual sales of around €733* million. We have close ties with our industry sectors and serve our customers' business interests efficiently within the framework of our Fairs & Events, Locations and Services business fields. One of the Group's key USPs is its closely knit global sales network, which extends throughout the world. Our comprehensive range of services – both onsite and online – ensures that customers worldwide enjoy consistently high quality and flexibility when planning, organising and running their events. The wide range of services includes renting exhibition grounds, trade fair construction and marketing, personnel and food services. Headquartered in Frankfurt am Main, the company is owned by the City of Frankfurt (60 percent) and the State of Hesse (40 percent). - www.messefrankfurt.com ■

New CEO For Tridonic

Hugo Rohner was appointed CEO of Tridonic, the lighting technology arm of the Zumtobel Group. Mr Rohner joins as an internationally experienced manager in the fields of digitalisation and IoT (Internet of Things) and was most recently the CEO of the Skidata Group in Salzburg. Prior to that, he held leading positions at international companies in Switzerland, the USA and Germany. Born in Switzerland, he holds a Master's degree in Business Administration from the University of St. Gallen (HSG) and a Master's degree in International Management from the Community of European Management Schools and International Companies (CEMS). "We are delighted to have

Hugo Rohner

acquired the services of such an experienced manager in Hugo Rohner. Tridonic will benefit from his know-how from the IT industry, among other things," says Alfred Felder, CEO of the Zumtobel Group. "The Tridonic leadership team with CFO Thomas Erath and COO Alexander Jankovsky is now complete again. ■

Full Spectrum LEDs Outperform Standard LED Lighting, Study Shows

Full Spectrum LED products outperform conventional solutions, according to a study into the visual impact and perceptual performance of LED lighting by the Fraunhofer Institute for Building Physics (IBP) in Stuttgart, Germany. Research

High Performance Indoor Environment Lab (HiPIELab) at Fraunhofer. Image provided by Fraunhofer Institute

conducted by the organization at its High Performance Indoor Environment Lab (HiPIELab) indicates that Full Spectrum LED lighting delivers greater visual comfort and an improved perception of naturalness (including color, condition and quality) compared to standard LED products. Researchers concluded that unrivalled color rendering for different color temperatures can be provided by Full Spectrum LEDs.

“There is limited research on the impact of Full Spectrum LEDs on people’s perception, with a focus instead on the psychological effects of natural and artificial light in general”, said Dr. Ulf Meiners, Managing Director at Nichia Germany.

Full Spectrum LEDs are usually categorized as those emitting light similar in composition to natural sunlight. NICHIA, for example, has developed a range of proprietary Full Spectrum LED solutions with specific benefits. For example, Optisolis™ technology accurately mimics sunlight but without producing any ultraviolet light (which can degrade precious artefacts) making it ideal for museums, art galleries and jewelry stores among other retail settings. Vitasolis™ products target human centric lighting applications with a color spectrum richer in cyan content to promote greater alertness.

The soon-to-be published Fraunhofer IBP study incorporated a technical comparison of the LED spectra to daylight spectra, a literature review addressing the effect of light spectra on humans, and a psychological study with 83 persons in an office setting. Each participant was tested for one hour in one of four different lighting settings comparing Full Spectrum LEDs with conventional LEDs on various aspects such as visual comfort, naturalness, concentration, general glare rating, sleepiness, alertness and glossiness.

> *”As a pioneer of true daylight white LED emitters, NICHIA welcomes the findings from Fraunhofer IBP. We hope new studies are developed to further demonstrate the performance of Full Spectrum LEDs on perception, behavior and health.”*
>
> DR. ULF MEINERS, MANAGING DIRECTOR AT NICHIA GERMANY

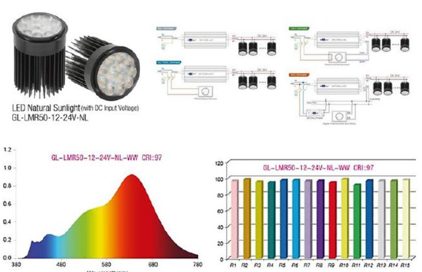
■

GlacialLight - New Natural Sunlight GL-LMR50-12-24V-NL with DC Input Voltage

GlacialLight, the LED lighting division of GlacialTech Inc., announces the natural sunlight GL-LMR50-12-24V-NL with DC 24 V of 3000 K warm white. With a CRI of 97, as well as the CQS (Color Quality Scale) is up to 97. The color fidelity index (TM-30-15 Rf) and color gamut score (TM-30-15 Rg) are close to natural sunlight. It can be non-dimmable and dimmable, given the appropriate DC electrical signal; brightness can be adjusted freely with a DC constant voltge PWM signal. GlacialPower GP-CVM constant voltage series driver provides non-dimmable and most popular three dimming functions include AC-TRIAC dimming, 3-in-1 dimming and DALI dimming for greater lighting flexibility and are suitable for GL-LMR50-12-24V-NL.

The GL-LMR50-12-24V-NL offers optional round and square single housing in black and white. Besides that, it also provides round double housing and round triple housing. The beam angle comes in 30° and 40°, making this new product a flexible lighting solution for any space. The elegant, simple design, with a rounded lighting fixture, makes it perfect for creating a lighting atmosphere. The GL-LMR50-12-24V-NL is suitable for spot lighting, residential lighting, commercial lighting, hallway lighting and cabinet lighting.

The user friendly GL-LMR50-12-24V-NL features a mistake-proofing design to connect DC 24 V power input. Installers do not need to distinguish the polarity between the positive and negative poles of power input, making it easy to avoid damaging the units with wrong polarity power input. This new product also comes in a parallel expandable design. It can directly connect lots of DC lighting fixtures with one constant voltage driver if it provides enough watts. It saves extra LED drivers fee and working hours. The natural sunlight



Glacial's new GL-LMR50-12-24V-NL is characterized by high CRI, high CQS, and high Rf respectively Rg values due to its continuous spectral distribution across all wavelengths

GL-LMR50-12-24V-NL with high color rendering index 97 produces a continuous spectral distribution across all wavelengths and no color gaps, just like the spectral distribution of sunlight. It is uniquely designed with full spectrum technology that lets you see each color as natural, real light.

About GlacialLight:
GlacialLight, the lighting division of GlacialTech, manufactures LED lighting solutions for indoor/outdoor applications and both residential and commercial uses. As well as having a wide range of finished LED lighting products, GlacialLight also offers its clients the option of customizing products for specific needs. - www.GlacialLight.com ■

SOLID STATE LIGHTING

MARKET

LG Innotek Sells off LED Business

According to THE ELEC, Korea Electronics Industry Media, and other industry sources, on April 21, LG Innotek has sold off its LED business, with Wooree E&L and Seoul Semiconductor taking over the BLU LED sales rights.

BLU LED are necessary light sources for LCD panels. They are used in LCD TVs, laptops, monitors and others. Wooree E&L, a part of Wooree Group, has secured rights to sell BLU LED in laptops, monitors and signage along with some right for TVs. With the rights, Wooree E&L is permitted to supply to companies such as LG Electronics, Dell and HP via LG Display.

Wooree E&L is currently selling LED packages for laptops, monitors, smart PCs, TVs and automobiles. This latest deal with LG Innotek is expected to spell out bigger sales for the Kosdaq-listed firm, which recorded sales of KRW 133.2 billion in 2019, and an operating profit of KRW 3.5 billion.

Meanwhile, Seoul Semiconductor secured more than half the sales rights for LCD TVs. It also can sell via LG display, which is likely to boost its revenues from this year. In 2019, its sales stood at KRW 1.29 trillion won, and an operating profit of KRW 49.5 billion. Both

Wooree E&L and Seoul Semiconductor took over the orders from LG Innotek early this year to begin mass productions. LG Innotek plans to drop the business altogether within the first half of this year. Wooree E&L and Seoul Semiconductor did not acquire the BLU LED-related assets from LG Innotek, mostly because they had sufficient production facilities already.

LG Innotek is planning to sell such assets to a Chinese company, said one source close to the matter.

In October, 2019, LG Innotek decided to restructure its LED business that was bleeding money. It tried to sell via turnkey, but failed to find the right partner. In the process, LG Innotek decided to keep its automobile module business. It is currently in the midst of developing them with partners.

LG Innotek's LED business recorded 12 straight years of deficit since it was first listed on the main bourse in 2008. Up until 2019, the division's accumulated operating deficit stood at KRW 1 trillion. To help cut away the losses, LG Innotek also shuttered its HDI business in 2019, triggering speculation that the firm will post better bottom figures this year. ■

SYSTEMS

ERCO Delivers New Spotlight Range Eclipse

The new Eclipse spotlight range from ERCO would have been showcased at Light + Building in March. ERCO specialise in lighting technology for: prestigious museums, art galleries and exclusive retail projects. Clients have come to expect individual lighting solutions that simultaneously offer perfect quality in terms of design and lighting technology. A requirement that ERCO meets 28,000 times with the Eclipse range – the new spotlights, floodlights and wallwashers not only impress with innovative technical details but also with unprecedented system scope. Never before has ERCO had a range of spotlights with so many sizes, optics, light colours and connectivity options – as well as such a wide range of accessories that further increases possibilities.

But what must a lighting system look like that emphasises precious objects in display cases as brilliantly as it uniformly floods the walls of art galleries or highlights large sculptures in atria? Definitely unlike anything else before, thought the ERCO developers and designers. The original appearance of Eclipse is characterised by its new type of optics. A bayonet connects these interchangeable lens units with the slender, cylindrical luminaire bodies made of cast aluminium.

Apart from a few interesting exceptions to be discussed below, the optics create their specific light distribution by means of special Darklight lenses from only one light point. Due to the clear, highly non-reflective lenses, the beam path is virtually invisible and the light emission is free of spill light – for a magical appearance and superior visual comfort.
Consistent and scalable

The dimensions of the Eclipse system score points even without the element of magic: five sizes from XS to XL provide an enormous range of lumen packages for applications of any scale. The most compact Eclipse spotlights with a diameter of only 32mm fully exploit the miniaturisation potential of modern LED technology. They enable highly nuanced lighting concepts even under tight space conditions, especially with the variant for Minirail 48V track. In any size, the interchangeable lens units ensure that the light distribution is precisely and flexibly matched to the lighting task at hand.

The complete toolbox

The complete gamut of characteristics from the ERCO luminaire system are available to lighting designers. High-precision Darklight lenses define the rotationally symmetric light distributions ranging from narrow spot (5°) to extra wide flood (80°). There is also a range of ERCO speciality features: two axially symmetric light distributions consisting of oval flood (18° x 65°) and oval wide flood (55° x 85°), the wallwash asymmetric light distribution for uniform vertical illumination, the contour spotlight for crisp-edged projections onto surfaces and the two compact zoom optics of zoom spot (17° – 67°) and zoom oval (25° x 65° to 62° x 68°). In short, an entire toolbox with which all conceivable situations can be mastered, for example, in museum lighting – with accessories such as sculpture lenses and soft focus lenses enabling further fine-tuning.

Perfectly matched LED spectra

The same principle – a modular design with accessories – also makes the system extremely versatile and flexible in terms of light colours. Eclipse comes with LEDs in six light spectra with colour temperatures from 2700K to 4000K and colour rendering indices from Ra 82 to Ra 97. Four conversion filters as accessories create 24 additional spectra for colour fine-tuning. Alternatively, tunable white and RGBW are also available, especially for dynamic scenes. In the case of Eclipse, ERCO offers various conventional and wireless connectivity solutions to control such functions and for infinitely variable dimming down to 0.1% – in an even larger selection than usual.

Connectivity – from Bluetooth to Zigbee

Most options are available for the Eclipse InTrack luminaire model with its ultra-slim, flush-rail adapters for the ERCO track. The options for wireless control via Casambi Bluetooth or Zigbee 3.0 are especially noteworthy here – but also the new Multi Dim control gear which is extremely flexible with DALI, Push Dim or phase dimming. Eclipse (sizes XS to M) is also available with the proven ERCO transadapter specifically as an upgrade for existing track installations. Eclipse 48V for Minirail can be controlled wirelessly via Casambi Bluetooth, Zigbee 3.0 and DALI via Casambi Gateway. The options “switchable” and “on-board Dim” with rotary control on the luminaire are available in all versions.

A future-oriented high end system

The technical details outlined above make it clear: with its Eclipse range, ERCO breaks new ground in many areas and thus reinforces its claim to leadership in the lighting industry for museums, exclusive shops and comparable applications that demand high-end lighting tools. To solve demanding lighting tasks, Eclipse is set to become the premier choice for all lighting designers and users in the future. ■

First Outdoor LED Luminaires Received Zhaga-D4i Certification

The Zhaga Consortium (Zhaga) and the Digital Illumination Interface Alliance (DiiA) have reached a key milestone in their joint Zhaga-D4i certification program. Several luminaires from Signify and Schréder have been certified according to this new program. They can carry the dual logos of Zhaga and D4i which together indicate interoperability of luminaires, sensors and/or communication nodes.

”The use of the Zhaga and D4i logos together on luminaires and nodes will provide clarity and confidence in multi-vendor product interoperability,” said Paul Drosihn, DiiA General Manager.

Based on complementary specifications from Zhaga and DiiA, Zhaga-D4i makes it easy to add or upgrade sensors and/or communication nodes. This enables smart, future-proof LED luminaires with IoT connectivity.

”With the Zhaga-D4i certification program, decision makers in outdoor road lighting can combine the long-lasting nature of the lighting infrastructure with the rapid changes in digital communication and sensor technology,” said Dee Denteneer, Zhaga Secretary-General.

Zhaga-D4i luminaires have a powered Zhaga receptacle, which can accommodate a sensor or communication node with a corresponding Zhaga plug. Also, Zhaga-D4i luminaires use LED drivers meeting the D4i requirements, including the availability of DALI-2 luminaire, energy and diagnostics data. Zhaga-D4i

Several outdoor LED luminaires have received Zhaga-D4i certification as a result of the joint program from Zhaga and DiiA

certification of sensors and/or communication nodes will become available later in 2020. Zhaga-D4i luminaires are listed on the Zhaga website at zhagastandard.org/products.htm , while D4i drivers can be found in the DiiA online Product Database at digitalilluminationinterface.org/products

The first Zhaga-D4i luminaires are outdoor fixtures that are certified in accordance with the requirements of Zhaga Book 18 Ed 2.0, published in late 2019.

Zhaga-D4i certification will be extended to include Zhaga Book 20 for indoor applications, which will be published in April 2020 for Zhaga members. Preliminary information was published in LpR 73 (the May/June 2019 issue).

About DiiA:
The Digital Illumination Interface Alliance (DiiA) is an open, global consortium of lighting companies that aims to grow the market for lighting-control solutions based on Digital Addressable Lighting Interface (DALI) technology. DiiA is driving the adoption of DALI-2, the latest version of the internationally-standardized DALI protocol. DALI-2 includes more product types, more features, clearer specifications and increased testing. DiiA operates the DALI 2 certification program, bringing the promise of significantly-improved interoperability compared with current DALI systems in the market. DiiA develops test specifications for DALI-2 product compliance testing, and also creates new specifications for additional DALI-2 features and functions. - www.digitalilluminationinterface.org

About Zhaga:
Zhaga is a global association of lighting companies that is standardizing interfaces of components of LED luminaires, including LED light engines, LED modules, LED arrays, holders, electronic control gear (LED drivers) and connectivity fit systems. This helps to streamline the LED lighting supply chain, and to simplify LED luminaire design and manufacturing. Zhaga continues to develop specifications based on the inter-related themes of interoperable components, smart and connected lighting, and serviceable luminaires. - www.zhagastandard.org ■

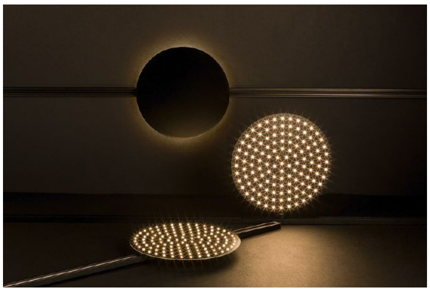
Tom Dixon and Prolicht Collaboration Leads to a New Lighting Range - CODE

British designer Tom Dixon and leading manufacturer of architectural lighting Prolicht, announced their collaboration and unveil their new lighting range: CODE. The common ambition was to rethink track lighting and to celebrate the fast-developing world of electronics and LEDs. Their partnership enables a unified proposal for architects and designers: a unique combination of highly technical and decorative lighting in one product.

Tom says: 'For the past year, we've been obsessed with printed circuit boards (PCBs). So flat, so efficient, and so very luminous! Our collaboration with Prolicht started high in the mountains of Innsbruck where we shared our first thoughts on a Minimal Track System that would attempt to remove the superfluous and reveal the light engine in all its naked glory.'

Walter Norz, Prolicht CEO adds: 'It was amazing how quickly the connection with Tom and his team started. From our very first meeting, the spark of creativity was there, and we all immediately felt an urge to start something together. Our first joint adventure, CODE, represents the epitome of our collaboration: something neither of us could have done without the other. Two different backgrounds and complementary skills merging to create the perfect product.'

CODE is an LED track system which combines Prolicht's expertise in technical lighting engineering with the discernible Tom Dixon design and aesthetic. It utilises bare LEDs on circuit boards that can be used to create thin strips, delicate chains and continuous columns of light. CODE has three LED light sources: Dot, Dash and Grid. These elementary shapes of round, square and line form the basis of a kit-of-parts, which allow infinite possibilities to design graphic lighting sculptures. Tom says: "The mystery to us was why so much time and effort had been expended hiding and minimising these extraordinary boards that have become so ubiquitous. We wanted to get to the essence of modern light, which has so swiftly moved from incandescent electrical to pure electronics, transforming the way we are able to illuminate and radically reduce our electricity consumption at the same time. The question was how we could expose and explain the simple and intricate beauty of the circuit board and strip away any peripheral decoration or structure." Through this strategic partnership,



CODE - A new lighting range as a result of the cooperation between Tom Dixon and the Austrian architectural lighting specialist, Prolicht

Prolicht will also be able to offer fully customised solutions on the existing Tom Dixon lighting range, including best-selling families MELT, MIRROR BALL and COPPER. Walter Norz says: 'In practice this means that a customer who requires 200 Melt lights for his/her project with 20-metre long cables or with a cool white high-powered LED or with a specific driving system can order these through Prolicht. The configuration options are endless.' ■

Xicato's New Premium Smart Linear LED Lights Join Their End-to-End Solutions with Smart Drivers and Controls

Xicato, the leading provider of Bluetooth smart building wireless controls and highest quality light sources, announced the introduction of XFL, the next generation of smart enabled linear lighting solutions that live up to quality standards the company's LED spot lights have set for the market over the past 12 years. The complete and focused portfolio is designed to support creativity and ease of product selection for lighting designers, specifiers, and customers without the typical pain of searching through endless legacy SKUs often associated with other product portfolios in the market.

Xicato's XFL line of linear lights are designed to accompany all versions including the premium version of Xicato's unique XTM/XOB series of spot lights with unmatched quality

Highlights:

- XFL is a next generation portfolio of quality flexible linear sources with consistent flux and color accuracy with options that match the Xicato color point and the XTM/XOB Spot lights
- The XFL portfolio includes Vivid White, High Density, Full Natural Spectrum, Tunable, Dim-to-Warm, RGBW, Neon and Specialty light options to suit designer's targets
- 24 V input for ease of selection and integration
- Selection of approved 3rd party AC drivers with 0-10V and DALI inputs at a wide range of power outputs are available with the option of Xicato Bluetooth Mesh for smart wireless controls
- The optional Xicato Bluetooth mesh works seamlessly within Xicato's Bluetooth controls system and is over-the-air (OTA) updateable to Bluetooth Mesh standard

The XFL line of linear lights includes premium Vivid White, High Density, Full-Natural Spectrum, Tunable, Dim-to-Warm, RGBW, Neon and Specialty lights. Unique to Xicato, the XFL line also offers options that closely match the Xicato color point in XTM/XOB series of spot lights to make a perfect lighting complement. The matched color point solves a key challenge for lighting designers and specifiers when the job requires a mix of spot and linear lights to create a seamless lighting experience. This new ability with Xicato spot and linear sources, enables the lighting designer the freedom to fulfill the architecture design targets, all with beautiful whites and vibrant color rendering for which Xicato lights are famous.

”Xicato’s holistic approach with smart linear lights positions the XFL line above any other offering in the market, enabling the designers to create sophisticated lighting scenarios no matter what kind of light source the job calls for”.

AMIR ZOUFONOUN, XICATO’S CEO

”When seeking for a trusted source for high quality LED lighting solutions, Xicato immediately comes to mind, especially in today’s market where quality and reliability are often compromised.” said Stephan Blass, Buschfeld CEO. ”Xicato has been at the forefront of LED lighting innovation for over a decade. It is encouraging to see that they have brought this expertise to the flexible linear segment with a comprehensive line of high-quality next generation LED lights with options that match the Xicato color point.”

The smart enabled linear lights are part of Xicato’s end-to-end solutions with a host of approved 3rd party AC driver options that eliminate the need for additional controls wiring and support Xicato Bluetooth Mesh controls. This wireless option enables the smart XFL line to have complete support of Xicato Controls Panel software, sensors, switches and gateway, all backed by Xicato services. Designers can configure sophisticated scenes with thousands of nodes alongside any combination of linear and spot lights while achieving energy efficiency targets set by their end customer.

”The addition of XFL portfolio to our extensive family of smart controls, spot lights and smart drivers allows Xicato to provide a high quality one-stop-shop for customers and partners who are involved at the building project level and need to streamline their product selection and procurement processes”, said Mr. Zoufonoun.

All the new XFL linear sources are part of Xicato Onboard, a series of embeddable products by which any 3rd party luminaire or device can be upgraded to be wirelessly controlled and monitored via Bluetooth mesh and operate seamlessly with Xicato’s award winning Controls Platform. ■

COMPONENTS

WAGO’s New Lighting Connection Box Promises Unlimited Freedom in LED Light Design

Increasing miniaturization and popular flat LED lights require universal connection options. WAGO’s new lighting connection box offers the best solution because it is housed outside the light. This gives lighting manufacturers more design freedom. Additionally, no dirt and dust can get into the light during installation because it no longer has to be opened for the connection.

WAGO’S new lighting connection box: A connection solution for all installation types

The new lighting connection box has ample installation space and is suitable for a large range of conductor cross-sections up to 5x2.5 mm2. Regardless of how the project is installed, lights with the WAGO Lighting Connection Box fit into every concept – it doesn’t matter if you choose a pluggable building installation, such as the WAGO Pluggable Connection System WINSTA® or a conventional installation type.

The integrated Linect® Interface also contributes to this, a connector with a conventional conductor connection is also available in addition to the pluggable version.

For additional information, please visit www.wago.com/global/electrical-interconnections/discover-pluggable-connectors/winsta

About WAGO:
The WAGO Group is an international, standard-setting supplier of electrical interconnection, automation and electronic interface products and solutions. This family-run company is the world market leader in spring pressure connection technology. Whether in industrial, railway, or energy technologies, in the marine and offshore sectors, or in building and lighting management, WAGO products and solutions provide safety and efficiency. WAGO has grown steadily since it was founded in 1951, with a current worldwide workforce of more than 8,500 – approximately 3,900 of whom work in Germany at its headquarters in Minden (North Rhine-Westphalia) and in Sondershausen (Thuringia). The company achieved sales of EUR 932 million in 2018. The WAGO Group consists of nine international production facilities and primary sales locations, 20 additional sales offices, and the software specialist M&M Software. In addition, it has representatives in over 80 countries, giving the company a strong global presence. WAGO has been in the manufacturing business since 1951: initially at the company headquarters in Minden (North Rhine-Westphalia, Germany), expanding in 1971 to Roissy (France), in 1977 to Domdidier (Switzerland), in 1979 to Milwaukee (USA) and in 1990 to Sondershausen (Thuringia, Germany) and Tokyo (Japan). Other production sites include Delhi (India) founded in 1995, and the 1997 expansions into Tianjin (China) and Wrocław (Poland). - www.wago.com/global/ ■

MEASUREMENT

Gigahertz-Optik's BTS256-EF now Offers Enhanced Flicker Frequency Range up to 40 kHz

The BTS256-EF by Gigahertz-Optik GmbH, a well-known measuring device manufacturer, has already been up to that challenge for many years. It offers a wide selection of measuring quantities relevant in general lighting and hence acts as universal measuring device in its field. Now, the device has been updated to record and analyze even higher flicker frequencies than before: It supports signal sampling with up to 40 kHz. The

BTS256-EF – The flicker meter now supports measurements with up to 40 kHz

lighting industry requires very versatile and reliable measurement devices when spectral light and flicker meters are concerned. The field of measurement applications and quantities is very broad: Besides illuminance and spectrum, there are many additional, more specialized properties of light sources that need to be measured like their performance in context with human centric lighting (HCL), their flicker properties, their efficiency in plant growth and many more. In all of those applications, it is crucial that the meter needs to be reliable and precise.

The enhancement of the BTS256-EF to support signal sampling with up to 40 kHz does not only apply to brand-new devices: By applying the latest firmware and software updates, this new feature also becomes available for devices that have been out in the field for many years. Updates are offered on request.

For additional information, please visit www.gigahertz-optik.de/en-us/product/BTS256-EF

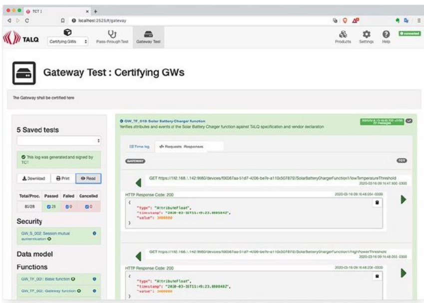
About Gigahertz-Optik:
Gigahertz-Optik GmbH was founded in 1986 as an independent company by Dipl.-Ing. (FH) Anton Gugg-Helminger and Wolfgang Dähn. The continuous development of its product range has resulted in a comprehensive selection of light measurement devices, finely tuned accessory products, and services. With its US subsidiary, Gigahertz-Optik Inc., Gigahertz-Optik GmbH is a global manufacturer of metrological solutions for optical radiation. Since January 1, 2020, Gigahertz-Optik Vertriebsgesellschaft für Technische Optik mbH is part of the Berghof Group GmbH. - www.gigahertz-optik.de/en-us/ ■

SMART & IOT

STANDARDS

TALQ Integrates Further Smart City Features - Updated TALQ Specification 2.2.0 Includes Additional Functions

The TALQ Consortium, which has developed a global interface standard for managing street lighting networks and other smart city applications, has released and approved a new version of the TALQ Specification, 2.2.0; an updated version of the Certification Test Tool was also released. All the changes and added features are backward compatible with the former 2.1.0 release, guaranteeing reliable interoperability of all certified TALQ-compliant products certified against any TALQ 2 version. The range of smart city applications in which



Screenshot TALQ certification test tool V2.2.0 (credits: TALQ Consortium)

local authorities are investing is wide. The solutions include outdoor lighting as well as waste, parking and traffic management, E-Mobility, environmental sensors and various other public services. Currently, eighteen products of ten different manufacturers have been certified as TALQ-compliant. All of them target easing investment decisions of cities by enabling interoperability, which in turn fosters competition and allows purchasers of fixed installations to invest in open systems to guarantee future-proof solutions.

To keep the software protocol up-to-date, the Technical Work Group and the Requirements Work Group within the consortium continuously review and expand the functions supported by the protocol. Member companies can suggest and request additional features to be included in the protocol to reflect the functionality offered by their own systems. Version 2.2.0, approved by TALQ Steering Committee, embraces a bundle of new features.

Novel, integrated smart city features:
Of the numerous new features that have been added to the Specification, the functions related to smart cities applications are of particular interest. Some of them, for example, provide statistics on the number of vehicles passing on a road, detect changes in asset location or identify and record asset orientation changes. Some others are more related to metering, e.g. filling levels of containers or fluid levels in gullies, lakes, tanks, or wherever. Yet further functions are related to energy and battery levels: monitoring charging and discharging; or managing solar panels such as those used for public transit information, traffic control, public security (CCTV) and many others. All of these additional features are backward compatible with the previous 2.1.0 release.

"The integration of smart city applications in a former pure lighting standard has become reality and shows the significance of the TALQ protocol as a future-proof global standard."

JOSÉ SANCHIS, CHAIRMAN OF THE CERTIFICATION WORK GROUP

"But other interesting capabilities have also been added to the Certification Tool, for example, supporting multiple profiles in one certified product and a new command line version of the tool, which eases its integration into a CI/CD software development system" explains José Sanchis.

Version 2.2.0 is now the new official TALQ version. - For more information visit www.talq-consortium.org

About the TALQ Consortium:
Founded in 2012, the TALQ Consortium is establishing a globally accepted standard for management software interfaces to control and monitor heterogeneous smart city applications. The TALQ Smart City Protocol is a specification for information exchange, suitable for implementation in various products and systems. This way interoperability between Central Management Software

(CMS) and Outdoor Device Networks (ODN) from different vendors will be enabled, such that a single CMS can control different ODNs in different parts of a city or region. TALQ is an open industry consortium currently consisting of more than 40 member companies. ■

Thread Group and DiiA Collaborate to Shape the Future of IoT Lighting for Commercial Buildings

The Thread Group, an alliance addressing convergence, security, power, and architecture challenges at the network layer, and the DiiA, the global DALI alliance of companies from the lighting and sensor industries, have announced a liaison agreement with the shared intention of accelerating IoT adoption in commercial buildings. The organizations will collaborate to

The two alliances will co-develop wireless IP-based DALI lighting control and a certification program for lighting and sensor networks in smart commercial buildings

implement the DALI lighting-control application on top of Thread's low-power, secure and self-healing wireless mesh network. The goal is to offer a certification program to ensure interoperability and enable IoT developers to more quickly bring their lighting and sensor products to market.

"When fully realized, IoT technology will bring unprecedented efficiency, cost-savings and functionality to commercial buildings," said Sujata Neidig, vice president of marketing, Thread Group. "This liaison agreement furthers Thread's commitment to the convergence of IoT with IP as the foundation and the expansion of smart solutions both in the home and where we work."

"Running the DALI application layer on top of Thread's wireless network solution will become a core offering for DiiA and will accelerate the integration of these technologies into the commercial space," said Paul Drosihn, DiiA General Manager. "We're excited that Thread is the first IP-based carrier for which DiiA plans to offer certification."

Thread is a low-power wireless mesh networking protocol, based on the universally supported Internet Protocol (IP) and built using open and proven standards, that is accelerating IoT adoption.

DiiA identified that Thread can serve as a wireless network transport for its well-established DALI application-layer protocol. Likewise, Thread identified DALI as a suitable application layer for Thread in lighting and general commercial building applications including sensor networks. Together, DiiA and Thread will implement protocols for commissioning and operating devices in lighting and building networks. These will include credential delivery, service discovery and network management.

DiiA intends to make an IP-based version of its DALI application layer available. The fundamental specifications are published as Part 104 of the IEC 62386 standard, which specifies the use of Internet Protocol (IP) and User Datagram Protocol (UDP) for IEC 62386 application-layer transport. To enable interoperability and certification for developers, DiiA plans to add further crucial details to this published standard.

About Thread Group:
Formed in 2013, the non-profit Thread Group is focused on making Thread the foundation for the internet of things in homes and commercial buildings. Built on open standards, Thread is a low power wireless networking protocol that enables direct, end-to-end, secure and scalable connectivity between IoT devices, mobile devices, and the internet. And, because Thread is IP-based, it seamlessly integrates with many environments, apps, devices and clouds. The Thread Group provides a rigorous certification program to ensure device interoperability and a positive user experience. Thread is backed by industry-leading companies including Apple, Arm, Google/Nest, Lutron, Nordic Semiconductors, NXP Semiconductors, OSRAM, Qualcomm, Siemens, Silicon Labs, Somfy and Yale Security.- www.threadgroup.org/

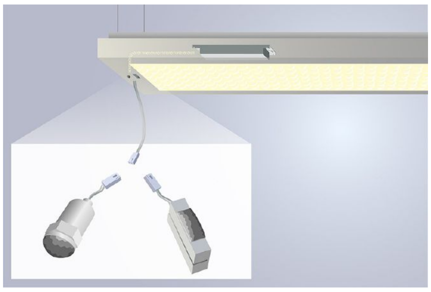
About DiiA:
The Digital Illumination Interface Alliance (DiiA) is an open, global consortium of lighting companies that aims to grow the market for lighting-control solutions based on Digital Addressable Lighting Interface (DALI) technology. DiiA is driving the adoption of DALI-2, the latest version of the internationally standardized DALI protocol. DALI-2 includes more product types, more features, clearer specifications, increased testing, and product certification. The DALI-2 certification and trademark program, operated by DiiA, builds confidence in cross-vendor product interoperability. DiiA develops test specifications for DALI-2 product compliance testing, and also creates new specifications for additional DALI-2 features and functions. The D4i certification program from DiiA brings standardization to intra-luminaire DALI. - www.digitalilluminationinterface.org ■

Zhaga Publishes Book 20: Smart Interface Between Indoor Luminaires and Sensing/Communication Modules

Zhaga Book 20 defines a smart interface between an indoor LED luminaire and a sensing/communication module. The module connects to the LED driver, and typically provides sensory inputs or enables communication between network components. Zhaga member companies can now access the specification and certify luminaires according to the Zhaga-D4i certification program. Dekra and Intertek are the accredited test centers.

Book 20 brings together complementary specifications from the Zhaga Consortium and the D4i specifications from the Digital Illumination Interface Alliance (DiiA).

Zhaga Book 20 eases invest decisions for end-users, as luminaires can be adapted when needed with modules for different functions, like air quality sensing, presence detection or light levels controlling. The specification provides benefits to luminaire makers, when certified modules from multiple suppliers providing a wide range of different functions are available and it helps installers, as a certification on the interoperability of components exists. The new Zhaga-D4i



Book 20 brings together complementary specifications from the Zhaga Consortium and the D4i from DiiA

certification is available for LED luminaires and LED control gear fulfilling the D4i requirements. Luminaires can now be certified by Dekra and Intertek, as the Zhaga accredited test centres. Zhaga-D4i certification of sensors and/or communication modules will become available later in 2020.

More information on the Zhaga-D4i certification program is available in an article in the LED Professional Review. Zhaga Book 20 is available to Zhaga's Regular and Associate members.

For more information, visit www.zhagastandard.org or contact Axel Baschnagel, Marketing Communications, marcom@zhagastandard.org ■

Zigbee Alliance and DiiA Collaborate to Standardize DALI-Zigbee Gateways

The Zigbee Alliance, an organization of hundreds of companies creating, maintaining, and delivering open, global standards for the Internet of Things (IoT), and the Digital Illumination Interface Alliance (DiiA), the global industry organization for DALI lighting control, announced they are working together to bring further standardization and system interoperability to the IoT luminaires space. This development will help stakeholders realize the benefits of combining wired DALI lighting-control systems with wireless Zigbee networks as the IoT progresses. The two organizations are collaborating on the development of a gateway specification to support a forthcoming certification program. This blending of reliable, cost-effective, low-power Zigbee technologies with DALI's proven digital lighting control gives users a

Organizations to develop a gateway specification and certification program for lighting-control networks that utilize DALI and Zigbee-based products

best-in-class combination for intelligent illumination systems.

"Our liaison agreement with the Zigbee Alliance is part of DiiA's commitment to address different options for combining wireless communication links with DALI lighting control."

PAUL DROSIHN, DIIA GENERAL MANAGER

"Developing specifications and testing requirements for gateways between Zigbee ecosystems and wired DALI networks will ensure interoperability that's backed by certification," said Mr. Drosihn.

"The intersection of wired and wireless is where industry can work better together during this IoT transition to benefit those invested in both technology camps as well as consumers as they embrace connected devices," said Tobin Richardson, President and CEO, Zigbee Alliance. "Pairing DiiA's wired control solutions with Zigbee wireless standards brings more choice to markets that rely on these technologies for various use cases and as a springboard for future innovation." ■

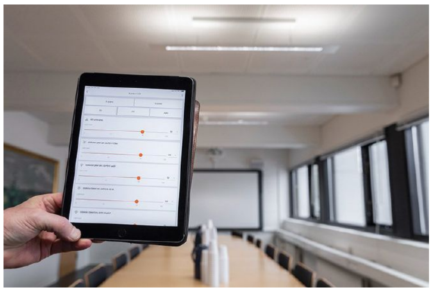
CONTROLS

Making Office Lighting Smart with HubSense from Osram

Osram presents the HubSense intelligent lighting management system, an easy-to-commission and scalable solution for retrofitting LED office lighting. HubSense is based on standardized "Qualified Bluetooth Mesh" technology and is ideal for upgrading existing lighting systems in small and medium-sized businesses. Existing installations can therefore be updated without new cabling and without the use of a gateway or any other IT equipment. HubSense is also suitable for new installations in single offices, open-plan offices, corridors and conference rooms and offers the flexibility needed to adapt the lighting to changes in room usage.

First project in Kolding, Denmark:
When the aging lighting system in an office building in Kolding, Denmark no longer worked properly, the owners looked for an economic upgrade solution. Their lighting designer chose HubSense. With the intuitive HubSense commissioning app provided by Osram, the requirements for the new system could be planned and commissioned in advance off-site. On-site implementation of the system took only one day and did not affect ongoing office operations. Installation work was limited to installing control gear and a sensor in each luminaire. App-based wireless identification of the luminaires enabled the luminaires to be quickly assigned to the desired lighting zones. Predefined lighting control profiles simplified and sped up commissioning.

Operating the HubSense light management system in Kolding is as straightforward as planning, installation and commissioning. With the new system, the lighting can be flexibly adapted at any time to changes in room usage via the mobile app. There are benefits for employees in terms of more comfortable and convenient lighting, and the operators of the office building benefit from much better energy efficiency thanks to daylight control and presence detection. Thanks to its scalability and great flexibility, the system can easily handle changes in room usage and office concepts. About Osram:



HubSense from Osram is the quick and easy path to smart office lighting thanks to an intuitive touch screen user interface (Credits: Osram)

Osram, based in Munich, is a leading global high-tech company with a history dating back more than 110 years. Primarily focused on semiconductor-based technologies, our products are used in highly diverse applications ranging from virtual reality to autonomous driving and from smartphones to smart and connected lighting solutions in buildings and cities. Osram uses the endless possibilities of light to improve the quality of life for individuals and communities. Osram's innovations enable people all over the world not only to see better, but also to communicate, travel, work and live better.

Osram had approximately 23,500 employees worldwide as of end of fiscal 2019 (September 30) and generated revenue of around 3.5 billion euros from continuing activities. The company is listed on the stock exchanges in Frankfurt and Munich (ISIN: DE000LED4000; WKN: LED 400; trading symbol: OSR). - www.osram.com ■

DRIVERS

Signify Upgrades Sensor Ready LED Driver Portfolio with New D4i Standard

Signify, the world leader in lighting, has upgraded its portfolio of compact Philips Xitanium Sensor Ready Xtreme LED drivers for outdoor applications with the recently granted D4i certification. This certification program is designed to deliver standardization in the market, drive wider adoption of IoT connectivity in lighting and aid smart city or building projects. It makes it very attractive and easy for customers to switch to connected lighting or install Connect Ready luminaires with D4i certified drivers now, and upgrade to connectivity later. By Q2 2020, Signify will also upgrade the complete non-isolated Philips Xitanium Dimmable Sensor Ready driver portfolio for indoor applications to the new D4i standard, to facilitate the rapid market adoption of energy-saving technologies and drive standardization. Launched by the Digital

Signify started upgrading LED drivers to D4i certification with drivers for outdoor applications. The first drivers for indoor applications will follow by Q2, 2020

Illumination Interface Alliance (DiiA), the new standard's specifications and requirements cover critical features including digital communication, data reporting and power requirements. Qualification of this certification demonstrates plug-and-play interoperability of luminaires, sensors and communication nodes. Products with the D4i standard will enable smart, future-proof LED luminaires with IoT connectivity.

In addition to being relevant for outdoor drivers, D4i certification is also relevant for indoor drivers. It brings standardization to intra-luminaire DALI and defines how data relevant for connected lighting networks is stored and communicated. D4i extends the existing DALI-2 program by adding a standard for power supply to control devices such as sensors (DALI part 250). It also standardizes how drivers store and report data, including luminaire info (DALI part 251), energy metering (DALI part 252) and diagnostics (DALI part 253). This standardization enables luminaire manufacturers to create luminaires that can easily be integrated in connected lighting systems.

"Years ago, we pioneered with Xitanium Sensor Ready Xtreme LED drivers and we are very proud of now having a broad D4i driver portfolio in place. The D4i standard is key for our customers as it makes it easier than ever before to adopt connectivity within smart cities."

PAUL SLOEKERS, PRODUCT MANAGER OUTDOOR LED DRIVERS AT SIGNIFY

"The new D4i standard is an important step in the journey of connected lighting. Standardization helps to ensure that different elements of a system, such as luminaires, sensors and controls, work together seamlessly. As a result, more end-users can start to enjoy the benefits of connected lighting," said Simone van Leeuwen, Product Manager LED Linear Drivers at Signify.

All verified products will now carry the certification logo and be listed on the DiiA website at www.digitalilluminationinterface.org/products

About Signify:
Signify (Euronext: LIGHT) is the world leader in lighting for professionals and consumers and lighting for the Internet of Things. Our Philips products, Interact connected lighting systems and data-enabled services, deliver business value and transform life in homes, buildings and public spaces. With 2019 sales of EUR 6.2 billion, we have approximately 32,000 employees and are present in over 70 countries. We unlock the extraordinary potential of light for brighter lives and a better world. We have been named Industry Leader in the Dow Jones Sustainability Index for three years in a row. - www.signify.com/global/

About DiiA:
The Digital Illumination Interface Alliance (DiiA) is an open, global consortium of lighting companies that aims to grow the market for lighting-control solutions based on Digital Addressable Lighting Interface (DALI) technology. DiiA is driving the adoption of DALI-2, the latest version of the internationally standardized DALI protocol. DALI-2 includes more product types, more features, clearer specifications, increased testing, and product certification. The DALI□2 certification and trademark program, operated by DiiA, builds confidence in cross-vendor product interoperability. DiiA develops test specifications for DALI-2 product compliance testing, and also creates new specifications for additional DALI-2 features and functions. The D4i certification program from DiiA brings standardization to intra-luminaire DALI. - www.digitalilluminationinterface.org ■

Inventronics Releases Robust IP66/IP67 LED Driver Series for Challenging Power Conditions

Inventronics is pleased to announce the expansion of the new EAM LED driver series that leverages Inventronics latest next generation platform design with special features specifically for markets who face challenging power regulation. The expansion provides models supplying up to 75 W of power in addition to the already existing models supplying up to 150 W of power. The EAM-075SxxxSB/SG series offers industry-leading surge protection and is IP66/IP67 rated for rugged applications. The series also offers design flexibility with an adjustable output current to reduce SKUs and is ultra-compact to fit inside a multitude of luminaires. The EAM-075SxxxSB/SG series is

Organizations to develop a gateway specification and certification program for lighting-control networks that utilize DALI and Zigbee-based products

built for long-term reliability and utilizes a robust thermal design for increased dependability. This series is equipped with an advanced, innovative circuitry design that helps protect against poor input power conditions on the main power lines supplied to the LED driver, reducing maintenance costs and safeguarding the luminaire. This is achieved by providing Input Over Voltage Protection (IOVP) that can withstand voltage increases up to 440 Vac at a maximum of 48 hours.

Inventronics understands the struggles of OEMs selling in markets with challenging power conditions and constructed the EAM-075SxxxSB/SG series to provide a wide input voltage range of 90-305 Vac / 127-300 Vdc to help with varying voltage swells and sags on the main power lines. The series is also equipped with market-leading input protection of 4 kV (differential mode) and 6 kV (common mode) and is capable of handling challenging market conditions, such as frequent power outages or operating from a backup power generator, while providing a reliable, cost-effective solution.

The EAM-075SxxxSB/SG series allows for design flexibility with optimal results and various configurations through the adjustable output current (AOC) function using a potentiometer feature providing constant power at a wide output current range from 700-2100 mA. It provides a low output current ripple to ensure a uniform, quality light and an optimized, more compact form factor. The series delivers full-load efficiency up to 92% and has a calculated lifetime up to 105,000 hours at Tc 70°C and an operating case temperature for warranty of 80°C.

Their IP66 and IP67 rating and compact metal housing enables them to protect against dust and particles and supplies a high level of protection against water and humidity. The EAM-075SxxxSB is certified to BIS and CE standards and the EAM-075SxxxSG is certified to CB and CE standards facilitating safety certification for the end user. Production quantities of the EAM-075SxxxSB and EAM-075SxxxSG are available now.

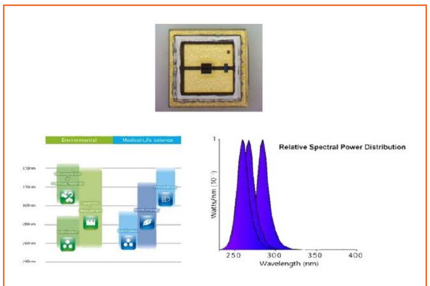
About Inventronics:
Established in 2007, Inventronics is one of the world's top LED driver manufacturers specializing in building innovative, highly reliable and long-life products that are certified compliant to all major international safety and performance standards. We design our own drivers at our headquarters in Hangzhou, China and have specialized teams that focus on low, mid and high-power designs as well as teams for network controls and accessory products. Our drivers are manufactured within our Science and Technology Park in Tonglu, China. We encourage factory visits for a first-hand experience of our commitment to quality. We provide superior products, exceptional technical support, and best-in-class customer service. We also seek to create value for our customers by working to extend and increase the return on investment for solid-state lighting systems. - www.inventronics-co.com ■

UV & IR

SYSTEMS

Effective UV-C LED Solutions for Pathogen Containment, Medical and Biotechnical Applications at euroLighting

Short UV-C light has been proven to kill 99.9 percent of bacteria, viruses and other pathogens. euroLighting offers new product solutions in the form of UV-C LEDs, the effect of which can be used specifically to effectively sterilise air, water and surfaces and greatly reduce the risk of infection. Based on the current virus pandemic and in view of statements by experts that such situations could occur more frequently in the future, solutions are urgently sought to contain the spread of pathogens as quickly and effectively as possible. Specifications of the UV-C3535



Smart Eco Lighting's UV-C LED from the UV-C3535 series with peaks at 255, 265 and 280nm for medical and biotechnical applications, are available from euroLighting

series:
The new UV-C LED series UV-C3535 from Smart Eco Lighting is available from euroLighting in three different power levels and wavelengths. Depending on requirements, the patented UV-C LEDs are available with a radiant flux of 4 mW (at 0.12 W output), 10m W (at 0.63 W output) or as a particularly powerful version with 45m W (at 1.57 W output). The series is available in the peak wavelengths 255, 265 and 280 nm.

A special patented LED packaging technology, in which the quartz glass of the UV LED is (inorganically) welded onto the metal substrate instead of (organically) glued, enables a significant increase in the service life of the LED. This inorganic method of production prevents the adhesive from being damaged by UV light, the chip is oxidized after a short time due to oxygen ingress, and the lifetime is reduced to less than 200 hours. The big advantage: even after a service life of more than 50,000 hours, the luminous flux remains at over 70% of its original value.

With the compact design of 3.5x3.5x1.5 mm and a beam angle of 120°, the UV-C LEDs can be used flexibly in compact to large systems.

UV-C LEDs are a mercury-free and therefore environmentally friendly alternative to conventional UV lamps. Despite frequent on/off cycles there is no reduction in service life. The low-pressure UV lamps used so far, on the other hand, have the disadvantage that they contain toxic mercury, are limited in design and require a warm-up time of 20 to 30 minutes before effective use.

Medical applications and individual solutions: Based on the new UV-C LEDs, Smart Eco Lighting has already developed a complete system for air disinfection and water disinfection and applied for a patent. With the professional support of its developers, the manufacturer can supply customized solutions from modules to complete LED systems with the required UV dose. In addition to applications for water treatment, air disinfection, surface disinfection and sterilization, the UV-C LEDs can also be used for inspections and measurements, for DNA analysis in biotechnology or similar applications. ■

LEDS

Nichia UV LED Technology Supports Evolving Markets

Nichia, a leading global specialist in LED technology, is now aiming to extend its dominance to the UV market following its impressive showcase at the recent RadTech 2020 conference and exhibition in Orlando, Florida, USA. The company's latest solutions remain ideal for curing applications, but an extended portfolio is of particular benefit, as UV is known to be incredibly effective in killing viruses, bacteria, fungi and protozoa.

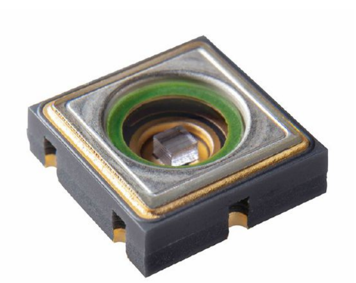
Already at the forefront of the UV LED field through its established UV-A and UV-B series products, Nichia is extending its offerings to a new wide range of both SMD and COB LEDs. Additionally, Nichia's portfolio is now being bolstered by the 2019 introduction of its 280 nm Deep UV / UV-C LED. At RadTech, the new products attracted ample attention, with Nichia receiving extremely positive feedback and a high number of enquiries.

Erik Swenson, General Manager of Nichia America, commented: "The level of excitement and interest for solid-state UV lighting at RadTech was tremendous to experience. Much focus is justifiably on deep UV for sterilization, especially considering the global COVID-19 pandemic. However, many different creative approaches at various wavelengths are being developed."

"Similar to the rise of LED technology for general lighting, the UV LED sector is on a rapid growth trajectory with Nichia's innovative solutions leading this market transformation."

ERIK SWENSON, GENERAL MANAGER OF NICHIA AMERICA

UV light technology has momentum and is a hot topic in the industry, as the light emitted kills biological impurities. In particular, LEDs in the UV-C band promise to revolutionize sterilization and disinfection, and could bring safer conditions to medical facilities – much needed in the current global environment. Medical equipment OEMs can benefit from



Nichia provides a wide UV portfolio: COBs, ideal for ink curing applications; the latest UV LEDs with high sterilization characteristics, vital for medical equipment OEMs

UV-C technology as it delivers infection prevention and control in portable devices. Equipment of this type can be deployed by healthcare workers at point-of-care, or to sterilize frequently touched surfaces such as personal electronics, medical trolleys and diagnostic devices.

The latest Nichia Deep UV LED, the 280 nm NCSU334A, is designed to address mass-market demand for sterilization using solid-state lighting. Importantly, this small yet highly efficient LED delivers a typical radiant flux of 55 mW (350 mA) – nearly double the efficiency of competing LEDs. For designers, the solution delivers better system miniaturization and highly stable long-life performance compared to previous technologies.

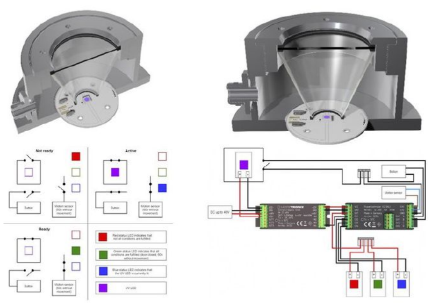
"With the NCSU334A we have a leading technology today. To support expected market demand growth, we will be increasing the production capacity and releasing the next generation NCSU334B by the end of this year, further extending Nichia's leadership position. Our unique crystal growth technology, which has been cultivated for many years, has helped to successfully develop the world's highest quality, highest performance, long-life UV LEDs, spanning UV-A, UV-B and UV-C, and achieving a significant lifetime improvement over conventional UV lamps," adds Erik Swenson.

Nichia expects its UV portfolio to be play a significant role in completely replacing conventional mercury lamps and their associated environmental issues. In turn, the technology will further develop a market that leverages the characteristics of solid-state lighting and hopefully address a major global issue.

About Nichia Corporation:
Having 'Ever Researching for a Brighter World' as a motto, Nichia takes great pride in being the technology leader and world's largest LED manufacturer. Founded in 1956 as a specialist chemical producer, Nichia quickly became the leader in luminescent materials (phosphors). Nichia later developed and commercialized the first high brightness blue LED in 1993 and the first white LED in 1996. Additional nitride-based LEDs in various colors were developed, including ultraviolet and visible laser diodes. Nichia believes that its products will remain at the forefront of energy efficient solutions throughout the world for years to come. Nichia will continue to be a company that makes contributions to the world by evolving its original and unique technologies and 'Ever Researching for a Brighter World'. - www.nichia.com ■

Lumitronix Provides Solutions for Use of UV-C LED Under Real Conditions

As an official distributor of Nichia in Europe, the Hechingen-based LED company Lumitronix offers access to the most powerful UVC LED currently on the market. The NCSU334A emits a wavelength of 280 nm in the ultraviolet range and especially in the UV-C band and enables immediate sterilization and cleaning of air, liquids and surfaces. Bacteria, germs and viruses can be reliably killed in this way. This means that the UV LED from the world's largest LED manufacturer can also act as a possible weapon against the novel corona virus. According to Nichia, the NCSU334A, which measures only 6.8x6.8 mm, delivers one of the best performances in the solid-state lighting (SSL) sector with 55 mW (at a current of 350 mA). The LEDs are expected to have a significantly longer life than conventional UV lamps. In addition, the NCSU334A uses a newly developed, hermetically sealed housing that makes the LED less susceptible to external environmental influences, thus enabling it to be used in various harsh environments.



Lumitronix's UV-C solutions include a safety concept that ensures the professional use of UV-C LEDs without risks

At Lumitronix, the disinfecting light emitting diode is available in various versions: as a component for later assembly, preassembled on an aluminium board measuring 30x30 mm and in a hermetic spot housing with a quartz glass reflector, which enables a particularly narrow beam angle of 13.5° and offers permanent UV stability thanks to the highest possible transmittance. The housing is made of stainless steel and is therefore antibacterial and permanently insensitive to UV radiation. It can also be easily cleaned. Due to the complete tightness of the spotlight, the extreme temperature stability of the materials used and the fact that the construction does not require any additional cooling, it can be used in ambient conditions of up to 100° C without any problems.

This opens up a wide range of possibilities for potential users to take advantage of the sterilizing properties of the NCSU334A.

Ultraviolet radiation in the wavelength range from 200-400 nm has an extremely destructive effect on organic and inorganic tissue. It can lead to inflammation of the cornea of the eye or to UV erythema (sunburn) of the skin. Materials that are exposed to ultraviolet radiation for too long begin to decompose. It is therefore extremely important that the light of the highly efficient NCSU334A LED does not come into contact with people and is only used for a short period of time on objects that require sterilization.

The Swabian LED specialist has addressed this problem and developed a concept for the safe operation of UV-C LEDs. "A combination of button, switch, motion sensor and three signal LEDs ensures the room in which the NCSU334A is to provide a sterile environment is free of people. The UV LED can only be activated via the switch if the motion sensor registers no more movement after 60 seconds, if the button is activated by closing the door and if all safety conditions are fulfilled by means of a green signal LED," reports Christian Hoffmann, CEO of Lumitronix.

All of the solutions offered by Lumitronix are aimed at professional users who are familiar with ultraviolet radiation and can ensure that UV-C LEDs are used without risk.

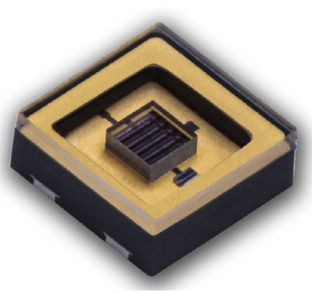
For further information about the various solutions and samples of Nichia's new UV-C LED, please contact Lumitronix, the official Nichia distributor in Europe.

For additional information, please visit the Lumitronix Distribution website or contact Lumitronix at mail@leds.de

About Lumitronix:
Lumitronix has been one of the leading specialists for LEDs and LED products for many years. As a competent partner for the industry, Lumitronix possesses broad application knowledge from numerous sectors. The Swabian company, based in Hechingen, Germany, has ISO 9001 certification and is also the official distributor of market-leading manufacturers of LED technology. Lumitronix is not only involved in the distribution of LED products, but also develops and manufactures in-house according to customer-specific requirements. Two ultra-modern production lines with the latest machine technology allow the assembly of both rigid and flexible PCBs. A special feature of the flex production is the reel-to-reel processing, with which almost endless lengths can be realized. The production site in Hechingen furthermore provides the benefit of being able to respond quickly and reliably to individual customer wishes and requirements. Quality Made in Germany. - b2b.lumitronix.com/en/ ■

Luminus Breaks the USD 0.10 per mW Barrier for UV-C LEDs

Luminus Devices announces the immediate availability of its newest UV-C LED, the XBT-3535, with performance ranging from 50 mW to 80 mW in the 275-285 nm range. With the global need for disinfection and sterilization devices increasing, the price-performance combination of the XBT-3535 will allow companies to quickly bring novel and affordable solutions to market. Scientists The germicidal effectiveness of



Breaking the 0.10 USD/mW barrier enables the large-scale deployment of UV-C LEDs in disinfection applications and accelerates the displacement of mercury lamps

UV-C LEDs against E-coli, MRSA and a variety of pathogens has been well documented. UV-C LEDs with wavelengths less than 280 nm are shown to be as or more effective than mercury lamps for disinfection and sterilization. However, performance, cost, and lifetime have been, in some combination, the factors slowing adoption of UV-C LEDs.

"Our latest devices, like the new XBT-3535 from Luminus, now have median lifetimes well in excess of 10,000 hours at nominal operating conditions, their increased power output minimizes the number of LEDs required in a system, and pricing in volume has been reduced to a level below USD 0.10/mW."

MURALI KUMAR, DIRECTOR OF SPECIALTY MARKETING

"Luminus' mission is to improve people's health and wellness by making LED based disinfection technology universally affordable in healthcare, water- and air-purification applications," said Murali Kumar. The convergence of the three factors lifetime, power output and pricing makes the large-scale deployment of UV-C LEDs practical and accelerates the phase-out of lamps containing harmful substances such as mercury."

The new XBT-3535 complements Luminus' current portfolio including the XBT-1313, a 5 mW LED optimized for low power, cost-sensitive applications and the XST-3535, a 60 mW UV-C LED designed for applications requiring focused light.

About Luminus
Luminus, Inc. develops and markets solid-state lighting solutions (SSL) to help its customers migrate from conventional lamp technologies to long-life and energy-efficient LED illumination. Combining technology originated from the Massachusetts Institute of Technology (MIT) with innovation from Silicon Valley, Luminus offers a comprehensive range of LED solutions for global lighting markets as well as high-output specialty lighting solutions for performance-driven markets including consumer displays, entertainment lighting and medical applications. Luminus is headquartered in Sunnyvale, California. For additional information please visit http://www.luminus.com ■

MEASUREMENT

UV-C Radiometer for Disinfection Effectiveness and Safety of UV-C LEDs and Germicidal Lamps

The X1-1-UV-3726 radiometer enables the effectiveness of UV germicidal irradiation (UVGI) to be accurately determined for both low pressure mercury (254nm) germicidal lamps and UV-C LEDs. Additionally, the device has sufficient sensitivity to detect if undesired exposure poses a photobiological safety risk to users. UVGI is a sterilization

Mobile UV radiometer with separate measuring device and detector for measuring irradiance and dose of germicidal Hg lamps and UV-C LEDs

method that uses UV-C light to break down microorganisms such as viruses and bacteria by altering their DNA and RNA, rendering them unable to replicate. The germicidal effectiveness of UV-C radiation depends on its dose (µJ/cm2) and wavelength. The dose is determined by measuring the irradiance (µW/cm2) and duration of exposure. The effectiveness of germicidal activity is wavelength dependent with a maximum around 265 nm which makes the potential germicidal efficacy of available UV-C LEDs greater than 254 nm emission Hg lamps.

The X-1-1-UV-3726 radiometer measures UV-C irradiance over a very wide dynamic range to beyond 100 mW/cm² with a resolution of 0.0001 µW/cm². It is calibrated for its spectral responsivity from 250 nm to 300 nm. Wavelength dependent calibration factors given in 5 nm increments are incorporated for measuring UV LEDs with known nominal wavelength. Additionally, a 254 nm calibration is included for Hg lamps as well as a general purpose 260 nm to 290 nm calibration for non-specific UV-C LEDs.

The X1-1-UV-3726 offers sufficient sensitivity to check for safety compliance and the effectiveness of personal protection equipment

(PPE) in accordance with the accepted occupational exposure limit to actinic UV (ICNIRP). This requires irradiance levels to be < 0.2 µW/cm2 at 254 nm and < 0.1 µW/cm2 at 270 nm over 8 hour's exposure.

The handheld meter provides a real time display of irradiance or dose and includes a peak-hold function. The device may also be operated via its USB interface. Each meter is supplied with a traceable calibration certificate from the Gigahertz-Optik laboratory.

About Gigahertz-Optik GmbH:
Gigahertz-Optik GmbH was founded in 1986 as an independent company by Dipl.-Ing. (FH) Anton Gugg-Helminger and Wolfgang Dähn. The continuous development of its product range has resulted in a comprehensive selection of light measurement devices, finely tuned accessory products, and services. With its US subsidiary, Gigahertz-Optik Inc., Gigahertz-Optik GmbH is a global manufacturer of metrological solutions for optical radiation.devices, finely tuned complementary products, and services. At January 1, 2020, the Berghof GmbH has completely taken over the Gigahertz-Optik Vertriebsgesellschaft für Technische Optik GmbH. - www.gigahertz-optik.de/en-us/ ■

HORTICULTURE

LRC Releases New Horticulture Luminaire Calculator

The Lighting Research Center (LRC) at Rensselaer Polytechnic Institute has developed a free, easy-to-use online tool that will assist growers to evaluate the performance, efficiency, and economics of a wide variety of horticultural luminaires, typically used in greenhouses and other controlled agricultural environments. This online tool, called the horticulture luminaire calculator allows growers to accurately compare several luminaires and select the one that will be most effective for their particular application.

Electric lighting is essential to providing supplemental light in many greenhouses and is the only source of light for indoor agricultural environments. These lighting systems are extremely expensive to purchase and install, so it is important for growers to select a lighting system that will provide the most effective lighting for their application at the lowest overall operating cost.

The horticulture luminaire calculator developed by the LRC, is based on a metric called photosynthetic photon flux density (PPFD). PPFD is analogous to photopic illuminance on a work surface in an architectural application. Just as it is only valid to compare the power densities of alternate lighting systems at equal illuminance levels on the work plane, the power densities of alternate horticultural luminaires should only be compared when they provide the same PPFD on the plant canopy.

Growers can easily be misled by considering luminaire efficacy alone, when selecting lighting products for horticultural applications. Luminaire efficacy does not take into account important factors such as the luminaire intensity distribution, optimal luminaire layout, and the number of luminaires that will be required to reach a criterion PPFD. All of these factors are significant when evaluating the overall cost-effectiveness of various horticulture luminaire options. The horticulture

LRC's horticulture luminaire calculator provides an easy way for growers to conduct complete system energy and lifecycle cost analyses

luminaire calculator allows a grower to determine the best arrangement and mounting height of each luminaire they are considering. Using the calculator, growers can determine the number of each type of luminaire that will be needed to light their space to their desired light level, and select the product that will provide the optimum lighting, at the lowest cost. It would take several days to make these calculations using traditional methods. The horticulture luminaire calculator does it in a manner of minutes.

"Energy use and lifecycle costs vary widely among LED lighting systems used in controlled environment horticulture," said LRC Professor Dr. Mark Rea. "It has been the standard approach for many years in the field of architectural lighting, and is becoming readily apparent in horticultural lighting, that we must conduct complete system energy and lifecycle cost analyses to generate an accurate picture of which technology would work best for each particular application. The horticulture luminaire calculator provides an easy way for growers to make this determination."

This project was funded by Natural Resources Canada and other members of the Lighting Energy Alliance, including Efficiency Vermont, Energize Connecticut, National Grid, Northwest Energy Efficiency Alliance, and ComEd.

Access the calculator at https://hortcalc.lrc.rpi.edu

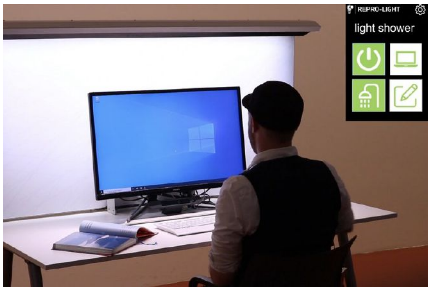
About the Lighting Research Center:
The Lighting Research Center (LRC) at Rensselaer Polytechnic Institute is the world's leading center for lighting research and education. Established in 1988 by the New York State Energy Research and Development Authority (NYSERDA), the LRC conducts research in light and human health, transportation lighting and safety, solid-state lighting, energy efficiency, and plant health. LRC lighting scientists with multidisciplinary expertise in research, technology, design, and human factors, collaborate with a global network of leading manufacturers and government agencies, developing innovative lighting solutions for projects that range from the Boeing 787 Dreamliner to U.S. Navy submarines to hospital neonatal intensive-care units. In 1990, the LRC became the first university research center to offer graduate degrees in lighting and today, offers a M.S. in lighting and a Ph.D. to educate future leaders in lighting. - https://www.lrc.rpi.edu

About Rensselaer Polytechnic Institute:
Founded in 1824, Rensselaer Polytechnic Institute is America's first technological research university. Rensselaer encompasses five schools, 32 research centers, more than 145 academic programs, and a dynamic community made up of more than 7,900 students and more than 100,000 living alumni. Rensselaer faculty and alumni include more than 145 National Academy members, six members of the National Inventors Hall of Fame, six National Medal of Technology winners, five National Medal of Science winners, and a Nobel Prize winner in Physics. With nearly 200 years of experience advancing scientific and technological knowledge, Rensselaer remains focused on addressing global challenges with a spirit of ingenuity and collaboration. - https://www.rpi.edu/ ■

RESEARCH

Repro-Light Consortium Announce Intelligent Workspace Lighting Concept

The pioneering design team at Bartenbach unveils a brand-new intelligent lighting concept set to revolutionize workspace personalization. It is set to deliver a truly user-centric, workspace lighting blueprint for lighting designers to transform workspaces for healthier living. The story began with Bartenbach's involvement in the Repro-light project consortium, funded through the European Commission's Horizon 2020 work program. The scope of the project, "To successfully initiate transformation in the European LED lighting industry, by creating the 'Luminaire of the Future'." Part of this remit was to develop a new customizable lighting system. Bartenbach approached this project



The Personal Table Light effectively delivers up to 1,500 lux at eye level, meaning missing daylight is supplemented

with extensive user surveys to fully understand the requirement for better lighting. The research results established the requirement for an easy to use, customizable lighting system. Following a meticulous development process and numerous prototypes, the final result called the Personal Table Light (PTL) is impressive.

The PTL achieves exceptional lighting for vision and health at the workplace, and is fully personalizable. Visual performance is perfectly supported as both vertical and horizontal workspace surfaces are lit separately, and illuminance levels are controlled along with light colour temperatures, and light distributions. Furthermore, the PTL effectively delivers up to 1500 lux at eye level, meaning missing daylight is supplemented and is able to exert non-visual effects on mood, alertness, performance and night time sleep. The PTL also allows full customization of scenes by the user via a desktop application.

Equipped with single-point LED controls and a highly innovative sensor technology that recognizes the actual activity of the user, lighting scenes adjust discreetly and automatically according to changing visual activities.

Additionally, environmental quality is assessed continuously by ambient temperature, humidity, air pressure, volatile organic compounds, and sound level sensors. Therefore, the luminaire uses highly standardized IT-protocols, which enable an easy integration of nearly all sensors available on the market.

Finally, using cloud connectivity, user activities can optionally be recorded which allows an on-going optimization of the lighting system tailored to individual needs.

The application possibilities of the PTL are numerous and range from student areas, offices, to medical and manufacturing workspaces.

The future of human centric lighting has arrived. With patent pending, the PTL has the potential to transform workspace lighting. To measure effects of this innovative lighting system on human beings, impact research is currently being conducted in two laboratory studies and a multi-centered field study.

For additional information on PTL, please see https://youtu.be/yYygYZkum5w, visit the Repro-Light Website or contact Bartenbach at chiara.messina@bartenbach.com

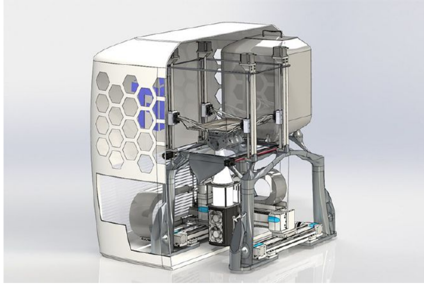
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 768780.

About Bartenbach:
Bartenbach is an award winning lighting design and research consultancy nestled in the mountains above Innsbruck. A team of architects, physicists, psychologists and designers forging individual lighting solutions. This interdisciplinary team is proud to be part of the international scientific community network, always at the cutting edge of research. - www.bartenbach.com/en/

About Repro-Light Consortium:
The Repro-light consortium consists of leading European experts including; TRILUX, a driving force of the European lighting industry, components manufacturers including BJB, Grado Zero Espace, and Rohner Engineering, innovative members of the lighting industry, Bartenbach and Luger Research, as well as experts in lighting sustainability and Life Cycle Assessment IREC and Mondragon University who are prominent in Social Sciences. - www.repro-light.eu/ ■

Austrian Tech University Graz Revolutionizes 3D Metal Printing Using LEDs

A technology developed at Graz University of Technology uses LED instead of laser sources for the additive manufacturing of metal parts and optimizes 3D metal printing in terms of construction time, metal powder consumption, equipment costs and post-processing effort. Selective LED-based melting (SLEDM) – i.e. the targeted melting of metal powder using high-power LED light sources – is the name of the new technology that a team led by Franz Haas, head of the Institute of Production Engineering at TU Graz, has developed for 3D metal printing and has now applied for a patent. The technology is similar to selective laser melting (SLM) and electron beam melting (EBM), in which metal powder is melted by means of a laser or electron beam and built up into a component layer by layer. However, SLEDM solves two central problems of these powder bed-based manufacturing processes: the time-consuming production of



The 3D printer developed at TU Graz melts metal powder using high-performance LED light sources and then processes it into components in additive manufacturing (Credits: TU Graz)

large-volume metal components and the time-consuming manual post-processing.

Reduced production time
Unlike the SLM or EBM processes, the SLEDM process uses a high-power LED beam to melt the metal powder. The light-emitting diodes used for this purpose were specially adapted by the west Styrian lighting specialist Preworks and equipped with a complex lens system by which the diameter of the LED focus can be easily changed between 0.05 and 20 millimetres during the melting process. This enables the melting of larger volumes per unit of time without having to dispense with filigree internal structures, thus reducing the production time of components for fuel cell or medical technology, for example, by a factor of 20 on average.

Tedious reworking is no longer necessary
This technology is combined with a newly designed production plant which – in contrast to other metal melting plants – adds the component from top to bottom. The component is thus exposed, the required amount of powder is reduced to a minimum and the necessary post-processing can be carried out during the printing process.

"The time-consuming, usually manual reworking that is necessary with current methods, for example, smoothing rough surfaces and removing supporting structures, is no longer necessary and saves further valuable time."

FRANZ HAAS, HEAD OF THE INSTITUTE OF PRODUCTION ENGINEERING AT TU GRAZ

The Institute of Production Engineering and the Institute of Materials Science, Joining and Forming are currently working intensively on the set-up of their own additive manufacturing laboratory, the AddLab@tugraz.

Fields of application and further plans
A demonstrator of the SLEDM process is already being considered in the K-Project CAMed of the Medical University of Graz, where the first laboratory for medical 3D printing was opened in October 2019. The process will be used to produce bioresorbable metal implants, i.e. preferably screws made of magnesium alloys that are used for bone fractures. These implants dissolve in the body after the fracture site has grown together. A second operation, which is often very stressful for people, is therefore no longer necessary. Thanks to SLEDM, the production of such implants would be possible directly in the operating theatre, because "an LED light is naturally less dangerous for the operation than a powerful laser source," says Haas.

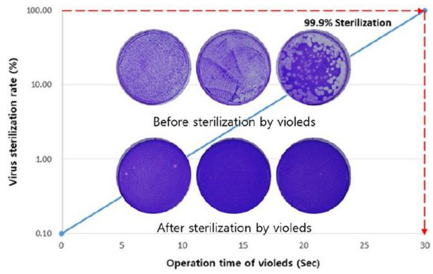
The second focus is on sustainable mobility, namely the production of components such as bipolar plates for fuel cells or components for battery systems. "We want to make additive manufacturing using SLEDM economically viable for e-mobility and position SLEDM in this field of research at an early stage," says Haas, who will produce a marketable prototype of this 3D metal printer - "made by TU Graz" - in the next development step: a further innovation in the university environment.

The SLEDM process was developed in the FoE "Mobility & Production", one of five scientific research foci of Graz University of Technology.

In Planet Research, Franz Haas tells more about the project (with video). To learn more about the partner company and lighting specialist Preworks and the , FoE "Mobility & Production, please visit preworks.at/index.php/en/ and www.tugraz.at/en/research/forschungsschwerpunkte-5-fields-of-expertise/mobility-production/overview-mobility-production/ respectively. ■

Seoul Viosys and SETi's Violeds Technology Proves 99.9% Sterilization of Coronavirus (COVID-19) in 30 Seconds

Seoul Viosys and Sensor Electronic Technology, Inc. ("SETi"), leading global innovators of UV LED products and technology, announced that it has been successful in achieving 99.9% sterilization of coronavirus (COVID-19) in 30 seconds. Tests were conducted with the research group of Korea University, Korea's top ranked university, by using a compound semiconductor Violeds technology that is being mass-produced. As



According to Seoul Semiconductor, Seoul Viosys and researchers from the Korea University, 30 seconds of UV light from Violeds might be sufficient to destroy 99.9% of coronavirus (COVID-19)

COVID-19 spread throughout the world, SETi and Seoul Viosys, the fourth-largest global LED maker of Seoul Semiconductor's affiliates, devoted resources to show how Violeds technology can directly sterilize the virus. The goal has always been to provide technology for a cleaner world, and this includes minimizing the spread of COVID-19, while the company will quickly offer strong sterilization solutions for coronavirus in air as well as surface of goods such as facial masks and smartphones.

In the study by SETi and Seoul Viosys, Violeds technology is used to show just how strong the sterilization effect can be on COVID-19 when exposed to Violeds photons for 30 seconds. The study also finds the coronavirus becomes even more sterile when placed closer to the photon with longer exposure time. In addition to testing the coronavirus, the Violeds technology also proved to be successful in sterilizing 99.9% of other harmful bacteria such as Escherichia coli, Staphylococcus Aureus, Pseudomonas Aeruginosa, Klebsiella Pneumonlae, and Salmonella Typhimurium.

About Seoul Viosys:
Seoul Viosys is a full-line solution provider for UV LED, VCSEL (Vertical Cavity Surface Emitting Laser), the next-generation light source for 3D sensor and laser, and a single-pixel RGB "Micro Clean Pixel" for displays. Established in 2002 as a subsidiary of Seoul Semiconductor, it captured No. 1 market share in the UV LED industry (LEDinside, 2018). Seoul Viosys has an extensive UV LED portfolio with all wavelengths range (200nm to 1600nm) including ultraviolet rays (UV), visible rays and infrared rays. It holds more than 4,000 patents related to UV LED technology. Violeds, its flagship UV LED technology, provides a wide range of industries with optimal solutions for strong sterilization and disinfection (UVC), skin regeneration (UVB), water/air purification and effective cultivation for horticulture. In 2018, Seoul Viosys acquired RayCan, a leading optoelectronic specialist, to add the advanced VCSEL technology which supports smartphone facial recognition and autonomous driving, and has started its mass production. In January 2020, it introduced a disruptive "Micro Clean Pixel" that has the potential to be a game-changer in the display market. To learn more, visit http://www.seoulviosys.com/en/

About SETi:
Sensor Electronic Technology, inc. (SETi), a division of Seoul Semiconductor and Seoul Viosys, is a company based in Columbia, South Carolina, founded in 1999 by four Ph.D., for research and development of compound semiconductors in the United States. In 2005, SETi received the investment and R&D fund from Seoul Semiconductor and Seoulviosys. For the development project, SETi is also working with the University of South Carolina and the University of California at Santa Barbara, adding depth to its research and development. ■

TECHNICAL REGULATORY COMPLIANCE UPDATE

Segment	Product	Standard (Certification)	Region	Technical Regulatory Compliance Information
Safety	Self-Ballasted LED Lamps	Order No. 10930000800	Taiwan	Order No.: 10930000800 which was published on 19th of March 2020 defines relevant legal inspection requirements and inspection items for selfballasted LED lamps. The order came into force on the same day. The order published by Taiwan BSMI clarifies the following topics: Test items in CNS 15630-2019 which are applicable for LED lamps that are capable to sense motion: • electrical characteristics (without flickering) • light output (without luminous efficiency) • chroma characteristics All items which were not tested must not be marked with the standard. Neither on the product, nor within the manual nor on the packaging. LED lamp products with a greater rated power than 60 W or a lamp cap which is not mentioned in the CNS 15436 have to comply with the relevant inspection regulations. The measured values are allowed to be only 10% lower than the indicated values.
Safety	D.C. or A.C. Supplied Electronic Control Gear For LED Modules	TIS 3002	Thailand	The Thai Ministry of Industry announced on 25th of March 2020 the introduction of the new industrial standard TIS 3002–2562 for the particular requirements regarding lamp control gears for DC or AC supplied electronic control gears for LED modules under the Industrial Product Standards Act. The new standard specifies safety requirements for electronic control gear for use on DC, AC supplies not exceeding 1.000 V (alternating current at 50 Hz or 60 Hz) and at an output frequency which can deviate from the supply frequency, for the use with LED modules. The standard refers to the IEC 61347-1 and the IEC 62384 covers the performance requirements of the described and defined products.
Safety	Equipment for general lighting purposes	IEC 61547:2020 Edition 3.0 (2020-03-26)	World/ Europe	Equipment for general lighting purposes – EMC immunity requirements main changes are: a) extension of scope with end-user replaceable modules and the combination of end-user replaceable module and independent auxiliary; b) clarification of module testing in a host system; c) increased ESD and surge test levels for road and street lighting equipment; d) the introduction of ESD testing under normal operation and handling conditions; e) removal of line to ground surge test for self-ballasted lamps $\leq$ 25 W.
Safety	Organic light emitting diode (OLED) light sources for general lighting	IEC 62868-1:2020 PRV (pre-released version) Edition 1.0 (2020-03-06)	World/ Europe	Organic light emitting diode (OLED) light sources for general lighting – Safety – Part 1: General requirements and tests. This standard covers general safety requirments of OLED products for use on DC or AC supply. Specific OLED products will be covered by a part 2 that is to be published but when no part 2 is covereing a OLED product then this part 1 is applicable. It covers: marking, construction, mechanical hazards, thermal stress, fault conditions, material requirments and photo biological safety. It also provides an annex for information on luminaire design.
Safety	Controlgear for LED modules	IEC 62384:2020 PRV (pre-released version) Edition 2.0 (2020-03-06)	World/ Europe	DC or AC supplied electronic controlgear for LED modules – Performance requirements. Main changes will be: • scope extension (direct current from 250 V to 1000 V); • new specifications for measuring the power factor for controlgear with settable/non-constant output (for instance, to allow for constant light output); • deletion of audio frequency requirements; • selection of current test circuit by module capacitance (instead of selecting by having or not having logic circuitry) plus test circuit setup changes.
Energy Efficiency	Lighting products	(EU) 2019/2020	World/ Europe	The EU published a corrigenda on 24.02.2019 in the OJ: ErP regulation (EU) 2019/2020 for Light sources and separate control gear. Changes: • Chromaticity coordinates corrected • HLLS c-factor corrected • Control gear efficiency formular corrected

Personal Table Light - Intelligent Workspace Lighting

The pioneering design team at Bartenbach unveils a brand-new intelligent lighting concept set to revolutionize workspace personalization. It is set to deliver a truly user-centric, workspace lighting blueprint for lighting designers to transform workspaces for healthier living.

The story began with Bartenbach's involvement in the Repro-light project consortium, funded through the European Commission's Horizon 2020 work program. The scope of the project, "To successfully initiate transformation in the European LED lighting industry, by creating the 'Luminaire of the Future'." Part of this remit was to develop a new customizable lighting system.

Background

Bartenbach approached this project with extensive user surveys to fully understand the requirement for better lighting. The research results established the requirement for an easy to use, customizable lighting system. Following a meticulous development process and numerous prototypes, the final result called the Personal Table Light (PTL) is impressive.

The PTL achieves exceptional lighting for vision and health at the workplace, and is fully personalizable. Visual performance is perfectly supported as both vertical and horizontal workspace surfaces are lit separately, and illuminance levels are controlled along with light color temperatures, and light distributions. Furthermore, the PTL effectively delivers up to 1500 lux at eye level, meaning missing daylight is supplemented and is able to exert non-visual effects on mood, alertness, performance and night time sleep. The PTL also allows full customization of scenes by the user via a desktop application.

Equipped with single-point LED controls and a highly innovative sensor technology that recognizes the actual activity of the user, lighting scenes adjust discreetly and automatically according to changing visual activities.

Additionally, environmental quality is assessed continuously by ambient temperature, humidity, air pressure, volatile organic compounds, and sound level sensors. Therefore, the luminaire uses highly standardized IT-protocols, which enable an easy integration of nearly all sensors available on the market.

Finally, using cloud connectivity, user activities can optionally be recorded which allows an on-going optimization of the lighting system tailored to individual needs.

The application possibilities of the PTL are numerous and range from student areas and offices to medical and manufacturing workspaces.

The future of human centric lighting has arrived. With patent pending, the PTL has the potential to transform workspace lighting. To measure effects of this innovative lighting system on human beings, impact research is currently being conducted in two laboratory studies and a multi-centered field study.

Consortium

Bartenbach is an award winning lighting design and research consultancy nestled in the mountains above Innsbruck. A team of architects, physicists, psychologists and designers forging individual lighting solutions. This interdisciplinary team is proud to be part of the international scientific community network, always at the cutting edge of research.

The Repro-light consortium consists of leading European experts including; TRILUX, a driving force of the European lighting industry, components manufacturers including BJB, Grado Zero Espace, and Rohner Engineering, innovative members of the lighting industry, Bartenbach and Luger Research, as well as experts in lighting sustainability and Life Cycle Assessment IREC and Mondragon University who are prominent in Social Sciences.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 768780.

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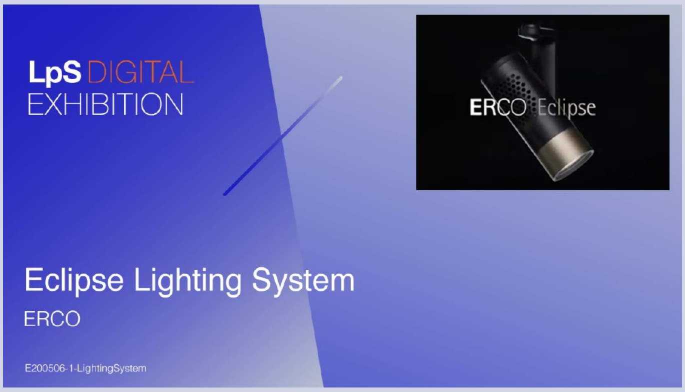

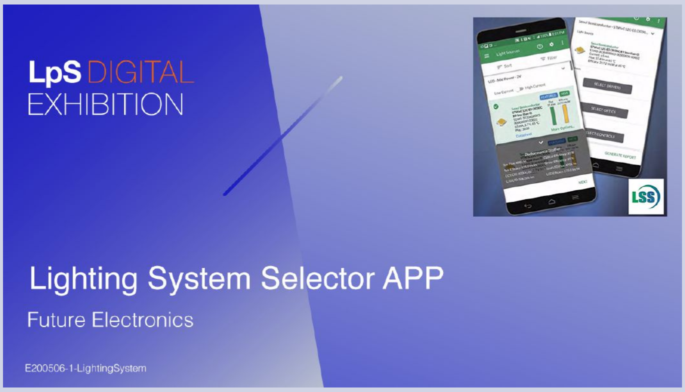

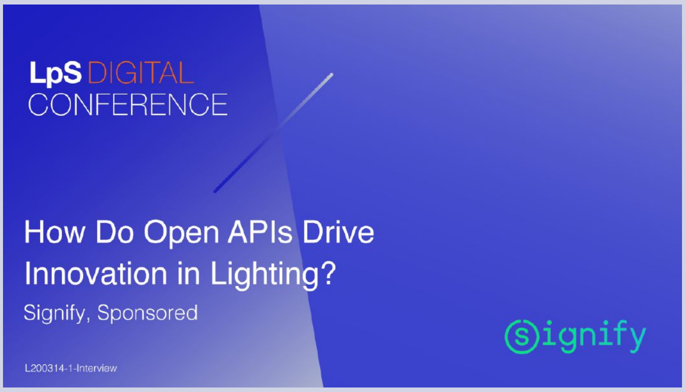

Tech-Talks BREGENZ Hani KANAAN, Smart Lighting Technologies Business Development at CEA-Leti, France

Hani KANAAN, Dr.

Hani KANAAN received his PhD degree in Electric engineering from the University of Toulouse in 2009, where he worked on electrical simulation and fabrication of OLED and Organic photovoltaic devices. He then moved to Belgium to work for Materia Nova on OLED fabrication using metallic substrates with Top configuration architecture. He has an extensive background in electro optical characterization, device design and optimization. He joined the CEA in 2010 where he worked on the development, optimization and characterization of microdisplays in a joint lab with the Microoled Company. He had the opportunity to work on several European and industrial projects as a project manager and coordinator. Since 2015 he has had the responsibility of developing the industrial partnership for the emissive components at Leti with a focus on the microLED activity for Lighting and Microdisplay.

Micro LEDs are the latest development in SSL. They are used for high-quality displays and compete with OLED displays. Dr. Hani Kanaan, a renowned specialist at CEA-LETi in this field and also OLED technology, gave a sound introduction to this technology at LpS. LED professional wanted to know more, so we asked him for an interview. The topics range from current limitations to materials, processes, efficiency, thermal issues, costs, opportunities and much more.

LED professional: **Thank you very much for coming to this interview. You gave a talk at the LpS 2019 about microLEDs. Could you explain to our readers what microLEDs are? How are they different from conventional LEDs and what applications can they be used for?**

Hani KANAAN: Thank you for inviting me. MicroLEDs are based on the same technology as conventional LEDs: epitaxial growth on a sapphire substrate. The size of these DIY chips is very small and compatible with the applications that we're targeting. As an example: for lighting applications a microLED pitch might be around 100 microns and for automotive applications it will be up to 25 microns. A display would use between 20 and 40 microns and if you want to do a micro display, the pixel pitch should be reduced to less than 20 microns.

LED professional: **Are these tiny LEDs driven with comparable current densities to conventional or is it a lower current density?**

Hani KANAAN: It depends on the application. What we know is: The smaller the LED, the higher the current density that is needed to get equivalent light output, because the efficacy of the microLED will be a lot less than in standard LEDs. For example, if I take one LED that is one millimeter square and pixelate it, to end up with 1,000 pixels, the sum of these 1,000 pixels will remain one square millimeter but the lumen output would be much less than the one millimeter LED DIY . That means if we want to get the same lumen output, we need to drive those microLEDs at higher current, which means higher power. This will cause droop in the LEDs and generate heat issues that may shorten the device's lifetime.

LED professional: **Can you explain a little about the size of a single microLED and the efficiency? Is there a clear dependency?**

Hani KANAAN: This question remains a research-level subject. We published a paper on this two years ago. When we measured the performances of LEDs of different sizes from the same epitaxy wafer, for instance from 1 square millimeter to 500 microns, 250 microns, or 150 microns to 10 microns, we noticed that the maximum efficiency decreases with pixel size. Non-radiative recombinations occurring at the edges of the LED were found to be the main origin of the performances reduction. You can imagine the LED structure being like a building with different floors. You must have the minus pole on the ground floor and the plus one on the top. The current must go vertically to cross the structure – these floors – in order to generate photons in the multi-quantum well. We are talking about a surface that is very tiny compared to its height and the current might not follow the optimal path, but follow the surface and just generate heat instead of the desired light.

LED professional: **So what you're saying is that there are practical limits when it comes to miniaturization – there is more leakage than usable current when you get down to a certain size.**

Hani KANAAN: Yes, while we are able to make very small LEDs, possibly down to two-microns square or below due to an advanced lithography process, the question is will it be useful. Will we be able to drive it and what would the performance of this device be? Right now, we know how to produce it. But how to resolve the current leakage issues still needs ongoing study because this field is still in the early stages. In my presentation, I emphasized that this is one of the remaining challenges because it is the key to resolving the heat issue. Any current that is converted into heat but not light is especially a huge problem for head-mounted-display applications. Furthermore, energy consumption is very high. It's much more complicated to have a good autonomous head-mounted system without a large external battery.

LED professional: **So, there are microLED displays, for example, that have already been developed. But as far as I understood in your lecture, there is a lot of research and development still going on. One of the fields is heat, as you just mentioned. Are there other fields?**

Hani KANAAN: I didn't mention in my presentation that all the major investments are for R&D – nothing is being invested in production yet. There are different challenges: One of them is heat dissipation. But more important, we need to reduce heat generation first, as already discussed: If we manage to make a microLED that is 100 lumens/watt, we have reduced generated heat by over 50 percent.

The second challenge is color conversion. For both lighting and microdisplay applications we need full color – that means we need RGB pixels. But when working with pixels below 20 microns, the standard phosphor for lighting doesn't work anymore because the size of the phosphor crystal or moniker is too big compared to the pixel. If you want to dispense or localize it, it will probably cover many pixels – or at least two pixels. So, you will face optical crosstalk. For this reason, scientists try to work with microphosphor or nanophosphor – and many are trying to work with quantum dots.

There are two major opinions in the literature on QDs: One is that QDs would be the solution. But others think quantum dots would not be stable enough. They might be stable with an OLED backlight of a comparable low brightness of some hundred nits, but not with very high LED brightness. See-through display systems must have at least 5,000 nits for outdoor applications. If you have fewer than that, the systems will never work properly in bright sunshine. For example, they will provide less than 10 percent yield for the optical system. Therefore, you should expect to have at least 50,000 nits on the display level to get those 5,000 at the end of the system. The question is whether or not quantum dots would be able to provide this from the blue flux and how long they would be able to provide it.

LED professional: Isn't it still a problem that quantum dots aren't stable at higher temperatures?

Hani KANAAN: They aren't very stable. So maybe researchers will have to design quantum dots with much better stability at higher energy. The advantage of quantum dots in this application is that they will absorb the blue light, which is emitted in a broad spectrum from the LED, and convert this flux in a very narrow spectrum of light. Instead of having a 50- or 60-nanometer-wide spectrum, you will have full width at half maximum (FWHM) of 25 to 30 nanometers. So, you can achieve high-color-purity RGB pixels. You also will have much better contrast, while covering 100 percent of National Television System Committee (NTSC) display color spaces. This is the main reason to use quantum dots. You also can make QDs in different sizes based on the same structure in the two-to-seven nanometer range, and when you change the diameter of the dot, you change the wavelengths. Therefore, it's compatible in terms of size with the microLED pixel size. For this reason, there is a lot of interest in this quantum dots technology. But it's not ready at the moment.

LED professional: It seems that microLEDs are a major focus of CEA-Leti. What are the primary topics you deal with in this field?

Hani KANAAN: I cannot speak for all of CEA-Leti, whose expertise includes miniaturization and integration of microelectronics and nanoelectronics in fields ranging from medical devices to defense & space applications to artificial intelligence. But obviously microLEDs are one of the key R&D technologies for our optoelectronics department, which has developed deep expertise in this area over many years. At the same time, we also have focused on lighting technology, so it made sense for us and our partners to merge these two R&D areas and develop very high brightness microdisplays. Our optronics department also developed a UVC LED source and new generation of InGaNOS-epitaxy-based LED for native red/green direct emission without color conversion.

Meanwhile, we are also publishing many papers on institutional and industrial projects and exploring new architectures called field-effect LED and nanowire LED. Nanowire LED is a new architecture dedicated to UV in order to get very highly efficient UVC LED at 250-to-260 nanometers for water purification, medical applications and other possible applications. In addition, we are working on very early-stage development in infrared VCSEL for LiDAR and other applications. So, we cover more than the visible range – from UV to infrared. And two years ago, CEA-Leti installed a new lab dedicated to X-ray detection for medical applications. Obviously, I can't say we cover everything involving optoelectronics, but we are active in a very broad range of photonics disciplines.

LED professional: What is the main focus in the field of microLEDs?

Hani KANAAN: The microdisplay is currently the driving application because globally the only areas that are attracting large-scale investment at the moment are TVs and microdisplays for automotive and virtual reality uses. Automotive display applications are an interesting challenge, in part, because while color conversion is less complicated then in microdisplays, achieving very high brightness and reliability in LEDs is difficult. Headlamps should deliver between 1,000 and 1,500 lumens on the road.

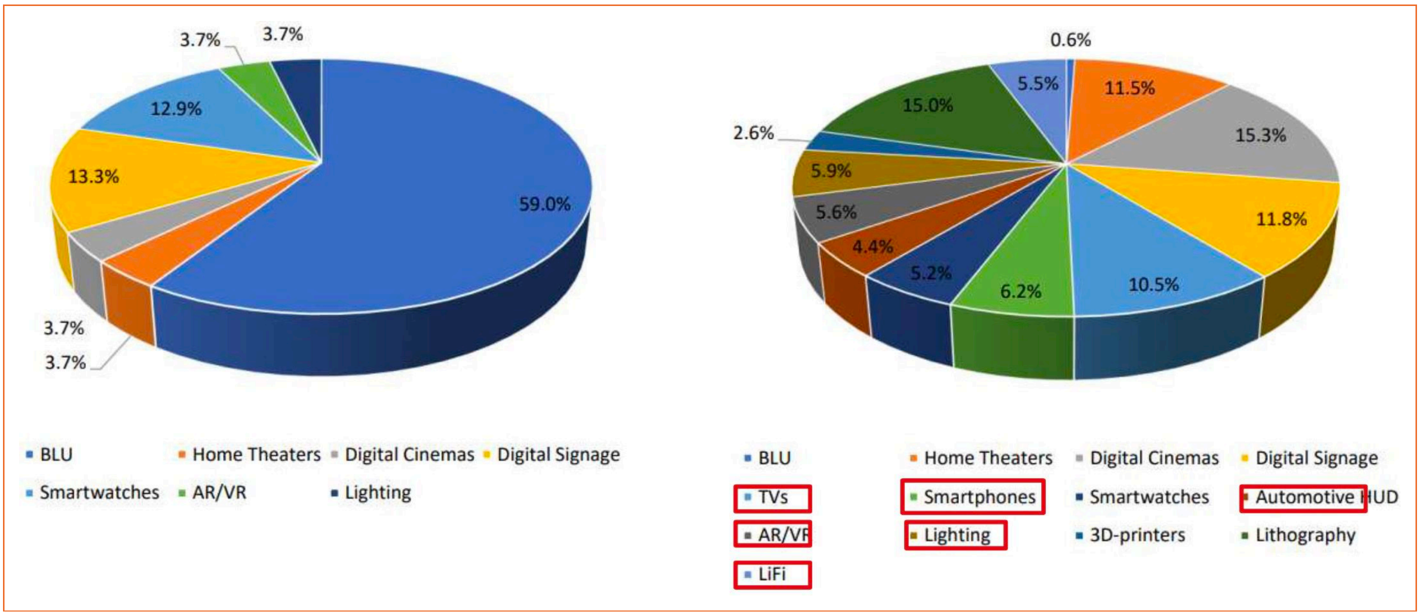

Figure 1: Market Segmentation 2019 (left) and forecast for 2025 (right). Source: Yole Developpement

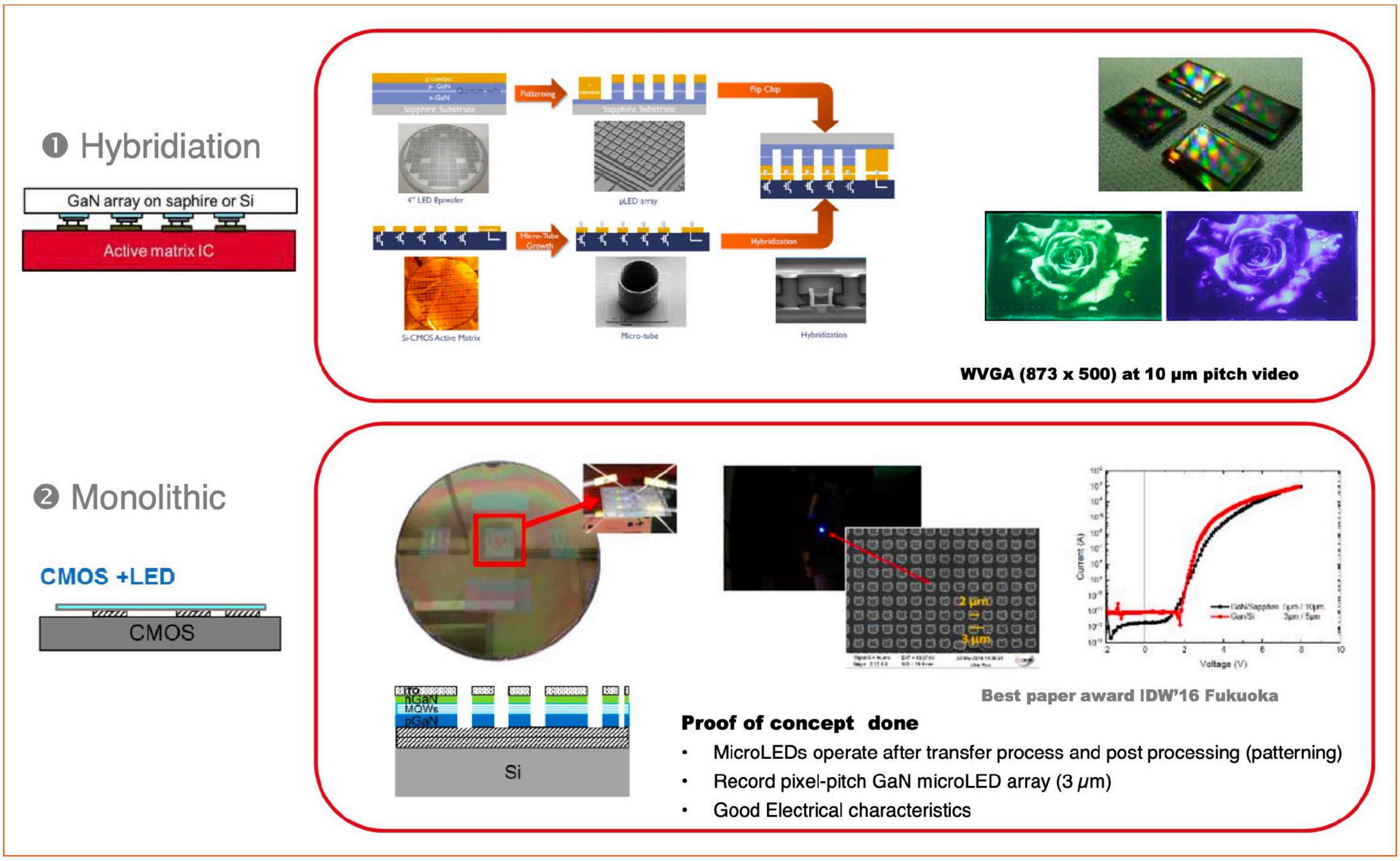

Figure 2: LED Micro-Display Demos @ LETI with Hybridiation and Monolithic

LED professional: Yes, we noticed that you talked about headlamps in your lecture and you emphasized that while being more expensive than conventional LEDs it may be an advantage to use microLEDs when looking at a system level, especially since it offers new design options to car manufacturers.

Hani KANAAN: Yes, a microLED source of light will be much more expensive than current LEDs in headlamps. But I don't think that the price of the headlamp in total will change. Instead the costs will be transferred to the components, so we'll have two or three manufacturers producing headlamps, rather than six or seven.

In fact, the microLED will integrate the electronics. The system gives you a lot of light and color and you are able to drive each pixel independently. So, you can move left, right, up and down and eliminate the mechanical system. The reflector is also already integrated and each pixel has its own reflector. The optical element will be an imaging lens or a microlens that could be integrated later. We're still talking about first generation and we don't know what will happen in the future. All the bulky plastic will probably be eliminated. In terms of price: Before we had a lamp, but now we have a projector. It's more expensive than a lamp but to integrate the headlamp and to have the same functionality, we don't think the price will change on the whole. The increase in the price of the headlamp will be offset by the decrease in the integration.

LED professional: And adding the value of being able to control it.

Hani KANAAN: Yes, several economic agencies made a cost model and so did we. As result, we expect that the engine module based on microLEDs for automotive will be around USD 50/cm². With mass production, the price could go down – it depends on the size of the market. Today, a high-end headlamp from some brands costs more than USD 2,000.

LED professional: If I got you right, one important advantage is the miniaturization of the system, and that is something that car manufacturers really like because they can play around with new designs. Is that correct? Or are there also other benefits?

Hani KANAAN: Yes, the light engine is based on microelectronics. But besides shrinking the size of the light engine you can increase the functionality of the system. For electronics, you are able to put sensors around or inside. In the next generation we will be able to use some pixels of the engine light to sense. With two headlamps, cars will able to perform 3D sensing and more easily detect obstacles. Of course, design must be considered: If it's smaller you have more freedom. But in the autonomous car of the future the headlamps will act like human eyes. They should detect, identify and even guide the car without waiting for the vehicle's main computer to make a decision. It should be able to avoid an obstacle in case of an emergency. That means that we are moving towards smarter and smarter headlamps. What kind of technology can we put inside? There are plenty of choices. The costs, the design and compatibility are the main limitation for the technology.

LED professional: It's interesting that you mentioned that one of the microsystems could be in LiFi. I've

Figure 3: High density array high adaptive street lighting. Special and dynamic control of light flux and color

heard about ideas to integrate LiFi in cars so they can communicate with each other. That would also be an option to extend the functionality.

Hani KANAAN: Recently we demonstrated transfer rates of several gigabytes per second. If a headlamp could do car-to-car communication, infrastructure communication, this would certainly bring some new functionality to the automotive industry, especially if the taillight of the car in front of you can communicate with your headlamp. For instance, if a car, five kilometers ahead, had an accident, the information would be transmitted back from car to car until it reaches you. There will definitely be some adaptations because LiFi needs a different way to drive the LED than lighting. These adaptations should be integrated into the design. I don't know of anyone who is working on that. I know that we are just beginning to explore the potential of microLEDs to deliver very high-speed Internet signals.

LED professional: Maybe before delving deeper into the technical details we should explain what is behind the idea of using a microLED array for LiFi.

Hani KANAAN: There are two primary considerations. First, LiFi is currently a new technology that was adapted to what already existed in lighting. For example, there are a few companies in Germany, Austria and France that will install an Internet modem and connect it in serial mode to a commercial luminaire driver. And you then you get Internet from your luminaire. The limitations of the system stem from the bulky LEDs compared to microLEDs. Therefore, you have limitations in your switching speed because it turns on immediately but there is a slight delay when you turn it off. You would always be limited by this switching delay because of this capacitive characteristic of the DIY. You have need to reduce the pixel size to reduce the delay. MicroLEDs are much smaller and allow faster switching cycles.

The second consideration is lighting includes the phosphor. Most of the phosphor is a yellow YAG phosphor. Phosphors have response times that can't be changed. So, we must consider that in our pursuit of a very fast microLED. If we remove the phosphor, we are working with a native emission blue or green or red and the size of the microLED will become again the limiting factor. In case of a blue 10-micron microLED – as we demonstrated – we got a data transfer rate of a few gigabytes per second, which is almost one 10 times faster than the best that exists. But it's still at an early stage of development.

Everybody is talking about LiFi and the question is whether it will be the ultimate source to distribute the Internet. I, personally, think it will be an additional source because if you have equipped your home with LiFi, how will the signal come to you? By cable! So, the advantage of LiFi is that you can reduce the number of systems in your home. Instead of having one for lighting and one for Internet, you will have one cable that you plug into your lighting system and you will use one hardware system. Secondly, you can limit the Internet signal to one room because light does not penetrate walls. Also, nobody can hack your system like a WiFi system.

We can also use LiFi for some medical applications and geo-positioning in a big mall, for example. If I have multiple light sources, I can take the signal from two or three lights and locate my position. So, there are new applications, but if we're only talking about Internet transmission, it's merely an additional way to distribute Internet.

LED professional: On one of the slides about LiFi, you showed a picture of where you are directing it from the microLED array to different positions. So different users have their own direct signal.

Hani KANAAN: In fact, this already exists. Last year we demonstrated a multi-user LiFi system that allows users to walk inside a building without losing the Internet signal . We made a grid from different downlights that will communicate with each other. I will catch the same signal without interruption walking from one place to another. So, the system should be able to identify me, identify what I'm searching for and then deliver it to my changing position. It is analog to a mobile phone network. At the same time, this microLED luminaire is able to serve 10 or maybe 15 people simultaneously. This is possible because you have an array with thousands of pixels driven by blocks to deliver enough light. Each block of microLEDs will be able to deliver a signal to one different user.

LED professional: You started your career in research and development of organic devices technologies. At the moment, the most modern display is the OLED display. What are the differences in the applications of the microLED display and the OLED display?

Hani KANAAN: OLED is used for a smart-phone display, tablet display, TV display and microdisplay. We are also trying to adapt those products to gallium nitride LED. OLED technology offers the best image quality between the commercial products with very low power consumption, but the technology lacks high brightness capability. It is difficult to have an OLED microdisplay that delivers very high brightness for outdoor applications, especially in sunlight.

This is possible with microLEDS. TVs are a possible new aspect for this application.

The manufacturing investment is another important aspect. A 55-inch OLED TV production line is about 50 meters long, 20 meters wide and almost 15 meters high to accommodate the size of the TVs and mass production. A glass substrate of 16 m², or even 5 x 5 m, passes through several different chambers to receive a deposit of organic material. All materials and the TFT circuits are deposited on glass and then the glass is cut into six or eight TVs screens from each batch. These production lines cost about few billion USD each.

In contrast, an eight-inch microLED display production line costs about USD 100 million USD. Moreover, the display-fabrication process consists of dicing the eight-inch wafer and then transfer the microLED to many possible substrates. They could be plastic, metallic or PCB or tissue. This allows building any display size. There are no other technologies that are able to do this. So, this is a major advantage of the microLED technology.

LEDs also offer other possibilities. By increasing the pitch to microLED-size ratio on a transparent surface, we can build transparent display. And with a plastic or metallic substrate you can make it flexible. Other possible applications will certainly come, but now we are just proving that we are able to do that.

LED professional: What are the technologies that are important or will become important in the field of SSL?

Hani KANAAN: At CEA-Leti, we have almost all the available systems and expertise to integrate heterojunction elements or components. In our photonics department, we work also on UV, visible and infrared sources and detectors. But we have departments that are working on a new generation of materials, too. They work on MEMS, memory, transistor, VCSEL (vertical-cavity surface-emitting laser) and other components.

We are also active in the area of optics. We design lenses and especially new concepts of optics based on microstructure or free-form optics. We are also working on light-field displays, and holographic displays, which are beyond conventional 3D. This requires a new aspect of optics combined with a display, or a microdisplay. So, we are covering a lot of technologies that are, or will be, used in our everyday lives.

There also are a lot of applications dedicated to medical uses that apply optoelectronics for in vivo and in vitro detection of cancer molecules and other applications. It's almost all for medical applications. We are also working on multi-wavelength spectroscopy – a new type of spectroscopy that scans a tissue under different wavelengths and provides different information.

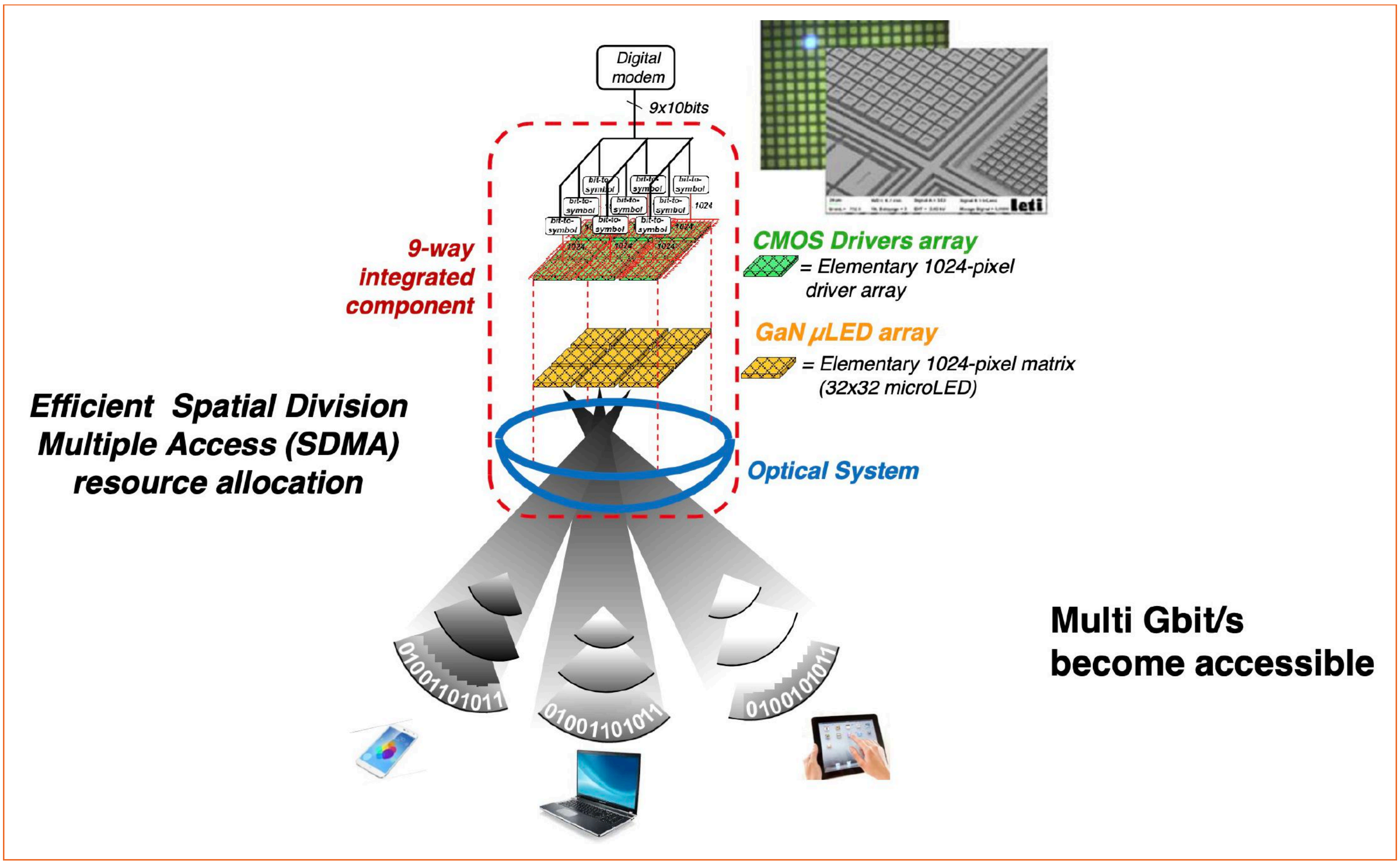

Figure 4: High density array for next generation of LiFi and optical beamforming

You also asked me about the Internet of Things and cyber security. CEA-Leti hosted a three-day workshop last July in Grenoble focusing on IoT, 5G, quantum computing, and artificial intelligence. We are very active in those areas, which include some of the most important R&D subjects right now. Everybody wants intelligent activism, especially for autonomous driving. And they want cybersecurity to prevent, for example, huge traffic jams or accidents caused by somebody hacking a car on the road.

LED professional: **One last question: What do you think are the requirements and challenges for SSL in the future?**

Hani KANAAN: For SSL in general, it's complicated. For example, for microdisplays, as I said, there are color issues and thermal issues. Perhaps a new type of epitaxy should be developed for the new generation because the characteristic of a lighting epitaxy seems to be not optimal for a display. Epitaxy for lighting is designed to support and maintain very high current density and low droop for lighting. For microdisplays, we need a different behavior. Secondly, we are generating colors and we want to be able to generate native colors without color shift. With white LEDs we have a color shift over angle, but we can eliminate this problem if we manage to do it with native color.

Electronics might be the weakest point in the automotive sector because we need very high current densities to project light on the road. Current standard CMOS technology was developed to display an image or to detect with a sensor, but never for this application, and it must be updated. We know how to deliver power electronics so we should design an architecture that can support very high current densities.

LED professional: **So, to summarize: A lot of very different tasks in the future.**

Hani KANAAN: Yes, I invite industrial partners to work with CEA-Leti to bring those products – and ideas for the future – to the market.

LED professional: **So, the future promises to be exciting! Thank you for your time.**

Hani KANAAN: Thank you. ■

Degradation of Green High-Power LEDs – Influence on Color Stability of Multi-Channel Luminaires

In the field of interior lighting, multi-channel luminaires are increasingly being used to present daylight-like lighting situations. Depending on the application, RGB or RGBW solutions can be applied. In order to evaluate the color stability of multi-channel luminaires, commercially available red, green, blue and white high-power LEDs were submitted to various stress levels. Due to the low efficiency and the material composition of green GaN-LEDs, an increased degradation can be observed.

IN order to describe the degradation behavior of green LEDs, the LEDs were aged at four different junction temperatures. In addition, by determining the thermal resistances, aging at three different currents with a constant junction temperature was performed. Due to the strong efficiency droop of green GaN-LEDs, the droop was measured over the aging period in order to separate aging mechanisms. The measurement of the spectral distribution as well as the measurement of the I-V characteristics provide additional information about the degradation mechanisms. The results show a significant degradation of the LEDs with respect to their optical and electrical properties, which varies depending on the applied current and selected junction temperature. Using the measured efficiency droop and the I-V characteristics, an increase in the non-radiative recombination can be observed, which initially mainly affects the range of low operating currents 100 Microampere – 10 Milliampere. As the number of defects increases, the range of practice-relevant operating currents is increasingly influenced by degradation, which could be visualized using a semi-log efficiency droop plot. Due to the degradation a differently pronounced color shift can be observed varying with the number of LED channels of the luminaire system. RGB systems have significantly lower degradation tolerances with regard to green LEDs than RGBW systems in order to guarantee color stability along the Planckian locus. The ageing results of the LEDs in combination with a simulation of multi-channel luminaires show that depending on the operating conditions, visible shifts in the color coordinates can occur in comparison to the initial state due to the degradation of green LEDs.

Introduction

In the past years, LED technology has increasingly been established in the general lighting sector due to its energy efficiency and compact design. Especially phosphor-converted white semiconductor light sources are of great importance in general lighting and have therefore been continuously optimized and further developed. By varying the phosphors applied to the chip, a large number of polychromatic spectra can be produced, which can achieve any color temperature of a Planckian radiator. A combination of two emitters with variable color temperature enables the implementation of dynamic lighting concepts which can be adapted to the ambient conditions depending on the time of day.

In various studies, these two-channel dynamic luminaires have shown positive effects on exposed subjects. For example, an increased attention of the subjects could be observed [1]. As a result, lighting systems in which the human being is the focus of the lighting system (HCL) have become increasingly important. Since future HCL lighting systems should offer the possibility to realize arbitrary color locations and spectra, an increase of the number of color channels is necessary.

Two-channel tunable white solutions are therefore extended by quasimonochromatic channels (e.g. red, green, blue) and enable precise spectral adaptation to daylight spectra or lighting conditions. Alternatively, depending on the application, three-channel systems can be used which are based on a mixture of the primary valences red, green and blue. However, in order to be able to design such lighting systems with colorimetric precision and reliability, it is necessary to know the spectral behavior of the semiconductor emitters for different temperatures and currents. In addition, knowledge of the degradation behavior of the semiconductors is essential if a long-term colorimetrically stable illumination system is desired. Due to the interaction of different aging mechanisms, these can affect the color stability of the systems through a decrease in optical power or a temperature-induced, package or semiconductor color shift. The complexity of these aging mechanisms makes experimental investigations of degradation mechanisms and behavior indispensable. Due to the existing green gap problematic, the ageing behavior of green high-power LEDs will be investigated in the following. In addition, its influence on the color stability of multi-channel luminaires evaluated.

Experiments

The experiments have been carried out using commercially available green high-power LEDs with a peak wavelength of 522 nm. The wall-plug efficiency can be quantified 16 % at 350 mA and a nominal current of 1000 mA is given. The silicon encapsulated SMD packages were mounted on a metal core board with a PT100 temperature sensor close to the LEDs solder point T_C. The optical measurements are performed using a spectrometer (CAS140CT) in combination with a PTFE integrating sphere. The system is absolutely calibrated and provides information about the electroluminescence (EL) spectrum and the absolute radiant flux. Due to the maximum integration time of 65 s with corresponding dark current compensation, measurements of low optical intensities are possible. On this basis, the current-dependent efficiency of the LEDs can be measured in a current range from 100 µA to 700 mA. The LEDs are powered with a source measure unit (Keithley 2450) with 4-wire setup and are pulsed for optical measurement at measurement currents above 1 mA to avoid effects of joule heating. The temperature of the LEDs during the measurement is controlled using a Peltier element in combination with a Peltier controller (Thorlabs ITC 4020). The thermal resistance is determined by a thermal impedance measurement system developed by Mentor-Graphics (T3ster system). The system provides information about the thermal structure function of the characterized sample.

After an initial optical, electrical and thermal characterization in the temperature range between 25 °C and 70 °C, four samples each are aged at a constant current of 700 mA and four different case temperatures which are measured at the solder point (55 °C,85 °C,105 °C,125 °C). In addition, the LEDs were aged at a constant junction temperature of 141 °C with forward currents of 350 mA, 700 mA and 1000 mA. In this way, a separate influence of the temperature and the current on the degradation behavior is to be determined.

Multi-Channel Luminaires – Theoretical Approach

In the following, the design and color mixing of multi-channel luminaires will be discussed. First, possible theoretical influences of the green color channel on RGB systems and RGBW systems are evaluated. The theoretical assessment is followed by a practical examination based on real ageing data.

The target colors to be mixed are selected along the Planckian locus. Based on the color temperatures of conventional temperature radiators, a range of 2200 K–6500 K is considered. The base spectra used in the following are spectra of red (630 nm), green (520 nm) and deep blue (450 nm) high-power LEDs. For the 4-channel system, a additional white LED with a color temperature of 4000 K is used. The base spectra are shown in **Figure** 1. For the

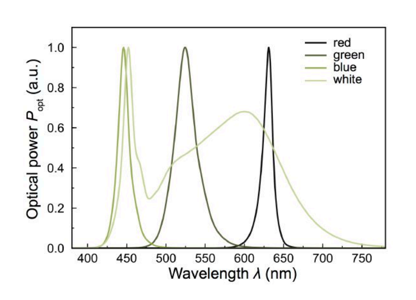

Figure 1: Base spectra for 3/4-channel luminaires Red (630 nm), Green (520 nm), Blue (450 nm), White (4000 K)

color mixing calculations of the LED system, the base spectra are first converted into the corresponding tristimulus values of the CIE standard valence system using the 2° observer color matching functions. Subsequently, a conversion to the tristimulus values is performed. A detailed description of the procedure for color mixing of multi-channel luminaires is not the subject of this publication and is therefore only described schematically.

The desired color coordinates of the luminaire can be calculated using

$$x_{mix} = X_{mix}/(X_{mix} + Y_{mix} + Z_{mix}) \quad (1)$$

$$y_{mix} = X_{mix}/(X_{mix} + Y_{mix} + Z_{mix}) \quad (2)$$

Initially, the brightness of the target color coordinates is only considered relatively. The combined color of the different channels CH_1, CH_2, CH_3 and CH_4 is given with the tristimulus values with:

$$X_{mix} = X_1 + X_2 + X_3 + X_4 \quad (3)$$

$$Y_{mix} = Y_1 + Y_2 + Y_3 + Y_4 \quad (4)$$

$$Z_{mix} = Z_1 + Z_2 + Z_3 + Z_4 \quad (5)$$

Using these equations, the proportions of the individual color channels can be calculated in relativity to each other. Subsequently, the ratios are scaled on the basis of the absolutely measured spectra. The brightness is maximized by a 100 percent output of the color channel with the largest proportion of the total spectrum. For the dimming of the channels, a linear PWM dimming behavior is assumed. Four-channel systems are designed analogous to three-channel systems, with the difference that two primary valences are combined into one primary valence using a weighting factor. The weighting factor is determined by optimizing the color rendering index (CRI) of the entire systems spectrum.

In order to be able to carry out a theoretical estimation of the maximum degradation limits of the green color channel with respect to the color stability of the overall system, a calculation of the luminance ratios for the corresponding color temperatures is carried out with the underlying base spectra. The luminance ratios of the RGB system for mixing the target color coordinates along the blackbody locus can be seen in **Figure** 2. The dimming conditions determined by taking the real measurement data into account are shown in the Inset of **Figure** 2.

The values for the 4-channel system are shown in **Figure** 3.

By weighting the spectra with the given dimming ratios, the desired target color coordinates along the blackbody locus can be precisely matched. In this way, the initial state of the system can be assumed without ageing or temperature influences. In order to calculate a tolerable degradation of individual color channels, a maximum tolerable color shift of the overall system must be defined first. Here, a 3-step MacAdam ellipse is defined as the maximum allowable color shift, since this color difference can be perceived by an experienced observer according to [1]. The color distance in the CIE 1967 color space is assumed by a simplified circle with a radius of $r = 0.003$. In addition, it is assumed that only the green color channel is under degradation, the remaining channels of the system therefore remain unaffected.

If the shifts of the overall system are calculated under these conditions, the color coordinates presented in **Figure** 4 result. Shown are the changes of the RGB, as well as the changes of the RGBW system to be able to indicate a maximum color distance of a 3-step MacAdam ellipse from the blackbody locus.

In addition, **Figure** 4 Inset shows the percentage of the initial radiation flux at which the overall system remains within the defined limits. Furthermore, it is assumed that only a decrease of the optical power occurs. Effects that can originate from a color shift of the semiconductor or an increased joule heating remain unconsidered at first.

Besides the decrease of the optical power, colorimetric shifts of the overall system can also occur due to temperature changes. To consider these influences different causes for temperature changes have to be taken into account. Due to dependence of the LEDs junction temperature, given with

$$T_j = R_{th} \cdot P_{th} + T_c \qquad (6)$$

a change of the thermal resistance or the thermal power should be considered. A decrease in optical power at constant electrical power results in an increase of thermal power P_{th}

$$P_{th} = P_{el} - P_{opt} \qquad (7)$$

In order to estimate a maximum tolerable change in junction temperature, the spectrum of the LED was recorded at different temperatures, shown in **Figure** 5. By interpolating the spectra between the measured temperatures, the maximum temperature change for the corresponding target color coordinates can be determined.

The maximum allowed temperature change of the green channel in RGB systems over the entire color temperature range from 2200 K–6500 K can be quantified as approximately 21.5 K and is almost constant. For RGBW systems, the maximum permissible change at a color temperature of 2200 K can be specified with ΔT =27 K, at higher color temperatures the maximum allowable change is above 40 K and can therefore be neglected.

In order to be able to estimate such a temperature change, the efficiency of the LED must be considered first. Initially, the electrical power at 700 mA can be specified with $P_{el} = 2.65$ W; with a wall plug efficiency of 13 %, the optical power results in $P_{opt} = 0.34$ W and the thermal power in $P_{th} = 2.31$ W. Since a large part of the electrical power is already converted into thermal power due to the low efficiency, in the case of $P_{el} = P_{th}$ a change in the junction temperature would result according to equation:

$$\Delta T_j = 9.3\,\text{K}\,\text{W}^{-1} \cdot 0.34\,\text{W} = 5.27\,\text{K} \qquad (8)$$

Due to the maximum acceptable change of 21.5 K, such a conditional color coordinate shift is negligible. The permissible changes with regard to thermal resistances can be estimated as follows:

$$\Delta R_{th} = \Delta T / P_{th} = 21.5\,\text{K}/2.31\,\text{W} = 9.3\,\text{K}\,\text{W}^{-1} \qquad (9)$$

Thus, the thermal resistance would have to change by 9.3 K W^{-1} during degradation in order to contribute to colorimetric instability of the overall system. Basically, however, it should be considered that the overall system may have lower temperature limits due to the temperature-sensitive red color channels. In order to be able to give an assessment as to whether these degradation limits are exceeded within the scope of real ageing, the degradation results will be discussed below.

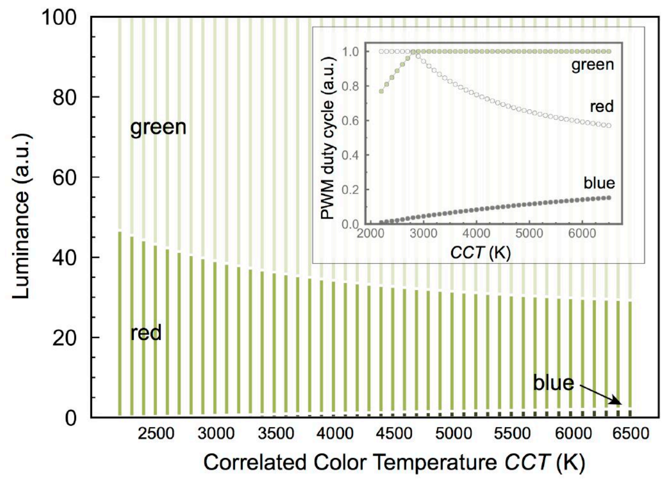

Figure 2: Relative luminance for the RGB system in a color temperature range of 2200 K–6500 K. Inset: Resulting PWM duty cycle

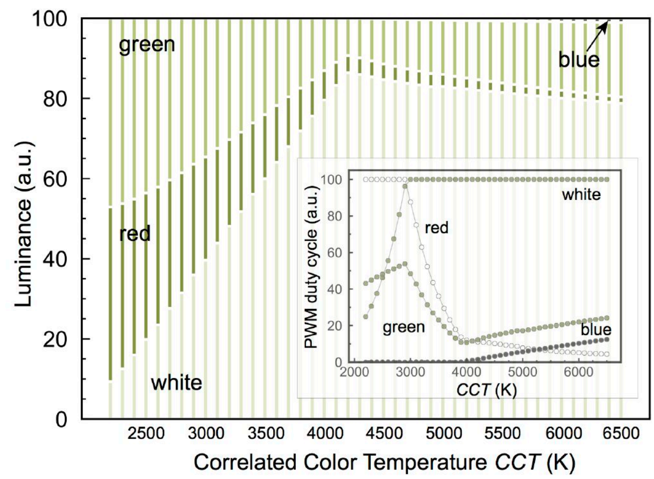

Figure 3: Relative luminance for the RGBW system in a color temperature range of 2200 K–6500 K. Inset: Resulting PWM duty cycle

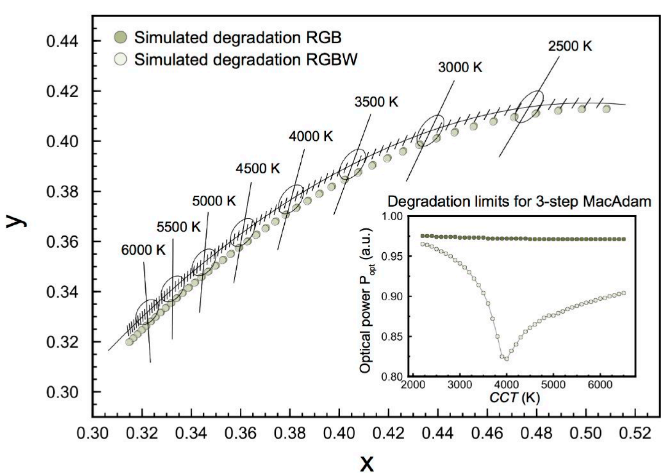

Figure 4: 3-step MacAdam degradation limits for the green channel of RGB/RGBW systems in CIE 1931. Inset: Optical power related to the initial output power value to stay within a 3-step MacAdam

Degradation of Green High Power LEDs

After a previous optical, thermal and electrical characterization, green LEDs were aged over a period of 3721 hours at four different temperatures. The case temperatures were 55 °C, 85 °C, 105 °C and 125 °C and were measured at the LEDs solder point. In order to estimate an additional current dependence of the degradation, a further test series with 350 mA, 700 mA and 1000 mA was aged over a period of 2610 hours. The junction temperature is set to 141 °C for all three operating currents. The EL measurements, which were carried out during stress, were recorded at measuring currents of 100 µA–700 mA and provide results regarding the absolute radiation flux as well as the behavior of colorimetrically relevant parameters of individual EL spectra.

The decrease of the optical power of an LED aged at $T_C = 55$ °C and 700 mA is shown in **Figure** 6.

Against the assumption that degradation results in a uniform change of the optical power, it is shown that the range of low and medium measurement currents is significantly stronger influenced by the degradation mechanisms. Measurements carried out at a measurement current of 100 µA show an 81 % decrease within 3721 hours. The degradation of the optical power is also shown in the measurement of the external quantum efficiency. The influence of the degradation mechanisms on the range of the operating current of 700 mA is only slightly pronounced and can be quantified at about 4 % for the LED shown above. The consideration of the external quantum efficiency (EQE) shows that a strong gradual decrease of the efficiency for small current densities can be observed. If the behavior of the EQE shown in **Figure** 7 is described using the ABC model given with

$$EQE = \eta_{\text{extr}} \cdot \eta_{\text{inj}} \cdot \frac{Bn^2}{An + Bn^2 + Cn^3} \quad (10)$$

It can be assumed that degradation cannot be explained by changing the light extraction efficiency η_{extr} or the injection efficiency η_{inj}. If these parameters are not current dependent, their degradation would result in a uniform decrease of the external quantum efficiency.

Rather, a change in the internal quantum efficiency can be explained with

$$IQE = \frac{Bn^2}{An + Bn^2 + Cn^3} \quad (11)$$

the carrier concentration n, the radiative recombination coefficient B, the non-radiative SRH recombination coefficient A and the

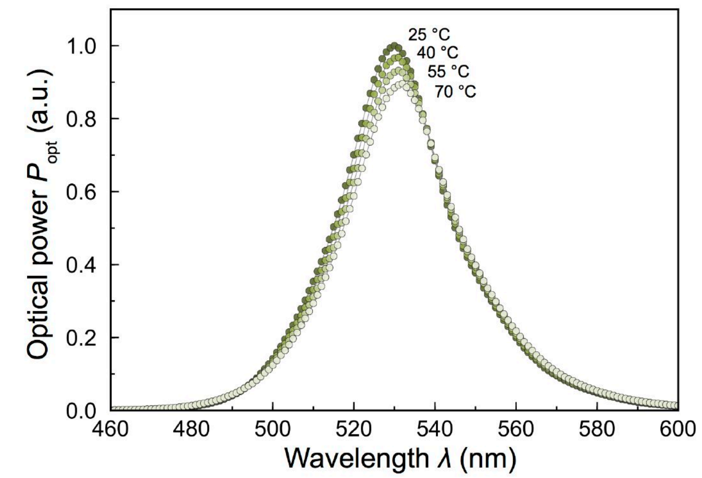

Figure 5: Temperature-dependent change of the spectrum at a measurement current of 50 mA and the case temperatures of $T_C = 25$ °C, 40 °C, 55 °C and 70 °C

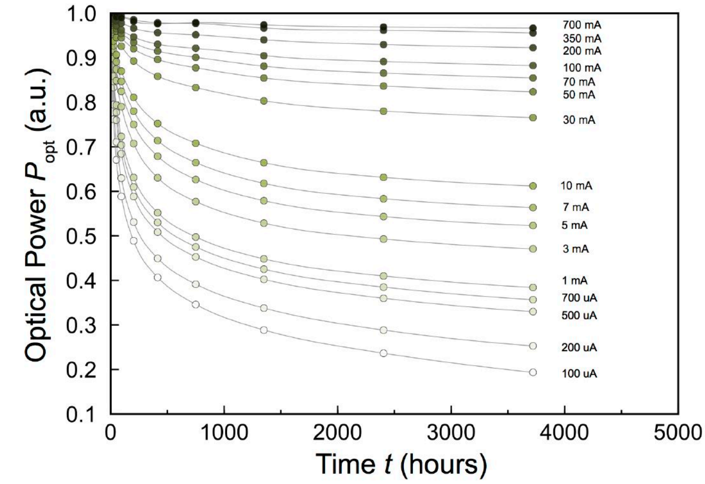

Figure 6: Decrease of the optical power for different measuring currents at a degradation at $I_F = 700$ mA and $T_C = 55$ °C

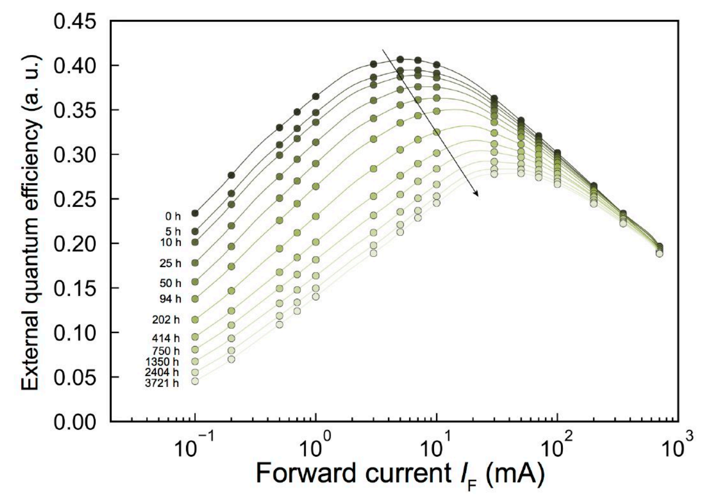

Figure 7: Decrease of the external quantum efficiency for different measuring currents at a degradation at $I_F = 700$ mA and $T_C = 55$ °C

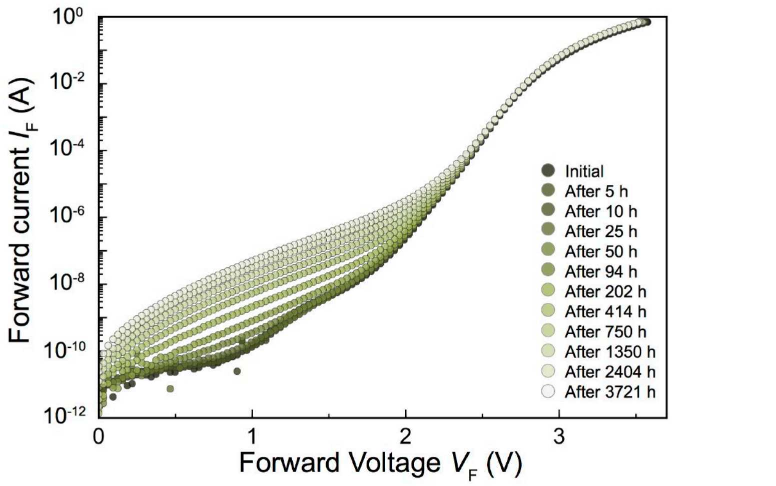

Figure 8: Changes in the I-V-characteristics at a degradation at $I_F = 700\,\mathrm{mA}$ and $T_C = 55\,°\mathrm{C}$

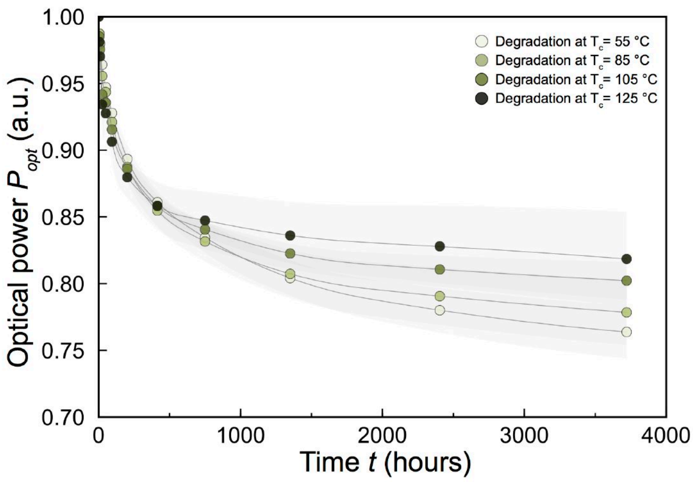

Figure 9: Temperature-dependent degradation behavior at $T_C = 55\,°\mathrm{C}$, $85\,°\mathrm{C}$, $105\,°\mathrm{C}$ and $125\,°\mathrm{C}$ with $I_F = 700\,\mathrm{mA}$. Mean values of 4 LEDs each, measured at $25\,°\mathrm{C}$ and $30\,\mathrm{mA}$

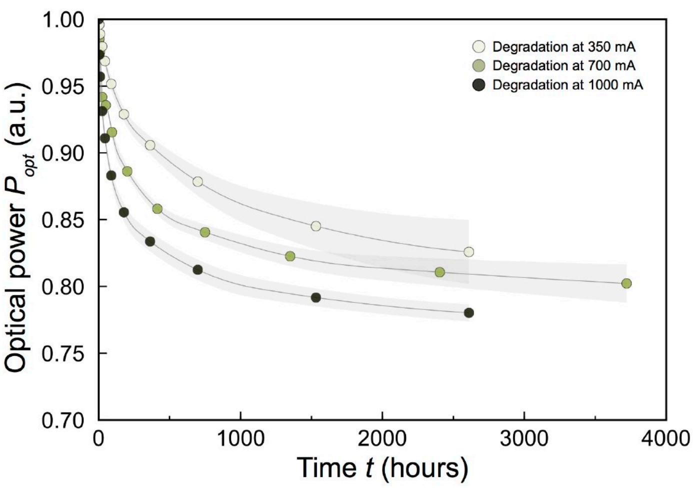

Figure 10: Current-dependent degradation behavior at $T_j = 141\,°\mathrm{C}$ with $I_F = 350\,\mathrm{mA}$, $700\,\mathrm{mA}$ and $1000\,\mathrm{mA}$. Mean values of 4 LEDs each, measured at $25\,°\mathrm{C}$ and $30\,\mathrm{mA}$

Auger recombination coefficient C. Due to $An \gg Bn^2 + Cn^3$ non-radiative recombination is dominant in the range of low carrier concentrations. Especially in this range a strong degradation can be observed, which could be assigned to an increase of the SRH coefficient [2].

This statement can be substantiated by considering the electrical degradation characteristics. **Figure** 8 shows the I-V characteristic for an ageing period of 3721 hours. Especially in the range of low forward voltages an increase of the forward current can be observed, which shows an almost linear slope in a semi-logarithmic plot. As a result, an energetically more favorable path for carrier transport exists parallel to the diode voltage that is to be overcome. According to [3], [4], [5] and [6], this can be assigned to a defect assisted tunneling, which is promoted by deep-level states. Ga vacancies, N vacancies or Mg vacancy complexes are named as possible causes for the origin of the deep-level states that increase non-radiative recombination.

The temperature-dependent degradation behavior recorded using the ageing conditions described above can be seen in **Figure** 9. Due to the standard deviation of the ageing data, no reliable statement can be made regarding an Arrhenius behavior. Within a degradation time of 250 hours, an expected behavior can be determined according to which the strongest degradation is associated with the highest junction temperature. After completion of this ageing process, however, such behavior can no longer be proven on the basis of the measured data.

The differences between various stress currents and identical junction temperatures are much more significant. A clear correlation of optical degradation and aging current can be observed within 2610 hours. Consequently, at a forward current of 1000 mA, the strongest degradation of the LEDs can be observed.

Furthermore, a shift of the peak wavelength is measured during degradation. **Figure** 11 shows that the LEDs red- and blueshift with respect to their peak wavelength with increasing aging time. Here it is noticeable that at currents below 3 mA, a decrease in the measured peak wavelength can be observed, while at currents above, an increase in the peak emission wavelength can be detected.

The maximum spectral shift occurs at a current density of 7 mA–30 mA and is thus almost at the maximum of the current-dependent efficiency. The mechanism can be identified as a combination of increased SRH recombination and changes of the internal electric fields within the quantum well structure [7].

A shift of the peak wavelength due to thermal influences can be ruled out both due to the pulsed measurement of the EL spectrum and due to the fact that a shift of the peak wavelength by 0.8 nm would correspond to a temperature change of more than $\Delta T = 20\,\mathrm{K}$.

The changes in optical power and peak wavelength described above have an influence on the colorimetric characteristics of the LEDs. According to **Figure** 12 a color shift over the aging period of 2610 hours can be observed depending on the measurement current. Particularly strong changes can be observed with measuring currents below 1 mA. The measurement current of 700 mA relevant for practical application shows colorimetric stability over the aging period and moves within a 1-step MacAdam ellipse.

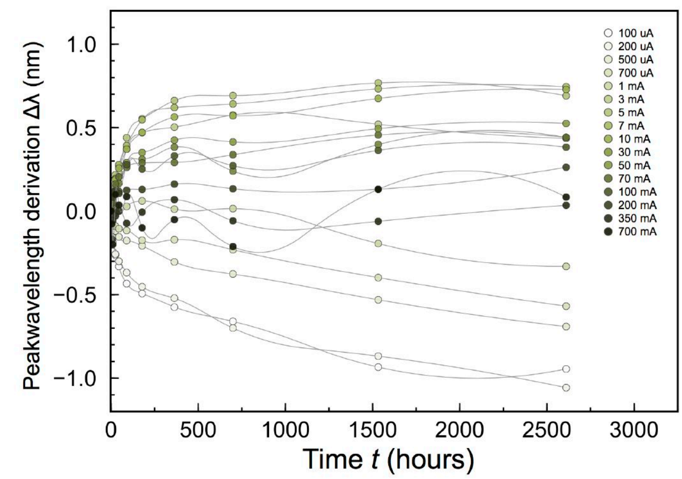

Figure 11: Shift of peak wavelength as a function of stress time for different measurement currents over a period of 2610 hours at $T_j = 141\,°\mathrm{C}$ and $I_F = 1000\,\mathrm{mA}$

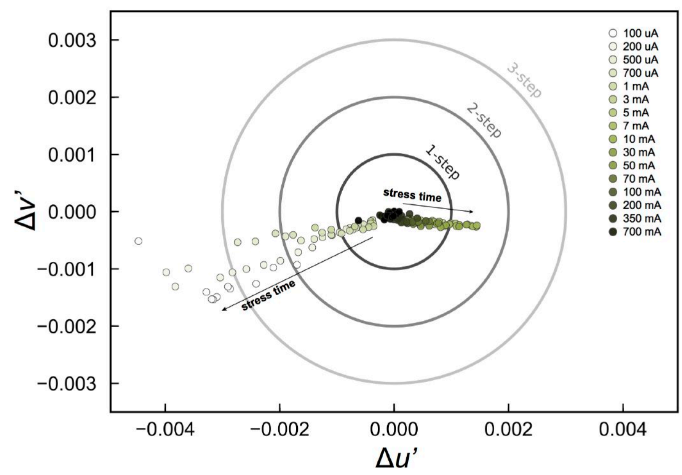

Figure 12: Color shift as a function of stress time for different measurement currents over a period of 2610 hours at $T_\mathrm{j} = 141\,°\mathrm{C}$ and $I_\mathrm{F} = 1000\,\mathrm{mA}$

Influences on Multi-Channel Luminaires

In order to assess the extent to which the real degradation data affects the colorimetric stability of the overall system, the RGB and RGBW systems are simulated with the real ageing data. The LEDs that are exposed to the highest stress condition (1000 mA) are used for the simulation. It can be proven that using a measurement current of 700 mA, a color shift can be observed that is pronounced depending on the system architecture. The changes for the systems are shown in **Figure** 13 and show the resulting color coordinates after a degradation time of 2610 hours. Due to the lower optical performance of the green LED channel, the overall system shifts below the blackbody locus.

Due to the higher relevance of the green color channel, the RGB system is affected by a stronger color shift than the 4-channel system. The colorimetric change can be estimated over a period of 2610 hours with $\Delta u'v' = 0.006$ and is therefore clearly visible, shown in the Inset of **Figure** 13. The RGBW system remains within the 3-step MacAdam ellipse from a color temperature of about 3000 K upwards, only below the influence of the green channel is critical. If the behavior of the system at a measurement current of 50 mA is also considered, the peak wavelength shift and the significantly stronger optical degradation

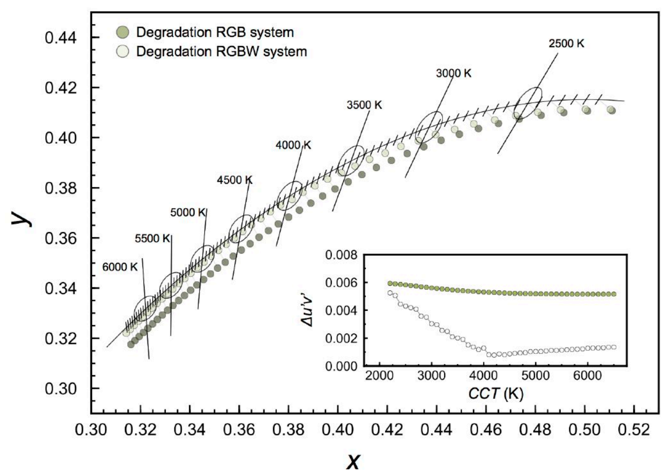

Figure 13: Shift of the color coordinates in the CIE diagram – CIE 1931 2° for 2610 hours for the RGB/RGBW system at a degradation with $I_\mathrm{F} = 1000\,\mathrm{mA}$ and $T_\mathrm{j} = 141\,°\mathrm{C}$ – measurement current $I_\mathrm{meas} = 700\,\mathrm{mA}$. Inset: Resulting color distance $\Delta u'v'$ to initial state

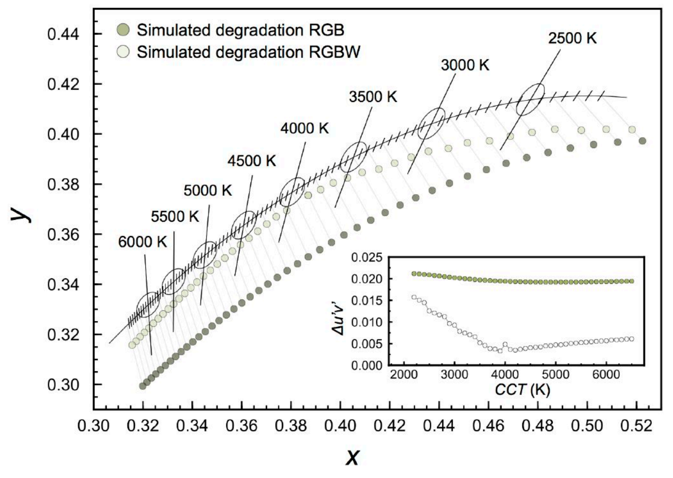

Figure 14: Shift of the color coordinates in the CIE diagram – CIE 1931 2° for 2610 hours for the RGB/RGBW system at a degradation with $I_F = 1000\,\mathrm{mA}$ and $T_j = 141\,°\mathrm{C}$ – measurement current $I_{meas} = 50\,\mathrm{mA}$. Inset: Resulting color distance $\Delta u'v'$ to initial state

results in color distances of up to 21-step MacAdam. Again, it can be seen that the four-channel system above 4000 K has significantly lower color shifts.

When evaluating the influence of one color channel on the stability of the overall system, it should be mentioned that the knowledge of the degradation behavior of all color channels is essential in order to be able to comprehensively record the design of multichannel systems. In the aging tests carried out, the white color channel has proven to be problematic in addition to the green color channel. However, its degradation is not characterized by a decrease in optical performance, but rather by a dominant colorimetric shift. The shift is strongly pronounced depending on the LEDs correlated color temperature and ageing conditions and can have a significant influence on the overall system.

Conclusion

Three and four channel lighting systems were simulated along the black body curve as part of the investigations. In addition to the theoretical color mixing luminance ratios, the degradation limits of the green LED channel were calculated in terms of color stability. These are between 2.5 % and 18 %, depending on color temperature and system architecture. As a result, if the limits are exceeded, color changes could be expected that shift the overall system by more than 3-step MacAdam from the original color coordinates. Possible temperature influences on the green color channel have no significant colorimetric relevance for the overall system. A subsequent analysis of real ageing data shows that, depending on the ageing condition, the previously determined degradation limits are exceeded. The degradation current has a decisive influence on the decrease in optical power, which can be attributed to an increase in point defects within the active region. Influences of temperature cannot be significantly separated at the present time. Depending on the ageing conditions the degradation behavior results in colorimetrically relevant shifts $\Delta uv > 0.003$ of the overall system. The characteristics of the color shifts indicate a strong dependence on the measurement current. ■

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Characterization of UV Sources for Disinfection Purposes

Advertorial, GL OPTIC

RECENT events related to the coronavirus pandemic have resulted in a significant increase in the interest in UV-lamp disinfection. When working on new projects using emitting diodes in the UV range for disinfection, mainly between 200 and 280nm, exceptional care should be taken to properly assess the quality of the emitted radiation.

Which Measuring Devices Should be Used?

With the conventional discharge lamps, the spectral emission is constant as it results from the physical properties of mercury vapors. Therefore, simple radiometers optimized for specific UV ranges were used for irradiance measurements $[W/m^2]$. In the case of UV LED systems, it is important to verify the wavelength because there are differences between the production batches of the same LED. For this type of measurement, a calibrated **GL SPECTIS 4.0** UV or a portable **GL Spectis 5.0 Touch** spectroradiometer can be used to verify any shift in spectral power distribution.

Typical Measurement Quantities

- For single UV LED measurements, a calibrated integrating sphere **GL OPTI SPHERE 48** or **205** with a spectroradiometer is suitable. In this way, a single measurement will collect data on radiant power $[mW]$, dominant wavelength and spectral power distribution.
- For irradiance measurements $[mW/m^2]$ a calibrated **GL OPTI PROBE 5.1.51** diffusor connected to the spectroradiometer can be used.
- The spatial distribution characteristics of LED sources significantly differ from conventional discharge lamps. For this reason the GL RID one UV measurement system should be used. It consists of a goniometer connected to a UV spectroradiometer. Such a measuring setup enables the spatial measurement of Radiant Intensity Distribution (RID).

How to Perform the Measurements Properly

Recommendations for UV LED measurements are very similar to those for measuring LED modules and lamps for general lighting purposes. However, due to the nature of the source, attention should be paid to the issues of safety and risks to skin and eyes from UV radiation.

Technical data sheets of light-emitting diodes provided by manufacturers contain photometric data. In the case of UV diodes, radiometric data is determined for a junction temperature (T junction) equal to the ambient temperature, usually 25°C. To verify the parameters of the diodes against the specification after they have been applied to the PCB, it is necessary to measure the system while maintaining the junction temperature.

One of the utilized methods can be the forced cooling of the PCB. Special mounts with temperature stabilization of the LED module like **GL TEC System** make it possible to maintain a constant temperature of the PCB. However, this method has its limitations because when different types of diodes are used on the module, it is impossible to obtain the same temperature of all junctions on one PCB due to different thermal resistances.

An alternative approach is the measurement made with a short DC current Single Pulse. The essence of such a method is to measure optical parameters before the connector warms up. This can be done precisely with a spectroradiometer equipped with a hardware trigger synchronized with the current source, enabling exposures for measuring times <30ms. Another measurement method is the so-called Train Pulse method, i.e. continuous supply with current pulses at a frequency of 100 Hz and pulse width below 0.5 ms. With properly selected pulse parameters, the result is identical to the value obtained by measuring a single pulse with the length of 30 ms.

Summary

In the case of UV LEDs, the optical parameters' dependence on the power supply conditions and operating temperature significantly influences their performance in disinfection. Small wavelength shifts are decisive in the effectiveness of specific impacts in the ultraviolet range, whilst the stability of the system's work over time is crucial for an effective fight against biological pollution. ■

https://gloptic.com

Figure 1: GL Opti Sphere 48

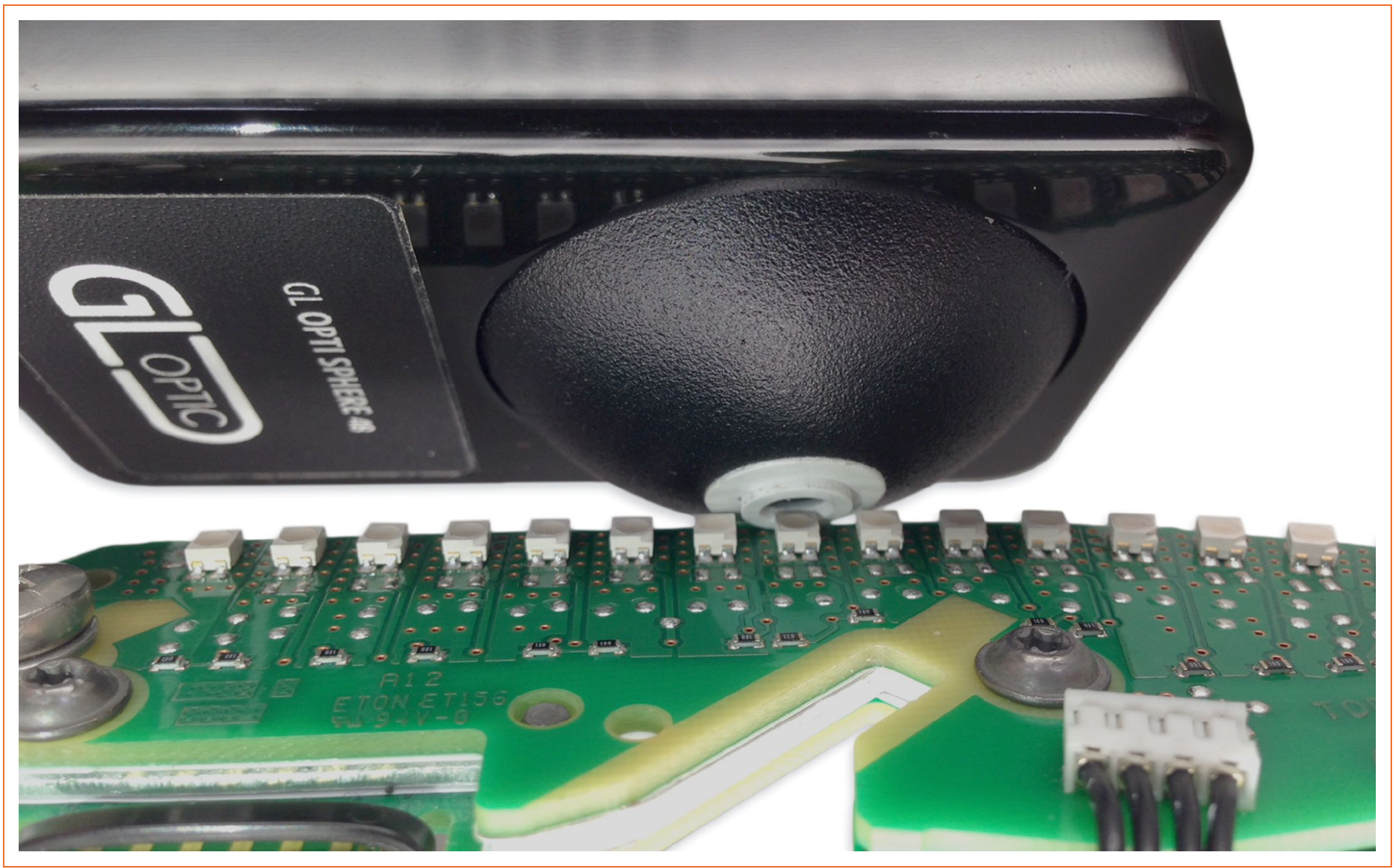

Figure 2: GL Spectis 4.0 with GL Opti Sphere

Current Trends in LED Phosphor Developments

LED phosphor, which is a types of solid luminescent material, is used widely in white LEDs to convert the (usually blue) light of an LED chip into another wavelength light. Based on the GaN blue LED chip, white light LEDs composed of GaN LED+YAG yellow phosphors are rapidly commercialized and popularized. The wavelength of LED phosphors was expanded from the pure visible light field (380-750 nm) to the vacuum ultraviolet and far-infrared (250-1200 nm). LED phosphor application cover general lighting to display backlight, agriculture / horticulture, medical health, security monitoring and other fields. Dr. Lin Zhang, CTO at Beijing Nakamura Yuji Science and Technology Co. Ltd., Deyao Liu and Chao Wang give an overview of today's typical LED phosphors with their product system, synthesis, performance, respective areas, performance and application solutions.

AN LED (Light Emitting Diode) is a light-emitting device with a semiconductor light-emitting material that converts electrical energy into light and emits it. LED phosphor is a solid luminescent material that is used to convert an emitted wavelength into light of another wavelength. The first white LEDs merely emitted blue light at a wavelength of 450-460 nm from blue GaN chips + YAG ($Y3Al5O12:Ce$) yellow phosphor converted light with a wavelength of 550 nm. The efficacy has greatly improved compared to incandescent lamps, but due to the lack of violet and red light, the color rendering index Ra (with sunlight as 100) was only about 70. In contrast, the Ra of the incandescent lamp reached over 90, which is closer to real sunlight. With increased R&D and the application of other LED phosphors such as red, green and blue, the color rendering index and luminous efficacy of LED devices improved. Packaging technology has also continuously improved, and blue light can be completely used without significant losses, avoiding reduced efficiency and without excessive, harmful blue light emission. With the development of violet and ultraviolet light chips, and the increase of research on blue and ultraviolet phosphors, violet LEDs and ultraviolet LED devices have gradually been introduced for different applications. Furthermore, the applications for LEDs have subsequently expanded to backlight, medical, and agricultural products. LED and LED phosphor technologies are still developing at a high speed, and they have been applied in various fields including manufacturing, life, scientific research and other aspects.

LED Light

Light Generation Principles of LEDs

Light Emitting Diodes are semiconductors [1]-[3]. Semiconductors are characterized by their "one-way conductive" material and structure. The core principle is the PN junction, where the P-type semiconductor has a positive charge accumulation and the N-type semiconductor has a negative charge accumulation with a bandgap Eg in-between. When a sufficient forward voltage is applied to the PN junction, the semiconductor becomes conductive and the electrons move directionally, forming a current. When the forward voltage is applied to the PN junction, with the energy transfer during the movement of the electrons, a part of the electrons undergoes an energy level transition. They are elevated to a higher energy level state, which is the excitation state. When the electrons fall back from the excitation state to the ground state, a part of the energy is released in the form of electromagnetic waves, i.e., light emission. The process of light emission in such a semiconductor, an LED, is shown in **Figure** 1.

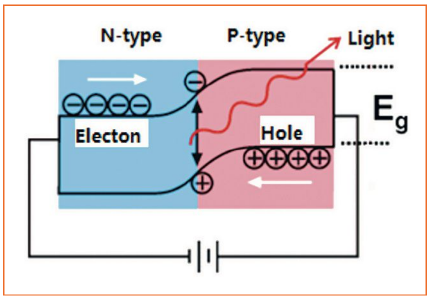

Figure 1: Light generation principle of Light Emitting Diodes (LEDs)

White & Various Color Generation Principles with LED

After a certain voltage is applied to an LED, it emits electromagnetic waves of a certain wavelength. Electromagnetic waves of different wavelengths are perceived as dif-

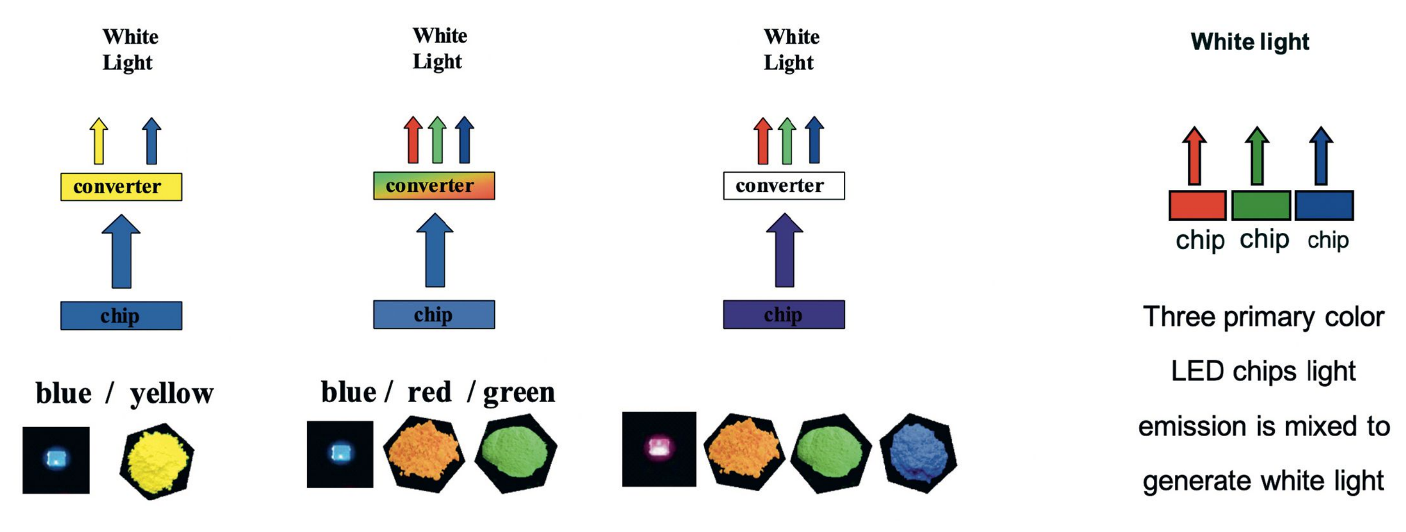

Figure 2: Comparison of white light generation. From left to right, a blue LED with yellow phosphor, a blue LED with red and green phosphor, a violet LED with blue, green & red phosphor, and an RGB LED

ferent colors. Red, green, and blue are the three primary colors, and these three colors can be used as the basic light sources. The combination of these three basic colors is perceived as white light or any other light color. In practical applications, there are usually four ways to generate white light or the other colors [2],[4]:

Blue chip & yellow phosphor

The GaN blue light chip emits 450–460 nm blue light and can excite the phosphor of YAG system to emit yellow light of 540–560 nm. Yellow light plus blue light is perceived as white light. This method is simple in process, low in cost, and high in efficiency. The disadvantages are a low color rendering index due to the lack of relevant parts of the visible spectrum like purple and red light. Additionally, the LEDs usually emit light of a high color temperature (CCT) resulting in a cold light, which limits its application.

Blue chip with green & red phosphor

The GaN blue light chip emits 450–460 nm blue light and can excite 510–540 nmgreen phosphor and 600–670 nm red phosphor, and the combination of blue light, green light and red light can form various colors of light including white light [5]. In this way, on the basis of ensuring certain efficiency, the color rendering ability is greatly increased. Ra is increased from 70 to more than 95, and even CRI parameters including R1 to R15 can be increased to more than 90. This method is based on a simple process and at relatively low costs. However, the major red phosphor material, nitride phosphors of the SCASN system has a relatively low efficiency and it is rather difficult to further increase the efficiency. While coming close, the color rendering index, especially in warm white applications, is still lower than natural sunlight as the purple light is missing and the amount of deep red light is low too. Since multiple phosphors are used at the same time, the performance of phosphors and the effects of their mutual interaction have a great impact on LED performances, and there is still much room for improvement in packaging technology. At present, this light conversion method occupies a good part of the market share.

Violet chip with blue, green & red phosphor

The violet light chip emits 380–420 nm violet light, and can excite blue, green and red phosphors. The combination of violet, blue, green and red light can form various colors of light including white light. However, at present, violet chips have low efficiency and poor stability. The performance and stability of blue phosphors and green phosphors that can be excited by violet light are also poor. In recent years, the applications of this high color rendering LED type has become more and more popular because it is closest to the solar spectrum. The principle of LED devices generating white light based on this method is shown in **Figure** 2.

LED Phosphor Luminescence

An LED phosphor is a photoluminescent material. Light that is emitted by an LED is absorbed by the LED phosphor and converted into light of another wavelength to being released. The process of combining the LED phosphor and the LED chip is part of the LED packaging technology: After the LED phosphor and the phosphor glue are mixed according a specific formulation, they are packaged with the LED chip through the dispensing process to form the LED point light source - the LED emitter [2]. The luminous characteristics of the LED phosphor must be compatible with the LED chip. The light emitted by the chip should be effectively absorbed and converted by the phosphor. The conversion rate determines the efficiency and luminous intensity of the LED device. Therefore, in the field of LED, the selection of the right phosphor strongly depends on the application. For example, for white LEDs in general lighting applications, the green phosphor is LuAG or Ga-YAG, the yellow phosphor is YAG, the red phosphor is SCASN system nitride, while LEDs for display and backlighting applications use β-Sialon green phosphor and KSF red phosphor. In addition, LSN nitride yellow phosphor and α-Sialon nitrogen oxide yellow phosphor are solutions for some special needs. They are not widely used.

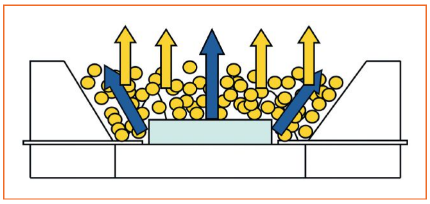

Figure 3: LED phosphor luminescence diagram

Classification of LED Phosphors

There are different options to group LED phosphors. They can be differently grouped by their materials, their characteristics, their applications or some specific requirements.

Phosphors by material system:

- YAG (Yttrium Aluminum Garnet) and Derived Aluminate Phosphors
- SCASN system nitride phosphors
- Silicate phosphors
- Halophosphate phosphors
- Nitrogen oxide phosphors
- Fluoride phosphors
- Sulfide phosphors
- Phosphors for other systems

Phosphors by wavelength (color):

- Blue phosphors
- Blue-green phosphors
- Green phosphors
- Yellow phosphors
- Orange phosphors
- Red phosphors
- Infrared phosphors

Phosphors by application:

- Phosphor for lighting
- Phosphor for backlighting
- Phosphor for medical use
- Phosphor for safety and security
- Phosphor for agriculture
- Phosphor for other applications

Phosphors by application requirements:

- Phosphor for high-efficiency lighting
- Phosphor for high CRI lighting
- Phosphor for wide color gamut backlighting
- Phosphor for security surveillance
- Phosphor for plant growth

While phosphors can be categorized in different ways according to different needs, excitation wavelength, emission wavelength, emission properties and stability are always the major considerations for application. For instance, standard white light illumination mostly requires yellow-green phosphors such as YAG, Ga-YAG, LuAG, and high CRI SCASN nitride phosphors. Backlighting needs oxynitride green phosphors and fluoride red phosphors, and SCASN red phosphors and YAG yellow phosphors will just be used under certain circumstances. Medical applications use UV phosphors for disinfection. Agricultural applications prefer SCASN red phosphors and infrared phosphors for plant growth, food preservation and inspection, and some special applications may need halophosphate blue phosphors, oxynitride green phosphors, fluoride red phosphors, to name just a few.

Overview on Commercially used LED Phosphors

YAG (Yttrium Aluminum Garnet) and Derivative Aluminate Phosphors [1]-[20]

Tycical phosphors:

- YAG ($Y_3Al_5O_{12}$); λ_{em} = 540–570 nm; yellow phosphor
- Ga-YAG (Ga replaces part of Al); λ_{em} = 515–545 nm; green phosphor / yellow-green phosphor
- LuAG (Lu replaces Y); λ_{em} = 510–540 nm; green phosphor / yellow-green phosphor

While the invention of GaN blue chips opened the door for a broad application of LED technology, YAG yellow phosphors open this door even wider. Blue chip and YAG yellow phosphor create white LED lighting, thus promote the rapid development of the LED industry. However, the simple "blue + yellow = white" formula cannot meet the market's growing requirements on LEDs. Well suitable for cooler (bluer) solution of high CCT, with its low color rendition (Ra=70), it is becoming increasingly insufficient for today's requirements; high CRI lighting, wide color gamut display and ultraviolet and infrared applications. Therefore, derivatives and substitutes for YAG yellow phosphors have gradually attracted attention. In particular, LuAG green phosphor (with Lu replacing Y), Ga-YAG and other green phosphors (with Ga replacing Al in part) are replacing YAG yellow phosphors' share in the lighting market because of their low cost, high efficiency, high stability, and high compatibility with SCASN red phosphors. YAG, Ga-YAG, and

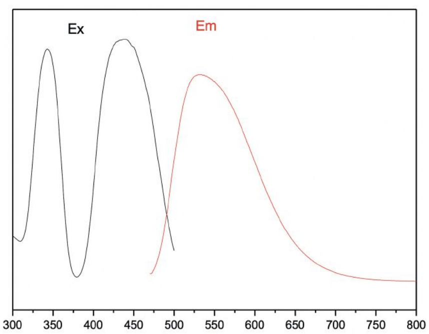

Figure 4: Typical spectral power distribution of YAG phosphors, excitation (Ex) and emission (Em); x-axis in wavelength nm

LuAG phosphors are synthesized by the high-temperature solid-state method. Normally they are calcined at 1400–1600 °C for 4-8 hours in a weakly reducing atmosphere. The semi-finished product after calcination will go through processes of classification, cleaning, coating and packaging, and then become LED phosphor. **Figure** 4 shows the spectral power distribution of YAG and its derivatives. Their typical excitation wavelength is between 400–500 nm, and the excitation peak is at about 450 nm. This is highly compatible with GaN blue chips, which together are a good solution for high-efficiency lighting. In addition, YAG and its derivative phosphors have a wide full wavelength at half maximum (FWHM) that is wider than 100 nm, which guarantees relatively high Ra values of these LED devices. Yet a lack of high-intensity red above 600 nm makes the white light color temperature too high and impedes the further improvement of Ra thus the photometric performance of the LED. However, by adding up a longer wavelength red phosphor, the performance of LED devices can be further improved. At

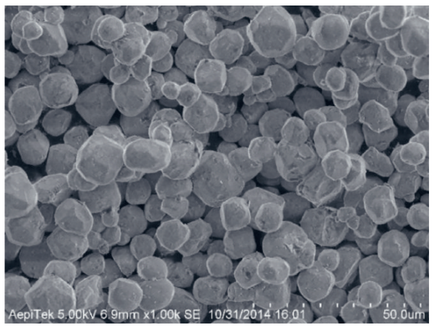

Figure 5: SEM image of a YAG phosphor

present, the performance and market potential of YAG and its derivative phosphors have hit the bottleneck. Breakthroughs are hardly foreseen in the short term. The market price is close to the bottom line and almost touches the production costs so that its market share could be barely maintained. The share will continue to decrease if there is no significant technical upgrade in the subsequent development of the LED industry.

Nitride Red Phosphors [21]-[33]

Tycical phosphors:

- $SrCaAlSiN_3$:Eu; λ_{em} = 605–670 nm; red phosphor
- $CaAlSiN_3$:Eu; λ_{em} = 645–670 nm; red phosphor
- $CaAlSiN_3$:Ru; Re = some of Eu, Ce, Sm, Pr, La and Lu

SCASN nitride red phosphors are one of the most important phosphor products

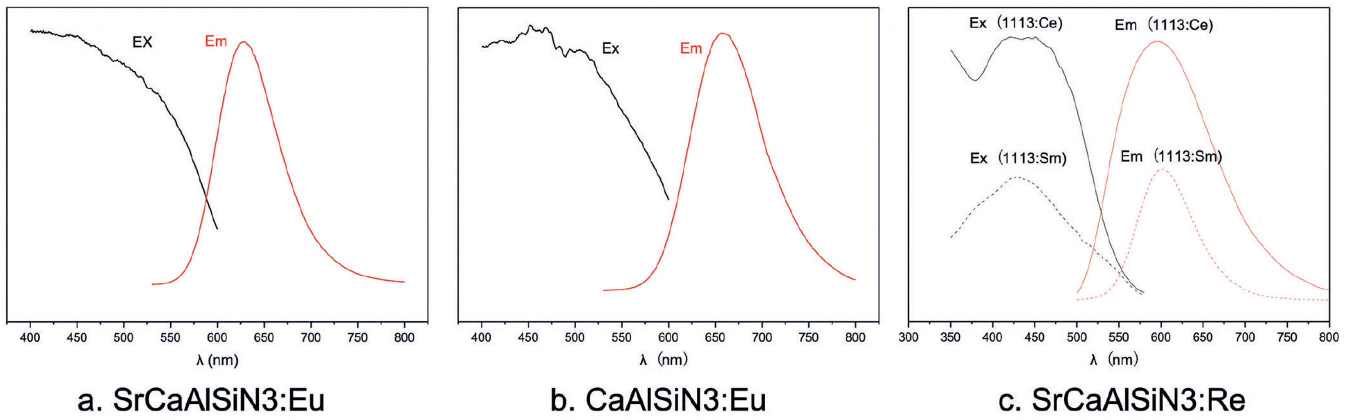

Figure 6: Spectral power distribution of several SCASN nitride phosphors

in the LED industry, since its excellent properties such as high efficiency and high stability far exceed other phosphor types. Among long-wavelength phosphors, silicate orange phosphor and oxynitride phosphor have been applied for a while. Yet they have low stability and make the LED devices poorly reliable. They are now gradually replaced by SCASN nitride phosphors. After years of R&D efforts, the cost of SCASN phosphors could be greatly reduced and their efficiency and stability has significantly improved. In the LED lighting market, they take up a dominant percentage. In backlighting, they share 95% of the market together with KSF (fluoride phosphors) and quantum dot materials. SCASN nitride phosphors are produced via

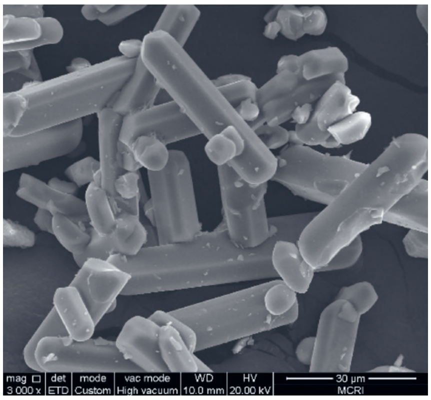

Figure 7: SEM image of SCASN nitride phosphor

the high-temperature solid-state method. The raw materials for production are mostly nitrides, with oxides and fluorides taking a small proportion. The calcination conditions are highly demanding: the temperature should be above 1800 °C, inert gas or weakly reducing atmosphere is required for protection, the multi-step method is normally adopted in the process. This is one of the reasons for the high cost of SCASN nitride phosphors. The semi-finished products after calcination will go through classification, cleaning, coating and packaging, and then become SCASN nitride phosphor. **Figure** 6 shows the spectral power distribution of SCASN nitride phosphors. The SCASN phosphors' excitation spectra have higher intensity between 350–500 nm and can be wide-band excited with a high intensity within this range. This is one of the significant performance advantages of SCASN phosphors. They can be excited not only by 450–460 nm blue chips, but also by 380–420 nm violet chips, which has broader application. The emission spectra of SCASN red phosphors vary depending on the activator. The mainstream in the market is the short-wavelength SrCaAlSiN3:Eu and the long-wavelength $CaAlSiN_3$:Eu (CASN) phosphor. In addition, by adding Ce, Sm, Pr, etc. as activators, the peak wavelength range of SCASN phosphors can be extended to 570–650 nm. With higher efficiency and higher stability, the phosphors can be applied more broadly.

SCASN red phosphors are the absolute mainstream of red phosphors in the LED market. They attract much attention because of their high stability and wider applicability. However, the improvement of efficiency becomes increasingly difficult, impeding the efficacy improvement of LED devices and the development of the LED industry. Moreover, compared with YAG and its derivative phosphors, the production cost of SCASN red phosphors is higher. This needs to be solved urgently. Besides, compared with KSF (fluoride) red phosphors, the SCASN phosphors have wider FWHMs. This limits their application in backlighting solutions due to a lower gamut and can no longer meet the boosting requirements. But there is still much room for improvement of the SCASN phosphors' performance, as well as for production process and application solutions.

Major manufacturers and research institutes are devoting more efforts in the R&D of it. SCASN red phosphors' role in the LED industry will be increasingly important.

Barium Strontium Chlorophosphate Blue Phosphors [34]-[51]

Tycical phosphor:

- (Sr, Ba, Eu)$_{10}$(PO_4)$_6$$Cl_2$; $\lambda_{em} =$ 440–470 nm; blue phosphor

Silicate phosphors used to be a common three-primary-colors phosphor in the time of fluorescent lighting. Yet it cannot be applied in LED lighting because of its low moisture resistance and low stability. Then, chlorophosphate phosphor appeared and showed better stability and efficiency, meeting the requirements of LED devices. Barium strontium chlorophosphate is one of those blue phosphors that is getting adopted because of its emission wavelength at 450–470 nm. Barium

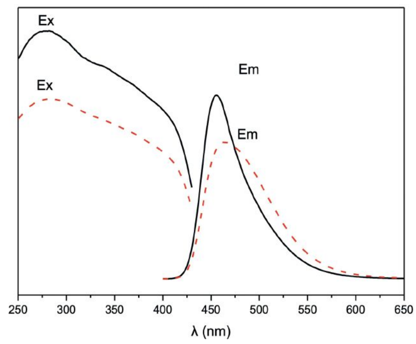

Figure 8: Spectral power distribution of bisphosphonate blue phosphors

strontium chlorophosphate is produced through the high-temperature solid-state method, with ammonium salts and other easily decomposable inorganic salts as raw materials. During the production, the ammonium salt volatilizes and releases irritating odors, and the yield rate is quite low. This is also the reason for the high price of chlorophosphate in terms of environmental protection, cost and production. The chlorophosphate can be obtained from high-temperature calcination. Then in an anhydrous ethanol environment, it becomes barium strontium chlorophosphate blue phosphor after classification, cleaning and coating. **Figure** 8 shows the spectrum of barium strontium chlorophosphate blue phosphor. The emission peak wavelength is 450–470 nm, which coincides with the emission peak wavelength of the blue chip. The excitation spectrum has a wide and high excitation intensity from 250–420 nm. Therefore, chlorophosphate is the preferred blue phosphor for violet LED or ultraviolet LED.

With the violet LED technology getting broader acceptance and the violet LED market expanding, chlorophosphate phosphors have gradually drawn attention. There are still challenges for violet LEDs because of the high cost of violet chips and the LED's performance and reliability. However, the sunlight-mimicking spectrum and violet LEDs are becoming more popular in recent years, and the demand for blue phosphors especially chlorophosphate phosphors is growing. With the improvement of violet chip performance and violet LED packaging technology, violet LEDs and calcium strontium chlorophosphate phosphors will become increasingly significant in the market.

β-Sialon Green Oxynitride Phosphor [52]-[76]

Tycical phosphors:

- β-Sialon ($Si_6 - zAlz - xOzN_8 - z$):Eux; λ_{em} = 515–545 nm; green phosphor

The structure of the β-Sialon was derived from the β-Si_3N_4 by equivalent substitution of Al–O for Si–N, where the chemical composition is written as $Si_6 - zAlzOzN_8 - z$ (z represents the number of Al–O pairs substituting for Si–N pairs and $0 < z < 4.2$). β-Sialon has a hexagonal crystal structure with continuous channels parallel wherein the Eu dopants are situated. The major feature of β-Sialon is the narrow FWHM (generally less than 60nm), resulting in more saturated green light. Thus, it has unique advantages in the field of backlighting since wider gamut can be obtained from this saturated emission. Its excitation efficacy between 250 nm and 450 nm is furthermore sufficient to being applied with ultra-violet, violet, or blue LEDs. **Figure** 9 shows the excitation and emission spectrum of β-Sialon phosphor. β-Sialon could

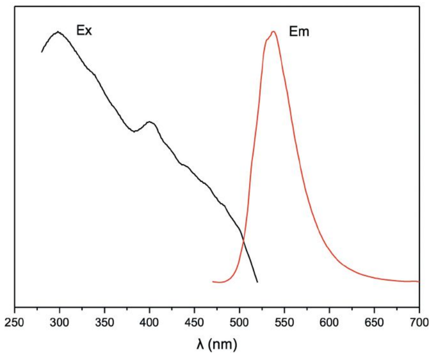

Figure 9: β-Sialon green phosphor spectrum

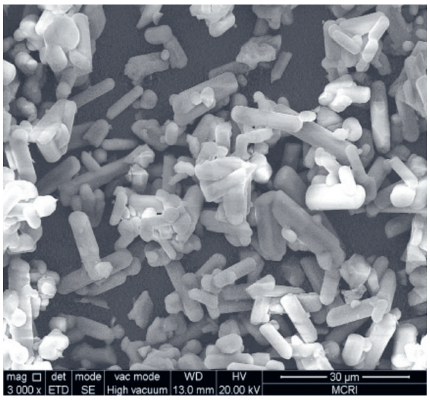
Figure 10: β-Sialon under SEM

be obtained by a high-temperature solid-state method. The manufacturing process requires conditions of temperature above 1900 °C and pressure above 1 MPa, as well as the protection of inert gas such as N_2 or Ar. β-Sialon also demands high purity raw materials since its structure needs minute Al-O to replace Si-N and the trace elements Al and O exist primitively in Si_3N_4 have a significant impact on the result. This factor has to be considered in the production process, e.g. more precise mixing ratio needs to be achieved, which causes the elevated manufacturing cost and slows down the market adoption of β-Sialon phosphor. Currently, it is rarely applied in commercial lighting, but is indispensable in some fields where it provides high added value, like backlighting.

Fluoride Red Phosphor [77]-[95]

Tycical phosphors:

- KSF/KGF (K_2SiF_6):Mn / (K_2GeF_6):Mn

KSF/KGF (K_2SiF_6):Mn / (K_2GeF_6):Mn is the typical fluoride red phosphor. The spectrum shows that it could be excited by 400–500 nm light and particularly the peak wavelength of excitation, which is 450 nm, coincides with the emission spectrum of blue LED chips. The narrower FWHM spectrum of only 20 nm leads to more saturated red light, and thus could achieve wider gamut when used in LED devices. However, KSF/KGF is easy to decompose under high temperature or high humidity conditions, which limits its applications. Moreover, it has higher production costs compared to other phosphors due to the necessary treatment hydrofluoric acid (HF) or other fluorides, which may be harmful for the environment or human body. The manufacturing process and production technique are difficult as they are based on liquid phase processing.

As a result of the instability and high-cost, KSF/KGF is only applied in some particular applications. For example, on account of the narrow FWHM and high luminous efficacy, it is a competitive solution compared to quantum dots in the application of backlighting, especially when it collocates with β-Sialon. Nonetheless, the stability and application range of KSF/KGF is gradually increasing along with improvements of the manufacturing and coating process.

Future Prospects of LED Phosphor

Mini-LED

Mini-LEDs are developed upon the increasing demand for higher resolution and smaller pixel size in display applications. Although OLEDs and quantum dots (QDs) are current solutions, however, the high manufacturing effort, the low yield of OLEDs, the high cost, and the heavy metal contamination problems of QDs limit their market adoption. Thus, mini-LEDs are a possible solution based on traditional LED technology. Mini-LEDs reduce the dimension of conventional LED devices to less than 100 μm or even below 50 μm, which contributes to smaller luminescence units and thus higher display resolution. However, the conventional LED phosphor is not feasible for mini-LED as their median particle diameter is generally 20–30 μm, while the maximum particle diameter can reach 50 μm. The improved phosphor manufacturing technology cut down the median value to 5–15 μm and the maximum value to less than 20 μm to meet the requirement of mini-LED (100 μm magnitude). The next research focuses on decreasing the particle diameter further to 3 μm (median value) and 5 μm (maximum value) for micro-LED

(50 □m magnitude). The particles of conventional phosphor and phosphor for mini-LEDs observed by scanning electron microscope (SEM) are shown in **Figure** 11a and **Figure** 11b.

Although the phosphor with microparticles could be obtained by a physical crushing method, this approach damages the crystal lattice of phosphor severely and leads to huge loss in quantum efficiency (QE) and luminous efficacy (LE), and thus cannot satisfy the performance of mini-LEDs. In practice, the phosphor for mini-LEDs, which has microparticle size but similar QE and LE, must be obtained by an optimized and strictly controlled process especially the firing.

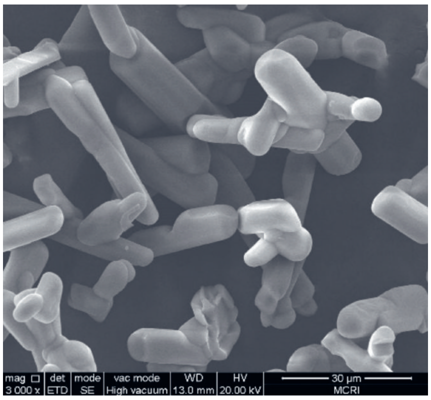

Figure 11: a) SCASN nitride red phosphor under SEM. - Conventional SCASN phosphor

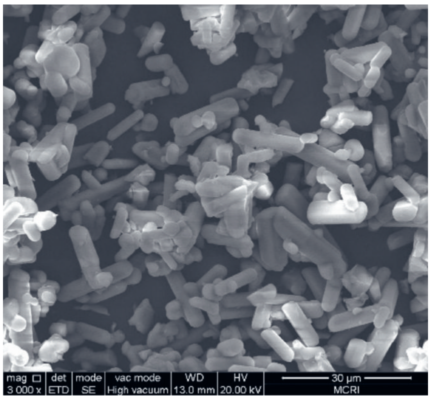

Figure 11: b) SCASN nitride red phosphor under SEM. - SCASN phosphor for mini-LEDs

Phosphor in glass (PiG) & ceramic phosphor plate (CPP)

Despite the rapid development of LED packing technology, some critical issues of LED devices remain unsolved. Heat is one of the challenges, which causes the aging of silica gel in LED packages. This affects the luminous performance and lifespan of LED devices. PiG and CPP technologies lessen the silica gel used in LED devices and enhance the moisture resistance and thermal stability. This results in extended lifespan and improved performance of LED devices. At present, PiG has already commercialized with continuing upgraded performance, while CPP is still in the development phase and no products or schemes are available on the market.

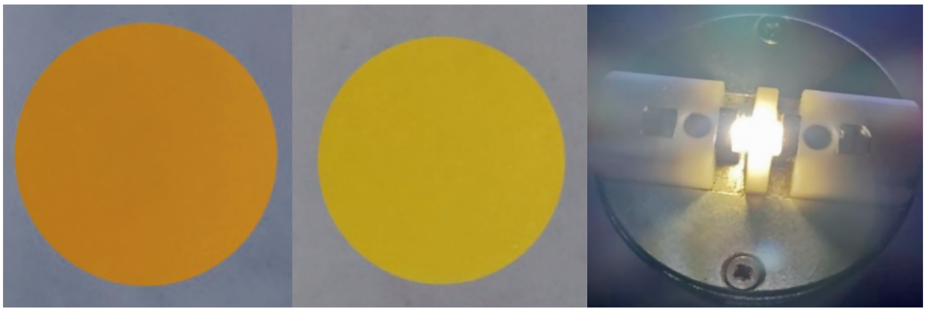

Figure 12: The plate of phosphor in glass and the illumination

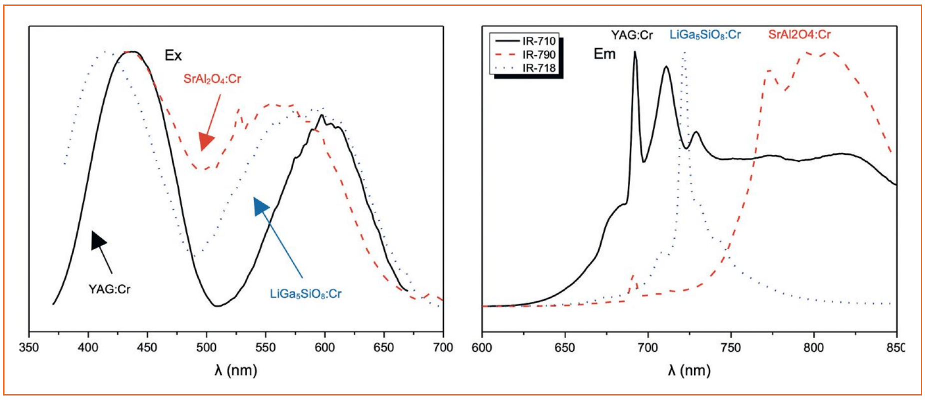

Figure 13: Typical characteristics of several infrared phosphors

Infrared Phosphor [96]-[11]

Infrared LED is an important class in LEDs, whose wavelength range is 700–1200 nm. The applications cover traditional security monitors, remote sensors and emerging fields including mobiles, wearable electronics, somatosensory detection for VR, food inspection, and medical care. Most common infrared LEDs on the market utilize semiconductor chip directly, which has weak points of low rated power, poor thermal stability, narrow FWHM and expensive cost. LEDs with infrared phosphor excited by the blue chip is the latest solution to this problem. It has the advantage of low-cost thanks to the large scale and rapid development of the white LED industry, which promotes the blue chip technology to be matured. Besides, the advantages also include high thermal stability, wide and tunable spectrum and high power.

Figure 13 shows the excitation and emission spectrum of 3 different red/near infrared phosphors, which are $LiGa_5SiO_8$:Cr, YAG:Cr and $SrAl_2O_4$:Cr. Their emission intensities or emission spectra are slightly different and thus are suitable for different applications. For example, $LiGa_5SiO_8$:Cr and YAG:Cr, which are excited by blue light have a peak emission wavelength between 710 nm and 720 nm. This is efficiently absorbed by chlorophyll, and thus beneficial for the photosynthesis of green plants. The peak emission wavelength of $SrAl_2O_4$:Cr is 790 nm with a wider FWHM extends to 840 nm. It can be applied in night vision surveillance, short wave near-infrared detection and other related fields.

Summary

Phosphor based LED devices provide high luminous efficacy and high stability. They have been widely used in every aspect of industry and daily life. They especially offer unique performance that cannot currently be replaced by other technologies and thus occupy the major market share in commercial lighting, display, horiculture, medical care and security monitoring. Further improvement and breakthrough of the technology will broaden its application field, and make phosphors play an even more crucial role. ■

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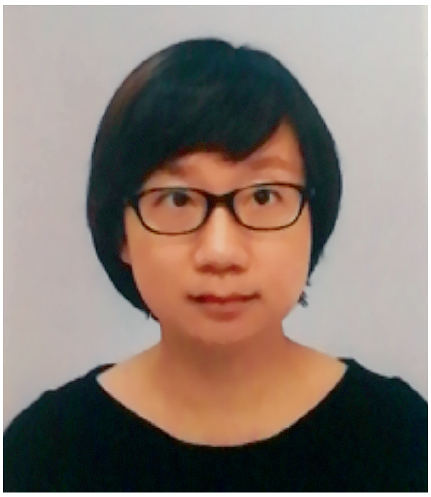
ABOUT THE AUTHOR



Lin ZHANG, Dr.: Dr. ZHANG, the Chief Technology Officer of Beijing Nakamura-Yuji which is a core member of Beijing Yuji Science & Technology Group, is presently in charge of comprehensive R&D issues at Nakamura-Yuji S&T Co., Ltd. She has led the present team for developing the brightest red LED phosphor. Now her interest focuses on backlight LED phosphor to improve performance in novel industrial applications. Before joining Yuji S&T Group in 2012, she worked as a postdoctoral research scientist at the National Institute of Advanced Industrial Science and Technology (AIST), after received her Ph.D. Degree from Kyushu University Japan in 2010.

ABOUT YUJI TECH

Beijing Yuji Science & Technology Co., Ltd. (Yuji Tech), headquartered in Beijing, China, was founded in 2005. Yuji Tech is a high-tech enterprise jointly founded by famous scholars and experts at home and abroad. Our core business covers fluorine chemical, LED phosphor and LED package.

In fluorine chemical, Yuji Tech has been dedicated to R&D of production of ODS alternatives, fluoropolymers and fluorinated fine chemicals for years, and has become an international leading innovation enterprise in fluorine chemical research and production. Yuji Tech has undertaken the projects of Development and Industrialization of ODS Alternatives from Ministry of Environmental Protection and Development and Industrialization of ODS Alternatives from the Industry and Information Technology Department of Shaanxi Province. In 2014, the project Development and Application of the Manufacturing and Catalytic Technology of Zero ODP and Environmentally Friendly Fluorides by Yuji Tech won the second prize of Beijing Science and Technology Award. In 2016, Yuji Tech won the first prize of "Shaanxi Provincial Science and Technology Award". In 2017, Yuji Tech won the second prize of "State Science and Technology Invention Award". At present, Yuji Tech has applied for 62 invention patents, of which 20 have been granted. Yuji Tech's main fluorine chemicals cover refrigerants, blowing agents, aerosol propellants, fire extinguishing agents, cleaning agents, electronic gases, Insulating gases, isocyanates, perfluoroalky iodides, fluorinated intermediates, fluoropolymers, etc.

In the field of LED phosphor, Yuji tech is the first manufacturer of nitrogen-oxide phosphors in China. At present, the special LED phosphors from our R&D department has won many national invention patent, some patent has applied for patent protection in the United States, Japan, Europe, South Korea and other countries and it has been already granted. In 2008, Yuji's red and green nitrogen-oxide phosphors won the "innovation award" of the second National Semiconductor Lighting Product and Application Innovation Contest organized by China Semiconductor Lighting Engineering R&D and Industry Alliance, and Yuji undertook the Chinese "863" project. In 2012, Yuji tech and Japanese Mitsubishi Chemical Corporation reached a strategic partnership. At present, Yuji's subsidiary Beijing Nakamura-Yuji Sci&Tech Co.,Ltd already owns an international leading level of R&D and mass production of phosphors for white LED lighting, and has multiple sets of equipment for LED phosphors production□testing and packaging applications. Our products are exported to Japan, Korea, Taiwan□European and American markets.

In the field of LED light source, R&D and industrialization are carried out by Beijing Yuji Xinguang Photoelectric Technology Co., Ltd, which is held by Yuji Tech. Yuji Xinguang is a manufacturer of special LED light source, which uses high-end LED light source and the light source is close to natural light to enter the fields of photography lighting, high-end indoor lighting, color measurement, museum lighting and so on. At the same time, the customized spectrum provided by Yuji has formed the influence in the world professional light source industry by using Yuji phosphor resources.

With the goal of contributing to the sustainable development of society and enhancing the competitiveness of the high-tech mission of China, we hold integrity, innovation, people-oriented work ethic as our corporate philosophies, and work to develop an energy and resource-saving, as well as an environmentally friendly enterprise. By taking advantage of the trend and the materials, Yuji Tech strives to become a leader in the world of science and technology.

http://www.beijingyuji.com/english/

Case Study: Thermal Analysis of an LED Design

Meeting customers' expectations requires pushing the technical limits of design, performance, and production to new levels, as well as expanding to new industries and applications. Producing high quality electronic systems means the embedded components must be maintained within their operating limits. These limits are set by manufacturers and defined under certain operating conditions - including mechanical stress, humidity, fatigue, vibration, and thermal loads. Arnaud Girin, Technical Marketing Specialist at SimScale discusses the thermal aspect and their simulation based on a project using a 3D model CFD simulation.

PREDICTING the temperature at the critical components is an essential part of the designers' duties when delivering a reliable and high-quality product. This task, especially when dealing with large, complex and detailed assemblies, used to be considered extremely challenging with traditional calculation methods. The design analysis could only be partially relied upon using analytical techniques and design guidelines of the time, often leading to poor performance or overdesign.

The emergence of numerical methods to solve complex thermal management engineering problems came as a fast, reliable, and accurate alternative. A prominent one is computational fluid dynamics (CFD), which is able to provide heat maps and temperature distribution plots but also indicates whether a component has reached a state of overheating. Using a representation of the tested design in the form of a 3D model, the distribution of physical quantities such as the temperature can, therefore, be visualized inside the air volume and through every key component.

Electronics Cooling Systems

Engineers must ensure they are kept within the recommended temperature and prevent overheating scenarios. A few options are available to the designer in order to mitigate the temperature rise in electronic components.

Some of these cooling strategies include:

- Air-cooled through passive cooling (e.g., heat sink)
- Air-cooled through forced convection, typically by mechanical means such as fans
- Liquid-cooled through flow circulation of fluid with a pump through a piping system

The benefit of predicting the performance of a prototype is paramount for the vast majority of manufacturing companies. Numerically evaluating design scenarios and assessing multiple working conditions upstream of any physical implementation can lead to significant savings. Indeed, the cost of changing a design down the line grows by factors of 10 at each stage of the manufacturing process.

In the following case, a 3D model is used to accurately evaluate product performance and demonstrate how engineers benefit from the advantages that CFD brings over traditional methods, including financial, labor and time savings.

CFD is used as a time-efficient and accurate method for thermal performance testing and validation. The temperature distribution and dissipation prediction capabilities that are offered by such numerical tools can help anticipate scenarios for which overheating may occur, where components experience temperatures above their operating limit. These scenarios could result in catastrophic failures, bring significant damages to the whole system and, more importantly, create safety hazards.

Improving LED Spotlight Thermal Performance

In this simulation project, a standard LED spotlight is analyzed under a 7 W thermal load and with passive cooling. This type of lighting is extensively used in current households as they make a very energy-efficient solution. The numerical simulation to be undertaken aims at ensuring that a certain design, under set operating conditions, does reach or exceed thermal limits at its electronic components. This is particularly essential for the heat generating elements since they very often experience most of the heat loads. These elements, namely the diodes, are designed to perform efficiently and reliably under specific operating conditions including a temperature range. In this example, the manufacturer of the heating diodes indicates that safe and reliable performance is guaranteed under a limit of 100°C. The thermal dissipation of the LED components will be assessed from the simulation results and their temperature will be compared against this component supplier operating limit data.

Simulation Setup

The CFD simulation to be run will use a 3D model of an LED spotlight, representing the components and parts that will have a significant effect on the airflow and the temperature distribution throughout the system.

The CAD model is made of different components including an aluminum core, heat sink, a glass cover, an electrical connector, and a base plate on which the diodes are placed.

In order to save on computational effort while keeping a relevant setup, a symmetric setup is assumed by only simulating a quarter of the model through its central axis. A rectangular volume enclosing this LED light model represents the air domain. The simulation to be performed will output steady-state results, which means that time-dependent effects are omitted. It will provide quantities such as airspeed and pressure, as well as temperature in both solid components and air volume. This is what is referred to as a conjugate heat transfer analysis, where both conduction and convective heat transfer phenomena are simulated. This is a very effective way of numerically testing the performance of heat sinks and other parts that are designed to dissipate heat by having heat transfer coefficient as large as possible, transferring as much heat as possible to the surrounding air.

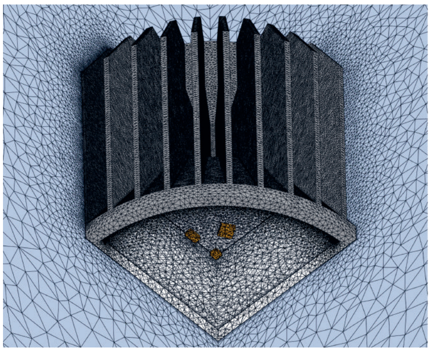


Figure 1: Mesh of the LED spotlight model with surrounding air volume

In this simulation scenario, a passive or natural cooling strategy is adopted. This means that the airflow is solely driven by buoyancy effects or the density difference in air. This is a type of condition typically very difficult to predict with other methods than CFD.

As a part of any standard CFD analysis, a mesh is necessary for any numerical computation to be performed. This operation of creating the mesh essentially consists of breaking down the CAD model volumes into small elements at which the quantity values such as velocity and temperature will be computed. The size of the cell depends upon the geometric size and the physics of the problem. It is best practice to perform a mesh independence study to ensure the mesh is fine enough.

Material Assignment

With the LED spotlight design made of different parts, material definition is an important step of the setup. Indeed, the material parameters play a major role in thermal distribution throughout the whole design. Among these parameters is the thermal conductivity value of the material. This is an important factor in the dissipation of heat through the solids, which is why the choice of material and their property is a crucial task for any designer.

The heat sink, whose role is to remove heat away from the heating diodes, is made out of aluminum, which is known for having a high thermal conductivity. The PVC baseplate supporting the diodes has anisotropic material properties, which means the conductivity value isn't identical in every direction. In other words, the board transfers the heat a lot better in transversally than through its thickness. This is a typical situation where a PCB board is made of many layers such as copper foil, laminate, and prepreg layers. The rest of the component materials are set with generic material values, as shown below.

Boundary Conditions

The last part of the setup consists of defining the operating environment conditions of the simulation. This means defining the direction of the gravity for the buoyancy effects and the components heating power.

In the full model, there are 7 diodes, each of them producing 1 W of thermal power. Since the simulated model is a quarter simplification, only one full, one half and one-quarter diodes are modeled, with their adjusted power values, as shown below.

The interaction of the air with the limit of our air volume is defined as a dedicated convection boundary condition, this means the air can flow freely in and out of the domain, depending on the pressure difference.

The faces of the symmetry plane are assigned a symmetric boundary condition, to indicate the solver that the flow pattern and temperature distribution are expected to be mirrored along these faces.

Results

In order to guarantee a high level of accuracy of the simulation results, the solver is set to compute over many iterations, with the temperature at the diodes plotted on a graph as the run goes. This is to ensure that the simulation runs towards a converged or stable solution state.

The heat map results show the temperature distribution at the surface of the components (see Figures 3 and 4). The heat-generating zones are shown with high-temperature surfaces and a temperature drop can be observed between the diodes and the rest of the components. This drop illustrates the importance that the conduction takes in the heat dissipation phenomenon. The higher the conduction value of a material, the larger the amount of heat can be transferred through the components. The base plate conduction value for example, where the diodes are attached plays a crucial role in transferring the heat away to the aluminum core and the rest of the component. Additionally, the less thermal resistance between the diodes and the surfaces exposed with the cool air, the cooler the components will be.

The maximum temperature at the diode is calculated at 103.35°C, which is consid-

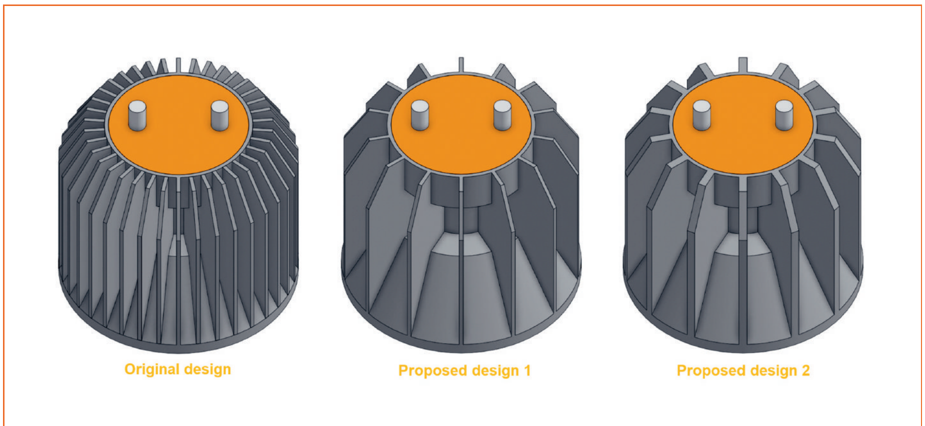


Figure 2: The proposed design changes. Source: SimScale

ered a non-acceptable value according to the diode supplier data. Consequently, a design decision needs to be made in order to improve the thermal dissipation of the component and therefore bring the temperature of the diodes below the stated limit.

As seen in the post-processed image (**Figure** 3, the airflow speed increases along with the outer faces of the LED spotlight. This is a demonstration of the buoyancy effect, where the air is heated up as it flows along hotter surfaces. Its density becomes smaller and therefore rises due to it being lighter. The air flowing between the fins of the heat sink gradually increases in temperature and carries heat away from the components.

By observing the flow pattern, together with the airspeed around the surface of heat exchange between the solids and the air, a few assumptions can be raised.

The equation

$$Q = U \cdot A \cdot dT \qquad (1)$$

can be introduced, where

- Q is the thermal power generated by the diodes in W,
- U is the heat transfer coefficient in $W/(m^2K)$,
- A is the surface area exposed to the air in m^2, and
- dT can be the temperature difference between the diodes and the ambient air in K.

Because the thermal power generated by the diodes is fixed (7 W), and assuming the heat transfer coefficient U remains constant, increasing the area exposed to the air might lead to reducing the temperature difference between the diode and the ambient air. This is why heat sinks are used.

The other strong impact on heat dissipation performance is thermal resistance. This is done within solids, the better the path of heat from the diodes, the less temperature at the surface. With the thermal resistance R in K/W, which can be described as

$$R = \frac{dT}{Q} \qquad (2)$$

This means that reducing R, with Q being constant (7 W), leads to reducing dT.

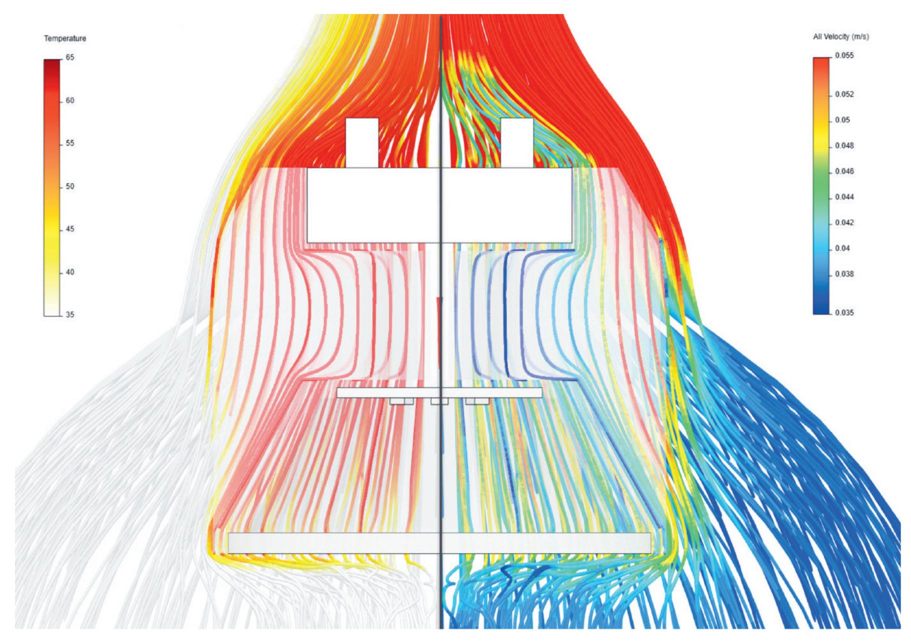


Figure 3: Airflow pattern, colored by temperature (left) and air velocity (right) around the LED spotlight. Source: SimScale

Design Decision

The design can be altered in many ways in order to reduce the temperature of the components. These include selecting materials with higher conductivity values in order to reduce the resistance of the heat path. Further options involve modifying the shape and size of the components, particularly the heat sink part, which is made of fins with a large surface area in contact with the airflow. Every design decision to be made is to be carefully considered, as they typically imply studying and taking into consideration many factors such as a material change or for generating more complex shapes that could result in higher production costs. Additionally, aspects of ergonomy, reliability, sustainability, and safety should also be accounted for.

With the set of result values obtained from the initial design run, improvements to the CAD model can be implemented and then tested numerically. The first change has the goal of increasing the amount of air that can circulate between the fins of the heat sink. By increasing the spacing between the fins, more air can flow through and therefore more heat could potentially be extracted. The first proposed design change includes an increase in the spacing of the fins by a factor of 2.

The second proposed design includes the changes of the first one, with the addition of increased thickness of the fins by a factor of 2, in order to investigate the effects of a larger cross-section, reducing the thermal resistance on the heat sink fins.

Comparative Results

After simulating these two proposed designs, using the same boundary conditions including the heat loads and materials, a comparison of results can then be performed. Both quantitative values such as the temperature at the diodes, and the qualitative plots such as the temperature distribution and velocity pattern are evaluated.

A few observations can be made; the overall temperature of the spotlight is significantly lower in the improved design, with a reduction of 2.5°C in the heat sink, for example. This shows that there is less resistance with the first proposed design.

The velocity plot through the center axis of the heat sink highlights that faster airflow occurs between the fins, as a confirmation of the previously made assumption. Fast air, of about 0.1 m/s, flows deeper to the center of the heat sink and removes more heat away from the surfaces than in the original design, where only a small portion of the fin faces is swept by significant airspeed.

With larger fins, the second proposed design shows significant improvements in heat dissipation having larger cross-section areas to conduct heat to the face in contact with the air. The average temperature reduction is clearly visible, dropping from 60.7°C to 58.1°C.

In terms of quantitative results, diode tem-

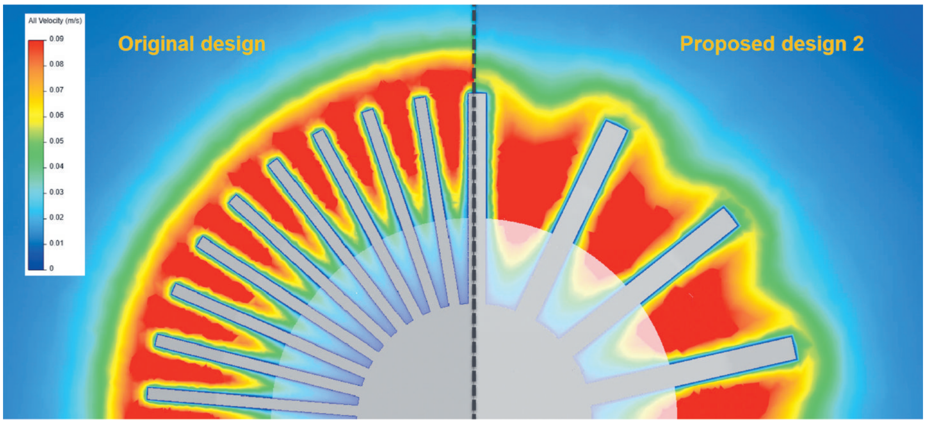


Figure 4: Side by side comparison between the original design and the first proposed design velocity through the heat sink

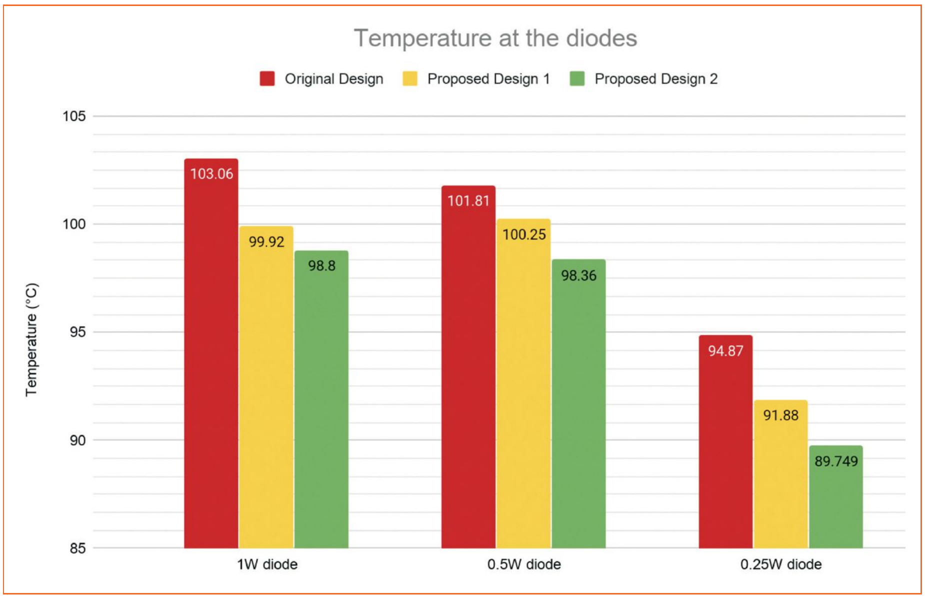


Figure 5: Temperature comparison at the diode, between the different designs

peratures are significantly reduced below the maximum acceptable limit of 100°C.

The gain, achieved by a lesser thermal resistance from the aluminum core to the heat sink fins, coupled with more airflow capacity, leads to a better heat dissipation performance of the LED spotlight. The newly recorded temperatures at the diodes make the improved design compliant to the diode supplier operating temperature.

Conclusion

This CFD project had the purpose of evaluating the thermal dissipation performance of diodes that heat up within a LED spotlight, so that the temperature of the diode is maintained under the supplier operating temperature.

The computational fluid dynamics solver used numerical modeling of heat transfer, both conductive and convective. The means of cooling was set to be passive, i.e., the airflow wasn't moved by mechanical methods.

The results of the simulation highlight the importance of both conductivity material property and geometrical shape for heat dissipation, as it happens the spacing between the heat sink fins. The diodes temperature was measured, for the design simulated, at 103.06 °C. This did not meet the target requirement values for guaranteed lifespan and reliability. Hence, a new design was proposed.

The valuable insights shown in the results lead to the proposal of two designs, the first one with the spacing between fins increased by a factor of 2, the second one, adding a doubled thickness of the fins to the first proposed design.

The result comparison between the second proposed design and the original design showed a superior heat dissipation performance, and a reduction of 4.2°C at the diode temperature.

With valuable input for both the mechanical engineer and the electronic engineer, CFD simulation comes as a useful tool in order to test different designs and evaluate if they meet specific performance requirements. This process brings valuable insights throughout the entire engineering design cycle, from concept design, preliminary studies, final design validation, and verification. ■

ABOUT THE AUTHOR

Arnaud GIRIN: With a mechanical design background, Arnaud Girin has worked for 6 years on design performance optimization with CFD and FEA tools. He is currently part of the SimScale team and is involved in simulation projects for multiple industries.

About SimScale: Founded in 2012 with offices in Munich, New York, and Boston, SimScale is the world's first production-ready SaaS application for simulation. By providing instant access to computational fluid dynamics (CFD) and finite element analysis (FEA) to over 150,000 users, SimScale has moved high-fidelity physics simulation technology from a complex and cost-prohibitive desktop application to a user-friendly cloud application accessible via a subscription-based pricing model. For more information, visit www.simscale.com.

Cost Benefit of Future Proof Solutions

Future proofness has always been a topic in building construction and building management. Due to the fact that the lighting business has always changed relatively slowly, it has never been a big issue. But systems melt together and many different approaches have evolved over the course of just a few years, bringing uncertainty to stakeholders. Dr. Walter Werner, owner and CEO of Werner Management Services takes an in- depth look into this topic and discusses what future proof really means and the costs and value of future proof approaches and businesses.

WHEN the topic of future proofness is discussed, there are many different views as to what it actually means, However, when digging deeper, they all end up asking the same questions: Is it worth being future proof? What are the costs? Does it pay for itself? Therefore, designing for future proofness is always a juggling act, making it necessary for the designer to understand what future proof means for devices, solutions and services, how to derive the current requirements and how to estimate future requirements. Once these questions have been answered, the next step can be taken and the benefits and cost balancing topics can be investigated. At the end of this process, a company should also be able to answer the important question of how to proof and market these benefits and how to monetize their effort. In the following article, all of these steps will be thoroughly discussed and conclusions will be drawn.

What Future Proof Means

The question of what future proof means is quite simple but the answer is neither simple nor short. In retrospect, it is easy to see what turned out to be future proof and what didn't, but when looking into the future, the features that will be future proof are rather ambiguous and easy to challenge – especially if they cost a lot of money. However, realized sustained features and functionalities provide mid and long-term sound benefits throughout the value chain: Pleased customers, lower cost of design maintenance, training, higher brand awareness, lower total investment etc. for the same result. Therefore, it is worth having a detailed look into defining future proof requirements and features for devices, solutions and services.

Future Proof Devices, Solutions and Services

For Devices

Future proof devices mean that they will continue to perform their tasks in a reasonable fashion in a future environment. This includes design and material choices in order to avoid rapid decay and early obsolescence. But it also considers some future needs, especially when integrated into communication networks (e.g. scarce processing power or memory and missing out reasonable software updates may stop the usage of net-worked devices early, due to missing ability to match upcoming network security requirements).

For Solutions

Future proofing solutions means that replacements of broken devices remain possible without the need for induced replacement of other network participants. It allows for the reasonable integration in future higher order networks, and for some flexibility in adaptions to future parametrization needs.

For Services

In order to be considered future proof, services need to be designed scalable to adopt to reasonable success, and are created in a modular way that allows for upgrading and adapting parts of the service, e.g. to future automation possibilities or changing integration strategy without the need for a complete redesign (and devaluation of existing results). This is especially true for services that are (partly) based on data base evaluation or cloud computing.

How to Derive the Requirements for Being Future Proof

Forward Compatibility

Some aspects of being future proof may be summarized under ”forward compatibility”. The term says, that devices will be compatible to future (interface) technology. At first glance it seems to be impossible to create forward compatibility without knowing the upcoming technology details.

Especially when expected future standardization is involved, the request to be com-

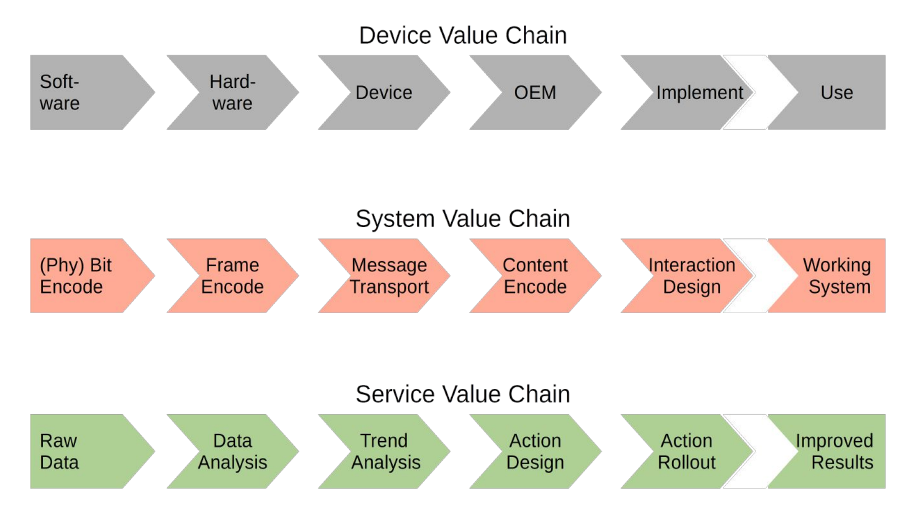


Figure 1: Future Proofness needs an integrated view across the value chain

patible with the expected future standard has the power to stop the innovation process completely, opening the field for vendors that ignore this need until the standard is established (establishing new standards may take from a few months (e.g. the first "jpeg" standard for compressed digital images) up to 7 or more years (e.g. DALI) - without any possibilities to estimate how long it will finally take. To avoid a "complete innovation lockdown" for an unknown period of time it is mandatory to understand what can be done right now to allow for being compatible to the future standard.

The only way to adapt to unknown future features is to embed sufficient flexibility in terms of update on site, processing power, sufficient memory and programmable, modularized interface behavior. Update on site, sufficient processing power and memory is also mandatory to be able to adapt to future communication security needs.

If the "version before the standard materializes" has sufficient success, a dual compatibility may be a need for a transition period. Again, the requirement is to care for sufficient available processing power and memory to make sure this can be covered.

Obsolescence

Engineering for design with little obsolescence is basically available. Just make sure to look for sufficient life time as a requirement. For lighting equipment in most applications this should be 25 years before a noticeable rise of ageing fails. Besides the obsolescence of devices in the field, the obsolescence of the design should be a major concern: Necessary changes in single component (more powerful processor, faster serial flash, capacitors that are better transient proof etc.) should not lead to complete redesign and re-approval of the complete design! The same applies for the software: Sufficient modularity with strict internal interfaces allow for continued re-use of already existing functional blocks. Of course, some risk of (indirect) cross- influence is always to be considered, but this risk should not be driven "by design".

Deriving Expectable Future Requirements – Focus on Rapid Technology Changes

Rapid changes in available technology are a fact, not a threat. In the long run, they seem to be relatively easy to predict: The ongoing rise in available semiconductor integration density leads to a massive increase of processing power and memory size available at reasonable cost, reasonable chip size as well as reasonable power intake and heat dissipation.

This single reason drives multiple paths of technology change. One of them is the ongoing replacement of (analog and digital) hardware features with (software-) processed features, allowing for more flexibility, especially in signal handling, interpretation and compression, and also in more detailed power handling. Saying this, it becomes clear that the chances to fulfil various customer needs rise dramatically. And this leads to a reasonable predictability of future requirements! Almost all future requirements are made of "invisible user requirements" that exist today, but cannot be derived in the standard requirements process.

"Brain filters" that are applied unwittingly are the main reason for this, when asking "users" throughout the value chain: The standard requirement research always provides answers that are based on perceived availability of technology (at reasonable cost). This is also true when trying to research "without filters applied", as the interviewed person will simply not catch the thought and idea behind the question and therefore cannot provide what we need. These "brain filters" possibly have a very strong effect: They e.g. stopped Nokia from enhancing their "communicator" to a real smartphone as we know it today, although they had already all the means in their pocket to achieve this well before Steve Jobs at Apple finally did it.

Many people say Steve Jobs was a marketing genius, and without discussing this I would like to add: He was a genius deriving future requirements, that remained opaque and hidden behind the strong filters of our brain. And he was a brutal tank that cleaned all the resistance his organization came up with trying to tie him down to "actual existing requirements".

So, How to Proceed? Do We Need Another Steve Jobs?

It will be difficult to find a person like him AND to allow him to proceed in your organization. The better way is to ask different questions to different persons. Instead of "what should it do" you may ask "what should happen in an ideal world", and instead of asking the purchase department specialists of your customers organizations down the value chain, better target the manufacturing, installation and final use persons.

On top of that: try to understand yourself, the roles and tasks of the various steps of the value chain, and try to estimate how the process could run smoother, create more value and less hassle; in other words, how the value chain may look in an ideal world. Once you have that, the question of "what should we have in an ideal world?" can be asked of the value chain, differently – clearing away the first layer of brain filters. There are other techniques: some of them create a kind of hype ("brainstorm", "leap frog" and alike), but all of them will need personal understanding and involvement of the situation throughout the value chain to allow for reasonable results.

However, this is just one side of the task. the other side is to get your organization behind these findings. Most organizations shy away from innovation that goes beyond the obvious, utilizing many arguments, leading from risk to cost and unacceptable complexity, and sometimes even to personal discrediting. So better be prepared and get support from (very) high levels first, to service the expectable tsunami afterwards. And, again, be prepared to acquire some knowledge of the actual process and tasks throughout the value chain.

Benefits Generated Throughout the Value Chain

A new product that is designed to be future proof will NOT generate any direct value throughout the value chain, today. But it will add value to this chain in the future. Therefore, it is an investment, that pays back in the future.

Accordingly, the two basic questions are:

- How does it pay back?
- When does it pay back?

The suggested answer is:
It pays back over time by reducing the cost and effort for the introduction, handling and transition of the replacements, that a less future proof design will need to stay successful in the market. This may be considered a pretty vague statement, but the figures are available, and they are substantial, and can be calculated by looking into past product replacements that have been made in the same value chain.

Balancing Cost

Cost is always a simple and straight forward argument. And it is necessary to keep cost under control to sustain the business: no deviations allowed.

When looking into achieving a future proof solution, future induced costs also need to be looked at. The fact itself is less disputable than the question of how far into the future this should reach and how much the induced cost may actually be. One of the troubles involved is that future induced cost by unimaginative design are actually much higher than believed. This is especially true for software in restricted environments (timing, memory), where cheap and fast approaches in the first place may lead to the need for a complete rewrite of the software already in the product introduction phase (where the worst case scenario would be the need to also replace the processor in the hardware design). But of course, induced future costs for unimaginative design is also substantial for hardware and processes.

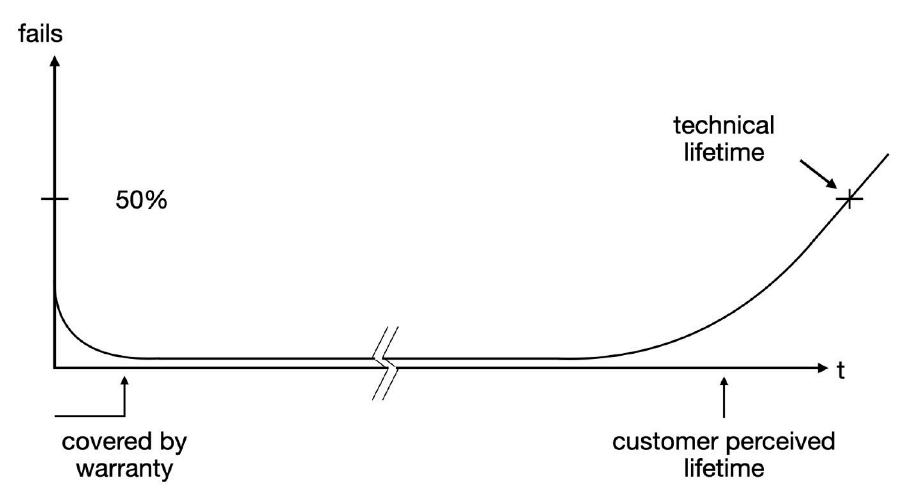


Figure 2: Obsolescense (technical & functional)

To catch the correct cost balance that fits the company and the product, all (possible) additional efforts to achieve a future proof setting should be seen /calculated as investments that have their payback at the moment in time when the risk for a redesign happens. This approach allows for fact-based discussions to balance today's and future cost for any of the ”future proof” requirements involved.

Proofing and Marketing the Future Proof Benefits

After all the efforts taken to create a really future proof product, the company will be proud of the effort taken and the result achieved and start promoting it. However, be aware that customers throughout the value chain might be deranged by a statement like that, as it inevitably raises several questions.

Possible customer questions and thoughts:

- What about the other products from this vendor?
- Are these non-future-proof products?
- What about the cost? - Must be much too high if they can invest in things I do not need today!

So, please, don't take ”future proof” in your campaign, just point out features that are in the range of your customers hopes, like better endurable capacitors, wider temperature range, higher levels of surge-burst withstanding than the minimum required, modular functionality or interfacing available etc.

There is only one way to really proof ”future proofness”: Look back from the future to what actually happened. Before you actually arrive in the future, you may look into what might happen in probable scenarios. This way you can proof that your product or design is ”scenario proof” for a specific scenario (or some scenarios), that you estimate could happen in the future. And the scenarios again can be fed using the expectations of the impact of technology changes (alongside your technology roadmap).

Conclusion

By nature, the future is unknown. However, future requirements can be researched properly, and future proof cost and benefit can be rigidly calculated.

Future proof design is an investment into the sustained future of your business. Sound business decisions can be made when calculating the additional cost as investment, and the payback as prevented future cost, that becomes available at the time the risk for a specific action is estimated.

Future proof properties of a design can be evaluated (and proofed) against scenarios that estimate probable future developments.

However, promoting to be ”future proof” is difficult and dangerous. Promoting essential aspects of being future proof will create much higher spirit. ■

ABOUT THE AUTHOR

Walter WERNER, Dr.: Dr. Werner is head of Werner Management Services, a consultancy company in the field of innovation, lighting controls and the Internet of Things. He worked as Head of System Architecture at the Austrian lighting enterprise Zumtobel Group from 2011 until 2014. From 2009 to 2011 he worked as an Innovation Consulter and parallel to that taught at the Institution for Higher Education in Rankweil, Austria. From 2006 to 2008 he was the Managing Director of the Swiss software startup mivune, situated in Zurich. He was employed at Moeller of Germany as Technical Manager Switchgear from 2004–2006 and prior to that, formed the smart lighting agenda of Zumtobel in the years 1985 to 2004. Dr. Werner completed his studies at Innsbruck University in Experimental Physics with a PhD.

Werner Management Services e.U. is a consultancy, that focuses on making innovation happen and successful. Well-managed innovation is a core success factor. However, it is often a major challenge to identify what innovation fits best, and to drive a success portfolio. That's where Werner Management Services offers a supporting hand: Implementing successful and tailor made systematics into the innovation process, unchaining the flow of valuable ideas, and designing processes to achieve self guidance to the point. In addition we are prepared to bridge missing expertise in technical communication and controls if required, both as reporting external experts, as team challengers or workshop organizers that help to come to a sound conclusion.

PCB Space-Constraint Woes Eliminated by 2 MHz Monolithic, Buck-Boost DC/DC Converter and LED Driver

As the size of electronic devices shrink, the circuitry inside them must do the same. This trend towards product miniaturization is evident across all industries and creates new design challenges for engineers tasked with fitting solutions in space-constrained designs. Kyle Lawrence, Applications Engineer at Analog Devices proposes and describes a solution based on their LT3942 monolithic buck-boost regulator IC that is used in their DC2404A demonstration board.

Introduction

To meet increasingly stringent size requirements for compact electronic devices, integrated circuit (IC) designers bring external components inside of their devices to minimize the external component count. Of the various circuits required to build any electronic device, dc-to-dc converters are as challenging to shrink in size as they are ubiquitous—everything needs power—as power supply designers often face the reality that shrinking solution size typically negatively affects performance.

For instance, one way to save significant PCB real estate is to use a monolithic dc-to-dc converter that integrates carefully selected power switch devices within the IC package, reducing required external components to a few passive devices.

In many cases, the resulting compact design brings the undesirable result of increased power loss in a smaller space for much higher temperature rise when compared with external power switch controller designs. Selecting the right monolithic dc-to-dc converter is critical in designing a power system that is both compact and efficient in order to avoid generating problematic levels of heat.

General Component, System and Concept Description

The used step-up/step-down converter meets the challenge of creating a flexible and compact dc-to-dc converter solution without sacrificing performance. It integrates four 40 V/2 A power switches, two gate driver bootstrap diodes, and all its control and driver circuitry into a small 4×5 mm QFN package. With the ability of operating at up to 2 MHz switching frequency, external component sizing is kept to a minimum, conserving PCB space as well as providing high bandwidth operation for any dc-to-dc converter.

The IC offers a peak current-mode control scheme and exhibits seamless transitions between 2-switch boost (step-up), 4-switch buck-boost (step-up/step-down), and 2-switch buck (step-down) modes of operation. The converter observes and compares its input and output voltages to determine the correct mode of operation. As the ratio of $PV_{IN} : PV_{OUT}$ changes and forces the converter to mode transition, the IC maintains regulation while it intelligently shifts control between switch pairs. In addition to regulating the output voltage over a variety of $PV_{IN} : PV_{OUT}$ combinations, the system can also be configured to regulate input or output current for use in constant current regulation applications. Current monitoring feedback from the ISMON pin provides a buffered voltage output proportional to the measured current, allowing connected circuitry to inspect the measured current levels. This ability to regulate current or voltage makes the IC perfect for use as an LED driver, compact battery charger, miniature solar panel-powered converter, or general-purpose voltage regulator.

14 V, 1 A LED Driver Example

Figure 1 shows a complete evaluation circuit for a compact LED driver. This solution is capable of providing 1 A to a string of four (up to 14 V) white LEDs connected in series. The maximum power delivery input voltage range is 7–36 V, with reduced current operation down to 4 V, which is ideal for unregulated automotive input supplies. The monolithic buck-boost regulator IC in this solution operates at a 2 MHz switching frequency, enabling the use of relatively small inductors and capacitors. The result is that the entire LED driver solution fits a 15×15 mm PCB footprint, with all components placed on the one side of the board, including the IC.

This solution also boasts high bandwidth operation, allowing for quick adjustments of

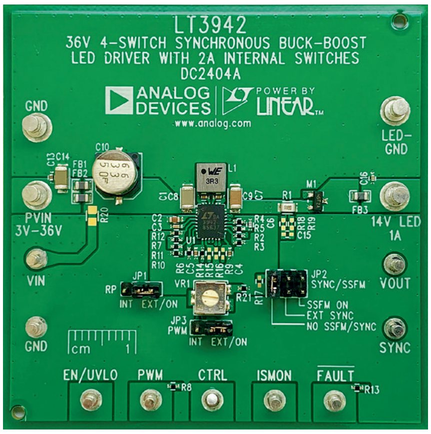


Figure 1: This demonstration circuit showcases a high performance, compact dc-to-dc regulator solution specifically for, in this case, driving LEDs

the output current. While in buck operation, the IC achieves dimming ratios as high as $5000:1$ using an external PWM source to dim the LEDs at a flicker-free 100 Hz. If an external PWM source is not available, it can also be dimmed using its internal PWM dimming feature. Internal dimming provides up to $128:1$dimming without the need for any external PWM signal source, requiring only a single resistor to set dimming frequency and a dc voltage to control the duty cycle of the output current. It also features analog dimming by applying a dc voltage at the CTRL pin for up to $20:1$ analog dimming. Analog and PWM dimming can be combined to achieve higher effective dimming ratios than either method can alone.

Spread Spectrum Frequency Modulation Reduces EMI Peaks

To help create a low noise dc-to-dc converter system, an optional spread spectrum frequency modulation (SSFM) feature is included. When enabled, SSFM sweeps the switching frequency between the value set by the RT resistor up to 25% additional switching frequency. This sweeping action distributes the emissions caused by switching over a broad spectrum of frequencies rather than concentrating those emissions into narrow bands, reducing EMI peaks overall. SSFM, when used in combination with input and output EMI filters, can help reduce EMI over a wide range of frequencies, making it easier to design an emissions-compliant system.

12 V, 1 A Voltage Regulator Example

The IC is not limited to driving LEDs. It is a capable, compact voltage regulator, well suited to solve the problem of producing stable outputs from wide-ranging, unregulated power sources. The 12 V, 1 A voltage regulator design (**Figure** 4) is similar to the 14 W LED driver solution (**Figure** 2), with a few small modifications. Like the LED driver application, the voltage regulator can maintain output regulation over a wide input voltage range, delivering full output power as low as 7 V and maintaining operation as low as 4 V with reduced output power.

The efficiency curves in **Figure** 4 show that even when operating at a 2 MHz switching frequency, the 12 V regulator boasts an impressive peak efficiency of nearly 95%, with most of its input voltage range exhibiting efficiencies of 85% and above. Over 80% efficiency is maintained even when powering its output at a tenth of its total output power, demonstrating its ability to operate efficiently in light load conditions.

The current sensing and control feature are geared toward LED dimming control, but it serves well in other situations requiring both voltage regulation and current control. When the sensing resistor is configured at the output, the IC can easily be configured to act as a compact constant-current, constant-voltage battery charger. For applications that have strict input current limitations, such as circuitry powered from small batteries, capacitor banks, or photovoltaic cells, the sensing resistor can be moved

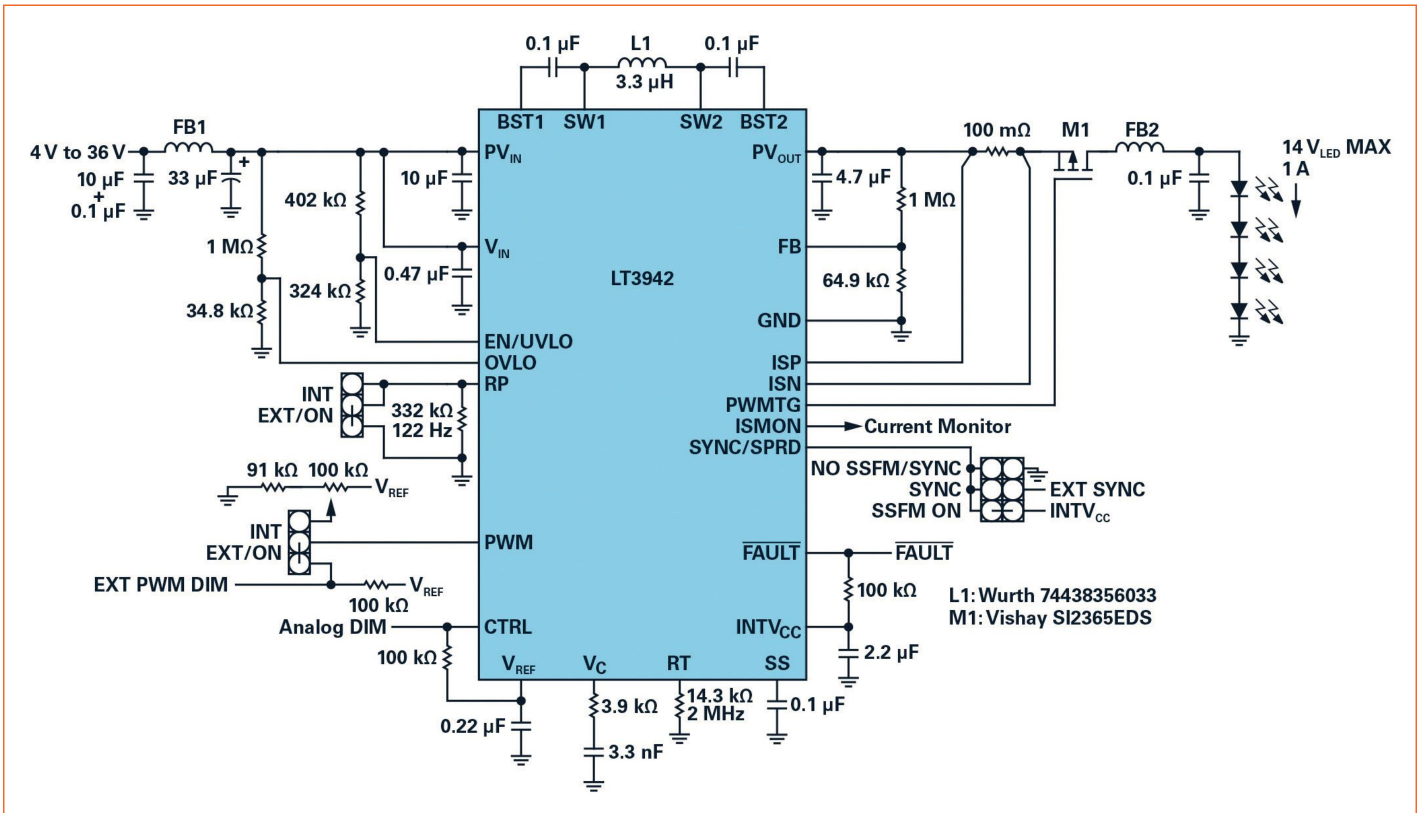


Figure 2: The demonstration circuit is used to create a compact 14 W LED driver application capable of providing regulated output current over a wide input range

to the input side of the regulator, providing an input current limit to the system, as well as monitoring. The IC seamlessly transitions from CC mode to CV mode (and vice versa), ensuring regulation of input and/or output at all times.

Automotive Sequential Turn Signal and Trim Lighting

Animated sequential turn signal lights commonly seen on newer luxury and performance cars are quickly gaining popularity, replacing the traditional blinker style indicators. Early implementations of the sequential turn signal use multiple step-down converters or linear regulators to power LEDs in the turn signal clusters, resulting in complex, relatively inefficient, and excessively large solutions, greatly limiting the field of possible lighting designs. Reducing the quantity of required power ICs to one efficient device is an obvious way to expand the range of a lighting designer's options.

A single converter solution requires a device that is capable of maintaining output regulation across the various LED combinations - hence, string voltages, that occur in the lighting design: from every LED on, to a single LED on, to all the other combinations in between. As the animated lights move through the configurations of connected LEDs, the input voltage can be higher than, lower than, or equal to the output voltage. This type of application requires a step-up/step-down converter that can intelligently select and seamlessly transition between modes of operation while maintaining output regulation. The buck-boost topology and high bandwidth operation enable it to easily navigate these changes without glitches.

The presented sequential turn signal design (**Figure** 5) powers eight LEDs at 330 mA from an automotive battery and selects between powering either an amber string of LEDs, for turn signal operation, or a white string, for daytime-running lights or other trim lighting used in headlight/taillight designs.

A microcontroller acts as an interface between the turn signal input from the user and the lighting system. This gives the lighting designer (or end user, if desired) complete control of all the timing and signals necessary to perform the animated sequential turn-on of the LEDs, as well as control over which color LED string is powered at any given time.

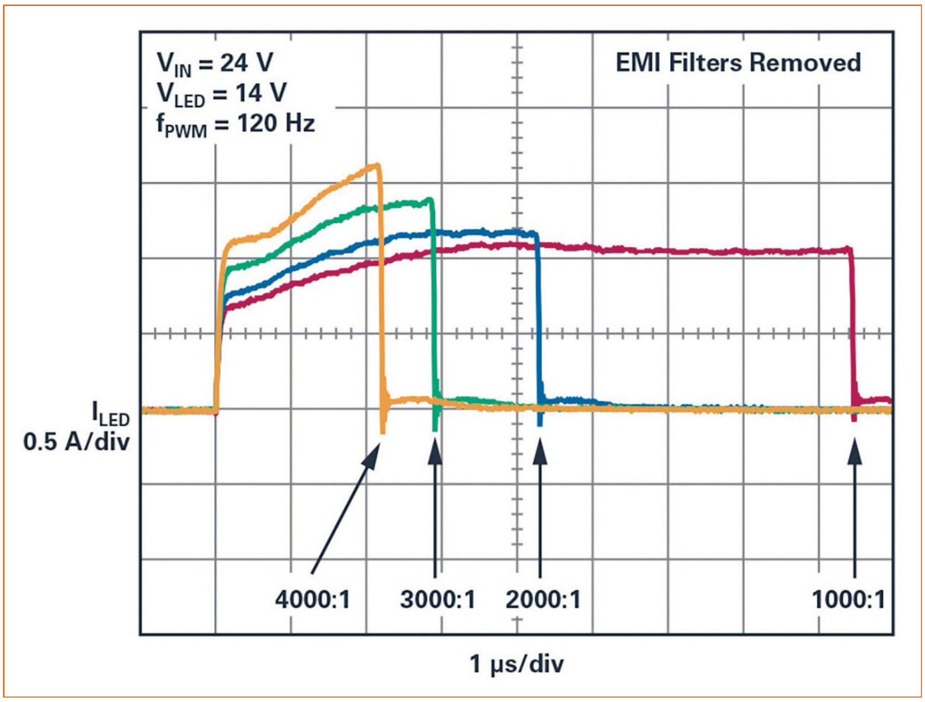


Figure 3: The high bandwidth operation helps achieve high ratio PWM dimming for LED lighting applications with wide dynamic brightness ranges. With EMI filters removed, DC2404A achieves up to 4000:1 dimming at 120 Hz and as high as 5000:1 dimming at 100 Hz

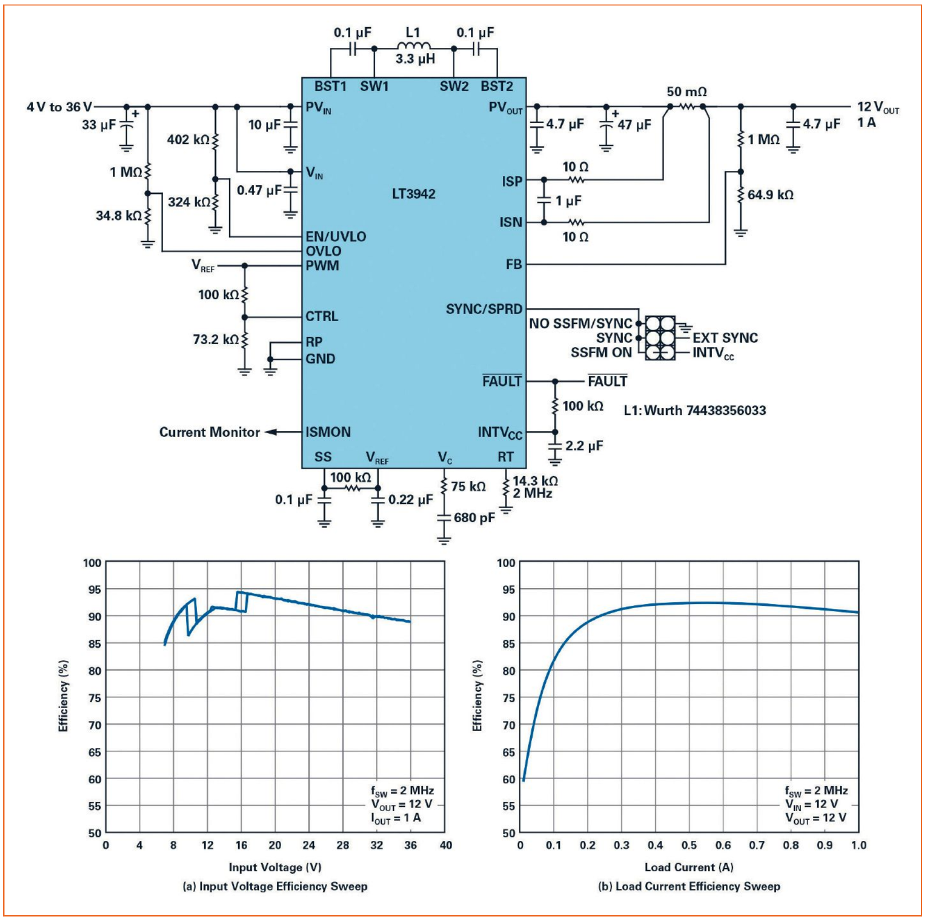


Figure 4: Configured as a 12 W voltage regulator, the driver exhibits excellent line and load efficiency properties over a wide input range

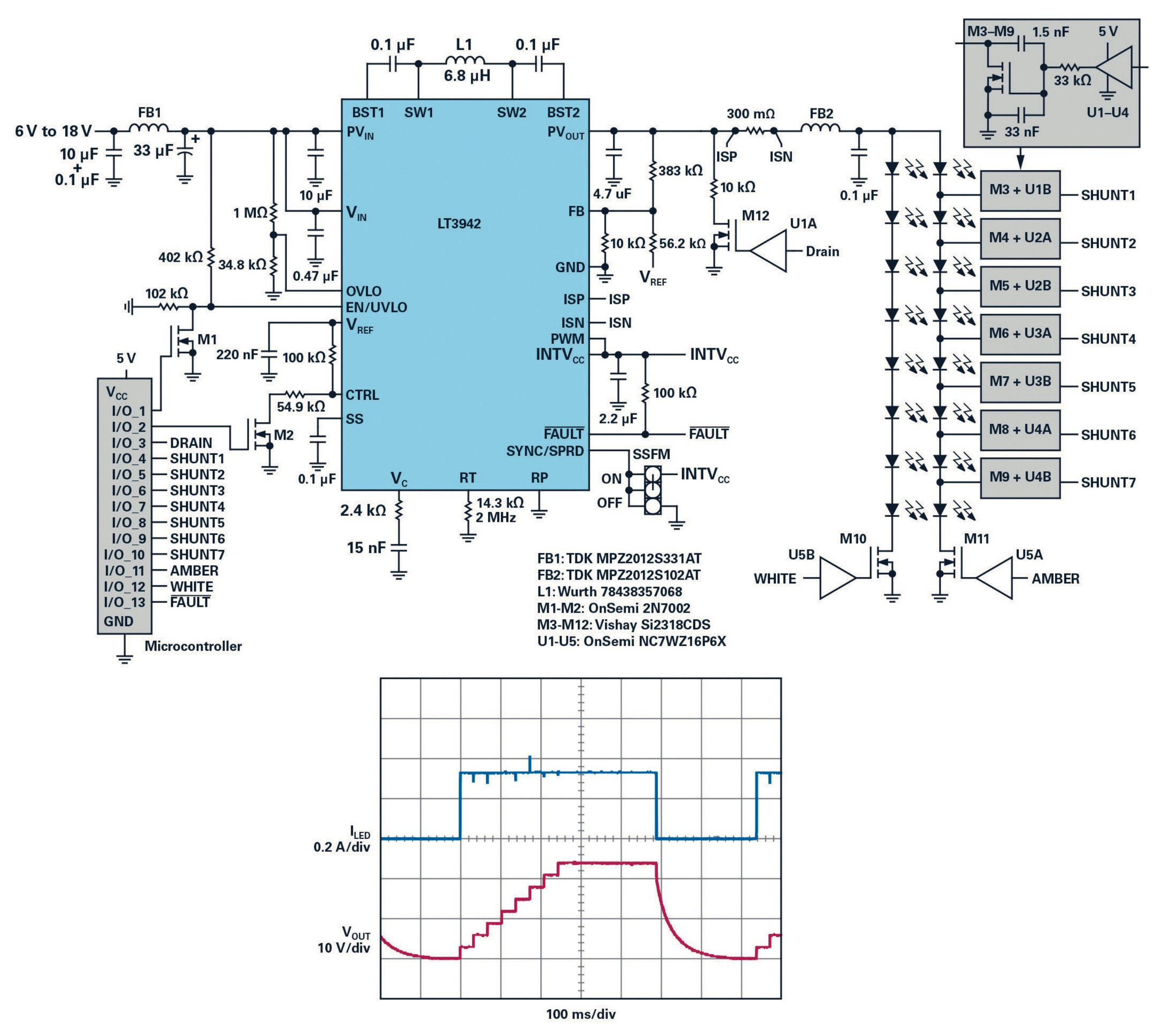


Figure 5: LEDs are turned on one at a time in sequential turn signal applications, forcing the dc-to-dc converter to rapidly adjust to new PVIN:PVOUT combinations. This is no problem for the driver, which seamlessly transitions from boost, to buck-boost, to buck operation during the sequential turn pattern, ensuring regulated LED current across the modes

In this design, during the sequential turn-on pattern, the turn signal LEDs are introduced to the string one at a time to produce the turn signal. As LEDs are added to the string by the microcontroller, the IC maintains regulation of the output current for consistent light brightness.

After all LEDs are illuminated, it stops switching operation and the output voltage is drained to set the converter up for the next sequential turn-on cycle. When the turn signal is not being used, the microcontroller reconnects the trim lighting LED string and continues to wait for turn-signal user input, combining two lighting functions into a single LED driver solution.

Summary

Electronic devices continue to force engineers to reach for smaller integrated devices to meet increasingly limited space requirements. The monolithic buck-boost converter and LED driver addresses space-constrained electrical designs by integrating a number of space-saving features without compromising performance. Its monolithic design and 2 MHz switching frequency operation shrinks solution size, enabling it to squeeze into cramped PCB designs. It is highly flexible - able to operate as both a constant current and constant voltage regulator - enabling it to fit a wide variety of applications.

For designs that require low noise power supplies to meet stringent EMI requirements, the SSFM feature helps bring down conducted and radiated emissions, and its convenient IC package pinout allows for compact switching hot loops. These features, plus a wide input range, simplify a designer's life when faced with compact power requirements. ■

About the Autor: Kyle LAWRENCE is an application engineer at Analog Devices. He is responsible for the design and testing of a variety of dc-to-dc converters, including 4-switch buck-boost voltage regulators and LED drivers targeting low EMI automotive applications.

New Flexible Lighting Systems Based on Atmospheric Plasma Metallization

The research and development of light-emitting devices (LEDs) has been excessively expanded and advanced in the last decade. The most recent generations of chip scale package (CSP) and flip chip LEDs enable high quality electroluminescent light over a wide range of correlated color temperatures (CCT) with a very small, compact size and high cost efficiency [1,2]. These achievements pave the way for more sustainable lighting systems on the large global scale. However, lighting systems may still fall behind the progress of LEDs and pose new challenges for the LED lighting industry. Yaser Haj-Hmeidi, Development Specialist at Lumitronix, proposes a newly developed technology, atmospheric plasma metallization and explains how it could solve some challenges and lead to new solutions.

THE harmony in innovation between lighting systems and LEDs will continue on a progressive level to explore new opportunities in the markets for the lighting industry in the field of LED systems. It is therefore encouraging to firstly re-evaluate the existing solutions based on conventional methods and probably even rethink the concept for the PCB itself as a core element for LED modules. Especially since the current production of printed circuit boards requires several complex stages of photolithography, clean room conditions, etc. These processes are becoming even more complex in the case of flexible printed circuit boards (FPC) and it is more challenging to achieve a reel-to-reel production line for flexible endless LED luminaires.

Introduction

There are many possible established techniques for the metallization based on solid state physics and chemistry, such as physical vapor deposition (PVD), thermal evaporation, electron beam evaporation and cathode sputtering, but they have several limiting factors, such as the required vacuum conditions, low incompatibility with reel-to-reel production form, limitation to certain thermally stable materials as well as insufficient processing speed.

Additionally, much more care needs to be taken to address the major physical problems, which are hindering the metallization, including the mismatch of lattice constant numbers for the different deposited layers. Furthermore, the heterojunctions possess different thermal expansion coefficients, which could be critical for many applications, especially in hybrid systems.

Indeed, there are trends towards new solutions for FPC metallization in order to realize the modification of lighting systems into large, ultra-flat, planar luminaires in arbitrary shapes with maximum freedom in the design of two- and three-dimensional luminaires.

Nevertheless, such an innovation requires that the challenges in nowadays' production steps of FPCs should be overcome and must fulfill the request of modern advanced production for a high degree of flexibility beyond the limits of the logistic process. These factors build up a barrier for the expansion into the market for new LED luminaires.

Although low-pressure plasma metallization is a well-established method, but it requires a high-vacuum chamber, which means high processing costs. In addition, the low deposition rate and low capacity of the vacuum chamber limit the size of the substrates to be processed.

Obviously, an innovative solution for metallization is an essential step towards creating a new solution. The new technology for the metallization of FPCs is based on atmospheric plasma, and a new complete solution has been found for the reel-to-reel production of flexible, almost endless LED

Figure 1: A prominent product example based on atmospheric plasma metallization technology. A professional tunable white solution based on Nichia's 2-in-1 Tunable White LEDs based on polyimide material with a width of 8 mm, of course in SELV and non-SELV option depending on the length of the strips. On request, all products can be manufactured with an "endless" length

modules. The system applies techniques that are capable of high-volume manufacturing. The processes can be continuously extended to include a wide range of components on the same flexible FPCs, such as infrared sensors, antennas, etc. Thus, the electronic portion of the final product can be attached to the flexible FPCs. It is distinguished from other atmospheric plasma metallization processes by its high-speed coating and reliable metallic layers even at large scale production. **Figure** 1 shows a product made possible by atmospheric plasma metallization. The special common feature of all flexible LED modules is the freedom of design with regard to the required dimensions, especially the length, which can basically reach a very large maximum and is only limited to the possible handling of the roll itself. The products offer additional value to the processes of the logistics chain, which makes it possible to reduce the overall ownership of the end products.

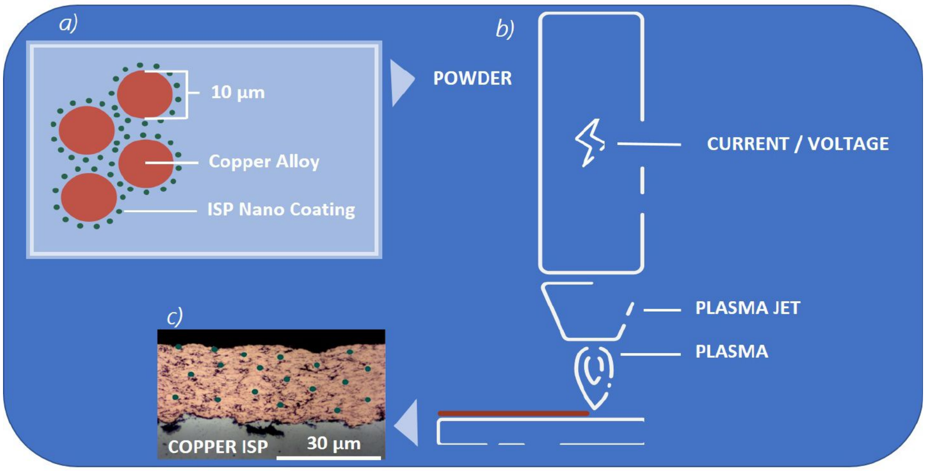


Figure 2: The copper spheres which are depicted in orange have a diameter of about 10 □m (a); note that the integrated surface protection nanoparticles are marked with dark green around the copper spheres. The simplified drawing (b) shows the plasma jet moving on the base substrate and shows the essential parts of the jet, e.g. the injection of the inert carrier gas from the top of the jet, which is later mixed with the metal powder. The high voltage/current source is necessary to control the plasma flame at atmospheric pressure. Finally, the base substrate is coated with the metallic layer. A microscopic image shows the cross-section of the deposited metal substrate on a flexible polymer substrate (c); the thickness of the metal layer in this example is about 30 µm

Processing

The plasma metallization method is based on the deposition of a functional layer on the substrate surface at atmospheric pressure. Plasma refers to a plasma in which the pressure corresponds approximately to that of the surrounding atmosphere. In contrast to low-pressure plasma or high-pressure plasma, no other pressure level has to be maintained on the substrate in the reaction vessel. In **Figure** 2a, the metal particles (usually copper) are shown in orange discs and they are surrounded by a protective surface in the nanometer range. This monolayer allows a better adhesion to the base substrate and improves the passivation quality of the obtained layer.

The main components of the plasma nozzle are simply explained in **Figure** 2b. The plasma in the nozzle is generated by either a voltage or a current source. The metal powder is transported by an inert gas, usually argon with a purity of at least 99.996 %. The excitation of the inert gas is achieved by an arc discharge between two electrodes spaced 5–10 mm apart. The energy threshold is achieved either by applying an AC voltage with low frequency or a DC voltage. However, excitation is preferably by means of a DC voltage source. It has been found that argon works at extremely low voltage to produce the arc discharge. Therefore, the electrodes for generating the arc discharge are connected to a power source in the range 10–300 A with a voltage of 10–100 V. The limitation of the voltage prevents the molecular chains of the coating material from being broken completely, even if there is very little clearance between the electrodes. On the one hand, this introduces a very high-energy plasma. On the other hand, it enables the start of the chemical reaction in the coating material, e.g. in the precursor. The inert gas flow is then fed to the nozzle so that the plasma temperature in the arc is in the range of 10 000–50 000 °C with a flow range of 5–50 l/m. The exclusion of atmospheric oxygen via the carrier gas prevents

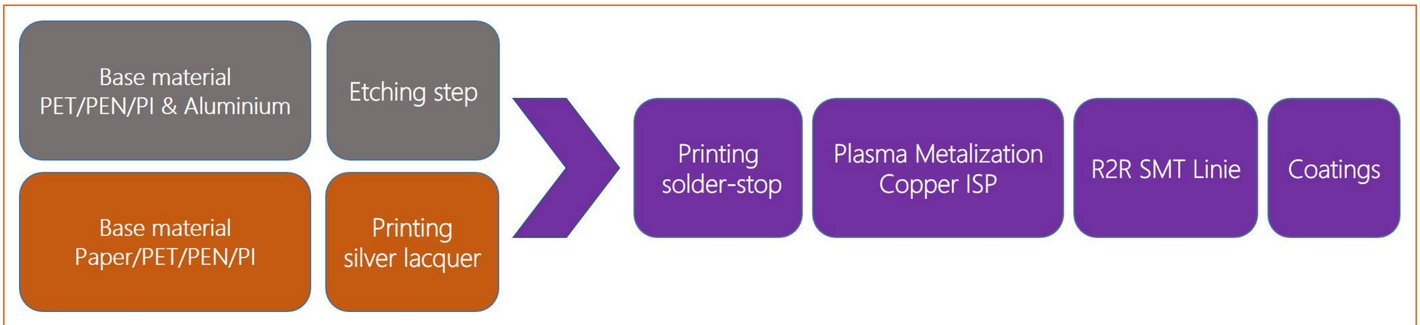


Figure 3: The block diagram illustrates the sequence of a mass production line from raw material to the final stage. A distinction must be made between two different paths as mentioned in the article: The first is based on polymer thin films covered with an aluminium layer with a thickness in the range of 100-180 µm. Next, an etching of the aluminium layer leads to the structuring of the desired layout of the flexible printed circuit board. The second path is based on printing the adhesive conductive silver ink onto the flexible substrate, e.g. polymer and paper, using digital printing. The printed structure can have almost any shape. Furthermore, both paths can now be processed in the same way. Namely printing the solder mask onto the FPC. This is necessary to avoid random plasma metallization on the substrate and allows metallization only on the desired area. Then the metallization of the integrated surface protection copper on the substrate was performed. Roll-to-roll surface mount technology (SMT) was applied to mount the electronic components that create an electrical circuit on the surface. Finally, the substrate can be covered with an optically passive or active layer, depending on their function

direct oxidation of the coating material in the plasma jet. The chemical reaction is controllable even with high-energy plasma. This makes the process particularly suitable for continuous industrial high-speed coating processes without compromising the advantages of atmospheric pressure. Note that the temperatures of the deposited particles are reduced on their way before reaching the carrier substrate without causing any thermal damage to the surface.

The options for the coating materials include a wide range of organic-metallic single and combined compounds. In particular, copper and zinc mixed compounds can cover many requirements in the FPC LED module industry. The choice of coating material is always related to desired specifications.

One Technology, Two Ways

High volume production is optimized to achieve a rotating coating speed in the range of 500-1000 mm/s. Furthermore, two different production methods can be distinguished depending on the core technology and carrier substrate.

In the first method, the carrier substrates are usually made of low-cost polymer films e.g. PET, PEN, PI with a thickness in the range of 20–125 µm. Next, the base material is embedded to an aluminum foil with a thickness in the range of 100–180 µm. Then, the wiring structure of the FPC is produced in wet chemical etching steps. Note that the aluminum is not suitable for the soldering process which is where scalable atmospheric plasma metallization comes into the play in order to passivate the surface via the copper micro-particles. However, a solder mask must be applied to the surface before plasma metallization to ensure the adhesion of the copper layer only in the desired area. Consequently, the FPC LED modules can be assembled via the fully automated reel-to-reel production line.

In the second process, the base material can be produced from polymer films, e.g. PET, PI, PEN, and paper with a thickness in the range of 20–125 µm. Next, the wiring of the circuit is printed on the base material with conductive adhesive ink, usually silver ink via digital printing. After this step, the solder mask is conducted to the films with retaining openings for the plasma metallization in order to deposit a copper layer with a thickness of 10–30 µm. It should be noted that in this application a layer of only 10 µm already ensures excellent soldering of the system. The further procedures are the same as mentioned in the first method, both ways are shown schematically in **Figure** 3.

Results and Discussion

The investigations and analysis of the metallography were carried out on random samples after mass production. **Figure** 4a shows an optical image for the FPC before assembly. The base material was a 50 µm PI with a combined aluminium layer of approx. 180 µm. An image of the LEDs before processing is shown in **Figure** 4b. Almost any type of LED can be used with this technology, there are no limitations yet. The X-ray image in **Figure** 4c shows a very tiny fraction of the underside of the LED as a cavity in the soldering material, which varies in the range of 1-5% depending on the measured position. The final structure

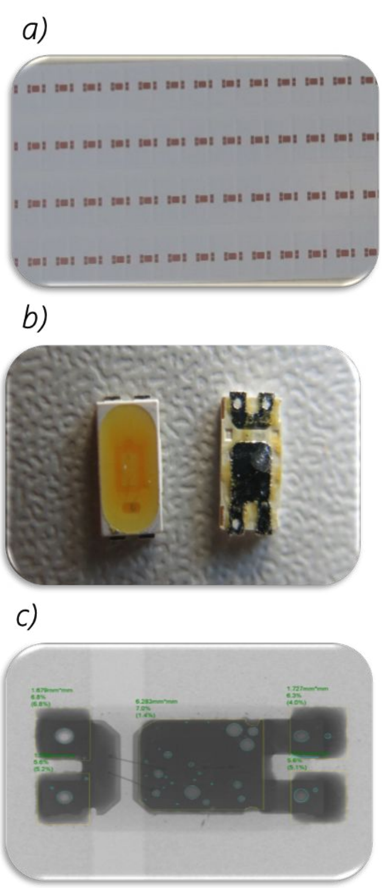


Figure 4: An optical image of the final plasma-metallized FPC (a) before reel-to-reel assembly. An optical image of the top and bottom of the LED (b) before assembly. An X-ray image of an assembled LED (c) showing a void ratio in the range of 1-5%, which is an excellent result

of FPC generally consists of the following main layers from bottom to top: the base material, which can be almost any flexible material, e.g. PET, PEN, PI paper. The second layer can be either a conductive adhesive paint, e.g. silver, or an aluminium sheet, depending on the method. Finally, depending on the structure, the previous one is coated either with copper film via plasma metallization or with an insulating protective mask, as shown schematically in **Figure** 5a. Cross sections of the produced combined FPC without and with LED were made to investigate the films. The different layers are clearly visible and spread continuously over the entire surface. Furthermore, the soldering material is homogeneously distributed on the metallized copper, which is very essential for the thermal management of the flexible LED luminaires, as shown in **Figure** 5b. How the case will change after mounting with LED is shown in **Figure** 5c. No voids are visible at the interface between the LED pads, the metallized copper and the solder. A more detailed view of the interface between the solder and the metallized copper is shown in **Figure** 5d.

The systems of the combined layers produced via this technology overcome the challenges of mismatch in the lattice constant and dangling bonds on the surface and enable reliable flexible luminaires. In addition, the new state-of-the-art technology enables a variety of new combinations based on printed electronics, which can be used for LED applications in many areas, such as in portable light therapy. Please note that there is still a continuous progress for intelligent new solutions available via this technology for offering further technical and economical advantages.

Lessons Learned

A close cooperation with partners, allowed a successful implementation of a serial production line for plasma metallization of flexible LED lighting applications. The advanced technology is based on plasma metallization at atmospheric pressure while maintaining a high coating speed at a temperature of less than 80°C. It has two different sequences; the first requires the use of an adhesive layer on the substrate, e.g. silver on the substrates. This stage ensures the production of a reliable metallic coating layer. The layers are solderable. Thus, any flexible substrate can become flexible electronic circuits and can be assembled with electronic components including the thermally critical substrate. The other one is based on a polymer-based material applied to aluminium foils, which are then structured into the wiring for the electrical circuit. Finally, the plasma metallization is conducted to the system.

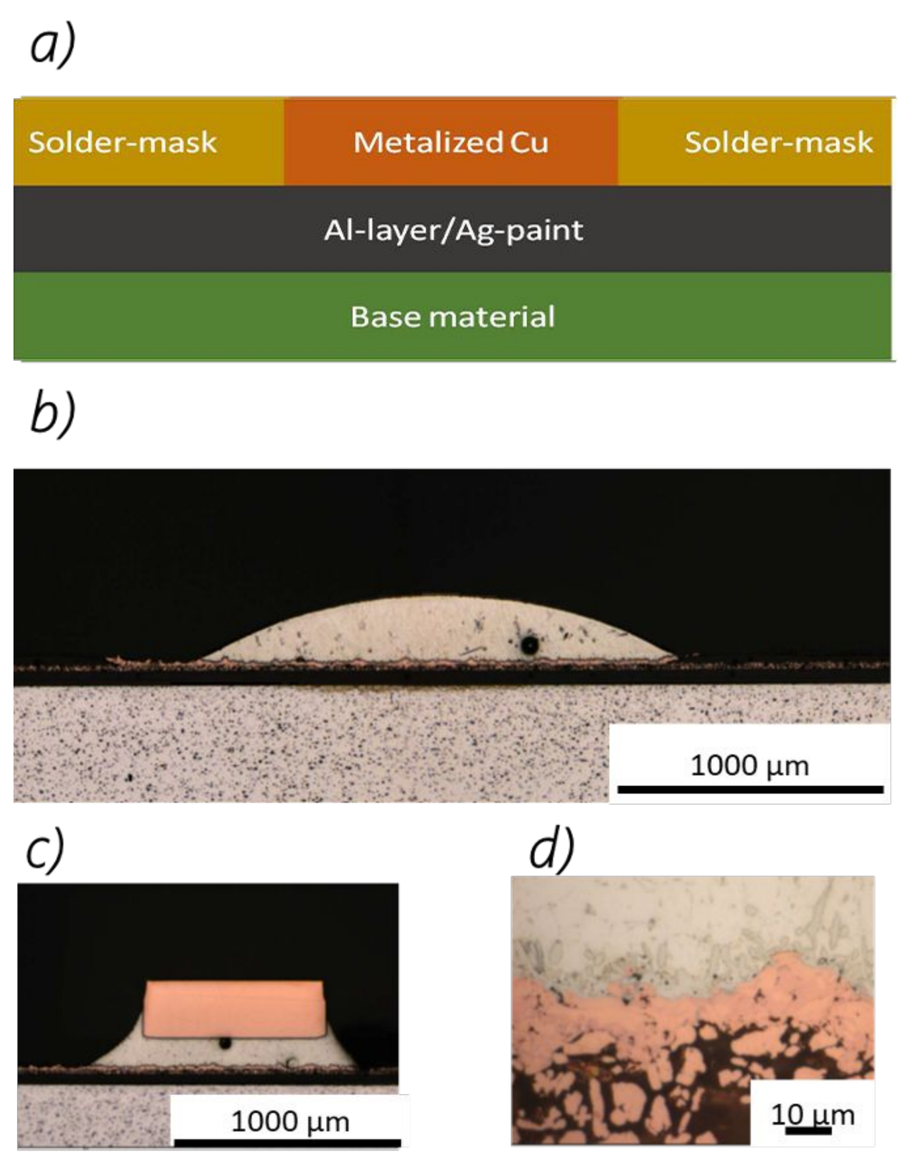


Figure 5: The scheme (a) roughly illustrates the cross-sectional structure of the final layers obtained after atmospheric plasma metallization. Microscopic image of the cross-section of the finished metallized FPC (b) with a drop of soldering paste on top. It shows the perfect interface between the metallized copper and the soldering paste. Microscopic image of the cross-section of the assembled LED (c) on the top of the plasma-metallized FPC; note that the focus in this image is on the interface between the metallized copper layer and the base material as well as the soldering paste after the production steps are completed. The detailed microscopic image of the cross section (d) shows only the overlap between the metallized copper and the soldering paste. It is clearly visible that there is no discontinuity between the two layers

Conclusion and Outlook

Both types of design offer new opportunities to make current lighting systems more advantageous, such as reducing the logistical costs of production in Europe. In addition, the deposited metallic layers have excellent homogeneity and maintain reliable reproducibility even in large scale processes. The innovations in LED applications based on this technology are too numerous to list here. The goal for the near future is to expand and grow the current business continuously, and to create much more exciting LED products that can perform excessive useful functions. ■

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ABOUT THE AUTHOR

Yaser HAJ-HMEIDI: Yaser is a graduate physicist with a master's degree in semiconductor physics with a focus on light-emitting devices. He also holds a master's degree in electrical engineering/optoelectronics. His theoretical knowledge and extensive experience are his excellent tools for comprehensive support in current and future projects. Applications vary from indoor, outdoor and industrial lighting. Light is a very powerful natural phenomenon and its physics still offer many advantages that need to be researched and exploited.

Lighting Controls – Futureproofing and Open Standards Lead the Way

The market for smart lighting and connected controls is growing at a good speed and will continue to do so in the foreseeable future. However, growth could always be higher. Pål Karlsen, Research Analyst for Lighting Technology at Omdia, shows that a conscious strategy of futureproofing can help reduce risk perception among buyers and secure contracts. Research suggests that lighting control protocols is viewed an essential component in futureproofing. Furthermore, Omdia forecasts say that various open protocols will become growth winners over the next couple of years.

THE global market for smart lighting and connected controls is estimated to have been at USD 10.3 billion in 2018. This is expected to have more than doubled by 2023. Average sales prices are expected to continue to go down, but this also means that volume is going strongly up. Customers are still chasing further energy saving gains and are starting to see opportunities for increased revenue, comfort and productivity through lighting. Lighting installations can now even become a revenue generator for the buying entity.

The residential segment is expected to continue to show strong growth numbers. End users there are now seeing the possibility of reduced entry barriers through the expected demise of the lighting-specific hub/bridges and can connect the light sources directly to devices such as their smart speaker or similar. This makes it even easier for customers to create smart homes and take this into the mass market.

Demand for smart street lighting is also expected to see significant demand for smart city projects. The commercial market is also expanding at a good pace. Lighting controls ability to help energy saving is a recognized truth and we are seeing promise in verticals such as retail, education and healthcare. Education and industry knowledge are increasing, and this is an important driver for the penetration of lighting control systems.

Smart Lighting Market

The market outlook is dampened by buyers who are hesitant to buy expensive equipment that might be outdated in a few years and if the seller will still be in business by that point. Research shows that futureproofing can be a great way of showing buyers they can negate these risks. One of the ways of future-proofing is to choose popular open protocols that have the possibility of capacities for the future.

Open protocols are usually backed and developed by the industry and representatives for the wider system of stakeholders. The fact that they are more or less open to use helps a wide variety of actors come in and launch their solutions and innovations in a way that is driving the market forward. It also means it's easier to have other actors come in and use existing infrastructure when upgrades are needed.

Futureproofing as a Sales Argument

With the continuing revolutions of LED, IoT, Smart Home, 5G etc., customers are looking for equipment with long lifetimes and many rapidly developing technologies in the start phase with uncertain futures. The industry is also becoming ever more fragmented. This poses risks for big and important investments with long contract times. Many decision makers are risk-averse and also not technology experts, and research shows futureproofing becomes an important sales argument.

A recent report into the financing of smart city projects has crystallized this argument in the case of public sector buyers, but this is also a general perception for many types of buyers. It is not just technological uncertainties that play in, but also questions of whether companies can fulfil their obligations in such a long time. Procurement contracts can be 20 years long. Customers also worry about vendor and technology lock-in. They want to ensure they won't invest in technology that is quickly superseded. Open protocols with an eco-system surrounding the technology is a way of assuring the availability of substitute suppliers should the unfortunate happen and the contract supplier goes out of business.

Suppliers can also reduce risk through innovative business models. Councils and any public sector groups are very risk adverse. Success depends on removing as much risk as possible and being very clear on the return on investment or reducing upfront cost to the city. Often those making the funding decisions are not technology experts. Futureproofing and a clear business case help reduce the risk of investment.

The Role of Lighting Controls

With the digitalization of current mainstream lighting control systems, communication protocols are becoming the backbone of advanced lighting control networks. A suitable protocol not only ensures the efficiency and interoperability of the current devices in the network, but also should be future proof, which means that when the lighting system is facing new technology upgrades in the future, the protocol should be still compatible as much as possible and update cost should be minimized. Lighting systems are no longer standalone, but usually integrated into building management systems and connected to the internet. More requirements and regulations would be needed for data security, interoperability, and transmission speed.

Wired solutions have historically been the standard solution for most lighting control systems. However, installing some wireless systems can offer some benefits over wired equivalents. For example, the installation time and cost can often be reduced because installers do not have to run cables. The easy installation of wireless lighting control even encourages DIY installation and configuration by owners.

Once a lighting network is formed and requires future expendability for automation parts such as sensors, a wireless network can offer the flexibility to extend the network in the future. Although some commercial applications of wireless controls lead to concerns about security or interference, others are taking up this technology quite quickly, particularly those with little new construction and many hard-to-access areas, for example, industrial/manufacturing and warehouse/storage applications.

Although there are benefits from a completely wireless system, the value proposition of communicating wirelessly between controllers is not as great as wireless communication to field-level equipment including switches and sensors. Communication between central controllers also typically has a higher bandwidth requirement, which requires greater power and is subject to greater interference, but field-level wireless communications to luminaires, sensors, and switches are more commonly low power and low bandwidth. Due to these requirements, field-level devices are often on a self-healing mesh network, where each device both transmits and receives data, leading to longer ranges and greater redundancy.

Similar to human languages, efficient and competitive connectivity protocols therefore have been developed to allow device to device communication and higher-level application customizations. With the rapid growth of Internet of Things (IoT) technologies, more and more new protocols for lighting have been introduced, and existing protocols are continuously upgraded to keep up with the pace of application innovations, a well-designed future proof protocol can be a strong driving force behind the development of smart and connected lighting industry. These protocols, no matter if old or new, can be distinguished by their basic physical layer: Wired protocols and wireless protocols, or by the types of transmitting signals: Analog protocols and digital protocols.

The Role of Lighting Control Protocols

Analogue controls are cheap and very easy to use and set up. They have been around since the incandescent age and installers are familiar with them. Protocols like 0-10V/1-10V are compatible with LED, fluorescent and incandescent lamps, but the ‘smart’ requirements like colour temperature tuning, individual fixture control and integration with various sensors has made digital controls a necessity. In this way lights can be controlled to act on commands according to logic determined by users, which is developed on the basis of lighting ergonomics. Thus, lighting systems can improve energy performance and improve people’s comfort.

Research shows that DALI is the largest wired digital open protocol in the world for lighting. This is particularly due to a strong presence in Europe. DALI only requires one single cable with a two-way signal where devices can communicate with each other. This decreases the need for a central controlling device. You do not have to replace the cabling if you want to change the lighting in a room, allowing for flexibility for future demands. The ‘bus’ topology of the protocol can easily be integrated into other topologies such as ‘star’ and ‘mesh’. DALI released an updated version of the protocol in 2017 called DALI-2. This has laid the groundwork for the continued success of the DALI protocol. DALI-2 is better suited for systems with colour-tuning, daylight harvesting and multi-platform compatibility. It is often combined with Building Management platforms such as KNX or BACnet via a gateway. The proven success and flexibility of this is alleged to be a major reason for the success of DALI. Proprietary protocols are also big, but are not expected to be as dominant as they have been. This is to a large extent due to an expected increase in wireless protocols, but also a preference for open protocols in the market.

Power over Ethernet (PoE) is also a possible way of doing wired lighting. It does cover the need for bandwidth and allows for great opportunities for granular control. However, it does have complications with driver compatibility and the need to involve IT departments. Furthermore, it is also holding closed standards making it difficult to build an eco-system around the technology. Direct integrated lighting control from building automation protocols such as BACnet and KNX is still quite rare. Futureproofing concerns on the buyer’s side has most often been concerned with making sure lighting systems are compatible with these protocols.

Wireless lighting systems with point-to-point or star topology has been popular due to the cost efficiencies of centralizing the processing in the central node. This has particularly been the case in smaller residential applications where Wi-Fi and early Bluetooth has had a meaningful presence as DIY solutions. However, mesh solutions are now set to take dominance. These systems have significant advantages compared to centralized topologies. Data can be exchanged with any node, leaving the system more scalable and robust. In mesh networks, each node can both receive and transmit signals to each other via multiple connection paths, which means each node is also acting as signal repeater and booster, and network range can be greatly improved. While the added intelligence in the various nodes is disadvantageous in terms of cost, the scalability and data capacity are believed to make up for this.

EnOcean has enjoyed some early success, particularly in Europe. It is widely installed and works well with HVAC and does not risk interference with 2.4GHz systems. This protocol is expected to see lower growth than Zigbee and Bluetooth, mainly due to cost, it being supplied through one vendor only and the lack of mobile device presence that Bluetooth has. The Zigbee standard has had a mesh network for some time and is widely used within smart lighting applications, particularly in the residential segment. The big advantage with Zigbee has been its scale and low power consumption, making it ideal for relatively low complexity systems and great for use with wireless sensors, switches and dimmers. Zigbee requires gateways and thus increase complexity. Zigbee has been used widely by lighting manufacturers such as Signify and Osram as being included in devices by other heavyweights such as Amazon and IKEA. The latter joined the Zigbee board of directors in late 2019 and appears set to utilize Zigbee technology going forward in their smart home prod-

ucts. Amazon has also started to integrate Zigbee into some of their extremely popular Echo devices.

Originally designed for short-range communication with digital equipment such as headphones, Bluetooth has the advantage of being present in smart-phones and tablets all over the world. The commissioning and recommission process is expected to be much simpler and less costly. This scale is proving to be a major advantage in many ways, including steadily decreasing costs and brand awareness. The technology was used widely in the earliest DIY applications of smart lighting with point-to-point control of light bulbs. Success was limited as the smart phone app turned out to be to difficult to use compared to switches. It has also been used in conjunction with other protocols such as DALI or 0-10V via a gateway. However, now it is coming in a very big way with Bluetooth mesh. This solves the limitation of scalability compared to the previous standard. It is compatible with most devices and net- works and can transmit data at around 2 Mbit per second. The futureproofing in terms of scalability, ubiquity and bandwidth for updates are alleged to be major selling points for customers.

Conclusions

While the market for smart lighting is growing at good rates, competition is fierce and vendors will be eager to get a leg up on the competition. The long equipment lifetimes, many new technologies and application areas has meant that buyers are valuing futureproofing as a sales argument. The choice of lighting control protocol is an important part of futureproofing a lighting system. Research forecasts that open protocols such as DALI, Zigbee and Bluetooth will be the growth winners over the next few years in smart lighting and connected controls. The main reason for the winners being their flexibility, most notably scalability. Open protocols have the advantage of allowing eco-systems to be built around the technology and thus inviting further innovation and safeguarding buyers to a larger extent against lock-in traps. ■

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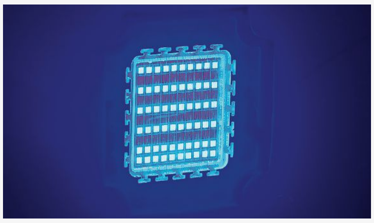

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A COB LED sample from BRT LED without phosphor coating showing the basic structures

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