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Review

LpR

The Global Information Hub for Lighting Technologies

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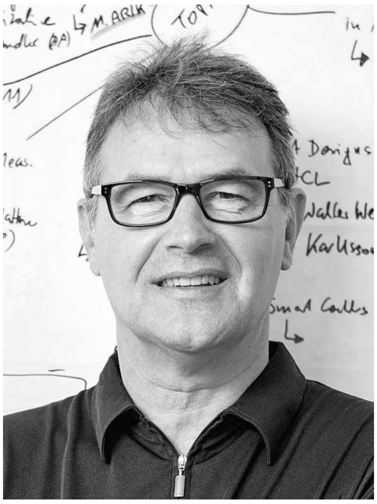
TTB: Dr. Ken T. Shimizu

Research: Hybrid Quantum Dot LECs

Environment & Quality: Energy Saving & Glare

Events: LpS Post Show Report



Five Lighting Trends

On September 26th to 28th, 2017 the 7th international LED professional Symposium +Expo together with the 1st Trends in Lighting Forum & Show took place in the renowned Opera House in Bregenz. 1,600 delegates from 38 countries attended the 110 lectures and 7 workshops and later had discussions with 125 exhibitors about the latest trends in lighting technologies, connected lighting and lighting applications. The TiL 2017 covered smart lighting topics dedicated to architects, lighting designers, lighting OEMs and IoT system integrators. The successful approach of combining these two events bridged the gap between the world of technology and engineering with the world of design and architecture.

There were five obvious outcomes that are important enough to repeat here:

Firstly, providing the "right" light is the elementary function of any lighting system. The light has to be spectra-wise optimized and further adapted to the needs of the specific application and its usage.

Secondly, the quality of light has to stay in the center point of any development. Human Centric Lighting is one aspect trying to find the best values for humans. Quality also includes environmentally friendly, sustainable and re-usable lighting.

Thirdly, IoT and/or more common connected lighting are major trends and every development has to take care about the connectivity to the environment and to the world of the Internet. At the very least, lighting systems have to be ready to connect via wired, wireless or LiFi.

Fourthly, LEDs are the light sources of the future and they show further improvement potentials based on new technologies such as Quantum Dots. For specific applications, Lasers and OLEDs will be applied and will show benefits against LEDs.

Fifthly, every known engineering development (e.g. from Smartphones) will continuously be applied in lighting designs respectively miniaturization, integration, closed-loop controls with more sensors and the change from hardware to software based approaches.

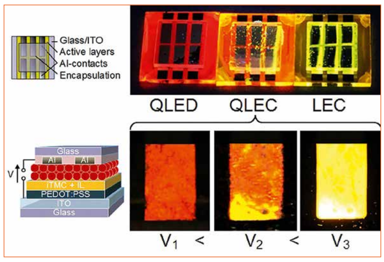
Besides the developments in technologies and applications, new business models such as Light as a Service were also discussed.

In this issue of LED professional Review (LpR) we've put together a full post-show report, an interview about Quantum Dots and also the winning paper of the LED professional Scientific Award, 2017.

This issue will bring you a step closer to the latest lighting trends. Enjoy!

Yours Sincerely,

Siegfried Luger
Publisher, LED professional



ADVERTISING INDEX

Klaus Ludwig
Mr. Ludwig is head of Osram's Central Light Measurement Laboratory I LMA LMs in Augsburg. He has 34 years of professional experience in the laboratory, 25 of which he has been the laboratory manager and quality management representative.

At the Vereinigte Motorverlage, headquartered in Stuttgart he led the laboratory for comparison tests in the entertainment and communications electronics segment, as well as in the optical sector for the magazines: audio, autohifi, connect, colorfoto, plus, stereoplay, video and videoaktiv for 17 years.

Since November 2008 he has been working as a segment manager for luminaires and multimedia at TÜV Product Service GmbH.

THE VALUE OF HIGH-END LABS FOR HIGH QUALITY LIGHTING

With the relocation to the Augsburg site in 2015, the Osram laboratory equipment includes a number of integrating spheres of different sizes up to 3 meters in diameter, several gonio-photometers A/B/C types, a rotary mirror light distribution meter and a hemispherical goniometer with a measurement radius of 2.65 meters, optical bench measuring systems with up to 35 meter measuring distance, corresponding high-quality photometric receivers and spectral radiometers as well as the necessary components for the electrical operation of lamps - according to customer or standardized specifications.

The competence of the lighting engineering laboratory has been confirmed by our DAkkS accreditation for lighting technology (luminous flux).
All photometric and physiological test methods and calculations for the determination of light properties and light quality are also accredited in the test laboratory.

An outstanding measurement technology, exceptionally high know-how and the continuous traceability of measurements to national and international standards ensure internationally recognized results. For this reason, the use of calibration lamps, which Osram manufactures in Augsburg, also guarantees a consistently high standard in all our quality laboratories and measurement services worldwide. Through regular comparisons with the PTB and through the participation in international round robin test with the best comparative results we control and ensure the permanently high quality of our services.

To see well we need good light quality. In order to be able to determine the light quality of lamps and lamps, photometric and radiometric measurements must be carried out. Only on the basis of broad and well-founded equipment and a recognized competence, a lab can offer the customers a comprehensive service for lighting technology questions.

For example, to reliably, repeatedly determine photometric and radiometric data from spotlights, countless influences which can falsify the result must be recognized, corrected or eliminated.

Light, however, has also many other facets which may affect humans. Daylight controls many biological processes in our body and thus our inner clock. It depends on the light whether we are active or tired, whether we can concentrate and feel comfortable. Some studies have shown that the reaction times can be improved when light contains a higher amount of blue radiation. We also feel better during the day with appropriate light, and our ability to concentrate increases. In addition, light promotes the formation of serotonin, a messenger that is known as a happiness hormone and is positive for us. - It's all a matter of the spectrum, intensity and distribution of the light!

Based on the spectral distribution of a light source, accepted statements can be derived for photometric properties (luminous flux, luminous intensity, luminance and luminous intensity), colorimetric properties (color shift, CCT, color rendering properties, etc.) as well as photo biological properties and effects of light sources. Furthermore, potential hazards for possible eye damage caused by radiation sources can be determined and made transparent by giving recommendations for a safe use (optical radiation safety). Gonio-photometric measurements in the far-field and near-field, can provide necessary information and data structures for light planning and simulation calculations (ray data processing). And finally, the evaluation of properties for the energy efficiency of lighting systems is a matter of electrical measurement technology for the system operation of lamps and luminaires.

In Brief: Well equipped lighting laboratories and a high competence are essential to fulfill all these tasks and to guarantee high-quality lighting. ■

K.L.

Samsung Introduces Highly Advanced, Enhanced CSP LEDs

Samsung Electronics announced two new additions to its chip-scale package (CSP) line-up: LM101B, a 1W-class mid-power LED, and LH231B, a 5W-class high-power LED. Built with enhanced CSP technology, the new LED packages deliver industry-leading efficacy and reliability for spotlights and high-bay lighting applications.

Samsung's latest CSP LEDs for spotlights and high-bay applications concentrates its light output toward the top because of the TiO_2 walls around the chip surface

The LM101B and the LH231B packages are based on Samsung's state-of-the-art, fillet-enhanced CSP (FEC) technology, which forms TiO_2 walls around the chip surface to reflect its light output toward the top, while previous-generation CSP LEDs create a wider beam angle by emitting light through the top and side surfaces of a package that has been coated in phosphor film, acting like a plastic mold in conventional EMC-based LEDs.

With their FEC design, the packages provide a higher light efficacy level compared to Samsung's previous generation of CSP LEDs. The more focused beam also helps to eliminate cross-talk between neighboring packages and enables the new packages to be placed in close proximity to one another, offering greater flexibility to luminaire designers.

"Our FEC line-up represents an outstanding set of highly advanced LED component solutions that accommodates a variety of luminaire designs from below 1,000 lm to well over 10,000 lm," said Jacob Tarn, executive vice president of LED Business Team at Samsung Electronics. "Samsung will continue to pave the way for widespread adoption of CSP technology in the mainstream lighting market, bringing greater performance and cost benefits to a growing number of lighting manufacturers."

LM101B: 1W-class mid-power FEC
The LM101B features the highest efficacy among currently available mid-power CSP LEDs with 200 lm/W (Ra 80 5000 K, 65 mA, 25˚C). With low thermal resistance (2 K/W) and high reliability (105˚C, L90>50000 hours, 0.5 W), the LM101B has been optimized for spotlights and high-bay applications where high efficacy and long lifespan are required.

LH231B: 5W-class high-power FEC
With an operating current of 2 A (max. 6 W), the LH231B offers an efficacy of 170 lm/W (Ra 70 5000 K, 700 mA, 85˚C). This is the same high efficacy level offered by ceramic-based high-power LEDs, one that can bring a high degree of cost-effectiveness when applied to high-bay applications that require an output between 5,000 and 10,000 lm. Thanks to Samsung's FEC structure, the 120-degree beam angle allows for simple optic designs, making it also suitable for outdoor applications, such as street and parking lot lighting. ■

Lumileds Adds New Deep Red, Far Red as Well as CoB Offerings for Horticulture Lighting

Lumileds has introduced three new products in its Luxeon SunPlus Series of award winning LEDs for horticulture lighting. The Luxeon SunPlus Series is the only line of LEDs on the market to be tested and binned by photosynthetic photon flux (PPF). The portfolio of colors enables wavelength tuning for maximum crop yield in both greenhouse and vertical farming applications.

The Luxeon SunPlus 35 Deep Red and Far Red LEDs combine with Royal Blue to enable spectrum customization, while the new Luxeon SunPlus CoB Purple ramps Photosynthetic Photon F

The addition to the Luxeon SunPlus 35 Line of Far Red and Deep Red will enable designers of vertical farm and interweaving fixtures to tune the spectrum specifically for the crop being grown. The new Luxeon SunPlus CoB Line, available in Purple, is designed for greenhouse applications where attaining high PPF and fast time to market are top priorities.

The Luxeon SunPlus 35 Line is optimized for vertical farming in shallow tiers so uniformity is optimized at very short distances. The Deep Red (650-670 nm) and Far Red (720-740 nm) wavelengths join the existing Royal Blue (445-455 nm), Lime (broad spectrum) and three shades of Purple with varying contributions of blue (2.5%, 12.5% and 25%) in a 3.5x3.5 mm format. "These essential red wavelengths are combined with blue to give the exact spectra needed for each crop. Our Horticulture Lighting Calculator is especially helpful in this context because lighting manufacturers can experiment with LED ratios and spectral power distributions before building the fixtures," said Jennifer Holland, Product Line Director of the Luxeon SunPlus Series.

Customer success and market adoption of the Luxeon SunPlus 35 Purple and the need for even greater PPF in a single device led to the development of the Luxeon SunPlus CoB Purple (12.5% blue) product. In contrast to vertical farming where lighting is positioned a short distance from plants, greenhouse lighting requires deep penetration into the plant canopy, which is achieved with a directional CoB. The CoB portfolio complements the Luxeon SunPlus 20 and 35 Lines, which offer a variety of colors to optimize the spectrum for greenhouse applications. The CoB form factor also means that standard optics, holders and drivers are available to help manufacturers accelerate time to market of their fixtures. "The chip on board approach allows us to maximize PPF to as high as 350 μmol/s from a single source," said Holland. The Luxeon SunPlus CoB Purple is available with 15, 19 and 32 mm light emitting surfaces. ■

Osram Launches Compact Ceramos Mini LEDs for Mobile Devices

Osram Opto Semiconductors is expanding its existing portfolio for flash applications with a product featuring a specially developed chip sized package (CSP). With Ceramos C, Osram is following the trend for miniaturization as the new LED is the smallest yet in its product family. It is ideal for flash applications on smartphones etc., producing perfect illumination for every snapshot.

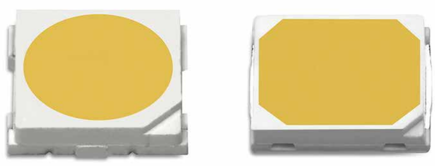
Osram's new Ceramos C generation is the first without a ceramic platform, making it extremely compact, hence it is highly versatile

The new Ceramos generation no longer has the conventional ceramic package and bond wiring of its predecessors. Instead it utilizes a CSP platform (chip sized package) specially developed by Osram Opto Semiconductors. This ensures that the entire chip surface is uniformly illuminated and that there is virtually no loss of light. Also Ceramos C has a smaller footprint: Measuring just 1.4x1.4x0.21 mm, it is three times shallower than its predecessor but produces the same brightness despite its smaller package size. This gives designers greater freedom. Ceramos C is suitable for use in smartphones or tablets that need a compact LED particularly for the front camera, but also for the main flash and for the flashlight function. With a typical color rendering index greater than 80, the LED offers natural colors no matter where it is used. Ceramos C has a luminous flux of 260 lm and a color temperature of 4,500 K.

“With our new Ceramos C, it will be even easier to take great pictures and selfies. The excellent illumination enables even absolute beginners to get fabulous results”, said Fiona Mak, Marketing Manager at Osram Opto Semiconductors. “Despite its small size, Ceramos C is extremely powerful and a real bonus for end customers. Our Ceramos C fits perfectly with the trend for miniaturization because it’s small enough to be easily installed in even the thinnest smartphones and tablets.”

Lumileds Expands Award-Winning Luxeon Stylist Series to Mid Power Packages

Lumileds announced a breakthrough in fashion retail and fresh food markets lighting. The transformative Luxeon Stylist Series is now available as a comprehensive portfolio, which includes new mid power packages in addition to the existing highly successful CoB, products, all built with the award-winning LED technology.



LUXEON 3535L LUXEON 2835

To allow for a complete retail and fresh food market shopping experience, the Luxeon Stylist Series is now also available in mid power 3535 and 2835 packages

"Customers using our Luxeon Stylist Series LEDs are so pleased with the light quality that they want the identical look and feel in all parts of the retail shop or market regardless of fixture type," said Eric Senders, Product Line Director for the Luxeon Stylist Series. "Lumileds enables this with our mid power additions to the Stylist Series, achieving a consistent shopping experience."

The Luxeon Stylist Series with CrispColor Technology for retail environments essentially provides a higher color gamut, enabling richer colors, brighter whites and increased contrast between colors. Previously available in CoB packages, CrispColor Technology is now available in Luxeon 2835 3V as well as on the popular Luxeon 3535L HE package for diffuse and linear applications, enabling the manufacture of TLEDs, troffers and other luminaires.

For fresh food markets that sell fresh meat, marbled meat, produce, fish and bread & pastries, Lumileds customers have determined that the freshness of the food products is accentuated by the Luxeon Stylist Series FreshFocus Technology. FreshFocus Technology also utilizes a higher color gamut and is now offered on either the Luxeon 2835 3V LED or Luxeon 3014 package. With FreshFocus Technology, meats, fish, baked goods and produce are highlighted in their most appealing light and are more likely to be purchased.

Known to deliver the highest quality of light, the Luxeon Stylist Series is now available in mid power packages to power linear diffuse LED lighting throughout fashion retail venues and fresh food markets. ■

Everlight Introduces the NIR-C19M Infrared LED Series for Iris Recognition

Everlight Electronics CO., LTD., a leading player in the global LED and optoelectronics industry, launches the NIR-C19M series with a wavelength of 810 nm which exert the clearest contrast effect to read the pattern of the iris. The recognition process is precise, quick and features excellent heat dissipation. This makes it perfectly suitable for iris recognition applications in security surveillance systems (access control) and portable handsets.

Everlight's 810 nm infrared LED NIR-C19M series for iris recognition/surveillance applications (structures and materials depend on demand of client)

Following the market demand and the resulting development of appropriate high technology, the concept of "body is access code" has been integrated into many systems and devices. Smart biometric identification allows measuring the users' unique patterns in the fingerprint, voice, iris and face quickly and easily to avoid the problem of recalling traditional long passwords. Infrared LEDs for non-contact optical identification have the advantages of compact size, strong security and quick recognition speed which make them to an increasingly sought-after advanced technology around the world.

Everlight's NIR-C19M series for non-contact optical iris recognition adopts a molding manufacturing process. Compared to the traditional glue dispense manufacturing process, molding results in a smoother surface which not only enhances the look but also increases reliability. The NIR-C19M series works with a wavelength of 810 nm and uses an advanced ISP image processor together with CMOS sensor to receive the infrared reflection by the human eye to authenticate iris identification. Its unique optical design achieves a clear high reflection rate, a small angle (FOV = 25°) and a radiant intensity of up to 2,700 mW/Sr below / less than 1000 mA. The heat dissipation with a thermal resistance of 4.38°C/W is superior to any other competing product in the market. The device has also passed IEC62471, a safety regulation to prove that no harm arises to human eyes and skin. In addition to these excellent optical features, the dimension of NIR-C19M series is merely 3.5x3.5x2.3 mm which is particularly desirable for space-constrained portable devices.

Everlight integrates its professional R&D, Sales and Marketing teams to continuously pursue innovation and technical breakthroughs, is able to provide the customers with the most comprehensive and top-quality LED related solutions. ■

LEDiL Introduces Four New Optics: Florence2, Gabriella, Carmen & Stella

In October, LEDil announced the release of four new products in all segments: indoor, outdoor and linear lighting. The releases include our 3-row linear industrial newcomer Florence2, an expansion of our color mixing family Gabriella, new beams and diameters in the Carmen family optimized for retail lighting, as well as a new spot in the Stella family for lenses up to IP67.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LEDiL's October new highlights from top left to bottom right are Florence2, Gabriella, Carmen & Stella

38 & 45 mm diameter RGB and tuneable white color mixing lens family:
Gabriella is an RGB and tuneable white color mixing family with LEDiL's unique floret-type hexagonal surface ensuring excellent color uniformity. The optic comes with a black holder with positioning pins in both holder and lens making assembly easy and accurate. Gabriella is available with or without tape. The 10° spot and wide beams will be followed by a medium beam in 45 mm diameter as well as in a smaller 38 mm diameter.

Features:
- Special optic surface for uniform color mixing
- Supports the latest RGBW LEDs
- Available in two sizes: Ø45 mm Gabriella, Ø38 mm Gabriella-MIDI
- Holder design allows more space for components
- Accurate assembly with positioning pins
- Can be assembled with screws or installation tape

Typical applications:
- Stage lighting
- Architectural lighting
- Accent lighting

Compatibility:
- Optimized for 5050 and compatible with up to 7070 size RGB LED packages

90 mm diameter up to IP67 family in silicone - Stella-RS:
Stella is a large family of self-sealing silicone lenses allowing ingress protection from dirt, dust and water with a rating up to IP67. STELLA lenses are compatible with the latest COBs guaranteeing enough power to back up your applications. The family consists of various street, wide area and high bay beams. Lens height varies from 11.3 to 39.2 mm and can fit a maximum Ø52 x 6 mm connector. Asymmetric beams compatible with up to 23 mm LES sizes and symmetric with up to 30 mm LES sizes.

Features:
- Massive lumen output with high intensity peak
- Minimum spill light and glare on high mast setups
- Designed with consideration to the whole system cost
- Ideal for floodlighting and sports fields
- Excellent thermal, UV and impact resistance
- Optimized for 23 mm and compatible with up to 30 mm LES size COBs

Typical applications:
- Outdoor area lighting
- Floodlighting and projector lighting
- High mast

Your choice for high quality retail lighting:
Carmen optics consist of high precision lenses and black reflectors ideal for non-glare retail lighting. Sharp cutoff and minimized spill light provides a high contrast between the highlighted objects and their surroundings. In addition the closed design protects the COB from tampering and dust. Compared to metal coated reflectors this results in improved optical performance and outstanding lighting.

Features:
- Redefined reflector performance with smooth cutoff, minimized spill light and low glare
- Perfect selection of beams for general and accent lighting with very narrow spot beam
- Aesthetic and convenient design protects the COB from dust and direct contact
- Ø50 mm, H: 25.5 mm
- Comes with black holder, especially optimized for low UGR applications
- Optimized results and fastening using LEDiL Hekla sockets and connectors

Typical applications:
- Retail
- Architectural
- Track and spot lighting

Linear lighting for 3x11 LED modules with great performance and value:
Florence2 is a lightweight 3-row linear optic family for industrial lighting. Designed with high efficiency and low UGR in mind it provides best in class performance from low to high installations. Compatibility with all Zhaga standard 3R PCBs, including the 2ft long versions, ensures you have a lighting module that is highly versatile and easy to modify for numerous luminaire fixtures.

Features:
- Lighter than original Florence-3R optics with a wider compatibility
- Very high efficiency
- Improved UGR for glare free experience
- Possible to build continuous fixtures without gaps
- Screw fastening similar to previous Florence versions

Typical applications:
- Industrial lighting
- Fluorescent lamp replacement

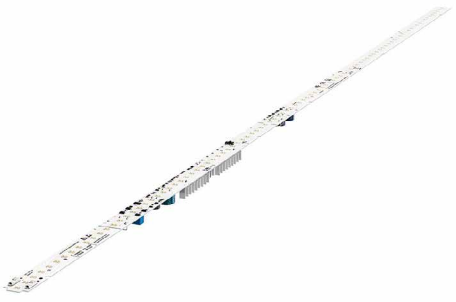
Compatibility:
- All Zhaga 3R PCBs including 2ft long boards

These new products were LEDiL's highlights at the Hong Kong International Lighting Fair. Besides the linear optics Florence2, retail and stage optics from the Carmen and Gabriella families, and the Stella-RS products, the company presented the Linnea family and their newest streetlight additions in the Strada and Stradella families. ■

Tridonic Introduces Complete Package for Luminaire Upgrades

Tridonic announces its LLE AC G1 modules, the first economic single-component solution tailored to linear luminaires. Their slim construction, integrated electronics and availability in different lengths open up a wide range of designs for elegant low-profile luminaires. This solution provides a simple upgrade option for conventional T5/T8 fluorescent luminaires.

Anyone looking to modernize a lighting installation with a view to not only improving efficiency but also minimizing costs will find the right components in the AC range for linear lighting. The driver is already integrated on the board and the module is self-cooling. It is therefore ideal for quick and direct installation in the luminaire - either for upgrading from T5/T8 to LEDs or for replacing existing LED modules. Generation 1 of the LLE-AC modules is available in three lengths (560 mm, 1150 mm and 1450 mm) and in three type-dependent lumen packages (2400 lm, 4800 lm and 6200 lm). These options enable most standard single-lamp luminaires to be upgraded. System efficiency depends on the switchable operating mode - 131 lm/W for High Efficiency (HE) mode or 120 lm/W for High Lumen Output (HO) mode.



LLE AC G1 modules are available in color temperatures of 3000 K, 4000 K and 6500 K with a CRI >80

Main features:

- Module with integrated electronics
- Ideal for linear luminaires
- Economic one-piece solution
- Enables thin designs of luminaires
- Typ. luminous flux (HO) 2,400 lm, 4,800 lm, 6,000 lm, 6,200 lm and 7,500 lm
- High system efficacy up to 131 lm/W (HE), 120 lm/W (HO)
- Color temperatures 3,000, 4,000 and 6,500 K
- Module dimensions 24 x 560 mm, 24 x 1,150 mm and 24 x 1,450 mm
- High color rendering index CRI > 80
- Color tolerance MacAdam 5
- Perfect homogenous light with LINEAR COVER SY Diffuse
- Push terminals for quick and simple wiring
- Simple installation (e.g. ACL ENDCAP PUSH-FIX)
- Self-cooling (no additional heat sink required)
- Long life-time: 50,000 hours
- 5-year guarantee

For upgrading two-lamp luminaires the range includes modules with a particularly high lumen output of up to 7,500 lm. With just one module from this series it is possible, for example, to upgrade a conventional two-lamp T5-2x54W luminaire.

There is also choice of high-quality covers for a wide range of lighting tasks - shelf lighting for example. The ACL Linear diffuser cover provides homogeneous distribution of light.

Upgrades made easy:
The module with integrated electronics, self-cooling, lighting technology and a packet of mounting accessories allows the LLE AC to be installed easily as a retrofit. Upgrading luminaires from broader modules to the new slim design of the LLE AC is made easier with the "Bridge" component, and the ACL push-fix end cap provides an attractive visual finish to the luminaire. Plug-in terminals are used for quick and simple wiring. The upgraded luminaires offer improved quality of light, an impressively long life of 50,000 hours and reduced energy costs. ■

Fulham Launches New 25 W Universal Mains Dimmable Driver

October saw the launch of a new LED 25 W universal mains dimmable driver from Fulham Europe, one of the leaders in electronic lighting components. The new dimmable driver is expected to be very popular as it is designed to be compatible with most dimmers from a wide range of dimming controls manufacturers.

One of the most catching features of Fulham's new LED driver is its support for Dim to Warm LEDs

The driver has been cleverly designed to auto-detect and work reliably with triac, leading edge and trailing edge dimmers, potentiometers and 0-10 V dimming controls. It is fully software controlled to analyze the behavior of all dimmers and is able to dim as low as 12 mA. The driver allows ultra-smooth dimming and linear dimming supporting Dim to Warm LEDs.

As part of the Fulham LumoSeries family of drivers, the new dimmable driver features the lowest inrush current in the industry meaning that more drivers and luminaires can be operated on a single circuit.

With very compact dimensions of just 110x52x23.5 mm, the lightweight plastic cased LED dimmable driver features surge protection, and a low ripple design for flicker-free lighting. It has a very wide output voltage and current, making it suitable for a wide range of LED luminaires and in applications from leisure and hospitality to retail and restaurant. It is suitable for COB arrays through to LED strips.

Complying with all relevant EN certificates and standards, the new dimmable driver comes with a five year warranty so that the power supply matches the reliability of typical LED lifetimes of 50,000 hours. Like other Fulham LumoSeries drivers, the new dimmable driver is engineered to exceptional standards of performance and reliability in LED systems. Highest grade critical components together with design features for thermal management ensure excellent reliability.

An option is also available to program the driver with a USB connected controller. Fulham's TPSB-100 SmartSet controller gives the user the ability to set the current for multiple drivers at the same time without using the driver dispatches. ■

Inventronics Expands Programmable, Low Power LED Drivers with More Design Flexibility

Inventronics new programmable IP20 LED driver is equipped with numerous features as well as a more compact size. With a UL Class P certification, it offers OEMs the driver flexibility they need in their fixture designs and increases their competitive advantage. These low power drivers are ideal for indoor projects such as panel, troffers, downlights and other fixtures requiring a lower profile.

Inventronics' new LUG-025S105DTE offers isolated 0-10 V dimming

The new LUG-025S105DTE compliments the existing 12-25 W programmable driver portfolio and adds a new option with the isolated 0-10 V dimming. Created with a tight tolerance in the low dimming range allows it to offer flicker-free, smooth dimming to 10% giving it a consistent light quality performance. Delivering the full power from 25 W to 13 W applications at almost any output current from 500 mA to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1050 mA makes them ideal for Class 2 applications and reduce the need to stock multiple drivers.

The LUG-025S105DTE operates over a 90-305 Vac / 127-300 Vdc input voltage and approved to UL, FCC, CE and Class P allows it to be used in many countries around the world. They are highly reliable and have a calculated lifetime to be at least 85,000 hours when operating at 80% load with a case temperature of 75˚C. Production quantities are available now. ■

Inventronics Introduces Zhaga Compatible IP20 LED Drivers with DALI Dimming

Inventronics has announced the expansion of their compact, Zhaga compatible line of drivers to include 120W models. These full-featured, constant-current programmable IP20 LED drivers are designed to be extremely cost effective. Providing two product offerings to include 0-10 V, PWM, DALI, AC Dim and multiple timer options increasing design flexibility, the EBS Series utilizes convenient push terminals for an easier installation which can simplify production and reduce installation costs.

Inventronics' new EBS Series is programmable and offers different dimming and timer modes

The EBS Series is suitable for use in outdoor luminaries of Protection Class I and II, built-in use for outdoor applications and they can also be upgraded to become an ‘independent’ LED driver so you can mount them outside a luminaire enclosure for IP20 applications. The Zhaga compatible square design makes it the perfect choice for the more compact and slimmer European street luminaires where the standard driver form may be too large to accommodate. They operate from 176-305 Vac input and the plastic housing is IP20 rated which allows for even more cost reductions when you need a full-featured LED driver but not the costs associated with an IP67 rating.

The new EBS Series offer 2 constant-power, programmable models delivering up to 120 W at output currents from 500 mA to 1500 mA. The EBS-120SxxxDTE models can be programmed for 0-10V, PWM or time dimming with 3 timer modes while the EBS-120SxxxBTE models can be programmed for DALI, AC Dim or time dimming with 3 timer modes.

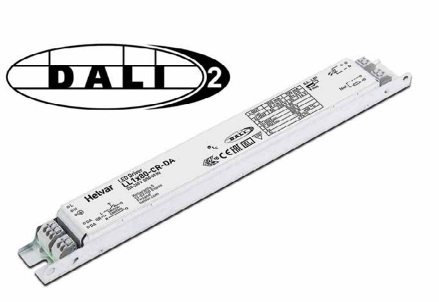
Each highly efficient model provides a 12 V / 200 mA auxiliary output and dim-to-off capabilities making them easier to integrate with sensors and control systems. Their low standby power consumption allows for even greater energy savings. They are highly reliable with a superior level of built-in surge protection, all-around protection which includes: over-voltage, over-temperature for both driver and external LED array, and short-circuit protection as well as thermal sensing and protection for the LED module. The lifetime of these drivers is calculated to be at least 120,000 hours when operating at 80% load.

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

This new family is approved to ENEC, TUV, CE, CB, CCC, KS, Double Insulation standards and the BTE models also include DALI. Production quantities of EBS-120SxxxBTE and EBS-120SxxxDTE series are available now. ■

Helvar to Launch the World's First DALI-2 Certified LED Driver

Helvar is proud to announce that our filtered hybrid dimming DALI LED driver LL1x80-CR-DA is the first DALI-2 certified product in the world. Helvar will launch more products and services that meet the DALI-2 standard, representing a major step forward in Helvar’s development of modern lighting components. Helvar continues to be at the very forefront of this technology, creating customer focused products that enhance the user’s experience of the built environment and reduce costs for property owners.



Helvar's LL1x80-CR-DA is the first DALI2 certified LED driver worldwide

LL1x80-CR-DA features:
- 80 W DALI-2 dimmable LED driver
- 350 mA - 700 mA adjustable current output
- Lifetime (h): 50,000
- Dimming range: 1% - 100%
- More Information: Hybrid Dimming

The DALI-2 standard, the latest version of the IEC 62386 standard for DALI technology, is administered by the Digital Illumination Interface Alliance (DiiA) which certifies that products that carry the DALI-2 logo are compliant with the standard’s protocols. The DiiA, a newly established body which administers the process, is an industry driven non-profit organization that promotes and supports the use of DALI and is driving further development of the DALI standard. ■

McWong Introduces Versatile Smart Sensor Control Platform

McWong International, a leading lighting and controls solutions provider, is expanding its PacWave® portfolio with the introduction of a new smart sensor control platform. The solution encompasses a range of occupancy and motion sensors, dimming power packs, fixture controllers, and mobile apps (Android and iOS) for remote configuration of sensor and dimming settings. The company anticipates future platform releases that will expand user interface capabilities as well as additional components. Engineered for compatibility with Bluetooth® standards, the platform provides exceptional versatility and future scalability.

McWong's PacWave® sensor and controls portfolio is engineered for Bluetooth® standards and can be configured and operated with Android and iOS devices

Comprehensive range of occupancy and motion sensors:
The control platform includes a comprehensive range of occupancy and motion sensors, offering multiple detection technologies, such as passive infrared, ultrasonic and microwave, as well as numerous form factors for challenging applications. Customers can select fixture-embedded models or remote head models for environments where conventional mounting might be difficult, as well as wall switch sensor models for convenience in applications such as small offices, executive washrooms and storage rooms. Both low voltage and line voltage models are offered to provide additional installation flexibility.

Light level and color tuning capabilities:
All the components - sensors, dimming power packs and fixture controllers - enable 0-10v dimming for compliance with energy code bi-level dimming requirements as well as other performance and energy efficiency strategies, including lumen maintenance, high-end trimming and task tuning. If color tuning is desired, for example, in private or open office environments, the new PacWave two-channel fixture controller offers this capability as well.

Wireless control options:
The entire platform is founded on a patent-pending design for flexible integration of various wireless protocols, including Bluetooth® protocols and other commercially-available wireless control protocols. This provides customers with maximum flexibility and simplicity, as it offers unsurpassed compatibility with the widest range of personal and commercial devices worldwide.

Wireless functionality beyond lighting control:
The occupancy and motion sensors and the fixture controller in this control platform feature built-in Bluetooth beacon capability. With this functionality, the platform supports technology applications beyond lighting control, from indoor positioning and navigation, RTLS (real-time location systems), asset tracking and more.

"The PacWave smart sensor control platform is the culmination of many years of listening to our customers and learning from the marketplace," says President and CEO Margaret Wong. "This offering represents our commitment to providing solutions with as much flexibility and versatility possible for our customers."

Casambi Launches Easy-to-Install Wireless Dimmer for LED Strips and CV LED Modules

Casambi, the world's leading provider of smart wireless lighting control technologies, has launched its easy-to-install and simple-to-use, four-channel pulse width modulation (PWM) wireless dimmer for LED strips and constant-voltage LED modules.

Casambi's new CBU-PWM4 wireless dimmer is intended for constant voltage applications like most LED strips and some modules

Cheaper, quicker and simpler to install:
The CBU-PWM4 is easy to add to existing lighting system designs and is simpler, cheaper and faster to install than conventional wired dimmers, because it eliminates the need to run physical wires to switches.

Exceptional ease of use:
Once installed, it enables users to control their LED lights directly, using a smartphone, tablet or computer. This type of wireless control makes lighting systems significantly easier to use and more convenient.

Importantly, because the CBU-PWM4 uses Bluetooth Low Energy (BLE), a technology built into virtually every modern portable device, it doesn't require a dedicated gateway. This removes a cost and single point of failure inherent in any Wi-Fi- or ZigBee-based lighting control system.

With four channels, the CBU-PWM4 can be configured in a variety of ways. This includes four-channel RGBW, three-channel RGB or two-channel tunable white (TW). It can also be set up with four individual channels, individually or jointly dimmable. This configuration can be done by end users, using free iPhone, iPad or Android apps.

Future-proof:
As a Casambi BLE product, the CBU-PWM4 can be used as part of a wider mesh lighting network, which can be expanded over time, using Casambi or Casambi-Ready products.

Timo Pakkala, CEO of Casambi, commented: "The Casambi CBU-PWM4 is an affordable, robust and easy-to-use way to add wireless dimming control to the increasingly popular LED strips and constant-voltage LED modules. For electricians and installers, it will save time and money, while for consumers, it will make lighting systems simpler and more convenient to control, using devices most people already own."

"This product furthers our approach of using robust Bluetooth Low Energy wireless communication to underpin our growing smart lighting ecosystem. BLE has numerous advantages, notably that anyone with a smartphone or tablet can control their lights directly, and that a BLE mesh network has no single points of failure."

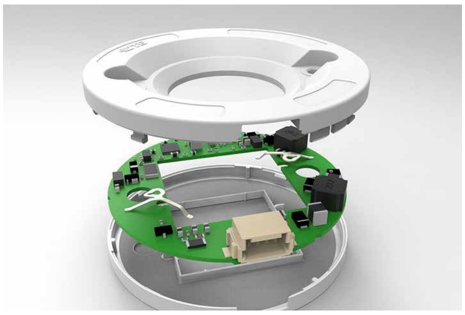
The dimmer has a maximum combined output current of 6A, which can be divided between the four channels. The unit connects between an existing 12-24 VDC power supply and the constant-voltage LED lights. It's protected against over-voltage, over-current and short-circuit scenarios.

Casambi offers comprehensive support for anyone wishing to incorporate the CBU-PWM4 or any other Casambi product, into their building designs. ■

TE's Lumawise Drive LED Holder Type Z50 Solves a Common LED Driver Problem

TE Connectivity (TE), a world leader in connectivity and sensors, introduces the Lumawise drive LED Holder Type Z50 for chip-on-board (COB) LEDs. The new Lumawise drive LED Holder Type Z50, used in track and spot lighting, integrates DC/DC driver and the holder into a single package that enables lighting designers to develop compact, better-looking and more cost-effective lighting products.

TE's Lumawise drive LED Holder Type Z50 integrates a 48 VDC powered constant-current LED driver into the same form factor as TE's popular 5 0mm diameter Zhaga-inspired range of Lumawise LED holders for COB LEDs. Until recently, most LED drivers have been housed in separate boxes, often larger than the light fixture itself, mounted to the side of the luminaire and remote to the COB light source. This configuration required wiring between the light source and driver, creating design and manufacturing complexity for the designer. TE's new holder reduces that complexity and allows more flexibility for lighting design, providing a more cost-effective and aesthetically pleasing solution.



Integrating the driver, the Lumawise drive LED Holder Type Z50 from TE solves common LED driver problems

Applications:
- Track Lighting
- Spot Lighting
- Downlights

Benefits:
- Driver on Board solution for elegant luminaire design
- Designed to meet the requirements of Zhaga book 12
- Provide thermal and electrical connection to four different CoB sizes: 16x19 mm, 19x19 mm, 20x24 mm and 24x24 mm
- Achieve design flexibility with an LED holder available with four different current outputs
- Obtain added functionality with 0-10 V dimming versions available

TE's Lumawise drive LED Holder Type Z50 integrates a 48 VDC powered constant-current LED driver into the same form factor as TE's popular 5 0mm diameter Zhaga-inspired range of Lumawise LED holders for COB LEDs. Until recently, most LED drivers have been housed in separate boxes, often larger than the light fixture itself, mounted to the side of the luminaire and remote to the COB light source. This configuration required wiring between the light source and driver, creating design and manufacturing complexity for the designer. TE's new holder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reduces that complexity and allows more flexibility for lighting design, providing a more cost-effective and aesthetically pleasing solution.

TE is unveiling several versions of the Lumawise LED Holder Type Z50, starting with an on/off model and a 0-10 V (sink and source) dimmable type. Both configurations are available in 350 mA, 500 mA, 700 mA and 1050 mA versions and a typical forward voltage of 36 VDC. Each of these drive currents work with common COB sizes of 16x19 mm, 19x19 mm, 20x24 mm and 24x24 mm, making this LED holder suitable for use with over 70 different types of COBs offered by LED manufacturers. The Lumawise drive LED Holder Type Z50 can be powered by any 48 V power supply and will dim down to 3 percent output current with less than 5 percent flicker. ■

Opalescent PU Potting Resin for LEDs Gives Diffused Light Effect

From high performance LED chip packaging encapsulants and potting materials to thermal management solutions and adhesives to bond lighting assemblies, Techsil provide a variety of materials to provide environmental protection, extend service life and improve light performance. Product chemistries include Silicones, Polyurethanes, Epoxies, Greases and Pressure Sensitive Tapes.

Techsil's new PU resin offers high transmission of diffused light while hiding the underlying electronic components

Product benefits:

- Opalescent in color
- Excellent UV stability
- Non-toxic
- Water resistant
- Tough & abrasion resistant
- Available in a twin-pack which can be mixed by hand and free poured

A rising star in Techsil's portfolio is PU23955 - a new pearl PU resin used to encapsulate electronic devices containing LEDs. It cures to a tough, scratch resistant, opalescent material that diffuses transmitted light. The cured resin allows high transmission of diffused light but hides the underlying electronic components offering the electronics environmental and visual protection.

Techsil PU23955 is a 2-part flexible 55 shore D pourable potting polyurethane which cures to a translucent material that is stable in UV light. Once mixed, the system reacts at room temperature to produce a tough abrasion resistant material with good hydrolysis resistance. There are many applications for this product including assemblies, tracks, LED arrays, luminaires, up lights and lighting.

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

Fischer Elektronik Introduces New Pasty Thermal Conductive Material

Fischer Elektronik GmbH & Co. KG extends their extensive product portfolio of contact materials especially for the application scenarios of the thermal contacting by a fluid gel thermal conductive material with its name GEL S 18.

TIM, equipped with various technical parameters, provide excellent solutions in terms of thermotechnical contacting. Fischer's new TIM, the GEL S 18, is a pasty, gel-like and fully hardening thermal conductive material

To operate electronic semiconductors in a temperature range given by the manufacturer is essentially important for its functional reliability and lifetime. The thermotechnical contacting of the electronic component on the particular heat sink plays a decisive role for an efficient working thermal management. Thermal interface materials, so called TIM, equipped with various technical parameters provide excellent solutions in terms of thermotechnical contacting. The thermal total resistance is composed by an addition of the single thermal transfer resistances along the thermal path which the heat flow has to overcome. The lower the figure of the thermal transfer resistance, the better the thermal conduction, and in sum, the thermal total resistance.

Fischer Elektronik's new thermal conductive material GEL S 18 is a pasty, gel-like and fully hardening thermal conductive material in a two-component system. GEL S 18 is well-suited for a compensation respectively filling of small or big empty spaces in electronic devices such as the mounting of PCBs on heatsinks.

The viscoelastic paste has a very good construction flexibility connected with excellent adhesive properties. This allows an easy handling as well as a secure mounting of the components to be contacted. Furthermore the material characterizes itself by a very good thermal conductivity with low thermal impedance as well as a wide range of operating temperatures.

GEL S 18 is easy, also fully automatic, dispensable and can be deformed effortlessly with lower compressive force whereby the load on the electronic components is reduced significantly which otherwise would lead to early functional failures of the device or to damage of the PCB.

The material is listed with UL 94 V-0 and durable six months at a storage temperature of 25°C. The pot life at room temperature is 60 minutes with the associated hardening time of 300 minutes at room temperature and 10 minutes at 100°C. The article GEL S 18 is supplied in a 50 cc double chamber cartridge with three additional static mixing tubes as a standard. Optionally, an applicator gun for this kind of cartridge is available. ■

GlacialTech - New Igloo SR Series Heatsinks of 300 mm Diameter

GlacialTech, the diversified lighting and thermal solution provider, announces a new series of heatsinks using stamping technology with a patented process suitable for high wattage LED bay light applications from 250 W to 500 W. The new Igloo SR series heatsink expands its models of 300 mm diameter: the multiple chips version (Igloo SR250-3M, Igloo SR300-3M, Igloo SR400HP-3M, Igloo SR500HP-3M) and the single CoB version (Igloo SR250HP-3S, Igloo SR300HP-3S, Igloo SR400HP-3S, Igloo SR500HP-3S).

GlacialTech's new Igloo SR series is ideal for bay light applications from 250 W to 500 W

Features:

- Rated for 250 W to 500 W single CoB or MCPCB LEDs
- Integral heat pipes for more effective heat dissipation and longer service life
- Light-weight aluminum heatsinks are manufactured using the patent stamping process
- Available as a semi-knock-down kit with power box, bracket, glass lens and waterproof rubber

The Igloo SR250-3M and Igloo SR300-3M of the multiple chips version without the heat pipe, the Igloo SR400HP-3M and Igloo SR500HP-3M with 2 heat pipes situated in the central of the heatsink help carrying heat from the bottom to up quickly. The single CoB version with 2 heat pipes situated in the central of the heatsink and 3 heat pipes at the bottom, making the heat dissipated evenly from the entire volume of the thermal module, and finally dissipates heat into the surrounding air.

The multiple chips version with the thermal resistance from 0.2411°C/W to 0.2861°C/W, and the thermal resistance from 0.2903°C/W to 0.3516°C/W of the single CoB version. These lightweight AL1050 aluminum heatsinks are manufactured using the patent stamping process that can provide high performance cooling at a very cost-effective price by maximizing surface area. This design enhances with integral heat pipes, achieves significantly better thermal efficiency than standard heatsinks.

The new heatsinks cut energy costs by keeping temperatures low to enhance LED efficiency, and in the long term, prolong LED and driver life by safely removing harmful thermal energy that gradually damages components.

In addition, GlacialTech also offers a bay light knock down kit that incorporates these new heatsinks. This set of easy-to-assemble bay light components includes a power box for housing the LED driver, a bracket, as well as glass lens and waterproof rubber. This semi-knock-down kit (SKD) allows lighting system integrators to easily assemble a custom lighting solution that makes best use of the LED modules and LED drivers of their choice.

Except the knock down kit, GlacialTech also offers the bridging accessory which can easily integrate the thermal modules with a number of LED drivers in the market. ■

Lumibright Bendable LED Profiles for Curved LED Lighting Applications

Fitting aluminum LED extrusions to a curved surface was a hassle in the past. Giving you complete freedom to alter the LED extrusion in any way you need, the flexible construction of the LED profiles will definitely fit your tastes and even a demanding customer will be literally delighted with the smart design that meets most demanding lighting designs. Brighten entire living rooms, kitchens or hallways– it couldn't be easier with the super bright bendable LED aluminum extrusions. Light up your residential/commercial spaces & enjoy pleasant rays, coming out of a subtle, LED aluminum extrusion.

Being compact, slim and easy to install, the aluminum LED profiles allow the creation of virtually any curved design

Bendable aluminum extrusions are an excellent option to take your strip light installations to the next level. These LED aluminum channels/profiles are not only a great housing for strip lights but also act as a heat sink for them as well, which in turn will expand your LEDs lifetime as well as brightness over time. The frosted covers conceal the LED strip and make for a professional looking light fixture. Included polycarbonate Opaque Cover protects the LED strip inside the channel and the end caps protect the extrusion from dust & undesirable elements, which can make LED strips dirty, which prevent consequent deterioration of the lighting parameters. Easily assembled, the extrusion can be mounted to surfaces using mounting brackets.

Being compact, slim and easy to install, aluminum LED profiles are a versatile solution with only your imagination being the limit of their perfect application. The LED strip profile accessories are easy to assemble and install.

Applications:
- Floor, wall, cove and ceiling extrusions for architectural, retail, office and home projects
- Corner profiles for Retail and Jewelry display
- Under stairs, Mirror corners and aisles
- Furniture's such as under cabinets, ledges, shelves, drawers, cupboards &closet
- Exhibits, office furniture & workstations

The LED strip profile accessories include:
- End caps
- L-shaped brackets
- Special mounting clips
- Milky diffusers/covers

They are ideal for straight linear runs or can be bent, shaped to curved surfaces for easy installation. Made from high quality aluminum alloy and double-anodized, it can be used with strip lights that allow the strips to be mounted in such a way that they give off light in one direction (for instance, toward the ceiling) or even in dual directions (ceiling as well as towards the floor).

The mix and match of colorful strip lights would create a spectacular display crafting a floating look for ceiling or vibrant luminosity for walls, shelves or cove. The indirect light emitted from the profiles is widespread and very captivating. The best thing about indirect lighting: it is completely glare-free!

Lumibright offers a wide range of Aluminum Extrusion profiles, which enables architects, interior designers, retailers & home improvement contractors to create amazing interior designs. They are easily fixed on the ceiling, floors, in corners or in other places inside or outside of the building. Moreover, all extrusions can be easily cut to size, with the use of simple tools and, as a result - perfectly fit with the length of your stairs, mirror or wall. ■

LumiGrow Smart Light Sensor - Sun Manages Greenhouse Lights

LumiGrow, a smart horticultural lighting company, announced today the release of their integrated light sensor technology, named the smartPAR Light Sensor Module. Now greenhouse growers can ensure their crops experience near perfect lighting conditions year-round, regardless of changes in season, climate, or inefficiencies in greenhouse infrastructure. The sensor technology works by simply plugging into your LumiGrow Pro Series or Pro Series E fixtures, then connects to your smartPAR Wireless Control System to begin automating your lighting strategy. Once connected, the smartPAR Light Sensor Module measures ambient sunlight within the greenhouse, and adjusts your LumiGrow lighting to hit your crop's ideal daily light integral (DLI) goals day in and day out.

LumiGrow's new smartPAR Light Sensor Module is the first integrated light sensor to hit the horticultural lighting industry. It offers a game-changing advanced lighting control technology as a fully automated solution controlled by the sun

"This is the first time in the history of agriculture that ideal lighting conditions have been possible with LEDs in the greenhouse year-round." says LumiGrow VP of Research, Melanie Yelton. "Prior sensor technology made early attempts to automate lighting by turning HPS fixtures on and off. Still, this type of rigid control really didn't address complex plant and light interactions in a way that could benefit grower's profits. What we've achieved at LumiGrow is to ensure crop quality as far as meeting your greenhouse lighting requirements, creating much more consistency in your production. When pairing a sensor capable of processing huge amounts of solar data with our powerfully dynamic lighting fixtures, lighting becomes one less thing that our growers need to worry about, as they deploy horticulture's most advanced lighting strategies with an automated solution."

The smartPAR Light Sensor Module is just one easy way that growers can use smart horticultural lighting to improve crop quality and yields. LumiGrow LED fixtures can also be adjusted for spectrum, intensity, and photoperiod to elicit further beneficial plant characteristics through even more advanced spectral strategies.



LUXEON 5050

High efficacy and lumens in a multi-die, high power package, enabling low system costs

LUXEON 5050 is a multi-die, high power package that provides high luminance from a single package to enable cost effective, single optic and directional fixture designs. LUXEON 5050 uses an industry standard 5050 surface mount package with the smallest round Light Emitting Surface (LES). LUXEON 5050 comes in 70CRI, 80CRI and 90CRI with a wide range of CCTs, and offers hot-color targeting to ensure that the LEDs are within color target at application conditions of 85°C. System applications requiring a high lumen per watt which may be submitted for DLC Premium will benefit from this groundbreaking package.

- Small LES (4.6mm) enables good optic design for great punch
- Enables highest efficacy system design by driving at low current
- Hot-color targeting ensures color is within ANSI bin at 85°C
- Binned within 3-step and 5-step MacAdam ellipse, ensuring color uniformity
- Compatible with low cost and high efficacy drivers

Primary Applications

- High Bay & Low Bay
- Outdoor
- Streetlights
- Spotlights
- Directional Lamps

Achieve DLC Premium

Obtain Your
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FUTURE Lighting Solutions

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LUMILEDS

"Our in-house Plant Research Group has proven time and again through their university and commercial partnerships, that crop lighting requirements are in fact very specific." says LumiGrow VP of Sales and Marketing, Jay Albere II. "We understand that with so many recent advances in LED lighting, growers have a tough time understanding what's best for their crops and profits. That's why we're using the power of data to simplify the world's most advanced horticultural lighting solution. Now all our customers have to do is install their smartPAR Light Sensor Modules to rest assured that their lighting is optimized for their growing environment."

Once plugged in, growers are guided by in-app lighting recommendations in their smartPAR software. Simply answer a few questions about the types of crops that you're growing and some environmental variables, then smartPAR takes over, using the sun the manage your lighting strategy. In an upcoming smartPAR software update, growers using LumiGrow sensor technology will also gain access to lighting reports and metrics. As your LumiGrow lighting automatically hits your targets, solar and electrical data are recorded. You will then gain insight into reports for understanding energy-usage, solar light trends, and climate factors that will inform your entire cultivation strategy. Apply this data to keep improving your crop production season-by-season and year-over-year. ■

Osram Presents Innovative SMARTRIX Modules for Compact, Intelligent Headlamps

Matrix light not only contributes to greater road safety but also gives headlight designers greater freedom thanks to its smaller dimensions. This technology is therefore very much on the march. To meet the demands of the automotive industry for more and more compact smart headlights Osram has taken this technology an important stage further with the development of innovative SMARTRIX modules. SMARTRIX is an amalgam of "smart" and "matrix". "By using new materials for the lens systems we have been able to make the SMARTRIX modules even smaller and more durable, so our customers have even more freedom in designing their headlights", explained Hans-Joachim Schwabe, CEO Specialty Lighting at Osram.

Osram's new SMARTRIX modules with innovative silicone lenses enable vehicle lighting systems to be extremely small and compact

Matrix headlights provide ideal visibility at night and poor weather conditions. The smart distribution of light ensures that the road is illuminated with a high level of precision and maximum light output without dazzling oncoming drivers. Several individually controllable LEDs are combined into a matrix (array) with common optics. The LEDs can be controlled individually, "pixel by pixel", so specific areas of the road and its environs can be illuminated or masked out as required.

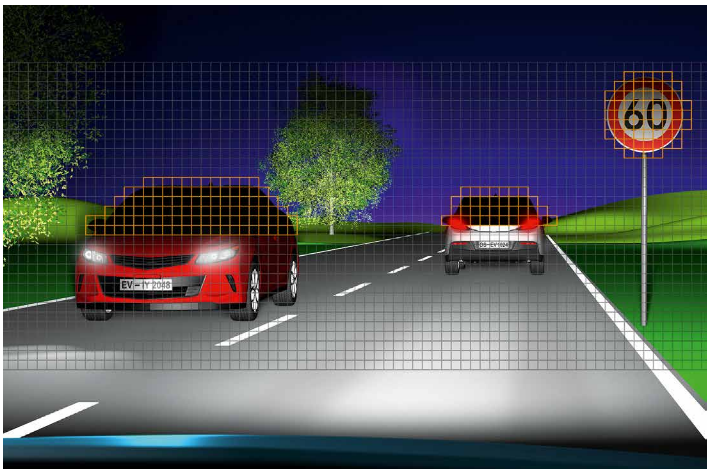
Smaller modules for new headlight designs:
The standard plastic lenses which have been used in the past few years for matrix systems could no longer meet the requirement to be placed closer and closer to the light source. Osram therefore looked for a new material for the lenses and developed the SMARTRIX modules which are equipped with lenses made of silicone as this material emerged as the best alternative to plastic. The lenses offer properties such as long life and high resistance to heat and radiation, and are also less expensive than glass lenses. In addition, silicone lenses can be attached directly to the LEDs, making the product much smaller overall. Headlight designers have much greater freedom as a result and can more easily follow the trend for narrow low-profile headlights.

First-generation SMARTRIX modules from Osram will appear on the roads in the fall of 2017. As the leading player in automotive lighting, Osram is already working on the next generation which will offer multi-line matrix functionality in one module, and the chance to make headlights even more compact. ■

Eviyos LED Prototype Revolutionizes Smart Headlights

The Eviyos prototype developed by Osram Opto Semiconductors is the world's first hybrid LED and represents major progress toward the first market-ready smart controllable high-resolution LED. As soon as oncoming traffic is detected the appropriate pixels are automatically switched off so drivers of oncoming vehicles are not dazzled. The prototype, integrated in a demonstrator from Osram Specialty Lighting, was on show for the first time at ISAL from September 25 through 27, 2017 in Darmstadt.

Eviyos has its basis in the µAFS research project which was completed in the fall of 2016. The project involved various partners from the industrial sector and was coordinated by Osram Opto Semiconductors. The prototype combines two technologies in one component: a light emitting chip and individual pixel control electronics. This combination means that the 1,024 pixels of Eviyos plus the driver are all accommodated in a footprint of approx. 4x4 mm. The light source has minimum luminous flux per pixel of 3 lm at 11 mA. Initial prototypes have already exhibited more than 4.6 lm per pixel. Customers can vary the number of hybrid LEDs in their applications and supplement them with conventional LEDs, depending on the particular requirements that need to be met.



Eviyos illuminates surroundings in high-beam quality, ensures other road users and drivers are not dazzled. The prototype is the first integrated hybrid LED of a µ-structured LED-chip with 1,000+ pixels and individual pixel control in a single component

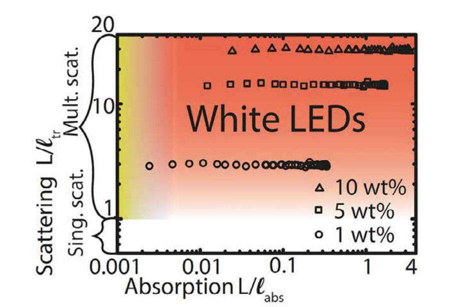
"The hybrid LED is another example of our products making a major contribution to improving the quality of life in many different areas. With Eviyos we are helping to make the roads safer and improve comfort and convenience for drivers. We are proud that we can present the first prototype so soon after completing the research project. We are now another stage further towards series production", said Thomas Christl, Marketing Manager at Osram Opto Semiconductors.

Eviyos is not only compact and powerful but also energy-efficient thanks to the precise control and dimmability of the individual pixels. The only pixels that are ever on are the ones that are actually needed at the time.

At its planned launch at the start of 2020 Eviyos will form a separate product family offering a wide range of possible applications. Smart headlights are just one of the potential areas in which intelligent selective pixel control can be applied. ■

Inside an LED

The performance of white LEDs can be improved, based on better knowledge of the absorption and scattering of light inside the LED. A new method, developed by the University of Twente in The Netherlands and Philips Lighting, can lead to efficiency improvement and powerful design tools.



Transport parameters in the plane spanned by absorption and diffusion (for a detailed description, see Optics Express publication)

White LEDs can be made even more efficient and powerful, researchers of the University of Twente and Philips Lighting now prove. They found a detailed way to describe the light that stays inside the LED by absorption and scattering. This is very valuable information for the design process.

From relatively weak light sources to strong lights at home and in cars, for example: since the blue and white LED were invented, we've seen a rapid development in possible applications. Low energy consumption and long lifetime are major advantages over existing lighting solutions. White LEDs consist of a semiconductor emitting blue light, with on top of that phosphor plates that turn the blue light into yellow. What we see then, is white light. The light will be scattered by the phosphor particles, but it is absorbed as well. What part of the light will exit the LED, is not easy to predict. Unless you look at absorption and scattering in another way, according to Maryna Meretska and her colleagues. Theory from astronomy helps.

What makes good prediction particularly difficult: Some of the light is absorbed, but re-emitted in another color. One way is trying to define all possible light rays, and use a lot of computing time to get a result. This doesn't give much insight in what is actually happening. A theory that is often used for light propagation in an LED is diffusion theory. In strongly absorbing media, however, this approach isn't valid anymore. Meretska therefore has built a setup to collect all the light around the phosphor plates, in the whole visual spectrum. Based on this, absorption and scattering can be deduced using the radiative transfer equation, well known in astronomy. This results in a full description of light propagation inside and outside the phosphor plates. Compared to a description using diffusion theory, the absorption level is up to 30 percent higher. At the same time, the method is about 17 times faster than the numerical approach.

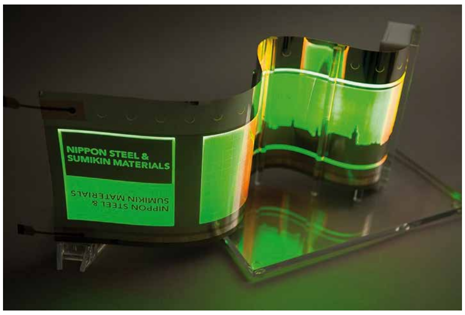
These new insights can lead to powerful and predictive tools for LED designers. They help in further improving the efficiency and overall performance.

The research has been done in the Complex Photonic Systems group of UT's MESA+ Institute for Nanotechnology, together with Philips Lighting in Eindhoven. The University of Twente has a strong concentration of research groups and facilities within the rapidly growing field of photonics.

More information:
M. L. Meretska et al. Analytical modeling of light transport in scattering materials with strong absorption, Optics Express (2017). DOI: 10.1364/OE.25.00A906 ■

OLEDs Applied to Paper-Thin Stainless Steel

Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP, a provider of R&D in the field of organic electronics, presented OLEDs on gauzy stainless steel foil during aimcal 2017 in Tampa/USA, from October 15-18, 2017. The novel application on display in Booth 22 was developed in cooperation with the Nippon Steel & Sumikin Materials Co., Ltd. (NSMAT) and Nippon Steel & Sumitomo Metal Corporation (NSSMC).



The research team expects this new, flexible OLED onpaper-thin stainless steel foil to be used in cars in about three years from now. Possible applications are turn indicator and back-up lights

Stainless steel is normally associated with kitchenware and chemical plant pipes. However, stainless steel foil has also been utilized for several years in thin-film photovoltaics and batteries. Now stainless steel can also serve as a substrate for flexible electronic components.
In comparison to the conventional substrate materials like glass or plastic web the material possesses special properties for this purpose and is well-suited as a substrate for organic light-emitting diodes (OLEDs), for example. Thanks to the planarization layer developed by NSSMC as well as the comparatively good thermal conductivity of stainless steel, homogenous large-area lighting surfaces with current densities of more than 10 mA/cm^2 have become better applicable.

Moreover, OLEDs need to be protected from water vapor and oxygen in order that the organic layers remain fully functional. Stainless steel provides excellent barrier properties against environmental influences and is therefore suitable as a substrate for OLEDs from this standpoint as well.

Jun Nakatsuka, Manager of Business Development at NSMAT, is looking to the future: "Thanks to the smoothness and high thermal conductivity of the stainless steel foil we obtain extremely homogenous OLED light. We see OLEDs on stainless steel in perhaps three years from now being used in automobiles as turn indicator and back-up lights, as cladding for fascia, and as advertising displays."

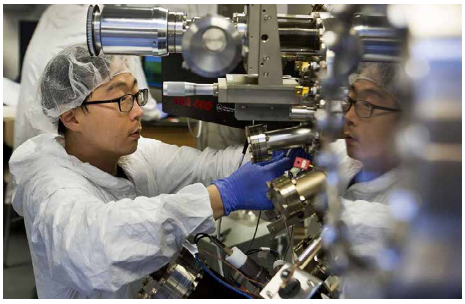
There is some ways to go before reaching that juncture. Following the expensive development of stainless steel foil, it still needs to be made suitable for production purposes. Fraunhofer FEP has at its disposal roll-to-roll processing lines for manufacturing OLEDs on flexible materials and an OLED process that has high reproducibility. This is what has made possible the development of stainless steel foil with a clean and smooth planarization layer.

Michael Stanel, Project Manager within the R2R Organic Technology department at Fraunhofer FEP explains: “In addition to machinery design and construction, we also possess comprehensive know-how in handling sensitive substrates. To be certain the stainless steel is suitable for the nanometer-thick organic layers, an R2R-compatible smoothing planarization layer was developed that is easy to integrate into the process.”

It was also important during the collaboration with NSMAT and NSSMC to work out quality standards for the future OLED fabrication. In particular, the surface properties of the substrate were specified and are being continuously improved in cooperation with NSMAT and NSSMC. ■

Tracing the Light Nanoparticles Could Spur Better LEDs, Invisibility Cloaks

In an advance that could boost the efficiency of LED lighting by 50 percent and even pave the way for invisibility cloaking devices, a team of University of Michigan researchers has developed a new technique that peppers metallic nanoparticles into semiconductors.



Preparation of the molecular beam epitaxy apparatus that’s used to make the nanoparticle-infused gallium nitride semiconductors that could boost LED efficiency by up to 50 percent (Image credit: Joseph Xu, Michigan Engineering)

It's the first technique that can inexpensively grow metal nanoparticles both on and below the surface of semiconductors. The process adds virtually no cost during manufacturing and its improved efficiency could allow manufacturers to use fewer semiconductors in finished products, making them less expensive.

The metal nanoparticles can increase the efficiency of LEDs in several ways. They can act as tiny antennae that alter and redirect the electricity running through the semiconductor, turning more of it into light. They can also help reflect light out of the device, preventing it from being trapped inside and wasted.

"This is a seamless addition to the manufacturing process, and that's what makes it so exciting," said Rachel Goldman, U-M professor of materials science and engineering, and physics. "The ability to make 3-D structures with these nanoparticles throughout is going to open a lot of possibilities."

The key innovation:
The idea of adding nanoparticles to increase LED efficiency is not new. But previous efforts to incorporate them have been impractical for large-scale manufacturing. They focused on pricey metals like silver, gold and platinum. In addition, the size and spacing of the particles must be very precise; this required additional and expensive manufacturing steps. Furthermore, there was no cost-effective way to incorporate particles below the surface.

Goldman's team discovered a simpler way that integrates easily with the molecular beam epitaxy process used to make semiconductors. Molecular beam epitaxy sprays multiple layers of metallic elements onto a wafer. This creates exactly the right conductive properties for a given purpose.

The U-M researchers applied an ion beam between these layers - a step that pushes metal out of the semiconductor wafer and onto the surface. The metal forms nanoscale particles that serve the same purpose as the pricey gold and platinum flecks in earlier research. Their size and placement can be precisely controlled by varying the angle and intensity of the ion beam. And applying the ion beam over and over between each layer creates a semiconductor with the nanoparticles interspersed throughout.

"If you carefully tailor the size and spacing of nanoparticles and how deeply they're embedded, you can find a sweet spot that enhances light emissions," said Myungkoo Kang, a former graduate student in Goldman's lab and first author on the study. "This process gives us a much simpler and less expensive way to do that."

Researchers have known for years that metallic particles can collect on the surface of semiconductors during manufacturing. But they were always considered a nuisance, something that happened when the mix of elements was incorrect or the timing was off.

"From the very early days of semiconductor manufacturing, the goal was always to spray a smooth layer of elements onto the surface. If the elements formed particles instead, it was considered a mistake," Goldman said. "But we realized that those 'mistakes' are very similar to the particles that manufacturers have been trying so hard to incorporate into LEDs. So we figured out a way to make lemonade out of lemons."

Toward invisibility cloaks:
Because the technique allows precise control over the nanoparticle distribution, the researchers say it may one day be useful for cloaks that render objects partially invisible by inducing a phenomenon known as "reverse refraction."

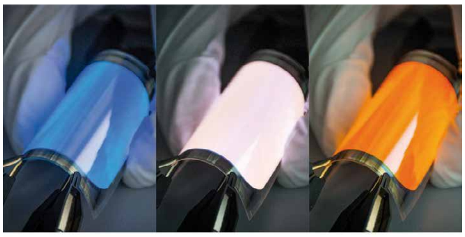
The team is now working to adapt the ion beam process to the specific materials used in LEDs - they estimate that the higher-efficiency lighting devices could be ready for market within the next five years, with invisibility cloaking and other applications coming further in the future. ■

About the research project:
The study is titled "Formation of embedded plasmonic Ga nanoparticle arrays and their influence on GaAs photoluminescence." The research was supported by the National Science Foundation through the Materials Research Science and Engineering Center at U-M.

The original article has been released on the University of Michigan News Site:
http://ns.umich.edu/new/releases/24969-nanoparticles-could-spur-better-leds-invisibility-cloaks ■

Flexible OLEDs with Adjustable Colors - New Design Options for Lighting Designers

The Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP, one of the leading R&D partners for surface technologies and organic electronics specializes in the development and fabrication of OLED modules with unconventional properties for specific client designs.



Adjustable-color OLED on flexible substrates
© Fraunhofer FEP

Processing adjustable, color OLEDs on rigid substrates is a big leap forward - opening completely new design opportunities

With their unique characteristics like bendability, segmentation, transparency, and their nearly unlimited range of shapes, organic light-emitting diodes (OLEDs) facilitate diverse new design opportunities by virtue of their being efficient areal lighting sources fabricated on flexible substrates.

In 2015, scientists of the Fraunhofer FEP were successful for the first time in processing adjustable, color OLEDs on rigid substrates. This facilitated the extension of the application spectrum of OLEDs, such as for integration into vehicle interiors where the lighting levels should be controllable as a function of the time of day. Imagine employment as ambient or accent illumination, such as for lighting in museums and exhibitions, where the adjustability of color from just a single lighting component can present the works exhibited in different colors of light.

Just two years later, the next big development goal was reached: the Fraunhofer FEP now offers OLED emission systems featuring an adjustable color range integrated on flexible substrates. These types of OLED modules are able to switch the emitted color between two different color temperatures. In this way, a yellow-blue bi-color emission system cannot only be switched between the pure emission colors of yellow and blue, but white light can also be generated through simultaneous activation of both colors.

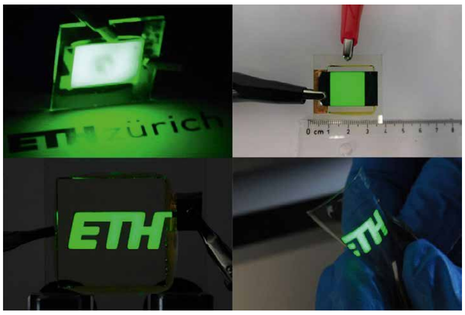
The integration of adjustable-color OLEDs on flexible substrates brings their employment on curved surfaces in vehicle interiors such as roofs and curved fixtures into the realm of the tangible. In the meanwhile, the range of choice for substrates has also been broadened. Flexible OLEDs can be fabricated on metal and plastic films just as they can be on ultra-thin glass. The scientists will debut the new flexible variable-color OLED modules at the International Symposium on Automotive Lighting (ISAL). The symposium takes place directly after the International Motor Show Germany (IAA Pkw 2017) and addresses lighting applications in automobiles. The wide range of possibilities for OLED technology on flexible substrates for applications upon and in automobiles will be on display at the Fraunhofer FEP booth (No. 31) at ISAL.

Claudia Keibler, head of the Sheet-to-Sheet Organic Technology department at Fraunhofer FEP welcomes you: "I am looking forward to being able to personally discuss with conference visitors the astonishing opportunities of flexible OLEDs right on site. Our technological know-how and the features of our fab facility allow us not only to discuss the wishes of interested visitors, but also produce OLED samples afterwards."

About Fraunhofer FEP:
The Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP is located in Dresden and focuses on developing innovative solutions, technologies and processes for surface modification and organic electronics. Fraunhofer FEP is a key partner of the public funded project PI-SCALE (FKZ 688093) with the aim to install a European Open-Access-pilot line for the production of OLED. ■

Green Light from 2D Formamidinium Perovskites for Ultra-Fine Display Colors

Chemical engineers from ETH Zurich have succeeded in generating ultra-pure green light for the first time. The new light-emitting diode will pave the way for visibly improved color quality in a new generation of ultra-high definition displays for TVs and smartphones.



ETH chemical engineers have produced the purest green with a light-emitting diode. The LED is flexible and bendable and can even be produced at room temperature (Photos: Sudhir Kumar, Jakub Jagielski/ETH Zurich)

Chih-Jen Shih is very satisfied with his breakthrough: "To date, no one has succeeded in producing green light as pure as we have," says the Professor of Chemical Engineering in his laboratory at the Hönggerberg campus. He points at an ultra-slim, bendable light-emitting diode

(LED), which displays the three letters “ETH” in a fine hue of bright green.

Shih’s progress is significant, particularly in terms of the next generation of ultra-high resolution displays used for TVs and smartphones. Electronic devices must first be able to produce ultra-pure red, blue and green light in order to enable the next generation of displays to show images that are clearer, sharper, richer in detail and with a more refined range of colors. For the most part, this is already possible for red and blue light; green light, however, has hitherto reached the limits of technology.

This is due mainly to human perception, since the eye is able to distinguish between more intermediary green hues than red or blue ones. “This makes the technical production of ultra-pure green very complex, which creates challenges for us when it comes to developing technology and materials,” says Sudhir Kumar, co-lead author of the report.

Up to 99 percent ultra-pure green:
It becomes clear from reference to the Rec.2020 standard just how much progress Shih’s ultra-green light has made in the development of the next generation of displays. The international standard defines the technical requirements for ultra-high resolution (known as “Ultra HD”) displays and provides a framework for further research and development. The requirements also include an improvement in color quality visible to the naked eye. The standard provides the color scale that a display can reproduce and therefore a broader range of color hues.

Ultra-pure green plays a key role in extending the color range, or gamut. Ultimately, new hues are created through the technical mixture of three base colors: red, blue and green. The purer the base colors, the broader the range of hues a screen can display. Shih’s new LED is in line with 97 to 99 percent of the Rec. 2020 standard. By comparison, the purest color TV displays currently available on the market cover on average only 73.11 to 77.72 percent; none exceeds 80 percent.

Inexpensive, producible LED technology:
Wendelin Stark, ETH Professor of Functional Materials Engineering, along with researchers from South Korea and Taiwan, also contributed to the project results, which have been published in the scientific journal Nano Letters. Shih not only made a breakthrough in terms of the results, but also in the material and method. He and his colleagues have effectively developed an ultra-thin, bendable light-emitting diode able to emit pure green light using simple room-temperature processes. Shih says that this is the second aspect of his breakthrough and is at least equally important, as until now high-temperature processes were required to produce pure light with LED technology. “Because we were able to realize the entire process at room temperature, we’ve opened up opportunities for the simple, low-cost industrial production of ultra-green light-emitting diodes in the future,” says Jakub Jagielski, co-lead author of the report.

More specifically, Shih and his team used nanomaterials to further develop the LED technology. A light-emitting diode usually contains a semiconductor crystal that converts electrical current passed through it into radiant light. The raw material is usually indium gallium nitride (InGaN); however, this material does not have the ideal properties for production of ultra-pure green light. So Shih’s team instead used perovskite, a material that is also used in the manufacture of solar cells and which can convert electricity into light relatively efficiently. It is also inexpensive and helps make the manufacturing process simple and fast - it takes just half an hour to chemically clean perovskite and make it ready for use, says Shih.

The perovskite material in Shih’s light-emitting diode is a miniscule 4.8 nanometers in thickness. This is an important factor, since the color quality depends on the thickness and form of the nanocrystal used. In order to reach the desired pure green, the crystals should not be any thicker or thinner. These flexible, ultra-thin light-emitting diodes are as bendable as a sheet of paper. Hence, they can be produced inexpensively and quickly using the existing roll-to-roll process for example. Shih says this will also benefit industrial production in the future.

Next step - improve efficiency:
However, it will still take some time before we see the first industrial application of ultra-green light-emitting diodes. The next step for Shih is to first improve the efficiency. Today, his LED works at 3 percent efficiency when converting electricity into light; in comparison, TV screens currently available on the market have efficiency values of 5 to 10 percent. Shih is hoping that the next version will be 6 to 7 percent more efficient. He also sees potential for improvement in the lifespan of his light-emitting diode. Currently, it illuminates for about two hours, whereas screens available on the market should work for many years.

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The original article from Florian Meyer has been published on the ETH Zurich news page at:
https://www.ethz.ch/en/news-and-events/eth-news/news/2017/09/green-light-for-ultra-fine-display-colors.html

Color Reproduction and Measurement of 3D Objects

CIE Division 8 Image Technology is responsible for the study of the optical, visual and metrological aspects of the communication, processing, and reproduction of images, using all types of analogue and digital imaging devices, storage media, and imaging media. The Division is continually working on recommendations to improve color image reproduction techniques, including, for example, color-appearance models, color-difference evaluation and gamut-mapping algorithms. Current technology is able to transform color images from one digital medium to another, under various viewing conditions, while maintaining the appearance of each color in the image. This process has been applied in the graphic arts industry with great success. According to Kaida Xiao, Chair of CIE's Division 8 TC 8-17, the CIE standard observer and psychophysical data for color-appearance and color-difference modelling were developed using flat, 2D color samples. He explains that to meet the increasing requirements for color image reproduction for 3D objects, new research and recommendations are highly desired.

3D Color Imaging Reproduction

3D color printing technology, also known as additive manufacturing technology, is a revolutionary process that has been developed during the last decade to produce full color, solid objects utilizing a range of printing materials that include polymers, metals and even biological tissue. With the evolution of a number of 3D image capture techniques, accurate acquisition and transformation of the geometric data that describes a 3D object can lead to accurate digital models. In addition these models can originate in CAD software as part of the overall design process.

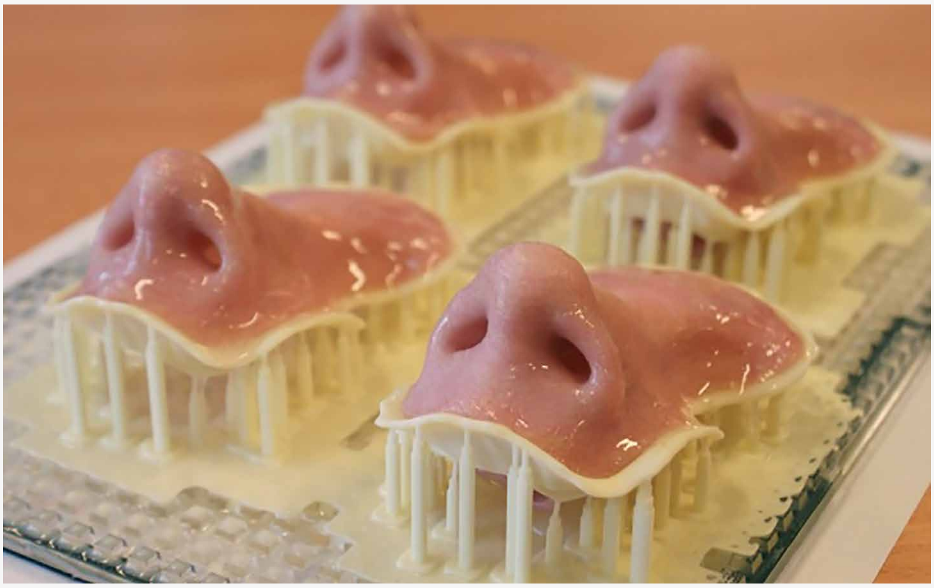
By combining 3D image generation with 3D printing techniques, it is possible to produce an accurate 3D reproduction of the original object, be it real or virtual. Moreover, the process has the ability to directly connect with other advanced manufacturing techniques, allowing customization with excellent accuracy, yielding savings in time and cost.

The process has found a number of diverse applications - for example:

- Lighting–3D objects are more sensitive to the lighting design; both the specular and non-specular aspects of reflection need to be considered as well as the shadows associated with 3D texture
- Rapid prototyping - for one-off manufacturing of devices or components for conceptual prototyping and providing unavailable repair components [1]
- Medical prosthetics - for example, to construct artificial noses for patients who require prosthetic skin replacement after tumor removal, where a custom fit is essential and accurate color reproduction is very desirable - these devices often require annual replacement and 3D printing technology provides a cost effective way to make them [2]
- 3D design - the design process often starts out with a 2D sketch followed by a concept model on a computer display leading to a 2D print - 3D printing extends this concept to produce a 3D prototype model

As compared with 2D image reproduction, appearance reproduction of 3D objects must satisfy a greater number of requirements. These include visual attributes, such as surface color, translucent color, reflectance, gloss and surface texture. Reflectance itself is a complex topic, characterized by the bidirectional reflectance distribution function (BRDF), which portrays how the reflectance of a surface depends on the 2 dimensions of incident angle and the two dimensions of viewing angle. Further, it must be considered that many surfaces are curved and they may intersect at various angles.

Characterization of the color appearance of 3D objects requires design software that captures the optical properties of the constituent materials and properly takes into account visual adaption processes of human vision, so as to avoid constraining possible observing conditions. These challenges cannot be solved sufficiently by a simple extension of 2D color image reproduction and measurement



Example of facial prostheses manufacturing (University of Sheffield/Fripp Design)

techniques [3]. Interestingly, some 3D object printers call their color process CMYK printing, even though, unlike most 2D CMYK printers, there is not possibility of using halftone printing techniques.

New scientific models and new engineering ideas will be necessary to develop and implement widespread successful accurate 3D printing of colored objects. Likely an important part of ensuring quality of large scale 3D printing will be the development of rapid 3D-object proofing methods, in analogy to analogous methods used with 2D printing, to ensure that the desired output color matching will ultimately be obtained in the final 3D printed objects.

Future Research Plans

Future research can be divided into three aspects:

- input
- processing
- output

Input: The research on input will mainly be concerned with the design and characterization the intended object. In addition to the measurement of its shape and dimensions, the appearance must be quantified with regard to color, texture, and reflection. The techniques developed can also be used to determine the reproduction quality of the printed object.

Processing: The research on processing will concern converting the input date to a smaller number of parameters, by means of models of various levels of sophistication, into simpler forms that are more amenable to subsequent use. Techniques such as parametric sub-sampling and reformatting will yield information formats that are more conducive to subsequent efficient 3D printing of manufactured objects.

Output: The research on output will concern the realization of the intended shape, with the required color, appearance and texture attributes. The various attributes will be compared with those of the original as defined in the input stage. Objective assessment is required for quality control in the complete industrial or medical manufacturing chain from the designer to the customer/patient.

Key research goals:

- To develop the metrology of non-uniform 3D objects, including the 3D shape, the local roughness, the surface texture and other properties that affect their appearance.
- To develop new ideas for measurement instruments and their application to 3D objects. Ideally this should lead to new, relatively simple instruments.
- To define a minimum set of metrological distance/similarity metrics between two objects that embed the set of differences in 3D shape, color, texture, and surface morphology.
- To consider how to make a simple but comprehensive surface model, including the physical and visual characteristics, to develop the market and industry of 3D-printed objects.
- To consider how to reproduce the desired shape, color, appearance and texture, especially when the target surface has translucent characteristics, for example, human skin. This will be a major challenge since this problem has yet to be fully resolved even for 2D materials.

In early 2017, CIE TC 8-17, Methods for Evaluating Color Difference between 3D Color Objects was established to study subjective assessment methods and recommend a dataset for color difference evaluation of pairs of 3D color objects. Eventually, the TC will report on investigations of the influence of 3D shape, gloss and optical characteristics on the perception of color difference between 3D object. ■

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Tech-Talks BREGENZ - Ken T. Shimizu, Research & Development Director, Lumileds

Ken T. Shimizu

Ken T. Shimizu is Director, Novel Technologies and Devices, Research and Development at Lumileds. His team explores next-generation material systems and novel LED designs to improve overall LED performance and reliability. Ken's past experience includes a post-doctorate from Stanford University, examining surface plasmon interactions with molecular switches, and as Director of R&D at Stion Corporation, developing novel tandem thin-film solar cells. Ken received his Ph.D. in Chemistry from the Massachusetts Institute of Technology, where he investigated quantum dot optical properties under high excitation flux.

QDs have been a hot topic in lighting for a while already, but up until now they haven't been adopted on a large scale in lighting. The adoption began in display devices because some of the technical issues were of less concern in this application. With continuing development, QDs are now also becoming interesting for general lighting applications. Ken Shimizu, Director of Novel Technologies and Devices, Research and Development at Lumileds, attended the LpS in Bregenz and made a presentation about the company's QD technology. In this interview he gives some background information about the QD program and future steps.

LED professional: Thank you for coming to our TTB here at the LpS 2017!

Ken T. Shimizu: My pleasure.

LED professional: Like any top LED manufacturer, Lumileds is continuously improving their products. What is striking for me is that meanwhile most LED manufacturers tend not to primarily push efficacy but rather push performance in light quality. That not only means high CRI but they even attempt to come close to sunlight and whatever that brings with it. But the bottom line is quality and I think that quantum dots, which are a fascinating subject for me, could be a way to push light quality because you have more specific opportunities to shape the spectrum. So could you just give us a short explanation of what's so special about quantum dots for Lumileds?

Ken T. Shimizu: Sure. I think in the phosphor converted LED space one of the key limitations that's been highlighted, is the absence of narrow red converter material at different wavelengths. We identified colloidal quantum dots for potential use in LEDs almost twenty years ago. Quantum dots can provide you with custom wavelength emission offering a full width at half maximum (FWHM) that's even as narrow as 30 nm or less. They are solution processed, so in terms of integrating into LED the colloidal quantum dots can give you quite a bit of flexibility, including use of existing manufacturing methods. We identified the most promising material systems and then we went and evaluated the landscape. We've done a lot of work with partners as well as internal research, looking at the technology readiness.

You mentioned color quality versus efficacy. But in our viewpoint, it's not either or. We think that quantum dots can give you both performance improvement and a higher quality of light. We believe that this is a first step of many to come where we think that you'd have different colors of quantum dots available - more suppliers and vendors and even more mature systems that you can access.

To understand our aims and approach it is also relevant to understand that in the lighting business, which is different to displays, I think the form factor has to be more efficient. Meaning that it's a space budget- it's a cost budget, which is more important because of how competitive, the market place is. There are so many different customers with so many different needs that you want to have a simplified and universal product as opposed to having a very confined product.

There have been examples of remote phosphor type integration with quantum dots in the past, but we think that is really not the way to go. We think that for quantum dots to make a big impact in performance and energy efficiency we want to have an on-chip configuration. And that's how we ended up where we are.

LED professional: Before going further, I'd like to come back to the quantum dots in general as most people don't really know what quantum dots means and how they work. Could you please give a short explanation?

Ken T. Shimizu: Yes, of course. QDs are semiconductor particles with a diameter in the range from 3 to 10 nanometers.

Quantum dots are semiconductor particles that are 3-10 nm in diameter and can be tuned to downconvert light to any desired color

So they are very small particles. Colloidal quantum dots can be made from II-VI or III-V compound semiconductor material. There is usually a higher band gap shell that's grown to help with the quantum confinement inside the inner core and also provide a passivation layer. An organic surfactant that surrounds the quantum dot surface makes it solution processable. So you can put it into a solution, into polymers and into silicones. Compared to the size scale of phosphors, they are very small. Today most phosphors range from 2 microns to about 20 microns in size. Quantum dots are typically under 10 nanometer in size. So they are different in terms of their handling and their scattering property as well.

LED professional: So you can compare the quantum dot in its function with phosphor but they are smaller and it's a semiconductor material, and you can use them in a similar way as conventional phosphors. Is that correct?

Ken T. Shimizu: Yes - in our geometry of the LED we've chosen the Luxeon 3535L HE Plus mid power LEDs. This is a standard footprint device using blue LED chips that are attached by a silicone bond material and therefore giving a cup around the die for filling the phosphor slurry. So yes, we do indeed have the quantum dots integrated into the silicone matrix along with the various phosphor mixtures.

LED professional: So these quantum dots convert light or do they also themselves emit light?

Ken T. Shimizu: In this case the QDs serve as a down converter from the blue pump of the LED. There are electrically injected quantum dots that can emit light, referred to as QLEDs. These are similar to OLEDs that utilize direct emission from electrically injected organic molecules. The QLED technology is in an earlier stage of development.

LED professional: And is it also possible to pump quantum dots like with the phosphors, in that you have different injection colors like blue or purple to convert to another wavelength or is it limited to one narrow blue range?

Ken T. Shimizu: No, the absorption band of the quantum dots is fairly broad. This allows for a reasonable flexibility in terms of which color to use such as a violet or blue LED but of course there are technical details in achieving the desired final color and LED efficacy. But there's no difficulty of absorption of blue or violet light for the quantum dots.

LED professional: For a conventional phosphor converted white LED, you have a volume emitter for blue light and a surface emitter for yellow light. And sometimes this is problematic, because you may see color effects depending on the direction of where you look into the LED. Is this the same with QD converted LEDs?

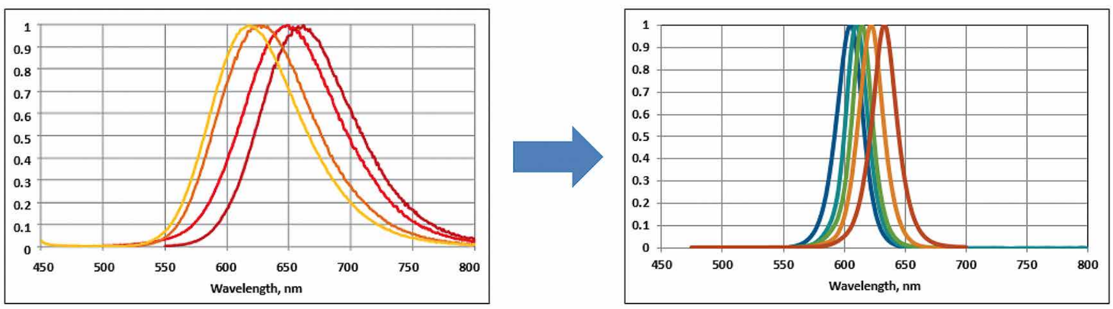
Ken T. Shimizu: Well I think it's actually very similar to a phosphor package LED, in terms of the emitting surface, the main surface as a package is the same. For mid-power LEDs a lot of design work has been done to correct for color over angle to meet the requirements of our customers. We employ optimized designs and processes to minimize the color over angle variation for both phosphor and QD based LEDs.

LED professional: So you still have the variation?

Ken T. Shimizu: Well, although PC LEDs have a limited color over angle variation and a color over source variation; the current LEDs have been engineered to correct for the color over angle to meet the market needs. Again, the same design rules apply for both phosphors and quantum dots.

LED professional: If we look at the converter - the phosphors - it's not that we don't have red converters, but we only have red converters with poor efficiency. So is the conversion efficiency for quantum dots in the red area better than for the phosphor?

Ken T. Shimizu: Well, modern conventional nitride based red phosphors can have very good quantum efficiency performance. Unfortunately, they also have a fairly broad emission. When these red phosphors are chosen to emit the required light at 620 or 630 nm this also results in a significant percentage of light emitted between 650 to 700 nm. With quantum dots, you can tune the emission to be exactly at the target wavelength, for example at 620 nm, with almost no emission beyond 650 nm. So you'll not have this excess emission beyond the sensitivity of the eye.



In comparison to QDs (right), conventional phosphors (left), have a much broader FWH emission spectrum. This sometimes has advantages, but in the case of the red spectrum, the disadvantage is that a good portion of the emission lies in a spectral range that is useless in respect to color rendering

In terms of the quantum efficiency comparison between quantum dots and phosphor; this is fairly close but the phosphors are more efficient today, especially at higher temperature and drive currents. However, with narrower full width at half maximum, the lumen equivalence is much higher for QDs compared to the red phosphor. This can lead to a dramatically improved QD based LED performance over nitride red phosphor based LED performance even if your quantum dots have a little bit lower efficiency. The narrower FWHM and the precise wavelength of the emission is very important - the tuneability means that you can get the CRI and R9 value that you want for the color quality and maximize the efficiency.

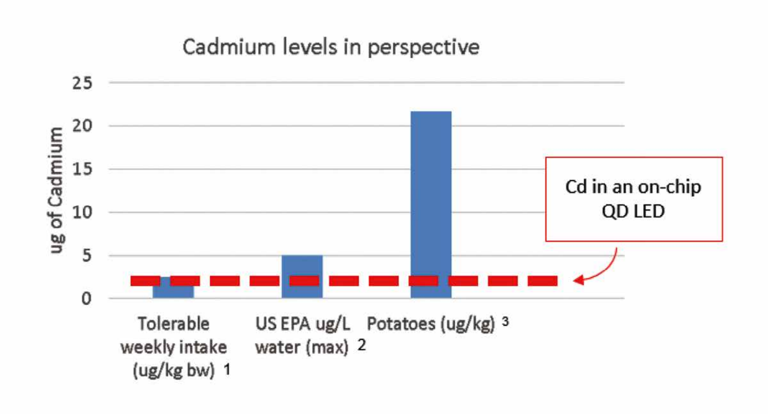
LED professional: So you have the better control on the spectrum?

Ken T. Shimizu: Yes. We can control the spectrum without having to sacrifice efficiency.

LED professional: If we look at the materials used for the quantum dot technology, often materials are used that the industry tries to eliminate due to health concerns and environmental reasons like, for instance, cadmium. What about the impact of QD LEDs on the environment?

Ken T. Shimizu: Cadmium is a restricted material that is regulated by the directive on ROHS compliance. Our first generation of QD LEDs do contain cadmium. We evaluated both the Cadmium containing and the cadmium-free material landscape and we found that the Cd-free QD material was not yet ready and we also investigated how much Cadmium would be used in a Cd-based QD LED.

The first QD based TV's also contained cadmium based quantum dots. The technology performance and readiness allowed for the highest color gamut and efficiency over conventional LED based backlight TVs with Cd based QDs.



While cadmium-free QDs currently don't provide the required performance, the used QDs contain a small amount of Cd.
The graph shows how the amount in one mid power LED compares to some legal limits or measured concentrations in popular foods

Now the market is slowly transitioning and there are many TV's using cadmium containing QD's and a number of TV's that don't contain cadmium in their quantum dots. We think that similarly, in the lighting field, the cadmium based quantum dots offer the technology readiness and performance to achieve the required spectral performance, quantum efficiency performance, the process compatibility, and the reliability requirement.

Historically, the initial research in the quantum dot space started using cadmium selenide material. We've seen now a lot more work happening in the indium phosphide space as well as other materials that are cadmium free. We see the technology roadmap such that in three to five years we think that the same technology that is cadmium free would be ready for on chip use as well.

As mentioned earlier, there is RoHS compliance directive regulating the use of cadmium in electronic materials. There is also a RoHS exemption for cadmium use as a color converting material.

Lumileds is committed to providing environmentally responsible products. We have demonstrated LED efficiency improvements of 17 percent at the module level where each QD LED contains approximately 1 micro gram of Cadmium encased in an oxide shell and embedded in a silicone matrix. We believe that the net environmental benefits from the efficiency improvements outweigh the limited use of Cd in Cd-based QD LEDs.

LED professional: Do you have a road map that shows how long it will take you to reduce cadmium to a certain value?

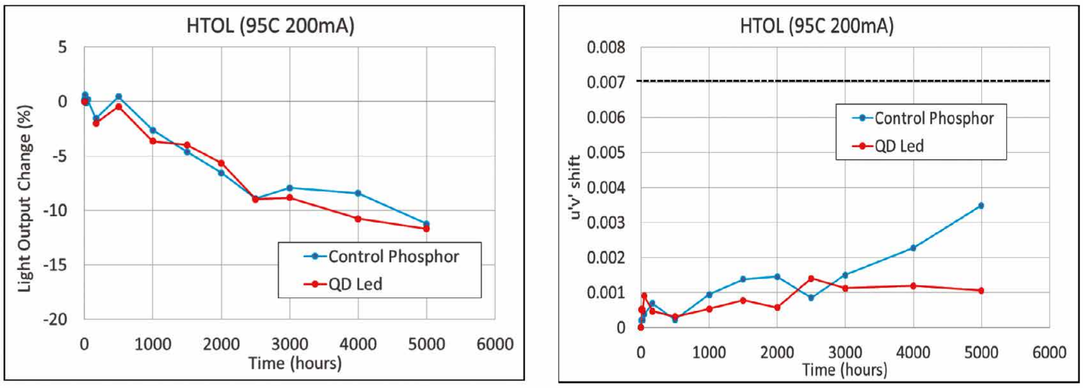
Ken T. Shimizu: Yes. We think that there could be reductions in the cadmium amounts used in QD LEDs over the course of next few years of materials improvement. We also think it will be a 3 to 5 year time frame to develop cadmium free QD LEDs. This is an active research effort and in the display space we have seen that conversion from only cadmium based quantum dots to now having a lot of cadmium free quantum dots in display products. Similarly, we think that trend will continue in lighting.

LED professional: What about the stability of quantum dots?

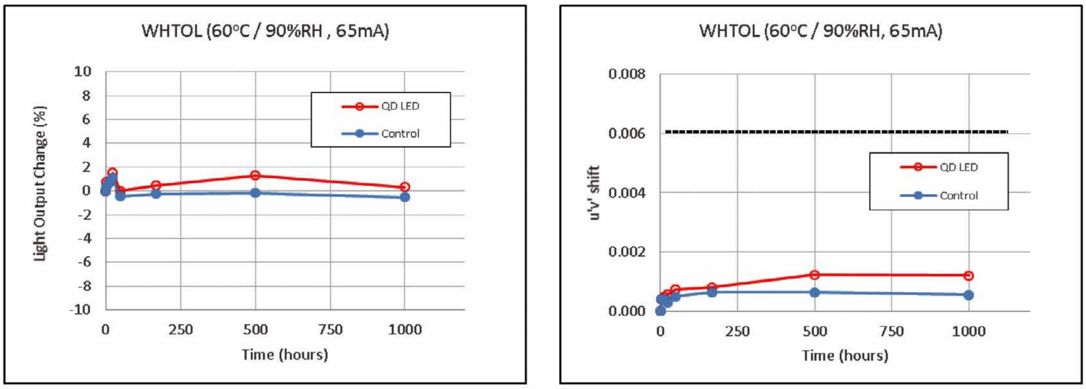
Ken T. Shimizu: QD stability has been a big issue for many years We've partnered with a QD vendor who has worked very hard to improve the QD materials and provide reliability on the LED level that is actually matching that of conventional phosphor material. This is proven by 5,000 hours of high temperature operating life data for our QD LEDs. Also, we can pass over a thousand hours of WHTOL testing. So we've actually met all of the reliability testing criteria for mid power LEDs.

LED professional: For conventional phosphor material there are some patents and all of the LED

In mid power applications, the new generation of QDs shows similar or even better aging behavior in a HTOL test than a conventional phosphor. Lifetime of mid power QD white LEDs is therefore expected to be suitable for the foreseen applications



The 1000 hour WHTOL test shows a similar result and therefore, suggests a similar conclusion to the HTOL test



manufacturers have access to the same materials. What happens with the quantum dot materials? Does each LED manufacturer have its own materials or are there common materials that they all have access to?

Ken T. Shimizu: Patents play a significant role in defining the specific designs used by different QD materials companies similar to the role patents play in the LED industry. The QD vendors will develop different types of QD materials that will then be accessible to the LED industry. We do not expect huge barriers to QD LED adoption from an IP perspective.

LED professional: We were talking about QDs and the reduction of cadmium but currently I don't think there are any products available from Lumileds that use quantum dots. Will they come out in the near future?

Ken T. Shimizu: Yes, the QD LED product has passed all of our technical and manufacturing milestones and it is now released to production. We have also begun engagements with lead customers.

LED professional: And regarding the current packages including the one that you used for the comparison chart; they were all mid-power LEDs?

Ken T. Shimizu: Correct.

LED professional: I think it's the same issue again - with high power you have high temperatures, and so on and I assume degradation would be too fast. Are you thinking about going into high-power products at a later stage?

Ken T. Shimizu: High power is a bit more challenging. We show that most phosphors suffer from photo-thermal quenching and quantum dots are no different. In fact, the quantum dots have so far shown more photo-thermal quenching at high power LED operating conditions. So our priority is to address the quantum dot material performance at high power LED operating conditions and then the reliability.

LED professional: In high power applications we always have high temperatures. Is the quantum dot material stable in relation to high temperatures?

Ken T. Shimizu: The high power LED applications certainly can have high temperatures. We have performed the reliability and performance studies in mid-power LEDs and see no issues at mid-power LED operating temperatures. Again, work is on-going to improve both the photo-thermal quenching and operational reliability in the QD materials for high power LED applications.

LED professional: If we look at possible products for the future, what kind of applications or markets do you want to approach with this product? Where do you want to go with these products?

Ken T. Shimizu: The first QD LED products are 90+ CRI white LEDs in the 3535L HE Plus package. We would like to consider products that can meet the general illumination customer needs for high color quality and high efficiency.

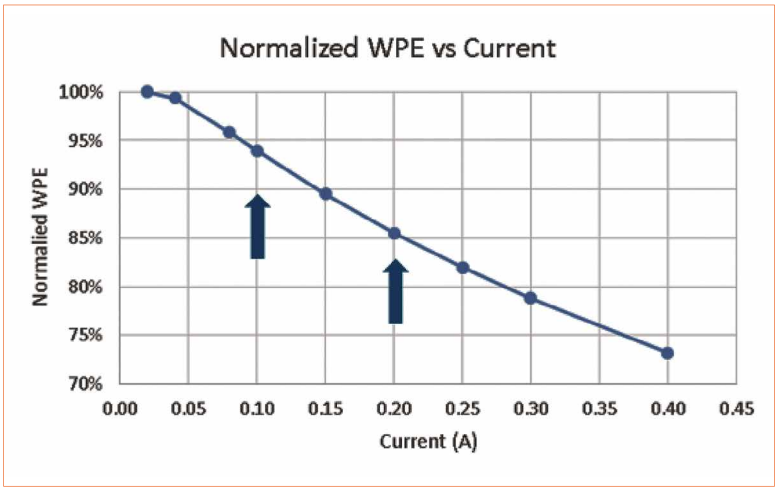
As the QD materials continue their development in terms of optical performance, reliability and lower Cadmium, we hope to see the material become more common as a color converter in LEDs in various applications such as outdoor lighting, horticulture, and specialty lighting. We also believe the on-chip QD LED design allows for greater flexibility for the luminaire or lamp vendors to design in the LED for their applications.

LED professional: You said that you're doing your research in-house but also with a partner who delivers the quantum dots. So your role is to find the right way to apply the quantum dots and to find the right mixture of the ingredients with silicone, make them stable and make them work properly. Is that the major direction of work on your side?

Ken T. Shimizu: We've had a very close collaboration to understand the requirements, to develop and characterize the QD materials, and to develop processes for integration into LEDS. And going forward, yes, we continue with materials and process engineering to optimize the next generation of QD based LEDs.

LED professional: How do you see the future of quantum dots in general lighting?

Ken T. Shimizu: We have always been looking for an ideal phosphor material and quantum dots uniquely fulfill some of those needs. We hope that QDs have a bright future in general lighting as future improvements to both phosphor materials and QD materials continue. Lumileds can trace back a history of over a 100 years of innovation and we hope to continue this effort in both phosphor and quantum dot development.



Ken T Shimizu named droop, efficiency reduction at higher currents, to still be one of the most important issues in LED technology that has to be solved. A current way to keep efficiency high is to increase the number of LEDs: Doubling the number LEDs increases efficiency by 10%

LED professional: If I understand you correctly, you're saying that quantum dots are a possible way. There are a lot of problems that we now know can be overcome, but we're not sure today whether it is really the technology for the future or if another technology will come.

Ken T. Shimizu: Yes, I think that there is no clear winner today, but I think that you need to have the fundamental properties. And quantum dots can claim to have a lot of these fundamental properties, but it remains to be seen whether other materials can claim to have these fundamental properties too. Today, interest is very high in quantum dots and I think excitement is high as well.

My personal viewpoint is that quantum dots are part of a toolbox where we can now think of, if the market moves towards really high quality of light, that would require really fine tuning of phosphors to fit those tailored spectra requirements. And it's good to have that available.

LED professional: Beyond QDs, in general, what do you think will be most important for solid-state-lighting in the future?

Ken T. Shimizu: At Lumileds, we continue to work on areas such as high luminance light sources and overcoming the challenges with LED droop. There is a trend towards smaller LED chips and high brightness light sources so droop may become even more critical, and we want to continue to maximize the performance of those LEDs.

LED professional: You just mentioned high luminance light sources. Another competing semiconductor technology comes into mind, in that respect: laser lighting. What are your thoughts on that?

Ken T. Shimizu: I think laser lighting will have its role. It can generate a very bright and very directional light. It also allows for designing a very narrow beam angle. We are already seeing laser based lighting in headlights for the high beam as long range light sources. As high power LEDs continue to improve, the question remains if lasers will be the solution or whether LEDs will also be able to fulfill that market need. It's a question that is still to be explored.

LED professional: Thank you very much for your time and this very interesting conversation.

Ken T. Shimizu: Thank you.

Hybrid Quantum Dot Light Emitting Electrochemical Cells

Several new light generation technologies that are overshadowed by LEDs and OLEDs are investigated. Most of these technologies are in a very early stage of research. One such technology, the LEC technology, was presented at LpS 2017. Light emitting electrochemical cells can be compared to OLEDs, but they are based on a much simpler inorganic architecture. The innovation in the presented approach lies in the combination with quantum dots, resulting in a hybrid solution. This novel attempt with all its consequences and future prospects was the reason that the LpS Scientific Award jury voted to bestow the award on Dr. Ekaterina Nannen, Group Leader of the Research Group „Solid State Lighting“ at the Nano-Energie-Technik-Zentrum (NETZ) of the University Duisburg-Essen and her research team, Julia Frohleiks and Svenja Wepfer.

The solution based processing makes light emitting electrochemical cells (LECs) a promising device alternative for large area flexible lighting solutions. Compared to organic light emitting diodes (OLEDs) and Quantum Dot (QD) LEDs, LECs exhibit a much more simple device architecture comprising ionic components, which facilitate charge carrier injection into the device under an applied electrical field. Despite the potential benefits of LECs as well as recent advances, the market entry of these types of devices is challenging mainly due to the lack of coinciding efficient, bright and long-term, stable emitter materials of different colors. We present an all solution based hybrid device concept implementing colloidal QDs as an additional active light emitting layer in Ir-iTMC based LECs. The hybrid devices show light emission from both QDs and LEC emitter. Electro- and photoluminescence measurements indicate that in the chosen device architecture, charge carriers can be injected directly into both light emitting species, which is beneficial for the implementation of QDs with various band gaps, and thus creation of white light emitting hybrid devices. The additional QD layer furthermore improves the electron injection into the active LEC layer which leads to a faster device turn-on and an improved charge carrier balance, resulting in an increased luminance and device efficiency. Hybrid devices containing yellow emitting iTMC and blue QDs emit white light at a maximum CRI of 78 with an external quantum efficiency of 0.03 %.

Introduction

Future lighting applications exceed the pure creation of light and get more and more inspired by innovative design possibilities due to large-area and at the same time flexible lighting technologies. The prototypes of light-emitting stickers, wallpapers and windows as well as animated rear lights are becoming reality [1-4]. Along with cost-effective and easy solution-based fabrication techniques, the next generation of lighting technologies can overcome challenges of epitaxial LEDs in flexible and shapeable design applications, leading to space-saving installation of light-sources in multiple applications. Light-emitting electrochemical cells (LECs) [4-7] represent a promising alternative for large-area device concepts, besides the more common organic light-emitting diodes (OLED) [8,9].
In contrast to OLEDs, the active layer of the LECs comprises ionic components in addition to the light emitting species (polymers or transition metal complexes).
The incorporated ions start moving due to the electrical field at applied voltage and thereby facilitate charge injection into the light-emitting component, so that the multiple charge injection and transport layers, which need to be carefully

controlled, specifically optimized and are thus mandatory for OLEDs, can be omitted. The whole layer stack can be simplified (even down to a single layer), only by the addition of mobile ionic species. Furthermore, air-stable electrode materials can be implemented and thickness variations of the active layer can be tolerated, so that easy solution-based fabrication procedures such as spin-coating, spraying, printing or slot die and dip coating can be established even in ambient conditions [4-7,10,11].

Since the charge carrier injection and transport in this type of device is initiated by the movement of the ionic species, the response and turn-on time of LECs is comparatively long, making LECs more applicable in lighting technology rather than high-end displays [5,12]. Based on the active light-emitting material, two different classes of LECs can be defined as it is also the case for OLEDs: polymer LECs (p-LECs) or ionic transition metal complex LECs (iTMC-LECs). iTMC-LECs are able to harvest both singlet and triplet excitons and thus allow for intrinsically higher quantum efficiencies than fluorescent p-LECs, resulting in typically higher brightness above 1000 cd/m^2 [10,13-16]. In case of yellow iTMC-based LECs, intramolecular π-π stacking interactions led to a stable emitter complex and, together with the introduction of a pulsed operation mode, yielded yellow LEC devices with lifetimes exceeding 4000 hours at maximum luminance over 650 cd/m^2 and sub-second turn-on times [15,17].

Despite the potential benefits of the iTMC-LECs as well as recent advances [5], the market entry of these types of devices is challenging mainly due to the lack of at the same time efficient, bright, and long-term stable emitter materials of different colors, resulting in challenges in the realization of white emission [18,19]. Combining the stability of semiconducting materials with their solution-based properties, colloidal quantum dots (QDs) offer an alternative approach for large-area lighting concepts due to their high color purity which is tunable over a broad spectral range by tailoring their size, shape and composition [20]. The expansion of the iTMC-LEC device by incorporation of colloidal QDs of different colors opens an alternative path not only for the variation of the LEC emission color. Even white light-emitting or color tunable hybrid devices can be realized depending on the chosen QD type and device geometry.

Development of Quantum Dot LEC Hybrid Devices

The device concept of a Quantum Dot LEC Hybrid Devices (QLEC) was presented to potentially improve two critical issues of the iTMC-LEC, the performance and the emission color, simultaneously. Therefore, the typical LEC device design, comprising the transparent ITO, coated by the poly(3,4-ethylenedioxy-thiophene): poly(styrenesulfonate) (PEDOT:PSS) as an anode, and the active LEC layer (iTMC + ionic liquid, IL), is complemented by an additional QD layer prior to the Aluminum cathode (Figure 1). In this case, the iTMC layer can be expected to act as a hole injection and transport layer for the QDs [2], on the other hand the QD layer can also improve the electron injection into the iTMC. Additionally, the device design gives the opportunity to combine the emission of two active light-emitting species, which enables the color tuning of the QLEC device.

Figure 1 shows the schematic device design of the QLEC. The glass substrate is covered with a 150 nm thick sputtered ITO layer, serving as the device anode. The anode is followed by PEDOT:PSS (Clevios by Hereaus, filtered, annealed at 150°C for 20 minutes), iTMC+IL ($[Ir(ppy)_2(pbpy)]^+[PF_6]^-$, $[BMIM]^+[PF_6]^-$ dispersed in acetonitrile, filtered) and QDs (dispersed in toluene) which are all deposited subsequently via the spin-coating procedure. The selected CdSe/CdS QDs were synthesized with a slightly modified procedure from the literature [22]. They have typical core/shell structure and are capped with insulating ligands as schematically shown in figure 1. The QDs have average size of 7 nm (TEM image), with CdSe core radius of 2.1 nm, 6 monolayers CdS shell and zinc blende crystal structure.

Red QLEC: Color tuning properties and operation mechanism

The combination of QDs and iTMCs in a hybrid device (QLEC) by adding an additional QD layer prior to the cathode to the conventional iTMC LEC architecture already showed promising results for the implementation of red QDs. We observed light emission from both light-emitting species which can be adjusted by the applied voltage (inset in Figure 2). For an applied voltage in the range of

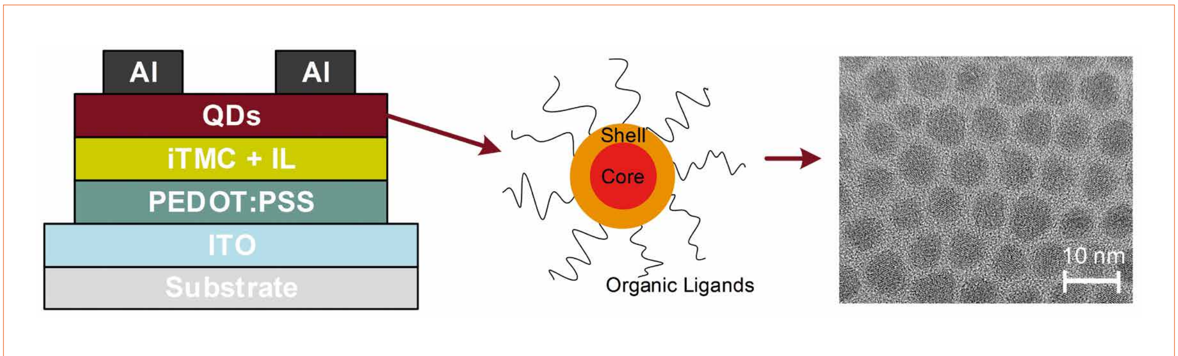


Figure 1: Schematic of the device design, schematic of core shell QDs and TEM image of QDs

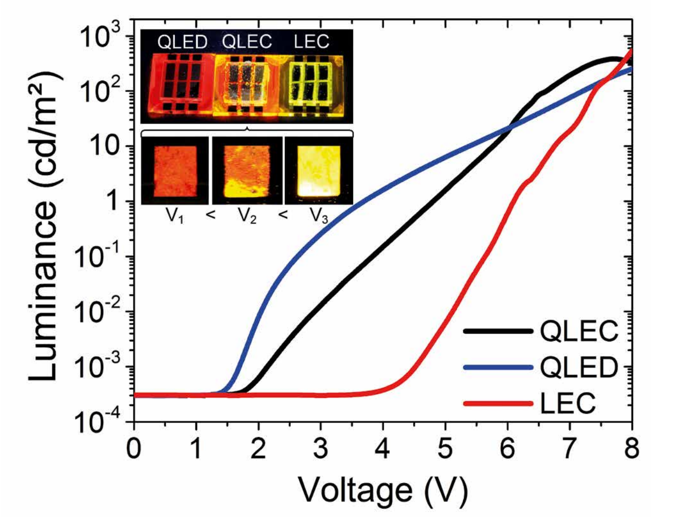


Figure 2: Luminance of QLED, QLEC and LEC with increasing applied voltage. Inset shows the prepared QLED, QLEC and LEC devices under UV illumination as well as photographs of the light-emitting QLEC with increasing applied voltage

2.5-3 V the device shows large area red emission which is caused by the red QDs. In this voltage range the device seems to operate as a QLED with active, light-emitting QDs and an iTMC layer acting as a hole injection and transport layer for the QDs. With increasing applied voltage, the iTMC contribution is raised so that the emission color of the device is shifted from red to orange. At a voltage higher than 5 V the emission is dominated by the iTMC, so that the device shows large-area yellow emission (inset of Figure 2).

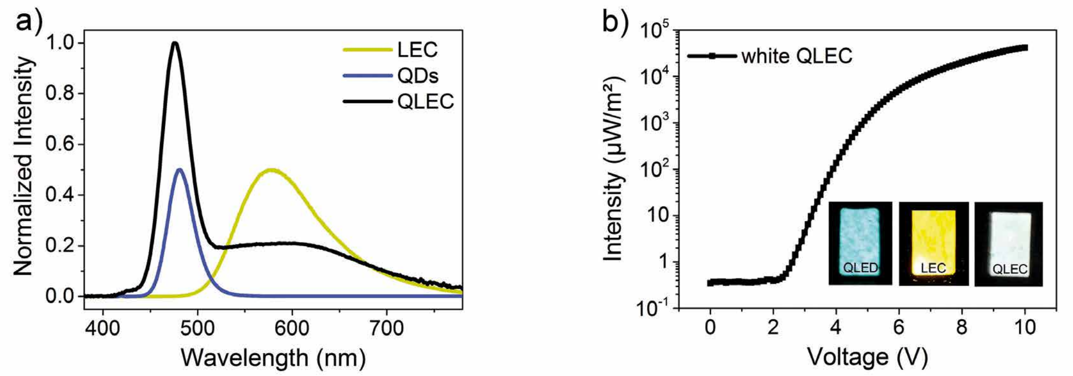
The voltage dependent luminance behavior of the QLEC is shown in figure 2 in comparison with the reference LEC (device structure ITO/PEDOT:PSS/iTMC+IL/Al) and reference QLED (device structure ITO/PEDOT:PSS/poly-TPD/QDs/Al) devices (also photographs in the inset). While the QLED and LEC reference devices show maximum luminance at 8 V of 342 cd/m^2 and 548 cd/m^2 respectively, with a tendency of further increase at higher voltages, the QLEC reaches its brightness maximum of 385 cd/m^2 at 7.7 V followed by a slow reduction of the luminance at higher voltages, e.g. 335 cd/m^2 at 8 V. Nevertheless, the QLEC exhibits a higher brightness compared to the LEC reference device over a wide range of operating voltages. Moreover, the additional QD layer has a significant impact on the turn-on voltage of the device. The reference LEC shows a turn-on at about 4 V, whereas the QLEC starts emitting light already slightly below 2 V. The reduction in turn-on voltage can be attributed to pure QD emission in this low voltage range with the iTMC layer working as a hole injection and transport layer. At the same time, the injection and transport of holes by the iTMC layer into the QDs in the hybrid device is obviously less efficient than in case of the poly-TPD layer: the reference QLED has a turn-on voltage of 1.5 V in agreement with state of the art red QLEDs [21,23]. In addition, it shows more than one order of magnitude higher luminance in the low-voltage regime compared to the QLEC.

At voltages above 3.5 V, the contribution of the iTMC emission to the total emission of the QLEC increases and even becomes several orders of magnitude higher than the iTMC emission from the reference LEC in the range between 3.5 V and 6 V. We attribute this behavior to the improved electron injection into the iTMC layer by the QD layer, which was also observed during long-term measurements at constant applied voltage [24]. Thereby, an improved charge carrier injection into the iTMC layer results in a faster build-up of the doped regions, resulting in a faster turn-on of the devices.

The QLEC exhibits pure QD emission at a voltage range, where the LEC reference does not emit any light at all. This excludes color conversion as a possible mechanism for light generation and gives further confirmation of direct charge injection. In addition, time-resolved PL measurements indicated that the emission is not dominated by energy transfer excitation (e.g. Förster transfer) but rather by direct charge injection into both active layers which is contrary to mixing concepts as suggested for p-LECs by Norell Bader et al. [25] and for pure QDs by Qian et al. [24, 26]. Thus, the excitation mechanism of the QLEC device enables the application of blue QDs yielding white light-emitting hybrid devices.

Towards efficient white QLEC: integration of blue QDs

Since charge carriers can be injected directly into both light-emitting species in the QLEC device geometry, the implementation of QDs with various band gaps should enable the creation of white light-emitting hybrid devices.
For this purpose, the red QDs were replaced by blue ZnCdSe/ZnS core/shell QDs with emission wavelength of 488 nm. The normalized emission of the blue QDs and the iTMC based yellow LEC are shown in Figure 3a. The iTMC shows a broad emission (FWHM > 100 nm) in the yellow color range, which is typical for iTMC emitters based on charge transfer transitions [27]. The first hybrid device shows superposed emission from both light-emitting species. A maximum CRI of 78 can be reached when the proportion of the QD emission is almost doubled compared to the LEC component emission. The voltage dependent light intensity of the white QLEC is shown in Figure 3b. The QLEC shows light emission at a slightly increased turn-on voltage of about 2.5 V. The emission intensity increases with increasing applied voltage, reaching the maximum intensity at 10 V. All three devices (LEC, QLED and QLEC) show large area emission as shown in the photographs of the light emitting devices in the inset in Figure 3b. Although the maximum CRI values, turn-on voltage and the emission



Figures 3a&b: Normalized emission spectra of LEC, QDs and QLEC device (a); Intensity of white QLEC depending on the applied voltage and photographs (inset) of blue QLED, yellow LEC as well as white QLEC (b)

profile of the white QLEC hybrid already show promising characteristics, it should be admitted, that the hybrid device shows yet a maximum external quantum efficiency (EQE) of only 0.03 %. We attribute this mainly to imbalanced charge injection and transport within device. Especially hole injection into the blue QDs with significantly higher injection barrier, compared to red QDs, needs to be improved in future devices.

Conclusions

In conclusion, we demonstrate large area, solution-processed hybrid devices made of red and blue core/shell CdSe-based QDs and an Ir-based iTMC that shows light emission from both QDs and yellow LEC emitters. The additional red QD layer prior to the device cathode facilitates the electron injection into the active LEC layer, which improves the LEC device performance.
This demonstrates the possibility of creating color tunable iTMC LECs by implementing additional QDs and simultaneously improving the device operation. The direct charge injection into both light-emitting species enables the electrical excitation of blue QDs together with the yellow iTMC component and thus creation of white light-emitting hybrid devices. Although the performance of the developed white QLEC devices needs further improvement, they already exhibit large area emission with promising CRI values of 78. ■

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Thermal Issues Posed by Compact Packaging and IoT for Next Generation SSL

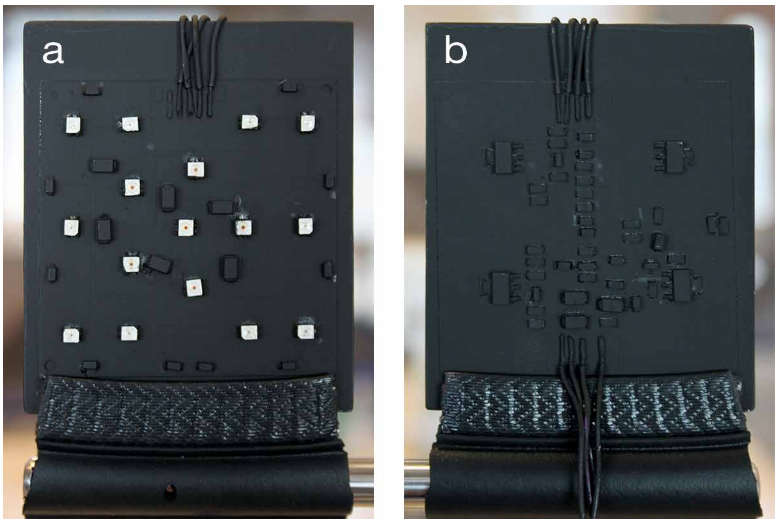
Besides general lighting, LEDs are penetrating many areas. At the same time, Internet of Things (IoT) has been rapidly evolving. Added electronics are expected to add an additional 70% to overall heat generation. Therefore, solving thermal problems will become more important again; on a par with footprint area and cost. Prof. Mehmet Arik, Director of EVATEG Center for Energy Efficient Electronics and Lighting Technologies at the Ozyegin University, and Umut Zeynep Uras, master student at the Ozyegin University, present some of the current, local, hotspot thermal issues caused by tight packaging. The severity of the problem for future lighting systems with added IoT will also be discussed. Finally, possible technologies to meet those challenges will be shown.

While light emitting diodes (LEDs) have been penetrating in many areas of general lighting and automotive lighting, display applications are some of the first adopters of the technology. White and many color offerings as well as high quality characteristics provide unique advantages to end customers. However, thermal management is still one of the major bottlenecks due to impact on light extraction and lifetime as well as weight adder in the physical system. Internet of Things (IoT) has been rapidly evolving, and lighting systems with over 550 Billion fixtures globally are seen as a great opportunity for a widespread application space.

Added electronics for communication, control, sensing and power for IoT features are expected to contribute an additional amount of over 70 percent to overall heat generation. It will be shown how a big problem becomes more critical at the same volume, footprint area and cost. In this paper, some of the current local hot spot thermal issues due to LED tight packaging for a number of applications with attention on IoT added future lighting systems and the severity of the problem will be shown.

Introduction to the Set of Problems

Light emitting diodes (LEDs) bring unique advantages to a wide range of lighting applications such as automotive lighting, security lighting and display technologies. Due to their various color options with high luminous efficacy, LEDs have dominated the lighting industry. Although LEDs are considerably high energy efficient sources compared to conventional old-fashioned systems, still 70-80% of input electrical input power is converted to heat [1, 2]. If released heat cannot be transferred to ambient, it causes elevated junction temperatures of LEDs which lead to optical losses, catastrophic defects and lifetime problems [3, 4]. Therefore, thermal management is a significant concern for sustainability of LED lighting systems. Several thermal management solutions have been studied in the literature. According to the ambient conditions and requirements of problem, passive or active cooling technologies can be used to overcome some of those thermal issues. Internet of Things (IoT) has



Figures 1a&b: Automotive lighting system: LED side (a), electronics side (b) [6]

gained tremendous attention during the last decade and more focus on how to utilize IoT in LED systems for the last five years. Though smart sensors and network capabilities are some of those first technologies in smart lighting systems, they will offer tremendous opportunities in upcoming years. However, none of the current LED lighting applications reach the dream of IoT goals yet. Therefore, it would be interesting to see some of those high ends and high functionality features in possible LED systems. As thermal management is still a major challenge in LED systems, more functionality with IoT will pose substantially harder problems for scientists and design engineers. It is important to review some of the current approaches to understand the thermal issues in LEDs, and then attention will be turned to IoT embedded LED systems.

A current automotive rear lighting system is perhaps the closest LED technology in a compact packaging form factor that will IoT features will pose on new systems. A double sided LED light engine houses LEDs at the front side, while densely populated electronics and sensors are used in the backside of the board [5, 6]. A detailed study has been presented by Uras et al [5] on the thermal management issues of an LED automotive lighting system. The system has tight packaging problems, limited lifetime, vibration issues, aggressive power needs. It cannot easily adopt active cooling technologies, so they have chosen to investigate passive thermal management solutions. As a passive thermal management technique, thermal performance of conventional PCB can be enhanced via high thermally conductive PCB substrates [7]. Due to poor thermal conductivity of conventional FR4 PCBs, LEDs and electronic components cannot diffuse excessive heat. Therefore, local hot spots occur over the PCB and junction temperature gets higher. In this regard, metal core PCB improves thermal performance of the system because of its higher thermal conductivity [8]. However, in compact and dense lighting engines, MCPCBs are not efficient to meet operational requirements of LEDs as well. Thus, a novel heat spreader technology is required.

Tamdogan et al. [9] reports that high power LEDs and electronics require novel thermal management techniques such as micro jet, micro channel and immersion cooling methods. They studied computationally and experimentally thermal characteristics of a high-power LED light engine utilizing various cooling methods with different coolants. Despite of the fact that multiphase liquid cooling performs better, bubble generation around the LED chip leads to significant lumen degradation. However, light engine with single phase liquid cooling showed efficient thermal performance while enhancing light extraction by 15%. Therefore, the study reveals that single-phase immersion liquid cooling is a possible cooling method to enhance the thermal performance of high power LEDs. In another study, Arik et al. [10] presented synthetic jets as novel cooling devices for high power electronics. Synthetic jets are practical for many applications due to their small sizes compared to other forced convection devices.

IoT will bring along many sensors and communication features so electronic component density of the PCBs, possibly light engine, will increase significantly while power consumption of the present electronic components rises.
IoT is an environment that smart devices, sensors and actuators are connected and able to communicate with each other via an Internet platform [11]. In recent years, IoT has been rapidly evolving, and it is expected that in five years 50 billion smart devices will be connected [12]. Smart devices will be effective in many different areas such as healthcare, energy, lighting, automotive, smart grids and home automation [12, 13]. IoT will also integrate these individual areas. Such as smart buildings will manage energy efficiency of houses, it will also analyze the comfort and health of households [13]. Although IoT provides many benefits, it also has some challenges and concerns such as privacy, security, openness [14, 15] and power consumption [16]. As mentioned, by 2020 approximately 50 billion smart devices will be connected to each other. Therefore, the number of smart sensors, communication devices and electronic components will be considerably higher than today and their power consumption will be higher. Thus, power will be a significant concern for the IoT applications. For IoT devices, mobility is very important so they should operate with batteries [11]. However, present batteries have limited lifetime and energy storage problems. With the enhancing utilities of smart devices, more power requirement will occur.

In order to solve the high power consumption problem, Ju and Zhang [16] suggest that energy harvesting for low power IoT devices with small size and proper energy storage volume is a need and they propose Internet of Battery-less Things (IoBTs). One of the major goals of the Internet of Things is to enhance the capacity of devices and electronics while reducing their energy consumption. In this regard, besides investigating novel low power technologies, minimizing the power loss of the components is crucial. New devices have been developed with the concept of low power consumption. However, due to small size constraints and high usage of sensors, actuators and electronics, increase in total heat flux of the system constitutes efficient thermal management requirements.
As mentioned before, even today thermal problems in electronic systems, with the increasing number of sensors and electronics that provide connectivity of things, heat flux over electronics is expected to increase over 70%. Because of poor thermal conductivity of conventional PCBs, local hot spots which affect the reliability of the system will occur. Thus, novel PCB solutions should be improved.

Lighting systems with over 550 billion fixtures globally are seen as a great opportunity for a widespread application. Lighting systems are used almost in all living spaces and a large number of outdoor areas. IoT applications will also be active in all of these places so lighting fixtures may constitute a platform. According to Lowe [17], automobiles have a great number of microcontrollers, and due to their mobility, they can be recognized as ultimate smart mobile devices so the automobile industry will take a critical role in IoT conversion. Lighting fixtures of automobiles can be enhanced to collect and sense data from the environment due to their present electronic structure and the place where they mounted on the automobile. Therefore, in this study an automotive rear lighting system is studied. Thermal challenges which are caused by the increase of heat flux from components with IoT will also be faced in automotive lighting systems. Due to size and cost concerns, LEDs and electronics are integrated on the same board. Moreover, all lamp functions, stoplights, signals and positions operate on a single PCB. Therefore, even in the present condition, complex thermal problems occur on the selected LED lighting system. When IoT added over traditional lighting fixtures are considered, hard problems will be harder at the same volume and footprint area.

In this study, thermal properties of an FR4 light engine with compact packaged electronics is analyzed, then as an alternative solution a metal core PCB is investigated. When it is understood that MCPCB is not adequate for compact light engine, a heat spreader which consists of an advanced nano-structured vapor chamber is studied due to its high thermal conductivity. It can provide solutions for the current thermal issues by abating local hot-spots. Later, attention is turned into mimicking the same system adding IoT features like imposing a higher heat generation rate. Computational models are developed and results are discussed in detail.

Experimental Study

Vehicles are expected be one of the major parts of the IoT due to their current electronics infrastructure [17]. Electronics have already been used in several purposes in a

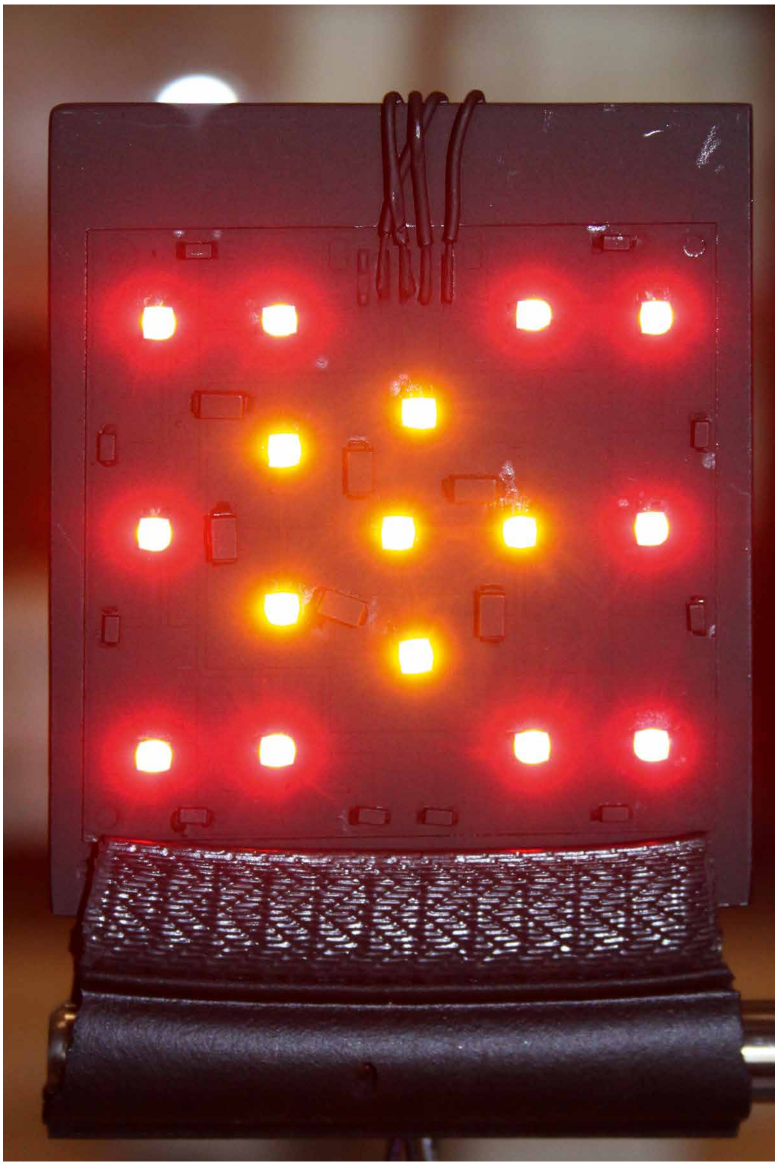


Figure 2: FR4 based LED engine while all functions operated simultaneously

number of areas in vehicles. For instance, power electronics are used in lighting systems of automobiles in order to drive LEDs. These electronic systems can establish a substructure for IoT applications. Therefore, in this study, an LED light engine which is used in automotive rear lighting system will be analyzed. Rear lighting systems consists of three different functions which are signal, stop and position (Figure 1). Conventionally, for these three functions, three separate light engines are typically used. Due to the unique advantages of LEDs, to integrate all these functions on a single light engine is possible. Although LEDs are energy efficient sources, if all three functions operate simultaneously, heat generation of the combined LEDs and driver electronics increase. Industry preferred PCB material for light engines is FR4 due to availability, ease of processing and cost. However, due to poor thermal conductivity of FR4; heat generated from components over PCB cannot diffuse uniformly so local hot spots occur over components and PCB. Thus, junction temperature of LEDs can surpass 100°C which is the critical temperature for most LEDs [3]. Therefore, LEDs and driver electronics are placed over separate PCBs due to thermal limitations of conventional boards. However, this study aims to combine electronic components and LEDs on a single compact PCB. When IoT features are added into the current system, the number of electronics and their power consumption will increase so thermal problems will continually increase. Therefore, a novel heat spreader board technology should be developed to overcome these thermal issues.

In order to develop a novel heat spreader board, understanding the current problem in conventional FR4 boards via observing its thermal performance is the first step. Metal core printed circuit boards (MCPCB) have also been used in recent years to improve the thermal performance of LED light engines. Therefore, initially, three identical 66x80x2.75 mm light engines with FR4, Al and advanced heat spreader base are produced. Flex PCBs are designed for each substrate because vapor chamber surfaces are not convenient for printed circuits directly. Flex PCBs consist of 40 µm copper layer and 160 µm epoxy-glass fiber layer. Highly conductive double-sided adhesive with thermal conductivity of 0.60 W/m·K is used to assemble flex PCBs to front and back of each substrate. Then, 16 LEDs; 10 red LX E6SF and 6 amber LXG6SP LEDs; are mounted in the front of the PCBs. Electronics that drive LEDs are placed at the back of the PCB as figure 3.

Computational Study

In order to observe the thermal effect of a possible power increase on driver electronics of LED light engine when IoT applications are adapted to the current system, a computational study has been conducted in the commercially available computational fluid dynamics software, Icepak 14.5 [18]. CFD simulations allow users to change model parameters and experimental conditions easily. Therefore, the computational study consists of four cases that represent expected scenarios when IoT applications are integrated to LED light engines. The first case stands for current performance of the LED light engine without any smart features addition. In the second, third and fourth cases, only power levels of driver electronics are increased by 25%, 50% and 70%, respectively. Geometrical models of the LED light engines are identical for all cases.

In the computational study, thermal performance of the FR4 based LED engine is modeled. Therefore, substrate material is chosen as FR4 with thermal conductivity of 0.35 W/m·K, while type thermal conductivity of flex PCB is chosen as orthotropic and thermal conductivity of the material is

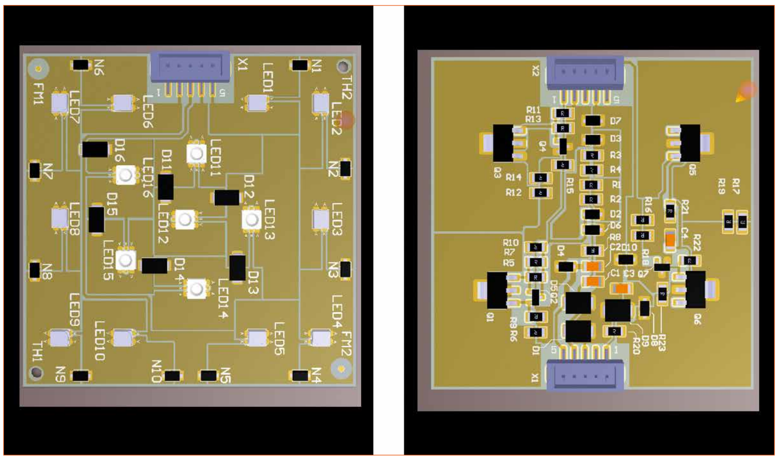


Figure 3: Schematic of the front and back of the LED engine

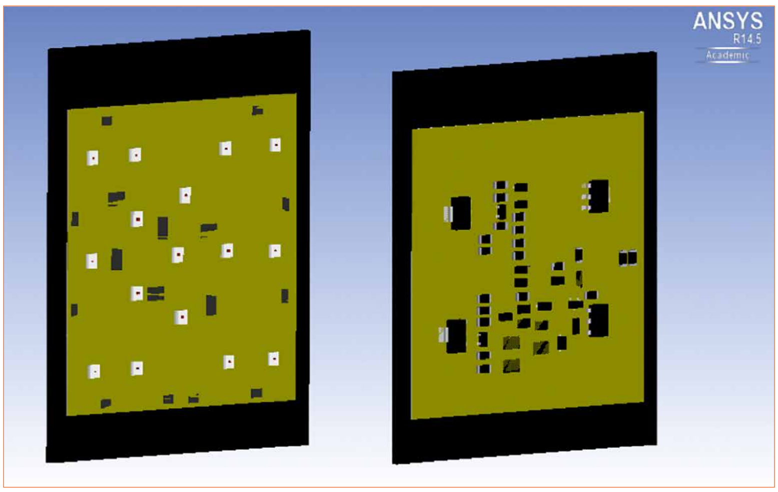


Figure 4: Computational model of the compact light engine - front view (LEDs) and back view (electronics)

12, 12, 0.35 W/m·K (kx, ky, kz). LEDs are modeled as LCC package with its original geometry according to the manufacturer's specifications. Transistors Q1, Q3, Q5 and Q6 are modeled as package SOT223 and transistors Q2, Q4 and Q7 are modeled as SOT23 package. Radiant powers of red and amber LEDs are measured with the integrated sphere method. Hence, red and amber LEDs' efficiencies are obtained as 27% and 4.9%, respectively. Efficiencies of the electronic components are accepted at 10%. In order to increase the mesh accuracy, separate assemblies are created for almost all LEDs and electronic components. A mesh sensitivity study has been performed before each computational model.

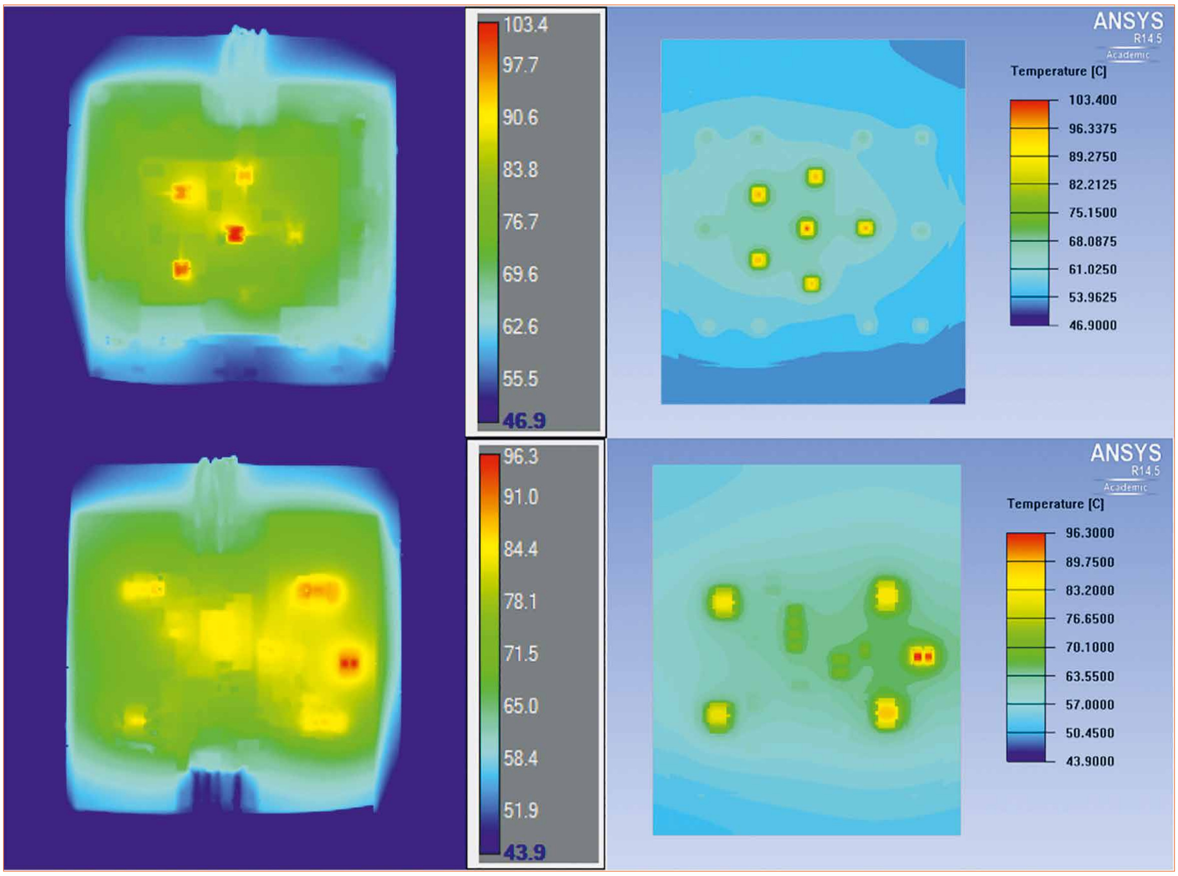
Results and Discussions

IoT features integration to current technologies will soon be essential. These new features will cause an increase in the number of electronics and their power consumptions in the same or smaller footprint areas. It is expected that overall heat generation of electronics may increase as much as 70%. Therefore, this study aims to investigate advanced heat spreader substrate technology to solve possible thermal problems of new generation electronic systems.

To understand the impact of IoT on the system, first the thermal performance of a baseline system, three FR4 based LED light engines, utilized in automotive rear lighting systems is analyzed via infrared thermography technique. With the help of IR thermography, surface temperatures of the front and back of the engine are captured while ambient temperature is 25°C. While maximum and minimum surface temperatures in the front of the engine are observed on amber LED- LED12 as 103.4°C and on PCB as 46.9°C, respectively, maximum and minimum surface temperature at the back of the engine are observed on resistor-R17 as 103.4°C and on PCB as 46.9°C. Figure 4a indicates the thermal distribution over the PCB based on infrared thermography.

Due to the low thermal conductivity of FR4 PCB material, heat cannot diffuse uniformly over the PCB so hot spots occur over the PCB as well as on the LEDs and electronic components. During the operation, the junction temperature limit for typical LEDs and electronics is about 100°C. However, as thermal performance of FR4 based LED engine is analyzed, at the LEDs side maximum temperature of some LEDs exceeds this critical temperature. Moreover, at the back side of the board, temperatures of two resistors are very close to operational temperature limit.

In order to validate experimental data and investigate possible thermal effects of IoT addition to the current system, the light engine is modeled in CFD software with higher power generation rates. Firstly, CFD model of FR4 based light engine with its original power is solved. Then, for the validation process, CFD results are compared with experimental results as figures 5 and 6. For comparison, 10 points are selected from LEDs and electronics. As it is presented in



Figures 5a&b: IR thermography results (a) and CFD temperature distribution (b) of FR4 based light engines operate simultaneously during all functions (LED side at the top and electronics side at the bottom) figure 6, among these ten points, the maximum difference is experienced on transistor Q5 as 4%. During CFD model creation, original geometry of the LED engine is simplified which caused differences between experimental and computational results.

Since a very good agreement between computational and experimental results is observed, the model is solved for other CFD cases to analyze thermal performance of the current LED engine with smart applications. It is expected that IoT features leads to a 70% increase in power consumption of electronics. Thus, the model is modified via increasing power consumptions of electronics by 25%, 50% and 70% which represents future smart LED engines.

Significance of the thermal problem can be seen from figures 7a-d. While the power consumption of the electronics increases by 70%, the maximum temperature that is experienced on the electronics increase by ±25%. Temperature rise on the electronics is indicated in figure 8. The maximum temperature on the light engine goes up to 130.9°C which can lead to catastrophic failures.

Although power consumption of LEDs are not changed in different cases, as it is shown in figures 9a-d, temperatures of LEDs and thermal distribution over the board is changed due to power addition to electronics. As it is indicated in figures 9 and 10, while maximum temperatures of amber LEDs increased by +8.5%, a +12% temperature rise is experienced on red LEDs respectively. While with 25%, 50% and 70% power addition to electronics, maximum temperature experienced on LED-12 reached from 103.4°C to 104.9°C, 108.4°C and 111.0°C, respectively. Because of the fact that when FR4 material used as substrate, the junction temperature of LEDs exceeds critical temperature even in the current situation when there is

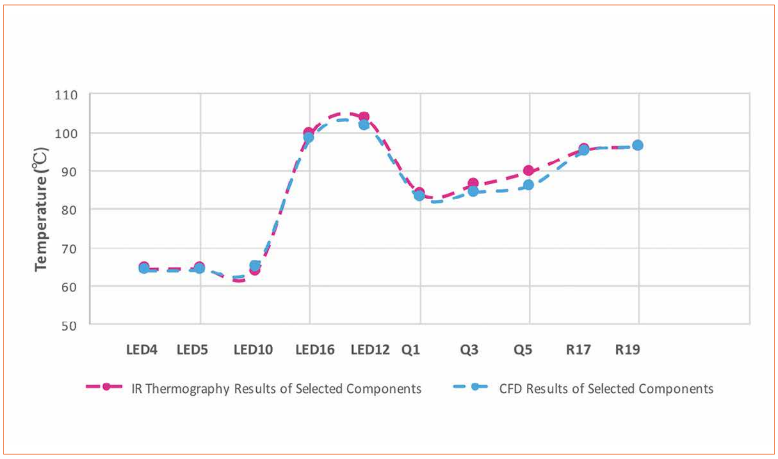
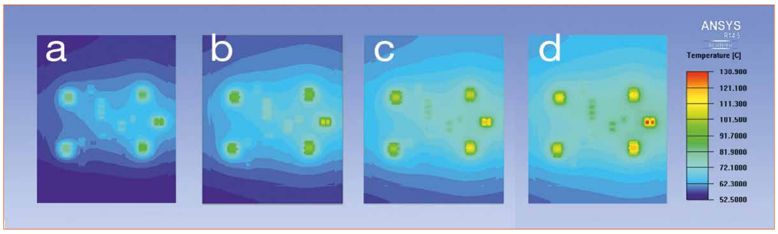


Figure 6: Comparison between IR thermography and simulation results



Figures 7a-d: Temperature distribution of electronic components placed over light engine: (a) Baseline without IoT added heat generation (b) 25% (c) 50% and (d) 70% added heat generation rates over electronics

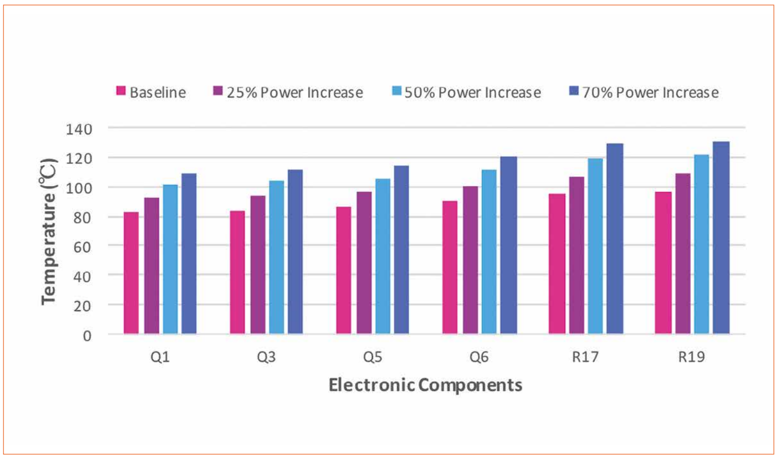
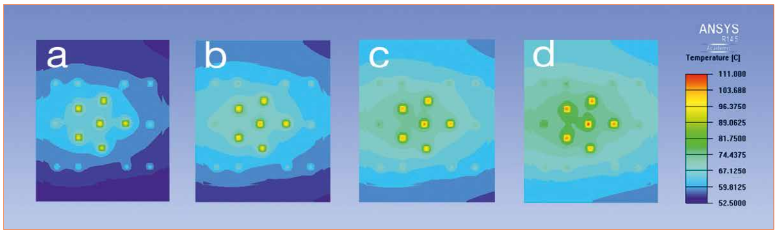


Figure 8: Temperature increase of electronic components as a result of power increase



Figures 9a-d: Temperature distribution of LEDs placed over light engine: (a) Baseline without IoT added heat generation (b) 25% (c) 50% and (d) 70% added heat generation rates over electronics

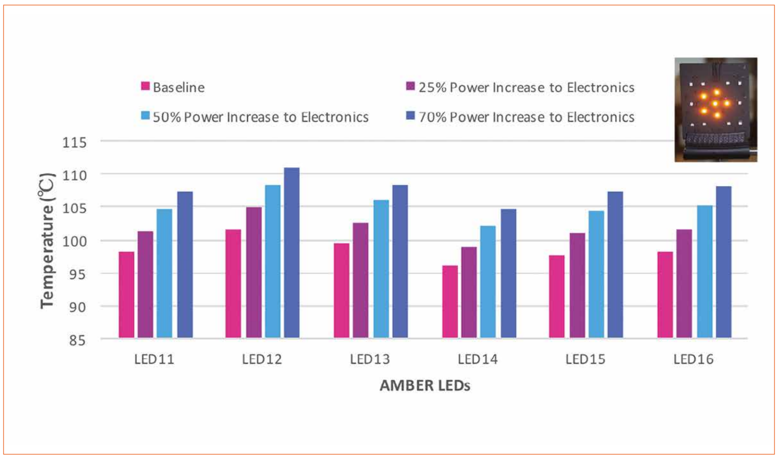


Figure 10: Temperature increase of amber LEDs as a result of power increase to electronic components

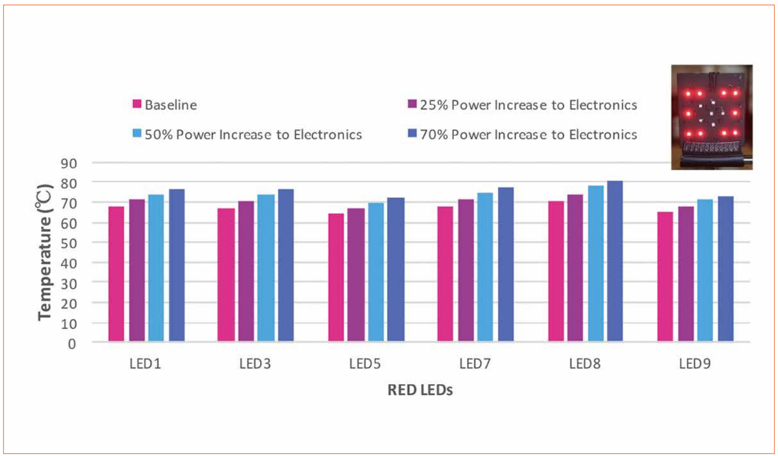


Figure 11: Temperature increase of red LEDs as a result of power increase to electronic components

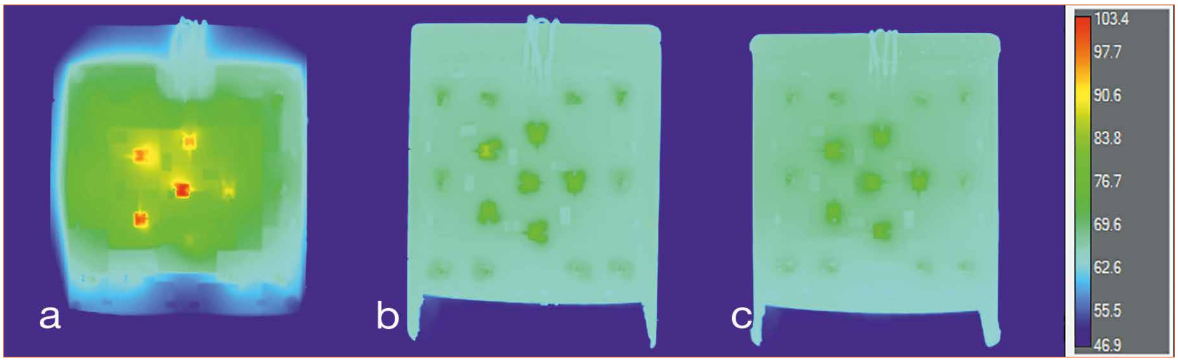
no IoT added power, an additional heat generation in electronics gets this situation more critical.

It is found that the highest temperature is observed at the centerline LED (LED-12) due to the fact that local heat generation is highest and the heat transfer path is rather limited compared to other LEDs on the light engine. Although there is approximately 13% elevation in temperature, this can be perhaps eliminated by improving the conduction performance of the board by having either highly conductive boards or vapor chamber based systems.

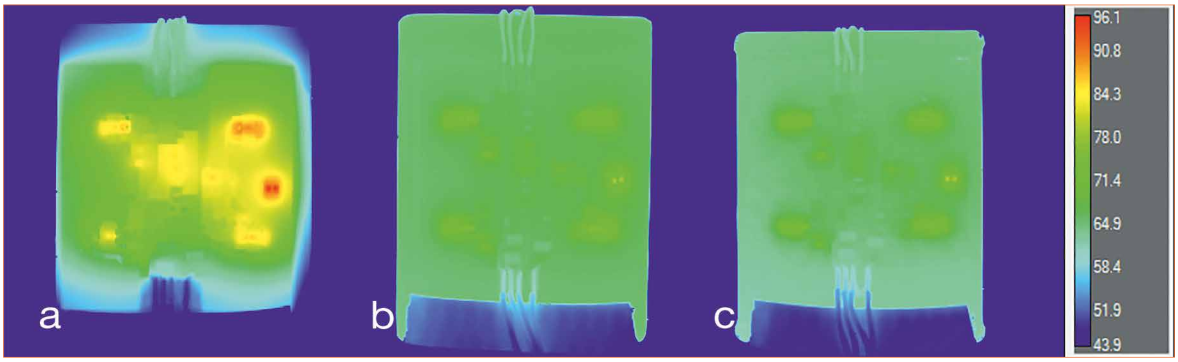
Figure 11 presents the results for red LEDs which has the minimum driving power requirements and the lowest heat generation rates. Although the heat generation at the electronics is increased by 70%, temperature rise only increased about 12%. When real automotive environment is evaluated, ambient temperature will be considerably higher than room temperature. It can be inferred that if IoT features are added to current system, the system will be more compact than today so current thermal problems will be harder. Therefore, while FR4 substrate is not adequate for even current application, for future more complex technologies, novel heat spreader PCB substrates should be developed.

In recent years, metals have been used as PCB substrate material to enhance thermal performance of the LED engines. MCPCBs allow heat diffusion in three dimensions while FR4 PCBs conduct heat only in one dimension [8]. An alternative solution with an Aluminum board is designed. While all three functions operate at the same time, maximum LED temperature is measured as 84.1°C. Besides, maximum electronic temperature is obtained as 78.6°C. Thus, at the LEDs' side and the electronics' side, Al based board performs 18.7% and 18.2% better than FR4 based LED engine. According to figures 12 and 13, over the Al based board, more uniform thermal distribution is observed compared to FR4 based board.

Although metal based board improves thermal performance of the light engine significantly, for IoT added applications it may not still be adequate. Therefore, in this study, a heat spreader substrate which comprises vapor chamber structure proposed as a possible substrate for new generation IoT features added LED engines. Thermal performance of the advanced heat spreader substrate can be observed on figures 12 and 13. Maximum



Figures 12a-c: IR Thermographs of (a) FR4, (b) Al and (c) Advanced heat spreader based light engines, operate simultaneously during all functions (LED side)



Figures 13a-c: IR Thermographs of (a) FR4, (b) Al and (c) Advanced heat spreader based light engines, operate simultaneously during all functions (electronics side) temperature of the LED is experienced as 77.9°C as the maximum temperature of the electronics is obtained as 79.4°C. Therefore, at the front side, advanced heat spreader board shows 24.7% better thermal performance than FR4 based board and at the side of the board advanced heat spreader board shows 17.4% better thermal performance than FR4 based board. Most uniform temperature distribution is observed in advanced heat spreader technology. In this regard, advanced heat spreader substrate can be an applicable solution to overcome expected thermal problems of future technologies.

Summary and Conclusions

Unique advantages of LEDs such as high lumen efficiency, wide range color alternatives and nontoxic structure, brings LEDs into the forefront. Automotive, general lighting, and display industries are dominated by LED applications. Although their electrical energy to photons conversion rate is considerably high compared to conventional light sources, still about 20% of power supplied to LEDs turns into heat which causes thermal problems. In recent years, the paradigm of Internet of Things which will be effective in all areas of our lives is in the foreground and lighting systems with over 500 billion fixtures globally are seen as a great opportunity for a widespread application. In addition, automobiles may constitute a platform for IoT applications due to their current electronics system and mobility feature. Thus, in this study, a possible candidate automotive rear LED lighting system is evaluated in terms of thermal performance for new generation IoT added applications. Firstly, thermal performance of FR4 based LED engine is evaluated and it is modeled in a CFD program. Then, the computational model is solved for different cases such as; 25%, 50% and 70% power addition to electronics to determine the adverse effects due to IoT power needs. Metal and advanced heat spreader substrate technologies are presented as a solution to overcome thermal problems.

Consequences of the study can be listed as follows:

- While power consumption of electronic increases by 70%, maximum temperatures that is experienced on electronics increase by ±25%. Maximum temperatures of amber LEDs increased by ±8.5%, when temperature rise of ±12% is experienced on red LEDs
- In case of 25%, 50% and 70% power addition to electronics, maximum temperature experienced on central LED reaches from 103.4°C to 104.9°C, 108.4°C and 111.0°C respectively
- At the LEDs' side and the electronics' side, metal board performs 18.7% and 18.2% better than FR4 based LED engine
- At the LEDs' side, advanced heat spreader board shows 24.7% better thermal performance than FR4 based board and at the side of the board advanced heat spreader board shows 17.4% better thermal performance than FR4 based board
- With the usage of advanced heat spreader substrate, the most uniform temperature distribution is achieved
- As conventional FR4 substrate is not adequate for future electronic systems, advanced heat spreader board technology which consists of vapor chamber structure can be a possible substrate technology for new generation smart applications

While IoT is slowly getting into smart lighting systems, EVATEG research center is working on possible technology scenarios and thermal implications. Developing novel technologies and implementing for rapid deployment of the technology is the primary goal for EVATEG team. ■

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LpS Gets a Younger Sibling to Foster a Holistic System Approach

For the most part our readers are aware of the fact that the LpS has a strong focus on the component level, but after the 6th event, the Luger Research team realized that it was time to find a way to push the more holistic system approach. After much consideration and careful planning, the Trends in Lighting (TiL) Forum and Show was initiated and took place in conjunction with the LpS 2017. Arno Grabher-Meyer, Editor-in-Chief at LED professional took a close look at both exhibitions and the lectures to find out what the audience thought of the extension and broader outlook.

With about 90 LpS exhibitors and an additional 30 TiL exhibitors, the 2017 event was a great success and has certainly evolved into central Europe's meeting point for lighting engineers, architects and lighting designers alike.
Because of the new approach, which included several new highlights, changes had to be made in the structure processes to allow for a smooth running schedule. This year, in addition to the LpS Scientific Award, two new awards were introduced: The LpS Technology Award and the Trends in Lighting System Award. While the technology award honors the most innovative and market-influencing component, the system award pays tribute to the most innovative, versatile and trendsetting product on a system level.
The second day of the events hosted the awards ceremony as well as a panel discussion and the Get Together event in the evening. Different interest groups sharing their views at the Expo Reception on the first day triggered discussions throughout the event.

A broad range of topics was covered again this year in more than 100 lectures and six workshops. While the industry workshops were held in one block at the beginning of the event, the lectures were split into four parallel tracks.
One of these tracks, the TiL Forum, covered topics dedicated to themes at the TiL show. Many technicians, who traditionally attend the LpS were enthusiastic about the opportunity to listen to a variety of renowned speakers at the TiL Forum, that they wouldn't ordinarily get a chance to hear. Because of the extended lecture program, topics ranged from highly scientific talks which included the six Scientific Award nominees and lectures shedding light on complex technologies to strongly application related lectures that gave practical advice and covered artistic-philosophical views, health and perception aspects and future perspectives.

One Established Award and Two New Awards – High Quality Submissions Make Evaluations Difficult

The LpS Scientific Award has established itself over the years and the large number of excellent submissions attest to how coveted it is. In 2017 the LpS Technology Award and the TiL System Award were added because the Luger Research team felt it was time to honor innovative technologies and systems as well. Because of the newness of the awards, the judges weren't expecting the amazing amount of companies that submitted products and systems with an exceptionally high standard of excellence. Just shortlisting the entries took an enormous amount of time – not to mention trying to pick the winners out of so many outstanding submissions.

The Scientific Award papers were evaluated on the basis of their novelty, scientific work, usability and applicability. The shortlisted papers were all of such a high level that the deciding factor was the novelty of the paper. In the end it was Dr. Ekaterina Nannen, from the

▼ **The established LED professional Scientific Award is now accompanied by the LED professional Symposium +Expo Technology Award and the Trends in Lighting System Award**

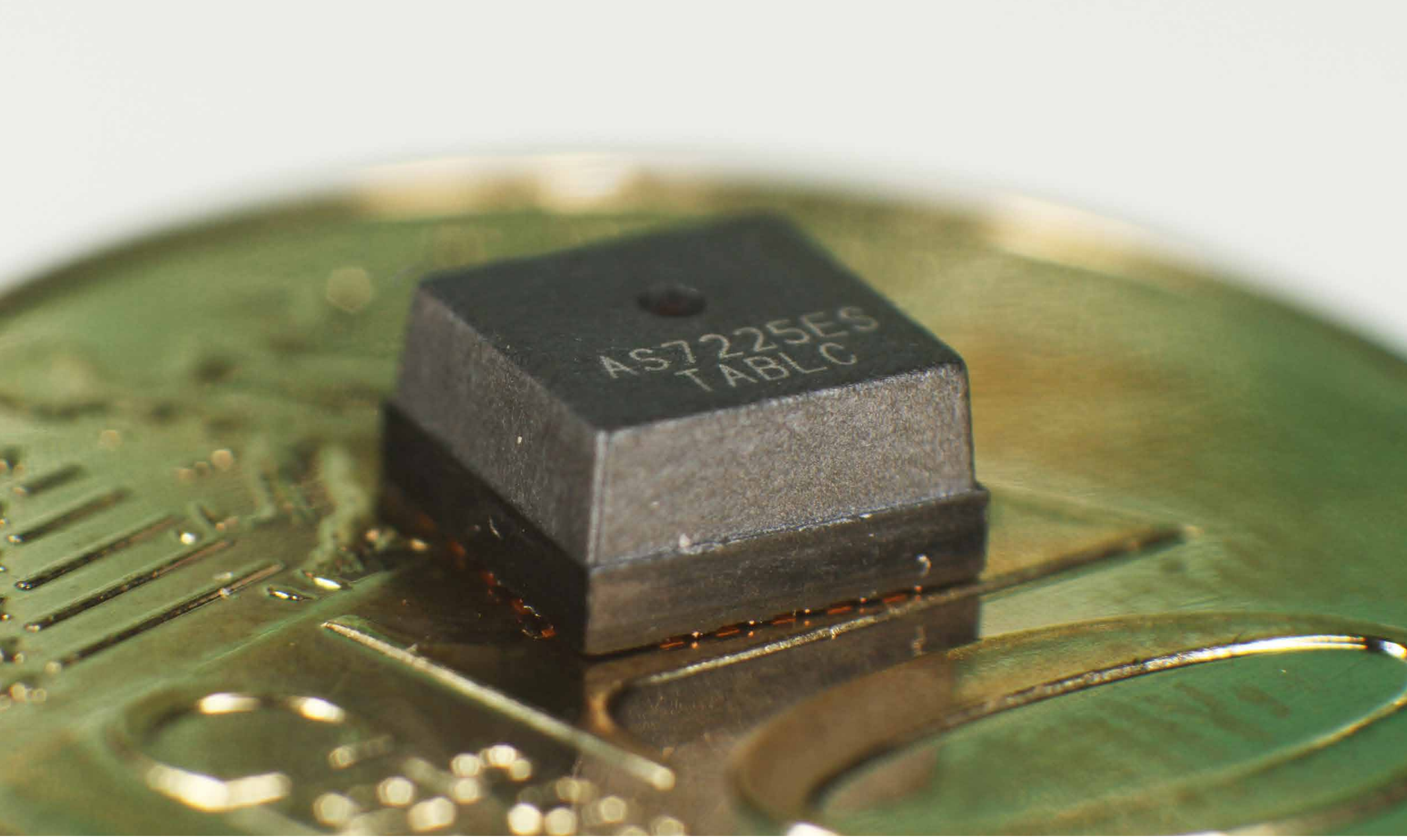
▲ **Florian Nübling demonstrates the capabilities of the volatiles**

▼ **Presentation of the awards to the winners**

Nano-Energie-Technik-Zentrum (NETZ) at the University of Duisburg-Essen's paper, "Hybrid Quantum Dot – Light-Emitting Electrochemical Cells" that had the best score. The paper is concerned with alternative techniques for light generation, combining Light Emitting Electrochemical Cells (LEC) with quantum dots.

Dr. Nannen starts with an introduction to state-of-the-art LECs and then goes on to explain the modification using quantum dots and its effect. The paper discusses the experimental setup and results. The jury's verdict was, "The work has a notable degree of novelty. Although quantum efficiency is quite low in the current state of fundamental research the paper could have an important impact on further research and development." The full paper can be read on page 40 of this issue.

The winner of the LpS Technology Award was also a very close competition. The winner was determined based on the three parameters: technical excellence, usability, and potential market impact. Usability was finally the key to success for ams AG with their AS7221 Tunable White IoT Smart Lighting Manager; a controls IC that exhibits various functions in a small footprint - making it highly innovative. The board's reason for choosing this particular technology was, "The combination of a tri-stimulus sensor with a UART bridge to the IoT infrastructure for building smart lighting systems is an especially unique feature. In combination with its reasonable cost, this IC can have considerable



▲ The AS7225 is a close relative to the award winning AS7221

impact on the market; fostering the development of cost effective smart lighting systems."

Choosing a winner for the LpS Scientific Award and the LpS technology award were difficult, but the TiL System Awards winner was probably the most difficult of all. The proposed solutions and applications were too diverse. While this award was initiated to honor approaches that go beyond illumination, the jury finally agreed that "volatiles" should be the recipient of the award because, "volatiles displays the combination of diverse technologies such as IT, RGB-W lighting, pixel controls and touch technology in a neat, new lighting system. Due to the novelty of its appearance, operation and control options, the system could provide new impetus to the lighting application market."

The prizes were awarded on the second day of the event before the Expert Panel Debate and the Get Together Evening in the electric atmosphere of the Great Hall in the Bregenz Festival House. In the absence of Dr. Ekaterina Nannen who unfortunately wasn't able to attend, Ms. Julia Frohlikes received the trophy from Dr. Guenther Sejkora, Science Manager at Luger Research. Arno Grabher-Meyer, Technology Manager at Luger Research and LED professional Editor-in-Chief, had the pleasure of handing over the LpS Technology award to ams AG's Senior Marketing Manager, Tom Griffith. Finally, Siegfried Luger, the organizer of LpS and TiL and Luger Research CEO, presented the TiL System award to the CEO of volatiles, Florian Nübling.

Eloquent Speakers - Inspiring Talks

This year's keynote speakers clearly reflected the new vision and spirit of the event. Helmut Kinzler, Senior Associate at Zaha Hadid Architects and a highly qualified representative of the company, showed modern to avant-garde architecture and the role of light – not just artificial light – in these concepts. Jan Denneman, who represented The Global Lighting Association and Philips Lighting, presented the industry roadmap and depicted a clear view of the future of lighting. CISCO's Business Development Manager, Akshay Thakur, covered the IoT and network topics that are becoming increasingly more important for anyone that deals with lighting. And finally, Fred Maxik, founder of the Lighting Science Group, inspired the audience with his knowledge of light quality and human centric lighting. The audience was awed by his visions of what else could be done with light in the future.

The complete LpS program once again enjoyed great popularity and was praised for the high quality of the lectures and its versatility. Three parallel tracks covered every topic on people's minds, from enabling technologies to thermal management, from the light source to the controls, from engineering to system quality, and from system qualification to application.

The first TiL program was highly commended, even by those skeptics who couldn't imagine that the organizers, who are known for their technical expertise, could set up a valuable program for architects, planners and designers. Many hot topics were covered, from case studies to straightforward installation advice, from future outlooks for the lighting business to the challenges and chances of IoT, from emotions to IT.

LpS - latest science and technology comprehensibly presented

While all sessions were chock full of interesting topics and highly qualified speakers, there were a few favorites. Of course everyone was interested in hearing all of the nominees for the scientific award. But besides these six lectures there were some others that deserve to be mentioned.

One of the top runners in regards to attendance was Ki-Bum Nam. After an introduction to the company, Seoul Semiconductor's CTO went through the different technologies that will drive the company's future. Some of the slides he showed were especially remarkable because they depicted the idea that LED manufacturers are looking far beyond their original core technology, growing semiconductors. While Dr. Nam sees LED efficacy still growing, he emphasizes the great potential in respect to the ecosystem by limiting the power factor, which he identified as still being an issue in many products. Another important point for customer satisfaction is quality and reliability. CSP, namely SSC's completely substrate-less WICOP has, in his opinion, big advantages in both fields. The simplification and reduction of the necessary elements promise higher reliability. In addition, this concept offers better homogeneity over the emission angle than packaged LEDs. A factor that accounts for the popularity of this lecture was that attendees could learn directly from the CTO about the recently introduced SunLike product series, developed jointly with Toshiba Materials based on SSC TRI-R technology. While the basic concept was already shown by Toshiba Materials at Light + Building 2016, it has been improved by using SSC's purple/UV chip. This technology currently outperforms the other approaches in any color metrics. Furthermore, the company claims that it satisfies the often-postulated requirements for health and well being because of the better match with biological functions of the sun-like spectral distribution that should also reduce glare and increase good visibility. At the end of his lecture Dr. Nam identified four key-challenges for

High class presenters like Dr. Ki-Bum Nam mesmerized the attendees the future that also give an idea of SSC's technology roadmap: Efficiency droop that could be solved by the company's proprietary nPola technology; achieving 240 lm/W by 2020 in standard products; improving efficacy over 150 lm/W for LEDs with high color quality like the SunLike; and the miniaturization of drivers with over 24 W, very likely to extend the Nano Driver series.

Dr. Ken T. Shimizu, Lumileds' Novel Technologies and Devices, Research and Development Director held another remarkable lecture during the same session. Lumileds is researching and working on Quantum Dot LEDs intensely, hoping to kill two birds with one stone; efficiency and light quality. In their current prototypes, they relied on QDs with a reduced amount of Cd that lies far beyond all limits, but as they are committed to environmentally friendly manufacturing and products, they hope to be able to replace them step-by-step. According to Dr. Shimizu, the main advantage of the used colloidal quantum dots is their accurate color tunability in combination with their narrow bandwidth. This is especially important in the red spectrum range of white LEDs. While QDs are basically a little less efficient than conventional phosphors, the narrow bandwidth allows for tuning the white light to a very high CRI, respectively TM-30, without emitting too much light in a spectral range that does not contribute to the visible light quality, namely deep red to near infrared. This leads to a higher system efficacy than pure phosphor converted high CRI LEDs can provide. The presented results are also quite promising in regards to reliability and longevity. For more details on this topic you may want to also read Dr. Shimizu's article in LpR 63 on page 72 or the Tech-Talks Bregenz on page 34 of this issue with Dr. Shimizu.

For all who were interested in learning what is coming next, the presentation by Pars Mukish, Senior Market and Technology Analyst at Yole Développement, was a must. His sound understanding of both market and technology makes his lectures unique. He explains why the time to make the big bucks with conventional LEDs for lighting is almost over. For LED manufacturers, the future is in application diversification or product diversification. The first is especially automotive where further growth can be expected because of the rollout of the technologies from luxury cars to the premium segment and finally to the medium segment to become the standard. However, the manufacturers must then consider producing OLEDs and lasers. Product diversification means developing UV or IR LEDs for various applications as well as micro-LEDs for display applications. These three technologies are developing especially fast with huge progress being made over the last few years.

From a technical point of view, one highlight was the contribution of Prof. Dr. Fred C. Lee from the Virginia Tech University entitled "GaN Based High Frequency Power Supply with Integrated Magnetics". While the example was based on a true high power application, a 1 kW server power supply, the approach gives an idea of what this could mean for LED lighting. Using a high frequency design is not new and a logical step for system miniaturization, but this is usually done at the cost of efficiency. GaN power devices are one key element to compensate for this disadvantage but it is, by far, not the only measure. Intelligent product design utilizing the advantages of different technologies as presented, leads to unexpected efficiency in a tiny package. Two of these technologies are zero-voltage switching and transformer structures with shielding embedded in a multi-layer PCB. Another concern in regards to high switching frequencies, EMI, can be reduced below the critical threshold with some simple measures.

TiL - practical hints and innovative application of the technologies

Targeting planners, architects and lighting designers, the multifaceted TiL Forum is less technical and covers the broader view on a system level. The track also proved to be of interest to sales and marketing people who could learn from technicians and understand the systems better. This counterpart to the technical LpS program was well received by the audience. The following two summaries will give you an idea of the breadth of the lectures:

Martin Woolley, Technical Program Manager at Bluetooth SIG, gave some insights into the recently adopted Bluetooth mesh networking standard and its application. He gave a short introduction to the evolution of Bluetooth and explained the main advantages of wireless systems over wired systems, in general. Then he emphasized that the Bluetooth (BT) technology is a standard that spans all layers of a full protocol stack, and BT mesh was especially designed to satisfy the demands of lighting. He explained that controllers that link sensors and lights are software components without the need for external controller units. Using examples already implemented, Mr. Woolley emphasized that lights could act as beacons and broadcast a unique ID, and therefore allow for ways of finding unexplored applications for use in large buildings. In addition, he presented the steps that need to be taken for provisioning and configuration. “Provisioning” is required to add them to the network and this is achieved by using a smartphone or tablet and an application. A Bluetooth device that has joined a mesh network becomes known as a node that will be configured more. He also explained the publish/subscribe communication model and the mandatory BT mesh security standard that cannot be reduced, consisting of encryption and authentication, separate security for network and each application, area isolation, message obfuscation, protection from replay and trashcan attacks and secure device provisioning. The easy to understand lecture gave a perfect overview of the technology and the application of BT mesh.

On the other hand, Dr. Helena Gentili, lighting designer and professor at the Politecnico di Milano, informed the technicians and industry about the work of designers, how they could contribute to society and how to develop better products. Dr. Gentili emphasized that the designers’ interpretations of the problems and related solutions given should be one of several viewpoints within a multidisciplinary team. She also pointed out that the need to create and understand new forms of innovation in ICT (Information and Communication Technology) leads to new questions and perhaps a redefinition of the designer’s role. She explained that lighting design is both an integrally functional and distinctively aesthetic discipline. Ms. Gentili also recognized new roles for lighting designers; for instance, adopting the role of a facilitator or guide rather than acting as the singular creator. This places the designer in a new mediator role,

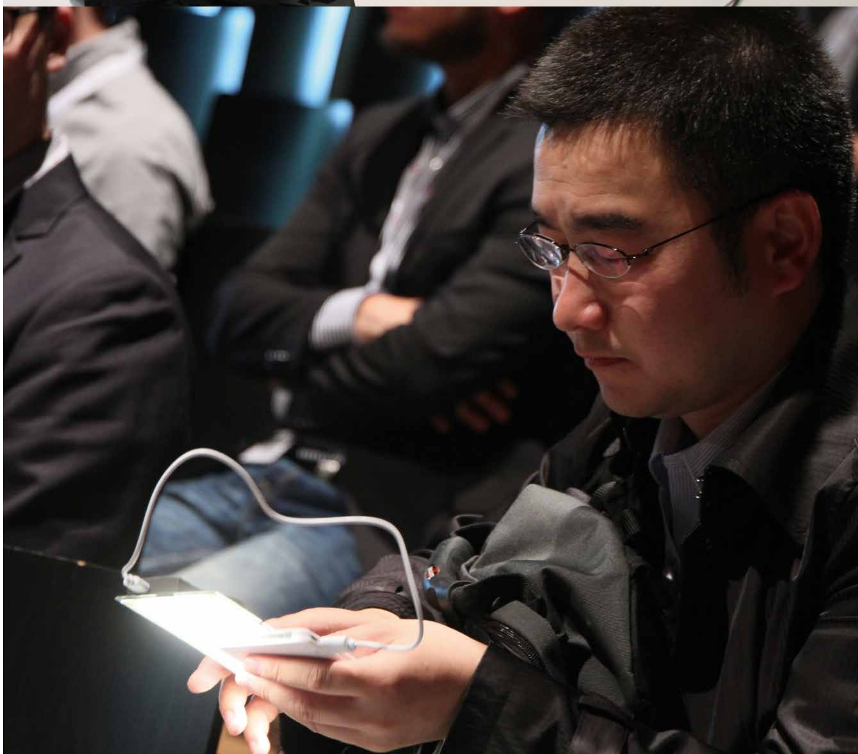
The Trends in Lighting Forum turned out to be suitable addition to the LpS. The audience was incited to ask questions of the presenters

requiring new skills than were previously evident. Finally, she warned, “Lighting is an innovative tool, but if not applied with regards to the context and related to human perception it can become a threatening weapon.” She went on to say, “Lighting design has a multidisciplinary approach, which crosses the boundaries between art and science, humanities disciplines and technology.”

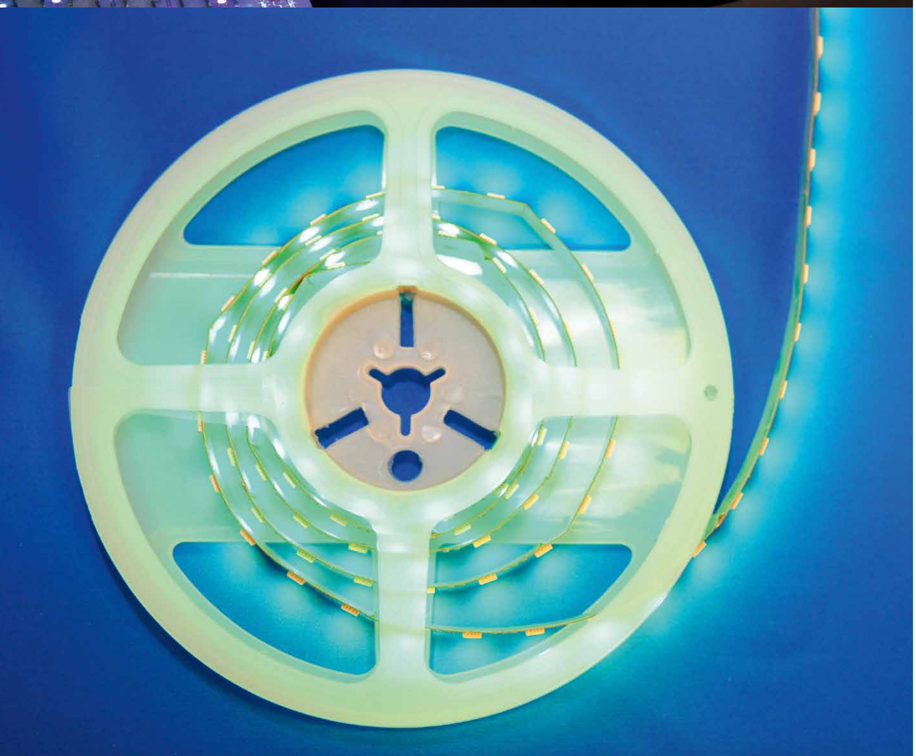
Workshops - merging LpS and TiL

The workshops were held in a condensed form on the first and last day. On day one four workshops were held in parallel. The workshops were conducted by OLEDWorks, Bartenbach, Photonics Austria & Fraunhofer, Silvair & Bluetooth SIG, Luger Research with their scientific partners, and EPIC. In “OLEDs - Bring Your Design To Light” basics as well as opportunities and examples for OLED lighting were shown, and the demonstration samples were attentively inspected. A vivid introduction from Wilfried Pohl in the topic “Visual Perception - Theory, Practical Demonstrations, Limitations” was followed by a practical part where the participants could experience the effects of often subtle differences in illumination. The hot topic “Challenges and Opportunities of LiFi” gave a good overview about the status quo of this relatively young technology. “Bluetooth Mesh and IoT/Smart Control” was set up as a panel discussion with participation of the audience, animated and brisky. The last day started with the workshop “Science Meets Application” followed by the last workshop of LpS 2017, “Miniaturization of Solid Stat Lighting Systems” in which all technologies from optics to electronics including manufacturing were covered from the current state to the future prospects.

A special highlight was the “Science Meets Application” workshop. The idea behind it was to bring scientists from universities or other research institutions together, talk about problems or possibilities and therefore to facilitate knowledge transfer from generator to applicant. Luger Research invited its scientific partners to join this workshop: Paul Hartmann from Joanneum Research (Austria), Mehmet Arik from Evateg (Turkey), Nicola Trivellin from University of Padova (Italy), Paola Belloni from Steinbeis Transferzentrum Furtwangen (Germany), Rolando Ferrini from CSEM (Switzerland) and Walter Werner, member of the LpS advisory board (Austria). After introducing themselves and their research areas the scientific experts formed work groups for four technology areas (LED and OLED; driver, thermal management and reliability; optics and light quality; smart lighting and IoT). Everybody from the audience could join one of the groups to get into closer discussion with the experts. Some of the participants started in the discussion with general questions regarding the technologies but some of them also brought their special problem and made use to get specific answers from the scientists. After 60 minutes of intense conversation the workshop ended but some of the discussions will go on even after the end of the conference.



▶ **The LpS workshops were informative, inspiring and hands-on. Many of the discussions started in the workshops continued during the breaks**



Sophisticated Components and Fascinating Systems

With the addition of TiL to the LpS exhibition, it became immediately clear how technologies and applications are influencing each other and how they are melting together. There are products and companies that fit equally well in either show concept. This was also apparent with the submissions for the two new awards as well as with the decision of the companies of where to exhibit. From the 24 applications for the two awards, 16 were classified for the LpS Technology Award and 7 qualified for the TiL Systems Award. Although the author would love to do it, it would be impossible to mention every product shown at the events. Therefore, the following two sections have been written to give the reader an impression of the multitude of products that were on display.

LpS - showcasing the key components and materials an engineer needs for his project

Not only were visitors able to renew their acquaintances with well-known manufacturers, service providers and distributors – many of whom are loyal LpS exhibitors, but they also had the chance to get to know new faces. Anything and everything necessary to build a complete luminaire or lighting system could be found at the show. It didn't matter if you were looking for optics made from polycarbonate, silicone or glass, a standard driver or customized drivers; nothing was missing. Test equipment providers or test services could also be readily found.

About 20% of the exhibitors on the LpS floor applied and qualified for the LpS Technology Award. To qualify you had to be a manufacturer (not a distributor) and you had to have your own booth. Of those sixteen that qualified, four were related to controllers, another four to light sources, three to drivers, two to measurement systems and one each to thermal management and manufacturing equipment and software. One of the contestants, HSI Elektronik, exhibited as a "Start-Up Innovator". This is a special exhibition category introduced by Luger Research to support young and innovative companies. The shortlisted companies were GL Optic Lichtmesstechnik GmbH, Plessey Semiconductors Ltd. and ams AG (the winner). While all the exhibitors displayed really noteworthy products, because of space constraints and the fact that the winning product was described above, the author will outline the products from just a few of the qualified exhibitors.

HSI Elektronik's application concerns Visible Light Communication (VLC) with low data rates to support lighting controls tasks. The technology allows for swarm intelligence solutions and can be applied to different products. One example is floor lamps. The lamps can be placed arbitrarily around a room and the underlying

◀ From manufacturing tools for customized flexible LED modules to cutable LED strips, drivers, optics or thermal management, no relevant component was missing

logic controls the brightness dependent on the manually set brightness of the other lamps in the room. The crux of the matter is the use of the common problem of losing data when the receiver is far away from the transmitter. The failure is interpreted as information about how far away the transmitter is. So the weak point is used as the "heart" of this solution.

Nordic Power Converters, who exhibited as a Start-Up Innovator in 2016, came to the show again this year to present the 60 W amendments to 20 W LED drivers they introduced last year. The company's specialty is the extremely small size in relation to the driver size. This is achieved by zero-voltage switching at ultra-high frequencies. The applied technology still allows very high efficiency over the whole dimming range, which also characterizes the new 60 W driver: 2%-points at 50% and 3%-points at 25% dimming. The driver has a wide output range of 50-1,620 mA allowing it to serve multiple luminaire specifications. The built-in surge protection is 10 kV / 5 kA for differential mode and 8 kV / 4 kA for common mode surge protection. The driver is designed for a lifetime beyond 120,000 hours.

Plessey Semiconductors exhibited, amongst other products, their latest product based on the "Stellar" technology, described in LpR 58 on page 60. The Orion LED modules offer 3000 lm at a thickness of just 5.6 mm. Integrating GaN-on-Si LEDs and optics into a tiny module lead to a narrow beam angle of 25° without secondary optics. This can be achieved without any multi-shadow effect at more than 1-meter distance. Excellent thermal performance and high efficiency allows the use of small heatsinks in the application. Hence the luminaire can be designed much smaller than possible with conventional technology.

GL Optic is one of the most innovative light measurement equipment providers. The company introduced the photobiology safety measurement system GL PSM System 200– 800 nm. Photobiology safety measurement is a very time consuming task and something that only a handful of specially equipped laboratories in Europe have been able to provide up until now. This new system makes testing affordable for most luminaire manufacturers. Besides the wide measurement spectrum, the biggest revolution for the user is the intelligent software, which guides the operator through the measurement process step by step, leading to accurate results being gathered in customized reports. Another key element is the specially designed Irradiance Probe and Radiance Telescope that recreates the properties of the human eye according to the EN 62471:2008 (photobiological safety of lamps and lamp systems) and EN 14255 (Measurement and assessment of personal exposures to incoherent optical radiation) standards.

▶ **Technologies allowing for ultra compact designs, outstanding light quality and photobiology safety measurement were shown**

TiL - smart designs and smart controls are shaping the future

With the introduction of TiL, the event was able to offer an area especially dedicated to luminaires, lamps and system manufacturers. With the TiL System award, the most innovative approach was honored. Seven applications were eligible, which is equivalent to 25% of exhibitors. The qualified systems were: one smart retrofit lamp, one configuration software, one smart luminaire, one smart system and one smart controls solution, and two smart modules. The smart retrofit lamp was exhibited by the Start-Up Innovator Blume Labs Ltd. Besides the award winner, volatiles lighting GmbH, LEDON GmbH and Luke Roberts, a 2016 Start-Up Innovator, made it to the shortlist. Similar to the nominated LpS Technology Award products, these three applications were quite different from one another. LEDON GmbH entered innovative configuration software for solar streetlights; Luke Roberts submitted a smart luminaire for human centric lighting; and volatiles' decorative applied with their smart lighting system.

The Start-Up Innovator Blume Labs showed a futuristic smart replacement lamp. This was a case of design following function. Designed for over 100,000 hours (L80) lifetime due to the unique thermal management, with LED's separated thermally from the driver, the lamps offer a 360-degree light distribution using a patent pending optical design. The design can easily be upgraded with new LEDs or LED Drivers without the need for a soldering iron because they can be dis-assembled with a simple screw. Easy linear or step switch-dimming with Ledotron is provided, and a wall-plug efficacy between 135-150 lumens/watt, depending on the CCT, is achieved.

All types of smart solutions were on display at the TiL show. A cleverly designed replacement lamp and a complete smart lighting system in one lamp are just two examples

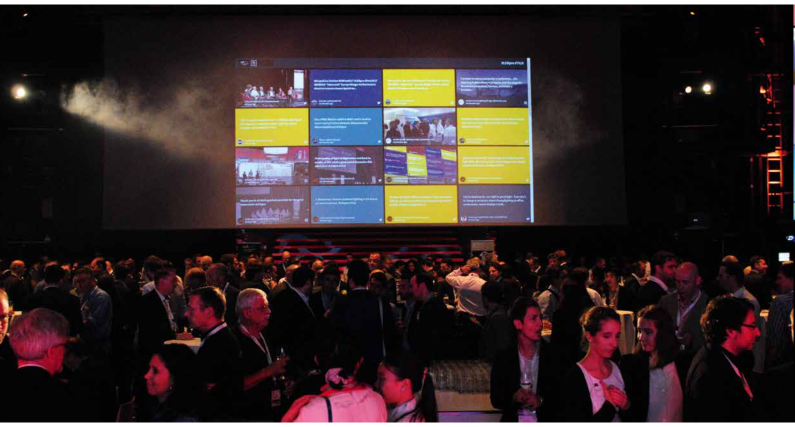
In addition to their modular LEDIVA solar street light, LEDON developed the unique LEDON Solar Lighting Configurator, an online tool specifically developed to calculate light levels based on the location of the self-sufficient, solar lights to help customers to obtain a perfectly configured, individual lighting solution. In just a few steps, based on the following parameters, the perfect illumination level is calculated and displayed: location of the luminaire; alignment of the luminaire; object to be illuminated; characteristics of the individual project; behavior of the luminaire and needed light output. This Google-based tool allows you to easily configure the luminaire perfectly before delivery.

The first prototype of the Luke Roberts Smart Lamp was displayed at the LpS 2016. This luminaire is a type of complete HCL fully color tunable lighting system. It is the first luminaire where the light can be directed in any direction by simply painting gestures on a phone. For example, the table can be illuminated for dining and the couch on the other side of the room for reading a book. This pendant lamp supports any setting with direct and indirect light. It also learns from user behavior and automatically supplies perfect lighting whenever it is turned on. After one year of detail development and software updating, the start of mass production is just around the corner.

The Supporting Program - Exchange of Ideas, Discussions and Culture

As in other years, activities to encourage communication in an informal atmosphere were also provided. On Day One straight after the keynote speeches and the official show opening, drinks and snacks were served at the

▶ **Smart mechanical solutions that allow easy installation and smart IoT capable solutions that offer easy commissioning and configuring were also part of the show**



▲ Networking to a background of live music, an introduction to the opera "Carmen" and the incredible technology that enables the amazing festival on the lake were all included in the Get Together Evening

▼ In a performance-like presentation, with infectious enthusiasm, Ken Munro informed the audience about security threats of poorly designed IoT products

Networking Reception in the expo area. During the informal reception many discussions were started and new contacts made. It was the perfect end to a long day.

On Day Two, after the Award ceremony and an interesting Expert Panel Debate, the organizer and Dow Corning invited all visitors, attendees, speakers and exhibitors to a Get Together Evening that was held in the Festival House for the first time. After 5 years of boat cruises, the capacity of the boat was exceeded, and opening the Get Together Evening for the whole audience of TiL and LpS alike would not have been possible. Instead, the rotating central part of the stage where the bar was located, led to some random contacts and inspiring discussions. The evening officially ended with an introduction to the opera, Carmen, by Elisabeth Sobotka, the festival director, outside by the floating stage. She told us the story behind the opera, the history of the Festival House and the stage. The spectacular set, props and scenery, and the technology needed to make the "Game on the Lake" possible was explained. Many of the audience were inspired to make a trip to Bregenz next year to watch the unique and breathtaking classic opera performance in impressive costumes, presented on the world's largest floating stage.

A Brilliant Highlight to End the Event

One of the hottest topics concerning IoT was at the culmination of the 2017 event. It was carried out in the exhibition hall so that every visitor or attendee could watch. Ken Munro, founder of PenTest Partners, was invited to demonstrate what can go wrong when designing, installing or using IoT suitable products. Ken Munro is an ethical

hacker, and he loves to hack any technical product he can get his hands on. Unfortunately, he succeeds all too often. It is important to note that hacking, per se, is not a bad thing. One can do it with one's own products to change or improve functionality, and that's nice. One can do it to learn about a product with which one is working – great. But unfortunately, one can also do it to do serious harm to others and that's terrible! Ethical hackers are the good guys. Like the second group they just want to understand a product in respect to their connectivity. But they go beyond that: They hack things to find design flaws in products and to give feedback to the manufacturers. If manufacturers don't improve these products, they might also inform the public directly. In a way, it seems like a fun job and Ken presents it in an entertaining way. But even though his performance is funny, some of the security leaks that he showed can wipe the smile off your face in a flash: There can be numerous harrowing deficiencies found where one would not expect them. Some demonstrated mistakes might look condonable, but one needs to be aware that all of them can be critical. From hardware to firmware and apps, there are numerous possibilities to make a product insecure and very often trivialities are crucial in making a product safe or vulnerable. Often it is simply the user or installer. It is hard to believe the things Ken brings to our attention in just a one-hour demonstration.

Although all of the above will be very hard to top, the Luger Research team is already excited about what they believe will be an even better event in 2018. See you there!

LiFi - What It Is, How It Works, What It Provides, How to Apply, and Its Future Prospects

The acronym LiFi (Light Fidelity) was born at the beginning of the 2010s. Its name derives from the very well-known WiFi (Wireless Fidelity). The term VLC (Visible Light Communication) is used in the restricted instances of visible light. Mr. Luc Chassage who works for Oledcomm and the Versailles University is also Scientific Committee President of the Global LiFi Congress that offers 20 lectures dealing with all aspects of LiFi. He is a profound expert in this technology field. Mr. Chassage explains the functionality, pitfalls and hurdles to overcome, the disadvantages and advantages, and best practice to apply LiFi.

LiFi relates to wireless communication technologies which rely on light as a power source. Owing to the incredible increase of LEDs (Light Emitting Diodes) over the last few years, which have become reliable and more affordable, LiFi technology can be integrated on a daily basis. The LEDs can be used like lasers in optical telecommunication in order to transfer data. LED light sources present in our surroundings can therefore be used for lighting but also used to transfer digital data.

Operating Principle

LiFi technology is very simple from a functional point of view. The majority of applications exchange data in digital form. A transmitter, essentially an LED, sometimes a laser, emits light and information simultaneously. We then find the standard elements of a data chain transmission: data, coding and a network. These digital networks modulate the LED transmitter which then allows the transposition of the electrical signal into a light signal.

Then the light signal is freely diffused into a room or outside. Depending on the distance, there is a greater or lesser reduction and according to the various environmental disturbances (rain, sun, other lighting, etc.).

A receiver, made up of a photodetector or a camera upon arrival is responsible for re-transcribing the luminous signal into an operational electrical signal. Coupled with this conversion it is quite frequent especially for high speed links to find the pre-amplification level adapted to the specificities of the chain.

The modulations used are essentially power modulations; the LED is therefore piloted by a switch circuit based on simple electronics. The selected rates of modulation are sufficiently high so as to ensure that the flickering is not visible to the human eye (> 200 Hz).

The receiver at the end of the chain is the most important element in

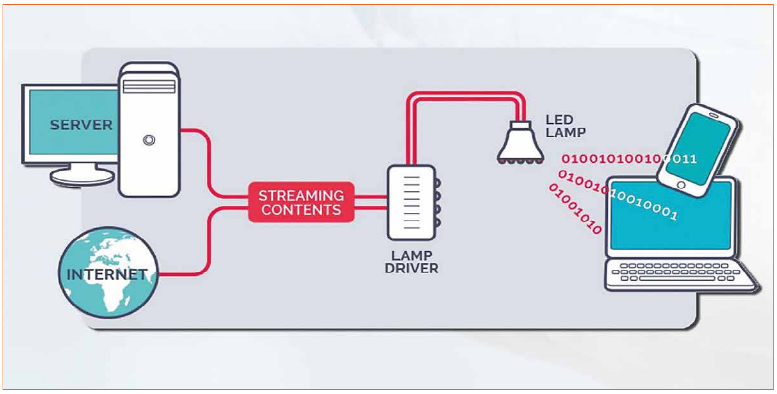


Figure 1: Implementation of LiFi in the current infrastructure showing the path data takes from a server to the end user devices

order to ensure a good signal. As well as a photodetector, it can be made up of an optical group more or less sophisticated consisting of lenses of ambient light caches and eventually chromatic filters which accentuate colors. The whole system is responsible for gathering the maximum amount of useful optical power.

Once the signal has been converted into an electrical signal and is sufficiently pre-amplified, various stages of amplification and filtering allow the reconstruction of digital signal and then it can be decoded in order to obtain the initial data. The reconstruction of digital data can be done according to the methods used in the optic fiber transmission chains or radio frequency transmission chains because we are faced with the same problems. Thus we find amplifiers, analogue filters at the beginning of the chain and digital ones at the end of the chain. An equalizer is responsible for adapting the filtering of the channel in real time. Synchronization at the beginning of the network, a reconstruction of timing and finally a decision making level.

The chain described here is unidirectional, which corresponds to the downward track of the emitter towards the user. This one way is sufficient in order to carry out the data transmission, but encounters limits in the case of data to be exchanged. In this case, it is necessary to reproduce the system for the ascending track and to be bidirectional. Current LiFi systems use infrared and non-visible ascending tracks, so as not to disturb the downlink and not to impose on each user a visible transmitter element, which apart from anything else would be extremely problematic.

About the Parallels Between LiFi and WiFi

If the term LiFi comes from the term WiFi, it is because there are number of similarities. These two technologies are competing with one another, but above all are complimentary. WiFi is based on radiofrequency waves and not on light.

Figure 2: Exemplary data transmission in an open office space via LED light bulbs

WiFi spreads in all directions with spans of more than tens of meters. It can also go through obstacles such as walls. In contrast, LiFi must have line of sight and is guided, with a span of a number of meters.

The available frequencies to emit WiFi are limited; the band which carries the signal cannot be extended. The number of channels simultaneously available is restricted. This is not the case for optical waves which have an almost infinite band in comparison with radio waves. You can therefore theoretically multiply the number of channels and increase the flow of data exchanged.

The two waves, radiofrequency or light, move at the same speed, the speed of light (roughly 300,000 km/s). But the frequency of light waves is far higher than that of radio waves, roughly 200,000 times faster. The theory of transmission of information shows that the higher the frequency of the wave, the more you will be able to carry out this famous and fast amplitude modulation, and have high upload/download speeds.

In good conditions current WiFi can achieve download speeds of around 50MB/s. Current records show that LiFi in the laboratory attains 8GB/s, in other words 160 times faster (8GB/s = a few seconds transfer for 1 DVD). These figures are constantly updated!

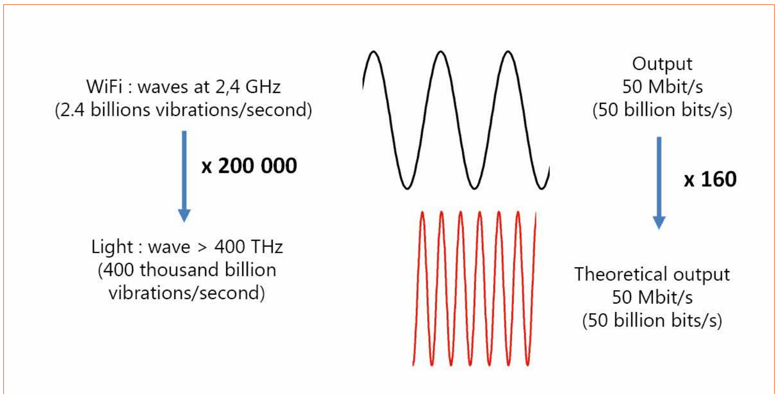


Figure 3 & Table: Brief technical comparison between LiFi and WiFi parameters and data transmission capabilities

Technology	Frequency	Data Transfer Rate
WiFi	2.4GHz (2.4 billion oscillations/second)	Current download speed = 50MB/s (50 million bits/second)
LiFi	> 400THz (400,000 billion oscillations/second)	Proven download speed = 8GB/s (8 billion bits/ second)
Improvement factor	~200,000	~160

LiFi in Applications

The presence of LEDs everywhere in our environment is a strong asset for the deployment of LiFi. In all new applications, one can differentiate between two major groups: interior applications and exterior applications.

Interior applications benefit from the buildings' lighting system. One can differentiate applications needing very weak output and applications needing a strong output.

For weak output, LiFi is already used a great deal to locate people or connected objects. In effect it is very simply that each lamp emits through LiFi a unique identifying signal. By linking this signal to a pre-existing mapped out network, one can find one's way in a complicated building, a station, a museum, a factory, a technical center. Localization can be extremely precise, between 10 and 20 cm, and clear. The increase of IoT nodes requires relatively weak connections and can also be a colossal opportunity for LiFi in the years to come.

In parallel, the LiFi industry is making an effort to ensure faster transfers in order to be complimentary to WiFi. Current speeds on industrial prototypes are around a few dozen MBs/s but the potential is far greater.

External applications are also numerous: transmitting between buildings in order to avoid having hard radiofrequency caps, by using the existing infrastructure of towns. The infrastructure, for example, can be the lighting network of towns but equally the road network. One can therefore envisage transmitting information in a targeted and localized fashion. In the very near future, the whole car industry, including vehicles and road infrastructure will use LEDs in their headlights, lampposts, signposts which will be able to relay information between vehicles, pedestrians, infrastructure, public transport, and the millions of connected objects.

Of course this type of data can be exchanged by a radiofrequency link. However, at high speed or in congested environments it is less practical. Moreover, one of the keys to the future of the autonomous vehicle is the duplication of information. Just as on airplanes there are a number of sensors in order to be able to overcome breakdowns and to be robust in all situations, it is also indispensable for the car to have various means of communication.

Conclusions

While there are, in practice, still some hurdles to overcome, the lab results are very promising and in some applications the technology has already proven the capabilities. Transmission speed and data reliability are already on a high level. But as for any technology, there are applications where it performs better or poorer. Therefore, it is important to understand: Radiofrequencies and light are not enemies but allies!

Acknowledgements:
This work was made possible by the Global LiFi Congress which will be held February 8th & 9th, 2018 at the Palais Brongniart, Paris. The congress is supported by the IEEE association and dedicated to LiFi/Visible Light Communication (VLC).

A New Technology Is Changing the Tunable White Solutions

Tunable white LEDs are one key element of human centric lighting. Until today, different solutions are currently available but none of them is easy to apply or cost effective enough to speed up the diffusion of human centric lights in building projects. A new approach for tunable white solutions is able to provide flexible lighting for multiple occasions without sacrificing output or going over project budget. Phil Lee, Senior Lighting Engineer from Meteor Lighting will compare this new technology, called ColorFlip™, to conventional tunable white solutions, and talk about current tunable white issues.

Before getting into the new tunable white technology, the disadvantages of conventional tunable white solutions need to be examined to fully capture the latest technological color tuning advancement. LED luminaires have been known to deliver varying light color since the early days of LED lighting with expanded range of potential applications. While tunable white lighting becomes one of the biggest trends in commercial lighting, the demand for efficient, affordable tunable white fixtures is on the rise. Let's have a look at the issues of conventional tunable white solutions and how the new technology brings changes to the lighting industry.

Issues with Conventional Tunable White Light Source

In a conventional LED luminaire light source, surface mounted LEDs with individual lenses are spread out over a large circuit board area where each light source is clearly visible. Most tunable white solutions combine two sets of LEDs: one with a warm-white color and the second with a cool-white color. White colors between the two color points can be created by raising and lowering the output of the two colored LEDs. Color mixing to two extremes of CCT range on a 100 watt fixture results in up to 50% loss of the light source's total lumen output because the warm and cold LED intensities are inversely proportional to each other. In order to get the full 100 watt output at 2700 K or 6500 K color temperature, double the amount of fixtures is required. In a conventional tunable white design, it delivers inconsistent lumen output throughout the entire CCT range and lumen intensity is lost when color mixing to both extremes without sophisticated control mechanisms.

Another critical element in tunable white lighting is the control system. Very often, tunable white fixtures can only be paired with specific drivers, which can cause incompatibility issues for retrofit or projects that already have their own dimming driver. In such a case, expensive, standalone control systems need to be specified for the tunable white fixture. Since cost is

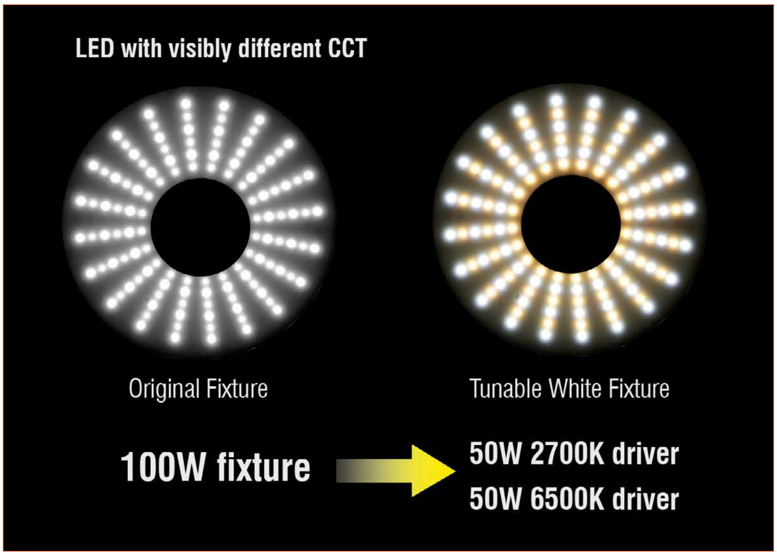


Figure 1:
100 watt conventional single-color and tunable white light engine

often the reason tunable white fixtures are not specified, a standalone control system makes tunable white fixtures less feasible. Loss of light intensity during color mixing, undesirable light source visibility, and expensive control systems in conventional tunable white solutions are common reasons why tunable white fixtures have not been used more.

Utilizing Latest Flip Chip Technology

The latest tunable white solutions utilize the flip chip CoB LED technology. Flip chip is a direct mountable LED chip that has 70% better heat transmission than traditional SMD (Surface-mounted Diodes). It significantly reduces thermal resistance and boosts the heat dissipation level which allows the flipped LEDs to be placed in tight formation that fits on a 1.2-inch chip. The goal of the new tunable white solutions is to reduce the price of LED components without a compromise of performance and quality. Flip chip CoB LEDs are not only more cost efficient to produce than SMD LED, the unique packaging style delivers large amounts of lumens at high wattages. Flip chip CoB technology provides also 30% more lumen output than traditional SMD LED.

The advantage of having the LEDs more condensed is the ability to deliver uniform light in all directions.

Having a compact light engine also allows tunable white capability in smaller aperture fixtures. The new technology provides the lowest thermal resistance on the market, only 0.3 K/W junction to Ts measuring point, which offers consistent performance and extended lifetime in higher wattage fixtures. Each of these 1.2 inch CoB LEDs produces 10,000 lumens which is currently the highest lumen output for tunable white solutions in the market. While other existing tunable white products have an efficiency rating of 40-50 lumens per watt, the new tunable white solutions have an efficiency rating of 105 lumens per watt and a color rendering index exceeding 85.

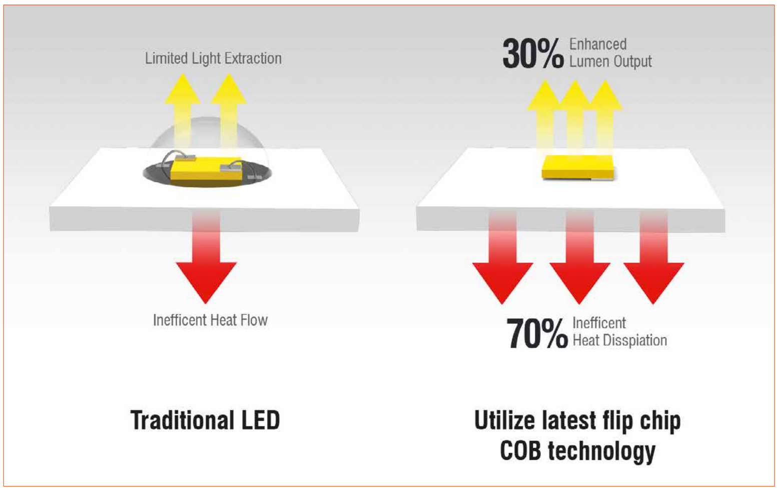


Figure 2: Traditional LED vs. flip chip CoB technology - luminous flux and heat transfer capability

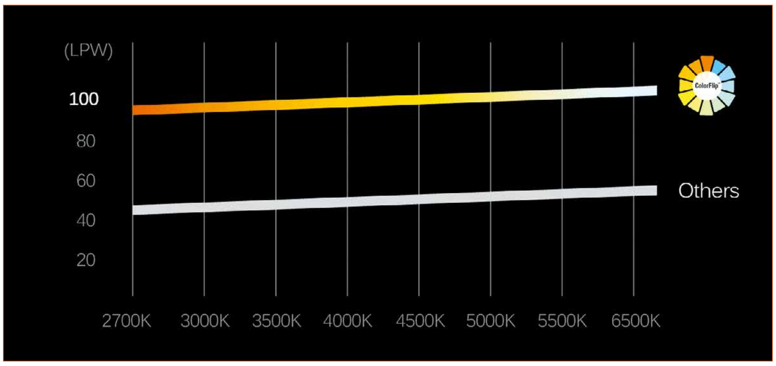


Figure 3: Lumen per watt comparison chart between a conventional tunable white solution and the new technology

Advantages of the New Technology

While traditional tunable white solutions require increasing the number of fixtures to equal the output of single-color lights, the new unique design and proprietary control board delivers maximum lumen output during color tuning. Its ability to maintain up to 10,000 consistent lumen output during color mixing from 2700 K to 6500 K is a new advancement in the lighting industry. Tunable white capabilities are no longer limited to low wattage commercial spaces. Large-scale projects with ceiling height over 80 ft. can take advantage of the versatility of having more than one color temperature.

With this new technology there is no need to double the number of fixtures to meet foot candle requirements. Tunable white solutions can now be more feasible than ever with the new advancement due to minimal additional cost. It also allows lighting designers to take total control of the color temperature even after lighting fixtures are installed. Color temperature no longer needs to be decided during the planning stage as field adjustable CCT is possible with the new advancement. At about 20% additional cost per fixture, there is no CCT limitations to any projects. Project owners and lighting designers have the flexibility to adjust color temperature of the space to meet its needs.

The precision engineering delivers a smooth and uniform transition between color temperatures. LED light source imaging does not appear with this technology which provides a more desirable illumination than conventional tunable white light engine.

What sets this new approach apart from other tunable white solutions in the market is its ability to deliver high lumen output for large-scale projects such as convention centers. The tunable white solutions not only change the ambiance but the function of the space to fit

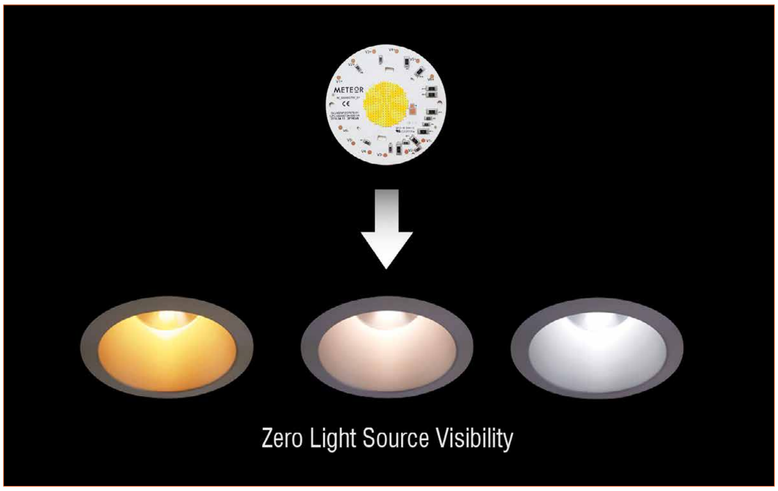


Figure 4:
Zero light source visibility because of the use of tiny flip chips on the CoB

different events. For example, it answers to a multi-purpose convention center's requirements to have a lighting fixture that would serve as bright intense light for tradeshows, consumer shows and also able to dim to softer and warmer light for banquets. By adjusting the intensities and color temperature in a space not only creates a mood change but allows the same space to be used for different occasions. It is an advantage that is not permitted with traditional metal halide highbay commonly used in convention centers.

When developing this new technology the objective was to allow maximum practicability, whether for new construction or retrofit projects. Its new control unit and driver technology allows it to bring full compatibility to every 0-10V and DMX control system that conforms to industry standards. The technology developers are aware that controlling tunable white luminaires can be challenging as different manufacturers use different approaches. Some even provide proprietary control devices, which often rely on an existing protocol with a customized user interface or hardware. It is paired with proprietary control units which allow it to work with all other 0-10V and DMX control systems.

Conclusions

What the new technology brings to the lighting industry can be summarized into three areas- efficiency, quality, and cost. This latest advancement brings flexibility to lighting a space, whether in a classroom, hospital, recreation center, convention center, or worship facility, lighting requirements can be fulfilled.

The light engine delivers up to 10,000 lumen consistent output during color mixing from 2700 to 6500K CCT. It beats all other tunable white solutions at 105lm/W efficacy. Specially designed with flip chip technology for improved heat dissipation and higher lumen output, consistent performance and extended lifetime in higher wattage fixtures is provided.

Due to the advanced flip chip CoB technology, LEDs can be arranged closely to keep the size of the light engine to a minimum. The compact sized light engine can be incorporated into smaller aperture fixtures, expanding high lumen tunable white capabilities to more fixture designs. The condensed formation of LEDs generates a more uniform illumination from all sides. With the flip chip CoB, LED light source imaging does not appear, which provides a more desirable illumination than conventional tunable white lights.

With conventional tunable white solutions, increasing the number of fixtures is needed to meet foot-candle requirements as lumen output is significantly decreased at both extremes of the CCT range. Doubling the number of fixtures means doubling the cost. The new technology delivers consistent high lumen output throughout the color temperature range. At about 20% per fixture, project owners can take advantage of the versatility of tunable white lighting without doubling the project budget. ■

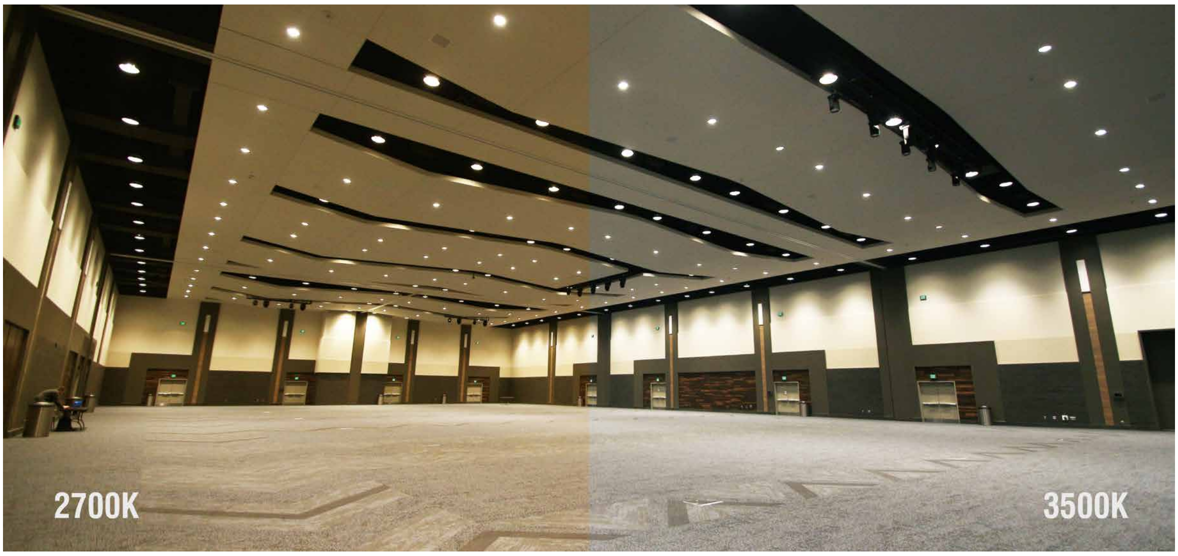


Figure 5:
Comparison between the appearances of 2700 K and 3500 K CCT in a convention center

Glare Reduction Made Easy

A pleasant lighting atmosphere due to low glare at the workstation is not only pleasant and performance-enhancing, but also legally required according to EU standard EN 12464-1. But what does "glaring" mean here? Dr. Claudius Noack, Technical Director at NORKA Leuchten, explains if luminaires with the same luminous flux are glaring to the same degree and if the same luminaires are glaring to the same degree at different workstations. He answers the questions of what a manufacturer does and if manufacturers are lying to themselves and therefore to their customers when providing information on the glare rating.

There are many important questions and there is a huge uncertainty about glare that need to be discussed.
For starters, the following should be clarified: whether light is perceived as glaring by a certain person in a certain environment cannot be predicted with certainty. Glare is a subjective feeling and therefore only the probability as to whether a certain luminaire will glare in the aforementioned environment can be predicted with quantitative values.

UGR - Unified Glare Rating

A person experiences glare when a high fluctuation in luminous intensity occurs in his or her field of vision. An easy example here is a flashlight. If you look directly into a flashlight from a distance of three meters in a dark room, you will certainly be blinded by glare. If you now look outside the range of the flashlight from the same distance, the light will certainly not seem as glaring. Instead of the flashlight, we can naturally also take a small spotlight as an example.

Figure 1:
Photo of a flashlight in a dark room and in daylight

Why is this the case? The process in the human eye is the same as for a camera: If the overall brightness is high, the shutter is reduced so that less light falls on the sensor. The sensor corresponds with the retina and the shutter with the pupil, which is regulated by the two ciliary muscles at the incidence of brightness. If the overall brightness is low, as in a dark room, a small luminaire is perceived as more glaring because the pupil is open wide. Or more simply expressed: The relationship between direct and indirect light is decisive. A luminaire with an indirect percentage, e.g. a pendant luminaire or floor lamp that shines upwards and downwards, is therefore usually perceived as less glaring than a luminaire without an indirect percentage.

The so-called glare rating takes advantage of this circumstance. In fixed values, this rating reflects the probability that a luminaire in a certain environment is perceived as glaring. Among other things, a calculation is used to evaluate in which areas and at which ratio the luminaire emits its light. The generally applied Unified Glare Rating, UGR for short, additionally contains specified rooms for consideration.

$$UGR = 8 \cdot log \left(\frac{0.25}{L_b} \sum \frac{L^2 \omega}{p^2} \right)$$

From this apparently simple formula, the glare limitation for various areas is indicated in steps of three in accordance with standard DIN EN 12464-1.

The most common area for many people is writing or computer work. This includes all classrooms, offices and so on. For this area, a maximum value of UGR <= 19 must be observed. Let's return to the original meaning of glare: the probability of whether a luminaire is perceived as glaring in this environment.

UGR <= 19 means that 65% of the test subjects in scientific studies did not perceive the luminaire as glaring in this area. If you select this luminaire in the respective constellation, there is a 35% chance that you will find your workstation to be glaring. At a low UGR value, this probability is therefore smaller.

Different Luminaires

The UGR calculation uses light distribution to evaluate individual emission ranges at various strengths. One would perhaps think that looking at the light distribution of the luminaire would provide information as to whether a luminaire is glaring. This is not always easy, however.

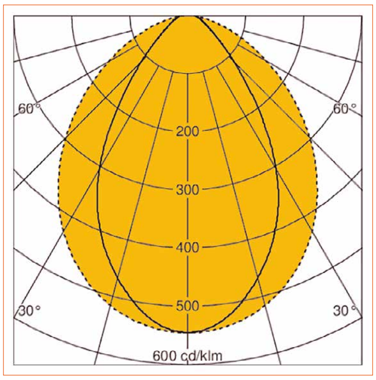


Figure 2: Light distribution of a narrow-beam, linear LED luminaire

On the one hand, a high luminous flux of a luminaire is understandably more glaring than a low one. It is therefore more probable that a luminaire with 3,000 lm is more glaring than a comparable luminaire with 1,000 lm. On the other hand, the emission angle is decisive.

Let's return to our flashlight. As mentioned above, a flashlight can be equated with a built-in spotlight with a narrow emission angle. If you hold it directly in your face, you will perceive it as glaring, but do luminaires generally shine directly in your face? In the most frequent cases, the luminaire is

Visual task	Maximum UGR value
Technical drawing	UGR ≤16
Reading, writing, classrooms, computer work, inspection work	UGR ≤19
Working in industry and trade, reception	UGR ≤22
Coarse work, stairways	UGR ≤25
Corridors	UGR ≤28

Table 1: A few examples of typical visual tasks

mounted on the ceiling and shines downwards to illuminate the workstation. A luminaire with a narrow emission angle, like our built-in spotlight, now no longer shines directly in your eyes since you are generally looking forward or down during your work and not up at the ceiling. In general, you can also assume that a luminaire with a narrow emission angle is perceived as less glaring. At present, this circumstance is leading to difficulties for a major section of the luminaire industry: the LED panel market. Today's market requires LED panels to be an extremely homogeneous lighting area. This requirement is frequently achieved using polymer planes made of PC or PMMA. These planes scatter the light of the individual LED in such a way that the lighting area is perceived as a homogeneous surface and not as individual points. The result, however, is that the emission angle of the LED panel is enlarged by this scattering. An LED panel with a homogeneous lighting area with an UGR of <=19 is therefore more difficult to develop and produce. Here, some manufacturers take advantage of a trick in the UGR calculation, which comprises an additional important factor: the size of the lighting area itself.

The larger the lighting area of a luminaire at the same luminous flux, the less it is perceived as glaring. In this case, as well, a comparison can be made between the spotlight and the LED panel. If both luminaires have a luminous flux of 2000 lm, the LED panel is perceived as less glaring with the same light distribution. But how large is the lighting area of a luminaire now? Let's look at the following two examples. Our example LED panel with a homogeneous lighting area has dimensions of 620x620 mm and a perimeter frame of 40 mm. Effectively, the lighting area therefore only amounts to 580x580 mm, which means that the lighting area is 25% smaller than the luminaire itself. If you compare the value for the lighting area in the Eulumdat-file, which contains the light distribution, with the real area, you can see that some manufacturers list the outer dimensions of the luminaire and not the lighting area itself. Since the manufacturer itself enters these values and they are not measured by an automated system, the probability of glare and therefore the UGR value are considerably higher than specified.

A further example of incorrect information is a panel available on the market that does not have homogeneous emission area, but rather 32 individual light spots.

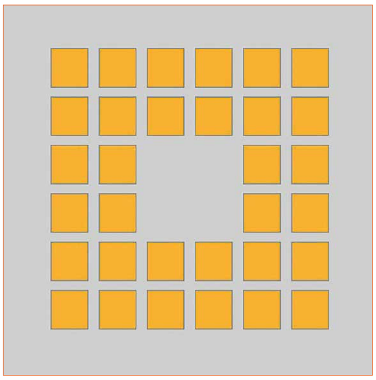


Figure 3: Schematic diagram of an LED panel with individual light spots and a "free" internal surface

This manufacturer specifies the lighting area of this luminaire as 325x325 mm, i.e., the outer edges of the light spots. The luminaire, however, has a center section that does not contain light spots. The surface is therefore about 6% lower and the risk of glare and the UGR are higher than specified.

This behavior of a few black sheep on the LED market is comparable to the current, well-known diesel scandal of the automobile industry, in which individual values have been manipulated to achieve the desired values demanded by the respective standards. A user and/or buyer of a luminaire should therefore closely examine the freely available Eulumdat-files and compare the lighting area.

Different Standard Rooms - Which Is the Right One?

Whether a luminaire is perceived to be glaring, however, does not depend on the luminaire itself, but rather on the environment and arrangement of the luminaires. In this case, as well, the direct and indirect lighting effect is a key factor. In a very flat room in which the light of the luminaires enters the eyes of the occupant horizontally, the occupant is dazzled more than when the luminaires are mounted higher and the light is therefore more likely to enter the occupant's eyes vertically. Not only the geometry of the rooms, but also the surfaces inside the room are decisive for the glare behavior. If ceilings, walls and floors strongly reflect the light, a higher individual percentage of the light arises and the light seems to be less glaring. In a matt, black room, the probability is high, on the other hand, that occupants will find the light to be glaring. For these different circumstances, 95 standard rooms that differ in geometry and degree of reflection have been defined for UGR. For each of these standard rooms, a UGR value can now be calculated. All values are listed in the UGR table of a luminaire.

The manufacturers of luminaires generally limit their data sheets to the publication of an individual value. A room with a geometry of 4H8H and reflectance's of ceiling = 70%, wall = 50% and floor = 20% has been established as quasi-standard. Many manufacturers specify the UGR value for this room in their data sheets. Very few manufacturers, however, indicate the room to which their UGR values concretely refer. Due to this missing reference, a comparison is no longer possible. The manufacturer can select the

Table 2: Uncorrected UGR table using the example of an LED panel

Uncorrected UGR Table

Test:	U: 222.02V; I: 0.1827 A; P: 39.17 W; PF: 0.9737	Lamp Flux: 3397.4xl lm
Name:	LED Panel Light	

ceiling/cavity		0.7	0.7	0.5	0.5	0.3	0.7	0.7	0.5	0.5	0.3
walls		0.5	0.3	0.5	0.3	0.3	0.5	0.3	0.5	0.3	0.3
working plane		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
room dimensions		**viewed crosswise**					**viewed endwise**				
x = 2H	**y = 2H**	15.5	16.9	15.8	17.1	17.3	15.6	17.0	15.9	17.2	17.4
	3H	16.7	18.0	17.0	18.2	18.5	16.7	18.0	17.0	18.2	18.4
	4H	17.3	18.5	17.6	18.8	19.0	17.1	18.4	17.5	18.6	18.9
	6H	17.8	18.9	18.1	19.2	19.5	17.6	18.7	17.9	19.0	19.3
	8H	18.0	19.1	18.3	19.4	19.7	17.7	18.9	18.1	19.1	19.4
	12H	18.2	19.3	18.6	19.6	19.9	17.9	19.0	18.2	19.3	19.6
4H	**2H**	15.7	16.9	16.0	17.2	17.4	15.8	17.0	16.1	17.3	17.5
	3H	17.1	18.2	17.4	18.5	18.8	17.0	18.1	17.4	18.4	18.7
	4H	17.9	18.8	18.2	19.2	19.5	17.7	18.7	18.1	19.0	19.3
	6H	18.6	19.5	19.0	19.8	20.2	18.3	19.2	18.7	19.5	19.9
	8H	18.9	19.7	19.3	20.1	20.5	18.6	19.4	19.0	19.8	20.1
	12H	19.2	20.0	19.7	20.4	20.8	18.8	19.6	19.2	19.9	20.4
8H	**4H**	18.1	18.9	18.5	19.3	19.7	18.0	18.8	18.4	19.1	19.5
	6H	19.0	19.7	19.5	20.1	20.5	18.7	19.4	19.2	19.8	20.2
	8H	19.5	20.1	20.0	20.5	21.0	19.1	19.7	19.6	20.2	20.6
	12H	20.0	20.5	20.5	21.0	21.4	19.5	20.1	20.0	20.5	21.0
12H	**4H**	18.1	18.9	18.6	19.3	19.7	18.0	18.7	18.4	19.1	19.5
	6H	19.1	19.7	19.6	20.1	20.6	18.8	19.4	19.3	19.9	20.3
	8H	19.7	20.2	20.1	20.6	21.1	19.3	19.8	19.8	20.3	20.7

best value for its application. In the example of the UGR table above, the manufacturer, for example, indicates that this special luminaire is suitable for technical drawing; i.e., it has a UGR value of <=16. If you check the UGR for the "quasi-standard room" 4H8H in the table, this value, at 18.9, is considerably higher than the permitted limit value. The UGR for room 2H2H, however, is in fact within standard at 15.5. Here, the manufacturer does not break its promise; but extremely limits it without telling the consumer.

In addition, only the uncorrected UGR values are listed in the displayed table. This means that only the values for a theoretical luminous flux of 1,000 lm are listed. Since, as described above, the luminous flux of a luminaire is also important and the luminaires shown here have a luminous flux of 3,397 lm, the UGR value must once again be adapted using the following formula.

$$UGR = UGR_{UC}\ 8 \cdot \log \frac{\Phi}{1000}$$

As a result, a UGR of 23.1 and therefore <= 25 develops for the standard room from the specification "Suitable for technical drawing," which requires a UGR of <= 16. For this luminaire, the probability of glare is therefore considerably higher than specified. Since this calculation was performed as described for standard rooms, however, this does not necessarily mean, that the light of this luminaire is perceived as being glaring in a certain room as only a few rooms can be mapped exactly to the standard rooms.

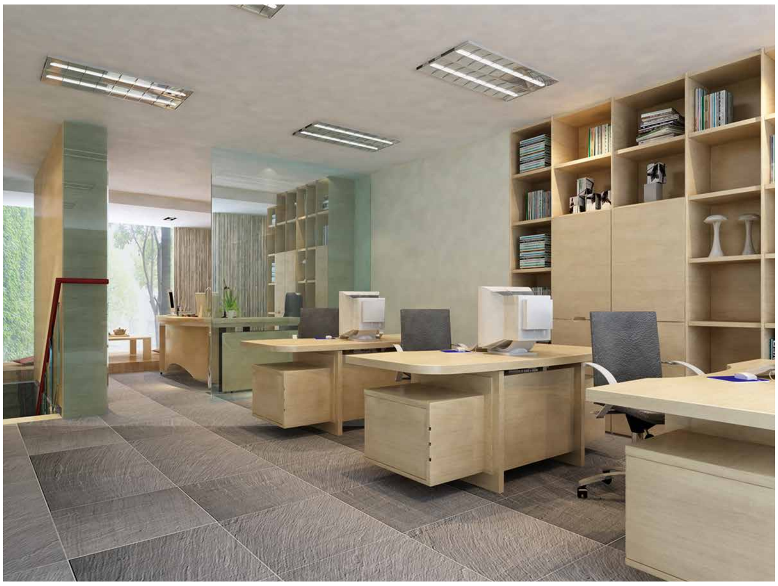


Figure 4: Modern, detailed lighting calculation takes furniture and other large objects into account

Proper Lighting Design

To take all these circumstances correctly and extensively into consideration, especially if glare reduction is a high priority for you, you should design your lighting with DIALux, RELUX or a similar lighting design tool in which the correct light distribution can be implemented in a room that is as detailed as possible. This means that furniture and other large objects must also be taken into account.

In addition, the glare values at the probable observer positions, and not just at the working area must be included in the lighting calculation. It is ultimately not of use to you if you know that your workstation does not have glare, but your visual range does. Professional lighting designers take this aspect into consideration, but even the lighting design departments of the manufacturers, which are increasingly offering such services, often require training in this area.

Conclusions

For a simple estimation of the probability of glare, it suffices to observe the following things:

- High indirect percentage of light
- Large and correct lighting area
- Narrow emission angle

If legal standards must be observed or if glare reduction is an important part of a project, a detailed lighting design with a correct UGR calculation must also be performed.

A World of LED Lights - The Cost of Waiting

Today, LEDs dominate the lighting domain. They are efficient and manufacturers understand how to implement them for different lighting applications. While energy efficiency is rather well understood, the impact of the adoption speed is rarely discussed is. Benoit Bataillou, guest author from Pi Lighting, will have a look at the environmental cost of LED production versus the significant energy savings that a full transition to LEDs would bring. In a fictive scenario, he assumes that a transition takes place in a heartbeat today and compares that with the usually supposed scenario of a full transition to LED lights in 2025.

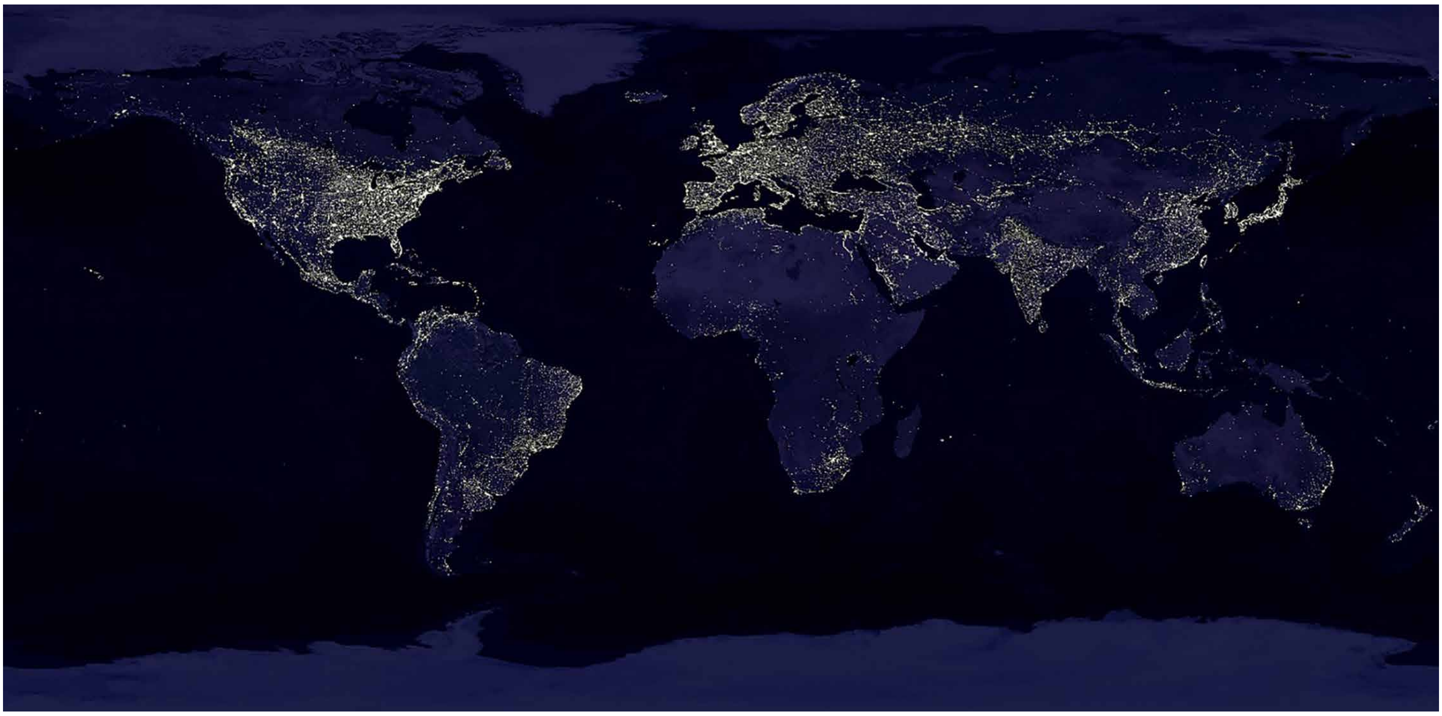
This article will be different from a typical technical article, as it will not go deep into technical details, but rather, give an areal view of a popular subject. The article is based on a hypothetical scenario: What if we changed all lighting to LEDs with a snap of the fingers?

It's common knowledge that LEDs help to save energy and there has also been talk about the impact on manufacturing. Circular Economy questions are getting more and more urgent, and debates are ongoing about the industry footprint, depending on who or what entity makes the study.

But the question is: What would it take to replace all the light fixtures in the world with today's LEDs? How would we produce all those LEDs and what would the result be? And if there is something that can be done within the lighting industry - does it matter?

After a first short analysis in an article last year [1], this article goes a little further on this subject using a similar approach. By gathering information and some hypotheses from different available sources a first draft of an answer can be made. The goal is to grasp the idea of the opportunity ahead. In many cases the Fermi estimation and the "Spherical Cow" [2] approximation are used to get an order of magnitude [3].

Figure 1:
Future view of LEDs from space (source: Wikipedia commons)



About the Goal

The goal is to estimate the impact of an arbitrary scenario: If we switched the entire world to today's efficient LED lighting, would that make a difference? Do we have an idea?

What is the challenge ahead? What does it take to produce an LED fixture? What should we do with everything that is replaced? Do it and finally see the impact by comparing it with the regular increase of the LED population that is currently going on.

Note that there is a large quantity of public data available for the US, so the "model world" here is a world in which all volumes, consumptions and costs are the same ratio of the GDP contribution of the USA (25.89 % source [4]). The world is roughly four times larger than the USA data. In all cases the data was double-checked with EU and China data (where available).

World Statistics

This sections shows the estimate of the total number of lights that need to be replaced and also tries to give some interesting numbers.

Careful estimations provided, lighting has only a share of 14% of the electricity consumption in homes, 22% in commercial environments, and 7% in manufacturing facilities. Given the relative total consumption we end up with 14% average of energy consumed for lighting in 2016.

Different sources [5&6] show that 22,000 TWh of energy were consumed for electricity in the world in 2016. With 14%, lighting has a total electrical consumption of 3080 TWh for 2016, which is roughly the electricity production of the entire European Union [7].

Calculating the energy in Joule for 2016 from 3080 TWh using EQ 1 results in 11 Exajoules (1M TJ). Transformed into watts using EQ2, for 2016, the average power dedicated to lighting is 300 GW.

Equations:

3080 TWh [TJ·hr/s] · 3600 s [3600s/hr] = 11 Exajoules (1EJ = 1M TJ) EQ1

$P = 11\ EJ/(0.5 \cdot Pi \cdot 10^7) = 0.3\ TW$ EQ2

where $0.5 \cdot \pi \cdot 10^7$ *is roughly the number of second in a year*

300 GW·38 = 11 Terra-lumens EQ3

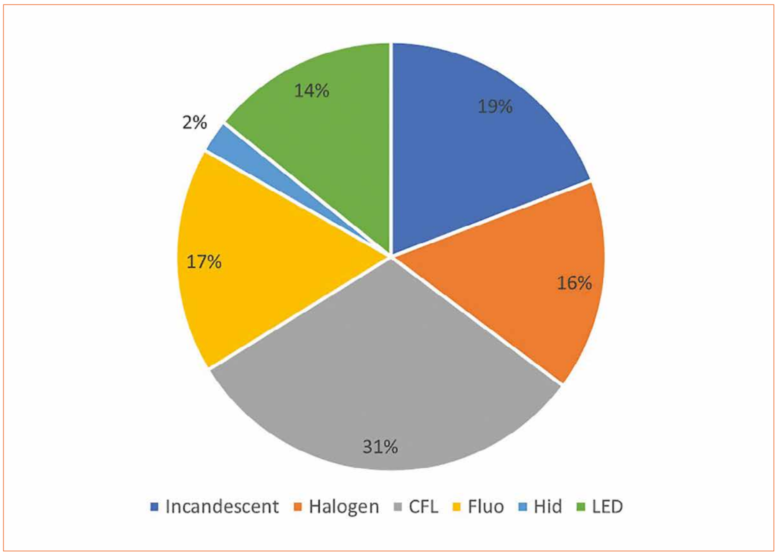


Figure 2: Breakdown of world installed based by technology (2016 data, forecasted to 2017 using source [8])

About today's efficiency of our lights

As of today [8], the total installed light sources of all sectors together can be broken down by lighting technology.

Based on the measured efficiency data, one can calculate the weighted average efficacy of the mix of all these technologies in lm/W. Gathering data from Caliper [9] for LED fixtures, and various manufacturer datasheets, we end up with the following weighted average: 38 lm/W as our world average, mostly raised by LEDs, HID and fluorescent technologies, and taken down by incandescent and halogens.

The same report gives a rough estimate of 30B fixtures. By multiplying the number of lamps with the efficiency using the calculation of EQ3 gives the amazing number of 11 Terra-lumens.

These calculations show that the average fixture consumes 10 W and produces 380 lm. It seems low for the power, but the order of magnitude is huge and the light output seems correct, given the large majority of halogen/ CFL/incandescent lights.

LED Fixture Production

Given our world statistics of the installed fixture base of 30B fixtures, the question here is: if we were to replace them all, what would be the impact?

NEMA in 2013 published a report in which the carbon footprint of several fixtures was analyzed [10]. An interesting finding of this study was that the carbon impact comes mainly from four components: Ballast (driver), Heatsink (Al), potting materials in the lamp base, and LEDs themselves.

The semiconductor and electronics industries use a large amount of energy and water, and as the NEMA report shows, the overall carbon footprint and energy cost of manufacturing an LED product is approximately twice the conventional counterpart.

Derived from 30B fixtures into the relative energy cost, and now having to spend quite a bit of energy to produce the 86% missing “non-LED” fixtures.

How much energy does it take to produce an LED fixture? - Unfortunately no exact data is available. Therefore a theoretical calculation based on some assumptions and published data from laptop computers was made, but fixture producers are welcomed to enlighten us with more accurate numbers.

An LED fixture in general does not have a battery or a screen, etc., and the electronics is simpler, but there is more and more PCB material involved for sensors, intelligence, communication and new features.

In the research paper “Economic-balance hybrid LCA extended with uncertainty analysis: case study of a laptop computer” [11], the authors found “Results show that manufacturing the computer requires 3010-4340 MJ of primary energy.” While LED fixtures have in general no screen, no battery, quite simpler electronics, the assumption was that it takes 1/10 of this energy consumption to produce a luminaire. In addition, the lower value from the cited research for energy consumption was used for the calculation, resulting in 300 MJ of energy.

To put things in relation, this 300 MJ equals 83 KWh or the equivalent of $10 of electricity in the US. To replacing all the fixtures, 172 GW of energy are necessary; that’s a lot for one year!

Circular Economy - Fixture Disposal

To see the whole picture, it is important to also have a look at the old fixtures. In the chosen scenario, the entire world is illuminated with LEDs. So apart from LED fixtures with the ability to replace the LED, everything must be replaced. In LED Lighting, replacing part of a fixture is an important debate, but very few solutions exist.

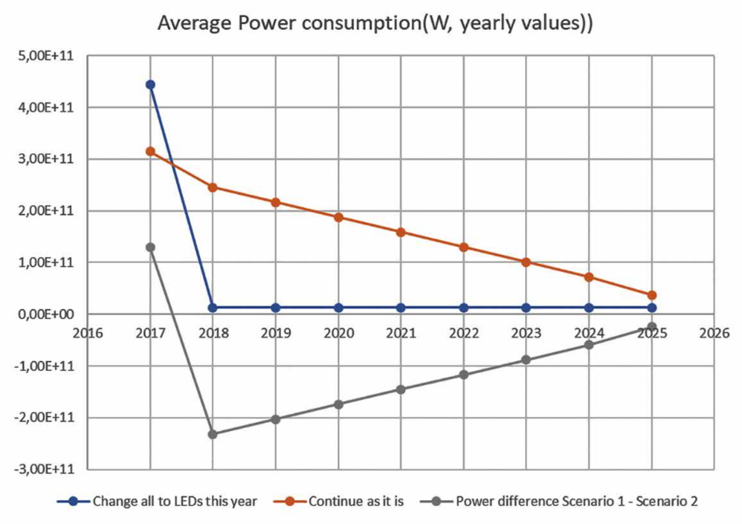


Figure 3: Hypothetical “change everything now” scenario and “just keep going as it is” comparisons. Note that numbers are large, but the blue curve plateau is at approximately 13 GW while the lifetime is ignored

This simplifies the calculation because the lifetime of any installed structure can be ignored.

Keeping the same “spherical cow” approach, there are currently about 30B “light points” in the world.

Data on large scale recycling varies quite a bit when reading through the literature. Our hypothesis is simply to add a “recycling factor”, a percentage of our new installed base that comes from recycling older materials. A study suggests that currently, between 20% and 40% of e-waste is recycled [12].

Even when assuming that proper recycling takes place with a recycling factor of 40%, this leaves a significant amount of waste. While the question of the waste raised many debates between the authors of this article, since the comparison concerns the scenario “change everything now” or “just keep going as it is”, in both cases, the waste will be the same, except there will new ways to deal with the waste that will be produced in the future. Then, maybe the second scenario might change.

Energy Savings

The latest generation of fixtures in 2017 easily exceeds 100 lm/W for the complete range of applications; and efficiency is still increasing. It is worth it to mention that this is a very careful estimate. Figure 3 is a comparison of the two scenarios “change everything now,” and the scenario “just keep going as it is” with the assumption of changing +10% a year, leading to a complete change in 2025 for the latter.

Discussion

As can be seen in Figure 3, the initial production cost makes a “change everything now” worse in energy balance in the first year. However, this changes very quickly.

The most striking value is the annual difference. With “change everything now” the first year with the effort to replace all translates in a negative energy benefit. But it’s more than covered the following year when 200 GW of energy can be saved. From then on, the “just keep going as it is” scenario catches up. Anyway, the savings increase dramatically over the years.

How does the benefit of saving 200 GW compare?

200 GW equals forty times the energy production of the largest coal plant in the world [13] and roughly equals the amount from 200 nuclear reactors. This should give a small impression of the usefulness of such a step. The earlier one implements an energy efficient source, even given the important production costs, it leads to a benefit.

The cost of waiting

The "cost of waiting" is even more important, since it's the cumulated variation between "change everything now" and "just keep going as it is". Reality will certainly lie somewhere between these two scenarios. However, this extreme theoretical case would lead to a cumulative saving of close to a Terawatt which is about a fourth of the total power consumption - not just electrical power consumption - of the US, including cars and coal. Waiting is just pure waste of energy on a very large scale.

The way to getting closer to the impossible

The largest contributor to improvements is the cost of production. Taking the very rough hypothesis above, there is close to 60% of an LED fixture energy saving which is spent in producing it. New processes will have a direct impact on that. Recycling value is obvious, recycling old parts lead to direct change in the return, as it's equivalent to fewer fixtures to "pay" in energy.

About the hypothesis

DOE states in an interesting report published last year [14]: ***"Decreasing lighting energy consumption by 75% in 2035 represents an even greater opportunity when the cumulative savings are considered. From 2015 to 2035, a total cumulative energy savings of 62 quads is possible if the DOE SSL Program Goal for LED efficacy and connected lighting are achieved - equivalent to nearly $630 billion in avoided energy costs."***

So it seems that the discussed hypothesis was actually quite conservative.

Thoughts about the LED lifetime

Lifetime calculation for the given time between 2017 and 2025 with 12h/24 running time results in 35,000 hours operation time. There are already fixtures with longer lifetimes of 50K hours and more on all the examples available, therefore it's long enough not to worry about it. Anyway, in the "change everything now" scenario (blue curve), the calculations take a 1% "accidents" every year into account. Adding these lifetime considerations to the full picture makes the results even clearer.

Conclusion

Would aggressively replacing everything to LEDs positively contribute to "the big picture"? - Yes, but what else? If emerging countries still are building up their power grid, they probably should be the first to heavily invest in LEDs. More generally spoken, if the industry provides a solution, would it not be best to apply it as soon as possible? Very likely also yes. ■

Acknowledgements :

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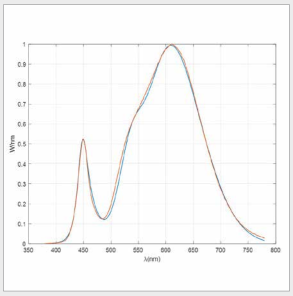

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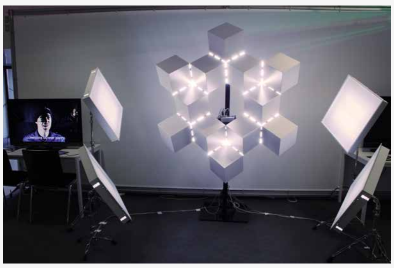

The "Cubical Demonstrator" for a unique lighting controls solution for video recording that makes it possible to record a scene with four different light settings at once

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TECH-TALKS BREGENZ

Julia Frohleiks – Co-Author Scientific Award Winner

The paper on "Hybrid Quantum Dot Light Emitting Electrochemical Cells" attracted a lot of attention. Light emitting electrochemical cells can be compared to OLEDs, but they are based on a much simpler inorganic architecture. While this technology is very young and efficiency is accordingly modest, the future perspectives and the takeaway from this research are paving the way to future research. Ms. Frohleiks gives insight in the current research and talks about LECs, QDs and future research plans. ■

RESEARCH

"Best Papers" at LpS 2017: Optimization of Freeform Optics Using T-splines in LED Illumination Design

Free-form optics is the game changer in the illumination industry in terms of its ability to redirect the light into the target area. However, the proper design is not trivial. Usually Non-Uniform Rational B-Splines (NURBS) is used to represent free-form curves and surfaces. But if modifications are only required at certain regions in the surface, this method fails. The research shows how in such a case the use of T-Splines helps. ■

TECHNOLOGIES

Multi-Pixel LED Technology Opens New Horizons for Smart Lighting Applications

The evolution of Multi-Pixel LED technology has initiated a giant leap in the development of intelligent lighting systems which are most visible in the automotive industry. Now the first hybrid LED provides smart headlights with more than 1000 individually controllable pixels. Automotive lighting, however, is just one of the potential areas in which intelligent selective pixel control can be applied. Options for the use in general lighting, such as information display for outdoor, indoor, retail or industrial applications, are very versatile. ■

AUTOMOTIVE

Flicker-Free Control of Individual LEDs in Matrix Headlights

LEDs combine design flexibility with practical, robust circuitry, enabling automotive designers to produce striking headlight designs matched by exceptionally long life and performance. But the full potential is not reached yet. Matrices of LEDs can be individually dimmed via computer control, enabling unlimited real-time pattern control and animation. The article shows how new matrix LED drivers make it easy to take the next step in automotive lighting design. ■

subject to change

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