LED professional

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Review

LpR

Trends & Technologies for Future Lighting Solutions

Sept/Oct 2016 | Issue 57

Research: Sky Radiance Distribution Pattern

Engineering: Design Process & Online Tools

Technologies: Full Spectrum LED

Environment: Botanical Light Pollution

Included: LpS 2016 Program

Fashion Retail

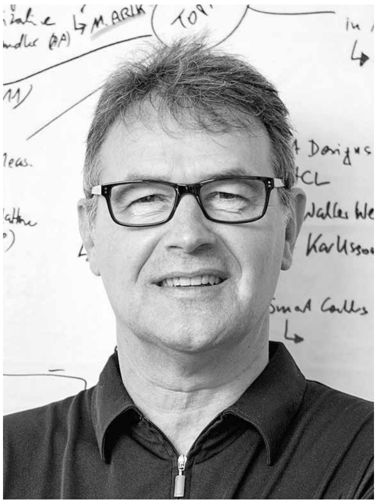
In the world of fashion, the appearance of merchandise can determine whether clothing goes home with a happy shopper—or stays on the rack. For lighting that sells, look no further than the new LUXEON Stylist Series with CrispColor Technology™. Designed to replace traditional halogen and incandescent lighting, these groundbreaking LEDs enhance vibrant, saturated colors to ensure garments—and your bottom line—look their absolute best. For LED product samples or more information, contact your Lumileds Sales Representative or visit us online.

See more. lumileds.com/StylistSeries

LUMILEDS

LUMILEDS ILLUMINATION LEDs

LUXEON HIGH POWER LEDs • **LUXEON MID POWER LEDs** • **LUXEON CoB LEDs** • LUXEON COLOR LEDs • LUXEON UV LEDs • MATRIX PLATFORM



Application Oriented Design

This Issue of LED professional Review is dedicated to Design and Engineering and will be distributed at the 6th International LED professional Symposium +Expo in Bregenz as well as at the electronica in Munich where design and engineering topics will be discussed intensively.

Due to further developments and the degree of maturity that lighting systems are based on, LEDs and OLEDs are more and more specifically designed and adapted for dedicated applications. In order to find optimized solutions, we require a deep understanding and knowledge of the applications needs and their environments. Applications oriented design requires both cutting edge technologies that match the needs of users, and applications with certain business cases. LED professional focuses on the fields of Indoor/Outdoor Lighting, Automotive Lighting, Horticultural Lighting, Art/Museum Lighting and Medical Lighting, which are all covered by the concept of Human Centric Lighting. Let's have a look at some examples from this issue.

LEDs Reveal Paintings Hidden in Paintings. Artists are often early adopters of new technologies that will bring their art to a new level. The two major elements that fine arts artists play with are light and materials. The article explains how Artist Clint Eccher uses LED lighting and LED technology to transform static paintings into some of the most dynamic, "living" paintings in the world.

Botanical Light Pollution. It is common knowledge that blue-rich light from high-CCT street lighting contributes to astronomical light pollution, but this is from a human perspective. From the perspective of wild and domesticated plants, it is red light in the range of 600 to 750 nm that is a concern. Therefore, lighting designers need to understand the issues of botanical light pollution. Plants rely on red and far-red light as environmental cues on when and how to grow. From soybean fields next to highways to greenhouse lighting, lighting designers need to understand the issues of botanical light pollution.

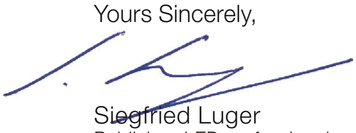
Metrics for Detection and Measurement of Optical Flicker and Stroboscopic Effect in LED Lighting. Optical flicker is a crucial and permanent topic in LED lighting. After briefly introducing optical flicker, the author describes how it impacts the quality of LED lighting and the lack of defined parameters to measure the presence of this phenomenon in lighting products. He explains why standards and standardized measurement are required, presents metrics for its detection, and finally proposes a test program and its parameters.

The LpS 2016 will go deep into application-oriented designs. Eight workshops and forums will be dedicated to those applications: ISA Forum, Design meets Technology Forum, Alternative Light Sources Forum, Risk Transfer & Investment Forum, Tunable SSL Lighting Workshop, IoT & Artificial Intelligent Lighting Workshop, Horticultural Lighting Workshop and SSL Lighting Measurement Workshop. The complete program is in this issue.

Application orientation is not a new idea, so what's the difference in lighting then? Primarily, it's the broad spectra of new technologies, the dynamics and speed of changes and the uncertainties of the acceptance of users and use cases that make us think.

Have a good read!

Yours Sincerely,



Siegfried Luger
Publisher, LED professional
Event Director, LpS 2016

LIFUD

LIFUD RF & ZigBee Smart LED Driver Solutions

It's simple. The key to keeping your customers happy is designing lamps and luminaires that not just meet but exceed the highest expectations. Fortunately, LIFUD LED drivers are up to the challenge.
The LIFUD newly developed RF LED drivers and ZigBee LED drivers deliver you smarter and more connected lighting control solutions. When it comes to selecting a smart wireless LED driver solution for your next indoor lighting or retrofit lamp project, go with the name what embodies the highest level of reliability and performance: LIFUD.

See more. **www.lifud.com**

Features:
Smart networking management of LED lamps;
Freely set different scenarios and switch over each scenario.
(A) version realizes dimming function and (B) version realizes dimming and CCT change.
The RF/ZigBee convertor changes the RF/ZigBee signal into 0-10V signal and enables the 0-10V LED drivers to function as RF/ZigBee LED drivers.

HKTDC

2016 Hong Kong International Outdoor and Tech Light Expo
Place: Asia World Expo, OCT 26-29th 2016, booth No: 10-F04

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Ruairí O'Brien

Ruairí O'Brien studied light and architecture at Universities in London, Edinburgh and New York. He worked in England, USA and Germany before setting up his own planning office in Dresden in 1995. His interdisciplinary work covers a broad spectrum of exterior and interior lighting design projects, street and market squares. He has also worked on numerous innovative light art projects, sculptures, installations and in theater. He initiated the light poetry festival "Light and Word" in Dresden in 2003. During his time as professor at the University in Wismar, O'Brien was a co-writer of the international master's program for Architectural Lighting Design and helped guide it to full accreditation in 2004. In 2014 he founded the Mobile School of Lighting Design and is a founding member and vice president of the Federation of International Lighting Designers.

THE GOOD THE BAD AND THE UGLY

We sit as lighting designers in our offices and look at beautiful pictures of beautiful lighting scenarios in beautiful glossy magazines. We are inspired by possibilities that new lighting technologies can offer us and allow ourselves to dream of the beautiful projects to come.

Reality hits us as soon as we enter the majority of our public buildings, schools, universities, hospitals, banks, offices, and even, sad but true, in the homes of our friends and families. Cheap and not so cheap, bad, glaring, soupy and creepy lighting everywhere you look. Bad daylight planning and obsolete artificial lighting concepts plague our interiors and at night the lack of light master planning destroys our romantic and playful encounters.

The emphasis on efficiency in the last years has not helped the situation (some have even mistaken this for lighting design). The long tradition of leaving the planning of lighting to technocrats has accelerated the negative effect that bad lighting has had on our buildings, towns and cities. The technocrat often has difficulty in understanding the philosophical and aesthetic dimensions of good lighting. They joke about the "art" of lighting as people often joke about things they are afraid of or do not understand.

Today with the huge array of new technologies available to us lighting is too important to leave to the unimaginative. "The Times They Are A-Changin..." sang Bob Dylan, this could be an inspiration for the lighting industry, politicians and decision makers, a wake up call for a true human centric lighting. Planning light is, as in all areas of culture, music, science or art, always about bringing the measurable and the Immeasurable together. The lighting designer brings the "art" of lighting and technology together; it is only with this holistic and humanistic approach that we can create a truly *human centric light*. As words and grammar alone cannot produce literature, successful planning of light is not just about energy consumption and light sources but also about the quality of light in terms of the mood and joy it can create. That is the true meaning of *human centric light*, a light that is healthy to the mind, the body and the soul.

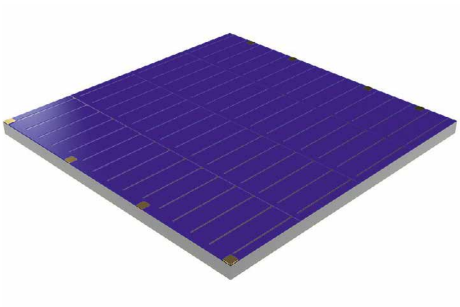
Good lighting can bring something godly to the simplest of buildings; lighting is the true king of spatial design and can transport humble spaces and structures onto another architectural level. Good daylight planning and good artificial lighting is the most cost effective way to create spaces of quality where people are happy to live, work and play. That is why lighting designers are becoming the most important design profession in the building industry. In times of BIM, modular building, dwindling resources and the internet of things, lighting designers need to step up to the block and play a leading role in the design team. In the future "Heavy-Ugly-Vanity Architecture", HUVA in short, will be side-lined and a new world of lighting design architecture with its mix and cross over of virtual and real will take its place. Perhaps we will call this the time of *light tectonic architecture*, a period of *light centric design* where building facades, interior and public spaces, towns and cities will be designed with the smart usage of light and shadow as its central idea.

In lighting design, efficient is not always effective, successful or even sustainable. Effective is when people use the space lit, enjoy the space lit and come back to the space lit, that is long term sustainability. That is why a market square requires different lighting scenarios, can cost more money and require more energy than a parking lot. After all, you do not have the same lighting in your living room as in your garage.

R.O'B.

Light Avenue Widens Portfolio to Offer High Voltage LED Chips

Light Avenue offers two new blue LED dies emitting at typ. 460 nm and typ. 5500-6000 mW @700 respectively @525 mA measurements current. The high voltage LED chip is suitable for general lighting applications like track lights or high bay lighting applications.



Light Avenue's new blue LED chips in 12 V and 24 V offer high performance for general lighting applications

The two new blue LED chips in 12 V and 24 V are intended for general lighting applications.

LA SB140VP1 (12 V):
This 140 mil chip in its dimension 3.5 x 3.5 mm emits form 450 - 465 nm and performs with a radiant power from of typ. 5,500 mW depending on the driving current and binning.

LA SB140VP2 (24 V):
The 140 mil chip emits from 450-465 nm and performs at typ. 6000 mW @ 525 mA depending on the driving current and binning.

The LA SB140VP1 (12V) and LA SB140VP2 (24V) LED chips offer high performance for general lighting applications. ■

New Cree MHB-B LED Lowers System Costs

Cree introduces the XLamp® MHB-B LED, a new high-power LED that enables a more effective way to deliver lower system costs for high lumen, high efficiency applications designed to meet the new DesignLights Consortium® (DLC) 4.0 Premium requirements. Leveraging key elements of Cree's SC5 Technology™ Platform, the ceramic MHB-B LEDs combine high light output, high efficacy and high reliability to enable high lumen LED designs that are not possible with mid-power LEDs. The MHB-B LED delivers up to 931 lumens at 85°C and 13 percent higher LPW than the MHB-A LED in the same 5 x 5 mm package, allowing lighting manufacturers to quickly increase performance for existing MHB designs without any additional investment.

Cree's new MHB-B LED delivers 13 percent higher LPW than the MHB-A LED in the same 5 x 5 mm package

"We evaluated many low-cost LED options but found that they require very large PCBs and optics and do not provide good lifetimes," said Frank Chen, VP fixture department, Shenghui/Sengled. "We selected the MHB-B LED because its leading light output, efficacy and reliability will allow us to meet increasing industry requirements such as the DLC® 4.0 Premium category at the lowest system cost."

The MHB-B LED enables designs that use significantly lighter and smaller heat sinks than designs based on mid-power LEDs. For example, a high-bay reference design built with MHB-B LEDs delivers 24,000 lm and more than 130 LPW system efficacy at 44 percent less weight and 36 percent smaller diameter than comparable high bays based on mid-power LEDs. Built on Cree's industry-leading high-power ceramic technology, the MHB-B LEDs have LM-80 data available immediately, delivering reported L90 lifetime projections of 60,000 hours at 105°C. The reference design demonstrates a cost-effective way to meet all of the DLC 4.0 Premium requirements for High Bay luminaires.

"Cree continues to deliver LED innovations that allow our customers to differentiate their products in the market place," said Dave Emerson, vice president and general manager for Cree LEDs. "The new MHB-B LED allows lighting manufacturers to achieve best system value for all high lumen applications including high-bay, roadway and other outdoor lighting without compromising performance or lifetime."

Featuring Cree's EasyWhite® technology, the XLamp MHB-B LEDs are available in 2700-6500 K with high CRI and multiple voltage options. Product samples are available now, and production quantities are available with standard lead times. ■

New Lumileds Stylist Series CrispColor Technology™ Arrived

Lumileds, the global leader in light engine technology, introduced chip on board arrays that use the innovative CrispColor Technology to deliver rich, saturated colors. Part of the extensive Luxeon Stylist Series, this new approach to lighting caters specifically to fashion retail, delivering a stunning palette to display merchandise more attractively.

CrispColor Technology enables fashion retail lighting that makes an impact, highlighting rich colors and increasing contrast to reinforce brand and build customer loyalty

"The Luxeon Stylist Series goes well beyond energy efficient lighting. This is about identifying the most appealing light for the environment and using it to attract and maintain a loyal customer base," explained Luis Aceña, Senior Manager, Stylist Series at Lumileds. "With Luxeon CoB with CrispColor Technology, all colors are immensely appealing, so customers are more likely to be captivated by the retailer's merchandise, want to purchase it, and feel like returning to your store again and again," he added.

CrispColor Technology from the Luxeon Stylist Series helps retailers strengthen the company's brand. By creating a signature lighting which is consistent in every store in the world, customers will feel confident and comfortable to spend more time in browsing and shopping. Spotlights and downlights made with Luxeon CoB with CrispColor Technology achieve a higher color gamut with an outstanding center beam candle power (CBCP). Available in multiple lumen packages and a wide color range (2700 K to 5000 K), these CoB arrays meet the exacting lighting requirements of fashion retail stores.

CrispColor Technology delivers more strongly saturated colors with a higher color gamut and will be available in a variety of product families from Lumileds, including CoB, Mid Power and Matrix Platform.

“Retailers tell us they can really see an amazing difference with these sources,” said Acena.

Perfect Restaurant Ambiance - Luxeon Stylist AtmoSphere

Lumileds, the global leader in light engine technology, today announced Luxeon LEDs with AtmoSphere Technology, which can be used to create the ideal ambiance for restaurants and other hospitality venues, making customers feel cozy, comfortable and relaxed.

AtmoSphere Technology can be used by lighting designers to cast a warm, inviting tone in restaurants and other hospitality settings, using single Luxeon LEDs or built-to-spec Matrix Platform light engines

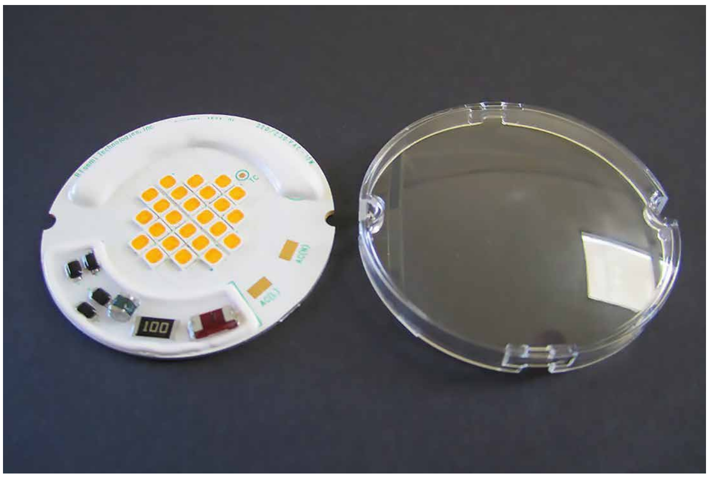
Features & Benefits:
- Warm color point of 2200K
- Available in 90CRI for optimal color rendering
- Color point on Black Body Locus (BBL) matching halogen lighting

Halogen lighting had long dominated restaurant, bar and other hospitality lighting due to its ultra warm light capability - even while LEDs offered a 70-80% energy savings versus halogen. “Standard LEDs do not offer the optimal replacement for halogen in restaurant environments, but Atmosphere Technology from the Luxeon Stylist Series does,” said Luis Aceña, Senior Manager, Stylist Series at Lumileds. Lumileds offers AtmoSphere Technology on its Luxeon CoB arrays in a candlelight-like 2200 K CCT with 90 CRI that is the industry’s choice for a warm atmosphere in restaurants. For downlights and spotlights, the portfolio of Luxeon CoB with AtmoSphere Technology meets a variety of restaurant needs including PAR 30 and PAR 38 replacements.

For dim to warm solutions, the Lumileds built-to-spec Matrix Platform with AtmoSphere Technology provides a variety of color tunable designs that use any combination of Luxeon LEDs to achieve the perfect “dim to warm” effect that is so coveted in many hospitality venues. The proprietary Oberon pick-and-place technology is used to pinpoint module color points to provide a consistent light appearance and performance.

New euroLighting LED Module with Particularly Low Flicker Index

The new LED module in AC technology from euroLighting scores highly with an extremely low flicker index of 0.029. An additional protective edge and an improved cap with click fastener increase safety even more. The module accommodates the LEDs and all the driver electronics on a board only 47 mm in diameter.



euroLighting's new LED module in AC technology scores highly with an improved Makrolon cover and an extremely low flicker index of 0.029

With power output of 15 W or 20 W, the DMA5001/5002 range is available in color temperatures of 3,000 to 5,700 Kelvin. One module has a color rendering index RA >90 and a Cosphi power factor of 0.98. It is only 4 mm in height, but together with the protection class 2 makrolon cover for protection of the driver ICs, the height is increased to 8.5 mm. This means that AC LED modules are well-suited for use in downlighters and interior lights of all kinds.

Their design provides one particular benefit: namely that all components of the driver circuit are accommodated together with the LEDS on the main board, which gives developers huge advantages for space-saving mounting in lamps. With a corresponding heat sink the operating temperature is 55.9°C, which means – at an ambient temperature of 21°C – the warming is only at +37°C.

The new modules are also available as plug-in modules in the Zhaga standard at euroLighting. ■

Luxtech Introduces the First Specification-Grade Flexible LED Strip

Luxtech, a leading American manufacturer of integrated LED module technology, introduces the first specification-grade flexible LED strip for luminaire manufacturers. Luxtech's low heat, super-thin flexible LED strips can be cut, curved, and adhered to fit nearly any lighting application.

Luxtech claims LED Flex to be the most flexible and most durable flexible LED strip on the market today

With high capacity copper traces and a rugged polyimide substrate, Luxtech offers the most durable flexible LED ribbon on the market, especially built for robust, high-performance lighting fixtures. LED Flex can easily produce over 1100 lumens per foot.

The flexible LED strip is far superior to others on the market because only Luxtech is built to perform to, or above, the demanding standards of spec grade lighting. Luxtech partners with the highest-quality LED manufacturers, including Nichia and Samsung, known globally for their luminous efficacy, quality, and reliability. The 3-step binning promises proximity to the blackbody curve, as well as minimal color difference among white LEDs.

The company also collaborates with 3M Corporation to offer authentic 3M VHB tape. High tensile strength, sheer, and peel adhesion makes 3M the toughest, most robust tape on the market. Not only does the tape offer outstanding durability but also excellent resistance to solvents, moisture and heat. And no other tape can claim a twenty-four month shelf life.

Standard Luxtech specification-grade LED strips can be cut to any length in increments of 2.6” and is offered with 120 LEDs per meter with a pitch of 0.3” - which guarantees more lumens per inch and better photometric distribution without glare or hot spots.

The specification-grade flexible LED strips are ideal for circular designs, including downlights, both indoor and outdoor lighting, cabinet lighting, hospitality lighting and linear extrusions. Luxtech specification-grade LED flex is available today in white, with color tuning LEDs available in the fall. ■

Toshiba Supports Downsizing of LED Modules with Single-Wire Input LED Driver

Toshiba Electronics Europe has introduced a 9-channel output LED driver IC that will save board space and reduce the size of LED modules in a variety of lighting and illumination applications.

Toshiba's compact 9-channel IC with integrated voltage regulation and daisy-chain pins reduces board space in illumination designs

The TB62D786FTG has a single-wire Manchester-encoded interface, which is often used for wireless communication. Built-in daisy-chain pins and a linear regulation circuit (LDO, 5V output) capable of handling inputs from 7 V to 28 V improve the extendibility of the IC.

In conventional designs, power has to be supplied to the LED driver ICs and LEDs separately. Using the TB62D786FTG, the number of wires between a host controller or MCU and the LED driver unit can be reduced to just four: a single power supply, single-wire input, single-wire daisy-chain output, and GND. Fewer connections, combined with the IC’s compact VQFN24A package, allows overall size of the LED unit board to be reduced and the IC to be used with smaller modules.

The new device is compatible with an IC control voltage of 4.5 - 5.5 V and can deliver up to output currents of up to 85 mA per channel. Input signal transfer frequency range is 0.5 - 2 MHz, and illumination can be controlled using PWM gradation (0 - 127). ■

New TRIAC-Dimmable LYTSwitch-7 LED Driver ICs from PI

Power Integrations, the leader in high-efficiency, high-reliability LED driver ICs, announced its LYTSwitch™-7 single-stage, non-isolated, TRIAC-dimmable, buck topology LED driver IC family. Capable of delivering up to 22 watts without a heatsink in a very small SO-8 footprint, these high-efficiency devices are suitable for bulbs, tubes and fixtures.

Power Integrations' bleeder-less, highly efficient, robust LYTSwitch™-7 IC family serves bulbs, tubes and fixtures up to 22 W

LYTSwitch-7 ICs deliver a phase-cut (TRIAC) dimming solution with a wide dimming range and monotonic dimming response. The LED drivers enable efficiency of greater than 86% - around 2% higher than conventional dimmable products – with high PF, accurate regulation and comprehensive protection. They suit low- or high-line input as well as wide-range universal-input designs for U.S. commercial lighting applications, which operate from 90 VAC to 305 VAC with TRIAC dimming enabled in low-line installations.

Hubertus Notohamiprodjo, director of product marketing at Power Integrations commented: “Our new LYTSwitch-7 LED driver ICs provide a highly robust solution while requiring a BOM count that is approximately 40% less than conventional circuits. The internal 725 V MOSFET delivers better withstand performance during line surges, while the bleeder-less design has high TRIAC compatibility but does not produce wasted heat, resulting in a more efficient and reliable driver.”

Like all Power Integrations LED drivers, LYTSwitch-7 ICs have a host of protection features including thermal foldback with end-stop shutdown, which protects the IC, driver and fixture at abnormally-high ambient temperatures by automatically reducing the current flow and dimming the lamp. Developers find that thermal foldback is the key to reducing costs associated with over-design of both electrical and mechanical components to meet reliability goals since the IC automatically limits unusual temperature excursions without extinguishing the lamp. Devices are also protected from open- and short-circuit conditions, input and output OV, overcurrent and SOA. LYTSwitch-7 ICs meet international standards including: DOE Level 6 (external power supply), CEC Titles 20 and 24, EnergyStar® Lamps Program Requirements Version 2.0, NEMA SSL-7A and EN61000-3-2 (C&D).

Key applications include low-cost A19 lamps, small-form-factor lamps such as candle-style and GU10 bulbs, commercial & industrial applications, ceiling lamps and downlights.

Diodes' New Dimmable LED Controllers for up to 150 W with High PF

Diodes' AL1663 and AL1663R single-stage dimmable LED controllers support flyback and buck-boost topologies to provide primary-side regulation that achieves an accurate constant-current output without requiring opto-couplers and secondary control circuitry. Operating at up to 150 W and featuring multiple dimming options, these controllers provide versatile and cost-effective drivers for LED backlighting, smart LED lighting and general-purpose dimmable LED lamps.

Diodes' AL1663 and AL1663R LED controller ICs support multiple dimming options

High efficiency and low EMI result from operation in boundary-conduction mode (BCM) with valley-switching control, which further ensures the AL1663 and AL1663R maintain high power factors with low total harmonic distortion under universal input-voltage conditions. The use of primary-side regulation simplifies design and lowers total BOM component count and cost. The AL1663 and AL1663R are also characterized by low start-up current and low operating current, and integrate multiple protection features including over-voltage, short-circuit, over current and over-temperature.

Analog and digital dimming modes are supported: The AL1663R has a single dimming pin that will accept either an analog signal between 0.3 V and 2.4 V DC or a digital PWM input when connected with a suitable input capacitor of several hundred nF. The AL1663 offers an additional digital dimming input pin that can accept a high-frequency PWM signal and provides built-in PWM-to-DC conversion. ■

Inventronics Upgraded 60 W Slim Programmable DALI LED Drivers

Inventronics has announced the release of a family of 60 W slim, programmable, constant-current LED drivers for panel and linear lighting. This can include classrooms, office buildings, hospitality, doctor's offices and museums. These 2nd generation drivers were redesigned to have a longer life and more compact size resulting in greater design freedom.

Inventronics' new DALI LED driver provides Constant Current Regulation (CCR) with low ripple for flicker free dimming

The LUD-060SxxxBS2 series can be programmed for Dali or push dimming and has 5 constant-power models to deliver the full 60 watts at almost any output current from 385 mA to 2100 mA. The output signal has been upgraded to use Constant Current Regulation (CCR) with low ripple which provides a higher quality of light allowing each model to offer low flicker free dimming down to 5%. They also provide a 12 V / 200 mA auxiliary output and dim-to-off with ≤ 0.5W standby power consumption, making it ideal for operation with a wide variety of sensors and controls for even greater energy savings. These products all operate over a 90-305 Vac input range and provide excellent power factor correction (0.99 at 120 V and 0.96 at 220 V).

The high efficiency and robust thermal design of these drivers enable them to run cooler, significantly improving reliability and extending product life. The lifetime of these drivers is calculated to be at least 107,000 hours when operating at 80% load with a case temperature of 60°C.

To help ensure trouble-free operation, these drivers also feature over-voltage and over-temperature protection for both driver and external LED array, and short-circuit protection. The slim metal housing is IP20 rated, making this 60 W DALI LED Driver a perfect choice for indoor applications.

This new series is approved to UL, ENEC, TUV, CE, FCC, CB, Circle K, Double Insulation and DALI standards. ■

GlacialPower Launches Efficient and Reliable 100 Watt LED Driver

GlacialPower, a division of LED technology manufacturer GlacialTech Inc, is pleased to announce the GP-LS100P-36 1E, a 100 Watt LED driver with a 40V DC output. This rugged and reliable driver is suitable for demanding outdoor or indoor applications – including locations with challenging environmental conditions and fluctuating power supplies – thanks to its very wide input range of 90 to 305 VAC and 47 to 63 Hz, IP67 waterproofing and dustproofing, and full OVP, OCP, SCP, and OTP protection. The GP-LS100P-36 1E is compliant with tough new EU directives for power efficiency, and also offers constant current and constant voltage operation modes.

Glacial's new GP-LS100P-36 1E LED driver handles a wide range of environments, variable power conditions, and offers extensive safety features

Key Features:

- Universal AC input, from 90 to 305 VAC
- Active Power Factor Correction is built in
- Safety protections include OVP, OCP, SCP, and OTP
- Constant current and constant voltage modes
- IP67 rated for protection from water and dust
- Compliant with the ErP (EU) No. 1194/2012, Stage 3 directives
- Consumes less than 0.5 W when the unit has no load
- Takes less than 0.5 seconds to start up at 230 VAC
- Waterproof connectors for convenient maintenance

Efficient and Eco-Friendly:

GlacialPower focuses strongly on environmental protection and power cost reduction with this new LED driver. The driver is fully compliant with Stage 3 of the stringent ErP (EU) No. 1194/2012 directive which aims to greatly enhance the efficiency of energy-related products. The GP-LS100P-36 1E provides active power factor correction for highly efficient use of input power, as well as high power output efficiency. Power consumption is reduced to a very low 0.5 Watts when the unit has no load, in order to easily achieve a much greater energy saving during inactive periods.

Smooth Power, Fast Startup:

The GP-LS100P-36 1E provides high output voltage quality to protect your LED lighting units from harm and also provides a pleasing lighting environment for your staff and customers. The driver's output voltage is clean and stable, with minimal ripple effects and very low noise (below 180 mV), ensuring a constant, flicker-free LED light or other adverse effects. This product provides a highly responsive setup time, under full load, of no more than 0.5 seconds at 230 VAC, and no more than one second at 115 VAC, ensuring extremely timely provision of attractive light on demand, whenever users require it.

Tough, Safe and Reliable:

In order to serve a very wide range of user applications and demands, this versatile LED driver can handle some of the most challenging lighting environments and weather conditions, indoors and out. It is protected from environmental threats by its IP67 rated enclosure, which is both waterproof and dustproof. Safety and long, maintenance-free life is further assured by a full range of electrical and thermal safety features including Over-Voltage Protection (OVP), Over-Current Protection (OCP), Short-Circuit Protection (SCP) and Over-Temperature Protection (OTP).

New Rugged 192 W LED Driver from GlacialPower

GlacialPower, a division of LED technology manufacturer GlacialTech Inc., is pleased to announce the new GP-LS200P-60 1E LED driver, providing a 192 Watt, 60 VDC output. With IP67 rated environmental protection from water and dust, this newest addition to the company's range of LED drivers can meet almost any lighting challenge, indoors or outdoors, even in difficult environmental conditions.

GlacialPower's new GP-LS200P-60 1E AC-DC LED driver is flexible, reliable and very efficient

Features:

- Universal AC input, from 90 to 295 VAC
- Active Power Factor Correction is built in
- Safety protections include OVP, OCP, SCP, and OTP
- Constant current and constant voltage modes
- IP67 rated enclosure, for protection from water and dust
- IP68 waterproof connectors, for convenient maintenance
- Starts up in less than 1.5 seconds at 230 VAC
- Class I Metal case

The GP-LS200P-60 1E is rugged, reliable, adaptable and very efficient. It handles a wide range of input voltages from 90 to 295 VAC, and 127 to 417 VDC, with support for frequencies of 47 to 63 Hz (the rated voltage is 100 to 277 VAC). The driver offers constant current and constant voltage operating modes.

A safe, energy saving and eco-friendly LED driver

Focusing on reduced power costs and environmental protection, GlacialPower incorporates numerous electrical and thermal safety features across the whole product range. The tough and dependable GP-LS200P-60 1E incorporates features to ensure safe operation and a long, maintenance-free life – these include Over-Current Protection (OCP), Over-Voltage Protection (OVP), Short-Circuit Protection (SCP) and Over-Temperature Protection (OTP).

With active power factor correction the GP-LS200P-60 1E makes efficient use of input power, and the driver also offers high power output efficiency. At full load, power factor is better than 0.98 at 115 VAC, and better than 0.94 at 230 VAC. Even at 80 percent load, the driver still achieves a power factor of at least 0.9 at 230 VAC.

LED driver with IP67/IP68 rating, ready for almost any application or any conditions

The flexible GP-LS200P-60 1E is able to handle a vast range of applications, thanks to its wide input power range support. Protected against environmental threats by its waterproof and dustproof IP67 rated enclosure, the driver handles challenging indoor and outdoor lighting tasks in extreme weather and wet, dirty environments. To save maintenance time and costs, the IP68 rated power connectors can be connected or disconnected without opening the IP67 rated housing.

Stable power ensures this LED driver creates a great lighting environment

For ensuring good lighting quality, without LED flicker, GlacialPower designed the GP-LS200P-60 1E to provide optimal electrical stability. There is minimal ripple in the clean, stable output voltage, with noise levels maintained at less than 600 mV. The high output voltage quality also protects your valuable LED units from damage, helping your LEDs reach their maximum possible lifetime, and slashing maintenance and replacement costs. The driver also achieves a startup time below 1.5 seconds at 230 VAC and full load, with a maximum startup time of 3 seconds at 115 VAC and full load.

Inventronics Launches Round Programmable LED Drivers

Inventronics has announced the release of a family of programmable 96 W, 150 W and 240 W constant-current LED drivers to provide easier installation on bay lighting applications.

The round programmable LED drivers are designed for easier installation and streamlined appearance for Bay lighting applications

The EUR family of drivers offers more design versatility with adjustable output currents through programmability or potentiometer and 0-10 V/PWM dimming as well as non-dimming versions, and can be ordered for hook or loop mounting to easily attach to the top of the light fixture.

The drivers can also be ordered in three different colors; white, silver or black to give your fixture a sleeker and more streamlined appearance. The rugged, round metal case offers durability that makes it suitable for hazardous indoor and outdoor applications such as factory, warehouse and sports arena lighting.

Each EUR series offers 4 programmable, constant-power models that deliver the full 96 W, 150 W or 240 W at a wide output current range between 1400 and 6700 mA. All models operate over a 90-305 Vac input range with excellent power factor. A full-load efficiency up to 93% and longer lifetime gives the EUR series an edge over the competition. The high efficiency and robust thermal design of these drivers enables them to run cooler, significantly improving reliability and extending product life.

To ensure trouble-free operation, the EUR product family also features built-in protection for surge, over-voltage, over-temperature and short-circuit events. The new EUR-DT/ST series is approved to UL, FCC, CE, and Circle K standards. The new EUR-DV/SV series is approved to ENEC, TUV, CE, CB, CCC, PES and Circle K standards.

TRP Releases ZigBee-Certified Wireless Driver Control Module

Thomas Research Products, a division of Hubbell Lighting, has announced its membership in the ZigBee Alliance - a non-profit association of organizations creating open, global standards that define the foundation for the Internet of Things (IoT) used in consumer, commercial and industrial applications. Thomas Research Products has joined the Alliance as an Adopter member and is proud to announce the release of its first certified product, the TCM-ZB-D control module, which is designed for use with LED luminaires powered by TRP's LED drivers.

Thomas Research Products has also introduced its ZigBee certified product as part of the Alliance. The TCM-ZB-D wireless driver control module is a Home Automation-certified lighting control product

The ZigBee Alliance's mission is to create, maintain and deliver the highest performing specifications, standards and solutions for the wireless IoT. The widespread availability of ZigBee-certified devices gives developers and users more flexibility to choose products they know will work with each other. The Alliance simplifies IoT product development and deployment, reduces industry confusion through the availability of a consolidated set of open application device definitions, and helps members bring the benefits and capabilities of connected IoT devices to a significantly broader range of applications and markets.

"Thomas Research Products is the newest addition to the ZigBee Alliance family, and we welcome them to the ever growing ecosystem that simplifies IoT connections and interoperability for commercial applications." said Victor Berrios, Vice President of Technology, ZigBee Alliance.

The TCM-ZB-D control module is designed for use with LED luminaires powered by TRP's LED drivers. The device provides wireless ON/OFF with full 0-10 V dimming control. This allows end users to take advantage of the full spectrum of today's lighting control strategies, such as daylight harvesting. The module also stores the last dim setting when powered off. With a small case designed to easily fit in most luminaires, the module operates fixtures on 100-277 V circuits. The module is also plenum rated for use in ceiling spaces.

"TRP focuses on wireless lighting controls for OEMs that provide simplicity and flexibility to our customers," said TRP Brand Vice President, Greg Andrews. "Being part of the ZigBee Alliance allows us to contribute to a meaningful IoT experience as the marketplace delivers smarter products and seamless connections. Adding ZigBee compatibilityto our control options helps our customers meet evolving energy codes and regulations." ■

XiTRON's Portable Micro-Spectrometer Offers Lab Instrument Performance

XiTRON Technologies, producer of precision test and measurement equipment for industrial and consumer product development, quality control and manufacturing, introduces the XT1600 micro-spectrometer designed to meet the needs of the LED lighting industry. The flexible unit performs essential lighting measurements (lux, lumens, CRI, CCT, CRI / CQS, PPF and color) in the field, in production and in the development process.

The new portable Micro-Spectrometer exceeds the performance of competing portable devices by providing laboratory-grade photometric measurement accuracy (±0.0004 xy coordinates for CIE-1931, 5-500 lux), resolution (4.2-5 nm) and repeatability (±0.04% + 1 digit) – and yet is priced to cost thousands of dollars less.

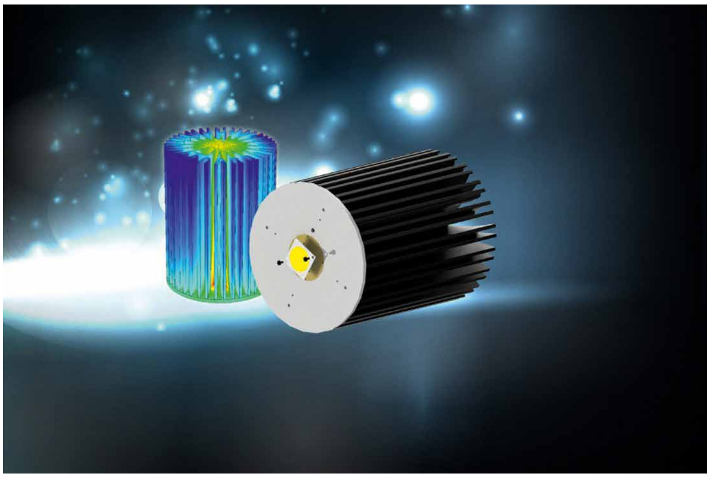
XiTRON's XT1600 micro-spectrometer addresses LED illumination needs - lighting design, fixture verification, LED binning, LED lamp/spot testing. The portable, user-friendly lighting-measurement tool is well-suited for engineering lab and field use

"The XiTRON XT1600 is unlike other portable micro-spectrometers on the market that require a PC to collect data and view results," said Alan Armstrong, XITRON Technologies' Director of Operations. "Our hand-held, battery-operated unit not only provides users with a portable piece of test equipment that gives instant feedback and results, it also offers full reporting capability with a built-in color touch-screen display, plus a full set of exportable pre-configured reports and editable Excel spreadsheets."

The flexibility and portability of the XT1600 micro-spectrometer makes it well-suited to a range of applications, including spectrum testing and analysis, light measurement (lux, lumens), LED binning, ISO/CIE standards compliance: color rendering index (CRI), correlated color temperature (CCT), color quality scale (CQS), CRI / CQS, Photosynthetic Photon Flux Density (PPF) and color.

MechaTronix CoolBay® Tera Is Approved for 50.000 lumen COB

New worlds of LED lighting are revealing themselves, worlds we couldn't dream about just a few years ago. When Citizen created the "Monster" COB package CLU550, capable of creating over 50,000 lumen of light output, it wasn't sure if anyone would be able to cool it down to temperatures which would lead to the life time this kind of industrial application would require.



MechaTronix claims CoolBay® Tera to be the most efficient fully passive LED cooler ever developed

Ledlink Optics,Inc.

NEW PRODUCT

Ultra-Thin Hybrid Lens & Connector

LL01CR-CENxxL02 / **LL01CR-CFExxL02**

DxH(mm) 70x17.5
FWHM 12° 24° 38°

DxH(mm) 70x17.5
FWHM 12° 24° 38°

LL01A00CSJB2-M2
Citizen CLU720
Edison HD30
Luminus CHM11

LL01A00CZMB2-M2
Cree CXA 15xx

LL01CR-CHQxxL02 / **LL01CR-CEWxxL02**

DxH(mm) 35x10.5
FWHM 24° 38°

DxH(mm) 50x15
FWHM 12° 24° 38°

LL01A00CZNB2-M2
Cree CXA 13xx

Narrow Beam Lens

LL04CR-CEC09L06

DxWxH(mm): 50x50x9.96
FWHM: 9°
CREE XP-E2 / XP-G2 / XPL-HI / XM-L
NICHIA NCSxx19A / NVSxx19A / NCSxx19B / NVSxx19B
OSRAM Oslon SSL 80 / Oslon Square
SAMSUNG LH351A / LH351B
Seoul Z5M1 / Z5M2 / MJT 4040

Wallwasher Lighting

LL01CR-CRI1055L02-M2

DxWxH(mm): 22x22x13.15
FWHM:10x55°
CREE XPE2 / XPG3
LG Innotek H35A / H35C1
NICHIA NCSxx19A / NVSxx19A / NCSxx19B / NVSxx19B

| www.ledlink-optics.com | service@ledlink-optics.com

With a dimension of just 38mm by 38mm and more than 500 watts of power, the “Monster” accommodates 936 micro dies. Triggered by this tendency of immense power concentration in a small surface, MechaTronix started mid of 2015 with a complete new approach of high power cooling. They developed their patented CoolTube® heat pipe structure, caable of transporting 2 kilowatts per second of heat from a tiny source. That was immediately the heart of their new high bay and industrial cooler, named the CoolBay® Tera. Coming in a diameter of just 19 centimeters and 25 centimeters of height, able to cool down the 50,000 lumen from the Citizen “Monster”, this is by far the most efficient fully passive LED cooler ever developed.

As an industrial lighting designer you can imagine what kind of new worlds are opening now, with just a few components… a COB, a led cooler, a driver and a handful screws… A warehouse of 30 meters height would still have over 100 lux on the floor, a building of 50 floors would suddenly look totally different when you beam the light up.

This tendency of immense power and light output on a small surface is a new trend in the LED market. Besides development of extreme high power COB modules, also the rise of flip chip and CSP (Chip Scale Package) LED emitters enable these markets. With the much lower thermal resistance of CSP emitters and the major reduction in size, this technology is extremely suitable for building compact high power engines. This again emphasizes the needs of advanced thermal management like MechaTronix is focusing on. ■

TECHNICAL REGULATORY COMPLIANCE UPDATE

Segment	Product	Standard (Certification)	Region	Technical Regulatory Compliance Information
Lighting	Lamps	Resolution No.1 2016	Brazil	Taking a major step in accordance with Law No. 12305, 2010, The Resolution No.1 2016 is put forth, which will come in force on Oct 03,2016. It specifies the priorities and timelines requirement of importers of fluorescent lamps, sodium vapour and mercury and mixed light and its components to collect their end of life products from consumers and reuse, recycle or otherwise manage the collected products to an environmentally adequate final disposition. For this to happen in a seamless process they will operate under a compliant reverse logistics system. This is confirmed by the Ministry for the Environment.
Electrical and Electronics	Electrical and Electronics	PVOC	Uganda	PVoC is an inspection and verification programme which is in force since June 01, 2016; is performed by appointed agents in the country of export. The purpose of it is to minimise the risk of unsafe and substandard goods entering Uganda and protect consumers against dangerous and substandard imported products. Under the scope of the programme, all exporters and importers falling into the PVoC scope are required to obtain a certificate of conformity prior to shipment of the goods. The list consists of a wide range of electrical and electronics products.
Electrical	Electrical	RTE INEN 227, Resolution 16 059, 2016	Ecuador	The technical regulation includes the development, adoption and application of specific safety requirements on electrical apparatus for heating liquids, cooking food and similar. It came in force on June 27, 2016. This regulation is mainly applicable to electrical apparatus used for domestic function where the operating voltage is not more than 250V. This is done to prevent risks that could bring harm to end users and protect the environment. The requirements include therein relate to product labelling, safety, testing and certifying conformity. Products to which it applies must meet the requirements set out in the following IEC standards: IEC 60335-2-9, IEC 60335-2-15, IEC 60335-2-13 and IEC 60335-1.
Electrical	Electrical	Resolution No. 1067, 2015	Ukraine	On 16 December 2015, the Ukrainian Cabinet of Ministers approved Resolution No. 1067, 2015 on technical requirements for low voltage electrical equipment which came in force on July 01, 2016. The objective of this Resolution is to bring Ukrainian legislation in line with EU requirements and align with EU Directive 2014/35/EU on the harmonisation of the laws of the Member States relating to making electrical equipment designed for use within certain voltage limits available on the market. The Resolution establishes conformity assessment, marking and technical documentation requirements which producers of electrical equipment must meet, as well as, authorised representatives, importers and distributors.
Electrical	Electrical	Decree No. 285, 2015	Armenia	This decree, which is in force since July 01, 2016; covers the health and safety risks of electrical equipments with voltage rating between 50 and 1000 Volts for alternating current and between 75 and 1500 Volts for direct current, other than the equipment specifically excluded therein. This ensures that electrical equipment within certain volatge limits which covers a large number of consumer and professional products follow the internal production control conformity assessment procedure as described and drawn up in accordance of EU declaration. This aims to ensure that only safe products are sold in the market.
Lighting	LED Lamps	10 CFR Part 429 and 430 - Amendment, Final Rule, June 2016	U.S.A	The supplemental notice of proposed rulemaking (SNOPR) proposed a method for calculating the lifetime of LED lamps, and defined the lifetime as the time required for the LED lamp to reach a lumen maintenance of 70 percent (that is, 70 percent of initial light output). New calculations for lamp efficacy and color rendering index (CRI) of LED lamps along with new and revised defination of time to failure and lifetime respectively have been incorporated in SNOPR. This test method shall be used for making efficiency and performance claims under FTC 16CRF 305 from December 2016 on. It will come in force from August 01, 2016.
Lighting	Luminaires	Interpretation Sheet ISH1 for IEC 60598-1:2014	Worldwide	IEC published an Interpretation Sheet ISH1 for the corrrect use of the IEC 60598-1:2014. It provides guidance on the application Clause 4.31; Clause 10; Clause 11; Annex M and Annex X to establish the correct working voltage for the application of the electric strength tests of Clause 10 and Creepage and Clearance requirements of Clause 11 for luminaires.

For further information on the latest upgrades and testing standards please contact cps@tuv-sud.com

electronica Again Presents a High Quality Forum Program in 2016

In more than 130 presentations in 5 forums, you will find out what moves the industry and the market. According to the TNS Infratest survey of exhibitors and visitors at the last electronica, 94% of the approximately 7,300 participants were completely satisfied with the forums in 2014.

electronica Automotive Forum 2016

New technology is changing the development and working world in the automotive industry more than ever before. Networked systems, new light technologies featuring LEDs, OLEDs and laser light and improved sensors for driver-assistance systems call for increasingly stronger interaction between individual controllers and actuators. More efficient components ensure added comfort and safety when driving or during (partially) piloted driving, and more elaborate software and faster data buses guarantee networking within the automobile and beyond. The topics cover: Consumer components in automotive; applications security in automotive; functional safety ISO 26262; connectivity; automotive lighting - exterior and interior; technologies for semi-/autonomous driving; software processes & methods for automotive.

Embedded Forum 2016

Embedded systems range from devices such as digital watches to large installations like factory controllers and complex systems like avionics. Simply stated, all intelligent electronics systems other than general purpose computer and IT solutions are embedded systems. An embedded system has software embedded into hardware, which makes a system that is dedicated for specific applications. Embedded systems are normally devices that are used to control, monitor or assist the operation of some kind of equipment. - They are an integral part of the system.
The electronica Embedded Forum's main topics include: IoT - smart factory, smart energy, smart buildings; security and IoT - challenges and solutions; technical trends with microcontrollers and microprocessors; motor control solutions; tools and software for embedded systems; embedded computing: boards, modules and more; technical trends with analog and power; embedded solutions for industrial and automation.

electronica Forum

The electronica Forum is a multi-themed forum that deals with and depicts electronica's highlight themes and other special content.

CEO Roundtable & Opening Event (November 8) - The industry's leading business giants hold a public discussion on "Connected Worlds - Safe and Secure!"

Wearables/Healthcare/Medical Technology Forum (November 8, afternoon) - The forum with a focus on sensor technology starts with a panel discussion with representatives component and system manufacturers in the healthcare sector. The following issues will be discussed: What requirements must be met by the electronic components in wearables that are worn by patients? How will wearables be incorporated into the overall patient-physician data-analysis system and what does that mean for the components themselves? What should the electronics look like to be able to satisfy the extensive requirements?

Industrial Internet of Things Forum (November 9, morning) - In this Forum, we will discuss the hardware and software issues surrounding the IoT and how they can be applied to your specific application. Presenters are experts in their field and will include coverage of wireless technologies, from the personal-area network (PAN) to the local-area network (LAN), to the wide-area network (WAN). This covers everything from RFID and Bluetooth up to WiFi and cellular. The major topics are: Select wireless transmission media, various microprocessor models, security using an RTOS.

Cyber Security Forum (November 9, afternoon) - The pervasiveness of electronics in every walk of life opens a myriad of possibilities across a wide range of connected products. With this pervasiveness comes a greater demand for secure systems in for example automotive systems, medical equipment, mobile devices and wearables. Topics that will be concerned are: Embedded security, automotive applications, medical electronics and information and communication technologies.

Solid State Lighting (SSL) Forum (November 10) - The SSL Forum 2016 is again organized by Luger Research e.U. and gives participants an overview of the technologies that are used in SSL (solid-state lighting) systems. Based on selected examples it will explain the current state of the art as well as the relationships and influences between the technologies used. The forum addresses electronics developers and system designers as well as project managers, production engineers and supply-chain managers who are involved in SSL development projects.

Student Day (November 11) - planet e is working with semica, the VDE and the ZVEI to put together an attractive and interesting program for some 300 aspiring engineers from throughout Germany. Besides a panel discussion on "Starting a Career" and a networking lunch with sponsors, the COSIMA Award will also be presented.

PCB & Components Marketplace

The PCB & Components Marketplace is one of the most important gatherings for the PCB, components and EMS industry.

Microsystem Technology/Sensors - no IoT without microsys-tems; No Industry 4.0 without sensors; new developments, challenges and applications from the MEMS Industry.

Packing Technology: Plug Connectors Network the World - in an increasingly digitalized world, plug connectors are the key to networking and connections. They are used in all segments of electrical engineering and electronics and suit every purpose and application.

Electronic Manufacturing Services - for a new product, its design is not the only thing that plays an important role. Its success also depends on collaboration with the customer, speed, reliability, expertise and excellence.

Repairing and Reworking Electronic Assemblies - fundamental considerations, opportunities and risks when reworking and repairing assemblies.

The smart path to electronics In-dustry 4.0: PCBs featuring RFID - what does Industry 4.0 mean for electronics manufacturing? RFID is a key technology that can be used to turn a PCB into a smart object. This event examines both the requirements and the effects of RFID for an electronic product's entire lifecycle.

LED professional Organizes electronica SSL Forum 2016

The electronica SSL Forum will be held on November 10th from 10:00AM to 4:00PM. It will communicate an outline of technologies applied in Solid-State-Lighting systems Selected state-of-the-art samples will be displayed and relations and obstructions between utilized technologies will be presented. The forum addresses electronic design engineers, system designers, project managers, production engineers and supply chain managers involved in SSL product development.

Developing efficient, optimized LED-systems requires usage of several technologies that have to correlate with each other. On the one hand, technologies that generate light with high efficiency and high light quality in the semiconductor are needed and on the other hand, suitable power electronics and good thermal management for cooling the LED are required. In the course of the forum these technologies and their interdependencies will be discussed. In respect to the current state of technology, LED lighting technologies will be focused on. In addition, OLED and its future prospects will be discussed in detail. A separate lecture will address lighting control of SSL systems, smart lighting and the Internet of Things (IoT). The mainly technical content of the lectures will be rounded off by an observation of the SSL market and LED applications.

The Solid State Lighting Forum will be comprised of a keynote and six lectures. It will end with a tech panel discussion on trends and future perspectives of SSL. ■

electronica 2016 Forum Program Overview - Nov. 8th - 11th, 2016

Forum	Location	Forum	Location
Automotive Forum	**Hall A6**	**Electronica Forum**	**Hall A3**
• Consumer Components in automotive • Applications Security in automotive • Products functional safety ISO 26262 • Connectivity • Automotive Lighting • Exterior and Interior Technologies for Semi-/ Autonomous Driving		• CEO Round Table: Connected Worlds – Safe and secure! • Sector forums: ◦ Cyber-Security ◦ Industrial IoT ◦ Solid State Lighting ◦ Wearables and Healthcare • Student Day	
Embedded Forum	**Hall A6**	**PCB & Components Marketplace**	**Hall A2**
• Internet of Things: Smart factory, smart energy, smart buildings, etc. • Security and IoT: Challenges and solutions • Technical trends with microcontrollers and microprocessors • Motor control solutions • Tools and software for embedded systems • Embedded computing: Boards, modules and more • Technical trends with analog and power • Embedded solutions for industrial and automation		• Microsystem technology/ Sensors • Packing technology: Plug connectors network the world • Electronic Manufacturing Services • Repairing and reworking electronic assemblies • The smart path to electronics Industry 4.0: PCBs featuring RFID	

After the successful cooperation in 2014, LED professional organizes again the electronica SSL Forum, held on November 10th, 2016

Color-Mixing Optics by Auer Lighting: Shopwhite

Auer Lighting presents a new color-mixing glass optic. It is designed for multi-color LED arrays, such as red and white modules, used in spot, track and down lighting. Complying with the retailers' requests for high contrast, high flux and superior color rendering it is the SSL upgrade to conventional CMH and CDM installations.

The optic consists of a base reflector with exchangeable diffuser lenses: a concept well known and tested with CDM systems. Likewise, the new color-mixing system provides multiple beam angles, depending on the diffuser lens used. The multi-shape facets of the reflector pre-mix the light while the lens with a double-sided, sophisticated facet design makes the color-mixing complete. "ShopWhite" has a very high efficiency >90% that can even be increased with an optional AR coating. The color uniformity for a red-white LED module is better than four MacAdam ellipses for an 18° spot.

The reflector and the lens can either be provided separately for your own assembly or as one piece with the glued-on diffuser lens. The reflector features Auer's SNAP IT® technology for easy mounting and exchange to other beam angles.

The base material of the optics is the durable SUPRAX® glass that easily withstands temperatures up to 450 °C. Additional benefits of "ShopWhite" are no yellowing, nor any degradation over time. The glass optics is scratch-resistant and thus easy to clean.

TPI21-TH: Measuring System for Testing and Binning of Back-End LEDs

LED binning by LED manufacturers in order to classify LEDs based on their tolerances is done in pulsed mode using pulsed current flow. Later on, the LEDs are mostly operated in constant current mode. The TP121-TH from Gigahertz-Optik GmbH is an LED testing system that is well suited for testing LEDs in both manufacturer-compliant, pulsed mode and constant current mode. The system's design conforms to the latest norms and regulations (such as CIE S025, LM-79-08, DIN 5032 Part 9) and is equipped with a high-quality CCD sensor spectral-radiometer with an integrating sphere to ensure accurate measurement of the luminous flux, spectrum, color, and color rendering index.

One of the ultramodern features that come with the system is the electronic zero setting (electronic shutter) of the diode array. This allows for precise, brief measurements within a light pulse. With 250W, the system has sufficient power for thermoelectric LED measurement of SMD and onboard LEDs to enable quick tests of the LED junction temperature in the range between 25 °C and 85 °C. The light-tight housing makes it possible for the system to be used outside dark rooms. Besides the attachment of samples, the system supports fully-automated measurement sequences with conclusive light analyses. Calibration is done by Gigahertz-Optik's calibration laborator,using a calibration lamp with simultaneous 2Pi irradiation of the test LEDs.

Dow Corning® IA-1200 Hot Melt Room-Temperature Vulcanization (RTV) Adhesive

Dow Corning® IA-1200 Hot Melt Room-Temperature Vulcanization (RTV) Adhesive is formulated to achieve instant green strength, which allows electronic assemblies to be handled immediately after its application.

The IA-1200 RTV Adhesive further speeds processing by offering primerless adhesion to common substrates.

The high thermal stability of IA-1200 Adhesive enables it to perform reliably and without yellowing in high-heat electronic and LED applications.

Able to be dispensed with standard hot-melt dispensing equipment, IA-1200 Adhesive further offers low volatile organic content.

Main Features:

- 100% Silicone
- Non-Hazardous composition and reaction by-products
- Neutral moisture cure RTV
- Can be used with standard hot-melt dispensing equipment

Ophir Photonics Introduces "FluxGage" LED Luminaire Measurement System

The FluxGage measures flux, color and flicker. It is 3 times as small as an equivalent integrating sphere, is robust, not sensitive to environment and is cost effective.

The FluxGage is a photometric test system for LED luminaires that uses solar panels as the light detector and is suitable for a manufacturing environment. The system measures the following variables in a 2ϖ geometry: total flux, spectrum and color parameters (CCT, CRI, Duv, chromaticity).

In the FluxGage system, solar panels are arranged on the inside walls of a box to create a measurement cavity. The panels are covered with black paint with a dense array of clear pinholes in the paint through which the light passes. This arrangement greatly reduces the reflectance of the solar panels, thus enabling the system to be only slightly larger than the luminaire source under test. This is in contrast to an integrating sphere which is at least 3 times larger than the source.

The FluxGage includes a spectrometer for the color measurements and a fast photodetector for the flicker measurement.

With a dimension of 770x560x230 mm, the FluxGarage is able to measure luminaires of up to 640x480 mm and it has dedicated SW and connects to a PC using a USB cable.

A calibrated, NIST traceable, LED source is used to calibrate the system in the field.

Plessey Orion™ PLWS3000 Series for New Concepts in LED Lighting Design

The new addition to the Stellar™ family uses Plessey's Optical Beam Forming technology to make a light module, which is simple to integrate into your product whilst solving many key challenges of existing COB type modules.

The Orion™ provides an innovative approach to directional lighting applications. The key is Plessey's innovative Stellar™ Beam Forming Optics allowing a super-slim module with a beam angle of 25° FWHM. The Orion™ module is only 5.6 mm in depth. The Orion™ removes common restraints found in a typical small COB, such as requiring a second optic that can be 100 mm in depth and difficulty to control color over angle.

Plessey's key combination of GaN on Si Chip technology and innovative Stellar Beam Forming Optics interact to help solve this challenge. In addition the superior thermal performance of this combination allows a different approach to Luminaire form-factor, in some cases reducing product depth by up to 85%. The Orion™ removes constraints and offers freedom in design.

By adding a PSU/ Driver and a heatsink the Orion™ will solve beam control, color variance over angle and challenges with thermal performance.

Dow Corning® MS-4002 Moldable Silicone

Dow Corning® MS-4002 Moldable Silicone targets secondary optics in LED lamp and luminaire applications.

The MS-4002 Moldable Silicone's comparatively high hardness and low surface tension results in a smooth, plastic-like surface.

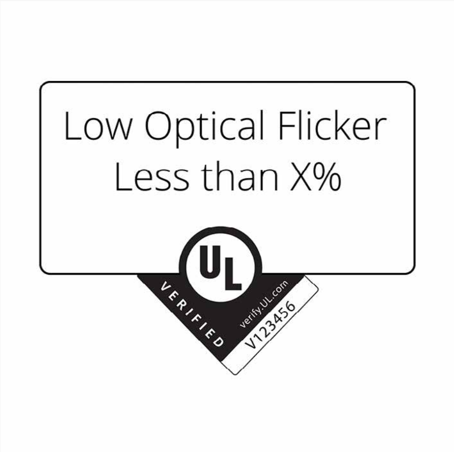
MS-4002's high thermal stability ensures it can retain high transparency even in harsh environment.

MS-4002 Moldable Silicone cures quickly to help enhance productivity, and is going to be recognized by Underwriter Laboratories' demanding UL-746C-f1 and UL-94 standards for outdoor applications.

Main Features:

- Two part material, fast curing
- Lighter than glass
- Medium viscosity for injection molding

UL Verification Service for Lighting Products: Low Optical Flicker



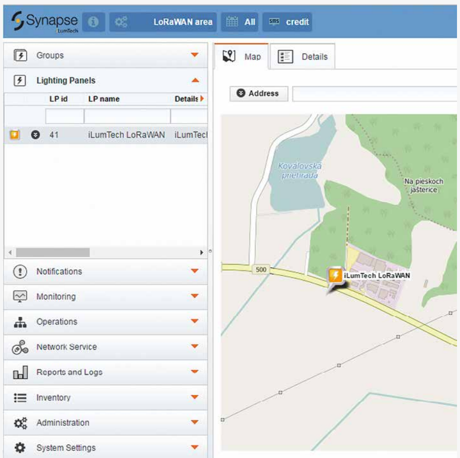
Optical Flicker is present in nearly all light sources. However, the degree to which flicker can be perceived, or is acceptable, can vary. If present at high level, and according to individual perception, optical flicker may cause discomfort among users and make a lighting installation unacceptable from a quality perspective.

Having developed an internal testing program, UL offers manufacturers the opportunity to have an independent third-party laboratory verify the validity of claims about the level of Optical Flicker in their products using a rigorous science-based assessment. Products not exceeding the identified thresholds are eligible to carry the UL Verified Low Optical Flicker Mark, allowing for easy identification and differentiation during product specification. The UL Verified Mark (see image) includes a unique identifier which allows a purchaser to review the verified marketing claim information at UL's verify.ul.com database.

"The third-party verification mark provides peace of mind and lets manufacturers whose product offers benefits, differentiate their service offerings on the shelf", said Roberto Inclinati, business development manager with UL's lighting division."

To learn more about the UL VERIFIED Mark and UL's Verification service, please visit the UL website.

Synapse – A Smart City System that Lives with You and for You



Synapse developed by iLumTech is an innovative, intelligent, and dynamic smart city control and monitoring system. It provides city administrators with comprehensive control of street illumination with additional functions: environmental and traffic sensing, security management and town management providing also data mining and recording for the whole sensor network.

To understand functionality, we can imagine a central nervous system. Synapse, similar like CNS, is composed of many neurons (nodes) that communicate with each other to ensure optimal operation. The nodes are incorporated into individual light points to harvest data about the luminaires (real-time power consumption, temperature, device status) and the environment (air quality, ambient conditions, traffic and parking, utilities consumption, waste status, etc.). City lighting as well as many other functions can be controlled based on the collected data, which is received and analysed by the Synapse software, and presented as understandable and actionable information.

Synapse is an easy-to-maintain open platform system, which allows for connection of 20,000 GPS locatable nodes within a range of up to 15 km. This smart city platform serves not just as a light management system but as well a base for city sensors, municipal wireless network, traffic monitoring, environmental monitoring and security infrastructure.

Flip Chip Opto Introduces 100 W & 200 W UV-A Flip Chip COB

Flip Chip Opto releases its first-in-class "Ares Series" UV-A spectrum flip chip COB, as part of the company's standard product line up. The Ares Series features two variations of the UV-A spectrum; 375 nm and 395 nm, with power options of 100 W and 200 W. The Ares Series is structured based on patented DBR LED Flip Chips and features a unique proprietary low temperature bonding technology which boosts lighting efficiency and decreases thermal resistance between the LED chip junction and the module's metal substrate.

The Ares Series features a 100 W and 200 W COB module that offers two unique variations of the UV illumination spectrums at peak wavelengths of 375±5 nm and 395±5 nm. The Ares 100A consumes a maximum power of 185 W for a peak of 375 nm and 167 watts for a peak of 395 nm and features a thermal resistance of 0.18°C/W. The Ares 200A consumes a maximum power of 360 W for a peak of 375 nm and 327 W for a peak of 395nm with a thermal resistance of 0.12°C/W. Both the 100 W and 200 W modules features a dimension of 42 x 42 x 3 mm with a difference on the light emitting surface of 30 mm and 32 mm, respectively.

This first-in-class single source UV LED module will open new applications and solutions to a wide spectrum of industries in medical, sterilization, disinfection, horticulture and indoor gardening, food processing, phototherapy, security, sensors, industrial curing, and many more.

Tech-Talks BREGENZ - Sebastian Huelck, Director Lighting, EBV Elektronik

Sebastian Huelck

Sebastain Huelck studied Electrical Engineering and Information Technology at the Technical University of Munich and has 14 years experience in the semiconductor industry. In his current position he is responsible for EBV's Lighting and Optoelectronics Segment, including a team of business development managers, sales engineers and marketers, selling and developing electronics, optics and thermal solutions for the general lighting, consumer, medical, automotive and industrial markets. In his previous job he was Regional Marketing Manager for Power and Lighting Solutions and Interface Products at NXP. Prior to that he was the Key Account Manager of Appliances at Everlight.

Solid State Lighting has not only changed the way that light is generated but also how areas or objects are illuminated. It has changed the whole industry and business. Sebastian Huelck, Director of Segment Lighting at EBV Elektronik GmbH & Co. KG, discussed these changes and the new requirements for modern distribution with Siegfried Luger and Dr. Guenther Sejkora. He explained the transition of distributors from pure logistic specialists to one-stop shops and full service providers, and commented on regional differences. He finished off by giving insights into the future projects of the company.

LED professional: Thank you for agreeing to talk with us about Solid-State Lighting in the field of distribution. Could you give us an idea about the changes in distribution, logistics and what EBV offers in general in regards to SSL?

Sebastian Huelck: I think that the whole story started around the year 2000 or 2001. In those days the electronics component distributors weren't involved in lighting at all. And distributors were what you might call "box shifters", so it was just basic logistics. If you look at the evolution of distribution you see that it has developed towards value added distribution. Today we do solution selling and application marketing. First of all you need to act as a one-stop shop. And it's not only the LED light sources from die to package to module to light engine, but it's also the whole eco-system that comes along with it like thermal solutions, optic solutions and electronic solutions which are ECGs (electronic control gears) and also RF controls.

LED professional: Is it only the Solid-State-Lighting sector that has changed so drastically, or is the entire business now different?

Sebastian Huelck: It's the entire business. It also refers to the whole semi-conductor world, in general, whether it is automotive, generic industrial applications or if it's healthcare or whatever market segment you look at.

LED professional: So your business nowadays not only offers components, but it also offers solutions or support to generate solutions, is that correct?

Sebastian Huelck: Indeed, it goes far beyond traditional distribution. We put together what we believe are the most suitable devices to optimize the solution in a particular application area. So if you split up the SSL business and look at it from a light or LED source, point of view, you have devices that are being used primarily for area lighting applications like troffers, panel lights and linear lamps. This is really the domain of the mid-power LEDs. If you look at the retail space, shop lighting and especially track lighting, this is a domain for COB (chip on board) devices. And then if you look at street lamps, tunnel lights, area lighting, and flood lighting, those still remain a domain of high-power emitters. We are also expecting a change there in the future, probably towards CSP (chip-scale packages). If you look at these three major segments, we need to put together the most suitable optics solutions - refractive optics, reflectors or hybrid optics or any kind of light guides. You need to sort out the right driver topology depending on the wattage and the efficiency you want to achieve. The right controls: so for example, indoors, people prefer BLE (Bluetooth Low Energy), esp. BLE 4.2 with mesh support and Zigbee Light Link and for outdoors we see a trend towards LoRaWAN (Long Range Wide Area Networks). And then there are the thermal solutions that need to be optimized as well.

LED professional: Do you select your suppliers according to your application specific solutions?

Sebastian Huelck: That is absolutely right. That's why we need a number of suppliers. We position the suppliers according to their strengths. Not everyone has a very broad portfolio. Some concentrate solely on COB technology, others have a particular strength in Mid Power, others in High Power and/or infrared products and others in UV-A and UV-C for industrial applications.

LED professional: In regards to the complete spectrum of your offer: we know that you opened a lab in Germany a while ago to measure SSL solutions where you also offer design-in support. What else is included in an offer from EBV?

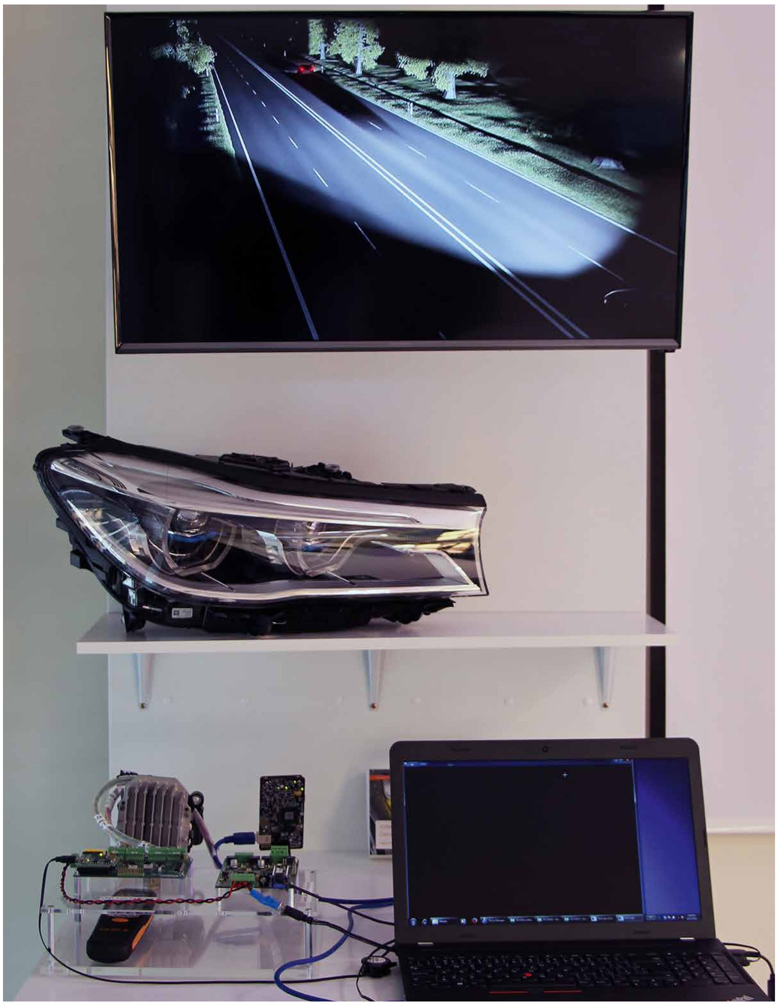
Sebastian Huelck: Services. In the end the question is always how to differentiate from our competitors and how to differentiate from low-cost offers from the Far East, for example. You mentioned the EBV Light Lab that was basically started about five years ago where we offer photometric and radiometric measurements for our customers.

In terms of thermal services we even provide CFD (computational fluid dynamics) analyses to make sure the customer is using an optimized thermal solution. We can analyze it, and based on the results we can come up with improvement proposals.

If you look at the electronics design it is often underestimated. People tend to squeeze out the last efficacy drop of an LED light source but they often don't look at the whole picture. If you lose efficiency in the LED driver part, of course the system efficiency will drop. We also do the analysis there so we come up with the right ECG (electronics control gear) solution.

LED professional: This sounds like your business is split up into a research and development part and the logistics and delivery part. How can you be sure that if somebody comes to you for the development of new lighting solutions he will come back to you to source the components?

Sebastian Huelck: First of all I need to figure out how we structure it. We have a sales organization. Parallel to that, EBV has founded. what we call the Vertical Segments. that are split up into market segments and technology segments. So we have, for example, FPGA and RF & wireless as technology segments and Automotive and Healthcare as examples of the market segments. There is also a segment we call Lightspeed, which takes care of the whole optoelectronics field besides optical fiber communication.



One very important segment for EBV is the automotive setor that is represented in their "Lightspeed Experience Center" by a LASER headlight

These segments are business development and marketing organizations. So there is the application marketing part putting together the single components to a most optimized, suitable solution and the consultancy part of it. Taking it even further, what we are currently working on is a further evolution from application marketing to application engineering.

LED professional: Can you explain what you mean by application engineering?

Sebastian Huelck: Our next project will be building up what we call the "Lightspeed Experience Center" in Munich. Our intention is to showcase future technologies that are just not here today, or which people have thought about but haven't yet realized. This will create a type of "think tank".

But going back to the question of our customers returning and buying from us: This is indeed our intention. In the end, from a pure marketing perspective, it would be a customer retention program. So usually people buy from the sources that they trust. A distributor needs to have justifications for his margins. If you look at the Asian distribution market it's just a few percent. We have higher margins and therefore customers do expect this consultancy role that we are fulfilling. And customers appreciate it.

LED professional: How do you handle the fact that you are required to have material in stock for delivery in the long run?

Sebastian Huelck: That's a very good point. The complexity and diversity has changed and increased dramatically. If you look at the good old fluorescent tube types and the according ballast, for example, you have product development cycles of roughly three to five years. Now you have a cycle of 6 months to a year. So you have a vast number of diverse products that need to be handled and the manufacturer, in general, doesn't like to keep stock because of capital lock-up. They are concentrating on production and they need to have a logistics partner that is actually taking out those parts from their warehouse. So the basic function of the distributor is the warehouse. It's all about availability. People cannot wait for weeks or months for their products. Secondly, if you look at a PCB consisting of many different parts, you can't buy directly from each manufacturer and purchasing managers like to do package deals. Thirdly, you are also playing the role of a bank. Depending on the region that you're selling to there are always different payment conditions. So, as you can imagine, in Eastern Europe or in Russia, you have different payment terms than you have in Central and Northern Europe.

LED professional: If we look at all the components delivered to the lighting industry, what percentage go through a distributor and what percentage are bought directly from the primary manufacturer?

Sebastian Huelck: It really depends on the regions you are looking at. For example, if you cluster the world into the Americas, APAC and EMEA: Japan has three major luminaire manufacturers: Sharp, Toshiba and Panasonic who share roughly 70% to 80% of the market. In the Americas, especially in the US, you have a similar situation - you have three to five major lighting manufacturers which are often served directly. In EMEA the situation is completely different. We have a very scattered, fragmented market. We have roughly 3,500 luminaire manufacturers in more than 50 countries. You can imagine that this is an ideal distribution market because you have a high mix and low volume and you have a long tail of customers that you need to address and do business with. This is something that manufacturers simply can't do.

LED professional: So the main volume in EMEA goes through distributors.

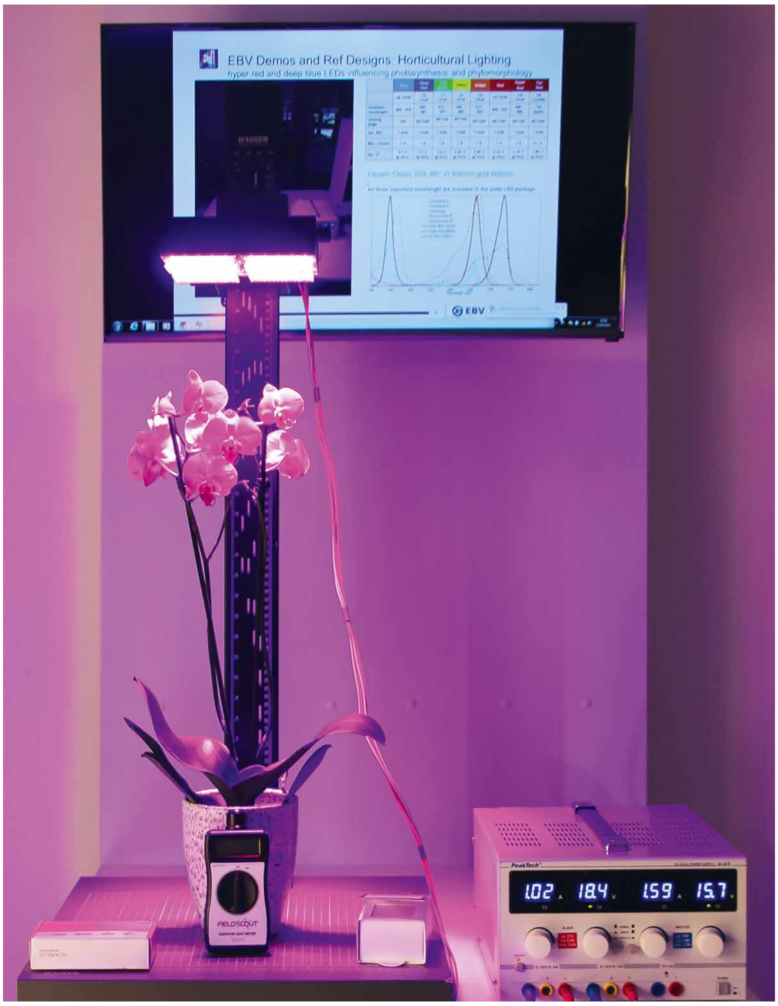
Sebastian Huelck: Yes, that's absolutely right for general lighting. But it's a different situation in the automotive world. In the automotive lighting market you have the big brands and just a few others which are served directly or where distributors only worry about fulfillment.

LED professional: And your distribution concept, including services – how are you networked on a global scale?

Sebastian Huelck: Let me put it this way: Avnet consists of Technology Solutions (TS), which addresses the computer world, including hardware and software solutions. And then you have EM, which is Electronics Marketing selling electronics components and providing engineering design-chain services. In the Americas it's all about Avnet EM which takes care of the whole area. In EMEA we have a different model that we call the "Speedboat Model". There are several companies: EBV Elektronik, Avnet Silica, Avnet Abacus, Avnet Logistics, Avnet Embedded, MSC and some others. This model combines the agility of smaller, focused companies with considerable resources of a major corporation, to serve the widely varying requirements of our customers. Our biggest LED partner is Osram Opto Semiconductors, followed by Samsung LED. With regards to LEDs we have no overlapping lines in between the speedboats in Europe.

LED professional: What do you see as the main future benefit for customers in applications? Will it be color changing, or IoT or something else?

Sebastian Huelck: That's a very important question. What added value can we provide? And one of the answers would be LiFi / VLC (Visible Light Communication).



Horticulture lighting is another application that is demonstrated in the "Lightspeed Experience Center"

The speed of WiFi is typically 100 Mbs or 1 Gbs whereas with VLC we talk about 10 Gbs or even more than that.

The modulation of choice for LEDs is amplitude modulation. It would be easy to vary the intensity of the light using ASK or OOK data formats. However multi-carrier methods like multi-tone (DMT) of orthogonal frequency division multiplexing (OFDM) boost data rates to these high bit rates of many Gbs if you use VCSEL (Vertical Cavity Surface Emitting Laser) diodes.

If you think about wireless transmission of ultra-high resolution video such as 4K or even 8K material this technology could be your choice. In addition, it has a major advantage that it causes no interference to RF-based devices. This makes wireless communication possible in RF hazardous areas such as hospitals and onboard of aircrafts. And if a person is standing underneath a dedicated luminaire source, i.e. the hotspot, you don't have to share the connection with others. You would have the full speed.

LED professional: But isn't the link unidirectional?

Sebastian Huelck: No, it's bi-directional. In general, both a receiver and a transmitter are placed at either end of the communications link, which is a transceiver. You need to ensure the two paths of data are being isolated from each other. In WDM (wavelength division multiplexing) two different wavelengths are used to isolate the paths. There is an optical filter at the receiver's end so that only the right wavelength is being received and processed. Usually the downlink is using visible light whereas the uplink is IR.

LED professional: But doesn't the luminaire need the sensor?

Sebastian Huelck is convinced that IoT based solutions are an important topic for value-added solutions. He feels that even more value could be added with a VLC implementation in the system

Sebastian Huelck: Yes, it does, and we have several solutions for that, ranging from PIR to 24 GHz radar sensors for presence detection up to ALS (ambient light sensors), all to optimize the overall power consumption.

You are heartily invited to our LightSpeed Experience Center once it's ready. We will showcase different technologies there.

LED professional: What about Human Centric Lighting? Do you see it as an additional benefit?

Sebastian Huelck: Yes, there is a lot of interest in this. We just had a global webinar together with Infineon on the subject with 500 registrants from all over the world. As you know, during the day we need to have a high cortisol level to help us concentrate and towards the evening you need to produce melatonin. That means that the cortisol level has to be reduced otherwise melatonin cannot be produced. So it is all about dynamic lighting instead of static lighting in order to mimic natural sunlight. You need micro-controller circuits because you have to control the two channels. I invited Professor Bob Karlicek from Rensselaer Polytechnic Institute in Troy, NY, Director of the Smart Lighting Engineering Research Center (ERC), to our EBV Lighting Academy in March 2016 in Frankfurt am Main. He who showcased light applications where the light system can also detect, for example, if someone is having a heart attack and collapses. It will call an emergency number automatically.

LED professional: How is that done? What is the idea behind that?

Sebastian Huelck: The principle is "time of flight": it detects or retrieves the reflections of light from an object. If someone falls down, the distance between the person and the light is increased so the time needed for the light to travel back is longer. A sensor detects this and it realizes what is happening. It's the same principle as LIDAR (Light Detection and Ranging).

LED professional: Can you comment on the Internet of Things?

Sebastian Huelck: IoT is indeed the buzzword in the industry today. I don't think we have any suppliers that aren't concentrating fully on the subject of IoT. For EBV it's the biggest marketing campaign in the history of our company because we're talking about another 50 billion nodes to be generated and connected globally during the next 5 to 7 years.

A "thing" can be anything - for example it can be a luminaire or a lamp. So often in the HABA-space (home and building automation) people are interested in connecting their light bulbs or their luminaires and controlling them via the Internet. But this could also comprise heater and ventilation controls, door locks up to controlling cleaning robots, baby monitors or even making sure that your coffee machine brews fresh coffee according to your wake-up habits.

LED professional: Can you give us an example from practice?

Sebastian Huelck: We have started a collaboration with a Romanian company, and we are about to install a new system in a French city where basically hundreds of streetlamps will be connected via LoRaWAN (Long Range Wide Area Network). You don't need a very high bandwidth because you're just sending over control data for turning the lights on and off or for dimming them, but these need to be transmitted over long distances. You also want to detect an error and then using a GPS system to locate the broken luminaire on a map. And the whole system, in that case, is connected to a cloud based system: here, the inteliLIGHT services. You log into a web-based

front-end and have control over the whole installation. This is a typical Internet of Things application.

LED professional: Can you tell us a little more about the LightSpeed Experience Center?

Sebastian Huelck: Yes, of course. We will have a HCL (Human Centric Lighting) panel light featuring MP LEDs and CCT color steering from 2700 K to 6500 K, shop lights featuring COB (chip-on-board) LEDs with new custom phosphor blends ranging from bread to meat, fresh meat and even a fish type and a street lamp with new HP multi-die arrays driven by a digital SMPS (switched mode power supply). The next street lamp version will contain future HP CSPs (chip scale packages) enabling cost-down with dedicated optics. As we are covering the whole field of optoelectronics you can also see future automotive front lights such as laser lights and laser beam scanning front lights featuring TI DLP (TI Digital Light Processing) and a 2D LIDAR (Light Detection And Ranging) scanner. In the scope of our “EBVchips” program we are defining our own semiconductor solutions, which we are developing with and for our customers. These are new product creations and fill gaps where there was no solution before. They don’t necessarily need to be chips but could also be modules.

We, for example, work on new high-irradiance UV-A-LED-modules for the printing industry and innovative UV-C-LED reactors and purification arrays. Among biometrics identification palm vein scanning belongs to the most secure methods where we have realized a functional model.

LED professional: Where will the LightSpeed Experience Center be located?

Sebastian Huelck: It will be at our headquarters in Poing opposite to the EBV Light Lab. The Light Lab was well-accepted by our customers from the very beginning, however, most mid-sized luminaire manufacturers have their own measurement equipment available these days, so that we wanted to come up with something modern and compelling - able to captivate our customers again.

LED professional: One last thing from our side. I’d like to bring up the topic of insurance. You deliver all kinds of different components in a solution so how to you ensure that the quality of the products are the same as what is required and what happens in the case of failures?

Sebastian Huelck: We follow the legal directives. So basic legal structure is from B2B (Business to Business) and there is a one year warranty. In lighting ECG customers usually want a 5-year warranty and we provide this. In some cases we provide up to 7 years for ECGs. Usually the claims are handed over to the component or device supplier.

LED professional: EBV will take part in the LpS 2016 in Bregenz again this year. Could you tell us what your expectations are?

Sebastian Huelck: I have personally attended the LpS from the very beginning. Our EBV booth wasn’t the best looking in early days but since last year we have been jointly exhibiting together with Osram Opto Semiconductors. I believe it will be one of the biggest booths at your show and from my point of view, among the most exciting ones. I’m really looking forward to coming to Bregenz in September with some new, fancy stuff again! We will bring along exhibits from our LightSpeed Experience Center and come up with two especially thrilling highlights providing an outlook on the future.

LED professional: Can you tell us any of the highlights you will be presenting?

Sebastian Huelck: “Pepper”, a humanoid robot able to recognize human mimic, gestures and hence emotions and adapting his behavior to the mood of his interlocutor, will entertain our guests and guide them through our booth. You can call presentations to each exhibit on Pepper’s tablet located on its chest. Next to three high-definition cameras and obstacle sensors, Pepper is also equipped with six LIDAR sensors that we want to highlight there.

We will also show a brand-new Audi R8 V10 featuring Osram OS and Osram GmbH laser front light technology. You can virtually walk through the Sistine Chapel as we are providing Virtual Reality headsets during the show. In addition to that, we will showcase a street lamp featuring the new Duris P10 device - a four die power package delivering more than 1200 lumens with an unprecedented thermal resistance.

LED professional: You will also have a lecture this year about logistics and market technology views so we are very excited about that.

Sebastian Huelck: Thank you. I’d also really like to talk about our new LightSpeed Experience Center so people get a glance of the future.

LED professional: Thank you very much for the interview. ■

Sky Luminance and Radiance Distribution Patterns: Empirical Assessment and Computational Models

Controls systems for lighting installations are becoming more and more sophisticated. To make use of the the capabilities of SSL technology to save energy while maintaining adequate light, increased system intelligence is a key issue when it comes to combining daylight with artificial light. Correct interpretation of sky dome luminance distribution pattern is critical. Univ. Prof. Dipl.-Ing. Dr. Ardeshir Mahdavi, Ehsan Vazifeh and Matthias Schuss from the TU Vienna focus on the evaluation of various sky models based on a large repository of high resolution measurements.

Intelligent control systems in architectural lighting require an integrated treatment of daylight and artificial light. Toward this end, high-resolution representations of the sky dome luminance distribution pattern are critical. Specifically, predictive control approaches require that sky conditions are accurately captured. Consequently, multiple efforts have been made in the past to estimate the intensity of luminance and radiance emanating from specific patches of the sky hemisphere. The findings of the evaluation of the various sky models suggest that existing models must be substantially improved.

Introduction

Background

Deployment of performance simulation in building design and control phase can enhance the buildings' performance in their life cycle. This requires reliable input data for simulation models. Specifically, obtaining high-resolution solar radiation data can represent a challenge. Several authors have proposed models to predict the distribution of radiance and luminance over the sky hemisphere based on global and diffuse horizontal irradiance and illuminance data [1-14]. Among these models, CIE [9 & 10] and Perez [3] are widely used and are embedded in the RADIANCE simulation application [15]. In this context, the present paper entails two studies. One study reports on the comparison of predicted vertical illuminance values (obtained using the above mentioned sky models) with corresponding measurements for the location Vienna, Austria. Moreover, predicted and measured sky luminance values were compared for 145 distinct sky patches representing the sky dome. The second study compares simulated vertical irradiance values generated by the RADIANCE software using two embedded sky models (GENDAYLIT [16], GENSKY [17]) with corresponding measurements. GENDAYLIT is based on Perez et al. sky model [3], whereas GENKSY is mainly derived based on CIE [2, 9, 10].

Data Collection

Department of "Building Physics and Building Ecology" at TU Wien is equipped with an advanced microclimatic monitoring station. This station is located at the rooftop of the main building of the university, which is situated in the Vienna city center. It houses radiometric and photometric sensors that measure global and diffuse horizontal irradiance and illuminance, global vertical irradiance and illuminance for four cardinal orientations, as well as sky radiance and luminance values

for discrete sky patches. To assess the performance of the models in capturing the sky luminance/radiance distribution, we used the measured illuminance/irradiance data incident on the aforementioned four vertical surfaces. We also collected patch luminance/radiance data using a sky scanner [18]. The measured horizontal global irradiance/illuminance data was used as input for Perez et al. and CIE models to generate the sky luminance distributions and to generate two RADIANCE embedded sky models. In the present contribution, we use 15-minutes interval data collected in the period between April and the end of the year 2014.

Models

The first study

Combining physical principles and a large set of experimental data, Perez et al. [3] introduced a model to predict the relative sky luminance for discrete sky patches (L_r). The model contains two variables and five coefficients (see the following equation). The variables are the zenith angle of the considered sky point and the angular distance between the sky point and the sun disk. The coefficients resulted from least square fitting of the data and can be obtained from a table.

Equation of the model:

$$L_r = [1+ae^{\frac{b}{\cos(Z)}}]\cdot[1+ce^{d\xi}+e\cos^2(\xi)]$$

Here, L_r is relative luminance, which is the ratio of sky luminance over zenith luminance (L_z), ξ is the angular distance between the sky element and the sun disk, Z is the zenith angle of considered sky element, and a, b, c, d, and e are the mentioned coefficients. In order to select the values of the five coefficients from the table, two variables, sky brightness (Δ) and sky clearness (ε) must be calculated.

Sky brightness (Δ) and sky clearness equations:

$$\varepsilon = \frac{\left[\frac{I_{h.dif}+I_{n.dir}}{I_{h.dif}} + 1{,}041 \cdot Z_S^3\right]}{1 + 1{,}041 \cdot Z_S^3}$$

$$\Delta = \frac{m_{air} \cdot I_{h.dif}}{I_{n.ext}}$$

Here, $I_{h.dif}$ (f is the horizontal diffuse irradiance, $I_{n.dir}$ the normal direct irradiance, Z_s the solar zenith angle, mair the optical air mass, and In.ext the extraterrestrial normal irradiance. In.dir is generated using a diffuse fraction model [19]. Zenith luminance (L_z) was calculated according to Perez et al. [20].

CIE (International Commission on Illumination) distinguishes 15 sky types [13]. For each sky type, CIE offers a specific formula to calculate the Luminance values. To deploy this version of the CIE model, we calculated 15 types of sky luminance distributions for each instance and chose the one with the least deviation (lowest RMSE) from the measurements.

The following equation expresses the ratio of the patch luminance L_i to zenith luminance L_z:

$$\frac{L_i}{L_Z} = \frac{f(X)\phi(Z)}{f(Z_S)\phi(0°)}$$

Calculation of X:

$$X = \arccos^{-1}(\cos(Z_S) + \sin(Z_S)\sin(Z)\cos(A_Z))$$

Here, Az is the azimuth angle difference between sun disk and patch element.

To calculate zenith luminance (L_z) for the CIE model, we used the formula suggested by Darula and Kittler [21].

None of the models estimates the sun disk luminance. In fact, they compute the diffuse luminance distribution. In order to estimate the sun disk luminance value for each instance, measured direct normal illuminance data was converted to sun disk luminance.

Measured illuminance data to sun disk luminance conversion:

$$L_{sun} = \frac{E_n}{\pi(\sin^2(\eta/2))}$$

Here, L_{sun} is the sun disk luminance, E_n is the direct normal illuminance, and η is the sun disk angle (assumed 0.533°).

After adding the sun disk luminance, all patch values were normalized to the corresponding measured value of the horizontal global illuminance:

$$L_i^{norm} = \frac{E_{h.g}}{\sum_{i=1}^{145}[\Omega_i \cos(Z_i)]} \cdot L_i$$

Here, L_{inorm} is the normalized patch luminance and $E_{h.g}$ is the horizontal global illuminance.

The second study

GENDAYLIT generates a RADIANCE scene description based on the Perez et al. [3] sky distribution model for the given atmospheric inputs (direct and diffuse component of the solar radiation), date, and local standard time. The default output is the radiance of the sun (direct) and the sky distribution (diffuse) integrated over the visible spectrum [16].

GENSKY generates a RADIANCE scene description based on CIE sky distribution model [17]. With regard to GENSKY, it is important to consider that four types of sky conditions are distinguished, namely: sunny, cloudy, uniform, and intermediate. Each sky category must be defined by the user as input for RADIANCE GENSKY program. To deploy the implemented GENSKY model in RADIANCE, we made use of the option to assign specific values to the tool's pertinent parameter in accordance with the

relevant sky category. Toward this end, we considered the following categories: clear (sunny in terms of GENSKY), overcast (cloudy in terms of GENSKY), and intermediate (intermediate in terms of GENSKY). In order to map our weather station data into these four categories, we used a simple assignment rule based on the magnitude of the direct normal and diffuse horizontal irradiance components (Table 1). The output of both GENDAYLIT and GENSKY sky models in RADIANCE consists of sky patch radiance values in $W \cdot sr^{-1} \cdot m^{-2}$.

Table 1:
"GENSKY categorization in the present study"

In.dir	Kt	Kd	Category
≥200	-	<1/3	Clear sky
<200	<1/3	≥1/3	Overcast sky
else			Intermediate sky

Comparison

The first study

We implemented both models in MATLAB [22]. For comparison purposes, vertical illuminance values were derived from patch luminance values of the two sky models:

$$\Psi_i = \Omega_i \cos(\Phi_i) \cos(\Phi_i - \beta)$$

$$E_{ver,\beta} = \sum_{i=1}^{145} L_i \psi_i$$

Here, ψi is ith patch vertical transformation function, Ωi is ith patch solid angle, ϕ_i is the i^{th} patch azimuth angle, β, is the vertical plane normal angle, L_i is i^{th} patch luminance values and $E_{ver,\beta}$ is vertical illuminance value in the direction of β.

Model-based predictions of vertical illuminance values were compared with corresponding measured vertical illuminance for the aforementioned 8 month period. Moreover, to evaluate the accuracy of the sky luminance distribution predicted by the two models, we also utilized the sky scanner luminance measurements for 145 discrete sky patches. Thus, a patch-to-patch comparison of calculated and measured luminance values could be facilitated for data obtained for the same period.

The evaluation statistics deployed included root mean square error (RMSE), coefficient of determination (R2), relative error (RE), coefficient of variation of RMSE (CVRMSE), and mean bias error (MBE).

The second study

Simulation results (vertical irradiance values) using the GENDAYLIT and GENSKY models were compared with corresponding measurement results. Moreover, to evaluate the accuracy of the sky radiance distribution predicted by the two models, sky scanner measurements for 145 sky patches were used. Again, the evaluation statistics deployed included root mean square error (RMSE), coefficient of determination (R2), relative error (RE), coefficient of variation of RMSE (CVRMSE), and mean bias error (MBE).

Results

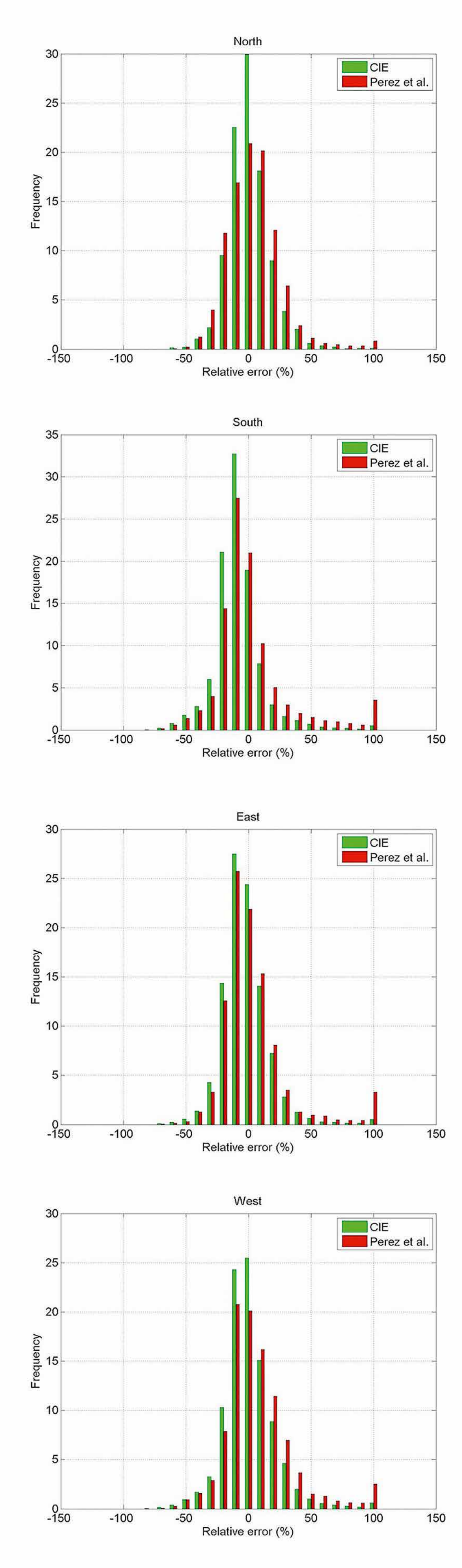
The first study

Table 2 provides an overview of the main results. Thereby, measured and predicted vertical illuminance and patch luminance values were compared. Note that the RMSE and MBE values for vertical illuminance values are given in units of klx, whereas those for patch luminance values are given in $kcd \cdot m^{-2}$. The distributions of the relative errors of the illuminance predictions for the four surface orientations are depicted in figure 1. Figure 2 shows, for both sky models, the cumulative distribution function of percentage of results with relative errors (%) of calculated vertical illuminance values. Likewise, figure 3 illustrates relative errors in calculation of patch luminance values in terms of cumulative distribution functions.

To evaluate the performance of data we can look at the percentages of results with relative errors less than 20% (Figure 2). This yields for the best performing model (CIE) 82% (North), 80% (East), 74% (South), and 75% (West) and for Perez et al. 72% (North), 77% (East), 71% (South), and 70% (West). Patch comparison similarly suggests a rather modest performance level (CIE: 51%; Perez et al.: 46%). The slightly better performance of the CIE model may be due to the fact that in this case, for each instance we used the best possible sky category as mentioned in the introduction.

Table 2:
Statistical evaluation of CIE and Perez models based on vertical illuminance predictions

Orientation	Model	R2	RMSE	CV_RMSE	MBE
Illuminance North	CIE	0.90	2.05	18.41	-0.05
	Perez	0.87	2.34	21.00	-0.13
Illuminance East	CIE	0.97	6.29	23.66	-1.56
	Perez	0.97	6.55	24.64	-0.60
Illuminance South	CIE	0.95	8.77	25.52	-3.56
	Perez	0.94	8.94	26.00	-1.76
Illuminance West	CIE	0.96	7.20	26.40	-1.11
	Perez	0.95	7.64	28.03	0.08
Patch luminance	CIE	0.88	3.54	43.13	-0.05
	Perez	0.82	4.32	52.65	0.32



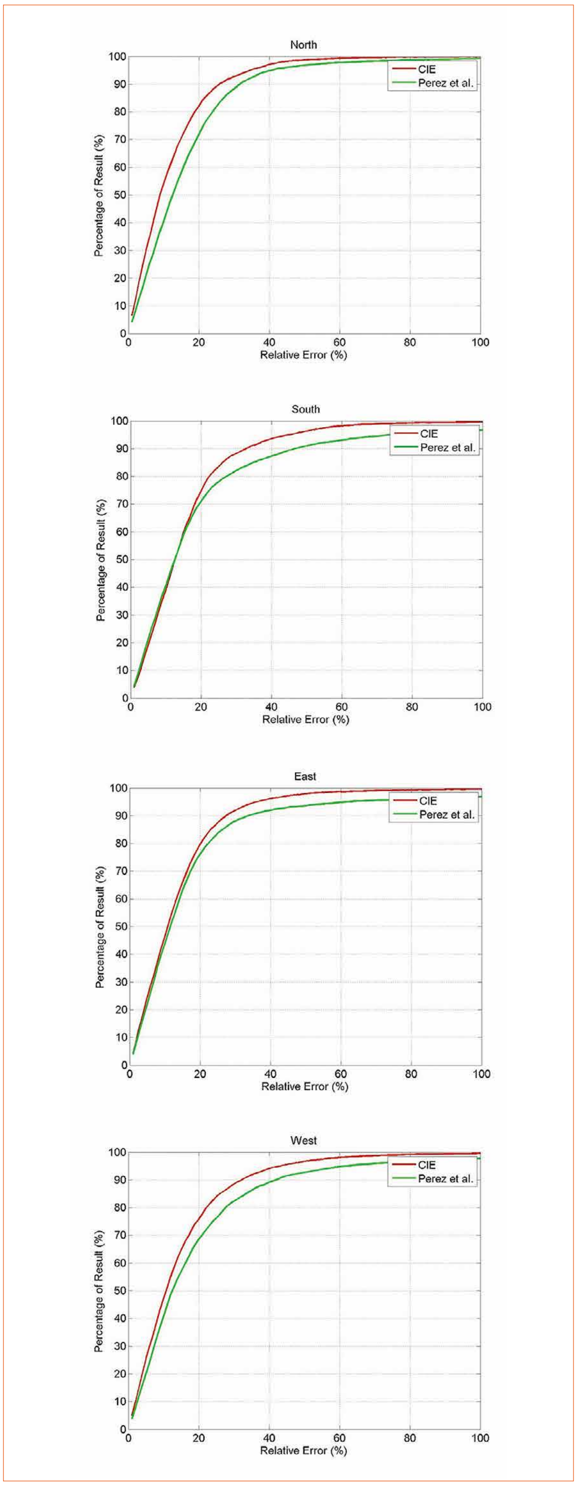


Figure 1 (left):
Comparison of the CIE and Perez sky models in terms of relative error distributions of predicted vertical illuminance values (Relative errors over 100% are merged into the 100% error bin)

Figures 2 (right):
Comparison of CIE and Perez et al. sky models' relative errors (%) for vertical surfaces facing the four cardinal directions in terms of cumulative distribution functions

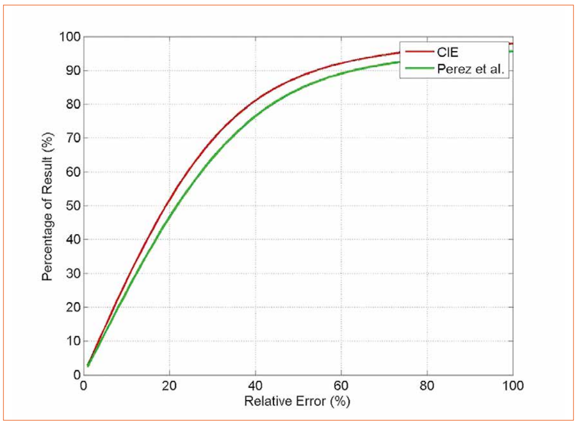


Figure 3:
Cumulative distribution functions of the relative errors (%) of the two models' patch luminance predictions with respect to sky scanner data

The second study

Table 3 provides a comparison of the measured and predicted vertical irradiance and patch radiance values. Note that RMSE and MBE values for vertical irradiance are given in units of W·m^{-2} whereas, those for radiance are given in W·m^{-2}·sr^{1}. The distributions of the relative errors of the irradiance predictions for the four surface orientations are depicted in Figure 4. Figure 5 shows a comparison of measured patch radiances with the respective predictions of the two sky models. Figure 6 shows the cumulative distribution function of the relative errors of the calculated vertical irradiance for both sky models. Figure 7 shows the cumulative distribution function of the relative errors of the patch radiance values for both models.

Table 3: Statistical evaluation of vertical irradiance (incident on surfaces facing four cardinal directions) and sky patch radiance as predicted via Perez et al. and CIE models

Orientation	Model	R2	RMSE	CV_RMSE	MBE
Irradiance North	GENDAYLIT	0.74	27.0	27.4	-1.49
	GENSKY	0.69	28.8	29.0	-3.00
Irradiance East	GENDAYLIT	0.97	64.8	22.5	8.11
	GENSKY	0.95	73.5	25.4	13.91
Irradiance South	GENDAYLIT	0.97	44.4	17.0	-0.69
	GENSKY	0.96	46.6	17.8	-2.97
Irradiance West	GENDAYLIT	0.96	64.9	22.8	2.53
	GENSKY	0.96	68.6	23.5	7.57
Patch radiance	GENDAYLIT	0.86	37.6	49.4	-1.13
	GENSKY	0.85	38.5	50.5	0.89

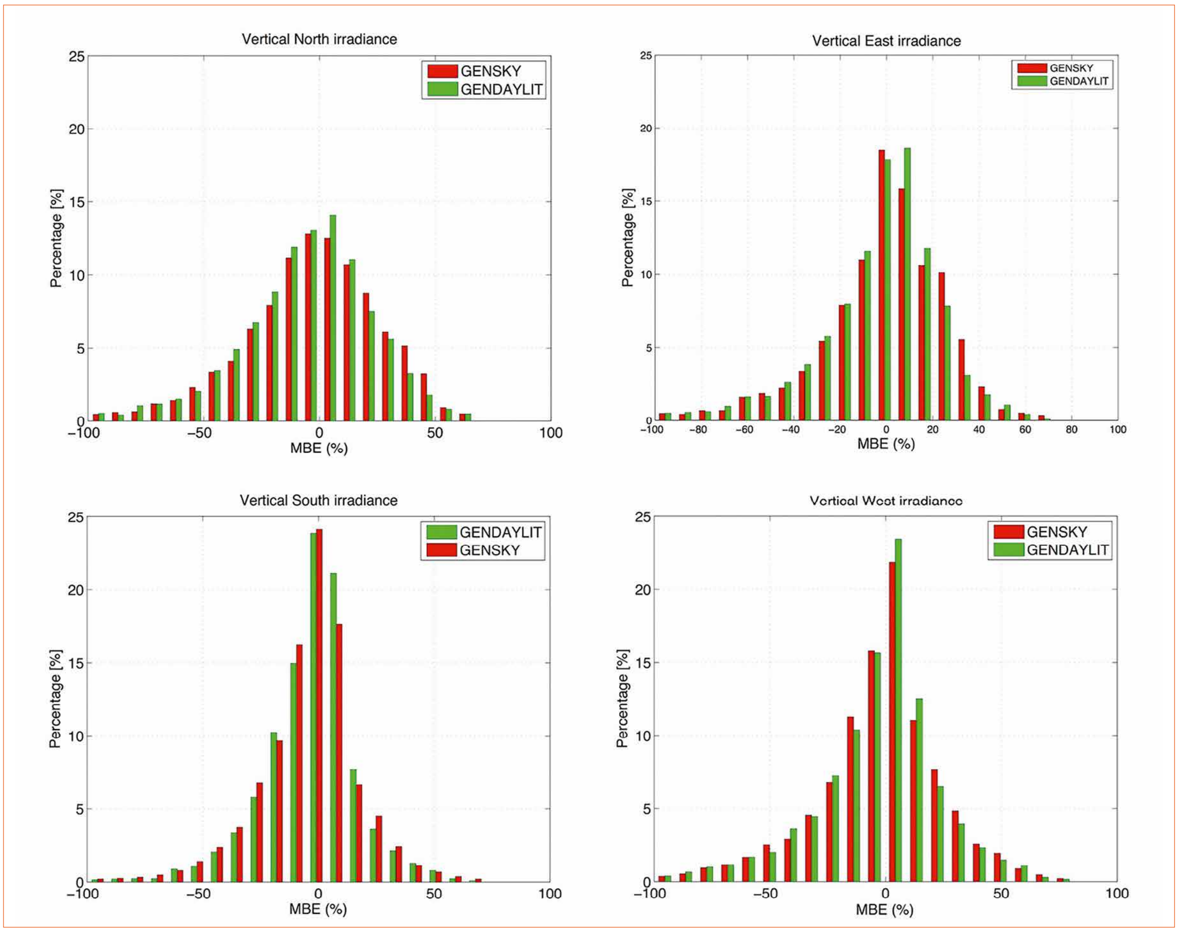


Figure 4 (right): Comparison of the GENSKY and GENDAYLIT sky models in terms of distributions of the relative errors of predicted vertical irradiance values

Conclusion

The first study

Illuminance on four vertical surfaces as well as luminance values of 145 sky patches were estimated using two sky models (Perez et al., CIE). The comparison of the computational results with corresponding high-resolution measurements conducted in Vienna points to a rather limited predictive potency. Hence, these sky models would have to be substantially improved – or at least calibrated – to reproduce the measured data with sufficient accuracy. Future research will pursue a collaborative multi-location model comparison using larger data sets and more detailed statistical analyses.

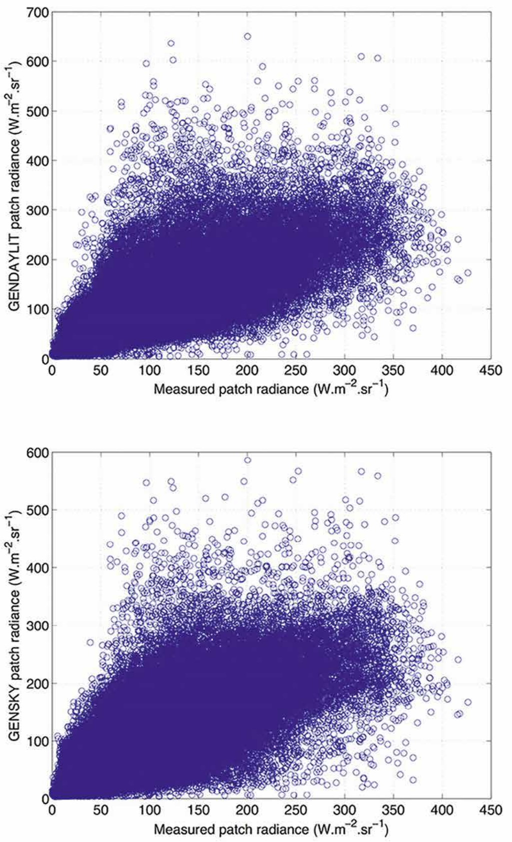


Figure 5 (left): Comparison of measured and computed patch radiance values (Top: GENDAYLIT; Bottom: GENSKY)

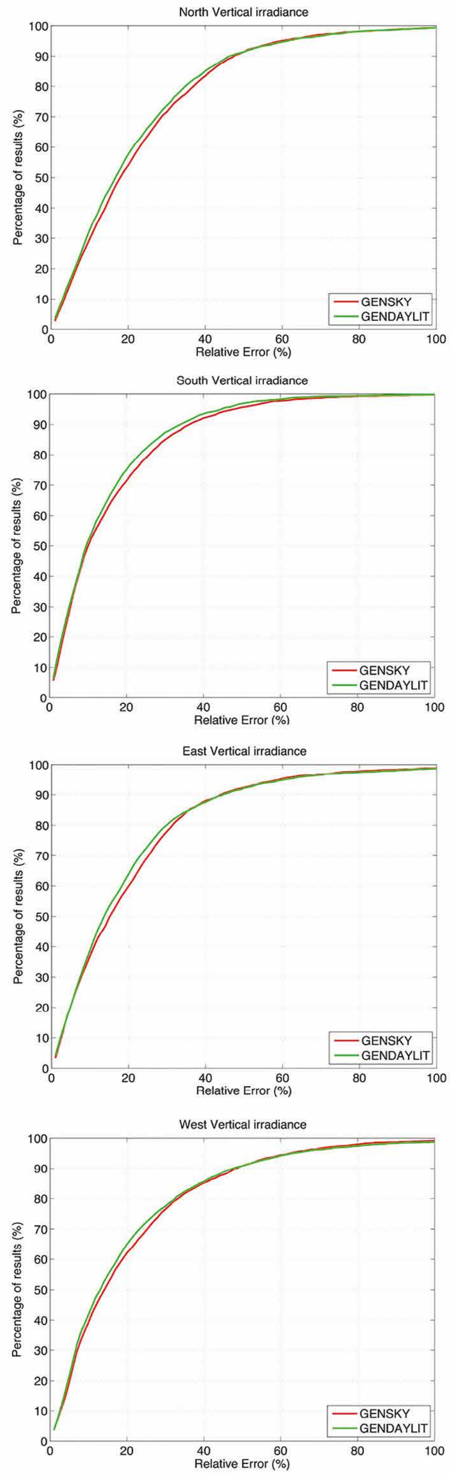


Figure 6 (right): Comparison of GENSKY and GENDAYLIT sky models' relative errors (%) for vertical surfaces facing the four cardinal directions in terms of cumulative distribution functions

The second study

Irradiance on four vertical surfaces as well as radiance values of 145 sky patches were estimated using two sky models (GENDAYLIT, GENSKY) embedded in the RADIANCE application. While the GENDAYLIT appears to perform slightly better, the comparison of the computational results with corresponding measurements conducted in Vienna points to a rather limited predictive potency of both models studied. In the case of a patch-to-patch comparison of measured and computed radiance values, large errors must be perhaps expected, given the chaotic nature of cloud distribution and corresponding radiance variance across the sky dome. In our study, only about 42% of patch radiance predictions display a relative error less than 20%. But the errors are quite large even in case of vertical irradiance calculations. For instance, the slightly better performing GENDAYLIT model yields the following percentages of results with relative errors less than 20%: 60% (North), 65% (East), 73% (South), and 64% (West). Hence these sky models would have to be improved – or calibrated – to more reliably reproduce the measured data. ■

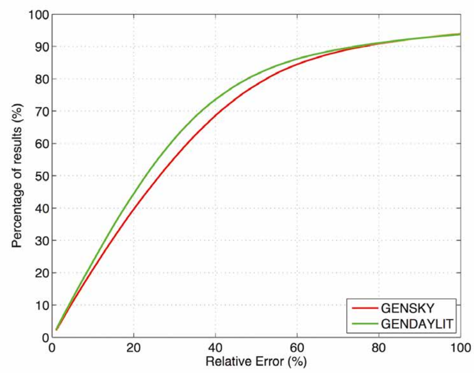


Figure 7: Comparison of patch radiance values of two models with sky scanner data using cumulative distribution of percentage of the results for different relative errors (%)

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How to Design with LEDs: Concurrent Engineering Yields Fully Optimized Lighting Systems

LEDs are often viewed as a replacement for other light sources. The right starting point for designing an appropriate replacement is crucial to the result. Brian S. Jasenak, Optical and Process Engineer at Kopp Glass, describes a concurrent engineering approach that optimizes the optics and other system components, and may help to reduce the number of LEDs needed as well as the overall cost of the LED lighting fixture.

LEDs are often viewed as a replacement for other light sources. As a result, the approach that many optical design engineers take when redesigning incandescent fixtures asks "What LED will replace the incandescent we were previously using?" However, the question that they should ask is "What light output am I trying to achieve?"

By beginning with the end in mind, engineers can evaluate all aspects of a lighting system that influence the LEDs and vice versa. The ultimate performance of an LED fixture is determined by different components of the lighting system, including the LED and electrical components, optical lens design, lens material, LED array design, and the thermal management design.

Light output is directly related to optical design, and because optics can increase the efficiency of the system, and even reduce the number of LEDs needed, their influence should be considered early in the design process.

If one uses optical design as the starting point and then move forward to the other components, the lighting system can be fully optimized, from both a performance and cost perspective. However, the process is not perfectly sequential; because the components of a lighting system are interrelated, it's important to continuously assess the design choices and modify a design accordingly.

Optical Lens Design

The first step in developing an LED system should be to evaluate the need for an optical lens; this can be done by examining the light output requirements of the system. Depending on the beam distribution, angles, and intensity required, an optical engineer can determine what type of optic is necessary. During this step, it is beneficial to engage the optic designer and manufacturer.

Often, the optical lens designer and manufacturer are separate parties, which can make it difficult to achieve a fully optimized design. The optical lens designer may create an optimized optical design that would produce ideal light distribution, but it is not well-suited for manufacturing. As a result, the optic could be more costly or even impossible to produce without design modifications. To produce an optic that is optimized for both manufacturing and light output, it is important for all parties to work closely together to reduce development time, prevent costly redesigns, and increase manufacturing yields.

Table 1:
Explanation of the most important optical material properties that need to be considered in a design process

Important Material Properties to Consider	
Refractive Index	The index of refraction determines how much light is reflected and transmitted at an interface, and also the angle at which it's refracted. It is used in ray tracing programs to determine the light path and output.
Absorption, Transmission, and Reflection	Absorption is the reduction of light as it travels through a material. Conversely, transmission is the amount of light that makes it through. Reflection for transparent materials usually occurs at the surface and is a function of wavelength and index of refraction.
Chromaticity	The perceived color of a material is determined by the output of the light source, the transmission of the material, and the human eye response. This is commonly described by a three-coordinate chromaticity value; many applications specify a narrow range for color requirements.
Hardness	Hardness is the ability of a material to resist being scratched, fractured, or permanently deformed by the sharp edges of another material. If the hardness of a material is known, one gets a sense of its resistance to abrasion.
Impact Resistance	Impact resistance measures the ability of a material to resist being fractured and to retain surface quality after being hit. This value is improved with higher values of strength, hardness, and toughness.
Chemical Resistance	Liquids such as hydrofluoric acid, jet fuel, and salt water can etch at the surface of a transparent material. If a lens is exposed to these and other chemicals, one needs to choose a material with high chemical resistance to maintain transmission.

Optical lens material

There are many transparent materials out there to consider when designing a lens for a lighting application. On the surface, they may look similar. However, not all transparent materials perform the same. They have unique properties that dictate how they control light; below is a table that reviews important properties to consider when evaluating optical lens materials (Table 1).

The design of the optic can also change the light output; for example, if the optic is too thick, it may change the color of the emitted light or decrease its intensity. In applications with specific color requirements, such as transportation signaling or airfield lighting, this could cause the light to shift out of specification.

When it comes to transparent materials, there is no one-size-fits-all solution. Every lighting system has its set of requirements and an operating environment that will influence the selection. It is important to understand the temperature range, light output, and durability requirements for the optical lens.

LEDs are still relatively expensive, and they contribute most of the cost of LED systems. Optimization of the optic and other system components can reduce the number of LEDs needed, allows using less powerful LEDs, or even using fewer LEDs in an array design. As a result, more affordable LED systems can be created. The following sections will demonstrate how optics can impact other components in the lighting system and improve the overall performance of the entire system.

LED Selection

The light color and intensity when using an optic is determined by both the spectral distribution of the light source and the optical properties of the lens material, as discussed in the table above. If one just thinks, "What LED will replace my incandescent bulb?" then one might fail to remember that the two

FACT BOX: COMMON MISTAKES MADE WHEN SELECTING AN LED

LEDs are still relatively new to many lighting engineers and there are two common mistakes that often occur when choosing an LED:

- <u>Using excessively powerful LEDs:</u>
  It is important not to select an LED that is excessive for the application. If the LED is too powerful, the cost of thermal management will increase, and if the LED is not correctly thermally managed, then the life of the LED will significantly degrade.

- <u>Selecting difficult to replace LEDs:</u>
  One of the many challenges that LED users face is product obsolescence. New LED products are rapidly being developed, and existing models can become difficult to obtain. Remember, LED replacements will be needed years from the initial installation so one should select an LED that can be readily purchased. When evaluating LEDs, select one that may have a longer product lifespan or consider buying replacements for the future. This is especially important if the product requires re-certification or testing if a new LED is used in the future.

light sources have different spectral power distributions. On top of that, every LED has a unique spectral power distribution. Selecting the best LED for the application should be an iterative process as the optic's material and design can change the light output.

At the beginning of an LED light fixture design, it is important to select an LED that best meets the application's requirements. After creating the initial optic design, the LED selection should be revisited. Once it is known which results can be achieved with an optic, the LED that will perform best in the application can be determined.

When the light source's spectral power distribution is known, the optical design can be modified to achieve the desired chromaticity and photometric results. If the material is not optimized to the LED, slight changes in color could require to select another LED entirely or to change the LED bin. The optic manufacturer and designer can help determine any color shifts due to the optic and ensure to make the best LED color choice.

LED Array Design

There are three components to an array design that should be considered simultaneously: spacing of LEDs, the number of LEDs, and their direction. The optic has a significant influence on these three aspects of LED array design.

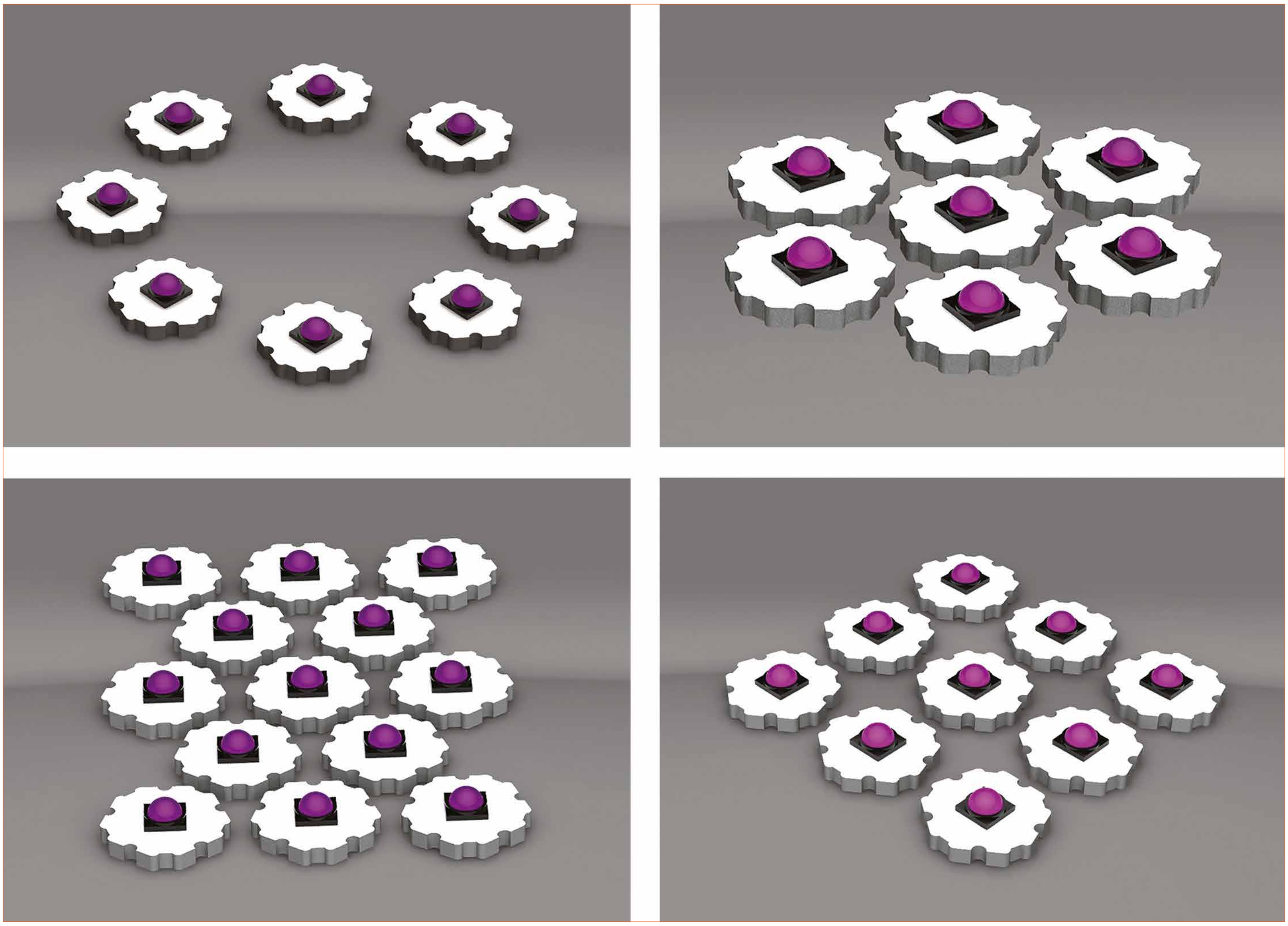
Spacing

LED spacing determines the efficiency and cost of the system, as well as the quality of the light emitted from the array. Simply, if LEDs are spaced too closely to one another in an array, one will have excess light. To correct this, the space between the LEDs could be increased and the number of LEDs reduced. The use of an optic ensures that one will still meet the light output requirements, but with fewer LEDs. This combination reduces the number of costly LEDs needed as well as improves the overall efficiency of the system.

In contrast, if LEDs are spaced too far apart, there could be quality concerns due to inconsistent light distribution patterns. Again, an optic can be used to improve the uniformity of the light distribution pattern while still limiting the number of LEDs used.

LEDs provide ample design flexibility; so consider all array possibilities. Depending on the desired output distribution, the LED array can be positioned in an infinite number of ways (Figure 1): circular, rectangular, offset rectangle, honeycomb, etc.

Figures 1: Some examples of how LED arrays can be arranged so they provide very different system properties



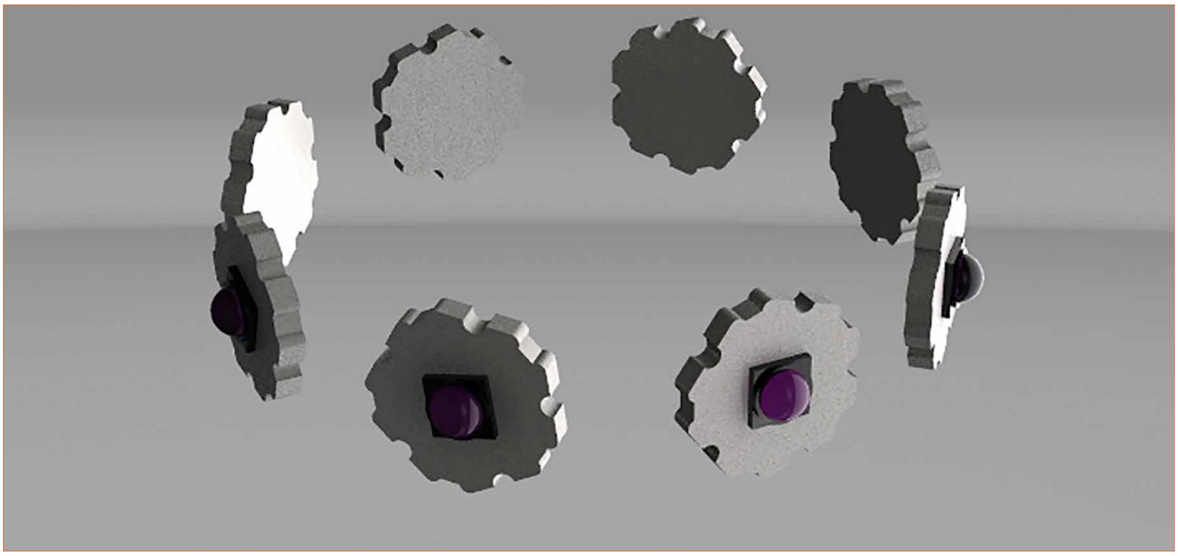


Figure 2:
A three dimensional arrangement of the LEDs is also possible and leads to omnidirectional light distribution

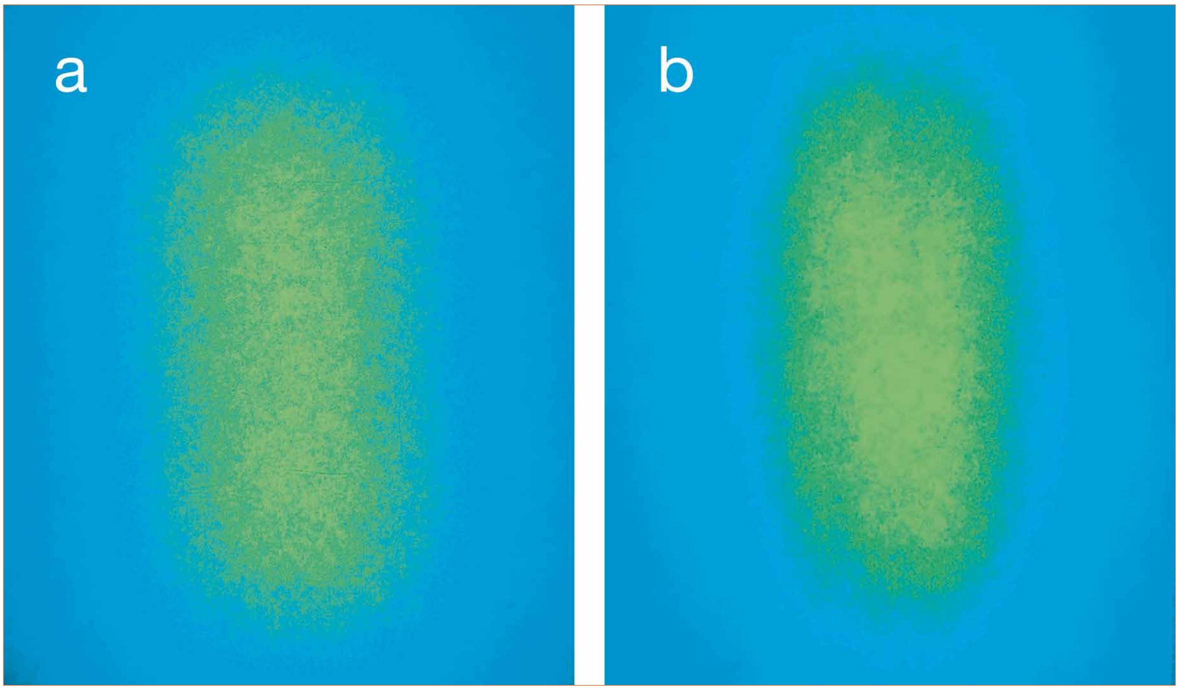


Figure 3:
Pictured on the left (a) is an irradiance pattern produced without an optic. On the right (b), the irradiance pattern that is produced when an optic is added to the same array. The optic increased irradiance by 20%. This increase enables numerous benefits to the LED system, including reduced power consumption and lower thermal management requirements, and potentially longer LED lifetimes

Number

It shouldn't be a surprise to learn that the number of LEDs also works side-by-side with LED spacing. The increased power output that an optic provides can increase the efficiency of the system and allows decreasing the number of LEDs in an array. Optimization of the number of LEDs and their spacing will produce an array that maximizes space and efficiency. The number of LEDs also dictates the level of thermal management that is required. Selecting fewer LEDs or a lower drive current can increase the useful life of the LED system [1, 2], which is discussed in the section on thermal management.

Direction

Since LEDs are directional light sources, they need to be positioned so that the light exits in the desired direction. The simplest arrays are positioned on a flat surface with all LEDs directed in the same orientation. However, some arrays can take advantage of the unique flexibility that individual LEDs provide. For example, an omnidirectional fixture that positions LEDs in a ring (Figure 2) pointing away from the center rather than using an upward facing array would reduce the need for a reflector to direct the light outward.

There are many array design options; some are more practical and affordable than others. optics play a big role in determining what is most feasible with the lowest manufacturing cost. When designing a new LED light, it is important to consider how an optic works with an array and how it can help to achieve the best performance.

Thermal Management: Use Optics to Improve Efficiency

Unlike conventional light sources, visible LEDs do not produce infrared radiation. The semiconductor processes that generate light in an LED are not 100% efficient, and they do produce some heat in addition to light. If the internal quantum efficiency of an LED is 30%, then that means 70% of the input power is lost as heat.

So where does that heat go?
Heat sinks, heat pipes, vapor chambers, and other heat-spreading devices are commonly used to provide a path for the heat to escape through the backside of the LED. These thermal management controls come in many different materials, shapes, and sizes and are a crucial component in dissipating excess heat.

Research has demonstrated that the primary cause of light output degradation is heat generated at the pn-junction [3, 4]. Unlike conventional light sources - which fail catastrophically - the light output from LEDs degrades over time. To increase the useful life of an LED, it is mandatory to use efficient thermal management systems and consider the design of the system as a whole.

LEDs are rated for specific drive currents; however, it is easy to drive them either higher or lower than what is recommended by the manufacturer. Overdriving the LED to increase the light output increases the junction temperature of the LED. As a result, the LED will degrade more quickly.

An alternative is to identify the target light output, and then determine how an optic can optimize the LED array. As discussed above, optics can be used to harness and target an LED's light output. This could allow decreasing the forward current to the LEDs, which would result in a reduction of heat at the pn-junction. One could also consider using an array design that allows reducing the number of LEDs in the light fixture. The addition of an optic allows maintaining the desired light intensity with fewer LEDs, and therefore, less heat that needs to be managed.

Conclusion: Start with the Optic for Fully Optimized LED Lighting Systems

Optical components are just one part of the LED lighting system, but they can have a powerful influence on the other components in the system. They can be used to create fully optimized LED lighting fixtures that are more efficient with longer useful lifetimes. This is why developing the optical component early in the design process is a necessity. Collaboration with the optical lens manufacturer not only reduces product development costs and time but ensures that one produces an efficient light fixture both for manufacturing and application purposes. ■

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Easing Lighting System Design with Online Tools

The technical intricacies of an LED lighting system design can be quite complicated. The interdependencies of design parameters such as light source flux, efficacy, lumen maintenance, drive current, series/parallel light source layout, compatible optics, compatible drivers, thermal dissipation and others make the calculation of system performance a laborious process if performed manually. One simple change in one parameter could potentially force the lighting designer to consult the datasheet for every other component considered in the design in order to calculate the impact on the system as a whole. Patrick Durand, Worldwide Technical Director, Future Lighting Solutions demonstrates the capabilities of modern online tools to solve these problems giving a typical application example based on the Future Lighting System Creator (LSC).

The lighting components market is not static or mature. In fact, solid state lighting technology continues to develop at a phenomenal rate, and thousands of new LEDs, light engines, drivers, optics, connectors and heat sinks are introduced to the market every year.

The choices available to the lighting equipment designer, therefore, continually become numerous. This means that there are ever more varied ways of achieving the same design objective. Given any one system specification, the number of potential combinations of components that could meet the specifications is significant and increasing steadily (Figure 1).

The overabundance of design options is creating the need for some form of design automation to accelerate and simplify the selection of components. A software tool can also enable the designer to pose 'what if?' questions in order to quickly compare the benefits and trade-offs of different component choices and configurations. Until now, the LED lighting market has responded to this need for decision support tools by releasing component-based online simulation or selection tools. However, these tools are insufficient because they only process a single lighting component at a time (i.e. only the LED from the LED vendor's tool or only the optic from the optic vendor's tool or only the driver from the driver vendor's tool) and not the lighting system as a whole.

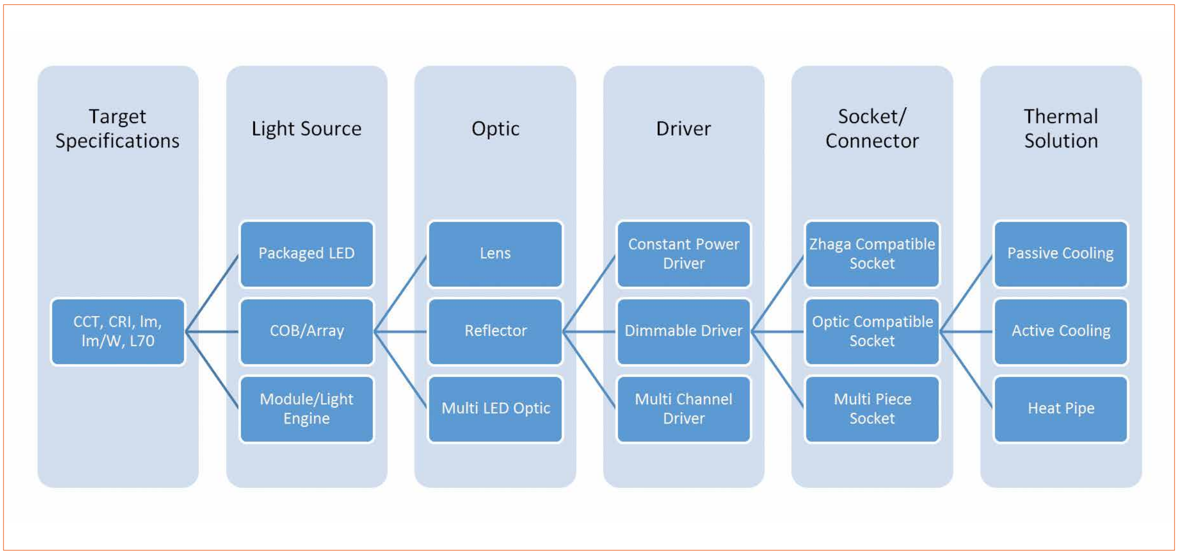

Figure 1: Multitude of design options for meeting the same target specifications

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- 0-10V Dimming
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- Programmable Dimming Options
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The Current Tools and Design Process

Regarding existing light source simulations tools, the user first selects the light source, then a drive current and a temperature where the tool outputs flux and efficacy values. Some of the more sophisticated versions allow the user to select the light source, a temperature, a target flux and target efficacy where the online tool will calculate the required forward current to meet the target specifications. Unfortunately, the existing light source simulation tools typically force the user to pre-select the light source component, temperature and even at times the drive current where many of these variables will not initially be known to the user. Experienced designers will have an instinctive feel for the number and type of light sources that could meet the requirements, and for the implications the light source choice will have on other system components such as the optic, driver and heat sink. But even the most experienced designers cannot maintain up-to-date knowledge of all the existing and newly introduced components available on the market.

There is a significant difference between selecting a good light source to meet the target specifications versus the optimal light source where the optimal selection will change depending on the target flux, target efficacy, target lumen maintenance, required light source count, optics compatibility, driver compatibility and cost. As an example, the existing online tools do not incorporate LM-80 data where the selected current that will meet an efficacy target in the tool may be too high in some cases to meet the target lumen maintenance. As a result, without the incorporation of LM-80 data in the initial analysis, the user may select the wrong light source where the user may be eventually forced to lower the drive current to meet the lumen maintenance target, which may increase component count and cost where a more optimal approach may have been to select a more expensive light source that can be driven at a higher current to reduce the light source count and total light source cost.

A new type of online design tool is required for the lighting industry that incorporates all the major variables in selecting the optimal light source and the related system components such as optics, drivers, connectors and heat sinks. Furthermore, this new tool must not require information that will generally not be known to the user before he or she runs the simulation such as drive current, temperature, or part numbers. In other words, the workflow of the tool must behave how a lighting designer thinks.

Advanced Design Tools Offer an Improved Process

The LSC [1] is a new type of proprietary online design tool that was developed with the lighting designer in mind. This new online tool significantly increases the lighting designer's productivity by combining thousands of light sources, optics, drivers, sockets/ connectors and thermal management solutions with a powerful proprietary algorithm to instantly and seamlessly develop luminaire designs. This tool reduces days or weeks of laborious research efforts to a matter of minutes. Every designer typically starts a new solid-state lighting system design with a basic set of requirements: CCT, CRI, flux, efficacy, lumen maintenance, and if applicable, a target optical beam pattern (Figure 2).

The Component Selection Process

Finding the right light source

After specifying the basic system parameters, the process then steps the user through the whole component selection process. This starts with the selection of the light source. The default proprietary algorithm leverages the light source LM-80 data from all candidate light sources to determine the maximum drive current (to minimize light source count and cost) to meet the target flux and efficacy at the

Figure 2: Specifying basic system parameters – the first step when using the Lighting System Creator

Luminaire Target Specifications	Reset
Market:	Indoor Lighting
Application Category:	Down Light
Application:	>4.5" Down Light - Energy Star 575lm Minimum (Load Default Value)
Nominal CCT:	3000 K
Minimum CRI:	80
Target Luminaire Flux:	3000 lm
Target Luminaire Efficacy:	90 lm/W
Target L70 Lumen Maintenance:	50000 hrs
Estimated Optical Efficiency:	85 %
Estimated Driver Efficiency:	85 %
Required Total Light Source Flux:	3,530 lm
Required Light Source Efficacy:	124.56 lm/W

Figure 3:
In the Suggested Light Sources section, the user can choose from a variety of light source types that meet the target specifications

Suggested Light Sources: Unselect

Sel	Part Number	Img	Light Source Type	Manufacturer	Product Family	Min. Light Source CRI	Light Source Count	Optic PN Count	L H
							1		
COB and Array (6)									
○	NFCLL060B-V1-sm303-R8000		Chip on Board	Nichia	COB-060B-V1 (NFC)	80	1	60	
●	NFCLJ108B-V1-sm303-R8000		Chip on Board	Nichia	COB-108B-V1 (NFC)	80	1	42	
○	BXRC-30E4000-F-23		Chip on Board	Bridgelux	Vero 18A Array (Gen	80	1	32	
○	L2C2-30801211E1900		Chip on Board	Lumileds	LUXEON COB Gen 2 -	80	1	37	
Board Level (5)									
○	929000750913		Rect. Board - Circ. LES - Mid Po	Philips	Fortimo DLM Flex L2 5	80	1	0	
○	929000751313		Rect. Board - Circ. LES - Mid Po	Philips	Fortimo DLM Flex L2 8	80	1	0	

Figure 4:
Refining the design parameters for the selected light source

Selected Light Source Refinement: NFCLJ108B-V1-sm303-R8000 {COB-108B-V1 (NFC)} Reset

Light Source Refinement	Value	Unit
Override Light Source Count (>= 1)	1	-
Override Light Source Cluster Count (>= 1 And <= 1)	1	-
Override Light Source Current (100 - 1180 mA) where Light Source Count will increase at 778 mA	945	mA
Override Typ. Flux of 4710 lm (4230 - 5190 lm) at Nom. Current (860 mA) at 25°C	4710	lm
Override Typ. Vf of 35.3 V (33.7 - 36.9 V) at Nom. Current (860 mA) at 25°C	35.3	V
Override Calculated In-Situ Temperature for L70 = 108,010 Hours Based on 10,000 Test Hours (<= 105°C)	105	°C
Override Calculated Junction Temperature Based on In-Situ Temperature (<= 133°C)	133	°C
Calculated Light Source Forward Voltage	32.7	V
Calculated Light Source Power Consumption	30.9	W
Calculated Total Light Source Power Consumption	30.9	W
Calculated Luminaire Power Consumption After Estimated Losses	36.36	W
Calculated Light Source Flux	4,148	lm
Calculated Total Light Source Flux	4,148	lm
Calculated Luminaire Flux After Estimated Losses	3,526	lm
Calculated Light Source Efficacy	134.26	lm/W
Calculated Luminaire Efficacy After Estimated Losses	97	lm/W
Light Source Warranty	1	yrs
Cost Category	Lowest Cost	-

maximum in-situ temperature (to minimize the size and cost of the thermal solution) in order to also meet the L70 lumen maintenance target. As a result, the user never needs to pre-select the light source drive current or temperature to start an analysis.

The user will then be presented with a table that lists the light sources separated by technology (i.e. packaged LEDs, COBs & arrays, board level modules, integrated light engines), which meets the requirements described in the Luminaire Target Specifications section. The user can then select the part number of interest by analyzing the trade-offs of different parametric values in the table such as (but not limited to) light source count, number of supported optics, maximum in-situ temperature and cost. It's important to note that the system also enables trade-off decision from a make or buy perspective as the user will be able to compare packaged LEDs (make), versus module or light engine based solutions (buy), which will reduce the time to market.

Setting Filters

In the downlight design example (Figure 3), the user has decided to filter and show only the light sources that can meet the target specifications with a single light source, which will eliminate packaged LEDs from consideration. The user then selected a COB light source by clicking on the radio button.

Optimizing Design Parameters

Once the light source has been selected, the user is able to edit several parameters (Figure 4 - darker blue cells) such as light source count, drive current, flux bin, forward voltage bin, in-situ temperature and junction temperature where all other parameters will be recalculated in real-time. Furthermore, for multi-light source applications such as troffers where there is often over 100 mid-power LEDs, the user is able to modularize the system by indicating the number of boards that the lighting system should contain. This will then affect the series/parallel configuration of the light source on a per-board level as well as the board-to-board interconnection for the light source driver, which will all be determined automatically.

From a trade-off standpoint, lowering the in-situ temperature (or junction temperature) will increase flux and efficacy and may reduce light source count but it may also require a larger thermal solution to maintain the temperature at the lower user-centered level. Another design trade-off (for multi-light source applications) is increasing the light source count, where the obvious disadvantage is that it will increase the total light source cost. However, it may provide more flexibility to find a suitable driver by increasing the available series/parallel options and it will increase the range of driver output currents (particularly for programmable drivers) to meet multiple target flux and efficacy requirements within the same design.

Selecting the Other System Components

Optics

The next step in the design process is selecting the system components such as optics, driver, connector/socket, and thermal solution. The optic is the first system component to select because it has the potential to change the light source if there is no suitable optic for the selected light source. Furthermore, the optic can potentially affect the driver solution if a multi-light source optic is selected as this type of optic may require an adjustment in the light source count to reflect the number of light sources that each optic can support.

The selected application and light source will directly impact which optics will be displayed. In the downlight design example, only symmetrical medium and wide viewing angle optics are displayed (Figure 5) to coincide with the application requirements. The feature to display product and application specific optics significantly reduces the number of optic options to assist the user in quickly selecting the appropriate optic.

Drivers

Once the optic has been selected, the next step is to select the light source driver. The algorithm supports all types of light source drivers from fixed current, to multi-current to fully programmable drivers where the driver output current will meet the luminaire target specifications (Figure 6). The algorithm considers the entire light source forward voltage bin range and the impact of temperature for displaying suitable drivers. For multi-light source and multi-board applications, also the series/parallel light source

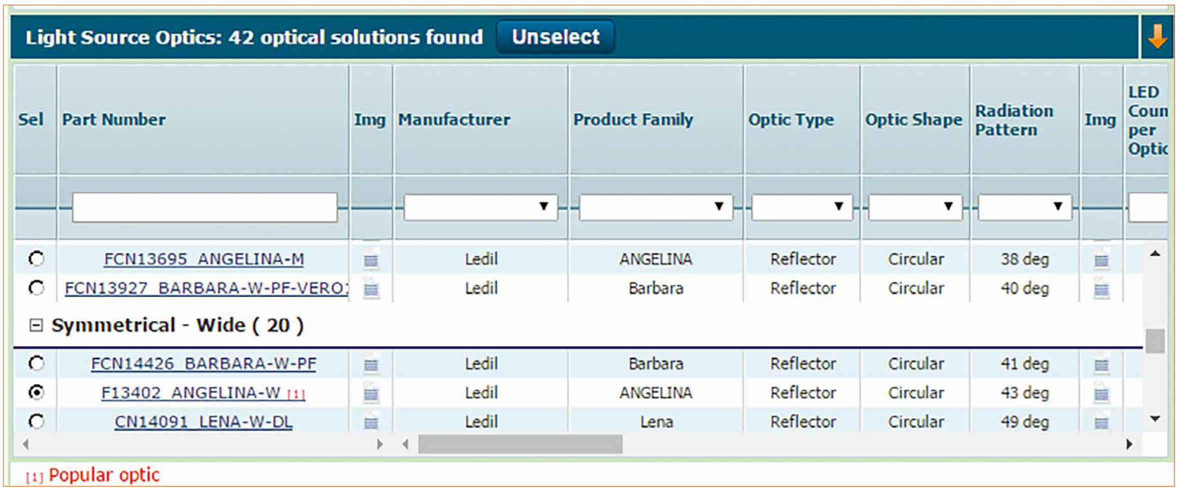

Figure 5:
Displaying application and product specific optics

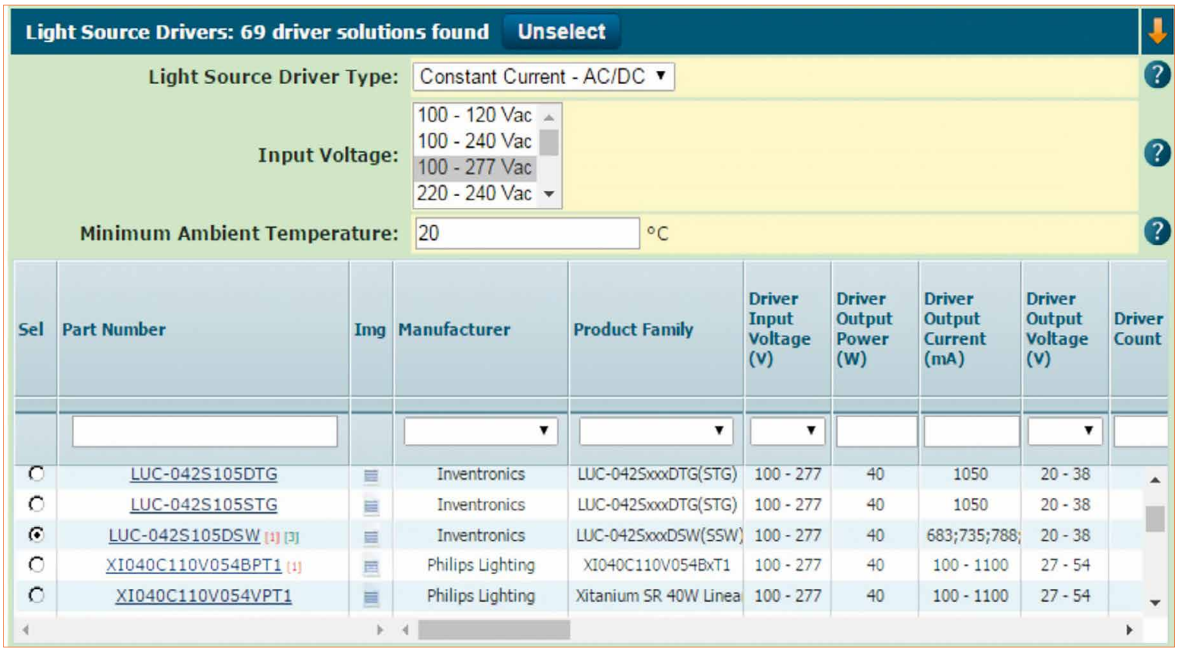

Figure 6:
Displaying compatible driver solutions

connection topology as well as the board-to-board interconnection topology will be shown.

The LSC also includes a proprietary driver algorithm that will ensure that a suitable driver solution will be found by automatically adjusting certain design parameters such as the light source forward current while keeping the light source count constant, light source count to increase the series/parallel array options for multi-light source applications and driver count for very high lumen applications, all while still meeting the target specifications.

In order to assist the user in selecting the most appropriate driver, several additional parameters are displayed such as (but not limited to), driver efficiency at full load, light source load percentage, dimensions, driver marks (i.e. UL, CE, CCC, PSE), driver class (i.e. Class 1, Class 2, Class I, Class II) and supported driver dimming signals (i.e. 0-10V, DALI, PWM, Triac). For the downlight example design, the selected driver had the required dimensions (rectangular versus linear) and driver marks to support multiple international markets, which made it an appropriate choice for this particular design.

Electromechanical components

If the selected light source type is a COB, which is the case for the downlight example design, a list of light source compatible sockets will be displayed in the Light Source Accessory section (Figure 7).

In some cases, the luminaire designer may want the selected optic to be held in place by the socket itself instead of the luminaire housing where there is a footnote to indicate when this socket/optic combination is possible. However, if the light source type is a packaged LED or a light engine with multiple connector options, a list of board-to-board connectors will be displayed instead of sockets. For the downlight example design, a low profile compatible socket was selected.

Thermal management solution

The final system component is the thermal management solution where options that maintain the in-situ temperature to meet the L70 lumen maintenance target are suggested

Figure 7:
Displaying compatible socket and connector solutions

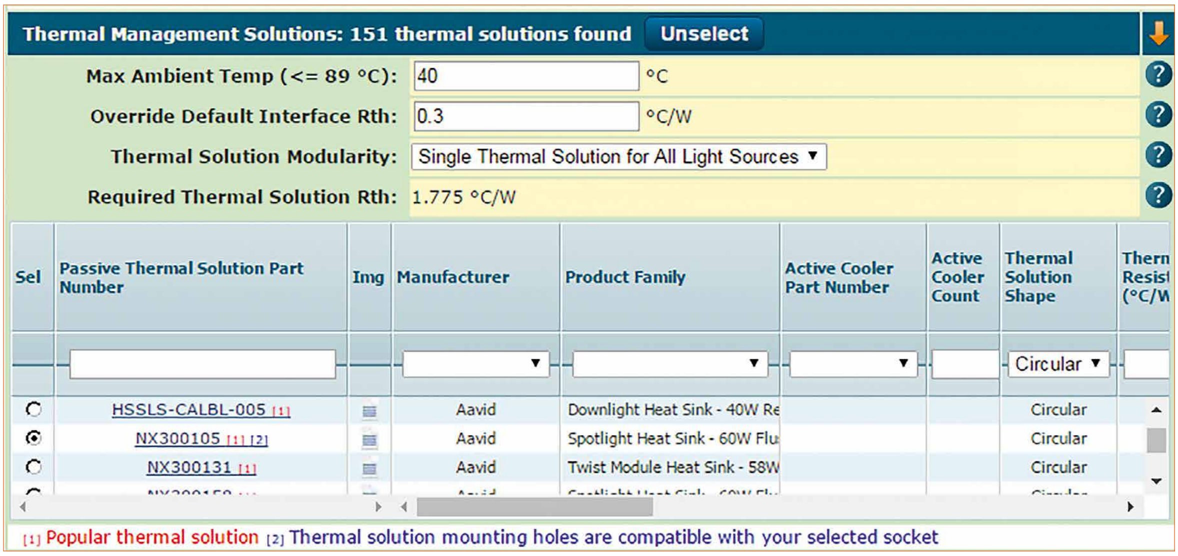

Figure 8:
Displaying compatible thermal management solutions

while ensuring that the light source will mechanically fit onto the thermal solution. Both passive and active thermal solutions are supported. For multi-board scenarios, the user will have the choice to select a single thermal solution for all boards or a thermal solution for each board for a more modular thermal design approach.

A key parameter for selecting the thermal solution is whether there are existing mounting holes that are compatible with either the selected socket or the light source itself. Availability of compatible mounting holes is often a deciding factor for a lighting designer to consider a standard thermal solution versus a custom one. As a result, for the downlight example design, a passive circular heat sink with compatible mounting holes was selected (Figure 8). The user can then generate a comprehensive Excel report of all the lighting system design choices to review with his or her peers and manager to obtain approval to begin the prototyping stage.

Conclusions

Developing a luminaire requires the designer to manage and optimize the complex interdependencies of the light source and all other system components. Due to the highly competitive nature of the lighting industry, it is becoming increasingly important to make optimal design decisions to meet both performance and cost targets. Furthermore, it's critical that design choices are made quickly and effectively in order to reduce the time from conception to the launch of new products in order to gain market share.

For the first time, the Lighting System Creator [1] gives designers the ability to adopt a system configuration tool which thinks the way they do. ■

References:
[1] www1.futurelightingsolutions.com/lsc

Willighting Releases Super Bright Flexible SMD2216 LED Strip with CE and CRI>90

Willighting announced a new and Ra>90 flexible SMD2216 strip.

- 24 V 280 LEDs/m in 2200 lm
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Lextar Debuts 150 lm/W COB in Typical Conditions Tj=85

Lextar launches Version 4 COB lineup bringing 15% higher flux efficacy (up to 150 lm/W), quality and cost competitive products for versatile lighting applications from indoors to outdoors and commercial lighting. The performance upgrade is based on improvements in both chip die development and also package design. The new lineup also provides wide range of luminous flux and various colors, and wide selection of connectors and optical part solutions. Thanks to Lextar's vertical integration capability, it provides high quality and rapid development.

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Technologies for Engineering an LED Light Closest to Sunlight

TRI-R is a next-generation LED light source made possible by Toshiba Materials technology and commercialization together with TOL STUDIO. Using natural light that recreates the solar spectrum, TRI-R suppresses glare, prevents the loss of object color, and gives fresher, clearer expression to textures and details. Based on professional research examining the relationship light has with humans and the environment, this is illumination technology that provides the world surrounding us with the true and real value of light. Masahiko Yamakawa, Senior Specialist of Toshiba Materials Co.LTD., presents how this technology was developed and applied in some projects.

White LED lighting sources were introduced into our social life over ten years ago and have become essential light devices. In comparison to classical lighting devices such as incandescent bulbs and fluorescent lamps, white LED lighting sources have all-round appealing powers; namely they have high energy efficiency, excellent life characteristic and low environmental burden to reduce running costs. And what is more, they can have unrestricted sizes, shapes and output powers to increase the freedom in design of the lighting devices. This is the reason why white LED lighting sources became popular in both facility and home lighting systems.

At present, in commercially available white LED lighting devices, blue lights emitted from LED chips are used as exciting light sources to make white light. In concrete terms, a part of blue light from an LED chip is used to be converted into yellow and red lights via appropriate phosphors. Then yellow and red lights are mixed up together with the remaining blue light to turn the mixture into a white light. On this occasion, because the blue light from an LED chip is higher in intensity than the yellow or red lights converted by phosphors, the white light produced by this method, in principle, tends to have a prominent blue region in the spectrum. Accordingly, some of those who have been long accustomed to sunlight, thermal radiation lights from incandescent bulbs make comments that they have little appreciation for such white LED light sources. These comments were the initial reason for developing and commercializing a new type of white LED light source.

The Technical Challenges

Two technical challenges exacerbate the development of an LED light source that has a specific light spectrum similar to that of the sunlight, with "Duplicate natural light out of artificial light sources!" as a theme.

The two major challenges are:

- Designing the ideal emission spectrum
- Holding down the degradation of energy efficiency

The first point aims to make an alternative system that does not employ blue light from an LED chip to make yellow or red light elements and to make a new phosphor design that renders broad visible light region in spectrum. The second point aims to develop new phosphor materials that have better quantum efficiency and better excitation light absorption rate and also to support process development in LED chips. The second point aims to develop new phosphor materials that have better quantum efficiency and better excitation light absorption rate and also to support process development in LED chips.

Commercialize a White LED Light Source that Duplicates Sunlight

Spectrum shows distribution of intensity of various lights alongside their wave length emitted from a certain light source. Figure 1 shows the light emission spectra of various lighting sources. Spectrum distributions of fluorescent lamps and white LED light bulbs show insufficient light intensity in some color regions. Especially, the white LED light bulbs have a distinctive feature that they have a precipitous intensity peak in the blue light region on account of the fact that they employ blue light as the exciting light source and what is more a transmitted part of that visible blue light is used as one of the mixing light elements of the white light. On the other hand, emission spectra of sunlight or an incandescent light bulb from thermal radiation are generally continuous.

In a social life, we seldom have the opportunity to see directly illuminated light sources excepting display devices. We perceive an object, its colors, its brightness or its textures by receiving its reflected lights. This means that in case a light source had a deficient color region in the spectrum distribution, somewhat different senses will be created in visual recognition, which will not come out under usual light source with continuous spectrum distribution. In addition, a phenomenon that ample amount of light component in shorter wave length region causes trouble in visibility came to be a subject of study, standing on a fact that shorter the wave length, the light will be more easily scattered.

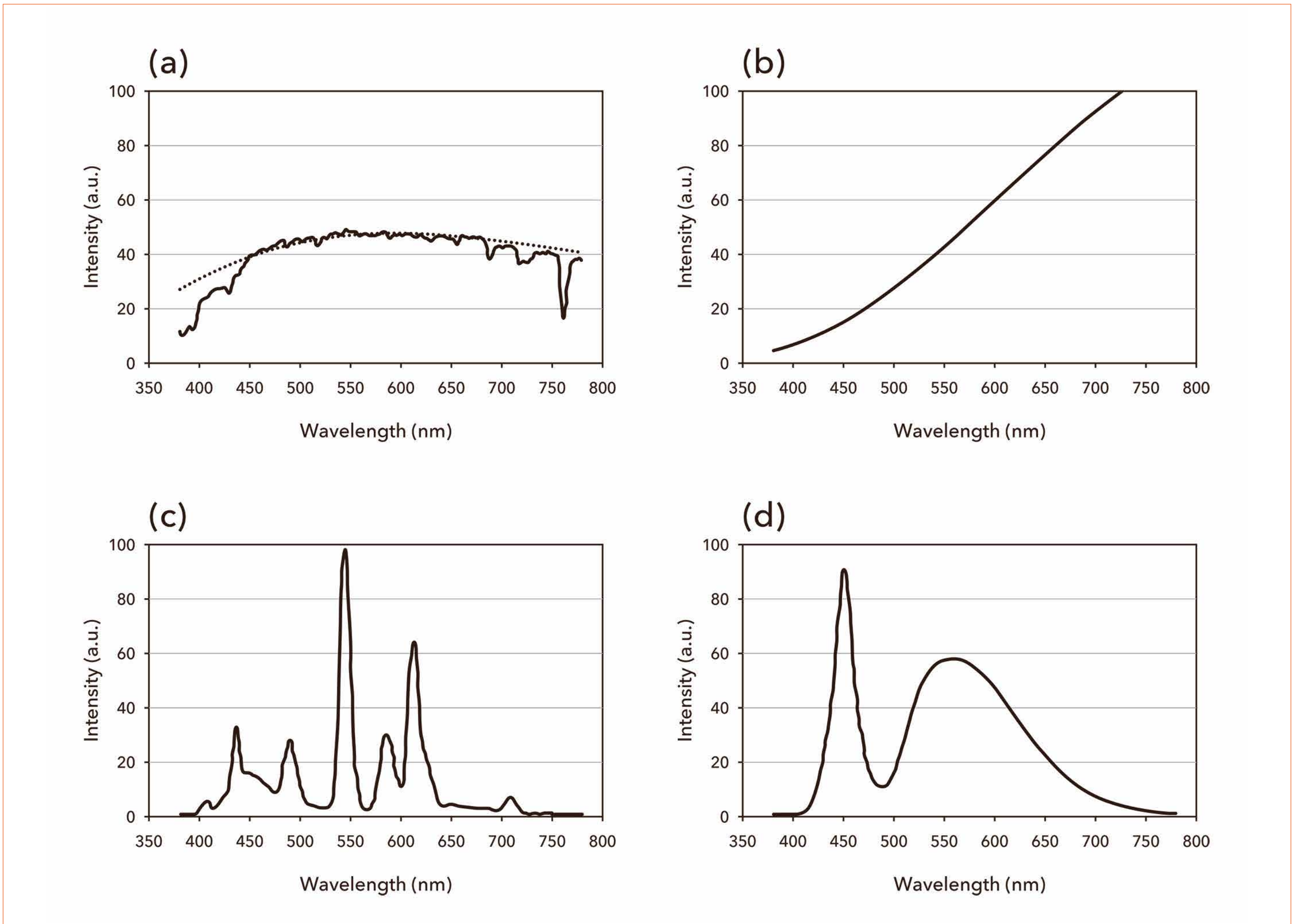
By the nature of light, spectrum pattern may vary unboundedly to make a similar color hue. Toshiba Materials Co. Ltd. has promoted the engineering development and commercialization of new type of white LED light sources that duplicate sunlight having the continuous spectrum distribution. To obtain a white LED light source with continuous spectrum distribution, there are two technical issues.

The exciting light should not be made one of the mixing light elements of the white light.

And it is necessary to develop a new type of phosphor that has an appropriate emission peak wavelength and emission half width in order not to make a deficient color region in the visible light region in the spectrum distribution.

The first issue was solved by employing a purple light emitting LED chip instead of blue light emitting ones. Figure 2 shows the schematic explanation of white light production principle and emission

Figure 1: Comparison of the emission spectra of various lighting sources - (a) sunlight (dashed line: black body radiation), (b) incandescent light bulb, (c) fluorescent lamp, (d) commercial white LED



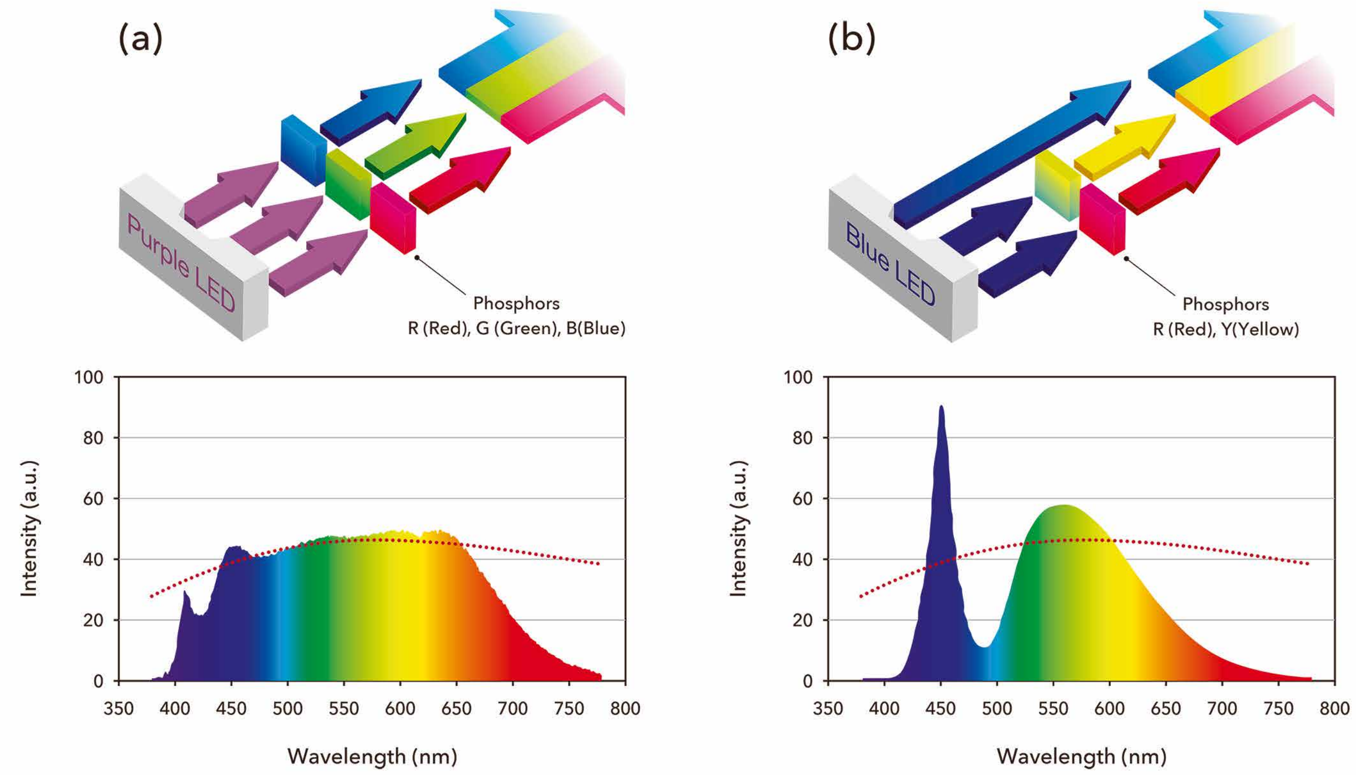


Figure 2:
Comparison of the TRI-R approach with a commercial blue light pumped phosphor converted white LED - (a) TRI-R, (b) commercial white LED (Top: Principle of the production of white emission; Bottom: Emission spectra; dashed line: black body radiation)

spectra. Moreover, a mechanism was developed to prevent the exciting light from transmitting by converting it into visible light by phosphor.

The second issue was solved by obtaining a new phosphor, on the basis material technology and optical simulation technology, by blending several kinds of phosphors so that the new one has an appropriate emission peak wavelength and emission half width. Obtaining a continuous spectrum distribution requires a close deployment of emission peaks along the wave length coordinate. A close deployment of emission peaks means the difference in energy levels of absorption and emission is small, suggesting causing loss in energy efficiency by mutual interference of adjacent phosphors. To cope with these difficulties, phosphor synthesis technology and phosphor layer structural design technology were applied.

Engineering Development of a White LED Light Source Excited by Purple Light

A purple light LED chip is used to make white light that duplicates the sunlight spectrum. The white LED light excited by a purple LED chip has a different emitting principle than that of those excited by blue LED chips.

New element technologies were required. Therefore, new phosphor material technology, phosphor layer formation technology, LED chip device technology and process technologies were developed. To produce the broad white spectrum, the design of the emission spectrum shape of each phosphor, the structure of the phosphor layer so as not to transmit the violet light, and the design to minimize the energy loss in the fluorescent layer are needed. Therefore, new phosphor material technology, phosphor layer formation technology, LED chip device technology and process technologies were developed.

Phosphor material technology

Phosphors are the ceramics-like powdery inorganic compounds with particle sizes varying from 10 to 30 μm. The phosphor materials are diluted doped rare earth elements. Phosphor materials include phosphate, silicate and oxonitrido-aluminosilicate, and as doping materials europium and cerium are often employed. When excited by some external stimulus or the purple light in this case, phosphors will emit a variety of colored lights from blue to red corresponding to the phosphor material and the doping material employed. Figure 3 shows the emission spectrum of various kinds of phosphors. A selection from these phosphors was blended to create the new phosphor mixture.

Phosphor materials are expected to have excellent optical properties, chemical properties and powder properties. The optical properties affect optical performances and energy efficiency. The chemical

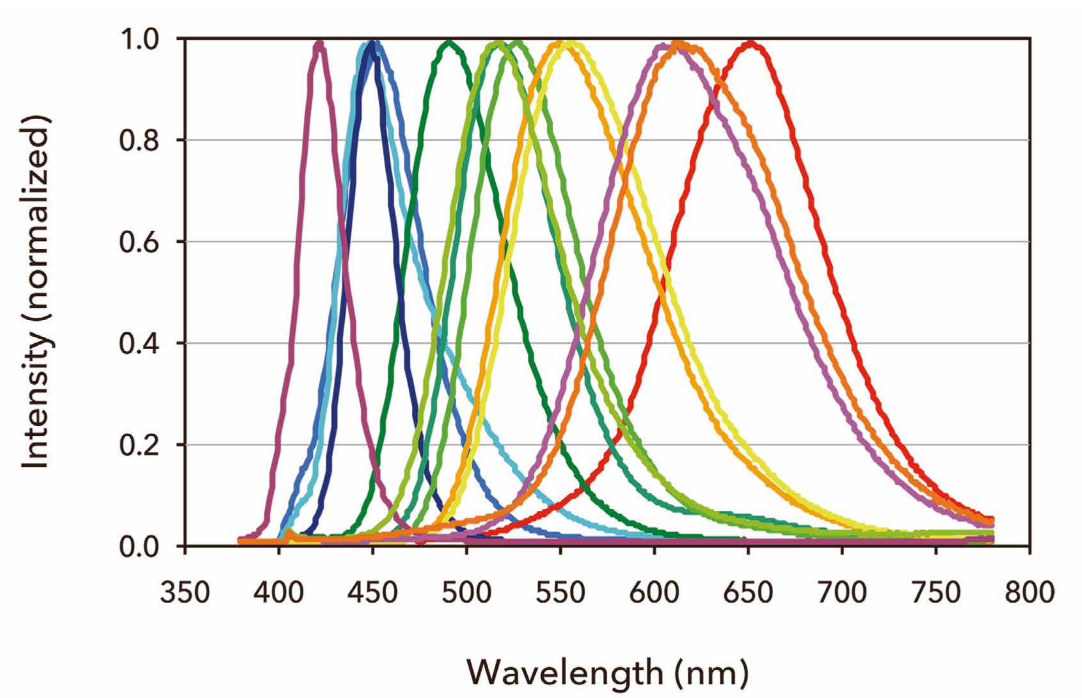


Figure 3: Emission spectra of phosphors for white LED excited by 405nm

Table 1: Optical properties, chemical properties and powder properties and the typically influenced performances

Optical Properties	
Concrete properties	Influences to the white LED performances
Emission peak wavelengths	Spectral shape, an average color rendering evaluation index and a peculiar color rendering evaluation index in a case where white light was produced by a mixture of plural kinds of phosphors.
(2) Emission half width	Spectral shape, an average color rendering evaluation index and a peculiar color rendering evaluation index in a case where white light was produced by a mixture of plural kinds of phosphors.
(3) Excitation light absorption rate	Emission energy efficiency
(4) Visual light conversion efficiency	Emission energy efficiency
(5) Light emission temperature characteristics	Characteristics degradation at high load running
Chemical properties and powder properties	
Concrete properties	Influences to the white LED performances
(6) Chemical stability	Process stability in phosphor coating process & characteristics degradation at long time lighting
(7) Particle size, particle distribution, particle shape and particle surface property	Emission energy efficiency & Process stability in phosphor coating process
(8) Body color	Emission energy efficiency

properties and powder properties affect energy efficiency and formation of production processes. Properties and the typically influenced performances are summed up in the table below.

However, there are not a few antonymic relations in these properties. For example, excitation light absorption rate is generally inconsistent with visual light conversion efficiency. Moreover, although higher concentration of doping materials, which absorb exciting light, will be agreeable to improve absorption rate, color conversion rate will be degraded on account of the mutual interference between phosphor and doping materials. Further engineering development of phosphor synthesis was made to overcome this technical issue. The working items are listed in table 2.

Table 2:
Major development items of phosphor synthesis technology. The numbers indicate the concrete properties from Table 1 that are affected

Development items	Influences to the phosphor properties
Material selection	(3), (4), (5), (6), (7), (8)
Synthesis process	(3), (4), (5), (6), (7), (8)
Stoichiometric ratio	(1), (2), (3), (4), (5), (6), (8)
Doping materials concentration	(1), (2), (3), (4), (5), (8)

Let us pick up a blue phosphor as an example. Blue phosphor is represented by chemical formula M10(PO4)6Cl2, where M denotes alkaline earth metal and Eu doping element europium. This phosphor emits blue light effectively.
This phosphor is made by burning the mixture of metallic oxides, metal carboxylate and phosphate metallic salts, which are the raw materials. In the burning process, target phosphor material will be produced by chemical reactions among molten raw materials, where the reactions will take place one after another in an orderly manner according to each one's melting point and along with the temperature elevation. Control of chemical reactions among materials is indispensable to produce chemically stable crystals.
To establish optimal synthesis process for producing phosphors, chemical reaction processes were investigated using both physical and chemical advanced analysis methods, namely X-ray diffraction analysis, elemental analysis and so on. Conditions for synthesis process were determined after investigation results were obtained.

Thus we have attained the optimal solution for the white LED lighting device after engineering development of every phosphor that makes up the device.

Phosphor layer formation technology

To install phosphor on the white LED, the LED is coated with the mixture of more than one phosphor mixed and dispersed in organic resin. Technical issues of this process are how to attain homogeneity of white light emission and how to prevent degradation of energy efficiency associated by mutual interference, which may be caused by the mixing of different kinds of phosphors. To attain homogeneity of white light emission, a lot of engineering effort was necessary to finally select the most appropriate transparent resin for the phosphor. Degradation of energy efficiency associated by a mutual interference is peculiar to the white LED that is coated with more than one phosphor. It was already explained above that phosphors, externally stimulated by an exciting light, attain broader emission at half width. The exciting light also has a certain wavelength range.
Concretely speaking, a red phosphor will emit red light when excited by purple, blue or green exciting light. In the early stages of white LED light source development, a blue LED and a yellow phosphor were combined to produce a white light where the yellow phosphor was excited by blue light from the blue LED. On the other hand, in case of a high color rendering LED, where a blue LED and green and red phosphors were combined, the red phosphor, stimulated by exciting lights from a blue LED and a green phosphor, emits red light. In this instance, as the phosphor layers are made in a cascade structure, a mutual interference between phosphors is inevitable and results in energy loss. The purple light excited white LED light source, where every visible light is emitted from phosphors deployed in a cascade structure, also has the same issue with energy loss.
To cope with this issue, a new phosphor paste coating process was developed, using a mixture of organic resin and phosphors to minimize the energy loss.

LED chip device and process technology

The emission wavelength of the light from a LED chip affects the energy efficiency. We have established the range of emission wavelength as 400 to 410 nm after studying the most appropriate range of emission wavelength of the light from the LED chip for our newly developed phosphors. Table 3 shows the results of the intense engineering developments.

Series	TWC1512	TWC1916	TWC2420	TWC2828
Size [mm]	15 x 12 x 1.5	19 x 16 x 1.5	24 x 20 x 1.5	28 x 28 x 1.5
Light Source Diameter [mm]	8	12	15	22
CRI	97			
CQS	96			
CCT [K]	Standard; 2700, 3000, 4000, 5000 | Customizable; 2000 - 6500			
Wattage [W]	6.8	15.9	25.4	53.9
Lumen Flux [lm]	565	1320	2075	4520
Efficiency [lm/W]	>80			

Table 3:
Characteristics of TRI-R white LED

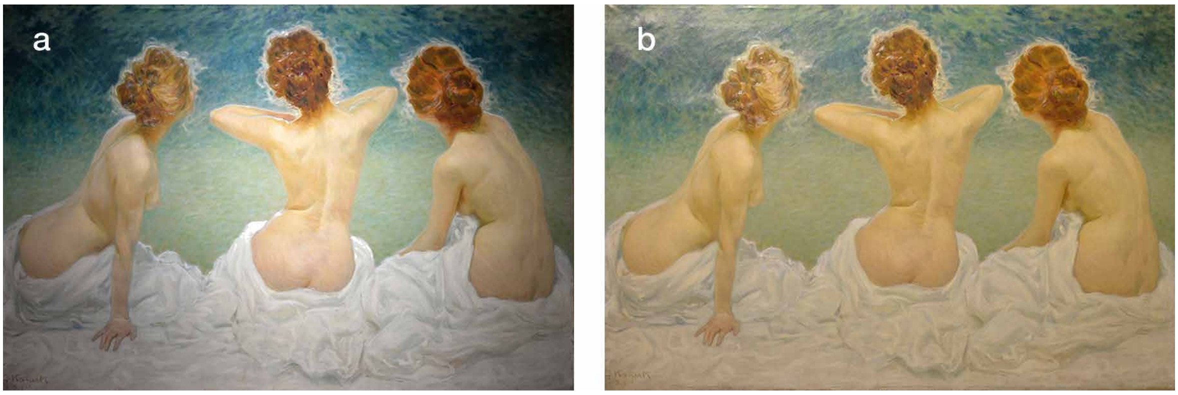


Figure 4: Comparison of the difference in a painting is seen - (a) TRI-R, (b) commercial white LED ("Symbolism. Art in Europe from the Belle Époque to the Great War", Palazzo Reale, Milan from 3rd February to 5th June 2016, La Giovinezza (Youth) by Giorgio Kienerk, 1902, Pavia, Musei Civici)

Applications to the Lighting Devices

White LEDs that use the new technology cover a wide range of color temperature varying from 2000K, or the color of a candle light, to 6500K, or the color of sunlight in a clear sky. And, what is more, they can duplicate the sunlight or natural light spectrum all over the said range of color temperature. Making use of these advantages, these white LEDs are employed as the alternatives to the incandescent light bulbs, as shadowless lamps or as lighting devices in display rooms.

These LEDs were employed in several new and innovative luminaires and projects, like the Lucellino LED of the Ingo Maurer Company, one of the German manufacturers of designed lighting devices. They have duplicated the features of incandescent light bulbs, namely the light spectrum, form and change of light colors when dimmed. In the lighting devices to illuminate the five central pieces of "Symbolism, Art in Europe from the Belle Époque to the Great War" held at the Palazzo Reale, Milan from 3rd February to 5th June 2016, they accurately reproduced the color, texture and 3D appearance of the pictures (Figure 4).

The technology is also applied in the Pinacoteca Ambrosiana, Milan. The museum is famous for housing a collection of pictures typified by "Codice Atlantico" of Leonardo da Vinci, "Madonna del Padiglione" of Botticelli and "Canestra di frutta" of Caravaggio. Finally, Shadowless lamp in Japan appreciated the characteristics for the hue and reproducibility at a higher color temperature, excellent visibility and the ability to reduce effects of visual burden of the operator, comparable to that of conventionally used halogen lamps.

Conclusion

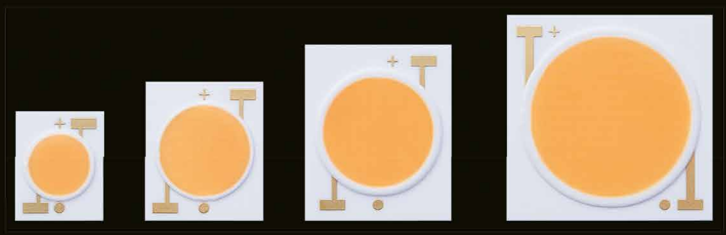
In recent years, relations between light and health are being discussed. Human beings have utilized lights as one of the means of living throughout their history. Light sources, in the early days were, were limited to natural light such as sunlight and fire flames. Accordingly, our bodily functions were adapted to those natural lights. Blue lights are absorbed in the retina and its signal is transmitted to the biological central clock (suprachiasmatic nucleus) to control biological clocks. In the morning, exposure to sunlight resets the biological rhythm. On the other hand, if exposed to light at night, the biological clock may go off kilter and sleep will be negatively affected. Because of this it is preferable to choose human friendly light, or it is important to avoid bluish lights at night. Research on the impact of lights on the human body are advancing throughout the world; it will be clarified and include sufficient medical verification.

Illuminations shine lights on various objects. Man recognizes objects by learning their features through sight which is created by the intensities or wavelengths of reflected lights. After that, man can respond in identifications or in emotions. The faculty of seeing something includes seeing beautifully and correctly. To enhance this faculty it is necessary to design and offer adequate illumination lights with low impact to visual organs and the nerve system of the human body.

TRI-R

THE LIGHT CLOSEST TO THE SUN

TRI-R is a state-of-the-art **LED** light source made using technology by **Toshiba materials** and produced with **TOL STUDIO**.
The natural light created by TRI-R is close to the **sunlight spectrum**, is glare-free, does not alter colors, and gives sharpness to details and textures.
The specialized research into the influence light has on man and on the environment has confirmed TRI-R's contribution to producing significant **lighting quality** in the design of architectural spaces.

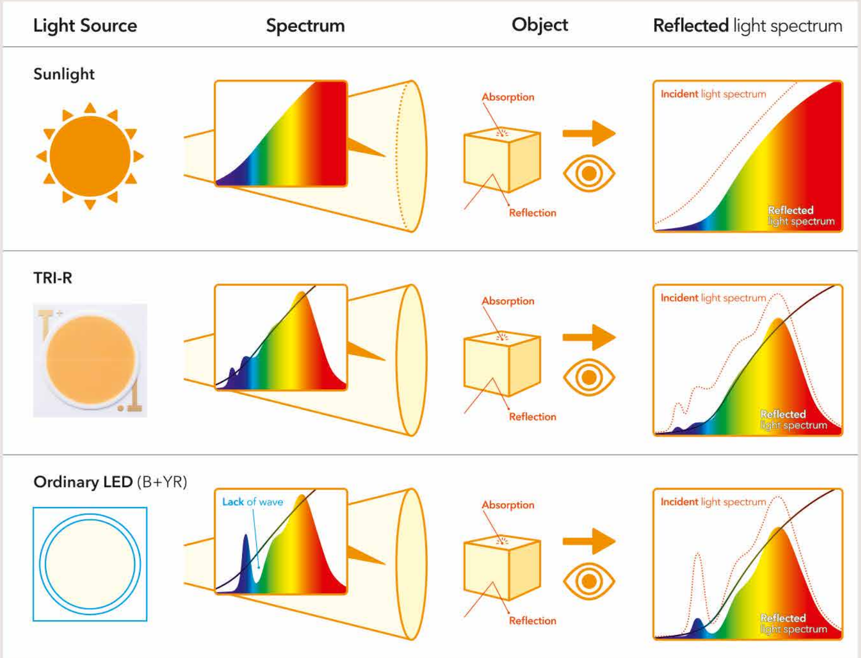


Cannot be described only by CRI

Light is exposed on an object and specific spectra are absorbed, with other reflected spectra entering the eyes and stimulating the color sensing apparatus, whereby we recognize the "color" of an object. Therefore, by measuring the difference in the spectrum produced from **reflected light** on an object when light is exposed to it by a light source against the spectrum for reflected light when natural light is exposed to the same object, we can adequately appraise what humans perceive as colors under **natural light**.

CRI and CQS are artificial indices for digitally defining the spectral shapes of light sources. Not equipped to define all of the colors in nature, CRI is unable to describe a light source whose spectrum has an especially high density or sparsity in a given spectral region. **TRI-R**, for its part, contains the entire spectrum of colors comparable to that of **sunlight**, so it is capable of reproducing the color of gold with all of its complex reflections, or even a pale flesh tone like skin through which blood vessels can be seen.

Analyzing the reflected light spectrum for metal, we see a gentle absorption across all regions, with marked reflection in the range of 400-500nm. For B+YR, there is a lack of short wave reflection, and a strong value in the 450nm (blue peak) region, so the color rendering leans towards green.



Lighting Fabrics - A New Approach for Flexible Light Sources

Different groups from the lighting business have been dreaming of truly flexible light sources for a long time. OLEDs are being promoted as the solution of the future but there are other solutions already on the market. Managing Director R&D at Carpetlight GmbH, Mr. Till Sadlowski, takes a look at the common history of light and fabrics, the evolution of flexible circuity and the latest development in form free scalable light sources.

Fibers and fabrics are an essential part of our technological history.
The treatment of fibers into threads, simple skills as braiding or twisting reach back to the Stone Age. Even the more sophisticated technology of weaving dates back 32,000 years - only surpassed by the treatment of wood and stone.

Our relation to textiles and fabrics started with the selection of natural fibers offering numerous possibilities for protection, shelter and comfort. The features of a lightweight, reusable flexible material to be manipulated by a simple technique such as sewing allowed a universal use. Next to clothing, structures like tarpaulins, tents and yurts where home to early mankind. Evolving with them, the progress in textile manufacturing and the use of artificial fibers today allows custom made solutions in all kinds of applications. In this context, it is interesting to note that even early artificial lighting depended on a small piece of fabric to light up: the wick of a candle or lantern as the first controllable sources of light followed by the gas mantle and finally a carbon filament inside the first light bulb.

Next to the generation of light the use of fabrics was always much more obvious in the shaping, modeling and directing of light. Curtains, drapes, shades, louvers, blinds and canopies are tools to separate our very own surroundings from the outside world in a simple, effective but also fashionable way. A curtain not only allows us to control the light and the looks passing through but is also a piece of craftsmanship reflecting style and state of textile technology. Lampshades not only form the light emitted by the light source, they are rather a key factor in the luminaire's design. A backlit textile works not only as an acoustic element in architecture but also as a homogenous glare free source of illumination.

As light and fabric are literally interwoven in our perception, it seemed just a logical step to actually combine both to create a luminous fabric. As a first attempt to do so, optical fibers were used. These were mechanically treated on their outer surface by abrasion changing the linear light transmission to a 90° angle at the treated areas. Combining these fibers with a fabric created a homogenous lighting piece of textile. Off course light still had to be „fed" in from a traditional light source. Due to the time and cost intensive treatment this technology never reached an industrial level. Only a small-scale application for photodynamic use in medicine was built. With the evolution of white LED's came the technical feasibility for bringing a light source directly to a textile surface.

Flexible Solutions

The idea of spreading LED's on a textile was already patented in 1996 (German Patent DE 19632719 A1) as a way of illuminating banners for commercial use at night. Followed up by an even more futuristic attempt in 2003 (German Patent DE 10320650 A1) combining textile based LED's and solar cells with batteries for creating a nearly self sustaining lighting device.

Though not all the technologies described in these patents were available at the time of publication, the groundwork was already laid by the use of tinsel wires (the winding of ultra thin wires or foils around a textile carrier thread) long before that. Based on a medieval technique, the so called "Lyonese Wares" used for luxurious decorative purposes in churches and palaces, a technology had been developed to successfully build long lasting voice coils, telephone and headphone cables since the 1940s.

But it was the need for special clothing to help people to withstand the most extreme environments such as arctic regions, underwater and space, that first introduced textile circuitry to larger areas. This lead to the development of wearable circuitry for the use of heating underwear first and later sensor suits, monitoring body functions of divers and astronauts. Today athletes are equipped with sensor suits to enhance their training and performance skills. Of course the military is the ultimate client when it comes to flexibility in terms of "working everywhere."

In the early stages of these projects tinsel wires were used, being the most flexible conductors at the time. The process of physical vapor deposition took the fabrication of conductive threads to the next level, a reliable way to permanently coat a fiber was found. These fibers, individually or as fabrics, work as excellent conductors when copper or silver is the metal used for the coating. The first use for conductive threads in mass production is heated seats in the automotive industry, taking full advantage of the unbreakable electric conductor capable of adapting to any form and surface. Further applications became electrostatic and electromagnetic shielding, healthcare and smart wearable textiles.

As a result of the European research project PLACE-it the first method for embedding low power LED's on a textile surface using conductive threads and sequins was developed in 2013 by TITV Greitz, Germany. In 2009, the STELLA research project focused on the other way of flexible circuitry leading Fraunhofer Institute IZM Berlin to the development of the SCB (stretchable circuit board) using meandering copper conductors connecting LED's sealed in thermoplastic polyurethane.

These two approaches seemed to have the most promising expectations to be picked up by the industry. Yet the difference in technology led to a split between traditional electronic PCB makers such as Würth Germany following the polyurethane based way (TWINflex®Stretch) and on the other hand pushing an even older tradition to new limits: Swiss company Forster Rohner accepted the technological challenge to adapt their decorative embroidery fabrication to e-broidery®.

Today a whole variety of lighting products claiming to use flexible technologies are on the market such as waterproof sealed led stripes, transparent bendable panels and sheets.

They all have one thing in common: Because of their copper conductors they can either not be bent at a 90° angle or have a limited amount of bending cycles according to the amount of copper used. The thickness of the sealing material on the other hand is a limiting factor for the adaption to given surfaces. This correlation between copper

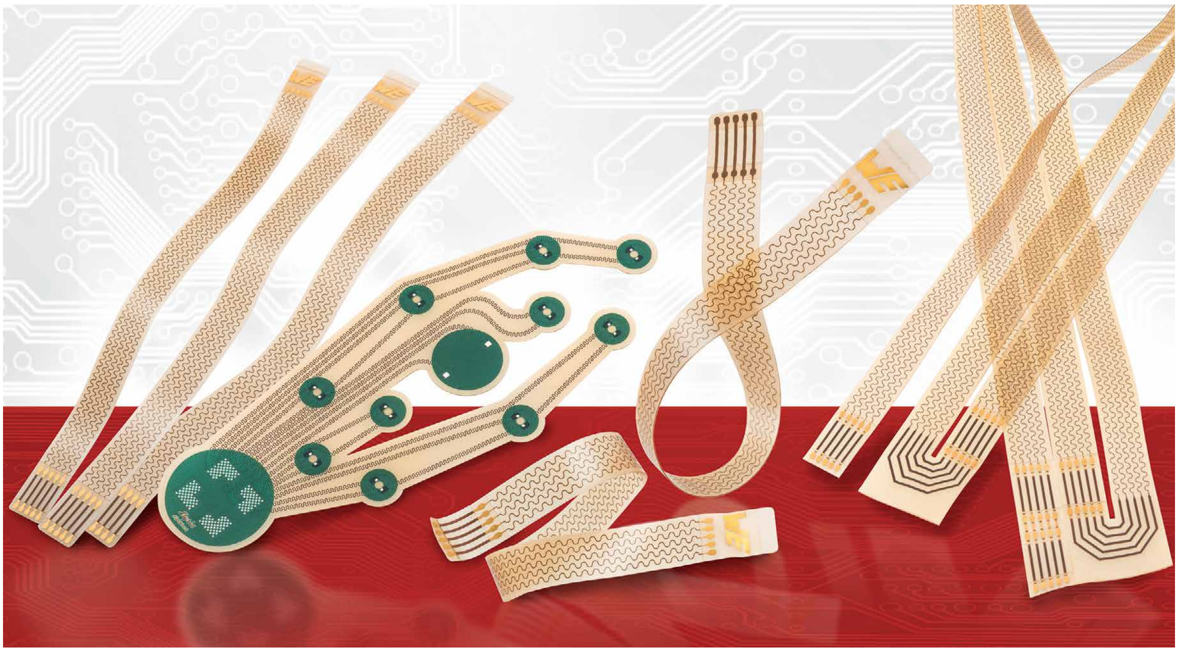


Figure 1: **Polyurethane based circuit boards**

conductors and sealing compound leads to a limitation in either power or flexibility. This limitation also applies to OLEDs being the only other relevant light source in the flexible world.

At this time, there is only one totally uniform way of light to cover its whole surface evenly: Electroluminescent inks can be printed on textiles and connected by conductive threads. Their luminous output and color quality is very limited, though, and therefore cannot be used for real general lighting purposes. This is where the difference between a flexible and a limp circuitry has to be defined: When the only limiting factor can be reduced to the size of the electronic (hard) component connected by a limp conductor, the most versatile use of this set up is given only to be accomplished by textile based technologies. Any other way of connecting components is subject to the limitations mentioned above.

Now this contemplation about flexibility leads to the question where and when it is actually needed in today's lighting world. Most of our every day lighting requirements work very well with the fixed lamps and lights made from metal, glass and plastic but there is a need when non permanent structures and situations are present. A major role in this area is played by the entertainment industry so it is worth to take a closer look at.

A Special Field of Lighting: The Film Set

The introduction of LED's in the media and entertainment industry has seen the same reluctance in use as in general lighting when it came to replace "traditional" sources of light with them. Since the producers of audiovisual media products traditionally never paid much attention to their energy balance - due to short production periods - and rather tried to cut on payroll expenses, it took the drastic increase in energy costs and environmental obligations to create an awareness for the need of energy saving production techniques. It was only in the last years that mayor film and TV studios changed their power consuming lighting concepts to led based solutions.

And there is even more to be changed: The daily routine on a TV or movie set requires effective, fast working solutions for assembling and disassembling lighting devices, making the equipment's weight and storage space essential factors. In addition to that efficiency, color rendition and stability, flicker free operation, robustness and compatibility are the other issues to look at. Most of the time the desired lighting effect is obtained by pointing spot or floodlights to large areas of foils, gels or fabrics suspended in frames, using these as reflectors or diffusers for the light source. From the early days of film production the white muslin studio curtains, used to control sunlight have lasted to the present day. Off course high tech fibers and special coatings have enlarged the range of light shaping textiles in the past decades. But because of the lack of alternatives this procedure is the „status quo" of professional film lighting still today.

This practice always requires a space between light source and diffusing or reflecting media causing bulky, inflexible setups, taking time and logistic resources .The slow technological progress in cinematography lighting is most likely based on the conservative attitude of leading directors of photography who are mainly responsible for he look of a movie. This look was primarily based on the choice of special film stock,

Figure 2:
Traditional film set using HMI Fresnel lamps and large diffusion fabrics

development and printing techniques, an all-photochemical process, mostly depending on the right way of exposure. For this purpose, well-established ways of lighting were at hand and therefore no need for innovation.

Tungsten and arc lamps became the worldwide standard beginning at the end of WW1, enabling image capturing with mechanical movie cameras at all frame rates.
When HMI bulbs were introduced in 1969, the generation of light became more effective (4 times more compared to a tungsten light source) but the magnetic ballast necessary to run these lamps limited the frame rate of the camera to a single fixed speed (24/25 fps) due to pulsation of the AC arc following the line frequency.
Later on, electronic ballasts that operated on higher frequencies solved these problems.

It took another 18 years until the first fluorescent fixture was used to light up a film set. From now on the increase in film stock sensitivity in combination with the growing number of electronic image capturing technologies (CCD/CMOS) prepared the ground for innovative lighting techniques. In 2010 the transformation from analogue to digital cinematography finally marked a new era for the lighting business. It was time for a lightweight, effective light source to be operated everywhere. In this context battery operation became a key feature since more film sets evolved on unusual spots and locations without the need for AC power lines or diesel-powered generators. All led fixtures on the media and entertainment market at that time just replaced the traditional ways of lighting described above by replacing the previous tungsten, HMI or fluorescent light source.

Not all developers of these early LED lights paid enough attention to the color rendition quality of the LED's used and the driver or dimming setup. The run for luminous output and efficiency led to some poor results that gave early LED lighting a bad name, just as in general lighting. The only progress made in this respect was the use of bicolor or RGB LED's, creating easy solutions for various color temperatures or even colored lights eliminating the use of expensive heat and UV resistant filter gels.
No revolutionary breakthrough had been made solving the problems of heat dissipation; heavy heat sinks or noisy fans are still state of the art.
Today's high end LED fixtures all have excellent color rendition, good thermal management and can be operated with a wide range of power supplies but still rely on traditional shapes and designs as if to mimic the old technology.

LED's on Fabric

The first attempt to focus on the flexibility advantages of LED technology took place in the area of large displays. But these products rely on traditional PCB, molding, and wiring techniques, resulting in relatively high weight (9 Kg/m^2) and are limited to be mounted in scaffolds and trusses when in mobile use.

After 20 years in the field as lighting technicians, the founders of Carpetlight are aiming at an amount of flexibility that is literally a "shining cloth", to be produced in various sizes, and which can be handled just like any other fabric. It will be able to replace the traditional setup of fixture

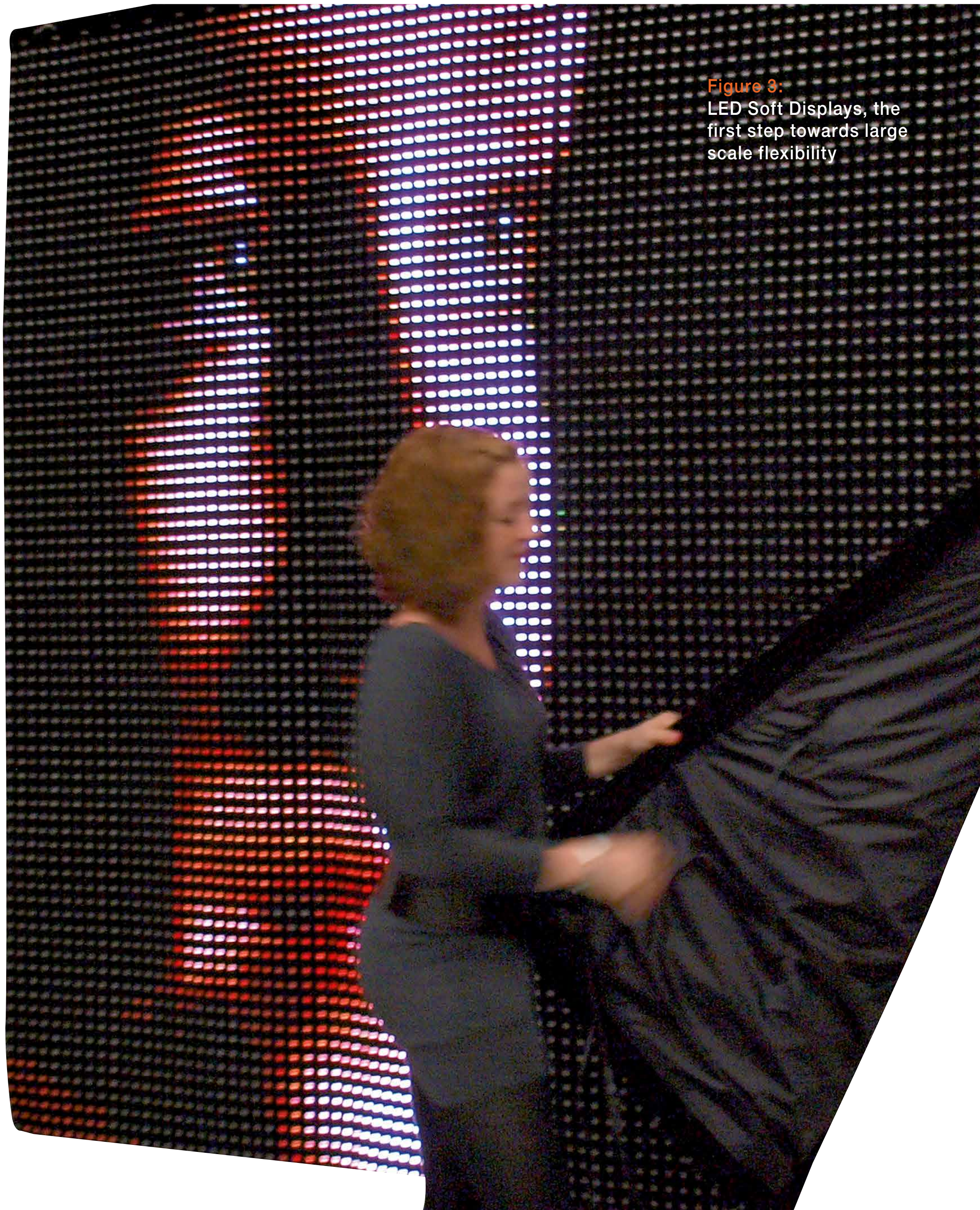


Figure 3:
LED Soft Displays, the first step towards large scale flexibility

and reflective or diffusing media with one single device. In order to give users the most adaptive, form free lighting tool, miniature PCBs are fixed on a textile circuit board, connected by conductive threads embroidered onto a lightweight fabric. By the use of highly efficient LED's it is possible to lay nearly any desired pattern of light on a piece of cloth, ranging from high luminous output for use as a flood light to low light applications such as ambient lights. The wide emission angle of the LED's in combination with a dense pitch creates a homogeneous effect over the lighting area.

The choice of materials for that purpose includes rip stop polyamide fabrics as they are used in parachutes, hot-air balloons and sails. They feature extreme tear resistance, low surface weight and a large variety of coating options (water repellent, flame retardant, heat reflecting /absorbing etc.). The textile shell covering the light emitting area from the back is made from this material to ensure maximum mechanical protection just as water repellent properties. It is matte black to make it nearly invisible in a studio or location background. The rip stop weave technique using reinforcement threads in a crosshatch pattern also ensures maximum stability for the textile circuitry inside. The conductive threads embroidered to this surface will not be disrupted when the fabric is punctured or minor tears occur. Extra protection is needed for the junction area between the light's textile conductors to the "hard" world. In this case a layer of ballistic Kevlar seals the end of the copper wires reaching into the "soft" edge of the lighting grid. This is the only part that is still limited to the restrictions of the rigid metal connectors mentioned before. Because it is only a small area of the total lighting area (approx.7%) the larger part of it has all the flexibility it was designed for.

The other materials used on the light emitting side are monofilament fibers which are individually mechanically treated to a helix shape before being woven into a fabric. The optical effect that is achieved here is a lenticular, three dimensional shift of a small circular light source (LED) to a larger rectangular pattern. Underneath this top layer, a spacer fabric is located, enlarging and diffusing the light emitting area as well as protecting the LED's themselves from direct mechanical impact.

The LED's heat dissipation is done through a patented multilayer textile compound to be convection cooled. Each LED carrier is connected to a carbon based layer by a thermally conductive adhesive. The carbon fiber structure spreads the heat to a larger area making the whole rear side of the light a "heatsink". Finally the whole textile is treated to be water and dust repellent.

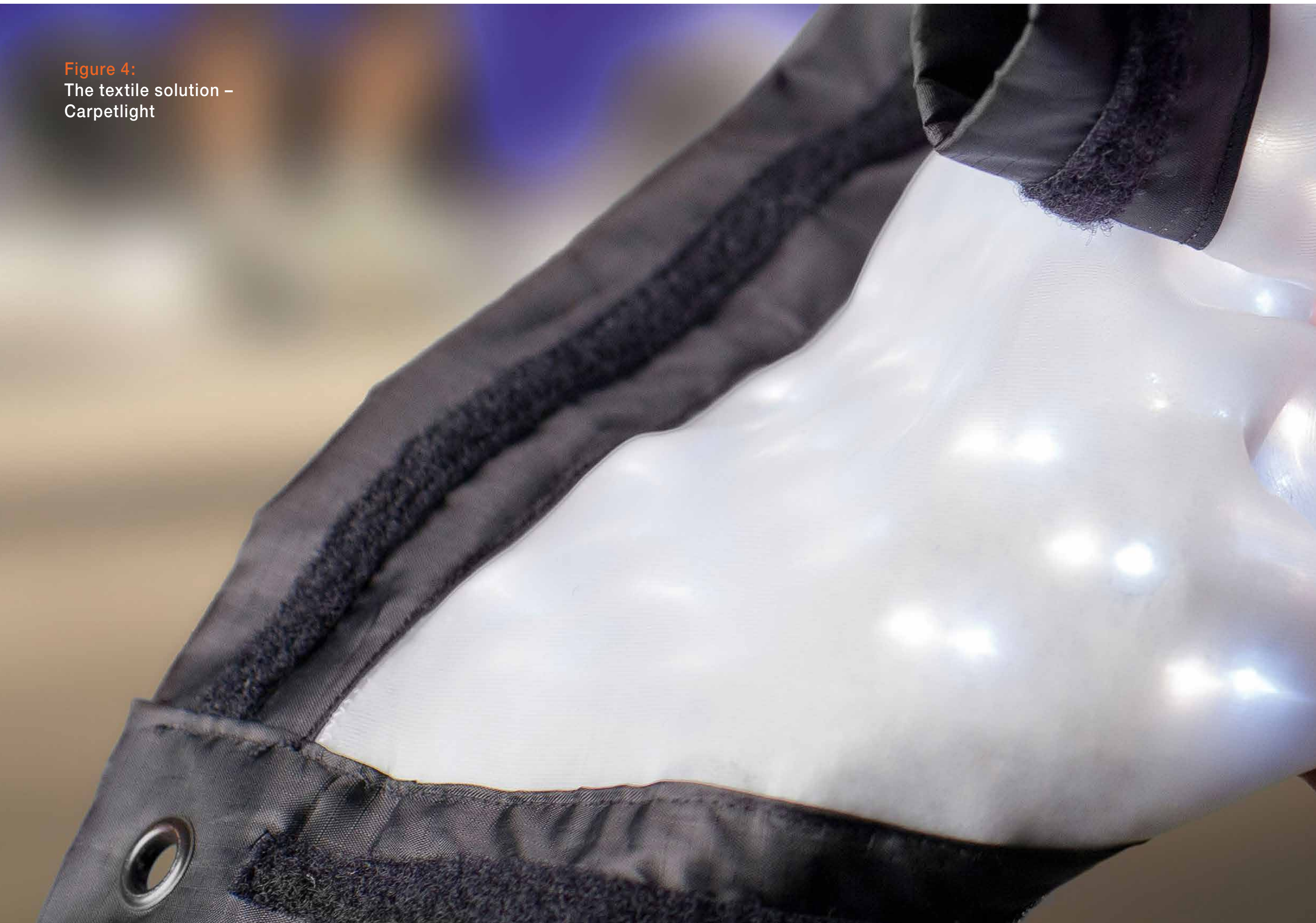


Figure 4:
The textile solution – Carpetlight

The standard 2x1 ft. model features a high CRI tunable white reaching from 2,800-5,400 K. Two white LED's are used to cover the CCT range that's essential when using movie or TV cameras.

It features low weight (300 g) and high luminous output (8,000 lm). For use as a standard floodlight an aluminum frame is supplied to take up the textile lamp and keep it in a rectangular shape. Velcro fasteners and metal pins are used to fix accessories as diffusers and directing grids.

Driven by a combination of high frequency PWM for ultra fine low light dimming and constant current control the flicker free operation is guaranteed to make sure various camera shutter systems can be operated simultaneously when using the light.

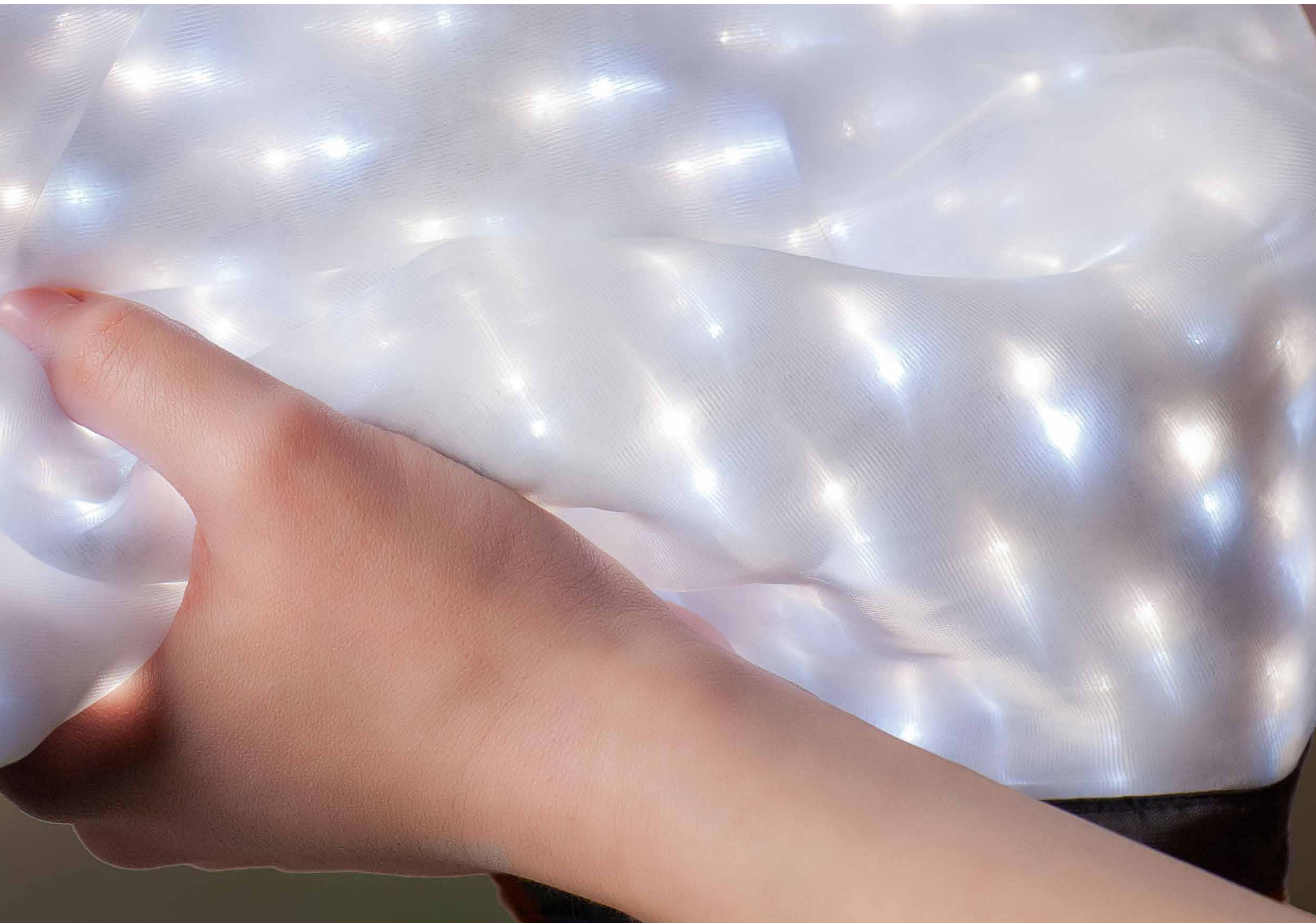
The control unit is powered by an external AC/DC power supply or any DC voltage between 12 and 36 Volts, as is common in the media industry. It can be operated manually to change light intensity and color temperature or by DMX protocol to be remote controlled.

The weight of the control unit is 800 g, making the system the most lightweight floodlight on the market.

Conclusions

The application scenarios for textile-based lighting can be transferred from its current use in the media industry to other fields. All its options can be changed and adapted to the customer's demands. Different LED combinations, lower LED pitch, variations in fabrics and the use of standardized LED drivers are possible. For example, the outdoor industry is permanently on the hunt for lightweight solutions and things that can easily be packed up and taken along by the modern customer. Creating built-in lights in tents and canopies, generally in textile structures, was the first step taken. In order to do this the basic protection features of the textile lighting module had to be enhanced. So far coatings of the outer shell and optical cover fabric worked as water and dust repellent but now polyurethane and silicon coatings were necessary to seal the light emitting part itself, to withstand harsh environmental conditions. Other possible use cases are exhibitions, fairs, presentations both indoor and outdoor, basically any non-permanent structure that requires low weight, quick installation and low power consumption lighting.

In the field of interior design, curtains and acoustic fabrics could be "enhanced" with a lighting option adding a new functionality without changing the basic characteristics of the materials used.



Botanical Light Pollution - Red is the New Blue

In the beginning, the industry argued that LED lighting could help reduce light pollution. Meanwhile, various organizations claim the opposite effect is true and often sight light color as an issue. The opinions of different groups are frequently quite the contrary to those of other groups. Ian Ashdown, FIES Chief Scientist at byHeart Consultants & Lighting Analysts, demonstrates and discusses the negative effects of light pollution through LED lights and how different light sources affect vegetation.

Blue-rich light from LED streetlights, we are told, is the nemesis of professional and amateur astronomers. Blue light is preferentially scattered by the atmosphere, resulting in potentially unacceptable levels of light pollution for astronomical observations. Unfortunately, LED streetlights emit more blue light on a per-lumen basis than the high-pressure sodium streetlights they are rapidly replacing.

Botanists and horticulturalists, however, may choose to differ. For them, it is red light from streetlights that is the problem. Depending on the species and various environmental factors, even low levels of light trespass from roadway and outdoor area luminaires can have harmful effects on both wild and domesticated plants. LED streetlights likewise emit more red light on a per-lumen basis than high-pressure sodium streetlights.

This is not a newly discovered problem. Botanists were aware of the deleterious effects of incandescent street lighting on trees eighty years ago (Matske 1936), while horticulturalists became aware of the problem with respect to ornamental plants some forty years ago (Cathey and Campbell 1975).

The lighting community can perhaps be excused for not following the latest research in publications such as American Journal of Botany and Journal of Arboriculture, but the community was in fact made aware of the issue through publication of an article in Lighting Design and Application (Cathey and Campbell 1974). However, given that the proposed solution then was to avoid using high-pressure sodium (HPS) lamps and instead use less-efficient mercury-vapor lamps with their ghoulish color rendering capabilities … well, understandably the advice was ignored.

Soybeans and Trees

This is not to say that farmers are not aware of the problem. If you are growing soybeans, you quickly learn not to plant them in a field adjacent to HPS roadway lighting (Figure 1). The nighttime illumination - even as little as two to eight lux - can reduce crop yield by 20 to 40 percent due to delayed flowering and ripening (Chen et al. 2009).

Landscape designers and arborists are also aware of the problem. A publication from Purdue University, for example, lists 65 trees and shrubs that are vulnerable to artificial light (Chaney 2002). Exposure to nighttime illumination, particularly from HPS street lighting, may result in disruption of the plant's shoot growth, flowering, leaf expansion and abscission, and bud dormancy. In temperate climates, this may make the plants more susceptible to frost, fungal infections, and insect infestations. Again, however, the advice was to avoid using HPS lighting and use mercury vapor lighting instead. For lighting designers, this is pointless advice - mercury vapor lamps were long ago replaced by high-pressure sodium lamps, and these in turn are being replaced by solid state lighting … and herein lies today's issue.

Figure 1:
Effect of light pollution on soybean crop. - Poor growth and crop yield (Source: Chen et al. 2009)

LED-based outdoor lighting may - and the emphasis is on the word may - exacerbate the problem from the perspective of wild and domesticated plants. High-pressure sodium lamps emit much more red light than mercury vapor lamps on a per-lumen basis, and white light LEDs may (depending on their correlated color temperature) emit even more. What was once a minor problem for landscape designers and urban arborists may become something that lighting designers will need to consider.

To better understand this issue, it is at first necessary to understand the role of photopigments in plant growth and development.

Phytochrome

Plants perform their magic of photosynthesis using a photopigment called chlorophyll, but this is only one of many different photopigments plants use to harvest and detect light. Equally important is phytochrome, which regulates a long list of plant functions.

Some plant functions that are regulated by phytochrome:

- Seed germination and development
- Stem elongation
- Leaf expansion and abscission
- Photosynthesis development
- Flowering
- Ripening
- Dormancy

Taken together, these functions basically outline the life cycle from seed to adult plant.

The sum of these light-induced changes is called photomorphogenesis. There are other photopigments involved, including blue light-sensitive cryptochromes (Lin 2002) and ultraviolet-sensitive UVR8 (Goto et al. 2006, Kami et al. 2010). However, it is phytochrome that dominates plant growth and development.

Phytochrome itself is an interesting pigment in that it has two states (or isoforms) called Pr and Pfr (e.g. Smith 2000). The Pr isoform strongly absorbs red light, with a spectral peak at about 660 nm (Figure 2), making it look turquoise-blue when dissolved in solution. This is its biologically inactive state.

When a phytochrome molecule absorbs a red photon, it switches to its Pfr isoform, making it look slightly more greenish. This is its biologically active state, which signals to the plant that red light has been sensed. While in this state, phytochrome has a different spectral absorption distribution (Figure 2), with a spectral peak at about 730 nm. (Horticulturalists and plant biologists refer to the spectral range of 700 nm to 800 nm as “far-red,” which explains the “fr” subscript.)

When the Pfr isoform absorbs a far-red photon, it reverts to its Pr isoform. Thus, phytochrome performs the function of a resettable biological switch to initiate or terminate photomorphological processes.

This biological switch behavior has some interesting consequences. While even low levels of red light can initiate many physiological responses, applying far-red light soon thereafter may reset the switch and terminate the response. Light pulses as short as one minute at night - think car headlights on a country road - are enough to induce or prevent the flowering of some plants (Borthwick et al. 1952). Worse, some plants have flower induction thresholds of less than four lux (Botto et al. 1996, Whitman et al. 1998).

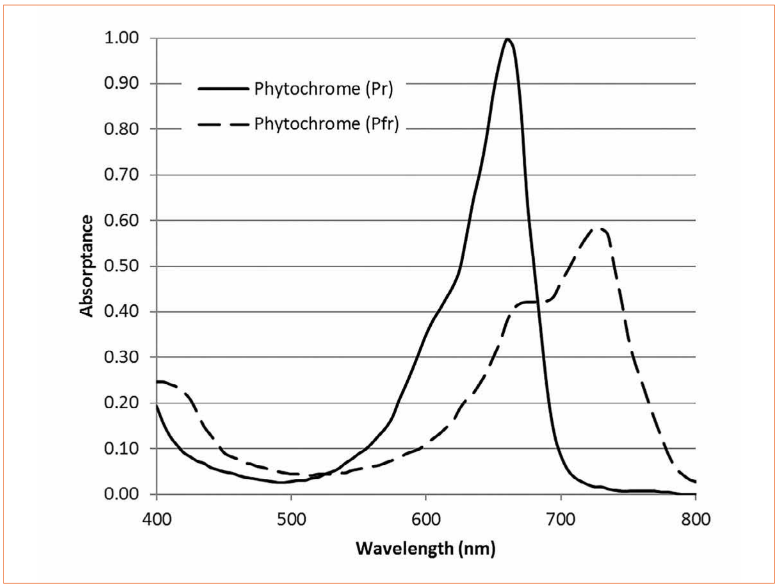


Figure 2:
Phytochrome absorption spectra. (Source: Plants in Action, First Edition [I])

Photoperiodism

Phytochrome may act as a biological switch, but how plants respond to its signaling varies by species and even cultivar. What all plants have in common, however, is photoperiodism, their physiological reaction to the length of the day. Like humans and all other animals, plants have circadian rhythms.

In terms of flowering, plants can generally be divided into three categories:

- short day
- long day
- day-neutral

For short day plants, flowering is initiated, advanced, or promoted when the dark nighttime period is sufficiently long to allow enough phytochrome Pfr to revert to Pr. For long day plants, the opposite is true: flowering is initiated, advanced, or promoted when the dark nighttime period is sufficiently short to increase nighttime levels of phytochrome Pr. As for day-neutral plants, their time of flowering is determined by other environmental cues, such as temperature and moisture.

From the perspective of wild and domesticated plants growing outdoors, artificial light can be a problem. For horticulturalists, however, it can be a boon. Florists have long used incandescent lamps with their copious red and infrared emissions to modify the growth and development of flowering plants in greenhouses. This promotes flowering in long day plants such as asters, azaleas, and fuchsias, while delaying flowering in short day plants such as chrysanthemums, begonias, and poinsettias.

The recent availability of high-power red and far-red LEDs has provided new opportunities for both florists and horticulturalists. Independently switching or dimming these LEDs enables greenhouse operators to precisely control phytochrome as a biological switch. This, combined with the secondary effects of activating cryptochromes using blue light, provides remarkable control of plant growth and development (e.g., Gautam et al. 2015, Islam et al. 2014, Kitazaki et al. 2015, and Lee et al. 2015).

Light Pollution

Outside of the greenhouse environment, however, adding red and far-red radiation to the environment is not a good thing. We can call it what it is: botanical light pollution. For soybean farmers and urban arborists, it may be a nuisance. However, there can also be more insidious and detrimental effects for wild plants and the pollinating insects that depend on them (e.g. Bennie et al. 2016).

The question is how to quantify this pollution? It is reasonably easy to quantify astronomical light pollution because there are comprehensive mathematical models of atmospheric physics and optics. However, the best that botanists can do for us is to identify plants as short day, long day, or day neutral.

Pragmatically speaking, there is no need to quantify botanical light pollution in an absolute sense of so many micromoles of radiation per square meter per second or whatever. From a lighting design perspective, the goal is to illuminate an area with so many lumens per square meter while doing our best to prevent wasted spill light. The question then becomes, what is the best light source for plants?

Comparing Light Sources

The phytochrome absorptance spectra (Figure 2) were obtained by extracting phytochrome from plants and dissolving it in solution for analysis in vitro with a spectrophotometer. When in the plant itself, however, phytochrome is surrounded by other photopigments, especially chlorophyll. Both chlorophyll A and chlorophyll B have absorptance spectra that overlap with those of the phytochrome isoforms (Figure 3), so it is reasonable to ask whether this influences (or “screens”) the phytochrome absorptance spectra in vivo.

Fortunately, a variety of studies of the effect of monochromatic radiation on plant growth and development have shown that the absorptance spectra of phytochrome in vitro reasonably predict the plant physiological response. For example, Withrow et al. (1957) studied the “induction and reversion of hypocotyl hook

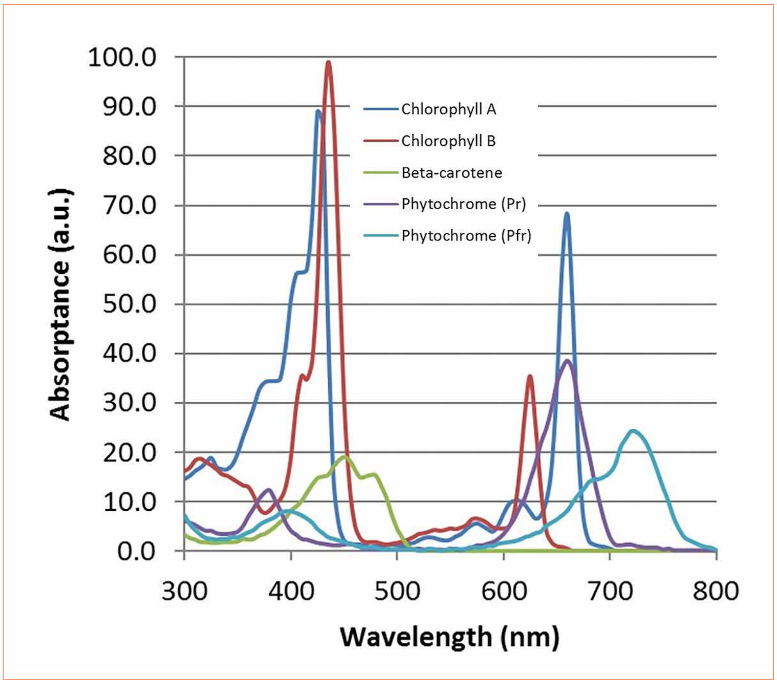


Figure 3: Photopigment spectral absorptances.

opening" in bean seedlings. A plot of their results as induction and reversion "action spectra" shows a remarkable correlation with the in vitro absorptance spectra of phytochrome (Figure 4).

Given this, the phytochrome absorptance spectra can be used as a species-independent measure of the effect of red and far-red radiation on plant growth and development (Sager et al. 1988). For a given light source, the probability of a phytochrome molecule absorbing a photon with a given wavelength is determined by the absorptance spectra of the isoform and the relative number of photons with that wavelength.

For a light source, typically its relative spectral power distribution (SPD) is given, which is measured in watts per nanometer. However, from the Planck-Einstein relation, it is known that a photon's energy is inversely proportional to its wavelength. Therefore, to determine the relative spectral photon flux distribution, one needs only to multiply the lamp SPD by the wavelength for each wavelength and normalize the resultant graph (Figure 5).

With this, now the means are available to compare light sources with different spectral power distributions.

Given a reference lamp (e.g. HPS) and a test lamp (e.g. a 3000 K warm white LED), the calculations consist of:

- Multiply the SPD values of each lamp by the CIE 1931 luminous efficiency function V(λ) shown in figure 6 from 400 nm to 700 nm
- Sum the results of Step 1 to obtain the relative lumens Φref and Φtest generated by the two lamps
- Multiply the SPD values of the test lamp by Φref / Φtest

The two SPDs now represent the same number of photopic lumens (i.e., luminous flux) emitted by the lamps.

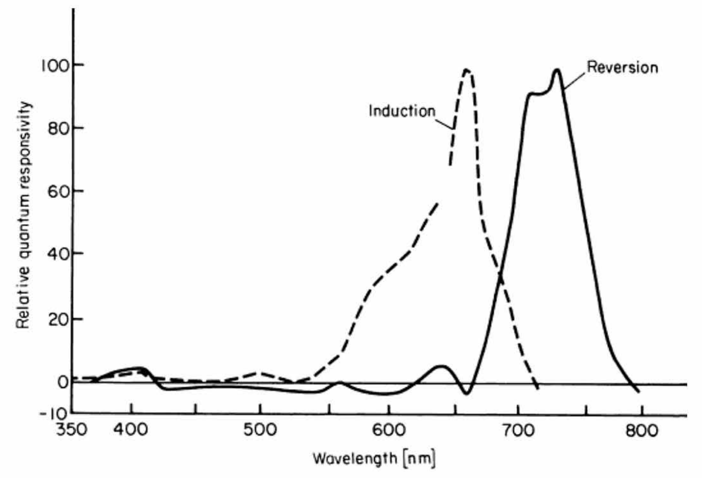


Figure 4: Typical phytochrome action spectra. (Source: Smith 1977)

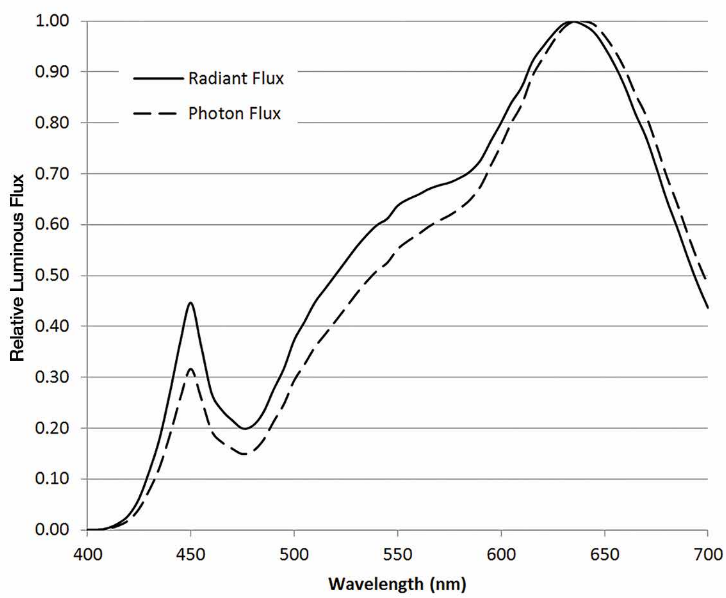


Figure 5: Radiant versus photon flux for a 3000K warm white LED

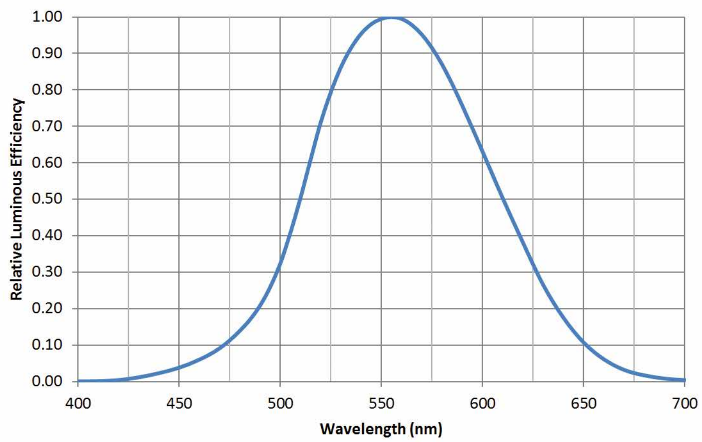


Figure 6: CIE 1931 luminous efficiency function V(λ).

With this:
- Multiply the SPD values of each lamp by the wavelength to obtain the lamp spectral photon flux distributions from 500 nm to 800 nm
- Multiply the results of Step 4 by the phytochrome Pr spectral absorptance spectrum
- Sum the results of Step 5 to obtain the Pr action values pAref,r and pAtest,r
- Multiply the results of Step 4 by the phytochrome Pfr spectral absorptance spectrum
- Sum the results of Step 7 to obtain the Pfr action values pAref,fr and pAtest,fr

And finally:
- Add the Pr and Pfr action values for each lamp to obtain the lamp phytochrome action values pAref and pAtest
- Divide pAtest by pAref to obtain the relative action value for the test lamp compared to the reference lamp

A few explanatory notes:
- Figure 2 clearly shows that the phytochrome absorptance spectra have secondary peaks in the near-ultraviolet. These are ignored because it is difficult to disentangle the effects of phytochrome from the effects of the blue-sensitive cryptochrome photopigments, and the photomorphological effects of blue light are less pronounced than those resulting from red and far-red radiation. The lower limit of 500 nm was chosen based on the phytochrome absorptance spectra minima
- The spectral peak of Pfr is only 60% that of Pr, but the area under each spectral curve between 500 nm and 800 nm is almost the same. Also, phytochrome action spectra for various plant species have shown that equal red and far-red radiant fluences at the spectral peaks of 660 nm and 730 nm have approximately equal effect on the physiological responses. This justifies the final step of adding the two action values

It must be emphasized that these "action values" are approximate at best, and should not be considered as formally quantifiable metrics. They are introduced here only to explore the potential effects of botanical light pollution.

With this caveat then, the light sources were selected for comparison according table 1.

The HPS lamp SPD was measured in the laboratory with 0.1 nm resolution and averaged to 5 nm bins, while the Lumileds SPDs were digitized from the published datasheet.
The equal-lumen SPDs for these light sources are shown in Figure 7.

Following the calculation procedure with the HPS lamp as the test source, the relative phytochrome action values are as shown in table 2.

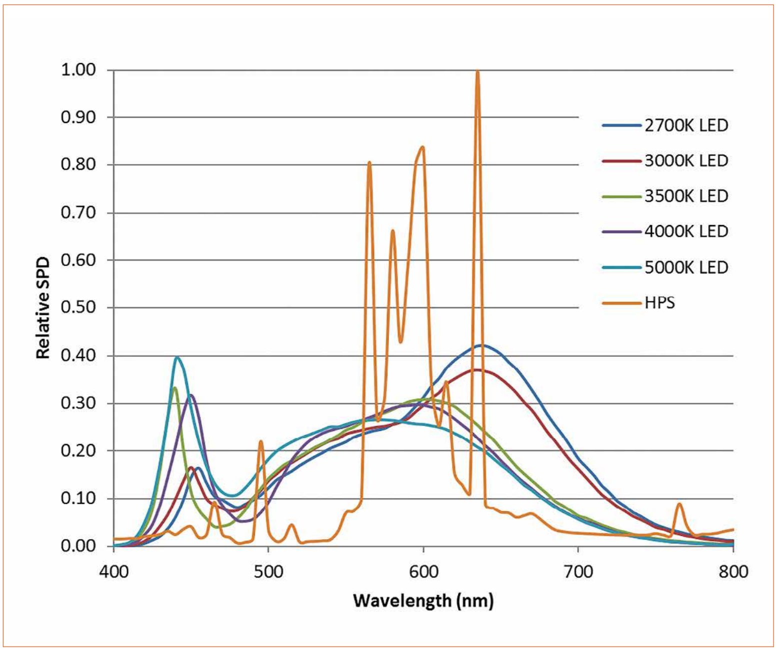
Table 1:
Compared light sources

Light Source	Manufacturer Product Code
High-pressure sodium (test)	Damar 1782 LU100M
2700 K white light LED	Lumileds LUXEON Rebel ES LXW9-PW27
3000 K white light LED	Lumileds LUXEON Rebel ES LXW9-PW30
3500 K white light LED	Lumileds LUXEON Rebel ES LXW8-PW35
4000 K white light LED	Lumileds LUXEON Rebel ES LXH7-PW40
5000 K white light LED	Lumileds LUXEON Rebel ES LXW8-PW40

Table 2:
Relative phytochrome action values

Light Source	Relative Phytochrome Action Pr	Pfr	Pr + Pfr
High-pressure sodium	1.0	1.0	1.0
2700 K white light LED	1.7	2.3	1.9
3000 K white light LED	1.5	2.0	1.7
3500 K white light LED	1.0	1.2	1.1
4000 K white light LED	1.0	1.0	1.0
5000 K white light LED	0.9	1.0	0.9

Figure 7:
Equal-lumen spectral power distributions



From this, it can be seen that while 2700 K and 3000 K white light LEDs produce the least astronomical light pollution, they also unfortunately produce the most botanical light pollution.

It should be noted however that these results apply to Lumileds LUXEON products only. Looking at Figure 7, it is evident that the 2700 K and 3000 K products use a different phosphor formulation than the 3500 K, 4000 K, and 5000 K products. Different major LED manufacturers will have their own proprietary phosphor formulations, and so the above results should not be applied to LEDs based solely on their nominal CCTs.

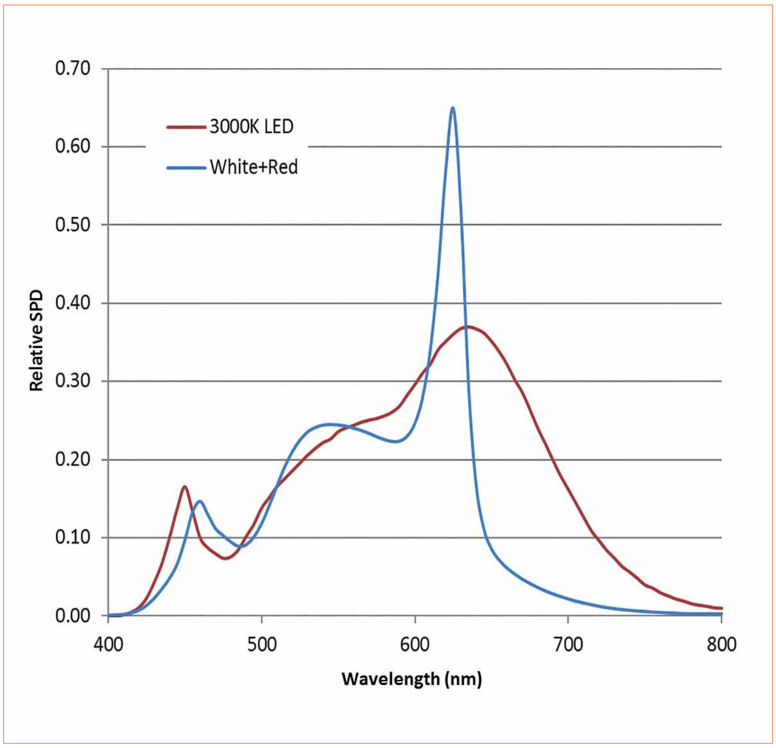


Figure 8: 3000 K LED versus 3145 K white+red LED equal-lumen spectral power distribution

Add More Red

It seems counterintuitive, but one solution to the problem of excess red light generated by low-CCT LEDs is to add more red light.

Some of the early LED modules combined phosphor-coated white and red LED dice in order to compensate for the low-efficiency red phosphors then available. This produced a warm white light with good CIE Ra values, but relatively poor R9 values due to the quasimonochromatic red emissions.

One roadway luminaire manufacturer has recently taken this approach with a new product line that was reportedly designed to comply with the International Dark Sky Association's Fixture Seal of Approval program requirements for a maximum CCT of 3000 K. While the approach works (with a measured CCT of 3145 K), the massive spike in red light peaking at 625 nm (Figure 8) would seem to be a botanist's nightmare spectrum.

Table 3: White+red relative phytochrome action values

Light Source	Relative Phytochrome Action		
	Pr	Pfr	Pr + Pfr
White+red LED	0.9	0.9	0.9

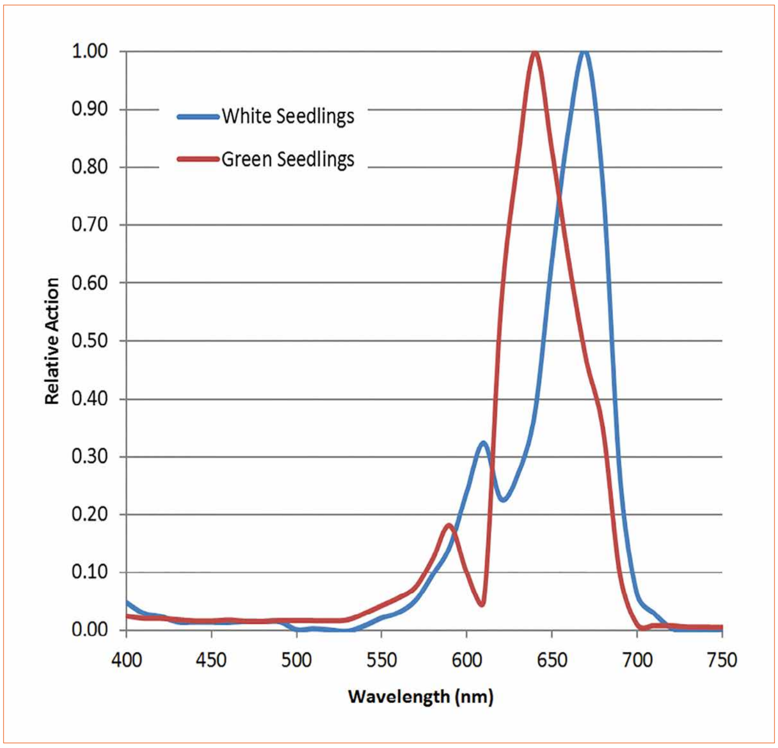


Figure 9: Chlorophyll screening of phytochrome Pr action spectrum. (Source: Beggs et al. 1980)

Surprisingly, the situation may not be as bad as it appears. First, there is relatively little far-red radiation being emitted. Second, the 625 nm peak occurs where the phytochrome Pr absorptance spectrum is only 50% of maximum. This results in a calculated phytochrome action value (relative to the HPS reference lamp) of 0.9 - half that of the 3000 K LED.

Color Filters

Another solution to the problem of excess red light is simply to add a color filter with a sharp cutoff at 625 nm. Red light beyond the cutoff wavelength contributes only ten percent to the luminous flux of a 3000 K white light LED, so it is may be a reasonable tradeoff. (The resultant color will, however, be slightly cyan in hue.)

Whether it is possible to develop a suitable dye or coating for the LED optics that is both inexpensive and resistant to fading is, of course, an open question.

Chlorophyll Screening

The preceding analysis necessarily assumes that the phytochrome is not screened by the other plant photopigments, and that the isoform absorptance spectra represent the phytochrome action spectra for any given plant. In practice, this is not necessarily true. Phytochrome is present in very low concentrations in plant tissues. As a result, the much higher concentrations of chlorophyll tend to screen phytochrome by absorbing much of the incident red radiation. (Figure 3 - spectral overlapping between phytochrome Pr and chlorophyll A.)

A study by Beggs et al. (1980) demonstrated that if mustard seedlings are treated with the herbicide Norflurazon, the chlorophyll in the plant tissue becomes photobleached, resulting in white rather than green seedlings.
With white seedlings, the phytochrome action spectrum had a peak at 660 nm, following the phytochrome Pr absorptance spectrum.
With untreated green seedlings, however, the action spectrum was shifted to approximately 630 nm - which is well within the range of the 625 nm LED emission of the white+red LEDs (Figure 9).

Summary

First and foremost, the phytochrome action metric presented in this article is not intended as a formal light source metric in any sense; it was introduced solely as a means of evaluating the potential impact of red and far-red light on both wild and domestic plants.

Second, the effects of applying red and/or far-red radiation will depend on the physiological state of the plant, the physiological response being mediated, and the time of application. Any excess (i.e. artificial) red radiation will convert the Pr isoform in the exposed plant to Pfr, while any excess far-red radiation will convert the Pfr isoform to Pr. Either action will upset the plant's phytochrome photostationary state (Sager et al. 1988). What effect this will have on a given plant species at any given time of the night and season is unknown.

While phytochrome may function as a biological switch for plants, how individual plants species respond to its signaling will vary.

Given that phytochrome mediates so many plant functions, the botanist's characterization of short day, long day, and day neutral flowering plants is probably about all they will have in common.

If the above analysis has shown anything, it is that by changing roadway and outdoor area lighting from high-pressure sodium to white light LEDs, it is possible - and again, the emphasis is on is possible - to upsetting the ecological balance in unexpected ways. By examining what is known and applying it on a theoretical basis, we can at least be better prepared to respond in the future if needed. ■

Notes:

[I] Plants in Action is a plant physiology textbook published by the Australian Society of Plant Scientists, New Zealand Society of Plant Biologists, and the New Zealand Institute of Agricultural and Horticultural Science. It is freely available online at http://plantsinaction.science.uq.edu.au

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LEDs Reveal Paintings Hidden in Paintings

Artists are often early adopters of new technologies and new solutions and methods that bring art to a new level. For fine arts artist, light and their material are the two major elements to play with. It's no wonder that LED lighting has become an important element for them. The artist, Clint Eccher, and Arno Grabher-Meyer from LED professional show how LED lighting is used to transform static paintings into some of the most advanced paintings in the world, in dynamic, "living" pieces that transform their appearance with LED light. Clint Eccher's work, how it is done, and the role of LED technology will be explained.

Since the very first cave paintings more than 30,000 years ago, such as Chauvet Cave in France and even older paintings recently discovered in Indonesia, paintings have been comprised of one static image and message. The new "Tiered Painting" method involves hiding a tier or painting (called "hidden tier") inside another tier ("visible tier") and then using LED lights to reveal the hidden tier.

And that's just the beginning. The hidden tier can be revealed with just white LED lights. When RGB LED lights are used, however, the colors of the paintings react to the changing LED light colors, creating a feeling of movement.

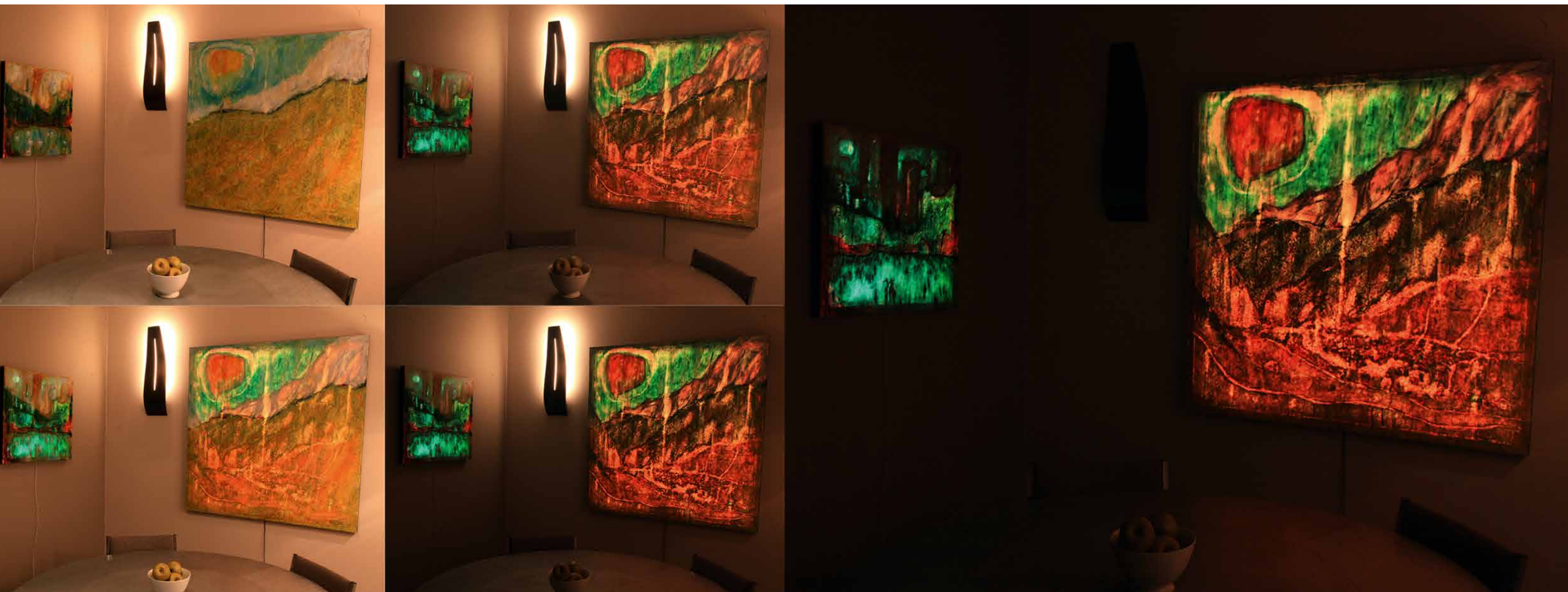
And then there is another stage. By adding a music controller, the lights can then change with the beats in the room, making the lights and painting sound-reactive.

LED technology exponentially increases the options a painter now has to work with. LED lights have the potential to completely alter painting and the traditional fine art world. An artist can now communicate so much more. Not only can two paintings be included in one piece, but there are also other states of those two paintings that exist by manipulating both the room lighting and LED colors.

How Tiered Paintings Work

Tiered paintings don't require any special material. They are painted on traditional canvas with every day acrylic paints and palette knives. It's an amazingly simple method. It requires nothing new for painters, except imagination. In the end, all they have to do is attach LED strip lighting to a back panel, which is then attached to the back of the painting. The light then shines through the canvas and paint to reveal both paintings and/or various states of them, depending on the lighting of the room.

While this sounds like a very easy task, modifying this method has been essential for the paintings to work in all lighted situations. It not only has to make the paintings work when the LEDs are turned off in a



Figures 1a-e:
Tiered Paintings work in rooms with all types of lighting levels and conditions and change their appearance depending on the LED backlighting intensity and color

normally lit room, as well as with the LEDS on in a darkened room, but they have to work for lighting in between the two extremes (Figures 1a-e).

While Tiered Paintings work best in a darkened room, it is possible to paint them in a way that makes them work in all lighting conditions. A new painting style enables enough light to show through the visible tier so that it lights up in a normally lit room. Some paintings are an amalgamation of the two tiers, while others simply glow. Either way, it's a subtle, magical feeling when you see a painting that looks alive in the middle of the day.

While there is great potential for the painting method to be adopted by artists around the world, for that to happen, similar LED light boards would need to be manufactured and made to be easily assembled because many artists don't have the technical expertise or interest to figure out to how build their own boards.

Basic LED System Configuration

Currently, strip lights with 5050 SMD LED RGB 150/300 are mounted in rows on the plywood back panel. They are connected to a standard LED driver, along with an RF, IR, and WiFi LED controller to make it easy for the patron to turn the paintings on and off - or even program the lighting sequence and timing from a smart phone.

We can assume that most artists won't have the time, patience or money to experiment with all the different brands of products. To find the current solution, hundreds and thousands of dollars were necessary to figure out what works best in terms of lights, quantity of lights, controllers, and various LED drivers. However, there is still a lot of room for improvement.

Due to the costs and controls effort, up until now no RGBA or RGBW lights strips were used, but there are indications that they could have advantages over the current RGB solution or allow additional subtle effects. The complexity involved with Tiered Painting, ironically, adds to the ease of creating the right color at the right time.

Controlling the Color

It is very likely that quite similar results can be achieved when adding white or amber because the color of the lights can also be controlled with the paint. Tiered Paintings are already difficult in terms of color because the artist not only has to consider the colors of the hidden tier, but also the colors of the visible tier. When adding all the various colors of the LED lights, it becomes more complex than any other painting method. The good news is that with all these options, the artist can create nearly any color they want. Therefore, Tiered Painting is one of the most technically difficult and advanced painting methods in the world. There isn't just one static layer.

From an artistic point of view, not only do the color issues to being considered, but also the composition and message as multiple paintings and states of the paintings working together has to be taken into account. There is something exciting about working with such a challenging painting method that allows the artist to go where no one has gone before. Traditional paintings are much less exciting because with Tiered Paintings, the artist has to wait for the finished painting including the technical elements to see what else the painting has to say.

Technology Versus Artistic Sensitivity

Tiered Painting didn't exist before LED's because the heat emitted by earlier light sources like incandescent, was not safe for paintings. Moreover, the UV light emitted by those sources has also proven to be harmful. Fortunately, LEDs don't produce UV rays, which is the leading source of paint degradation. What hurt the reputation of LEDs illuminating paintings was an erroneous report in 2013 claiming that LEDs were damaging the chrome yellow in Van Gogh's sunflower paintings [1]. It turned out that the lights they were testing weren't LED after all and that version of yellow paint is much more lightfast than it was 100 years ago, if used at all.

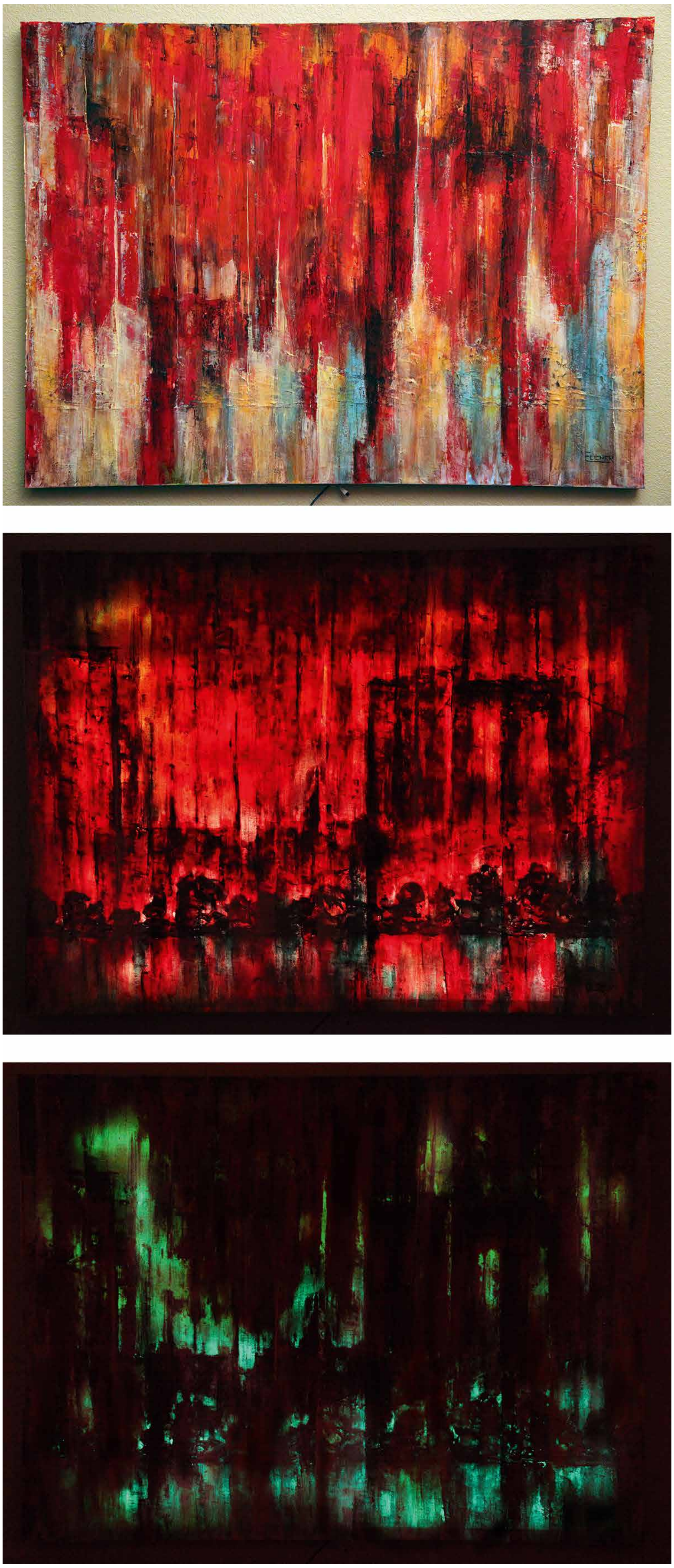
Despite the emergence of LED technology, the fine art aspect of the paintings needs to be maintained and the right balance has to be found. An artist's imagination can run wild with the possibilities of LEDs that can be programmed to create ever more advanced paintings. But true art needs to be able to stand alone as a work of art without the lights. Without the light board, holding a painting up to the sun, one can still see the magic of the hidden tier inside the visible tier. Employing more advanced methods of lighting for this work makes the artist dependent on a technology that may or may not be around 100 years from now. But the artist has the freedom to choose which way they will go.

Documenting and Presenting Tiered Paintings

While LEDs enable Tiered Paintings to exist, they make documenting them challenging. Moving and changing colors do not lend themselves to a static photo. Therefore, for an artist, discovering Tiered Painting is like getting off a ship and reaching an undiscovered land, but there's not much point in discovering a new land if one can't document it. Tiered Paintings can't be adequately shown by static photos, and it's difficult to video them. It might be necessary to hire a professional videographer.

Personal and practical experiences

Not being a technician, especially not an LED driver expert, means having



Figures 2a-c:
The painting "Future, Past, Present" demonstrates how LED colors and paints interact

to play around with LEDs and drivers. With the available LED drivers, a video camera that could have its frame rate modified to coincide with the refresh rate of the drivers necessary. Six tested video cameras did not work and then a professional videographer was found that had a camera that could modify the frame rate as needed.

Basically, what happens is that the used LED driver is refreshing the lights unsynchronized with a different frequency than the camera's frame rate. This means some of the lights begin fading before the camera could shoot a frame, thus the video captures that darkened bar that moves up the screen. This is similar to the effect that we see when an unsynchronized video camera is used to copy a video from an old CRT monitor.

Finally it emerged that the reason behind these difficulties is that the used driver pulse-modulates the current to set brightness levels and color. A better solution for this problem might be the right choice of the driver [2]. A constant current driver should avoid or reduce this effect because the LEDs are continuously powered on an adequate level. With high quality drivers the current ripple should be negligible. However, there are some remaining issues.

Capturing the color as accurately as possible is also difficult. Not only does the video need to be edited to show the various states and transitions of lighting options of the paintings, but also the colors of the video must also be edited. Otherwise the video does not represent the true character of the painting, as it would be when seen in natural light.

Capturing the actual color of Tiered Paintings is like trying to capture the magic of live music - it is nearly impossible. While trying to get them to be as accurate as possible, there is an inherent difficulty with videoing LED lights because their glow tends to over expose the video and it's always difficult to get those colors close to what the eye sees without degrading the rest of the video. I'm not sure if I'll ever be truly satisfied.

Results

Many of the first 18 paintings were about testing and experimenting. Every painting was painted with a specific aspect of the method to test. Following are a few examples of the work and some of the visual techniques that can be accomplished with it [3]:

"Future, Past, Present"

This painting illustrates how LED colors and paints interact. In the visible and hidden tiers, the painting is red; however, when the LED color turns to green, the reds become almost black, creating an abstract painting of its own in for the hidden tier. Note: The last image does not do a great job of capturing all the light emitted from the painting, as well as the subtle details (Figures 2a-c).

"You're Not Alone"

A sound controller makes painting appear more dynamic and energetic. Such dynamic painting, however, works better with abstract images where the mind doesn't lock onto a literal image (Figures 3a&b).

"The Tuftes"

This painting shows how LED lights can be seen through the visible tier in a well-lit room (Figures 4a-c).

"Cinque Terre"

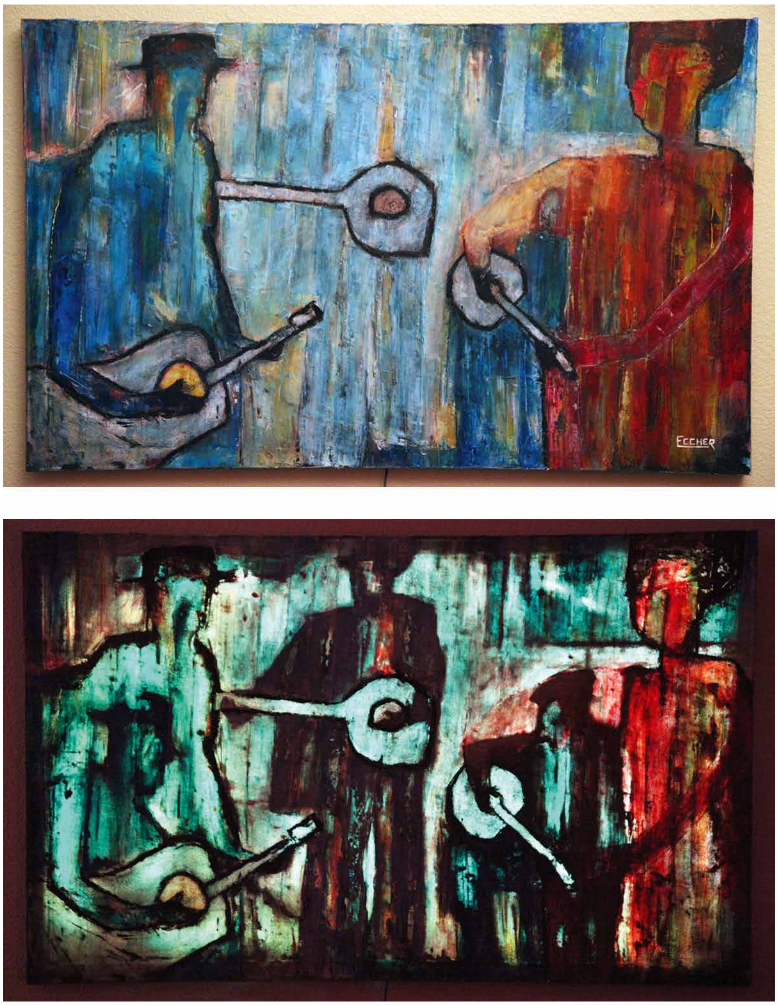
A lot can be communicated between a hidden and visible tier. The visible tier of Cinque Terre shows a woman waiting at a bus stop dreaming about "Italia." The hidden tier shows the woman with her dream man overlooking a colorful and romantic Cinque Terre (Figures 5a&b).

Figures 3a&b: Abstract paintings like "You Are Not Alone" are well-suited to being equipped with a sound controller to generate dynamic paintings

Figures 4a-c: "The Tuftes" show the transformation of a mainly monochromatic appearance to a colored image in a well-lit room, and finally an intense, colorful painting under low-level light

Figures 5a&b: "Cinque Terre" is an example of how beyond changing the color of a painting the content and message of an image can be changed

Figures 6a&b:
The season in the painting "New York, New York" makes a dramatic change from summer to winter



Figures 7a&b:
In "Five Blues"- the surreal appearance of the visible tier is transformed in a more realistic scene when the hidden musicians are revealed

Figures 8a&b:
The shy women in "The Women WIll Play" only come to life when the men disappear in the dark of the night

"New York, New York"

One aspect of Tiered Painting that has proven to impress nearly every time, is changing from one concept or place to a drastically different concept or place. That is the premise behind the New York, New York painting. It changes from swans swimming in a pond on a peaceful summer morning to people ice-skating on that same pond that is now Wollman Rink in New York City's Central Park at night.

"Five Blues"

This painting combines parts of the hidden tier into the visible tier, making the image more surreal and perplexing until the hidden tier is revealed, making the image complete.

"The Women Will Play"

The imagery of the visible tier cannot only remain in the hidden tier, but it can also disappear into it. Moreover, the main imagery in the visible tier can also change as the hidden tier is revealed. In this painting, a conservative version of women turns into them having fun and dancing as the men in the visible tier disappear into the night sky of the hidden tier.

Feedback and Future

While having sold more than one hundred oil paintings over the course of a 16-year career and even more prints of these paintings in stores, no creation has received near unanimous approval.

There is nothing more fun to show than Tiered Paintings because of people's reactions. For example, the reaction of a 70-year-old man who has been to galleries and museums all over the world when seeing a Tiered Painting was, "Holy …!". And if people don't cuss, they're saying things such as, "No way!, "How did you do that?", "Wait, what just happened?", or "This is so amazing" - or they simply laugh in amazement.

People in the professional lighting community are starting to take notice, as well. The Light Center, a professional lighting company in Fort Collins has helped in the marketing of Tiered Painting. "Combining LED lights with fine art takes them both to an

unprecedented level," says Jennifer Guerriero, owner of The Light Center. "I have been in the lighting business for 16 years, and I have never seen anything like these paintings. It's like turning a key and entering into a secret world you never knew existed. The LEDs bring you to a deeper level of a painting's essence."

Promotion of this work has just started. Experts have just recognized these artworks, and every possible avenue to get the paintings out into the world is welcome. There is no question that with the mass growth of LEDs occurring that it's the right time.

There is certainly still potential for technical improvements with regards to using the right LEDs, the perfect drivers and controls. Maybe further cooperation with luminaire manufacturers and LED specialists could lead to an even more spectacular presentation of the artworks. But finally, the technology behind is only the tool to support a great idea coming from an artist's unique spirit of discovery and eagerness to experiment. ■

FACT BOX: HOW TIERED PAINTING ORIGINATED

Back in 2000 when Clint Eccher started painting, he had a studio that faced west on the second floor of his house. As the sun was setting one night, the light began shining through the canvas, illuminating part of the piece with natural light that is impossible to show with paint.

Just before one of his shows in 2015, he decided to test a painting by putting white LED lights behind one of his paintings that was going to be in the show. While he liked the look, he decided to hold off testing the concept until after the show.

Eccher created a test painting and took it into his bathroom and sat down on the closed toilet seat. He and his daughter then turned off the bathroom light and turned on the painting. Once he saw an abstract tree appear through the painting, he knew he had discovered something unique. It wasn't until he used low-end SMD 5050 RGB LED strip lights on another painting that he truly understood the power of what he had discovered. When he changed the LED colors and began to see how the paint colors changed, he realized just how powerful the potential of this new painting method could be.

"It was at that moment that I felt like Jackson Pollack in "Pollack," where the movie shows the wonder and curiosity in Pollack's face when he realized what he had just discovered." He goes on to say, "This method is so powerful, it not only inspires me with way too many ideas, but it inspires those who see the pieces. I can't tell you how many times someone sees one of the paintings, gets really excited, and then says, "You know what you should do…"

Meanwhile Clint Eccher created a video* that shows and explains the Tiered Painting method. At the end of the video, there is a class of fourth graders he shows a painting to. Their reactions are very similar to what adults express, if only in a less overt way.

"That class of students is what I have experienced nearly every time I show the paintings," says Eccher. "It's like the Tiered Painting method transcends my style. No painter's style works for everyone. Still, when people see the paintings, they don't care about my style. They become transfixed at seeing an inanimate art object come alive."

* Video: https://youtu.be/mr4A9oAki-I

References

[1] Commentary: Latest LED Lighting Headline – "The Good, the Bad and the Ugly", Arno Grabher-Meyer, LED professional Review | Issue 38, July/Aug 2013

[2] http://www.xicato.com/technology/dimming-technology

[3] http://www.clinteccher.com/acrylic-paintings-tiered.htm

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Cover-page

Artwork: Thomas Klobassa, ©LED professional 2016

Main Image: Arno Grabher-Meyer, LED professional

Smart LED modules like Xenio's (Bridgelux) "Xenio Point" with different communication interfaces for advanced control options are becoming more frequent on the market

Next LpR

TRENDS & INNOVATIONS
Issue 58 - Nov/Dec 2016

TECHNOLOGY TRENDS

On-Chip Beam Forming Optics Paves the Way for New Luminaire Designs

An LED luminaire's optical system usually consists of primary and secondary optics. This concept always causes a trade-off between light quality, system size, efficiency and light distribution. New concepts to make secondary optics obsolete have already been researched. The article will introduce the first of its kind, beam forming optics approach available on the market. It will explain how it works and how it helps to overcome the limitations of traditional optical solutions for LED lighting. ■

Structured Glass Light Guides for Efficient Lighting

Glass injection molding technology (GIMT) for precision glass optics is a relatively new manufacturing technology. This expertise allows for producing efficient glass optics for LED lighting applications with special properties like undercut geometry or mounting flanges. A lot of progress has been made since it was introduced. The article shows how this improved technology supports making state-of-the-art light mixing structures for RGB/RGBW LED systems. ■

STANDARDIZATION

Flicker Standards and Test Methodss

Much has been written and said about Temporal Light Artifacts (TLAs), but what is essential about them is that they have flicker and/or stroboscopic effects that are undesired changes in visual perception induced by a light stimulus whose luminance or spectral distribution fluctuates with time, for an observer in a certain environment. The article discusses the current status of regulations and measurement standards and proposes a certification to help manufacturers to generate user confidence, and consumers and specifiers to find the right product for an application. ■

RESEARCH

"Best Papers" at LpS 2016: Scientific Award Winner Paper

This year the third LED professional Scientific Award will be presented to the author(s) of the best scientific paper at the LpS 2016. The winning paper, which will be presented at the LpS, and printed in the proceedings booklet will also be published in the 58th issue of LED professional Review. ■

EVENTS

LpS 2016 Post Show Report

At the time of printing, nine product launches were registered for the LpS 2016. For the first time, a number of start-up companies will be exhibiting and showing their newly developed products. Top speakers will talk about system quality, system qualification, smart lighting, IoT and the latest lighting trends. Traditionally, the post show report will give a brief summary of the news, activities, and proceedings of the three days in Bregenz. ■

subject to change

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LED professional Symposium +Expo 2016

The LpS 2016 is Europe's foremost solid-state lighting technology event for experts in industry and academia.

The event covers the building blocks for smart lighting designs of luminaires, lamps, controls, modules and components. It focuses on trends and technologies for future lighting solutions incorporating human centric lighting, Internet of Things, connected lighting and smart controls. The combination of a three-day multi-disciplinary symposium, workshops, forums, international exhibition and networking possibilities is a perfect platform to explore sophisticated semiconductor lighting in the fields of the major lighting applications.

Social Networking Opportunities

- Opening ceremony and expo reception
- Get-Together boat cruise on Lake Constance
- International press conference with more than 25 media partners

International Conference on Lighting Trends & Technologies

- Latest insights from research and industry leaders
- Nobel prize laureate Prof. Shuji Nakamura
- 100+ lectures in 5 conference tracks
- 1500+ professionals from more than 50 countries

International Exhibition for Lighting Technologies & Applications

- State-of-the art showcases for R&D and design engineers
- Cutting-edge products, equipment and services
- Highly-focused B2B sourcing and collaboration platform
- 100+ international exhibitors including the top leaders

Lectures from Renowned Organizations

EU Commission, LightingEurope, Zhaga, EPIC, IBM, NXP, Infineon, Silvair, DALI, Bartenbach, GE, Zumtobel, UniBright, Nichia, Lumileds, Cree, Osram , Fraunhofer, Yole, Holst Center, Joanneum, CSEM, UCSB, Cisco

Interactive Workshops

- Tunable Intelligent Lighting by HI-LED
- IoT & Artificial Intelligence by Jakajima
- Horticultural Lighting by EPIC
- SSL Lighting Measurement by Instrument Systems & TÜV SÜD

Discussion Forums

- Design meets Technology by APIL
- International Solid-State Lighting Alliance by ISA
- Risk Transfer & Investment for the LED Industry by Munich Re
- Alternative Light Sources by Photonics Clusters

Innovation Platforms

- Technical innovations presented by start-up innovators
- Light-Art-Designs by lighting designers and students
- Product launches presented by industry leaders

Interactive Workshops

Saal Bodensee | SEPT 21, 14.00-18.00

Spectrally - Tunable LED and OLED Lighting by HI-LED

This workshop, organized by the EU FP7 HI-LED project, aims to attract the participation of lighting professionals, photonics researchers, lighting manufacturers, end users from European museums, horticulture growers, health care centers, ICT research organizations as well as analysts and investors interested in smart lighting sector.

- Human centric lighting
- Horticultural lighting
- Art work and museum lighting

Saal Panorama | SEPT 22, 08.30-14.00

IoT & Artificial Intelligence by Jakajima

With Jakajima, organizer of the annual IoT Event in Eindhoven and Matchmaker for Innovators.

- IoT and machine learning (AI & IoT)
- Design of IoT & AI solutions
- New business models

Saal Bodensee | SEPT 22, 08.30-14.00

Horticultural Lighting by EPIC

EPIC is the industry association that promotes the sustainable development of organisations working in the field of photonics in Europe.

- Market and technology overview of horticultural lighting
- Latest research, case studies and key drivers of horticultural lighting
- Practical experiences and technology outlook

Seefoyer | SEPT 22, 12.30-14.00

SSL Lighting Measurement by Instrument Systems & TÜV SÜD

Solid-state lighting measurements from basics to recent developments by Instrument Systems GmbH and TÜV SÜD.

- New standard CIE S025
- Measurements with Goniophotometers and Integrating Spheres
- Regulation (EU) 1428/2015
- Application insights to SSL measurements

Discussion Forums

Saal Bodensee | SEPT 20, 14.00-18.30

International Solid-State Lighting Alliance by ISA

Forum with the leading Chinese based SSL organization. ISA members representing 70% of the global SSL industry output.

- ISA industry report 2016 - emerging markets and their developments
- Innovative application of LEDs in different fields and beyond lighting
- Introduction of ISA and its activities
- SSL development in ASIA and the cooperation model
- LEDs insure & LED performance insurance

Saal Bodensee | SEPT 21, 08.30-13.00

Design meets Technology by APIL

Design forum with APIL, the leading association of Italian independent lighting designers.

- Understanding design and technology requirements
- Key and common design criteria in applications
- Practical examples, cornerstones and lessons learned

Saal Panorama | SEPT 20, 14:00-18.30

Alternative Light Sources by Photonics Clusters

Photonics Clusters presenting and discussing new approaches in light sources.

- Overview of alternative light sources
- Technologies and market potentials
- Laser light sources

Seegalerie | SEPT 20, 18.30-20.30

Risk Transfer & Investment for the LED Industry by Munich Re

Forum by Munich Re Green-Tech Solutions in collaboration with DEKRA.

- LED global market trends – the consolidation continues
- Manufacturing risks and long-term warranties as unique selling proposition
- Emerging new risks in cyber, and IoT applications
- Testing of LED performance & warranty back-stop for LED manufacturers
- Financing models and risk transfer solutions for large scale LED investment projects

Social & Special Events

Opening Grosser Saal | SEPT 20, 10.00-10.30

Scientific Award Ceremony Grosser Saal | SEPT 20, 10.00-10.30

Keynotes Grosser Saal | SEPT 20, 10.30-12.00

Exhibition Reception Werkstattbühne | SEPT 20, 12.00-12.30

Press-Conference Parkstudio | SEPT 20, 18.30-19.00

Get-Together Boat Cruise Lake Constance | SEPT 21, 18.30-23.00

Artist Clint Eccher (USA) | Showroom | SEPT 20-22

- Tiered paintings exhibition with LED lighting technology.

LpS 2016 - PROGRAM

EVENT OVERVIEW

DAY 1
STRATEGY

SEPT. 20TH
TUESDAY

Opening

10.00 - 10.30	**Opening & Scientific Award Ceremony** | Grosser Saal
10.30 - 12.00	**Keynotes** | Grosser Saal
12.00 - 13.00	**Exhibition Reception / Opening** | Werktstattbühne & Seitenbühne

Parallel Sessions

14.00 - 18.30	**Lighting Trends** | Seestudio
14.00 - 18.30	**Lighting Intelligence** | Seefoyer
14.00 - 18.30	**Lighting Design** | Propter Homines

Forums

14.00 - 18.30	**International Solid-State Lighting Alliance by ISA** | Saal Bodensee
14.00 - 18.30	**Alternative Light Sources by Photonics Clusters** | Saal Panorama
18.30 - 20.30	**Risk Transfer & Investment for the LED Industry by Munich Re** | Seegalerie

Media Event

18.30 - 19.00	**Press Conference** | Parkstudio

DAY 2
TECHNOLOGY & DESIGN

SEPT. 21ST
WEDNESDAY

Parallel Sessions

08.30 - 18.00	**Light Sources** | Seestudio
08.30 - 18.00	**Smart Lighting Connectivity** | Seefoyer
08.30 - 18.00	**Engineering** | Propter Homines

Forum

08.30 - 13.00	**Design meets Technology by APIL** | Saal Bodensee

Workshop

14.00 - 18.00	**Spectrally - Tunable LED and OLED Lighting by HI-LED** | Saal Bodensee

Evening Event

18.30 - 23.00	**Get-Together Evening** | Boat trip on Lake Constance

DAY 3
SOLUTION

SEPT. 22ND
THURSDAY

Parallel Sessions

08.30 - 14.00	**System Quality** | Seestudio
08.30 - 10.30	**System Qualification** | Seefoyer
08.30 - 14.00	**Applications** | Propter Homines

Workshops

08.30 - 14.00	**Horticultural Lighting by EPIC** | Saal Bodensee
08.30 - 14.00	**IoT & Artificial Intelligence by Jakajima** | Saal Panorama
12.30 - 14.00	**SSL Lighting Measurement by Instrument Systems & TÜV SÜD** | Seefoyer

STRATEGY DAY SEPT TUE 20TH

Time	Lighting Trends	Lighting Intelligence	Lighting Design	Forums
10.00	Grosser Saal **Opening & Scientific Award Ceremony**			
10.30	Keynote | Grosser Saal **Solid-State Lighting in the Framework of Horizon 2020** *Dr. Ronan Burgess* *European Commission, Belgium*			
11.00	Keynote | Grosser Saal **LightingEurope Roadmap 2025: The Smart Lighting Strategy** *Diederik de Stoppelaar* *LightingEurope, The Netherlands*			
11.30	Keynote | Grosser Saal **The Future of LED and LD Lighting Technologies** *Prof. Shuji Nakamura* *University of California, USA*			
12.00	Werkstattbühne & Seitenbühne **Expo Reception / Opening**			
13.00	Seitenbühne **Lunch**			
14.00	Seestudio **Overview of the Global LED Market and Key Technologies** *Emmanuel Dieppedalle* *Lumileds, USA*	Seefoyer **IoT Lighting Businesses and Technologies for Cloud Service Providers** *Niklaus Waser* *IBM, IoT Watson, Germany*	Propter Homines **High Quality Lighting Designs with SSL - Practical Examples and the New Role of Lighting Designers** *Ruarí O'Brien, FILD, Germany*	Saal Bodensee **International Solid-State Lighting Alliance Forum** ISA
14.30	Seestudio **LED Lighting Modules - The Next Growth Opportunity in the Lighting Industry** *Pars Mukish* *Yole Développement, France*	Seefoyer **Scenarios and Use Cases for Smart Lighting Management Systems** *M.Eng. John Sayer* *Johnson Controls, UK*	Propter Homines **Light and Health - Newest Research Findings and Its Applications** *Mag. Wilfried Pohl* *Bartenbach, Austria*	Saal Panorama **Alternative Light Sources Forum** Photonics Clusters
15.00	Seestudio **The LED-Disruption** *Dr. Stefan Kreidler* *onlog, Kreidler Mgt., Switzerland*	Seefoyer **Individual Resistance to the Adoption of Intelligent and Connected Lighting Products** *Prof. Jörg Lindenmeier* *University of Freiburg, Germany*	Propter Homines **Gender and Age Specific Preferences Regarding Lighting Conditions in Activity and Recovery** *Dr. Susanne Schweitzer* *Joanneum Research, Austria*	
15.30	Expo Area **Coffee**			
17.00	Seestudio **Zhaga: Addressing Smart Lighting and Standardized LED Components** *Dee Denteneer* *Zhaga Consortium, The Netherlands*	Seefoyer **IoT Architecture for Future Building Management Embedded Lighting Controls** *Dr. Walter Werner* *Werner Management Services, Austria*	Propter Homines **Cultural Aspects in Lighting Design with LEDs - Case Study Guzhen Town China** *Arch., Prof. Roberto Corradini, Marco Palandella, Roberto Corradini, Italy*	Saal Bodensee **International Solid-State Lighting Alliance Forum** ISA
17.30	Seestudio **Standards for Smart Outdoor Lighting will Futureproof Smart Cities** *MSc. Brian McGuigan* *TALQ Consortium, USA*	Seefoyer **Integrated Controls - Creating the Beach-head for the IoT Invasion** *MA Tom Griffiths* *ams AG, USA*	Propter Homines **Color Quality of LED Illumination: Metrics and Experimental Data** *Dr. Peter Bodrogi* *Technische Universität Darmstadt, Germany*	Saal Panorama **Alternative Light Sources Forum** Photonics Clusters
18.00	Seestudio **LED Recycling for Circular Economy** *Dr. Jörg Zimmermann* *Fraunhofer, Germany*	Seefoyer **Enabling Smart Buildings Through the Internet of Light** *Dr. Christian Moormann* *Tridonic, Austria*	Propter Homines **Vertical and Horizontal Light Distribution Effects for Human Centric Lighting** *Volker Neu* *Vossloh-Schwabe, Germany*	
18.30	Parkstudio **Press Conference**			Seegalerie **Risk Transfer and Investment for the LED Industry Forum** Munich Re
19.00				
20.30				

TECHNOLOGY & DESIGN DAY SEPT WED 21ST

Time	Light Sources	Smart Lighting Connectivity	Engineering	Forum Workshop
08.30	Seestudio **Latest Developments in LED Light Sources: Multi-functional Emitters Delivering Tunable White** *Wojtek Cieplik, LED Engin, USA*	Seefoyer **Lighting Fixtures as IoT Devices** *Justin Jiang* *UniBrite Technology, Taiwan*	Propter Homines **Beyond Distribution: Application Marketing, Engineering and Value-Added Services** *Sebastian Hülck, EBV Elektronik, Germany*	Saal Bodensee **Design meets Technology Forum** *APIL*
09.00	Seestudio **Monocrystalline Garnet Based Lumino-phores in High Power Light Sources** *Tomáš Fidler* *Crytur, Czech Republic*	Seefoyer **Intelligent Control System for Tuneable Light Spectra and Study of the Impact on Humans** *Prof. Blas Garrido, University of Barcelona, Spain*	Propter Homines **Maskless Laser Lithography Based Manufacturing and Replication of Freeform Micro-optical Elements** *Dr. Ladislav Kuna, Joanneum Research, Austria*	
09.30	Seestudio **New Glass-Based Phosphors for White LEDs** *Dr. Franziska Steudel, Fraunhofer, Germany*	Seefoyer **Overview and Trends in Wireless Communication Technologies for SSL** *Luco Lo Coco, NXP, Italy*	Propter Homines **Ultrathin Direct-lit LED Module with Beam Shaping Thin-film Optics** *Dr. Oscar Fernandez, CSEM, Switzerland*	
10.00	Expo Area **Coffee**			
11.30	Seestudio **Direct Mountable Chip, Chip-Scale-Packaging** *Kei Haraguchi, Nichia, Japan*	Seefoyer **DALI 2 - Smart Lighting and Color Control** *Dr. Scott Wade* *DALI, UK*	Propter Homines **Highly Reflective Diffuse and Specular Coatings for Lamps and Luminaires** *Dr. Francois de Buyl, Dow Corning, Belgium*	
12.00	Seestudio **Efficiencies and Color Quality of Latest LED Technologies** *M.Sc.Eng Mauro Ceresa* *Cree, Italy*	Seefoyer **Bluetooth Mesh and the Role of Standards in Widespread Adoption of Commercial Smart Lighting Systems** *MSc.Eng. Szymon Slupik, Silvair, Poland*	Propter Homines **Glass Optics with Micro Structures** *Dr. Ulf Geyer* *Auer Lighting, Germany*	
12.30	Seestudio **Lifetime and Reliability: Design Parameters of Mid-Power LEDs** *Dipl.-Ing. Ingolf Sischka, Lumileds, Germany*	Seefoyer **Security for Lighting in IoT - Group Communication** *Dr. Abhinav Somaraju, Tridonic, Austria*	Propter Homines **Optical Design for Manufacturing - How to Avoid Common Pitfalls** *Dr. Angelika Hofmann, kdg Opticomp, Germany*	
13.00	Seitenbühne **Lunch**			
14.00	Seestudio **A New Binning Approach for White LEDs and Color Space Considerations** *Dipl-Ing. (FH) Alexander Wilm* *Osram Opto Semiconductors, Germany*	Seefoyer **Enhanced Visible Light Communications** *Dr. Majid Safari* *University of Edinburgh, UK*	Propter Homines **Customized LED and Optical Device Packaging** *Dr.Ir. MBA Marco Koelink* *APC, The Netherlands*	Saal Bodensee **Spectrally - Tunable LED and OLED Lighting Workshop** *Hi-LED*
14.30	Seestudio **Achieving Next Generation LED Lighting with Quantum Dots** *Steve Reinhard* *Nanoco Group, UK*	Seefoyer **Digital Power, a Shortcut to Intelligent & Efficient Lighting** *Dipl.-Ing Kurt Marquardt* *Infineon Technologies, Germany*	Propter Homines **Thermal Challenges In SSL Automotive Lighting Applications** *Prof. Mehmet Arik* *Ozyegin University, Turkey*	
15.00	Seestudio **Bio-Inspired White Hybrid Light-Emitting Diodes** *Dr. Ruben D. Costa* *Friedrich-Alexander-Universität Erlangen, Germany*	Seefoyer **Near-zero Flicker, High Power Factor and Deep-Dimming - Eliminating the Supposed Conflict** *M.Sc. Dave Bannister, AccurIC, UK*	Propter Homines **Thermoelectrically Cooled High Power LEDs for Automotive Applications** *Dr. Roman Dekhtiaruk* *SmarTThermoelectrics, Russia*	
15.30	Expo Area **Coffee**			
17.00	Seestudio **OLED Lighting: Technology Status and Manufacturing Capacity** *Dr. James Norman Bardsley* *Bardsley Consulting, USA*	Seefoyer **Advantages and Concepts of SSL Applications Utilizing Advanced Digital LED Drivers** *Mikael Pettersson* *SwitchTech AB, Sweden*	Propter Homines **State of the Art of Thermal Management** *Eduardo Benmayor* *Aismalibar, Spain*	
17.30	Seestudio **Latest Innovations and Breakthroughs in OLED Lighting** *Prof. W.A. Groen (Pim)* *Holst Centre, TNO, The Netherlands*	Seefoyer **LED-Retrofit based on AlGaN/GaN-on-Si Field-Effect Transistor Drivers** *M.Sc. Andreas Zibold* *Fraunhofer, Germany*	Propter Homines **AL Oxide Technology for Device Cooling** *Dr. Michael Naish* *RUSALOX, Russia*	
18.00				
18.30 – 23.00	Boat trip on Lake Constance **Get Together Evening**			

SOLUTION DAY SEPT THU 22ND

Time	System Quality	System Qualification	Applications	Workshops
08.30	Seestudio **Theory and Practical Measurement Results of Modulated Light** *Peter Erwin* *Lichtpeter, Germany*	Seefoyer **Photobiological Safety of SSL: Refining the New Approach** *Leslie Lyons* *Bentham Instruments, UK*	Propter Homines **The Light Pen - LED Direct Write Photolithography** *Dr. Nick Shepherd* *LEDesign, Austria*	Saal Bodensee **Horticultural Lighting Workshop** *EPIC*
09.00	Seestudio **Flicker of LED Light Sources** *Dipl.-Ing. Margret Hedrich-Goeppert* *Neumüller Elektronik, Germany*	Seefoyer **Measurement of Spectral Rayfiles with Conventional Nearfield Goniophotometers** *M.Sc. Ingo Rotscholl* *Karlsruhe Institute of Technology, Germany*	Propter Homines **An Innovative Lighting Control System to Allow Parametric Relations with the Natural Environment** *Dr. Nicola Trivellin* *LightCube & Artemide, Italy*	Saal Panorama **IoT & Artificial Intelligence Workshop** *Jakajima*
09.30	Seestudio **Electrical Overstress Robustness of Latest Generation LEDs for General Lighting** *Dr. Matteo Buffolo, University of Padova, Italy*	Seefoyer **A Photometric Test System for LED Luminaires Based on Solar Panels** *Dr. Efi Rotem* *Ophir Photonics, Israel*	Propter Homines **Software Architecture Implementation for Street Lighting Management** *DI Juan José González Méndez* *ELT, Spain*	
10.00	Seestudio **Life-time Calculation of White HP-LEDs from 16,000 Hours Aging Data** *Dipl.-Phys. Max Wagner* *Technische Universität Darmstadt, Germany*	Seefoyer **Practical Guidelines for Sphere and Goniometer Measurements in View of CIE S 025/E:2015** *MA Mikolaj Przybyla* *GL Optic, Germany*	Propter Homines **Comparison of Reflective and Refractive Optics for LED Light Sources in Outdoor Lighting Applications** *Peter Almosdi, GE, Hungary*	
10.30	Expo Area **Coffee**			
11.30	Seitenbühne **Lunch**			
12.30	Seestudio **Exact Control of Spatial Light Distribution in High Power LED Applications by Silicone Lenses** *Dipl.-Ing. Christoph Baum* *Polyscale & Fraunhofer, Germany*	Seefoyer **Solid-State Lighting Measurements - From Basics to Recent Developments Workshop** *Dr. Denan Konjhodzic* *Instrument Systems, TÜV, Germany*	Propter Homines **Optimization of Roadway Lighting Optics for Environment Adaptive Spatial Light Distribution with Two Channel Independent Dimming Control Capability** *Viktor Zsellér, Budapest University & Arrow Electronics, Hungary*	
13.00	Seestudio **Material Selection for LED Modules in Harsh Environments, Outdoor and Industry** *Dr. Martin Pfeiler-Deutschmann* *Tridonic Jennersdorf, Austria*		Propter Homines **Beam Shaping System for Outdoor Applications** *Dr. Oon Chin Hin* *Temasek Polytechnic, Taiwan*	
13.30	Seestudio **Comparison of Luminaire Ageing with LED Lifetime Test Data** *Dr. Wolfgang Scheuerpflug* *Diehl Aerospace, Germany*		Propter Homines **Compact & Cost Effective Luminaire Designs with On-Board Driver Modules** *Dave van Amelsfoort* *Viapaq Lighting, The Netherlands*	
14.00	**Closing**			

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