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LED professional Review

LpR

The leading worldwide authority for LED & OLED lighting technology information

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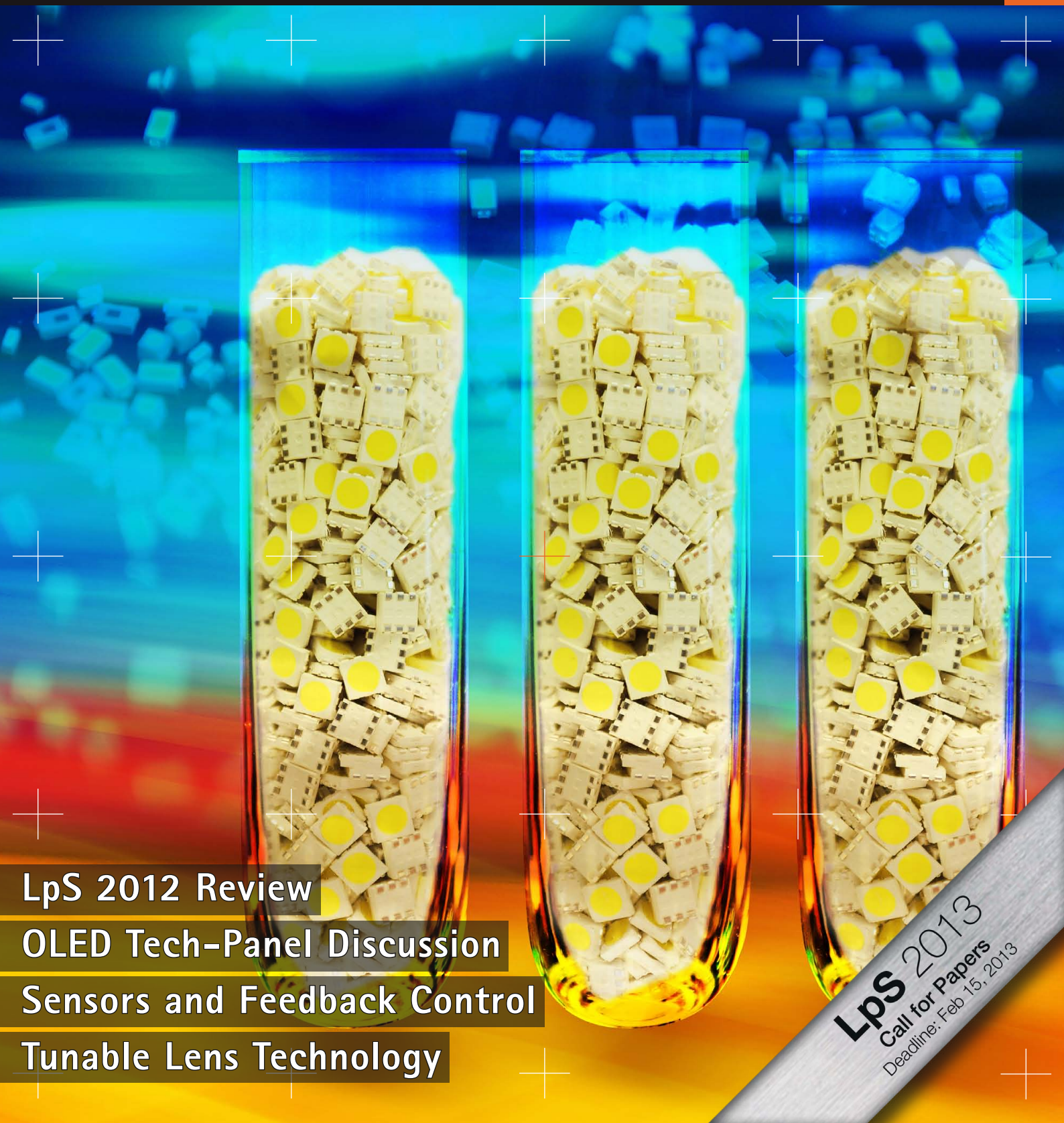

LpS 2012 Review

OLED Tech-Panel Discussion

Sensors and Feedback Control

Tunable Lens Technology

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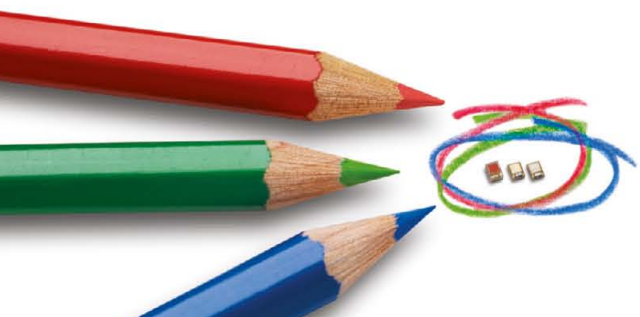

PHILIPS
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Import Duties for LEDs

In June of this year the ELCF (European Lamp Companies Federation) and CELMA (Federation of National Manufacturers Association for Luminaires and Electrotechnical Components for Luminaires in the European Union) published a statement about import duties for LEDs.

The statement said, “The clear distinction between lamps, luminaires and control-gear which was well-defined in the Harmonized System for conventional lighting is not automatically applicable to LED lighting.” This resulted in different classifications for similar products within the European Union. For example, in 2010 the customs office in Germany declared multi-chip LEDs and LEDs with parallel Z-Diodes as luminaries.
The related classification description for this group (HS heading 9405) was: *“Lamps and lighting fittings, incl. searchlights and spotlights, and parts thereof, n.e.s., illuminated signs, illuminated nameplates and the like having a permanently fixed light source, and parts thereof, n.e.s.”*

In this class, custom duties from 2.7% up to 4.7% have to be paid for these “LED luminaires”. Even the 6-year European BTI (Binding Tariff Information) from The Netherlands, which was a free-tariff for the European Union, didn’t make any difference in the validation of the customs office; these components were classified as luminaires.

The European Associations CELMA and ELCF are seriously concerned about the inappropriate classification of LED lighting products resulting, in certain cases, in significant cost disadvantages for the European lighting industry. Transparent guidelines for tariff classes are necessary for countries and customs offices.

As we are looking for a faster market break-through for LED lighting, custom duties are giving out the wrong signal. They particularly hinder the cost-cutting that is necessary to achieve increased demand from the market. The transition from traditional light sources to LED light sources should not be blocked by unnecessary and un-harmonized custom duty taxes.

We want to encourage the responsible persons on state and EU levels to clarify this situation and to enforce energy-efficient lighting according to the guidelines of the EU Green-Paper for SSL by harmonizing the customs tariff-system.

Yours Sincerely,

Siegfried Luger

Publisher, LED professional
Event Director, LpS 2013

Content

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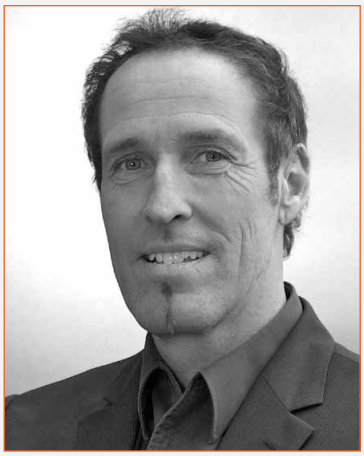

Stephan Wegstein

Stephan Wegstein, Dipl. Eng. studied electrical engineering at the Technical University of Darmstadt/Germany. He entered the Lighting Arena in 2008 as head of EMEA sales for Lighting at Arrow Electronics before he joined RECOM Lighting as VP Marketing & Sales in 2011. When he was responsible for the semiconductor marketing at Arrow in CE he was already focusing on LED technology and required the engineering and sales teams to support customers with this new technology. He has a well founded, deep knowledge of the LED lighting market.

IT'S THE OVERALL SOLUTION THAT COUNTS, NOT THE SINGLE COMPONENT

The LpS 2012 in Bregenz emphasized again that customers from the lighting industry are looking more for solutions and less for components. Without proper support and an understanding of the complete application, the lighting revolution will be prolonged.

As a supplier of LED drivers, the questions that concern us are: What is the best infrastructure? Is the existing distribution channel correct? Will suppliers like us have new responsibilities when completing a product offer in the future?

Are LEDs just one choice among many for creating light? A choice that is possibly more efficient? A choice that has a longer life span? Or are they the beginning of a global lighting revolution? A revolution that will change the rules in a single decade?

Many people today believe that the only answer to the above questions can be an emphatic YES. "Yes" because LED lighting triumphs over efficiency and reliability issues. "Yes" because it adds unlimited versatility. "Yes" because lighting has finally turned "electronic". And this change necessitates a closer look at a whole set of new criteria. It doesn't just affect the LED and optics, but the engine that drives the entire system as well.

LEDs contain no mercury and are known to be much more efficient than conventional light bulbs. They also have a much longer life span than CFLs that contain mercury. But as "electronic devices" they require thought in order to be able to operate correctly with our traditional mains. AC voltage needs to be converted into a constant current to make LED chains shine with uniform brightness and color. What are the effects of TRIAC dimming? What happens to the millions of devices that are installed in our houses? One thing people really loved was the dimmable light bulb - and that was one thing they really missed with the energy saving fluorescent lamp. But good flicker free dimming down to almost zero is not easy to achieve with LEDs, either. It took our engineers two long years to come up with an LED driver that provides the perfect solution.

AC is only part of the story, though. What about solar driven street lighting? When the battery is fully charged at the end of a sunny day the voltage will be high enough to drive 7 or even 8 LEDs. But when it drops during operation in the night it runs low far too early. A driver was needed that could generate more drive voltage from less supply voltage. Hence, the creation of a buck/boost driver.

When we look at LED lighting as a system, the LED-driver holds a similar position as the engine in our cars. It runs and runs but when it finally wears out, it is usually the end of the entire car. This is why the reliability of LED-drivers is extremely critical to the life time of the lighting system. LEDs easily last 50,000 hours and more - so ideally this should be matched by the performance of the driver. For many of our drivers we specify a "design lifetime" of >70k hours. Moreover, RECOM also confirms it by giving a 5-year warranty.

But in all fairness, there is much more to a car than the engine alone. First and foremost there is the body shape, size and color. LED technology provides light designers with almost unlimited opportunities. What about cooling? Even though LEDs are much more efficient they cannot dissipate heat and run hot at the junction of the silicon. As in a car, effective cooling is critical for the life expectancy of the entire system. And communication? This is a standard in cars today and will be very common in lighting systems tomorrow. We will be able to switch, dim and tune lights any way we want – even from a distance, by wireless or via the internet.

There are still many open questions that the market will have to answer itself over the next period of time and we are all part of this process! ■

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Cree Delivers Highest-Efficacy Lighting-Class LED Arrays

Cree, Inc. announces new CXA LED Arrays, boasting high lumen output and high efficacy in a family of single, easy-to-use components. Optimized to simplify designs and lower system cost, Cree's newest CXA LEDs can deliver system-level performance ranging from 500 to 5000 lumens and up to 146 LED lumens per watt, enabling applications ranging from LED replacement lamps to commercial downlights.

LpS 2012 visitors saw the first samples of the new CXA LED Array series

CXA LED Arrays are available in EasyWhite® color temperatures, providing the LED industry's best color consistency for designs that use only one LED. The CXA LED Arrays are designed to be used as a single component in an LED design – emulating the single-filament appearance of traditional lighting products. One component means simplified design, manufacturing and inventory management – enabling lighting manufacturers to shorten time to market and reduce manufacturing costs.

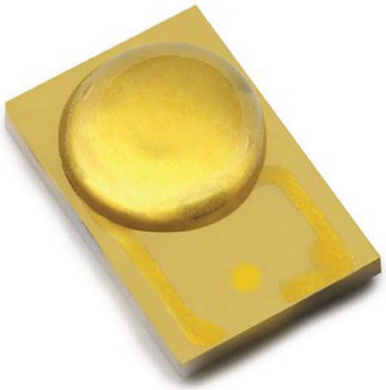
"We switched to Cree's new CXA1507 LED Array because it delivers higher performance over other LED arrays," said Jason Lee, president of Gama Illuminer. "The easy-to-use package of the CXA1507 LED Array with well-designed features and small optical source made design and manufacturing simple."

The new CXA family offers four new CXA LED Arrays (CXA1507, CXA1512, CXA2520 and CXA2530) delivering different lumen levels in two packages and optical sizes (minimum 80 and 90 CRI available).

"The CXA1512 LED Array can deliver over 1900 lumens at 120 lumens per watt in a very small 9-mm optical source size. Other LED arrays may come close to this level of performance, but not in this small of a form factor. The CXA1512's small size is critical for enabling low system cost in a wide range of lighting applications, from narrow-beam spotlights to wide-area lights," said Mike Watson, Cree senior director marketing, LEDs. ■

Philips Introduces LUXEON Rebel PLUS

Advancing its industry-leading LUXEON Rebel LED platform, Philips Lumileds introduces LUXEON Rebel PLUS, delivering a 15 percent performance upgrade over earlier versions of the product. This new family of single-emitter LEDs offers designers and manufacturers the quality and reliability that are hallmarks of the LUXEON Rebel LED, with a new level of performance and value. Designed to fit seamlessly into the existing Rebel LED ecosystem, Rebel PLUS enables designers to upgrade their products quickly and efficiently, fast-tracking their time to market.



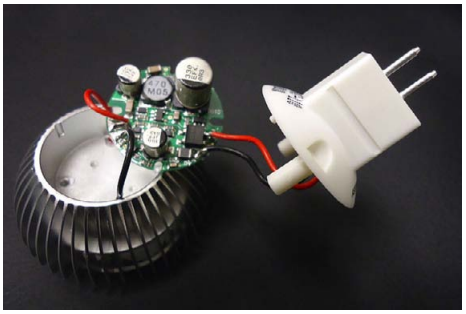
The new LUXEON Rebel PLUS LEDs are available in a range of CCTs from 2700K-5000K

"We understand the economic requirements driving LED adoption and Rebel PLUS is designed to deliver higher LED efficacy which drives system level efficiency and helps to reduce costs," said Raj Malhotra, Philips Lumileds Product Line Manager. "With the launch of Rebel PLUS, we offer our customers a Freedom from Binning, illumination-grade LED with a significant performance upgrade using the existing Rebel platform."

Designed with an industry-standard 4530 package and a 2.55mm dome, the Rebel PLUS is optimized for maximum light output. By using LUXEON Rebel PLUS LEDs, designers can create leading-performance, energy-efficient retrofit lamps, downlights and directional lamps that achieve between 90 and 110 lumens per watt with a minimum of 80 CRI. Moreover, LUXEON Rebel PLUS LEDs are hot tested at 85°C and color binned at 3 and 5 SDCM so that designers can be confident in color consistency from LED to LED. ■

Lynk Labs Offers 230V Tesla™ AC LEDs for Europe

Following the successful rollout of its 12V AC line of LEDs and Chip on Board packages, Lynk Labs has unveiled the Tesla TR28 - the first in its line of high performance, low cost direct line driven COBs and Modules.



AC-LEDs (in this case a 12V version of an MR16 lamp) help to eliminate driver electronics

"Drivers introduce cost, complexity and unreliability into what should be a very simple source of light," said Bob Kottritsch, Lynk's Vice President responsible for business development in Europe, who was speaking at a European symposium on LED technologies. "With AC LEDs all that goes away and we get back to a much more simple and elegant light engine concept." Lynk Labs has been building an LED technology patent and product portfolio since 2002 with a focus on AC LED technology. Its patents cover all aspects of AC LED design and implementation from circuit to chip level design, systems, applications and power schemes.

Working closely with its strategic partner Epistar, Lynk launched an integrated AC chip – "a 12V light bulb on a piece of Gallium Nitride" as Kottritsch described it. Further collaboration with packaging partners in Taiwan lead to a broad range of 12 V AC LEDs and COBs targeted at the low voltage MR11, MR16 and AR111 lamps, track and recessed fixtures as well as linear lighting a tape – all powered by 12/24V AC transformers – simple plug compatible replacements for traditional incandescent and halogen lamps.

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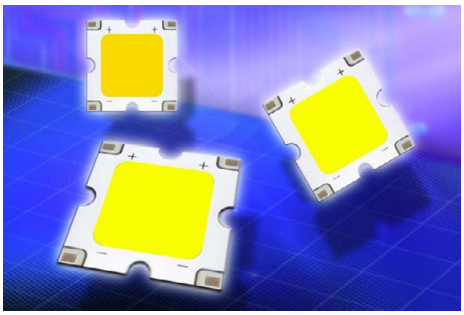
In much the same way, line voltage AC LEDs can replace the light engines in many lamps – GLS, GU10 and the higher power PAR lamps for example. “In Europe the focus is much more on lighting fixtures, as most lamps are made in Asia today,” observed Kottritsch “... but that is still a very large market with many thousands of competent and innovative companies. We believe that our driverless AC LED technology will prove very attractive to these companies as they look to implement simpler and less expensive LED solutions for their fixture designs.”

OMC SPECTRALUX® Light Engines Deliver 130 lumens/Watt

OMC, a pioneer in optoelectronics, have launched new light engines which offer very high luminous efficiencies of up to 30 per cent higher than alternatives currently available. 220-series SPECTRALUX® light engines deliver up to 130lm/W and feature life expectancies of up to 40 years.



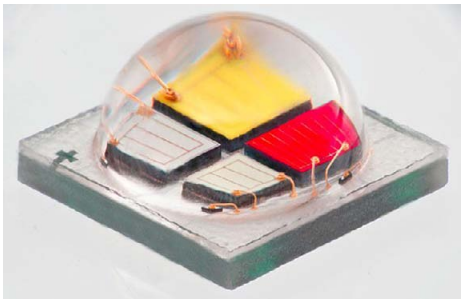
OMC’s new SPECTRALUX® light engines are designed for low current-density and offer high efficiency

In the SPECTRALUX® light engine range, highly efficient, tightly-matched LED die material is bonded to a thermally conductive substrate and encapsulated with a precision-applied phosphor coating. OMC is able to achieve such high performance in the 220-series because the company uses a greater LED chip area which has been optimally distributed across the substrate surface to enhance optical efficacy and reduce current density. In addition, the electronic configuration of the die elements has been arranged to keep drive currents low, thereby reducing the power dissipation further. Not only does this technique result in high luminous efficiency, it also ensures that heat is spread more effectively across the substrate surface resulting in lower junction temperatures and longer life expectancy. In applications where very high efficiency is not the main consideration, the die area can be tailored to reduce power consumption or cost so as to meet the requirements of individual customer applications.

The 220-series devices are compact at only 20mm square, and are simple to use, requiring only a constant-current supply to drive them. Heatsinking the devices is also more simple as the greater efficiency means lower power dissipation for a given light output. William Heath, OMC’s commercial director comments: “100lm/W has been a benchmark figure for exceptional light engine performance for some time now so to have achieved 130lm/W in our new 220-series devices is very exciting. They are suitable for a very wide range of applications, from lighting fixtures/luminaires to house, caravan, and boat illumination, cabinet and display lighting, industrial machinery, vending machine, chillers, photographic flashes and microscope illumination.”

More Efficient XLamp® XP-E2 & Next-Generation Color LEDs from Cree

Cree announces commercial availability of XLamp® XB-D color LEDs and XLamp XM-L multi-color LEDs and he new XLamp® XP-E2 LED, delivering higher lumens per watt and lumens-per-dollar to lower system costs for existing XP-E and XP-G designs.



The multi-color XLamp® XM-L Color is just one out of six improved color LEDs from Cree

The new XP-E2 LEDs can increase the lumen output of XP-E designs for the same cost and power or lower system cost with fewer LEDs – enabling lighting manufacturers to deliver a better lighting system with minimal redesign. “The price to performance ratio is an important consideration for our design process,” said Erik Milz, vice president of marketing, Terralux.

The XP-E2 LEDs use the same XP footprint (3.45mm x 3.45mm) and are optically compatible with all XP LED designs, including the popular XP-E and XP-G LEDs. The XP-E2 LEDs also enable a broad range of high-lumen applications, from indoor and outdoor lighting to portable and lamp retrofits.

The latest Cree offering to be built on the revolutionary SC3 Technology™ next generation LED platform, the XP-E2 LEDs deliver up to 128 lumens per watt at 350 mA, 85°C or 143 lumens per watt at 350mA, 25°C in cool white (6000K). The SC3 Technology next generation LED platform features advancements in LED chip architecture and phosphor and showcases a new package design.

The high-performance XLamp® XM-L color LEDs provide lighting manufacturers with discrete and multi-color LED options to more cost-effectively address a wider spectrum of applications such as architectural, vehicle and display lighting.

Cree XLamp XB-D color LEDs extend the double lumens-per-dollar performance of the XB package to color LEDs, delivering up to 40 percent higher maximum light output than XP-E color LEDs. The combination of performance and the small size of XB-D color LEDs enable better color mixing and lower system cost through fewer LEDs. Now available in color as well as existing white color temperatures ranging from 2700 K to 6200 K, customers can support a full range of color in the single XB footprint.

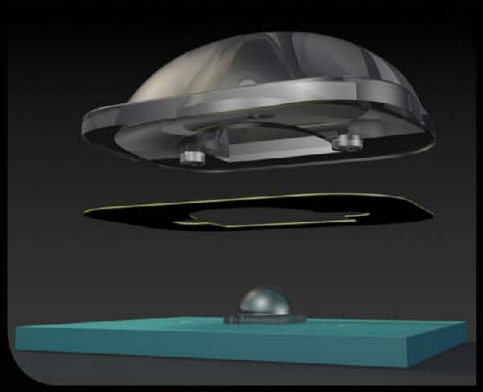
The XM-L color LED is 60 percent smaller than the MC-E LED, reducing the distance between LED die, to create a small optical source for excellent optical control, efficient color mixing and simplified design.

XLamp XB-D color LEDs deliver up to 1416 mW for royal blue, 92 lumens for blue, 198 lumens for green, 210 lumens for red and 261 lumens for red-orange, all at 1A in the 2.45 mm x 2.45 mm footprint.

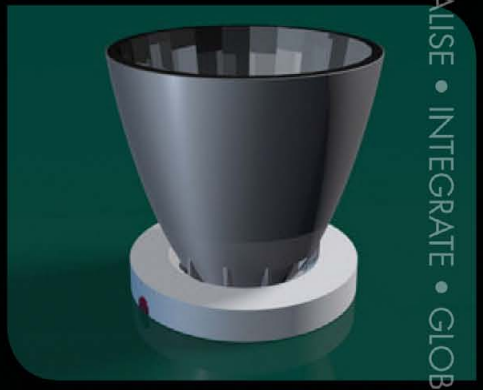
XLamp XM-L color LEDs deliver up to 89 lumens for royal blue, 214 lumens for green, 229 lumens for red and 272 lumens for white at 1A in the 5 mm x 5 mm footprint.

FOCUSED ON THE FUTURE OF LIGHTING

'Archimedes'



'Hubble'



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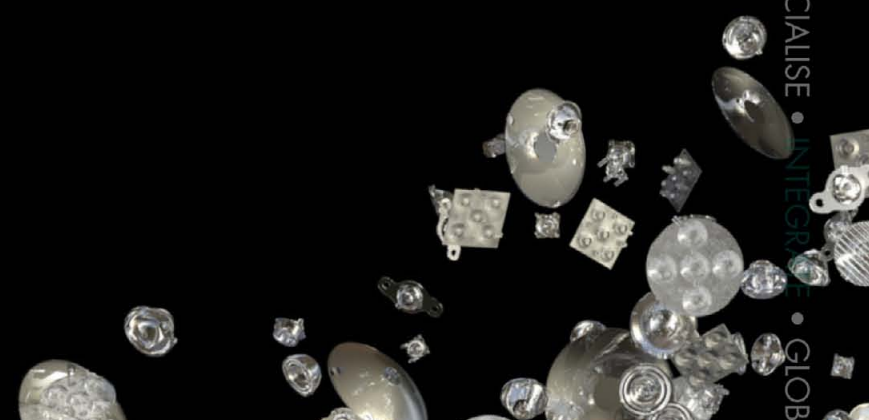


LED Engin Introduces Next-Gen MultiColor Multi-Chip Emitters

LED Engin, Inc., a leader in high lumen density LED products, demonstrated emitters and LED modules that enable the size of entertainment lighting products to be significantly reduced. The company's LuxiGen platform of white and multi-color compact emitters generate the high luminous flux density demanded in entertainment lighting, particularly for spot beams, distance lighting effects and in dynamic lighting scenarios.

The new generation of LED emitters were introduced at PLASA 2012

Patented thermal management technology allows the LED die to be driven to higher current levels and in a denser configuration than industry standards, without adversely affecting operating life.

Other benefits provided by LED Engin's emitters are very high lux-on-target, precise beam control and effective 'in-source' color mixing within the primary lenses of the emitters. Beams can be tightly focused (down to 8°) using Total Internal Reflection (TIR) secondary lenses that also minimize unwanted glare, and individual dies within each emitter can be driven with different current levels to provide accurate, flexible color control. The compact emitters also enable zoom lenses to be used and these will be demonstrated for the first time at the show.

Further advantages of LED lighting are consistency of performance over the operating life of the fixtures and very high reliability. LED emitters radiate much less heat than tungsten lamps in the beam and the typical operating life is over 50,000 hours, the company adds.

LED Engin's European Manager, Gerrit-Willem Prins, comments: "Lighting manufacturers have realized the significant benefits offered by compact LED emitters and our technology is now able to deliver the widest possible choice of colors, beam widths and lumen intensity from lighting fixtures." ■

Edison Launches the High lm/$, High CRI and High Efficiency ET-3535 Series

Edison Opto, a Taiwanese leading lighting manufacturer in the high power LED market has recently introduced the ET-3535 Series and broken the record for high cost-performance ratio products to maintain the leading position in the market, .

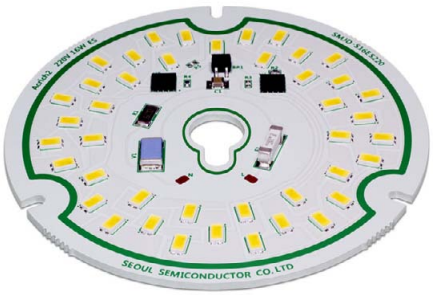
Edison Opto's ET-3535 Series can reach 100lm@350mA in warm white providing high lm/$

Featuring excellent luminous efficacy, the ET-3535 Series can reach 100lm@350mA in Warm White and provide CRI 80 in every color temperature. The ET-3535 Series has a high cost-performance ratio on the market. In addition, ET-3535 can operate under 1 Watt (350mA) and 3 Watt (700mA). This particular package has been designed for a reflow process application that can accelerate the speed of manufacturing process. In addition, the slim and miniature size can reduce optical components and minimize mechanical dimensions. As a result, designers have excellent flexibility in optical design. Unlike traditional PLCC Series, the ET-3535 Series improves the light extraction efficiency with the dome lens. Its low thermal resistance (4°C/W) can improve the efficiency of thermal management and extend the life time of LED.

The ET-3535 Series is RoHS compliant. Lead, glass and mercury are not used in the ET-3535 Series in order to provide an environmentally friendly product to customers. The great performance products can be used as the light source of PAR series, LED bulbs, down lights and general luminaires. ■

Seoul Semiconductor Updates Acrich 2

Seoul Semiconductor, a leading LED manufacturer, has announced that its latest Acrich2, AC LED module, is now available for volume production orders with 100 lm/watt performance. Acrich2 provides lighting designers a light source with high efficacy, outstanding Power Factor, and improved Total Harmonic Distortion (THD) performance.



SSC's new Acrich 2 modules offer an improved efficiency of 100 lm/W and an almost perfect power factor of up to 99

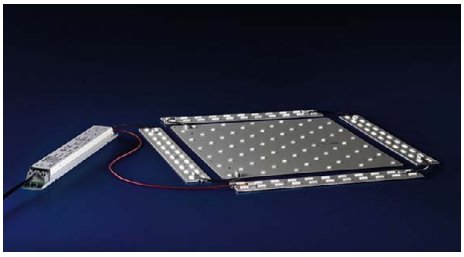
In traditional Solid State Lighting solutions, additional components and costs are required to provide an offline driver solution with acceptable dimming performance. The Acrich 2 solution can save about $2.00 over these traditional solutions. The Acrich2 AC module also provides a DC dimming interface that allows the designer to easily integrate new dimming functions such as Touch Sensor and WIFI control dimming.

The Power Factor improvement, to as high as 0.99, will benefit electric providers by saving electricity cost. Conventional LED Lighting products have lower Power Factors from 0.5 and mostly in a range from 0.7 to 0.8. Seoul Semiconductor's Acrich2 AC LED module with high Power Factor helps the performance of the power grid.

Seoul Semi's critical technology for Acrich is 'Integrated Multi-cell' technology. Acrich operates effectively due to its integrated multi-cell technology. Seoul Semiconductor has focused on researching multi-cell technology for over 10 years. As a result of this research, Acrich operates both alternating current and direct current. More so, it tolerates a wide range of voltages. ■

Tridonic - New LED-Engines for Wide-Area Lighting

Twenty percent more light output and even better lighting quality (MacAdam 3) characterize the second generation of TALEXXengine STARK QLE and LLE LED systems with a module efficiency of 135 lm/W.



Both TALEXXengine STARK QLE und LLE provide integrated emergency lighting functions

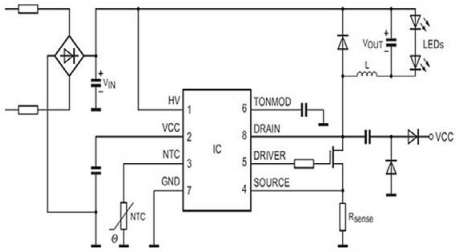
Tridonic introduced those LED engines for general illumination successfully in the beginning of 2012. These square (QLE) and linear (LLE) versions can be used separately or in combination. They open up new options for luminaire designers and can be used as alternatives to T5, T8 and TCL fluorescent lamps. The square version is perfect for area luminaires and long-run luminaires, and the linear version is ideal for creating clear lines of light. All versions will fit a wide variety of lighting systems, from diffusers to louvre luminaires. Tridonic has optimized the modules continuously and offers from November on the second generation with clearly higher efficiency.

The LED module has an operating current of just 300 mA and is now capable of achieving a luminous flux that previously required 350 mA. Condition: change to identical control gear with reduced output current. This reduces the power consumption of the luminaire by 20%. If one continues to run the LED module with an operating current of 350 mA as before, luminous flux increases by 13%, while the luminaire's power consumption remains constant.

Further-on Tridonic offers added integrated emergency lighting functions with TALEXXengine STARK QLE and STARK LLE. The LED modules are either equipped with additional LEDs for emergency lighting or are dimmed in emergency lighting mode. Combined with a matching control gear there is a round off LED system available.

Compact, Deep-Dimmable LED Driver IC from NXP

NXP Semiconductors N.V. announced the SSL2129A – a highly efficient GreenChip™ controller IC for compact, deep-dimmable LED retrofit lamps from 4 to 25 W. The SSL2129A offers best-in-class dimming performance measured in compatibility per watt, for a single-stage mainstream LED driver application. Its approach also allows the application to remain compact (GU10/PAR16) and highly cost-effective, with a high power factor (PF) of more than 0.9. The SSL2129A is designed for use with an external MOSFET and can be configured in both buck (non-isolated) and flyback (isolated) topologies, for 100-120V and 230V mains supply voltages.



Basic application diagram for NXP's SSL2129A driver IC

Key Features of the SSL2129A:

- Compact, single-stage LED driver solution reducing eBOM cost
- Benchmark dimmer compatibility per watt
- Controller-only SSL driver IC for both non-isolated and isolated topologies
- Designed for retrofit lamps from 4 to 25 W
- High efficiency, high power factor (PF >0.9)
- Easy to use and easy to manufacture

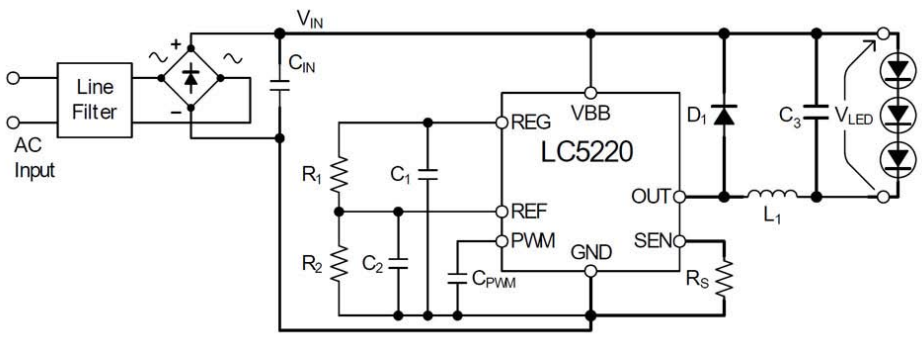
Evaluating Compatibility per Watt:

Today, commercially available LED lamps need about 7 watts to replace a 40-watt incandescent bulb, and 8.7 watts to replace a 60-watt incandescent, but it is precisely under 10 watts that dimmer compatibility becomes particularly difficult.

To address this, NXP has developed a "compatibility per watt" scoring method that takes into account the absorbed mains input power, as well as a metric for compatibility determined by both stability (the ability to avoid visual disturbances such as flicker, shimmer and flashing), as well as controllability (the level to which the user can control and reduce the lamp light output, including dimming range, control span and steps in light level). Based on this parameter, the SSL2129A has demonstrated outstanding dimmer compatibility. A white paper on evaluating dimmer compatibility per watt is available from NXP. ■

Allegro MicroSystems Announces New LED Driver IC Series

Allegro MicroSystems announces the release of a new simple and efficient family of LED driver ICs that can be configured as buck or buck-boost voltage converters. The LC5220D/S LED series is manufactured and developed by Sanken Electric Co., Ltd. in Japan.



Typical application example of a buck voltage converter circuit with Allegro's LC5220D/S LED series

These non-isolating devices operate off-line, having a high voltage capacity that allows direct connection to a wide range of supply voltages (from 25 to 400 V recommended). The LC5220 series uses PWM and constant current mode to drive LEDs with adjustable dimming. Each device incorporates a power MOSFET and controller IC as well as built-in protection and energy-saving functions, reducing external parts required, and making the LC5220 ideal for use in small-size LED light bulbs.

Main Features and Benefits:

- Buck and buck-boost topology; selectable by peripheral circuit structure
- Built-in fixed reference voltage limiting constant current control; high precision regulator improves current precision and simplifies setting of current level
- Sleep function, with latch mode; input high, 3 V or more, on REF pin turns off IC output to LEDs
- Enable function; input low on REF pin toggles IC output to LEDs
- High input voltage; up to 250 V or 450 V, depending on product
- Built-in constant current control; PWM method, output current adjustable by the voltage input on the REF pin
- External adjustable PWM dimming control

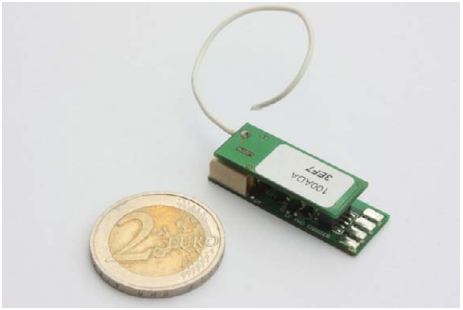
Protection Features:

- Open protection (OPP) with latched shutdown; protects IC when a free-wheeling diode is open
- Undervoltage lockout (UVLO)
- Overcurrent protection (OCP) with latched shutdown; variable OCP threshold linked to REF pin voltage
- Thermal shutdown (TSD) with auto restart

Standard through hole or surface mount packages are available. The LC5220 series is an updated version of the LC5200 series, and integrates most of those functions, while broadening the selection of AC input voltages and offering better protection features, for fewer peripheral components.

Barthelme Releases New Color Controller Chromoflex® Pro Mini

Barthelme LED Solutions® newly released the advanced CHROMOFLEX® Pro series. The PRO version consists of 1 to 4-channels and is totally radio controlled by 868MHz. The most recent member in this series is the Chromoflex® Pro Mini.



Barthelme's CHROMOFLEX® Pro Mini - offers 3 times 2A in 12V and 24V in an extraordinarily small footprint

Main Features:

- Very small dimensions, easy to integrate
- Totally radio controlled, easy to network
- Hidden assembly due to wireless technology

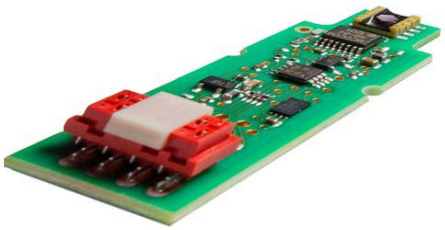
CHROMOFLEX® Pro was designed to attain sophisticated illuminations in the field of decoration and wellness with a minimum of effort. The unit is equipped with various color effects by default as well as editable programs. Several CHROMOFLEX® Pro can be linked in a network which makes it possible for all color changes/ scenes to alternate automatically in sync.

CHROMOFLEX® Pro Mini - Stripe with 3 x 2A in 12V and 24V is perfectly suitable for smaller and delicate profiles and LED linear luminaires due to its very small dimensions and wireless technology.

The CHROMOFLEX® Pro series is also available for DMX, DALI and KNX.

MAZeT GmbH Announces an OEM Sensor with Smart Color Control

MAZeT GmbH, a leading provider of Electronic Design and Manufacturing Services, presented their new JENCOLOR color sensor solutions for lighting applications during the trade show "electronica" in Munich from November 13th to 16th at booth 520 in hall A2.



MAZeT's JENCOLOR color sensor board MTCS-INT-AB3 displayed at electronica 2012 for the first time

The sensor board MTCS-INT-AB3 is based on two new IC solutions, which are specially developed to solve tasks in LED lighting control - for example: feedback color control of LED light sources. The True Color sensors IC in implemented on the board performs color measurements based on the standard CIE 1931 - the human eye perception. It is possible to directly process the data as XYZ values or within the Lab/Luv color space. The XYZ filters of the sensor show no temperature or aging drift effects and are long-term stable throughout the entire lifecycle of a product.

The on-board signal converter IC MCDC04 consists of an ADC with high bandwidth and I2C output. The IC processes via charge-balance method and converts lowest photocurrents at high accuracy (16 bit). Its full-scale range can be customized to the specific application forehand and during operation via programming. Therefore it is possible to realize a sensitivity of 20fA/LSB at a dynamic of 1 to 1,000,000. The IC is temperature compensated and features the possibility of external measurement synchronization.

The board is an ideal OEM color sensor solution within the Luv/Lab color space with simple implementation based on the two modules on the board in addition with a power supply and I2C interface. Together with a µC or FPGA it is possible to directly implement the XYZ sensor values within algorithms for measurement or control tasks at an accuracy of Delta u'v' <0,003. Therefore the OEM sensor is an ideal addition to all applications that require a high accuracy and stability of colors, even in harsh environmental conditions like temperature shifts. Examples are the calibration of cabin lights in airplanes, or the color management of backlights in displays or video walls.

LEDiL Extends Efficient White Reflector Series

We at LEDiL Oy are driven by innovation and the need to explore new areas and applications. Hyper-reflective materials we use in our products are just one example of this innovative spirit. Reflectors made of this pure white material give soft and even light for demanding lighting applications.

LEDiL's symmetric and asymmetric white reflectors are used for wide area illumination

Features and Benefits:

- Soft and even light distribution
- Highly efficient design
- Advanced hyper-reflective material
- No need for the diffusing sub-lens
- Stylish white reflector for architectural indoor lighting applications where design of the luminaire is important
- Product line contains both symmetric reflectors for general lighting applications such as downlights and asymmetric reflectors for wall-washing applications
- Wide opening angles suitable for low ceiling heights

With the wide beam distribution of these reflectors, there is no need for the diffusing sub-lens. Hyper-reflective white versions are available in LISA2-R, LENINA, BRITNEY, BARBARA, BOOM, LAURA, RITA and LENA-WAS families of reflectors.

New PLEXIGLAS® Molding Compounds for more Efficient LED Lighting Products

LEDs are indispensable for modern lighting design. Two new PLEXIGLAS® molding compound grades now enable lighting manufacturers and designers to use energy-saving LEDs to even better advantage.

Comparison of different materials with LED backlighting (photo: Evonik Industries)

Very good light diffusion for edge-lit elements:
Highly transparent molded and extruded parts that enable light to be simultaneously fed in via the edges and evenly emitted across their entire surface are no longer a contradiction in terms. The extremely efficient formulation of the new PLEXIGLAS® molding compounds makes it possible to combine these two properties. The new product has been specially developed for LED edge-lighting systems and appears crystal-clear when unlit.

The new PLEXIGLAS® LED molding compound is available in four grades that allow illumination of the entire component surface up to an area of 96 centimeters, with homogenous light output. The material is suitable for all thermoplastic processing methods.

Uniform direct lighting for slim luminaires:
PLEXIGLAS® LED molding compounds have been developed in two new specialty colors for extremely flat lighting installations with direct LED lighting. The light-diffusing molding compounds transmit over 60% of light and therefore prevent fluctuations in luminance, even at extremely low wall thicknesses. That offers entirely new creative scope to designers, who can now place LEDS very close to light covers, without visible hot spots. ■

Bayer MaterialScience Expands Polycarbonate Range for LED Lighting Systems

Bayer MaterialScience is seeing a growing worldwide demand for polycarbonate for the production of LED lighting systems (light-emitting diodes). The company is therefore systematically expanding its product range for this market segment.

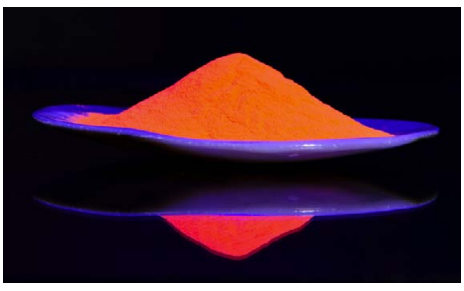
The new polycarbonates for LED cooling elements, such as Makrolon® TC 8030, are an alternative to aluminum

The latest examples for the company's development expertise are polycarbonates with particularly high thermal conductivity for cooling elements used for the thermal management of LEDs and a film that joins the points of light from individual LEDs to form a homogenous band of light.

The new polycarbonates for LED cooling elements, such as Makrolon® TC 8030, are an alternative to aluminum. "These allow the cooling ribs to be more delicate and lighter. Unlike their aluminum counterparts, the injection-molded cooling elements require no post-treatment, enabling cost-effective production with low energy consumption," said Reinartz. ■

Intematix Announces New Red Nitride Phosphors

Intematix, a leading innovator of patented phosphors and phosphor components for high-quality LED lighting, today announced the release of the Ruby series of red nitride phosphors that enable exceptional efficacy, color rendering and reliability for high-power LEDs. These unique phosphors, backed by Intematix U.S. patent No. 8,274,215, are ideal for applications like general lighting and backlighting for LCD TVs.



Intematix's new GAL phosphors, which are backed by U.S. patent No. 8,274,215, enable near-perfect color rendering up to 98 CRI

"The properties of our Ruby red nitride help ensure that customers will see long lifetimes and consistent performance across the operating conditions of their LEDs for all lighting applications," said Yi-Qun Li, Chief Technology Officer for Intematix.

Red nitride phosphors fill crucial gaps in the color spectrum and create quality light in the most demanding applications. Intematix red nitrides in combination with Intematix GAL phosphor enable near-perfect color rendering up to 98 CRI. Intematix red nitrides used in blends with GAL phosphors also enable 100 lm/W efficacy in warm white packages.

Intematix's U.S. Patent No. 8,274,215 is the 18th U.S. patent issued to Intematix in the area of LED phosphors and the 71st U.S Patent overall. Intematix also has over 300 pending patent applications covering LED phosphor and lighting technologies on a world-wide basis. The Ruby series expands the company's wide range of phosphors, adding to its extensive portfolio of nitride, silicate, aluminate, and garnet phosphors. ■

Astera Launches ARC3 Tablet Controller

Replacing the ARC2 RF Remote Control as Astera's main handheld LED controller, ARC3 is the most advanced controller available for wireless event lamps. Via a seven-inch, 1024x600-pixel captive touch screen, it can manage an unlimited amount of wireless Astera products with complete control over color mixing and calibration. The large screen ensures that every function is easily accessible and important parameters are always in view, allowing for fast and intuitive setup of event lighting.

Astera has launched a brand new tablet device, the ARC3, which offers an extensive degree of control over its wireless LED fixtures, aimed at decorative lighting for events and shows

The tablet features a 'target lamps' section that facilitates direct communication with a user-definable selection of individual fixtures or groups of fixtures, and does not require any WiFi gateways or relays. The user can quickly and easily customize effects, launch programs instantly or store them on the device in advance of an event. The ARC3 is also capable of communicating with third-party lamps and other appliances and, importantly, can easily be upgraded with new functions, which Astera's software specialists are continually developing. For example, a forthcoming feature will be the detection of music speed and automatic adjustment of lighting to suit the mood. ■

Philips hue - The World's Smartest LED Bulb

Building on its innovation capabilities, Philips unveils hue, the world's smartest web-enabled LED home lighting system. Philips hue signals a new era in home lighting both in the way we think about and experience light in our homes. It allows you to create and control the light using your smartphone or tablet. Bringing endless possibilities to help you get creative and help you personalize your lighting to suit yours and your family's lifestyle, Philips hue is available exclusively from Apple stores from 30th October. A starter pack includes three bulbs[1] that simply screw into your existing lamps, and a bridge that you plug into your home Wi-Fi router. Simply download the hue app to start experiencing light in a completely new way.

Philips hue, which is available at Apple stores, lets you create and control light using your smartphone or tablet. Download the app to experience light in a new way

Philips hue can be setup in minutes. The intuitive app allows you to remotely control your home lighting to help secure your home, personalize your home lighting experience with custom settings and program timers to

help manage your daily schedules, all through the convenience of a smart device. An intuitive and seamless system, Philips hue is upgradeable and future-proof, with the potential for more features to be downloaded and enjoyed in the future.

With its high quality energy-saving LED light, Philips hue allows you to tune shades of white light or create any color.
In addition, Philips hue can:

- Save your favorite light scenes for each room or time of day and recall them in an instant
- Use any photo on your phone as a color palette to paint your room with light and bring your memories back to life
- Tune white light from warm candlelight to vibrant, cool white light
- Create ambience or complement your decor with the colors of the rainbow
- Control and monitor your lights remotely when not at home for security and peace of mind
- Set timers to help manage your daily routine
- Let light wake you up refreshed or help your loved ones fall asleep

The app for Philips' hue also features expert LightRecipes: four pre-programmed lighting settings based on Philips' research around the biological effects that lighting has on the body. These scenarios adjust bulbs to the optimum shade and brightness of white light to help you relax, read, concentrate or energize.

Philips is opening up the hue app to the developer community and has created an open source platform at www.meethue.com inviting developers to explore the app and unleash even more possibilities to show what light can do to enhance your life. You can share light scenes or get inspired on the meethue.com community site. Philips hue uses the open ZigBee Light Link standard so that it can be integrated with other ZigBee certified systems.

Building on the success of its AmbiLight experience, Philips is developing future product features, such as allowing hue to integrate with other media including sound and video. Philips is also working on features such as geo-location services, allowing hue to sense when you are close to home and automatically turn on the lights, or turn them off when you leave. ■

RZB Offers MR16 Spotlight Lamps

RZB's newest lighting solution, its Professional Spotlight LED lamp, is a genuine trendsetter. The completely silent and flicker-free performance of these lamps is achieved thanks to advanced passive cooling technology that steals the thunder in every respect from all other actively cooled lamps.

RZB's Professional Spotlight lamps are available in stores now

RZB's Professional Spotlight LED lamps are compatible with all commercially available low volt halogen sockets, are fully dimmable, and replace 50 watt spots with an only 7 watt power consumption lamp (while competing products with active cooling use 10 watts of power). Thus with a service life of 35,000 hours – a realistic expectation for RZB's Professional Spotlight LED lamps – you can count on saving €150 per spotlight. Thanks to a color temperature of 3000 K, these spots provide warm white lighting with 450 lumens of light output that's easy on the eyes. And as RZB's LED lamps are UV radiation-free, neither fabrics nor works of art fade even when lit by these products for long periods of time. ■

Ledzworld Launches Ultra-Dimmable GU10 Perfect Fit

Ledzworld Technology, an innovative technology company that supplies customized LED solutions for professional users, launches its new LED retrofit perfect fit GU10 , a low power-consumption 7 W LED lamp that delivers an industry- leading high output of >500 Lumen. The lamp has an efficacy of >72 Lumen/W at a color temperature of 3000K.

Ledzworld's new 7W GU10 lamp, which will be available in Q1 2013, delivers over 500lm @ 72lpw efficiency

The lamp features the latest Cree COB technology, a new lighting class LED designed for high-output small form factor directional lighting.

Ledzworld's superior RGRT™ (Reduced Glare Reflector Technology) is boosting the lumen output of the lamp by a whopping 20%!

Ledzworld proprietary driver design makes the lamp ultra-dimmable, resulting in linear dimming to <3%. The lamp dims superbly on most commonly used dimmers, both leading- and –trailing edge dimmer types. ■

ALT Uses CREE Based 2200K Products for Warm "Golden" Light

To create important advantages in the LED market, the world's biggest leading LED chipset supplier CREE has announced the latest 2200K color chipset to meet the market demand for golden light. In light of CREE's pairing with ALT's (Aeon Lighting Technology Inc.) products, with over 2000 models worldwide including UL/CUL/ETL/TUV/LVD/FCC/C-Tick/CNS and more certifications, we are proud to announce a new era of high power LED lighting has begun.

ALT has integrated the super bright 2200K low color temperature chip into, but not limited to, the MR16 series, A55 bulb, PAR lamp, floodlight, and streetlight

Cree and ALT have co-developed the 2200K XTE high power LED chip. The XTE engine is known for high stability plus being a perfect replacement for incandescent and halogen lamps.

High power LED manufacturer Aeon Lighting Technology Inc. continues to spend tremendous effort cultivating high power LED products, and through the newly developed 2200K chip from Cree, ALT has integrated the super bright 2200K low color temperature chip into, but not limited to, the MR16 series, A55 bulb, PAR lamp, floodlight, and streetlight.

Cree and ALT, together, have overcome the problem of providing a warmer color while having a high luminous efficacy, especially with indoor applications, such as restaurants and galleries. In fact, the A55 bulb and PAR lamp were specifically designed for this exact type of market. Additionally, the penetration through limited visibility conditions by yellow light has become a critical requirement for road lighting. Yellow lighting has been known to be able to cut through low visibility conditions like fogs. By utilizing the 2200K LED streetlight, the low temperature warm light provide the driver a safer driving experience with more visibility. ■

Philips Fortimo LED Line Systems
for General Lighting Applications

Features & Benefits

- Breakthrough energy efficiency levels, up to 132lm/W
- High quality white light in terms of color rendition and color consistency
- Future-proof systems
- Designed so that no further heat sink is needed
- Average rated lifetime of 50K hours*
- Philips Fortimo LED Line systems come with the Xitanium family of drivers in a linear housing, for easy incorporation into existing luminaires
- A variety of lumen package/lengths available
- A choice of Philips Fortimo LED Line systems:
  - » 1R - 1 Row of LEDs
  - » 3R - 3 Rows of LEDs

* Average rated life is based on engineering data testing and probability analysis. The hours are at the B50, L70 point (50,000) hours life with 70% lumen maintenance at Tc max for 61°C for 1R and 56°C for 3R. Life will be 25K hours at Tc point of 65° C.

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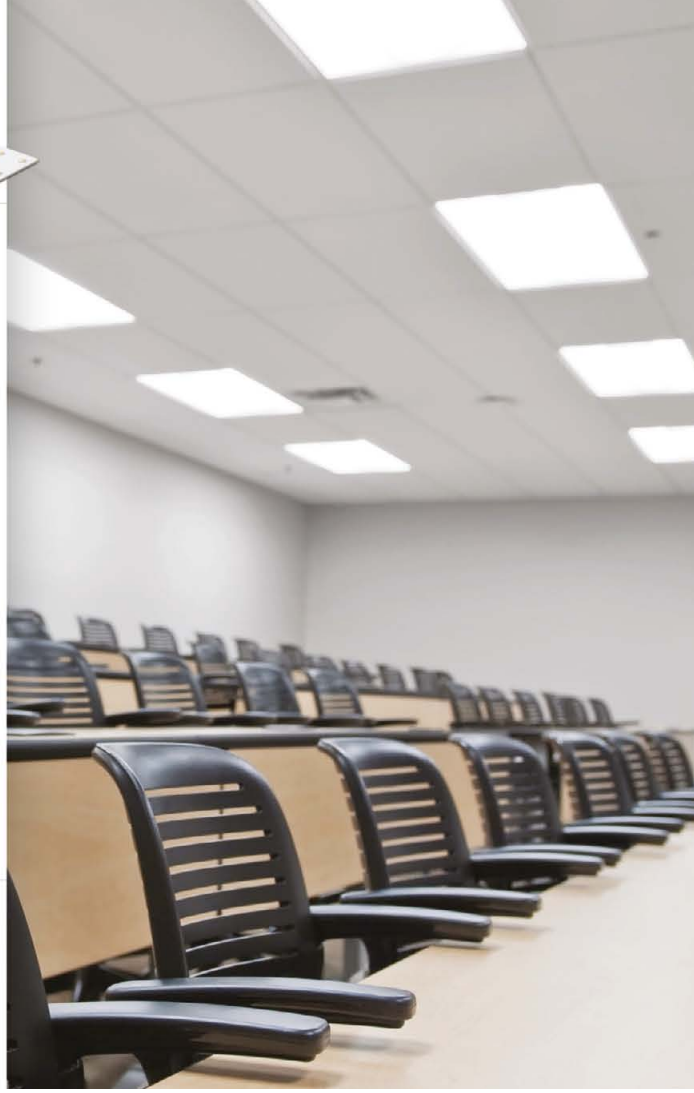

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Customize your own light tones in a few seconds?

Combine all LED luminaires in a *WiFi* network?

All in *PlayLED*™ system!

Compatible with:
monochrome / RGB / Digital / brightness and CCT adjustble LED lights

Play with iPhone,iPad ,iPod or Android device (Above iOS4.1 or Android2.1)

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Measuring Device in Pocket Format

The GL SPECTIS 1.1 is the youngest member of the family of handy mini-spectrometers from GL Optic, which allow for a reliable spectral light measurement. Together with the handy integrating sphere GL OPTI SPHERE 48, available as an accessory, brightness values can be determined with a current duration of 25 ms and very high precision.

The new GL SPECTIS 1.1 is a small, handy and powerful tool

The portable, easy to operate and inexpensive spectrometer GL Spectis 1.1 is used here: It can determine brightness values with a current duration of 25 ms and a precision of +/- 4%. A special trig-out-connection emits a signal at a fixed point of time of the measurement, for example, to an external current source so that the LED illuminates exactly during the measuring period. In this way, the user can simulate the measurement conditions that exist by the manufacturer during the production and development test.

In connection with the mobile integrating sphere GL Opti Sphere 48, the new device was designed so that it reliably measures lumen values and all photometric values of not only individual LEDs, but also other small light sources. Moreover, the system simultaneously scales the spectra. Thus, it determines reliable values for color coordinates, CCT and CRI in accordance with the CIE-standard. Through this, the radiant power and luminous flux can be determined quickly.

Different than by normal spectrometers that can only measure individual LEDs, the mini-spectrometer can take measurements for LEDs that are already found on a printed board through the integrating sphere with a diameter of 48 mm. Through this, the influences of electronic construction elements, drivers and current supplies can be determined on the spectral properties of the LEDs to be measured as well as the usage of dimmers and cooling elements.

The proprietary software included in the scope of delivery, GL Spectro Soft, contains a binning tool, which allows for the specification of the binning groups. It is also possible to import the respective binning system from different providers. The software includes binning libraries from Osram, Cree and Philips so that the respective bin number from the LED is automatically determined for the user.

Through its properties, it makes official measuring processes easier for the mini spectrometer and accelerates these. The system is suitable for measurements on lights and complete light installations, which are constructed of multiple LEDs. With this, it is possible to measure the performance of individual LEDs. Through this, the measurement instrument can be used for the binning of LEDs from different manufacturers according to color and brightness. The handy system can be easily transported and can be used immediately on site. Through this, it is particularly suitable for maintenance work on installed lights. Through the plug and play concept, the system automatically recognizes the corresponding accessories and loads the calibration file independently. Finally, the automatic base line correction makes frequent dark current calibration unnecessary.

B&W Tek Expands Smart Spectrometer Product Line

B&W Tek, Inc., an advanced instrumentation company producing optical spectroscopy systems, is proud to announce the expansion of their Exemplar® smart spectrometer platform. This release is the first of many steps that will propel smart spectrometers to become the new standard across the industry and secure B&W Tek's position in cutting edge technology of miniature spectrometers.

The Exemplar product line is already revolutionary for being the smartest, fastest and most synchronous line of miniature spectrometers available on the market. This makes them ideal for demanding applications such as high speed reaction kinetics, laser-induced breakdown spectroscopy (LIBS), and real-time process monitoring.

B&W Tek added a low straylight (LS) and a high performance (Plus) version to its unique Exemplar smart spectrometer series

Now, B&W Tek has added two new models, both featuring a low stray light "unfolded" Czerny-Turner spectrograph to provide exceptional performance, particularly below 400nm. The Exemplar LS provides all of the advantages of the low straylight spectrograph while still retaining an extremely small form factor, making it the perfect solution for integration into compact UV or UV/Vis spectrophotometer systems.

The Exemplar Plus builds on the advantages of the low stray light spectrograph by significantly increasing the focal length. This decreases the linear dispersion which dramatically improves the spectral resolution. Alternatively, this allows for the selection of lower groove density gratings in order to provide a wider spectral range. The Exemplar Plus also features a highly sensitive, high dynamic range TE Cooled back-thinned (BT) CCD detector with 2048 effective pixels. These features make the Exemplar Plus the most advanced miniature spectrometer available today.

"Our positioning statement of 'Smart, Fast, Plays Well With Others' is more than an advertising tagline, it truly embodies the philosophy behind the Exemplar smart spectrometer platform," says Dr. Mike Kayat, VP of Sales & Marketing for B&W Tek, Inc. "Our customers can expect to see even more innovative models in the Exemplar product line in the future."

The expansion of the Exemplar product line will truly change the community by setting a new standard for miniature spectrometers. As more smart spectrometers are delivered into the hands of researchers, engineers, and other members of the scientific community, these new, innovative tools will allow for the emergence of novel and unique applications that may not have been possible until now.

LedLink
Linking LEDs to The Real World
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Linking LEDs to The Real World

COB Lens / Convex Lens / Street Light Lens / Oval Lens / Diffuser Lens / Single Lens / Multi-Cluster Lens / Hybrid Lens

Founded in year 2008, Ledlink Optics Inc. is professional in designing and developing the secondary optics for LEDs industry.
We attach great importance to tooling precision and production quality; moreover, many of our new designs are rewarded with patent authentications. As the functional aspect, the secondary optical design includes COB Lens, Convex Lens, Asymmetrical Street Light Lens, Oval Lens, Diffuser Lens, Single or Multi-Cluster Lens, and Reflectors, etc.
Our product line can fulfill all customized and application demands.

300 Degree Bulb Cover

With integrating the optical design, diffused material, and injection blow moulding process, stable mass production and wider beam 300 degree spread can be achieved. Comparing with the diffused glass cover, this product has the following advantages as below:
1. Reducing the defect rate during the production.
2. Much better mechanical strength and it wouldn't hurt people once it drops.
3. The bulb cover can be manufactured and performed the same as the existing traditional or

White plastic can solve problem from the light source of LED.
This cover has advantages of low defect rate, unbreakable, lighter weight, and high transmission rate as of 90% or more.
It also can prevent glare and have high strength against hit.

We offer various appearances and diameters products.
We also provide customization service.

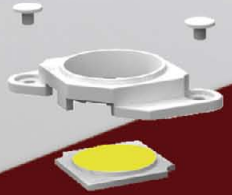
Reflector Series

Characteristics:
- Choose materials per your requirements: electroplated plastic reflectors or aluminum reflectors.
- Compatible with various brands of COB and High Power LED.
- Tolerance of +/- 0.1 millimeters.
- Electroplated plastic reflector has better plasticity, with less limitation of appearance.
- Customers can design structures based on different demands.
- Electroplated plastic reflector is an insulator and can attach the PCB directly.
- Aluminum reflector has sufficient strength and no heat-resistant problems.
- Lead-time of prototypes is shorter with good quality.

LL01ED-AJMxxR18
D x H (mm) 35.2x7.8
FWHM 24° 38°

LL01ED-AKYxxR18
D x H (mm) 50x30
FWHM 24° 38°

LL01ED-ALJxxR18
D x H (mm) 90.6x23.2
FWHM 45°



◀ Aluminum reflectors connector
Electroplated plastic reflectors ▶
Aluminum reflectors ▶

AZZURRO Offers Easy Migration to GaN-on-Si LEDs with 150 mm Templates

The easy migration of LED manufacturing to GaN-on-Si is described in a White Paper released by AZZURRO recently. Utilizing the company's 150 mm templates the advantages of GaN-on-Si can be gained after very short design-in times.

The White Paper outlines technical hurdles to be overcome when migrating to GaN-on-Si, covers key achievements possible when using the right technology, details the advantages for the move to GaN-on-Si obtainable with templates and shows development solutions to the LED epitaxy engineer. In detail data of GaN-on-Si products is revealed regarding very high crystalline qualities (EPD of $2x10^8 cm^{-2}$), excellent homogeneities (< 4 nm wavelength distribution) and very low bow values (< 20 µm). Enabled by AZZURRO's thick GaN-buffer as well as its patented and proprietary strain-engineering technology these achievements permit the full utilization of GaN-on-Si advantages. These include reduced binning due to superior homogeneities. Furthermore the large wafer diameter and low bow values allow the use of standard silicon processing lines which are offering cost breakthroughs for wafer processing and back-end manufacturing. In addition the advantages of using templates for the move to GaN-on-Si are covered as contributors for cost reductions, including better utilization of epitaxy reactors.

Commenting on the huge cost saving opportunities, Dr. Markus Sickmoeller, VP Operations at AZZURRO Semiconductors said: "Our plug-and-play approach, supported by our application note and engineering support assures a smooth migration from the legacy materials towards GaN-on-Si with easy to process, larger wafer sizes in standard silicon processing lines at much lower costs." ■

Key Milestone Reached in OLED Development: cynora Presents New Flexible Prototype

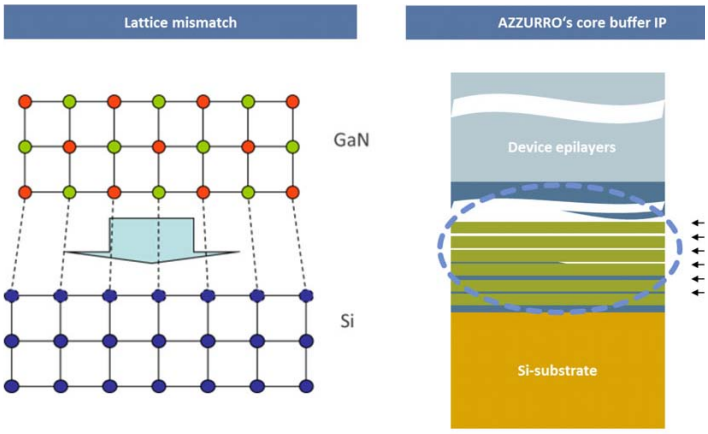
cynora recently unveiled a new flexible OLED prototype, demonstrating yet again the huge potential of OLED technology. One key aspect that sets organic light-emitting diodes (OLEDs) apart from conventional LEDs, is that they are two-dimensional light sources. Additionally, they are extremely thin. This property makes them ideally suited for lighting systems and flat screen displays. So far, however, OLEDs have only been used in rigid form in these application areas.

cynora's new prototype represents a major milestone in the development and use of flexible components, opening new application fields such as smart packaging, for instance. "Many people owning a smartphone are already experiencing OLED technology. The diodes used for those displays, however, are absolutely rigid. The potential of flexible foil-like OLEDs has so far remained untapped," says Dr. Thomas Baumann, one of cynora's CEOs.

Prototype opens new possibilities for packaging and lighting industry:
The new prototype offers a glimpse of what flexible light-emitting film layers will soon make possible: "Further enhancement will in the near future enable the manufacturing of, for instance, beverage cans, smart packaging or posters that feature light-emitting film components," Dr. Thomas Baumann ventures to predict. In further step, cynora will therefore tackle the integration of the wiring into the thin film layers.

The major part of cynora's prototype is made from a liquid solution. Solution-based manufacturing is particularly suitable for mass production because it enables substrates to be coated with thin light-emitting elements quickly, efficiently and cost-effectively using printing processes. "Using solution processing to produce components instead of conventional vapor deposition is a prerequisite for bringing production costs down to a level where flexible OLEDs are viable for mass-market applications," explained Dr. Tobias Grab, the other cynora CEO. In addition, the cynora emitters used are based on readily available copper precursors which in itself further support the material's suitability for mass production.

The prototype was developed as part of the cyFlex project. It won the 2012 SME Award of the Forum Organic Electronics Excellence Cluster initiated by InnovationLab GmbH. ■



The White Paper explains challenges like the lattice mismatch and AZZURRO buffer technology to compensate for the induced stress

A thin film replaces rigid glass to produce a flexible OLED (left). Flexible OLEDs pave the way for intelligent packaging in the future (right)

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LPS 2012 Awed Lighting Experts with Its Top Class Exhibition and a New Interactive Lecture Concept

Arno Grabher-Meyer from LED professional gives an overview of the most relevant occurrences at the LpS 2012, in the exhibition hall, at the lectures and from the panel discussions.

The LED professional Symposium +Expo, which was held for the second time this year, has already made a name for itself as one of the obligatory LED lighting events and LED lighting experts. The lectures once again covered the most relevant technologies for successful LED lighting product development, from the die to the final application. With a 20% increase in visitors over 2011, more than 900 experts from all over the world joined the event from September 25th to 27th. The newly established interactive Tech-Panels on OLED technology, thermal management and LED lamp technology, moderated by Ilka Mellert, were especially appealing and drew audiences.

Twenty six outstanding lectures were presented in eight sessions, starting with state-of-the-art LED technologies and culminating in the closing session with road lighting applications. The international speakers and attendees confirmed the global relevance of the event. There was a 25% increase in the number of exhibitors this year as well as an increase in the number of countries they represented.

Component manufacturers and international distributors from the Americas, Europe and Asia showcased their latest innovative products. Both visitors and exhibitors agreed that their discussions were on a remarkably high level, they made very interesting new contacts and that they would be taking a lot of new ideas and approaches home with them.

Key-Note Speeches about the Status and Future of LED Lighting in Europe

Siegfried Luger, the LpS event director, warmed up the exhibitors, attendees and invited guests for the keynote speeches and symposium sessions by emphasizing the importance of a common understanding in industry, component standardization and political support for rapid and successful market launches of resource-efficient LED and OLED light technology. The key-note speakers

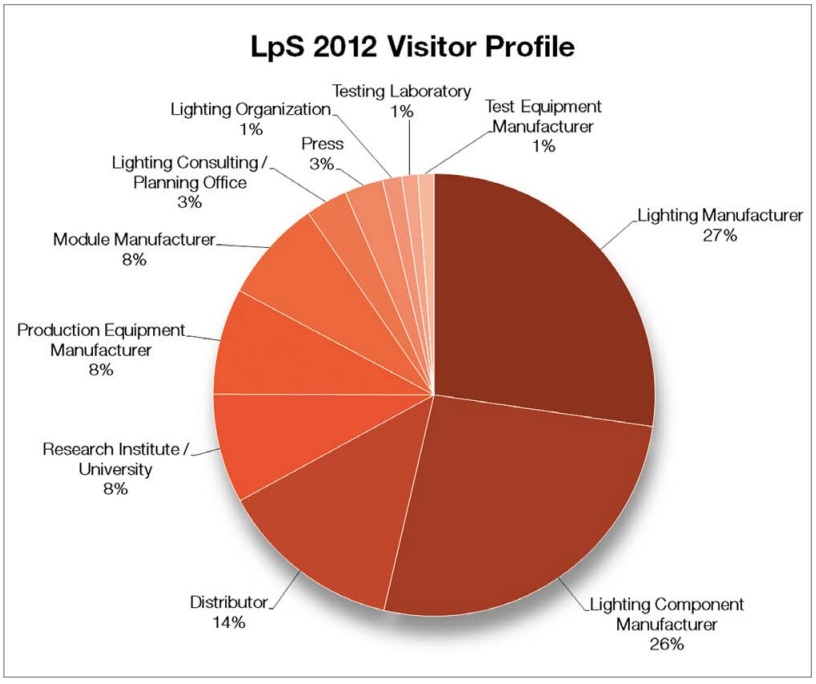


Figure 1:
This year's visitor profile shows that over 50% of the participants came from the lighting manufacturing industry

Figures 2-5: **Impressions from the Keynote session with Mr. Ziegler, Dr. Bechtel and Prof. Schulz, and the discussion with Prof. DDr. Ikovenko**

then followed his lead by unveiling the current directives and programs for LED lighting in the European Community, the technical visions of a big player in the LED lighting market (Philips) and creative, innovation, almost beyond state-of-the-art LED lighting solutions of an innovative and experienced lighting designer.

Michael Ziegler, member of the Photonics Unit at the European Commission's General Directorate for Information Society and Media in Belgium, presented the details of the Green Paper on SSL "Lighting the Future" and the findings of the consultation process. The EC investigated the interaction of consumers, (demand) and the LED lighting industry, (supply), and identified two lead market cities and buildings. As a result of the public consultation the EC found that Europe faces several challenges for the wider uptake of SSL. This finding is based on the input from the industry (39%), professional associations and NPOs (24%), citizens (15%), academia and research organizations (9%), and more. Mr. Ziegler explained, "We found out that there are concerns regarding the SSL product quality, and a lack of information and awareness. In addition, the high purchasing costs counteract a faster market penetration." He went on to say, "We also recognize three main challenges; namely, the currently inadequate market surveillance, critical gaps in SSL regulation and standardization, as well as uncertainties regarding health and well-being issues." Mr. Ziegler and the EC therefore clearly see that it is time for action and disclosed supporting measures from the EC. These would include the Eco-design and Eco-label for regulation, the FP7 and beyond for research and innovation activities. But he also reminded the industry to shoulder responsibility in enhancing cooperation and building up extended value chains for intelligent lighting solutions by establishing win-win platforms between large companies and SMEs. "One very important, not to say key to success, is to contribute to the training of lighting designers, electrical installers and resellers," he continued.

Regarding research initiatives he emphasized the "ICT Work Programme 2013, Objective 3.2" on photonics with a priority on OLED, SSL lamps and modules with added intelligence, and end-of-life issues like recycling. As actions to foster innovation, the EC recommends open innovation, enhanced cooperation between industry and end users, analysis of effects of SSL applications on health and well-being. Mr. Ziegler ended his presentation by telling people to contact him directly if any assistance from the EC is needed.

Dr. Bechtel, principal scientist and head of the group Converter Research at Philips Lumileds in Germany, outlined the understanding of a global player of innovation and how to make LED lighting mainstream. He began by showing the expected change in market penetration from 2008 to 2020. This was followed by a clear vision of when and why the transition from a LED lamp to a LED system market will take place. He highlighted the industry's enormous speed in development and innovation on the example of replacement A-lamps: While in 2008 just 25 W equivalent, mainly non-dimmable, lamps were on the market, in 2012 several companies presented dimmable true 100 W equivalent retrofit lamps. Dr. Bechtel emphasized "one of the most challenging issues for the industry is the 'green-yellow gap' that was recently overcome with a green phosphor that provides competitive efficiency values. But this technology has its own challenges. To constantly provide a high CRI, a very narrow binning of the blue LED is mandatory. "A very similar challenge is true for amber LEDs which are not only important for automotive or signage applications," he said. He also defined the company's philosophy of where the ideal replacement lamp mimics the behavior of an incandescent or halogen lamp, lowering the correlated color temperature (CCT) from 2700 K to 2200 K when dimmed to less than 20%. After speaking briefly about the Zhaga standardization he introduced what would appear to be the lighting technology of the future for Philips: OLEDs.

The final keynote presentation was given by Andreas Schulz, Professor at HAWK Hildesheim, CEO of LichtKunstLicht AG in Germany, and member of the IALD Board of Directors. Prof. Schulz demonstrated with compelling images of fascinating LED lighting projects that LED technology has really matured when applied properly. He showed the challenges that designers and technicians face, but pointed out that there is an LED solution for almost any application. In most cases this technology will make new solutions possible that could never have been technically or economically realized with conventional lighting technologies. "Especially for museum lighting, LED technology often enables more cost-effective illumination that better protect exhibits than any conventional light source." He added "… light quality is usually better and the architect is also happy because he can create a much more elegant or distinctive solution." Besides the classical museum illumination tasks, Prof. Schulz demonstrated projects with daylight saving options which not only adapt to the ambient light level, but also to the daylight color. This is certainly one of the most challenging applications. Even though he has been working with LEDs for several years now, Mr. Schulz still seemed to be fascinated by the opportunities that LEDs offer when he pointed out the advantages of this technology: "Lighting designers have got a technology that helps design more efficient luminaires, control light distribution better and adapt illumination levels more accurately to the desired levels, and to dynamize light better than ever before. Not to mention the energy saving and the reduced maintenance costs for the client."

Following this demonstration of high class LED applications, the exhibition was opened by Vorarlberg's Deputy State Governor, Karlheinz Rüdisser who acknowledged LED technology in his statement: "Energy is becoming more and more a strategic factor in the global economy. In 2010, Vorarlberg decided to become an energy autonomous state. Energy efficient technologies are the key, especially in the area of lighting; and LED technology is an important part of this strategy."

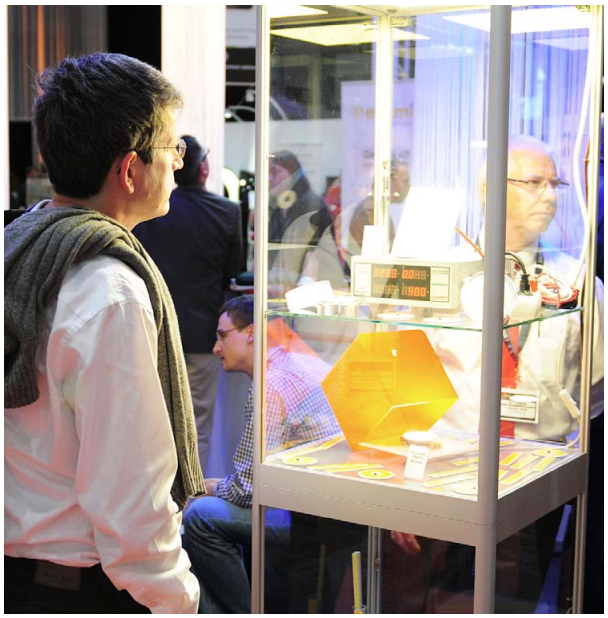
A Concentration of New Products Highlighted on 1,665 square meters

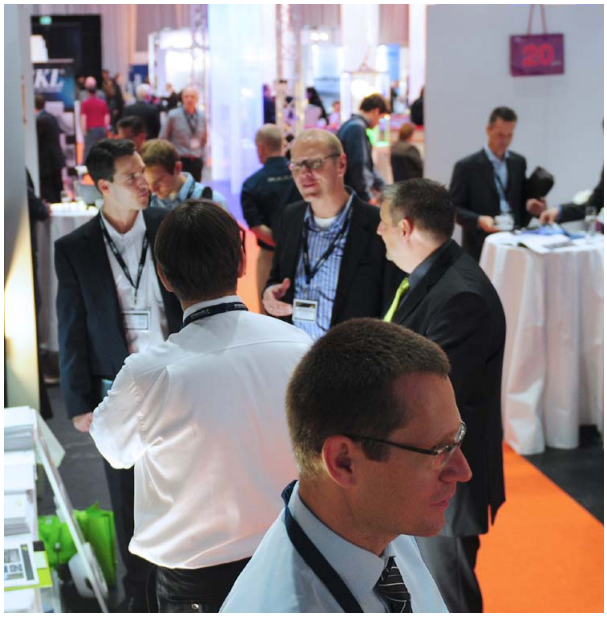
Attendees and exhibition visitors alike were attracted by the most recent developments presented by renowned manufacturers in the LED business. From components to semi-finished products to the sub-system and system, from the service provider to the testing specialist, the whole multi-facetted production chain was present and prepared for consultations and expert discussions.

Again, this year, exhibitors were impressed by the quality of the discussions with the visitors. On the other hand, the visitors appreciated the competent advice they were given by manufacturers and distributors as well as the opportunity to see many brand new products. The increased number of visitors combined with the new exhibition concept led to a rise in the amount of prospective clients visiting the booths. Volker Neu, General Manager at Vossloh-Schwabe commented, "I was really looking forward to going to some of the lectures at the symposium. There were so many clients at our booth the entire time, though, that I wasn't able to get away to see even one single technical presentation!"

The distributors, Arrow, Beck, Emtron, Glyn, Lumitronix, MSC, Neumueller, Rutronik, Silica and Telcona were present, making it easy for visitors looking for assistance in sourcing. Most of these distributors featured one or two of their major suppliers with the latest product highlight. At the Rutronik booth an application engineer from Infineon explained their power LED drivers in detail while Beck featured Sharp with their newly introduced range of diversified Mini Zenigata COB LEDs. Lumitronix, the official distributor for Nichia in Germany, exhibited Nichia LEDs and their own LED modules using Nichia products. Harvatek and Toshiba were represented by Glyn and

Figures 6-10:
"Pictures of the Exhibition"
Expert visitors and attendees were able to have discussions with the exhibitors about the challenges of LED lighting. Information was exchanged about new products and future opportunities. The competent booth staff also offered advice and tailor-made solutions for individual problems





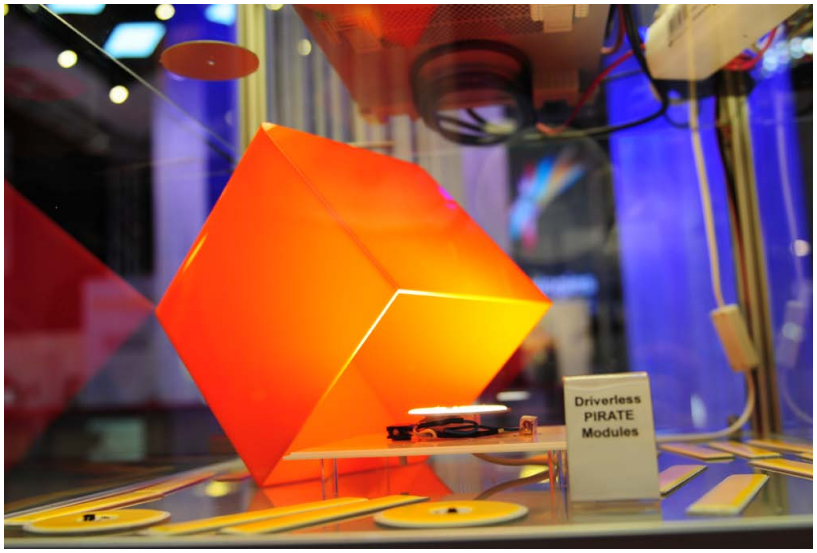
Emtron demonstrated the latest LED drivers and supplies from Meanwell like the highly efficient IP65 rated HLG-80H series. Neumueller and Silica showed Seoul Semiconductor's latest Acriche 2 updates with an efficiency of 100 lm/W which is now available in volumes, and MSC presented itself as an all-in-one service provider with its broad range of products and services. Telcona featured their main LED supplier Lustrous and the own branded TelcoLED replacement solutions while Arrow picked NXP as featured partner out of their wide spread portfolio in LED lighting components and services.

While Lumileds and Seoul Semiconductor were represented by their distributors, this year Cree, Osram, Everlight and e:lumix strengthened their presence with a conference speaker or having one of their experts participate in the Tech-Panels.

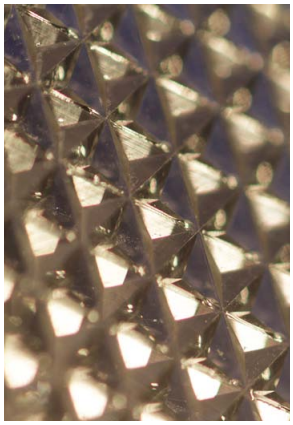
Cree was on stage with their brand new XLamp® XP-E2 LED that was already released on September 20th. Another highlight at the Cree booth was the new and improved CXA COB Array LEDs which are now manufactured on highly thermally conductive ceramic substrates. As is their tradition, Osram presented their products within the LED Light for You network in their partner applications and featured the remarkable Brilliant Mix Universal Control Demo Board to assist luminaire manufacturers with the complicated color tuning issue. The demo board enables CCT tuning from 2700 to 6500K along the Planckian Locus and offers numerous analog and digital interfaces. The demo board, officially released in November, was developed in a co-operation of OSRAM Opto Semiconductors, Infineon, Elec-Con und MAZeT. Everlight presented their module and luminaire brand Zenaro at the Zenaro booth. At their own booth they focused on their strength to provide the right LED for the right application. They recommend low and mid power LEDs for cost-effective omnidirectional replacement solutions and their COB or high power products for directional or less cost-critical high-end applications. Platinum sponsor, e:lumix, increased the size of their booth to 54m^2 and astonished visitors with a driverless module, 7 cm in diameter, that didn't get hot even when operated without a heat sink at approximately 10W. Even after hours of operation in a glass enclosure you could touch it without burning your fingers. According to CEO Thomas Zabel, this is the result of a special compensation layer that prevents hot spots and equalizes charge distribution in the p-n-junction.

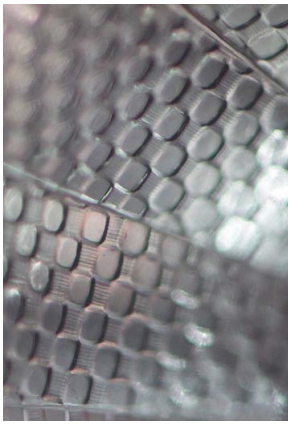
Several optics manufacturers were also represented by their distributors and the most recent developments were displayed. For instance, Khatod promoted their silicone lens PL50SIL and a comprehensive series of reflectors including an impressive number of round reflectors in many dimensions, the multi-round-reflectors based on modular systems in diverse configurations and the square beam reflectors for individual or modular use, as well as the unique anti-glare reflectors. AL Systems, a subsidiary of the Swarovski Group, demonstrated their high-quality glass lenses and highlighted the unique characteristics of glass and the advanced process methods which are based on the long lasting experience of the parent company. Gaggione is just one of the companies represented by Lightconsulting GmbH. The unique vertical range of the company makes it easy for them to provide custom-made solutions. Bryer, known for their high-class extrusion lines, presented a recently developed, ground-breaking technology that allows the production of extremely precise optical sheets that can vary the surface structure in the plane. According to the manufacturer, this leads to a much better light distribution and higher light efficiency while using less energy. Alanod featured their repertoire of highly reflective aluminum materials and demonstrated their service capabilities with examples from different customers and their presentation on glare reduced luminaire designs. The Dutch solution provider for printed optics, LUXeXceL, showcased examples based on their Print-Optical technology. They presented the latest advances in precision and the roadmap of their printers. Optotune, a Swiss spin-off from the ETH Zurich offers a unique system of focus tunable lenses. Their lenses are especially advantageous when adaptations for varying lighting requirements are necessary, for instance, in shop lighting or museum lighting with changing exhibits. Dependent on the combinations of LEDs and secondary optics, this system allows an easy adjustment of the light distribution angle from 40° down to narrow spot angles of below 10°.

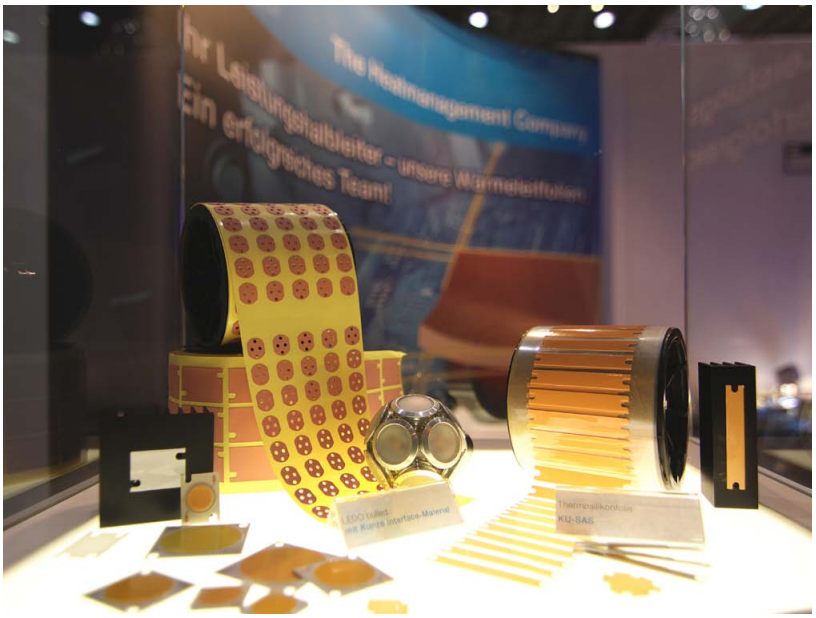
The luminaire manufacturers were also very interested in LED modules, driver modules, assemblers or testing equipment manufacturers. One such module and driver module manufacturer was Arditi who presented their range of ultra-compact dimmable drivers, controllers and brand new LED modules. All these modules achieve a color rendering index (CRI) of 85 with a color temperature of 3,000 K. While the two four-LED modules achieve remarkable 395 lumens corresponding to an efficiency of 90 lm/W, the twelve-LED unit realizes 453 lumens with an even better efficiency of about 96lm/W. Visitors were also very impressed with Vossloh-Schwabe's introduction of their Zhaga compliant product. Driver and supply specialists like HEC-Compucase, more or less a newcomer on the European market, Inpotron, Exscitron and RECOM showed AC/DC converters with and without PFC as well as DC/DC converters. HEC-Compucase came to the exhibition with its non-dimmable and dimmable LED drivers completed with two series of DALI compliant LED drivers. A special feature of some Inpotron drivers is their design that supports active cooling solutions and especially the capability to properly drive the Nuventix SynJet. Exscitron, a close partner of Inpotron, demonstrated their development capabilities for customized power supplies and LED drivers with some generic product samples. While focusing more on technical details to be discussed, like their symposium presentation topic dimming compatibility, RECOM



Figures 11-17: State-of-the-art technology was presented including driverless modules and optics in high end plastics, aluminum or glass. The most recent technology for measurement equipment was also shown, like sophisticated hand-held devices and high precision goniomemters. We also saw thermal management products and electronics







featured its series of DC/DC converters as well as the RACV and RACD off-line driver series with the most recent members, the IP67 sealed RACD100 and RACD150 for outdoor applications.

From the well-known driver IC manufacturers some, like NXP or Infineon, shared a booth with their distributors, whereby Fairchild presented their latest advances in driver technology at their own booth. Beside the FLS0116, FLS3217 and FLS3247, Fairchild presented the FL77xx series including the technical tidbit, the FL7701 with a smart digital technique to detect the AC input voltage condition. Among other ICs, NXP presented its brand new SSL2115x series of high-efficiency GreenChip™ driver ICs for non-dimmable, low-cost LED retrofit lamps and were very keen on promoting their IEEE 802.15.4 based wireless smart lighting solutions. Alternatively, Infineon stressed the superior dimming functionality provided with their ICL8002G IC that supports single-stage flyback or buck solutions with PFC.

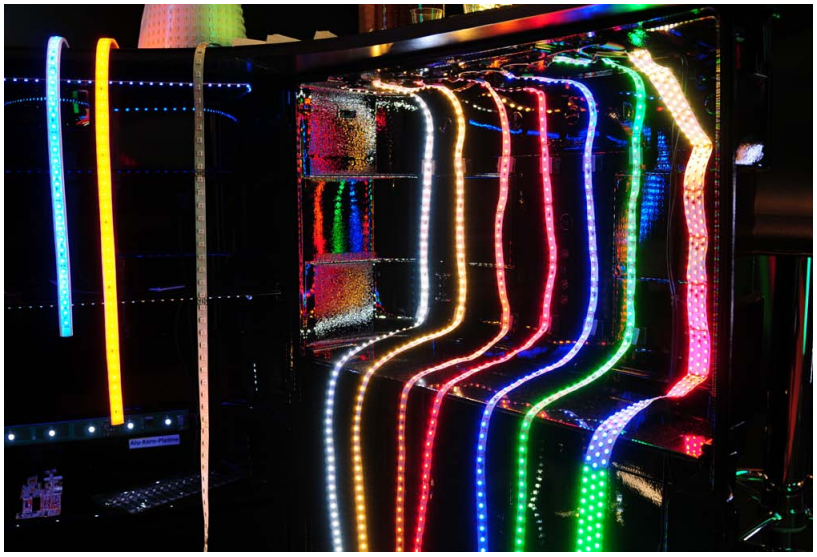
From the huge number of thermal management specialists, renowned companies like Pinblock, Brytec, Kunze, Bergquist, DK Thermal, CeramTec, EKL or Heraeus were present. While Pinblock demonstrated the excellent cooling capabilities of their heat sink designs, Brytec featured active cooling solutions. Kunze showed their advanced thermal interface foils. These are specially matched, both thermally and mechanically, to Zhaga compliant LED light engines. CeramTec displayed its exceptionally thermally conductive aluminum nitride ceramics heat management products and underlined the option to provide custom-made solutions. EKL also offers development and production of LED cooling solutions that fit the customer's requirements exactly by co-operating with the client in design and engineering. They presented heat sink examples based on their IP protected crimped fin technology. The UK based thermal management specialist DK Thermal came with samples of all their different thermal management products. The Formable Thermal LED PCB Solutions made from ceramic-filled fluoropolymer composite base material for IMS-based Power LED applications and thermal interface materials from several providers like Du Pont, DENKA or Laird are just a couple of examples of what they had with them. Bergquist was not only represented by DK Thermal but they also had their own booth where visitors could get information about various thermal interface materials, substrates and fans for active solutions. Heraeus also came with a broad range of products from interface materials to flexible substrates and the primarily featured cost-effective stamped circuit board technology and the Celcion circuits that should allow LEDs to run up to 10°C cooler than MCPCBs.

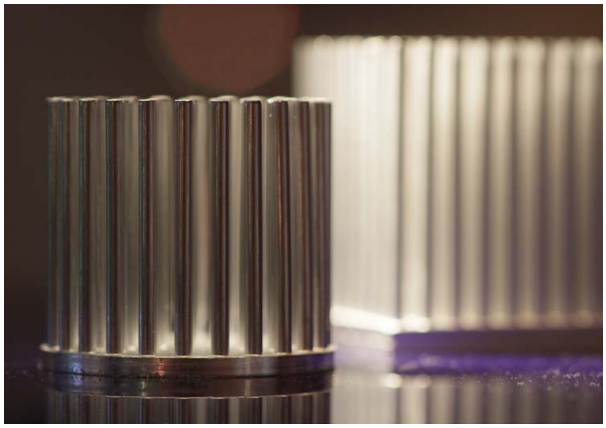
Fela, AT&S, Aismalibar, Melecs, Asetronics, LM Electronic and Haeusermann displayed their most advanced assembly technologies. Most of them now offer solutions that allow three-dimensional structures for advanced light distribution and designs without sacrificing thermal management issues. Depending on the requirements for any application, an appropriate solution could be found at one of the booths at the exhibition. Some of these companies not only offered assembly, but their proprietary PCB technology, as well. Some already provide Zhaga compliant solutions or assistance in generating Zhaga compliant end-products or they can manufacture according to automotive standards.

Lamp, module and system providers completed the manufacturing value chain. Compass Lighting, present at the Hungarian Investment and Trade Agency (HITA) booth, Aplux from the Netherlands, Taiwan based companies D-Wav, Unibrite and Zenaro, and from Austria, SoLED and Lumitech, all offered products with unique features. Unibrite showed a recessed louvre luminaire with up to 6500 lm and D-Wav displayed decorative luminaires. SoLED is specialized in solar LED street lights with a unique control and driver scheme. Lumitech offers highly efficient color tunable modules and custom specific luminaires with high CRI. Zenaro, an Everlight brand, showed retrofit and luminaire examples, like the SOHO Downlight, out of a rapidly growing product portfolio.

From the testing and measurement specialists, GL Optics, opsira, Instrument Systems, Gigahertz and Mentor Graphics showcased their innovative tools. Mentor Graphics showcased their T3Ster measurement system with its interface to FloTHERM that allows for a seamless construction of accurate thermal simulation models. Instrument Systems not only presented their high-end spectrometers, but also informed about their recently introduced solutions for LED testers, the LSM 350 basic module in bench enclosure and the CAS 120 CCD array spectrometer for price-sensitive applications. At their booth, Gigahertz featured their BTS256-LED spectrolightmeter for complete lumen, lux, color, spectral and spatial LED characterization, as well as other products like OEM models or custom design services. Opsira's booth attracted the knowledgeable audience with their gonio2π in action. The goniometers are driven directly; a principle that has indeed proven itself over many years as a tried and tested method, with absolute encoders enabling very high measurement precision. GL Optics introduced the brand new GL Spectis 1.0 touch. At that point in time, only a few prototypes existed and the software-development team was diligently finalizing and optimizing user-interface and firmware. The new spectrometer not only allows the measurement of lux, lumen, CRI, CCT, color coordinates according to CIE 1931 and CIE 1964, and mWatt, but also offers various communication features like Wi-Fi, blue tooth, USB, and a SD card slot.

For anyone looking for research partners or independent service providers to help them with their problems, the Competence Center Light, Joanneum Research and Yole as well as the service providers OEC and





Figures 18-23: Manufacturers, distributors and service providers presented their own products or the products of their clients. Here we saw LED strips, various LED packages from PLCC to COB, optical materials and final optics. LED bulbs, LED tubes and luminaires were used to demonstrate the innovative strengths of the exhibiting companies

Figure 24: **Professor Sergej Ikovenko's workshop "Operating Beyond Competition" was a highlight of the event**

RoodMicrotec were present to offer their assistance. The research institutes were ready with information about the most recent projects and studies as well as their research opportunities. Service provider OEC, presented a range of services to help luminaire manufacturers with their projects by developing tailor-made optics for the required application at the booth and tolerancing issues in the conference, while RoodMicrotec offered assistance in product design to optimize reliability and the lifetime of LED products, a topic that was also presented as a lecture by their manager, Reinhard Pusch. Further information could be gathered at the booths of the specialist press from LEDin and HighLight or the international trade press.

The Workshop – Operating Beyond Competition

Prof. DDr. Sergej Ikovenko held a workshop about IP in his second year at the LED professional Symposium. In his unparalleled approach, he checked the skills of the audience and, starting from the basics, he unerringly identified the risks and critical points and demonstrated how to generate viable solutions. He clearly defined how to gauge things like trimming, along with the tools to do it. The same is true for all other demonstrated approaches that he covered, like the competitive patent circumvention strategy, the antidote strategy, the picket fence strategy or the toll gate strategy, just to name a few. Addressing systematic approaches for patent circumvention was one of the key issues that he mentioned. This is because during the last few years many companies have started to analyze their patent claims, having patent circumvention in mind. They then adapt the claims until it seems impossible to bypass them. In parallel he explained the importance of doing the same using the antidote strategy which is supported by the TRIZ tools for function analysis, trimming, cause-effect chain analysis or function-oriented search. He also explained that the owner of the picket fence is in a position to force a cross-license of patents to acquire the core technology for his own use. In the end the attendees agreed that it would be beneficial to intensify the subject in their own companies and that it would be well worth it to call in an IP expert.

Figures 25 & 26: **The speakers were asked for more detailed information during the Q&A at the end of the lectures**

Figure 27-30: **The chair persons, experts in their own fields, also asked for more details about the technologies presented (Top left: Dr. Paul Hartman and e:lumix CEO Thomas Zabel) The informative lectures gave the audience a lot to think about (Top right: Janick Ihringer from Osram. Bottom left: David Nauth from Intematix. Bottom right: Steve Roberts from RECOM)**

26 Technology Lectures - Eleven Hours Brimming with Information

The 8 Sessions at LpS 2012 were arranged so that all relevant topics were covered spanning every significant subject from chip technology to application. Yole Dévelppement's semiconductor specialist Pars Mukish gave his insights on the results of their GaN-on-Si studies explaining that "GaN-on-Si LED technology could offer several opportunities to the LED industry in terms of cost reduction at the chip level. But several questions/challenges still remain concerning its development. The question if GaN-on-Si LED technology will be able to solve those issues and provide performance & yields at least equivalent to incumbent substrates (Sapphire, SIC) while demonstrating significant cost advantage, is still open." Tom van den Bussche from Bridgelux found an approach that could solve these difficulties and is convinced that "the GaN-on-Silicon performance levels currently reported by Bridgelux are comparable to state-of-the-art sapphire-based LEDs today." He added some future perspectives in his statement: "The potential of GaN-on-Silicon is the opportunity to produce competitive big dies that can be the basis of integrating complex concepts of system on chips (SOC)." Bob Kottritsch from Lynk Labs clarified when and how to apply driverless "AC" LED solutions. He sees a clear indication for using this technology when small form factor replacement lamps are required as well as for street lights or signage. The last speaker of the first session, Thomas Zabel from e:lumix disclosed that they produce LEDs using a Si wafer based Liquid Processing Epitaxy (LPE). One advantage of this process, besides the cheaper equipment, is the lower temperature and, hence, less stress and less thermal mismatch, resulting in a yield of over 90%. This is on par with or exceeds the sapphire process at a much lower cost. With this technology, e:lumix can alter the different chip layers in a way so that they act as compensation layers for electrical charges and temperature. "This prevents hot-spots and overheating on the one hand", Mr. Zabel explained, "and gives some degree of over-voltage protection." In addition to that, Zabel also sees many advantages for driverless solutions, especially based on his stress tolerant LEDs. He inadvertently introduced the next session's topic of LED light conversion by stating, "We can design any CCT within extremely narrow limits on demand, which makes classical binning obsolete."

Lena Pilz from Tridonic lectured on the fundamentals of light conversion materials and clarified mechanisms that cause losses and degradation. She explained the most important phosphor types and gave an introduction to quantum dots, which she pointed out, are of great interest but have some unsolved problems. "… their almost infinite efficiency drops drastically when they are deposited in a thin film," she explained, "however, maybe the application of QDs will become the next big step in this technology." In his speech, Prof. Nicoloics from the Vienna University of Technology showed theoretical, simulation and measurement results of temperature influence on the efficiency of phosphor converted LEDs. He was able to demonstrate that the substrate quality also has a clear influence on the phosphor temperature, and consequently, the conversion efficiency of the phosphor. In addition, the resistance of the silicone was

identified to be important. One promising approach to increase thermal conductivity was to add transparent YAG to the silicone. All in all, three critical points were delivered: improved light converter's quantum efficiency, increased thermal conductivity – also of the resin - and keeping the color conversion layer as thin as possible. In a very dedicated speech, David Nauth from Intematix demonstrated the remote phosphor concept and disclosed technical details of the new Ruby series of red nitride phosphors which enable a CRI of up to 98 which were to be released mid-October. In addition, he demonstrated that this technology allows new design options, but engineers and designers have to think creatively to exploit the full potential of the technology.

The lunch break not only offered sustenance, but also the chance to visit the exhibition and have lively discussions with other experts in the field.

The first speaker in the afternoon was Dr. Leis, the optics designer at Zett Optics. He showed the audience the challenges and presented solutions for using the current approach of multi-chip or single-bin LEDs. He demonstrated that optics and reflector designs not only need to be optimized for proper intensity distribution but also for color consistency. When several LEDs are used, homogenization can also be improved by a specific rotation scheme of the LEDs on a module. Dr. Leis identified filtering a system consisting of multiple single-bin LEDs as especially critical. This is common for high CRI surgery lamps. He explained, "In a worst case scenario, the CRI for an LED increases while the CRI of another LED drops dramatically, reducing the overall performance." Another very relevant issue was addressed in the lecture by Dr. Laschefski from Alanod. He pointed out that LED solutions can reach up to 300 times higher luminance levels than T5 systems which inevitably leads to glare. In his proposal the first step for a glare-free luminaire is an indirect LED position to prevent the direct visibility of LEDs as well as the correct choice of material and structure of the reflector to guarantee useful light distribution, colour neutrality, and high optical system efficiency. Dr. Angelika Hofmann, freeform optics specialist at OEC AG, showed the results of their tolerance analysis and the implementation of these results in an automated Monte Carlo simulation. She emphasized the advantage of interpreting all surfaces as free form surfaces to incorporate non-symmetric tolerances. In conclusion, she said, "Due to realistic modeling this tolerancing approach allows for the definition of well-balanced specifications for production."

The last session of the second day was on the topic of LED electronics from drivers to sensors. Harald Reichert, Application Engineer at International Rectifier, gave very useful hints on how to identify the appropriate driver technology for a given application. "The application defines the requirements and in consequence the converter topology with the resulting performance-to-costs tradeoff," he stated. Furthermore, he explained the TRIAC dimmer problem and gave two application examples to clarify the tradeoff and proposed an alternative LED matrix switcher approach to solve the TRIAC dimming problem. The following lecture held by Recom's technical director, Steve Roberts, explained the TRIAC dimming problem even more in-depth. He pointed out how important it is to distinguish the dimming level regarding measured brightness in contrast to perceived brightness. Mr.

Figure 31:
One of the major qualities of the symposium, both in 2011 and 2012 was its knowledgeable audience

Roberts also demonstrated the complexity and difficulties of achieving flicker-free dimming below 10% and concluded, "LED dimming may be presented as 'a done deal' by many ballast suppliers who confidently write specifications like 1:1000 dimming ratios in their datasheets even though their output accuracy is only +/-5% (1:20), but this short discussion shows that accurate, linear and flicker-free LED dimming still cannot to be taken for granted." Sajol Ghoshal, Director of Sensor Driven Lighting at AMS-TAOS disclosed how to add intelligence to LED lighting systems that enables energy saving while taking advantage of the unique capabilities of LED lighting technology by adding a smart color-managed ambient light sensor to the system. He could show that such a system adds an additional 20-25% cost and energy saving on top of the already achieved 25% reduction that can be achieved when installing an LED system compared to a CFL system. But the major benefit of that solution is the color-tunable approach that can adapt the artificial LED light to the natural ambient light or that can be controlled, for instance, to not disturb the natural melatonin day cycle and circadian rhythm. More mathematically, Mr. Hailer, application engineer at MAZeT, discussed optimization of absolute accuracy for a true color sensor in a multi-color closed loop system and finally demonstrated that the known intensity and wavelength drift of LEDs over temperature can be measured with true color sensors and the presented optimized calibration method. His research also showed that further improvements need to be done for warm white (2700K) colors and applications.

The third day began with a discourse on the use of glass as an optical material in LED lighting systems. Opening the session on production technologies and materials, Maximilian Herzig not only listed the advantages of glass lenses, but also gave an idea of the processing opportunities and the resulting products as well as preferred applications. Huub Claassen, the managing director of TOWA Europe explained molding options for HB LED primary optics. According to him, these technologies are very cost-effective and more precise compared to dispensing methods. He identified the singulation process as a main technical challenge that TOWA has solved. Finally he presented a new technology; the wafer level molding that allows a primary lens to be added directly onto the wafer. The stamped circuit board technology was the topic of the Heraeus project manager, Andreas Steffen Klein who showed measurements that indicated that this cost effective technology offers a lower thermal resistance than standard technologies and therefore can lower junction temperature by up to 10°C. The developed process also enables SCB multi-layers with thermal vias. "This technology allows new innovative functional surfaces, like silver. In combination with the new 'mAgic' die attach materials and silver based bonding wires, SCB technology provides great thermal performance at low costs," he stated.

The session about standardization and measurement started with the very recent topic of requirements, design and compliance for Zhaga compatibility. Guido Nattkemper, director of production management for LED products at BAG electronics gave an overview about the Zhaga Books and picked out the photometric interface of Book 3 LED light engines to go into more detail. He demonstrated that these specifications for the interfaces of an LED light engine leave the necessary freedom to ensure technological progress while providing benefits through interchangeability for the complete chain from the LED light engine producer up to the end user. Dr. Dirk Hansen from opsira demonstrated how to perform light measurement to obtain reliable data to generate a polychromatic raydata set for simulations. He pointed out that especially the trend to multi-chip packages with chips of different color characteristics a standard monochromatic rayset is insufficient. Peter Laepple from Instrument Systems reported on the photo biological hazards – standards, measurement methods and, in detail, how LEDs are affected by these regulations. He clarified that these days, blue LEDs alone may carry relevant risks in general lighting.

The session "LED System Reliability" was opened by Shawn Keeney, application engineer at Cree. He explained how to avoid fatal mistakes in a luminaire design. His advice was based on Cree's TEMPO (thermal, electrical, mechanical, photometric, and optical) approach. He identified criteria to select the LED as follows: "First, one must choose the right LED for the application. The basic question one needs to ask is not only how much light do I need, but also, where does it need to go?" He went on to say that there is always a trade-off that needs to be accepted. Reinhard Pusch, the general manager at RoodMicrotec, focused on failure analyses and prevention strategies to improve

Figures 32 & 33: **The Tech-Panels were highly appraised by the attendees and experts alike (left image: fotobility / Jürg Knuchel)**

lifetime. He gave a brief description of how lifetime is defined and then talked about the most common failures before disclosing methods to identify failures. Mr. Pusch classified three failure groups: failures in the manufacturing or assembly process, insufficient selection of devices or design, and a mismatch between capability of LED and application, for which he presented precaution strategies. “Besides these risk assessments, one also has to take into account the environmental conditions and the operating conditions of an application,” he said in closing. The next speaker of this session, Janick Ihringer, application engineer at Osram Opto Semiconductors talked about reliability in outdoor applications. He described three main issues for outdoor use. Firstly, finding the right coating material out of hundreds of possibilities, where even materials of the same group are not interchangeable. Secondly, protecting the system from corrosive gases where the sealing is made of inert materials. Thirdly, choosing a material and finding a design that withstands thermal stress caused by temperature cycles, for instance, preventing CTE mismatch.

The last session of the 2012 event concentrated on LEDs in outdoor applications, beginning with a very interesting study about the influence of the spectral distribution of light on visual perception. As a first result that could be presented, Andreas Ueberschaer from the TU Ilmenau said, “Additional and even more detailed research and analyses should be made.” There is evidence that for different impaired conditions a different spectral distribution is beneficial and as a result a dynamic-adaptive street light system would be the solution.

LEDiL’s director for business development, Bob Derringer, gave a lecture on optics selection for road lighting. After a short discourse into market opportunities, specifications and requirements, he analyzed the influence of the secondary optics in the whole system and came to the final conclusion: “Define the optical need and design your optics at an early stage of the project.” Daria Casciani from the Politecnico di Milano analyzed three street lighting concepts to develop an optimized design process. The three different concepts starting from a two-dimensional concept, followed by a complex three-dimensional system, ended up in a simplified planar system with free-form lenses. This third concept will be progressed and sophisticated. The clear advantages are the modularity that allows scalability, design freedom and cost optimization.

Tech-Panels - Knowledge Gained through Interaction

The beautiful Propter Homines Room was the center of discussions between the experts on the one side and the attendees and the authorities in the fields of OLED, thermal management and replacement lamps on the other side.

The OLED Tech-Panel was distinguished by the three discussion fields. The first question concerned the research status regarding efficiency, lifetime, and temperature limitations. The conclusions gathered were that depending on the OLED technology, extraction efficiency or the blue phosphorescent components have to be improved. With recent products, lifetime is limited to 10,000 to 20,000 hours. Temperature limitations are already a problem for outdoor and automotive applications. The second area was all about applications; for instance how OLEDs can be compared with LEDs in area lights, will flexible OLEDs become more than a niche product or is the pure Lambertian light distribution really desirable? Finally, the future developments and research goals were addressed. Some unexpected answers were: One research project showed that in many situations people conceive OLED light more comfortable than any other light. There is ongoing research to shape light from OLEDs into a Gaussian distribution. Besides lighting, OLEDs could be of great value for biological and medical analysis due to a perfect shapeable spectral distribution. In the discussion, the experts also explained that with OLEDs, creativity and inspired new designs are necessary to bring them onto the mass market, despite the fact that they could be mass produced very cheaply.

In the thermal management Tech-Panel, the audience was given a very good introduction in theory and an explanation why and where waste heat is generated in the light generation process. The specialists also agreed that thermal management is always a clear trade-off between costs and design expectations. They also agreed that the thermal impedance of the whole system is the key to a good thermal design. Excessive reduction of the thermal resistance in just one component or layer of the system is not reasonable. One design tip was that the best thermal design provides a well-balanced thermal path. Another tip was that if you need to use a small

Figure 34: **Networking opportunities are essential at any event. The unparalleled atmosphere of this year's Get Together Event was perfect for making contacts while cruising along the shores of Lake Constance. The MS Vorarlberg was the ideal venue for a relaxing evening after a busy day at the LpS**

heat sink, you need to lower the thermal resistance in the interfaces between the LED and the heat sink. Constant current driven designs have lower losses and allow smaller designs.

"Bulb is over." This is the statement that started the discussion of the replacement bulb Tech-Panel. The statement provoked a discussion about how long replacement bulbs will exist, or if they might last forever. Most experts were convinced that the bulbs will shrink to a niche market, but only if the consumer can be educated and if the industry can provide another comparably convenient solution. They also agreed that this will likely not take place for another 10 to 15 years. The next discussion point was the costs. For equivalents of up to 60 W, mid and low power LEDs are a very appropriate solution. Above that level, not all participants found that solution useful. For standard products AC-LEDs or driverless systems are another way to reduce costs. This raised the question of flicker. After an intense discussion, the experts agreed that the applicability strongly depends on the application. Another relevant topic was the motivation to buy LED bulbs. Is it a question of costs, or emotions or is added value an argument? No clear consensus was reached but it was agreed that all these factors can be used to improve acceptance to some degree. The discussion ended up far from technical issues, demonstrating that not the technology but rather the end-user market acceptance and strategies for better market penetration are the main issues. Several options were presented with some coming from the audience.

Networking

Networking is an integral part of any event like this and appreciation for those opportunities was expressed in 2011 by the exhibitors and visitors alike. This year as well, the coffee and lunch breaks were the perfect opportunities for discussions and making new contacts. However, to make the LpS 2012 even more memorable, Mr. Luger arranged a boat cruise along the shores of Lake Constance on the MS Vorarlberg. The evening not only provided important business opportunities for the almost 200 exhibitors, attendees and speakers on board, but also a chance to relax and socialize after a busy day at the exhibition.

Final Thoughts

With the world's biggest lighting event taking place just a few months before, the LpS 2012 planners wanted to make this event something that would catch the attention of the LED world, and the response and testimonials proved that they succeeded. The conference program, disclosing new and alternative approaches and sound explanations of fundamental challenges of LED technology, was well received by the attendees. On top of a comprehensive selection of speeches there were also the three highly praised Tech-Panels. Exhibitors and visitors found the event to be exciting and full of opportunity. There was a great diversity of products for the visitors as well as several absolute novelties, never before shown. The exhibitors, on the other hand, found the international audience to be interested and competent conversation partners; traits that are rare at other trade fairs.

The amount of positive feedback from attendees and exhibitors proves that the organizers' chosen path is the right one and encourages them to come up with new ideas to make the LpS event even better in the coming years. ■

LpS 2012 – OLED Technologies Tech-Panel Discussion

The OLED lighting experts Dr. Patrizia Melpignano from OR-EL, Jörg Amelung from LEDON OLED Lighting, Dr. Helmut Bechtel from Philips Lumileds and Dr. Volker Levering from BMW discussed the topic of Organic-LEDs application and technology. The OLED Tech-Panel took place at the second, international LED professional Symposium +Expo 2012 at the Festspielhaus Bregenz, in the Propter Homines hall, on September 26th, from 11:15 to 12:30 and was moderated by Ilka Mellert from Spracharchitektur.

Figure 1: **Experts discussed several aspects of OLEDs for general lighting. From left to right: Dr. Volker Levering from BMW, Jörg Amelung from LEDON OLED Lighting, Ilka Mellert, the moderator, Dr. Helmut Bechtel from Philips Lumileds and Dr. Patrizia Melpignano for OR-EL (image: fotobility/Jürg Knuchel)**

Why do we need OLEDs in general instead of LEDs?

Mr. Amelung: The main question is indeed: What new features can be expected from OLEDs when looking at the LED as the existing technology? In comparison, LEDs are point light sources and there's always the need to distribute the light into an area light source. It must go from a high-brightness level to a low-brightness level in order to reduce glare. On the other hand, OLED is an area light source from its origin in principal. At the moment we have a competition between LEDs and OLEDs in terms of specific parameters and costs.

Mr. Bechtel: Of course the large area light source is one aspect of the OLED. Nevertheless, there are some aspects of the OLED that are unique. For instance, an OLED can be a mirror or is transparent in the off-state. Also an OLED can have any shape; any form can be produced. This means there are no limitations to the shape of OLED lighting systems.

Ms. Melpignano: Organic LEDs can be built on flexible surfaces, like plastic sheets or on metal sheets. There are a huge amount of new opportunities that you don't have with inorganic LEDs. It won't happen tomorrow, but maybe the day after.

Mr. Bechtel: Last but not least, in the end it's also a question of costs. Light guides and optical installations, which are necessary for LEDs, always add to the costs. In the long term vision, at least, OLED production can be very cheap. There are only nanometer-layers of some organic materials, which can be very cheap in terms of material use and production technology in the future.

Let's have a look at the existing OLED technologies. Which are suitable for lighting applications?

Ms. Melpignano: Actually, the research is quite advanced but there are still a lot of things that must be investigated. One of the biggest problems that still exists in the organic LED technology is harvesting all the light that is really produced – so to say- the extraction of the light. Currently, with the standard technology only about 20% of the light is really extracted. Another thing is trying to find new organic materials, in particular for the blue. Currently, the phosphorescent material that can

produce blue is not very efficient and shows a short life-time. For general illumination we need the blue color for generating white light.
Right now there are hybrid solutions that use a fluorescent solution to obtain the blue color but a very big and interesting step in future research will be to have phosphorescent blue emitting material with a good life-time. I expect that this material will be available next year.

Mr. Amelung: The blue material only has about 10-20 k hours of life-time measured at a decay of 50%. But the overall life-time depends on how much of the blue material is needed. Also, there is a difference between a deep-blue and a light-blue. That's exactly the reason why warm white OLEDs do have a longer life-time than cold white OLEDs.

When will OLEDs be available in larger sizes? There seems to be a limitation right now.

Mr. Amelung: The first barrier comes from the yield in fabrication. You can produce a 30 x 30 cm OLED but the yield is pretty low. The second barrier comes from the side contacts because the whole current is flowing into the panel through these contacts. This gives a natural limitation in the size because otherwise you would get inhomogeneous lighting. I assume that in the future we'll see OLED sizes of about 30x30 cm or 60x60 cm. But we're also thinking of module based solutions based on smaller OLEDs, which can be put together to make larger areas and so reduce the costs for large area lighting.

Mr. Bechtel: I would even add that we could phrase it as a research challenge or as a material development challenge. In the end it's really a question about the conductivity of the transparent electrode that we have. We need to bring the current via transparent electrodes to the whole surface and of course due to the sheet resistance and the resulting voltage drop we can see a change in intensity over the surface. Of course we can add grids to distribute the current but this would be visible in the OLED. It will really also depend on the market - if, for example, grids are acceptable or not. Nowadays, the maximum size of an OLED panel that can be produced without the need for a grid structure with existing materials is 10 x 10 cm.

When we look at similar problems in solar-panels, they're structured so they have a lot of strips that are connected in series like you do with LEDs. Is there any way of doing this with OLEDs?

Mr. Bechtel: From the manufacturing point of view, it can be done. The question is really the market point of view where OLEDs are a light source to look at.

Our experience when making arrays based on smaller OLED panels were problems with the life-time or the different degradation of the panels. At the end of the running different panels had different colors and this made the whole array unattractive. Can you comment on this?

Mr. Amelung: To be honest, these are problems which also have to be solved in the future. Obviously, we are not finished with development and it goes without saying that we want to have the same color at the end of the life-time as at the beginning. We believe that this problem will be solved over the next several years. Regarding life-time there has been a lot of progress. The life span doubles every year and will continue to do so in the future.

I would like to invite Volker Levering from BMW to give us his opinion from the point of view of the automotive industry. Maybe you could tell us if you already use OLEDs. If you do, where do you use them and what are the objectives and requirements?

Mr. Levering: Yes, we are already using OLEDs in the Rolls Royce interior lighting. What is interesting to us is the design and its package. Space is scarce in a car so this is one big advantage of OLEDs. The other advantage is the possibilities for design. For example, you can use a mirror as a lighting device or you can have a transparent space and suddenly the light comes out of "nothing". These are very good design effects. On the other hand the application of OLEDs in a car is a very difficult one. As you probably know, there are very strong regulations for exterior lighting on a car which have to be fulfilled for the entire lifecycle. This means 10 years or more. Here we are talking about very long life-cycles and also the fact that OLEDs cannot be replaced like a light bulb. This means we have to guarantee that the lamp will work for the whole life-cycle of the automobile and this is a very big challenge.
In regards to the applications we see the first area as the interior of a car and the second area would be signal lighting at the rear of the vehicle or signal lights. They would be the start for exterior lighting.

Ms. Melpignano: We have different kinds of advantages in respect to inorganic LEDs, especially when we develop organic LEDs on plastic substrates. Weight is just one example. Imagine just having a plastic stripe that you can put on the ceiling of the car! This fosters new and interesting opportunities. And the same thing can happen for the stop-lamp at the rear end of the car. The problem with the stop-lamp, though, might be the light distribution for a targeted photometric specification. This is difficult to reach with OLEDs due to their lambertian distribution. But optical elements could be integrated directly into the plastic substrate. This is something for the future.

Mr. Levering: Another interesting idea is building up layers with OLEDs. We can have three-dimensional shapes with layers and, for example, when used as a brake light you could turn it on gradually or make a rear lamp that is almost hidden and when it is active it becomes visible. On the other hand OLEDs have to be able to withstand vibrations as well as temperatures from -40°C up to 100°C close to the engine. As a car manufacturer, we have to fulfill all of these requirements; otherwise the customer would never accept it.

What is the prospective in regards to efficiency in time, how far can we go and how much more light-output can we get from OLEDs in the future?

Mr. Bechtel: This is really the key for OLEDs. We need materials that can harvest all the excitons that are generated in the OLED layers. These materials are very successful in green and red but blue is really the issue. In this respect the industry is working very hard. At the moment we know there is this Konica-Minolta OLED with about 45 lm/W or the Philips OLED with 17 lm/W but they are designed for reliability and the possibility for mass-production. The chemical industry is working on these issues and there is a lot of progress. Yesterday in the keynote I briefly showed the roadmap of Philips OLEDs. Within 6 years we expect, in alliance with all material suppliers, to reach up to 100 lm/W level in efficiency with OLEDs. Philips just invested 40 million Euros in a production line in Aachen, Germany for producing OLEDs. This line will be capable of producing about 10,000m^2 per month.

Mr. Amelung: When you calculate real efficiency you have to recalculate it based on the application. For a good comparison between LED and OLED you have to include the diffuser system, or let's say the light-guide. With LEDs you lose about 20%-30% in the optical paths for an LED when going to area lighting. Therefore the market entry could be much quicker and I assume in 2014 about 80-100 lm/W in the first elements. But it is related to the color temperatures, so the first one will be the warmer temperature and later on the cooler ones will follow.

What's the vision for flexible OLEDs? When will we see these types of products? What are the main challenges of flexible OLEDs?

Ms. Melpignano: Regarding the plastic substrate, there is a lot of work going on all over the world. There is an American company that is making a lot of progress as well as the Fraunhofer Institute in Germany that is working on developing a roll-process to produce this kind of new light source. At this point in time they have samples available on the market. The big problem is the sealing because the life-time of an OLED is related to how well protected the OLED is against moisture and oxygen. This is the most important issue. Standard OLEDs are protected by glass but you can't use glass for flexible solutions. For flexible OLEDs you would normally use a different process like the atomic-layer deposition or particular kind of deposition which alternate organic and inorganic layers.

Mr. Bechtel: Plastic substrates are very attractive. They are very rigid and of course they are bendable. But with all the diffusion barrier layers you need to have reliable OLEDs, they become very expensive. There is ongoing research and the development of a simpler substrate. One approach is based on thin glass with a thickness of about 30um. These glass-sheets are very flexible but they can break. Nevertheless, in my opinion, the first flexible OLEDs will be based on flexible glass-sheets. We are considering going into production with this technology as well and bringing this to the market within the next 6 years.

Mr. Amelung: I would like to add another material - metal substrates. This is also an opportunity. We are working on that together with Alanod, who is also exhibiting here. Even so, it will take some time since the solution must be a good quality product. I believe we are looking at a time frame of 2 to 3 years for the first samples and longer still for mass-production.

How can OLED for lighting benefit from the OLED technologies used for displays?

Mr. Amelung: We have two markets for OLED displays – the bigger smart-phones and TVs. The technologies for TV sets, used by LG are, in principal, a large OLED lighting measuring about 1m^2. We can profit from these technologies and they will provide important improvements for fabrication technology as well. This, in turn, will help the lighting industry itself. The investments in OLED displays are huge and several billion Euros are being invested in new production lines this year.

How can we manage the costs to make OLED technologies successful?

Mr. Bechtel: That's a critical point and the question is what is really cheap when it comes to an OLED? This places the ball back on the application and the demand side. For example, one aspect we haven't touched on is that the OLED is already a luminary. LEDs or any lamp we put under light-absorbing elements are made inefficient but the OLED itself has to be design-integrated into the luminary. If the market started to value this property then it would go back to the designers and luminary manufacturers to really come up with smart designs. This would then increase OLED production which would mean that prices would go down. I think that even the automotive industry is too small to be an OLED market and cost driver. For automotive it's a matter of reliability.

Mr. Levering: It's often the case that the automotive industry breaks the ice and then the general lighting industry works to get the prices down. So it's a win-win situation for both industries. It would be splendid to have a monitor within the shapes of the interior design.

Mr. Amelung: It's really a question of when costs will be lower. It's always a triangle between performance, costs and unique features. At the starting point it will be an expensive solution and it's more like art and later on it will be more decorative and high-end professional applications. But the unique OLED features, especially the form factor and the homogeneous light-output, are key. Furthermore, some of our own research studies show that humans valuate the light coming out of an OLED even better than light from other light sources - they feel more comfortable. It's not really known why but further research has to be done in this area.

OLEDs also require some kind of driver. What are the specific requirements for a dedicated OLED driver? Can specific drivers support and speed-up the process of OLED entering the market?

Mr. Amelung: Basically, driving an OLED is about the same as driving an LED. It's a solid-state light source and

therefore the behavior is very similar. But we think that an OLED, from the market prospective, is not strong enough to generate its own converter industry. So we have to deal with and use the basic LED converters. The main difference, I would say, is capacity. An OLED is a large diode and they have a large capacity in relation to LEDs. Of course this generates some issues regarding dimming. Especially low dimming, where pulse-width signals are very short, problems might occur. The loads are not that large and so the architecture on converters has to be designed. But we would really start with LED converters and later on it would be important to have combined LED – OLED converter systems to have it easier to bring it into the market.

Mr. Bechtel: I agree with that. It's a diode with large capacity. This morning we also saw some papers about AC-LED topologies, which might also be an issue for OLEDs. I can think of a further difficulty with OLEDs then, because OLEDs can also short-circuit. For OLEDs this is more difficult than for LEDs because they do that at a point and then you'll get their heat and it could spread out. It can really result in catastrophic failures; the organic material can burn. So OLED drivers should have a kind of short-circuit safety feature in the driver. On the other hand, I don't think this is really an issue for the electronic industry.

We cannot illuminate rooms with huge areas of OLEDs. In such cases we would need optics as well. Is there any research going on to combine OLEDs with optics?

Mr. Amelung: The only comment I can make on that is: Yes, there is research in this direction.

Ms. Melpignano: From the research point of view there is the possibility of introducing micro-optics directly into the plastic substrate. This can be used to shape the light. My idea is to shape a small pixel, by shaping the area in small pixel and then use micro-optics directly on this pixel. This will reduce the efficiency, of course. The research target is to find beam-shaping structures without losing the efficiency for OLEDs.

Do we need a closer cooperation between component manufacturers and the lighting industry to find OLED solutions for the future?

Mr. Amelung: At the starting point our target was at 1000cd/m^2. Now we are at 2000-3000 cd/m^2, which is the glare limit at the moment. We continuously have to adapt the requirements to the applications. Therefore this communication is very important.

Can we also share the ITO as an input, like a touch panel?

Mr. Amelung: Yes, definitely. We have already shown similar approaches. We can use the ITO as one electrode for the capacitance detection. It's not a display, but it could be an important feature, especially because the OLED itself is cold and can be touched. So it might also mean an interface for humans for dimming or switching.

I think we should take the opportunity to learn from the LED technology. Right now everybody is talking about Zhaga, and standardization. What do you think about the standardization of OLEDs? Uniform sockets, uniform photometric, uniform definition of color temperatures and so on. Could we have a better or different start with OLEDs to avoid every manufacturer working on his own?

Mr. Amelung: It's really related to the market segment. There is an ongoing discussion within the Zhaga consortium about when we want to start with OLEDs. Up until now it hasn't started and it's not a topic there. But we are keeping an eye on it. I think it will take a few years and then it will be important enough to have standardization for high-volume OLED applications. One standardization is ongoing and this is the parameter measurement, so that we can compare the parameters from the different OLED panels on the market. That is one of the learning curves from the LED technology. A first draft is being discussed now.

Mr. Bechtel: I would also say that it will certainly be a topic at the end of the development. Currently, it's too early. Right now we want to inspire creativity in using OLEDs. In this phase, standardization would just be an obstacle. At the moment we invite people come and use them. Then we ask for different solutions like OLED shapes, colors, dimensions, etc.

Can we share the knowledge from the bio-chip development into general lighting with OLEDs?

Ms. Melpignano: What we are doing now is really to shape the spectral emission. We try to create bio-chips that take advantage of this possibility. We are looking to tune the emission spectra with OLEDs. This is difficult to obtain with inorganic LEDs. With organic LEDs we have much more freedom because the process to create the OLED gives you the chance to tune the thickness of the organic layer and use different kinds of electrodes. So you can really shape the spectral emission. This fact can be very important for medical applications.

We are discussing manufacturing costs for OLED which is a critical point for the integration of OLEDs. Today there is only one reference point, which is the DoE roadmap. What do you think about this roadmap? Personally I found it very aggressive because today with 1,500 U.S. dollars/m^2 they expect to have a very high decrease.

Mr. Amelung: I also see it as too aggressive. Prices today are higher than the DoE's forecast. There will be a drastic cost-reduction within the next couple of years. I assume there will be a reduction within the 2-3 years by a factor of 10 to 20. So then we will still have a difference of factor 5-10 compared to the LEDs.

Mr. Bechtel: With LEDs we are talking about Lumens per Dollar and with OLEDs we compare the square meter. Today, typical prices are at 6-8 EUR per cm^2. Of course prices will go down with volume. We see the prices in the area of 0.5 EUR per cm^2 in the next few years.

Thank you to all the experts! ■

Human-Centric Lighting: Sensor Technology for Full-Spectrum Lighting Solutions

While not necessarily common knowledge, research is rapidly validating the common-sense understanding that human beings are "tuned" to the natural lighting cycles of the sun, and can be equally "de-tuned", to the detriment of both health and productivity, by artificial light sources that operate contrary to these natural flows. Sajol Ghoshal, Director of Sensor Driven Lighting at the Opto Sensor and Lighting BU at ams, discusses the available approaches for full-spectrum solutions, and potential human-centric benefits, of fully integrated intelligent ambient/color light sensor and driver technology.

Decades ago, the need for both energy savings, and increased lamp longevity, drove commercial lighting away from the more "natural" incandescent lighting. While the primary substitute, fluorescent technologies, continued to improve on efficiencies and color quality over its 50+ year history, with the introduction of high-efficiency T5 luminaires, progress has effectively plateaued in both areas. With the advent of LED-based lighting, an entirely new palette of precision spectral and color-quality capabilities has been presented to researchers, luminaire engineers and lighting designers alike. These capabilities are the harbinger of a new era of "human-centric" illumination, that will be enabled by cognitive lighting, that will soon be working at an elemental level to increase health, well-being and productivity of people everywhere.

Common light sources, including daylighting, have dramatically different energy spectrums allowing ambient/color sensors the ability to distinguish between these different spectra and determine the actual amount of ambient light available, as well as the quality of the light on a quantitative basis. When combined with precision control of the LED lighting with white color tuning, a fully-integrated, fully-intelligent cognitive lighting system can provide not only provide human-centric lighting, but can additionally realize higher efficiencies by focusing directly on the kind of light needed. By way of example, later afternoon sunlight may still be in ample supply in the interior of the building, but the warmer color temperature of the light may not readily support the same visual acuity as the mid-day sun. The option can then be incorporated to allow delivery of electric lighting strictly concentrated in the cooler color temperature region, with substantially lower luminous flux and overall energy savings compared to continuous full-spectrum solution.

Introduction

Whether it is due to escalating insurance rates driven by rising health care costs, deeper recognition of the true value of maintaining and retaining skilled workers, or continually growing productivity demands, businesses are placing a new emphasis on the health and well-being of their employees. Up to this point in time, that emphasis has resulted in traditionally understood lifestyle "touch-points" including exercise, wellness exams, management of individual risk factors, or work-scheduling approaches for shift workers.

It has long been understood that poor lighting is not only associated with an adverse environment, as we all relate to the mental image of the "dark dungeon" or "dimly lit alley", but that there is a cause and effect relationship with human health. The most prominent example is season affective disorder syndrome, or SADS, which is a winter-season depression that effects sensitive individuals in the higher latitudes where the day/night cycle is more extreme, right up to the Arctic or Antarctic circles, where there will be winter days when the sun will literally fail to rise fully above the horizon. Experimentation with "light therapy" proved effective in extreme cases, adding momentum to a new realm of studies of the interaction between light and humans.

While something like SADS, or traditional jet lag provides a backdrop for the effect of day/night cycles on mood or restorative rest, a new body of evidence is clearly pointing to more subtle interactions between humans and their lit environment. While the detailed results are best left to the medical and behavioral journals, as always, technology will be applied to create solutions to the puzzles that will be rapidly pieced together. There is no doubt that the ability to precisely control not only the amount, but the delivered spectrum of light will be lynchpins in the both the extreme, and more subtle solutions that will be demanded.

Human Health and Wellbeing Related to Lighting – a Simple Case

Fluorescent fixtures in most commercial buildings provide artificial lighting with a spectrum that is incompatible, or incomplete, when compared to natural light illumination. New research in the area of color science and health shows that human health, wellbeing and productivity can be improved through the use of more natural lighting. The research also concludes that people who spend more time in natural light rather than in artificial light experience an overall increase in productivity and alertness [1].

There is evidence that there are two separate functional pathways that carry information about light to the brain. The non-visual pathway leads to the hypothalamus, the coordinator of many functions, including the release of many hormones. Melatonin is among the best known of these; it is a chemical signal that regulates circadian rhythms and keeps them in synch with environmental light. Melatonin is secreted as light turns to darkness, and is suppressed by bright light [2].

Light serves to synchronize the human body bio-chemical clock. For instance, it has been found that blue light (465nm wavelength) can reduce the melatonin in our blood stream, making us more alert – this is what sunlight produces from morning until afternoon. However, as the day progresses, the intensity of the blue-spectrum in sunlight reduces while there is an increase in reds and purples, thus triggering the increase in melatonin that enables sleep and body repair. The effect of light on melatonin, alertness, and cognitive performance is blue-shifted - a lamp with a correlated color temperature of 6500K (“cold light”) induces greater melatonin suppression and an enhanced alerting effect than does a lamp with a CCT of 3000K (“warm light”) [3].

Light directly influences the amount of melatonin, and other related hormones, that a person’s brain produces, which indirectly affects alertness. With artificially driven imbalances, it’s not just sleep that is affected; almost our entire metabolism, including immune responses, is regulated in this way, and there is the potential for more serious health effects [4]. Conversely, supplemental melatonin has been indicated with positive health effects including slowing down aging processes, and potentially slowing or reversing brain-involved conditions, including Alzheimer’s.

A recent study performed by researchers from the Barcelona Biomedical Research Institute (IIBB), and the University of Granada and the Autonomous University of Barcelona, showed beneficial results with the introduction of melatonin in mice which were experiencing an initial phase of Alzheimer’s. The experts analyzed the combined effect of exercise and melatonin in 3xTg-AD mice that were exhibiting the initial symptoms of the disease, including learning difficulties and changes in behavior such as anxiety and apathy. In fact, mice supported with the addition of the melatonin showed clear indication not just of slowing further onset, but also of actual regression of the Alzheimer’s [5].

Today’s office or factory lighting is constant with a high blue-shifted content, keeping us awake and alert during work, but will often impair the natural late-day shift towards warmer spectrums, thus impacting the sleep cycle for people who work late or work on computer screen at home in the evening (computer and FPTV also deliver a high blue content) [6].

In a sense, the wider direct health effects of properly tuned lighting are effectively still in the early stages of discovery, since the kind of spectral control necessary for such studies has really only become convenient with the advent of LED lighting. Even if we limited the discussion to the relationship between lighting, melatonin production and the importance of the circadian rhythm, it becomes clear in that area alone that LED lighting with tunable white light will provide substantial benefits in our daily lives. By better controlling the spectral content of the artificial lighting around us, we will enjoy more natural alertness with increased productivity in the daytime, while better synchronizing the circadian rhythm to maintain healthy melatonin cycles for better health and performance.

Cognitive Lighting Creates New Options for Control of the Lit Environment

Human-centric illumination is enabled by the coming wave of Cognitive Lighting which implements independent smart sensors that are ‘environmentally aware’ in order to provide not simply data on a number of aspects of surrounding environment, but answers to how best to respond, both to enhance lighting quality and to save energy.

Just what do we mean by Cognitive Lighting? Lighting fixtures and systems available today are relatively un-intelligent and require user input to adjust [the lighting] to specific requirements, if they can be adjusted at all. Unfortunately, the path of least resistance is simply to keep non-spectrally optimized lights on most of the time and at the lights’ highest intensity – irrespective of the occupants’ actual needs.

However, sensor-driven lighting that is easy-to-use is key to adopting more optimized and energy efficient lighting. Users cannot, and should not, be required to directly interact with the

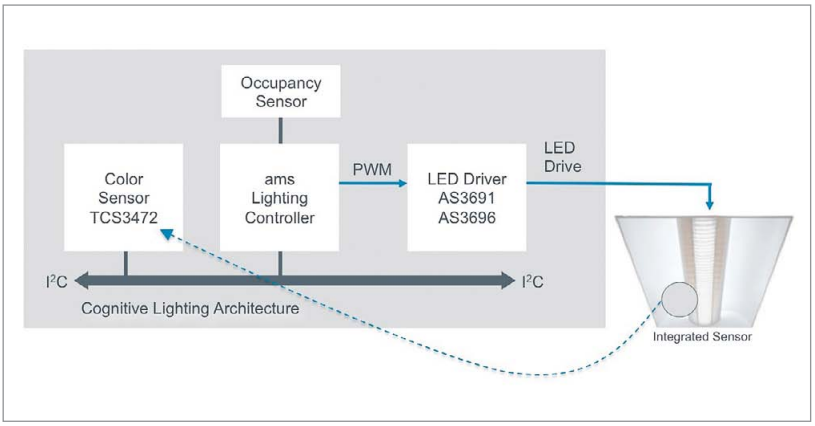


Figure 1:
A "cognitive" lighting management system

lighting in its default mode. Rather, it should be transparent, as the system "predicts" the arrival of an occupant to an otherwise dark or dimmed space and then "sets" the lighting to achieve pre-determined ambient level and spectral mix. From there, while the space is occupied, the system "adjusts" with continual, non-distracting tweaks to maintain both the time-of-day driven human-centric color "track" and the target level of overall illumination.

Should an individual need an increased level of illumination, as a result of a specific task or simply aging eyes, a simple touch, voice or gesture-driven user interface will allow that adjustment, as well as accepting "refresh" commands to extend those settings past the default period, or to return to the standard when the task is complete. Little, if any, training should be necessary. "Here's the new employee manual on controlling your office lighting," is not something that should be part of the HR's orientation process.

Tightly integrated sensing

Sensors built into the luminaire must be the "eyes and ears" of the lit space, delivering useful data on the overall environment – whether it's occupancy, available daylight, time of day or other variables – and delivers just the right amount of light — when and where it is needed.

Networked occupancy sensors provide the traffic data to enable the lighting system to move to normal operating levels as spaces are approached, traversed and occupied. Ambient light sensors combining photopic, human-like sensitivity with wide dynamic range are responsible for supplying the data used to maintain the correct amount of light to support visual acuity and basic functionality. High-precision color sensors provide both external spectral analysis, to drive color temperature and other required spectral compensation, and will separately provide color response feedback within the luminaire to maintain a balanced closed loop system.

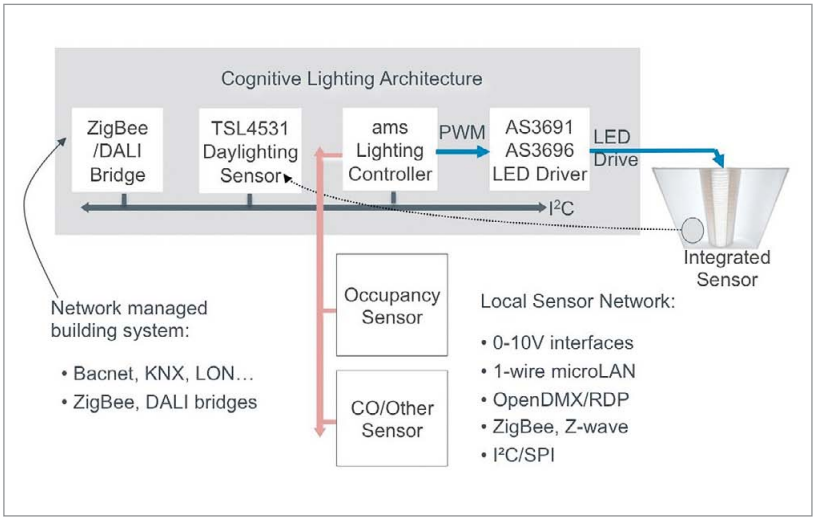


Figure 2:
An integrated building managed "cognitive" lighting system

Building Integration and Energy Savings: By-Products of Human-Centric Lighting

To realize the full potential of human-centric lighting, cognitive lighting system designers will have to consider each sensor- and intelligence-node to be a resource for the system as a whole, in addition to its localized functions. By way of example, consider the path of the first person to arrive in the office for the morning. As they approach the entry point and wave their RFID-equipped badge, the system is clear on their intention to enter the building, and can start to smoothly bring up the lobby interior lights from the "security" state to the "occupied" state. The building management system also should have a pretty good guess on where the user is going to head from there, having identified the user at the security threshold. Whether they are heading to coffee room or their work space, the system can stay one step ahead of them, applying appropriate lighting to the predicted path, as well as creating a level of nearby ambient lighting a the minimal level which provides a needed sense of security. No more "spooky" arrivals followed by the occupancy sensor or switch throwing that creates that typical "all lights on the floor to on" for an audience of one.

To achieve this, both the sensors integrated into the luminaires, as well as a few remote occupancy and motion sensors, need to incorporate both local intelligence and wider networking capabilities. These lights that "think for themselves" greatly reduce the back-end system complexity, while enhancing the overall responsiveness within an individually-defined space. With color and ambient light sensors built into each lighting instrument, on-the-spot decision-making can take place based upon the amount and type of ambient light that is present, along with the time of day and shift-work factors. With low-cost and low-power wireless networking (such as ZigBee), or wired networks (DALI), group intelligence - semi-autonomous controls aware of what each other is doing and able to self-organize the most efficient lighting

plan for each moment - tying in to centralized control systems can be readily implemented. What is critical is a sensor system that connects to today's existing building management structure like Bacnet, KNX, LONmarks [7],[8],[9],[10],[11].

Although current "smart" lighting controls enjoy a centralized approach that hinged upon occupancy to determine on/off requirements, by taking a more granular approach to supplementing the specific working space with only the amount of light needed, and coordinating that amongst area luminaires to maintain a uniformly lit environment, tremendous energy savings can be realized. In addition, a coordinated full-building system provides a new area of flexibility in response to the grid's future demand-response requests.

In the future, where flexible, autonomous dimming has been instituted, when a 10% cut in energy use is needed, it makes tremendously more sense to delegate the request down to the local spaces rather than applying some kind of "best guess" at the building level. Those individual spaces can be polled to respond with their best available dimming options based upon real-time user activities and occupancy. If one part of the system reports that it can cut 15% in lighting alone, perhaps by substantial additional dimming in the areas with outside light, and full off in areas that might be unoccupied, but that are normally on at some level to reduce the "black hole" effect, then the building level decisions can be greatly simplified. Lights down a lot here, less so here, and the HVAC can remain where it is. Everyone's happy.

Overall, simply by creating an autonomous, yet highly integrated building-level cognitive lighting system, facilities can realistically expect to save over 50 percent of their lighting energy while providing better, healthier human-centric lighting.

Conclusion

Environmentally-aware, decision-directed, multi-sensor networks and optimized light, this next wave of Cognitive Lighting systems will enhance not only the productivity of the built space, but also worker and group productivity, as well as increasing the health and well-being of individuals. The resultant energy savings will additionally be critical to meet worldwide government mandates to reduce energy consumption and lessen greenhouse gas emissions.

When fully integrated into a larger building management system, lighting that is aware of the immediate environment and broader operating concerns, and is able to intelligently adapt to user and facility requirements with autonomous local- and centralized-control, will re-define the built-environment to enhance comfort, productivity, safety and efficiency, all at the same time. ■

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Sensors and Feedback Control of Multi-Color LED Systems

To obtain stable and consistent lighting conditions within the black body range with LED systems, especially RGBx systems is a challenging task. Feedback controlled systems are expensive, but the best solution. Here, the question of which type of sensor accomodates the given application best, arises. Thomas Nimz, Fredrik Hailer and Kevin Jensen from MAZeT GmbH discuss different options based on their scientific studies on LED systems with four or more different LEDs considering secondary conditions like color rendering index.

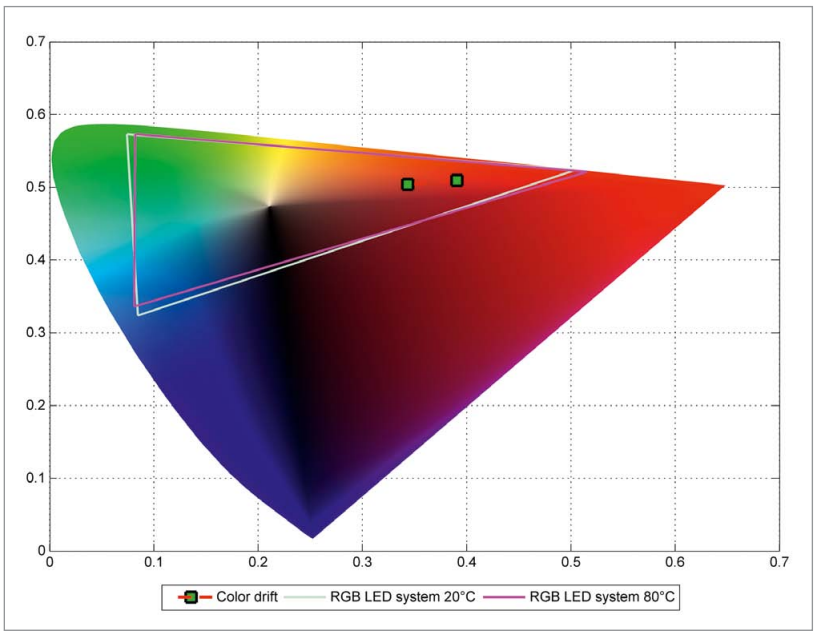


Figure 1:
Example of color drift based on RGB system

Despite many advantages of the LED in general, the lighting industry is facing difficulties maintaining stable and consistent lighting conditions within the black body range. When combining LEDs of different vendors and quality it has been a general procedure to rely on binning methods to ensure a stable light color value output. The utilization of LED technology is increasing in medical or high quality productions. These applications require not only accurate color value outputs but also need to be stable and consistent in the long-term. By implementing feedback control solutions, it is possible to directly regulate lighting conditions based on color values on the black body curve.

Modern solutions nowadays are the application of color sensors to achieve the feedback control loop. These measure the actual or target color values and trigger the LED drivers to adequate current output values. The most accurate method to measure spectral values is performed via spectrometer. However, this technology is often too slow and expensive to meet market needs. Therefore, color sensors are a cost-efficient solution and during initial phases of prototyping and development, spectrometers are used to determine reference values. The color sensor market knows technologies with various spectral properties. The most ommon are the traditional RGB, or True Color sensors based on the CIE 1931 standard (human eye perception).

The following evaluation is based on a lighting system prototype consisting of multiple LEDs with different spectral values. The pre-selection included ten different LED sources, such as narrowband LEDs like red, green, blue – or broadband LEDs like warm-, cool- and neutral-white. During these studies a pre-selection of possible color sensors was simulated. The goal is to achieve the best possible quality based on accuracy within the black body curve and therefore RGB and True Color sensors will be reviewed and compared. Subsequently, the following question needs to be answered: “Is it possible to improve the overall perception based on the Color Rendering Index by implementing intelligent feedback control algorithms?”

Fundamentals

Why to use feedback control

It is common knowledge that temperature and aging effects cause shifts in LED characteristics. The learning curve of the first generation of LED systems has shown that not only brightness, but also the color properties have changes over long-term operating hours. Figure 1 demonstrates the target color shift of a simple RGB LED system based on individual LED drifts. This example is caused by the physical properties of LEDs as they change their color point depending on temperature and the current flow. The LED system temperature increased continuously from 20°C to 80°C (68°F -176°F).

Solutions via temperature measurements are used to adapt the current and voltage of the LED drivers. This mentioned method is an indirect control of the target color. However, the system has insufficient information about the actual color values. The results are based on approximation rather than active color detection. A feedback control solution based on color detection sensors on the one hand, guarantees to be able to achieve the target color value and on the other hand, to enable an active control option. For example: if a single LED within the system fails it is possible to detect this error and to directly react to the negative side effects. A potential counter measurement in reaction to a red LED failure would be to increase the amber color values. Feedback control loops establish many new options to increase the quality and the operation time of LED systems.

Figure 2:
Schematic of feedback control system

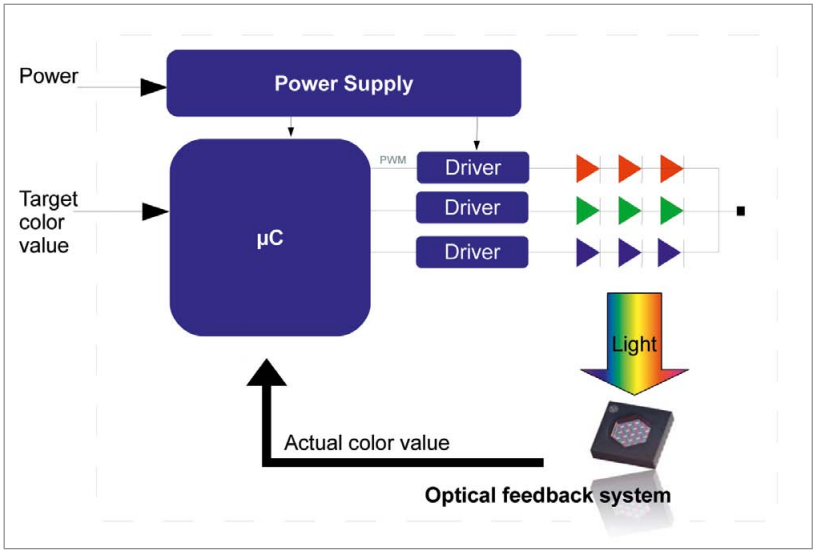
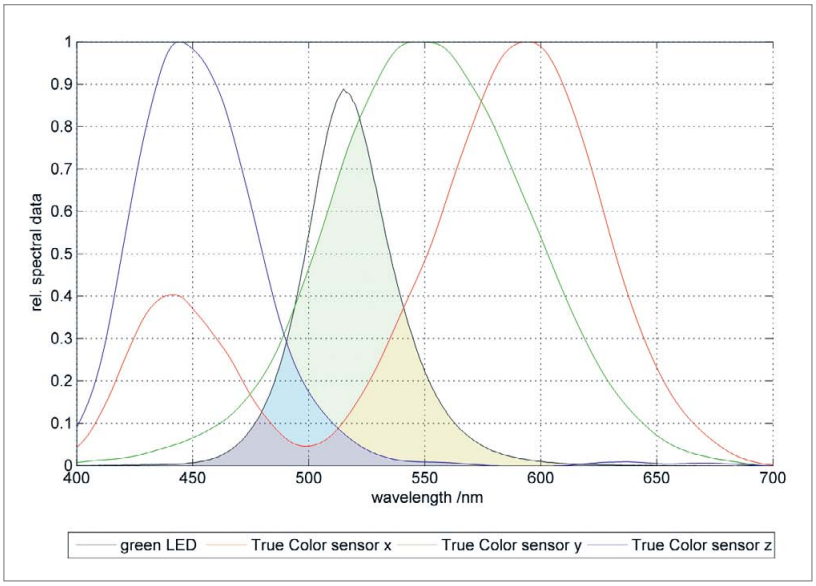


Figure 3:
Characteristics of True Color sensors



Feedback control system

Feedback control LED systems mentioned in this paper consist of a power supply, LED driver, microcontroller and color sensor. The goal is that the normal user does not need to know information about the feedback control system or algorithm. Normally, the user only sets the color values - for example, color temperature or direct color point. The system calculates the first LED combination and starts the controlled lightning process. Afterwards the color sensor measures the specific color values; the microcontroller compares the actual color values with the target values. If the color deviation is too high the correction algorithm values are used to trigger the current and power supply of the LEDs. In this way the LED system reacts automatically to external influences. Therefore, it is possible to increase the properties like long-term stability or avoid negative temperature drift effects without any visible change to the user.

RGB or true color sensor

The accuracy of the entire LED system mostly depends on the color detection sensor. The system cannot be more accurate or faster than its main component. Because of this, it is important to choose an adequate color sensor for the specific application at hand. As mentioned, the market mainly knows RGB and True Color sensors.

The RGB sensor has three characteristic curves; one for red, green and blue respectively. The measured RGB values can be transferred via the tri-stimulus values X, Y, and Z. The measurement values of a True Color sensor correspond directly to the CIE 1931 standard and the respective tri-stimulus values. The special feature of True Color sensors is that the characteristic curves comply with perception of the human eye. XYZ values enable conversion of the color point into every color space.

The selection of the ideal color sensor for this paper was performed after various simulations. The goal was to calculate the color measurement along the black body curve via RGB and

True Color sensors. Three LED systems have been used, one RGB- LED system (with red, green and blue LEDs), one RGB LED system with an additional cool-white LED and last but not least a LED system with 8 different LEDs. To compensate the manufacturing variances it is required to calibrate the systems. The calibration is based on the color points of the built-in LEDs. Therefore, three calibration matrixes have been calculated for each sensor. The calibration was performed at 20°C, while the measurement was performed at 80°C (68°F -176°F).

In the next step a spectral calculation of 450 color values along the black body curve for each LED system was performed (at 80°C). Subsequently, the generated spectrum data was measured via an RGB sensor, True Color sensor and spectrometer. The spectrometer results are later used as reference values.

The result of the simulation shows that the color deviation of the True Color sensor measurement was smaller than the color deviation via RGB sensor measurement. It is general knowledge that the human eye cannot detect color deviations smaller than 0.003 Δu'v'. The measurements have shown that the RGB sensor is not capable of measuring color values with the required accuracy. If an RGB LED system is used with True Color sensors a standard calibration achieves the limit of 0.003 Δu'v'. An LED system with more LEDs than just the red, green and blue generates a higher deviation – this applies both for RGB sensors and True Color sensors. Therefore, within an RGB cool-white LED system the maximal Δu'v' is twice as large as a standard RGB lighting system, for example. Via optimized calibration it is still possible to achieve the required limit of 0.003 Δu'v' using True Color sensors. The simulation has shown that True Color sensors achieved the best accuracy for color rendition in high quality applications.

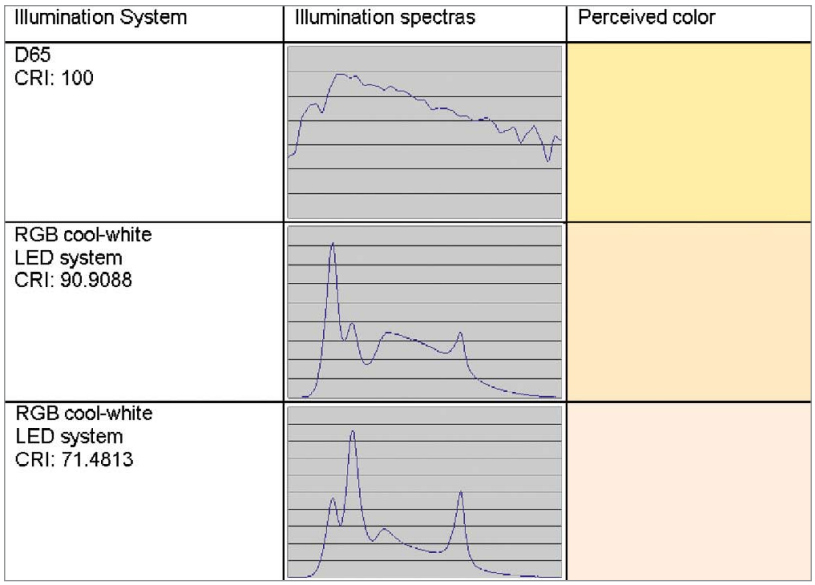
Table 1:
Color variations along the black body curves

LED system	RGB		Red, green, blue and cool-white		8 different LEDs	
Δu'v'	max	mean	max	mean	max	mean
True Color sensor	0.0021	0.0012	0.0072	0.0035	0.0088	0.0037
RGB color sensor	0.0210	0.0153	0.0512	0.0239	0.0360	0.0151

Table 2:
LED combinations for D65 /10° observer

red	green	blue	cold- white	warm- white	CRI
14.4%	45.6%	25.1%	91.8%	82.0%	92.85
27.9%	53.9%	33.0%	59.6%	70.8%	80.90
36.7%	59.5%	40,0%	45.8%	70.3%	71.00
52.2%	69.1%	48.8%	32.7%	56.4%	56.80

Figure 4:
Color perception within different visible spectras



Feedback Control Loop

Systems with four or more different LEDs

While utilizing a feedback control loop within a RGB LED system, three input parameters (Color - for example Lu'v') and three output parameters (PWM of the RGB LEDs) are used for the calculations. It is possible to determine one solution by means of a linear transformation - exactly one solution exists. For a system with more than three different LEDs, for example RGB and warm-white LEDs, multiple solutions are possible. The system has three input parameters - but four output parameters, which leads to an over determined system. Therefore, different combinations for one color point can be calculated. The result is a variation of the spectrum, depending on the PWM frequency of each LED, whereas every spectrum has its own properties. For systems with 5, 6, 7 or more different LED types, even further combinations are possible. Therefore, it is particularly difficult to find the optimal solution without defining specific side conditions.

The color quality does not solely depend on the chosen LEDs, but also on the respective LED control solution. Example 5 shows the different color perception in relation to the incoming light spectrum. Even though the same test 'RGB cool-white LED' system has been used, the results clearly show color variances within the visible spectrum, when illuminating with different LED combinations for one color value.

The task is to find the best PWM combination considering secondary conditions such as Color Rendering Index (CRI) or luminosity. The algorithm should be independent of the number of LEDs and also should be able to include the physical properties of the LEDs.

Solution approach

A simple algorithm is a solution with a feedback control matrix. This matrix is calculated using a linear ransformation. The input parameters are the sensor values for several color targets.

Usually, the preset LED color values are used for the initial calculation. Sometimes the result can be optimized if extra combinations of multiple LEDs are used, for example, color values along the black body curve. This method has insufficient information about a secondary condition like optimizing the Color Rendering Index. Because of this, it is expected that the quality of the spectra for some color values near the black body curve are suboptimal. It is useful to find improved algorithms, which integrate selected side conditions.

One solution is to split the color gamut of the LED system in many smaller sub-gamuts. Every sub-gamut is formed via three corner points. One corner point corresponds to a color point of an LED. The more LEDs are used the more sub-gamuts will exist. If the target color point is a part of the sub-gamut, the LED combination will be calculated using linear transformation. The results are various combinations for each different sub-gamut. In the second step one combination from the previous results depending on the secondary conditions will be used as calculation basis. For example: using one algorithm to combine the results and to guarantee an optimized Color Rendering Index value.

This resulting combination is used as the initial values of the control system. Via this combination it is possible to approach the target color point. The external effects of the LED system (temperature, flow current and aging effects) cause a minor color deviation. Therefore, to remove the final color drift, only little control calculation needs to be performed.

Conclusion

The simulation and concluding measurements have demonstrated that it is essential to use a feedback control-loop solution if long-term stable color rendition is a main goal of the application. While comparing RGB with TCS, the results have shown that in most cases RGB sensors are not accurate enough to provide optimal input values for accurate color regulation. (For example, medical applications.) To achieve the best quality possible one needs to focus on the following four aspects:

- The right choice of the color detection sensor for the specific application (in this test the TCS were the preferred choice)
- The right choice of LEDs regarding quality, quantity and cost-efficiency
- Calibration of the sensors to the specific application at hand
- Finding an idea control and regulation algorithm

Reviewing the initial question regarding intelligent feedback control algorithms to improve the overall perception based on the Color Rendering Index one must say that the color rendition quality is not solely enhanced by increasing the number of used LEDs. The quality also depends on the spectrum produced by the LED combinations. Via feedback control algorithms optimized with adequate side conditions (like CRI) it is also possible to improve the output quality/ color rendition. When evaluating these aspects during the development of a feedback control solution, it is possible to minimize the required number of LED light sources within a system to achieve an equal or better CRI value. Other options are to reduce the overall number of selected LED light sources while still achieving the required output values. These control options via optimized regulation algorithms make it possible to reduce costs or adapt LED lighting solutions to green technology standards like Energy Star. ■

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Focus Tunable Lenses for LED Lighting

Focus tunable lenses open up new possibilities in the design of LED based luminaires. With these shape changing lenses, the beam angle of a spotlight can be flexibly adjusted while keeping the efficiency on a constant, high level. Compact solutions combining a floodlight and a spotlight in one product can therefore be realized. This innovative technology reduces complexity and offers more flexibility in lighting design, especially for changing environments like museums, and shops. Joerg Wertli from Optotune AG demonstrates a very interesting technology for these applications.

For the design of a spotlight, there are components available for a great variety of different beam angles. As they are fixed, the customer has to decide in the design phase which angles to use for an installation. In some cases, it's possible to exchange optics for different beam angles. However, this is time consuming and cumbersome, especially as lamps are often hard to access after installation. Traditional solutions which are available to vary the beam angle without exchanging components usually exhibit a decreased efficiency and can be complex. One approach is to shift a lens away from an LED to focus the beam (up to a certain point). However, rings and shadows typically appear in the spot and with increasing distance from the LED, a lot of light is lost. On the other hand, large show lights or even some museum lights are equipped with a zoom lens for the adjustment of the spot size. While requiring lots of space and not being efficient, such a zoom lens is expensive in development and manufacturing, making it unsuitable for mass lighting applications. In contrast, a tunable lens allows the beam angle to be set on site and adjusted whenever necessary to the desired value. There is also the possibility of motorizing the tuning process for remote controlled adjustments. Having just one product from flood to spot lowers complexity and costs. Furthermore, a tunable lens offers new opportunities with varying beam angles for different settings, like in a museum with changing exhibits.

Working Principle of Focus Tunable Lenses

The manually tunable lenses for LED lighting from Optotune are shape-changing lenses. The core of the lens consists of a container, which is filled with an optical fluid and sealed off with an elastic polymer membrane. Through an inclination in the housing, this container is pressed against a ring or so-called "lens shaper". This causes a rise in liquid pressure in the container and hence, a spherical lens to form. This changes the focal length to shorter values (figure 1). The clear aperture as well as the position of the lens shaper remains constant throughout the whole tuning range. Therefore, no efficiency is lost when tuning from the wide flood angle to the small spot. This technology is both very efficient and compact and allows a flexible adjustment of the beam angle when implemented in a spot light. Turning a ring controls the movement

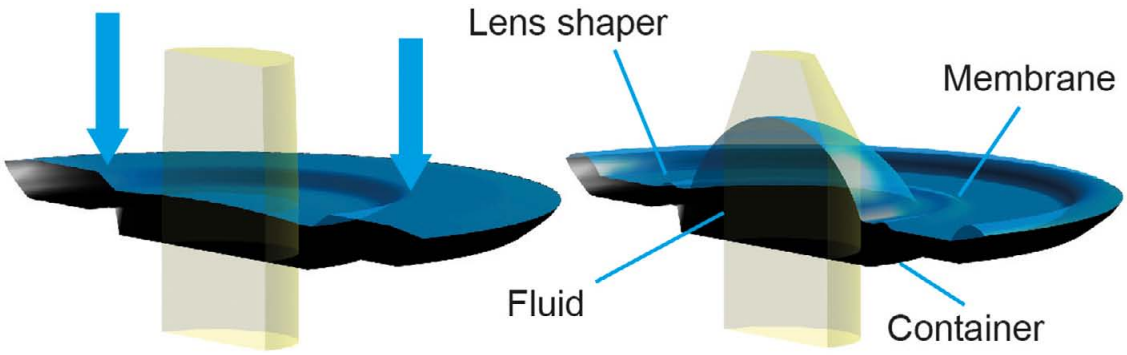

Figure 1: **Working principle of a tunable lens**

Figure 2: The application example of a GU10 replacement lamp demonstrates the compact design with the ML-25-50 Lumilens

of the lens shaper into the liquid filled container and therefore the shape of the lens. The liquid used for these lenses is polymer based, highly transmissible from the UV up to the near infrared range of up to 2500 nm. Furthermore, the material is UV stable. It can even be used for applications constantly operating in the UV range, all the way down to a wavelength of 250 nm. In addition, the polymer material has a high abbe number, providing excellent color quality in the spot with minimal chromatic aberrations.

Optics Design - in General

In figure 2, a spotlight design using Optotune's ML-25-50 Lumilens is shown, illustrating the compact design possibilities for a spotlight. When designing a spotlight with a tunable lens, the optical design is outlined as shown in figure 3. The LED and the secondary optics define the maximum beam angle. The tunable lens is then used to focus the beam from the wide flood angle to a small spot.
When laying out the optics design for a fixture with a tunable lens, the resulting tuning range largely depends on the light emission characteristics of the LED and the secondary optics. Combinations of LEDs and secondary optics with a beam angle of 40° and above have shown the best results, achieving ranges down to narrow spot angles of below 10° in some cases. In order to achieve the best possible tuning result, the tunable lens has to be placed with a distance to the secondary optics such that the whole aperture of the tunable lens is filled up. Therefore, with increasing aperture size in relation to the diameter of the secondary optics, the distance between the secondary optics and the tunable lens increases. For the exact distance, optical simulations are very useful to determine the exact layout and expected performance. Alternatively, it can also be efficient to use a practical approach with an optical setup allowing the flexible variation of the distances between the different components to determine the optimum optical design in the lab. When choosing a reflector to collimate the light

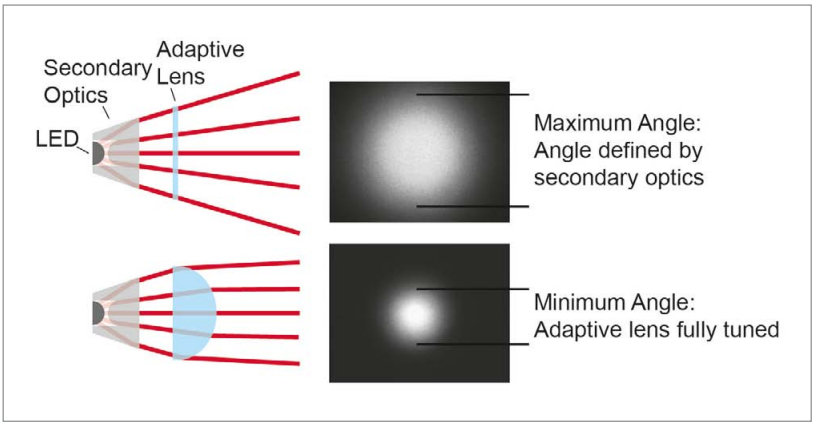

Figure 3: **Schematic view of the optical system at both ends of the zoom range**

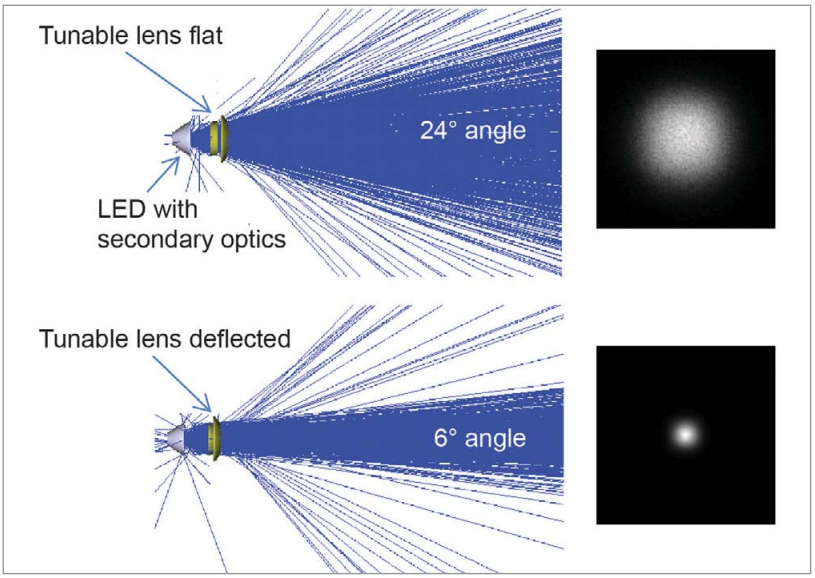

Figure 4: **Narrow angle optical design in a simulation**

before the tunable lens, a diffuser has to be implemented between the reflector and the tunable lens, to prevent an imaging of the LED chip when tuned to the small spot angle. Furthermore, the reflector should have a smooth surface or a very small structure to prevent the imaging of the reflector structure. With TIR optics, versions with frosted tops can be used to circumvent the integration of an additional diffuser.

Optics design – Special Designs

While optical designs with a wide angle of around 40°-50° provide the best results as described above, there are lighting applications requiring specifically narrow or wide angles with tunable capabilities. An example of a narrow angle design is shown in Figure 4. Using a narrow TIR lens with 24° divergence, a range down to 6° was simulated. On the other side, designs with wide angles up to 100° were evaluated with a practical approach. Using a fixed lens to collimate the LED to 100° before the tunable lens enables a range down to a 30° spot.

Optics design – Zoom Systems

While most lighting situations require a diffuse spot, it is sometimes required to have a homogenously lit up spot with a specific, determined shape, e.g. a trapezoid for perspective illumination of a painting in a museum. In such cases, an intermediate mask is imaged by projection optics. The same principle applies to gobo projectors, where the mask might contain a slide of a company logo, for example. Zoom optics including several lenses is required to vary the size of such a projection. Again, focus tunable lenses can help to reduce the size and increase the efficiency of such optics. Optical designs with plano-convex lighting lenses have shown zoom factors in the range of 4 times to 16 times zoom using two tunable lenses and a set of fixed lenses. With tunable lenses, the overall system is much more compact, in general, with the size of about 50% of the one of conventional systems. Furthermore, motorization is straightforward, as no lenses have to be shifted and the tunable lenses only have to be deflected. Therefore, lighting zoom systems can be fully motorized for a fraction of the cost of conventional, mechanical systems.

Focus Tunable Lenses in LED Arrays

For large LED lighting fixtures, arrays of several LEDs are often used to increase the light output. It is possible to design a grid to hold a focus tunable lens element over each LED. A second grid with lens shapers is pressed into the liquid filled elements to form lenses. That way, it is possible to achieve a large tuning range for different LED assemblies, e.g. big circles or rectangular LED arrays. Due to some overlapping of the light fields from adjacent LEDs, there is also an additional homogenization, which is advantageous for achieving a nice, smooth spot in total.

Conclusion

In summary, it can be said that focus tunable lenses offer new possibilities for various lighting applications. Based on polymer materials, these lenses have outstanding chromatic properties and a wide transmission range. The materials exhibit a high transmission over the spectral range from the UV range up to the near infrared. The material is UV stable. The tunable lenses are highly attractive for LED lighting application requiring a variable spot size. The principle of a lens shape changing lens where the distance to the LED stays constant, allows varying the beam angle without the loss of efficiency. Besides applications with variable spotlights for museums, shops and other fixtures that light up changing environments, the focus tunable lens technology is also beneficial for compact zoom lenses, for gobo projectors or lens arrays for large LED based light panels. ■

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Designing Integrated High-Power LED Systems

Albrecht Lohrer, Senior Product Manager at Endrich Bauelemente and Johannes Schäfer, Sales Manager at TURCK duotec take a look at the latest technological developments in LED arrays. Based on the current generation of Citizen LEDs – the CLL050-1825 series – they analyze the efforts of LED manufacturers to provide optimized thermal solutions and reliable high-power LEDs.

LEDs play an ever increasing role as a lighting source. While early requirements focused on providing sufficient durability, other factors have now gained importance, including efficacy, color accuracy, color stability and, of course, commercial considerations such as how many lumens per Euro are achievable. 200 lm/Euro was once considered the uppermost threshold. Nowadays, some vendors far surpass this limit even at color temperatures of 2,700 K.

In recent years, the rapid development of high-power LEDs has created some interesting product innovations. Following on from LEDs in the 1-3 W range, products with higher power ratings were introduced to the market in the shape of so-called multi-chip solutions. Here, several individual LEDs are attached to a substrate such as aluminum or ceramic and wired. This process yields very high lumen packages. Such LEDs are particularly popular for outdoor lighting where they enable many inexpensive solutions. Demand is not limited to cool white color temperatures, which are mainly used in street lighting, but many customers are specifically looking for neutral and warm color temperatures in the 3,000 - 4,000 K range for their object illumination solutions.

The latest generation of LEDs, such as the multi-chip Citizen LED mentioned above, offer a maximum brightness of 17,600 lumens at a maximum current of 3 A. The brightness is created by 450 individual LED dies, and requires approximately 178 W.

The availability of such high lumen packages opens up more options for the efficient and cost effective use of LEDs. However, while there are a number of manufacturers in the market who offer multi-chip LED solutions; customers are not actually using them due to a lack of system integration solutions for power supply and adequate thermal connection of these LEDs. Many customers currently still shy away from exploiting the maximum power of these LEDs and stick mostly to the rated current range.

Since LED lighting is not as easy to replace as a light bulb, product lifetime plays an important role in the selection process. The market is demanding 50,000 hours with a maximum light loss of 30%.

The key to achieving such LED lifetimes lies in suitable cooling. Each high-power LED must be adequately tested for each application to make sure that cooling is sufficient and that the LED is operated below the permitted $T_{junction}$ (T_j). The product of thermal LED resistance R_j and power dissipation P_d have to be added to the measured LED temperature T_c: $T_j = T_c + R_j * P_d$. If the junction temperature T_j remains below the permitted value, the required LED life can be guaranteed. ...

Heat Sink Calculations

The formula of figure 1 shows that the higher the power the lower the thermal performance of the heat sink ($R_{thermal(heat\ sink)}$), resulting in the need to use increasingly larger heat sinks to ensure that the system remains stable and the necessary lifetime can be achieved. Since options to influence $T_{junction}$, the maximum specified junction temperature, and $T_{ambient}$ (exterior temperature) are very limited, the values for $R_{thermal(total)}$ and P_{total} must be

$$R_{thermal(heatsink)} = \frac{(T_{junction} - T_{ambient})}{P_{total}} - R_{thermal(total)}$$

$$R_{thermal(total)} \downarrow$$

$$R_{thermal(LED)} + R_{thermal(PCB)}$$

Figure 1: Formula to calculate heat sinks

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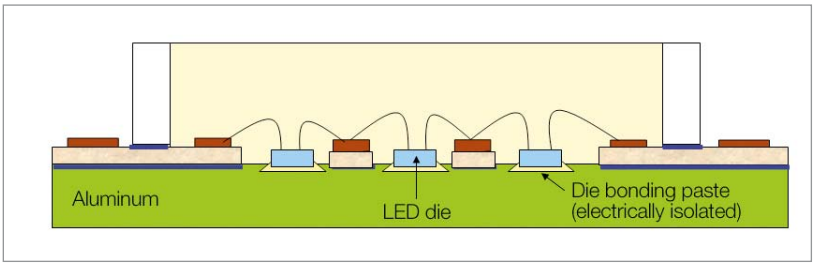

Figure 2:
Attaching LED dies directly using electrically insulating adhesive is advantageous compared to other technologies

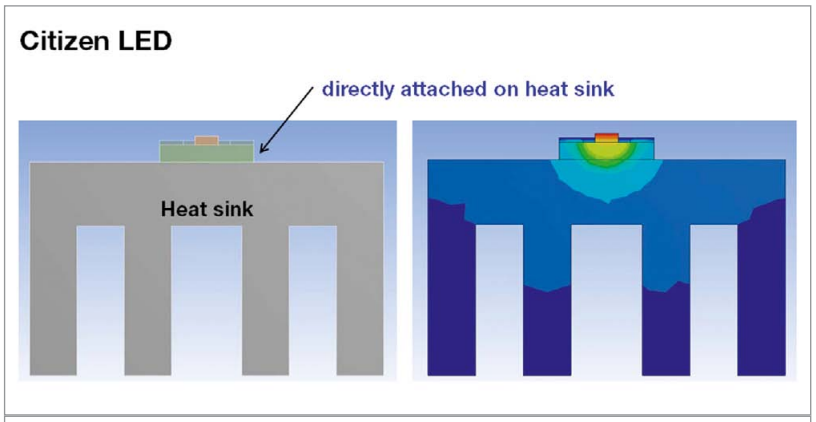

Figure 3:
LEDs directly attached to a heat sink provide lower thermal resistance than LEDs with additional aluminum plates

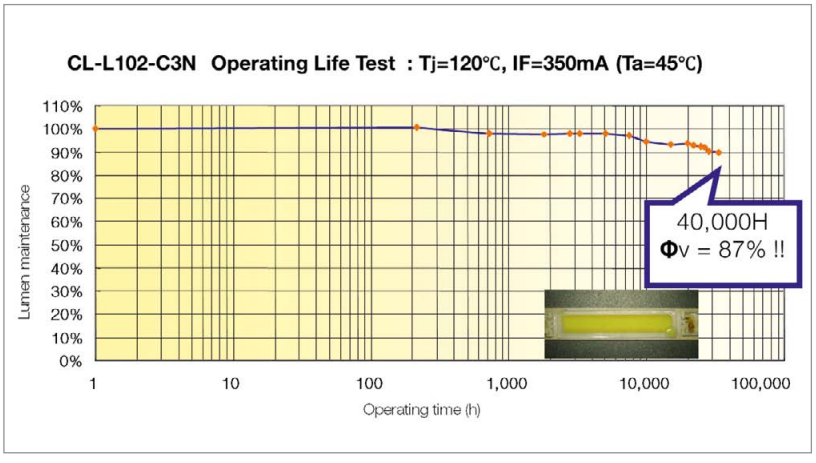

Figure 4:
Measured light intensity after more than 46,000 hours of continuous operation at a maximum specified junction temperature Tj of 120°C

kept as small as possible to allow the use of a smaller and therefore less expensive heat sink.

Reducing P_{total}

P_{total} can be reduced by the use of efficient LEDs. Therefore it can make sense for the user to run a very powerful LED below the rated current to achieve greater efficacy. The LED mentioned above achieves a brightness of 3,600 lm at 500 mA and an efficacy of 145 lm/W. This high efficacy opens up new possibilities for the use of bright LEDs when insufficient means of cooling are available: The lack of cooling is compensated by increased efficacy. Many customers use this option and deliberately select a more powerful, more expensive LED to be able to implement a smaller and cheaper heat sink.

The Impact of $R_{thermal(LED)}$

For a reduced $R_{thermal(LED)}$ some mechanical designs like theat one of the Citizen LEDs, offer a distinct advantage.

Figure 2 shows the schematic structure: The LED dies are directly attached to the aluminum substrate via a thermally conductive and electrically insulating adhesive.

The technology shown in figure 2 provides better heat distribution in the heat sink than a conventional LED. This is due to the low thermal contact resistance between die and substrate.

Even after 46,000 hours at a T_j of 120°C, the light intensity has decreased by only 16%. This is only possible thanks to the outstanding material properties of the LED dies and high quality workmanship.

About $R_{thermal(total)}$

$R_{thermal(total)}$ is the total thermal resistance of the individual LED dies up to the connection to the heat sink. $R_{thermal(LED)}$ signifies the thermal resistance of the LED (LED die - substrate); $R_{thermal(PCB)}$ signifies the thermal resistance between LED and heat sink.

Practical Approaches

While a chip-on-board (COB) module offers a number of advantages thanks to even heat dissipation, it also poses some challenges for the user. These are best solved in close cooperation with a competent system partner.

Multi-chip COB modules from the higher-performance ranges have significant mechanical dimensions of up to 38 mm edge length. While this provides a large surface for heat dissipation, achieving a safe and planar connection of such a large area to the heat sink can be challenging.

Because the screw fasteners are far apart, and such modules have a thickness of only 0.9 mm or less, it is extremely difficult to attach the modules via an extremely thin bond layer to the heat sink. Even with bond layers (thermal pads or pastes) of <100 microns thickness compression is often significantly inhomogeneous, resulting in poor thermal contact. This particularly affects the central areas of the modules where the critical thermal contact strength is no longer guaranteed. Unfortunately, this is not immediately obvious during bonding, but has to be established through thermal measurements.

Experiments with different materials have shown that this can lead to temperature variations of > 30°C at T_C. This makes it difficult to design a safe system.

COB module with the circuit board which holds the poke-in contacts. Unlike spring contacts, this technology provides a very sturdy and gas-tight, dirt-resistant electrical connection which is additionally protected by a glob top. Adding temperature sensors for temperature monitoring further increases protection of the LED modules from thermal destruction. All in all, the result is a robust and securely bonded module which is easy to install or change by the lighting manufacturer or user.

There is a wide range of printed circuit board technologies for LED applications. They differ greatly in performance and price, starting with RF4 PCBs with and without thermal vias and laminated metal substrate, ceramic PCBs and IMS PCBs to heat sinks, which double up as PCBs.

When to select which PCB? And which LED is best for which loads? To answer these questions it is first necessary to clarify how LEDs behave under different loads. Factors that need to be considered here are how much light the system emits, its luminous efficacy, required lifetime and, last but not least, the expected costs. As a rule, the amount of light an LED emits increases when the current increases. However, as the current increases, the efficacy of the LED unfortunately decreases. As a consequence, higher currents result in higher system and LED temperatures unless additional cooling is provided. To keep the temperatures stable, it is necessary to invest in additional cooling.

As the temperature increases, the lifetime of the LED decreases and the efficacy drops further.

For example, it is possible to create a system with high efficacy, low power and low junction temperature. The advantages include high lm/W efficacy, lower cooling costs and long LED life. The disadvantage is the need to use more expensive LEDs which also require more space.

Likewise, it is possible to produce a system with low LED costs and high currents. The advantage is a good, price to light ratio (lumen/€). The disadvantages are lower lm/W efficacy and higher costs for cooling. Without

Figure 5:
Connectivity solutions with the so-called poke-in contacts provide a simple and secure wire connection

The module is attached via a safe and very good thermal connection to a copper plate which is larger than the actual LED module. This copper plate not only provides the mechanical basis for a robust connection but is also used for heat spreading and as a platform for other components. In addition, so-called poke-in contacts provide a simple and secure wire connection, eliminating the need to solder the LED module onto the plate which would require very specific and reproducible conditions to prevent damaging the LED module.

Wire bonding is a particularly well suited technique in these circumstances. A thick aluminum wire bond connects the

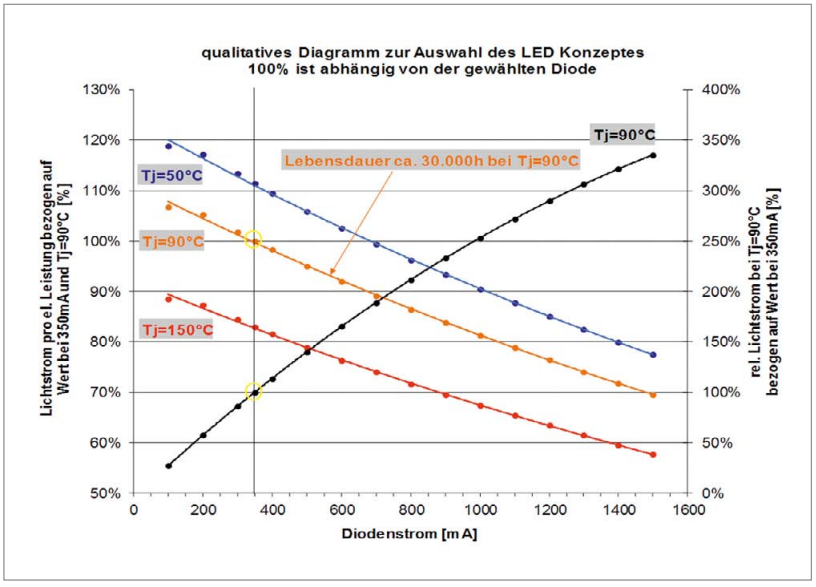

Figure 6:
The relationship between efficacy, durability and LED temperature suggests several system design options

additional cooling, temperatures in the system will increase resulting in lower efficacy and shorter LED life.

Ideally, specialists and users will sit down together to discuss and work out an individual solution that perfectly meets the specific requirements of the product and the application environment. For the optimum lighting design it is crucial to consider the overall system.

From a thermal perspective, the best PCB solution is to route tracks directly on the heat sink. Here, the tracks are laid directly onto the heat sink using the so-called thick-film hybrid technology and connected via a sintering process with the heat sink.

Figure 7:
Example of a heat sink structure as thick-film hybrid circuit board

Figure 8:
COB technology in detail showing bonding wires and semiconductor placement

Figure 9:
Highly integrated modules such as the "Oktagon-25 Watt", which is based on such a thick-film hybrid, are particularly well suited for lighting integration

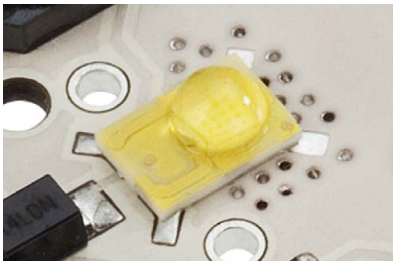

Figure 10:
Thermal vias are another option to improve heat management

Another option is to apply LED crystals without housing, thereby improving the thermal properties of the system. When processing pure semiconductors without housing – the COB technology – the facts that semiconductors and ceramics have suitable coefficients and that there is little mechanical stress are added benefits.

Classic solutions for good heat dissipation include SMD LEDs on thick-film hybrid ceramics and SMD LEDs on IMS printed circuit boards. Both technologies achieve equally good thermal resistance. Thick-film hybrid ceramic technology connects the track directly with the insulating ceramics, which serves as circuit carrier, via sintering. This construction provides excellent thermal conductivity and high levels of insulation thanks to the ceramic. A printed circuit board with a thickness of 0.65 mm can therefore achieve a dielectric strength of about 13 kV.

With highly integrated modules, power is supplied directly to 230 Vac. No additional components (external power supply) are required and the light source monitors its temperature independently so that the power is reduced automatically as soon as the temperature gets too high (overheating of environment; defective cooling). This prevents the LED from being destroyed or ageing prematurely.

When using IMS PCBs, the track is separated by a thin insulating layer from the metal plate. The quality of thermal conductivity and insulation resistance are determined by the insulation layer, which is available in different grades and thicknesses. However, any increase in the insulation resistance usually leads to a deterioration of the thermal conductivity.

If an application requires less performance, it is also possible to work with FR4 PCBs and thermal vias. Under suitable operating conditions and with adequate cooling, this represents a cost-effective alternative.

With thermal vias, heat is dissipated from the upper copper layer through holes in the metal – the thermal vias – and transported to the back of the printed circuit board, where the heat is then channeled to the heat sink. During this process it is important to ensure good mechanical contact between the vias and the heat sink because there is limited heat dissipation. In addition, the copper layer on the LED component side is also often used to dissipate heat by convection.

Another component of the thermal path is the LED itself. Different designs have different thermal resistances. The thermal resistance of an LED describes the temperature difference between the barrier layer on the semiconductor and a point on the housing relative to the power converted in the LED. Typically, this is the solder point. Such soldered LEDs provide between 250 K/W and 2.5 K/W (depending on design). However, the best values are obtained for LED dies without housing.

Conclusions

As a rule, LEDs with a lower thermal resistance provide more power. Ultimately, the crucial point is the temperature difference between the barrier layer on the semiconductor and the solder point during operation. If this value is low, it means that a good level of heat dissipation is guaranteed.

To design a system it is also important to know the maximum junction temperature permitted for each LED type.

When all parameters are known, a competent system partner is able to produce components which guarantee the stable and safe operation of an LED lighting system. ■

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Electronics: EMI Problems in Triac Dimmable LED Drivers
Power supplies often suffer an increased THD, a decreased PF and reduced efficiency when dimmed with a Triac. The topic of EMI for dimmed LED drivers has been ignored by almost all of the performance and EMC standards. The relationship between PF, THD and harmonics will be discussed and why dimmed LEDs may cause increased EMI and undesirable visible effects such as LED flashing and flicker will be explained.

Maufacturing: Copper Bonding Wire - a Feasible Option for LEDs
Manufacturing and packaging LEDs requires micro bonding wire. Like packaging for semiconductor chips, these wires have traditionally been gold. Gold, however, is expensive. Recently a new option, glass coated copper wire, has been introduced as an alternative.The new technology and advantages of glass insulated copper wire for LEDs will be looked into.

Coating Materials for LED Applications - Functional and Decorative
Coating materials or 2-pack casting compounds for LED lighting products should not affect the optical properties of the LEDs in the long run. Besides the actual colour impression, the degree of reflectivity is the new key parameter for the luminous efficiency. Colour stability, yellowing resistance, protection against moisture and electrical insulation in different atmospheres as well as storage temperature and UV and weathering resistance will be discussed.

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