LED professional Review

www.led-professional.com

ISSN 1993-890X

LpR

The leading worldwide authority for LED & OLED lighting technology information

Sept/Oct 2012 | Issue 33

Special Topic: Zhaga

Aspects of Light Quality

Photometry for Street Lighting

Thermal Simulations of Retrofit LED Bulbs

LpS 2012 ISSUE

New LED Lighting Strategies

Once the summer is over we are going to see a lot of motion in the world of lighting. Besides the announced product innovations, the updated market information, attempts at standardization and various lighting events, the Fall is the perfect time for strategic orientation and making room for insights concerning the 2013 objectives.

LED professional continues to provide you with a wide range of up to date information, like the complete, updated market report which can be viewed at www.led-professional.com. In addition to that, this issue features a series of articles on the topic of "Zhaga Specifications". These articles are being printed in connection with the publication of the "Zhaga Books" and have been written to introduce and explain the Zhaga standards.

In addition, we are also bringing to light other important topics in this edition like an interview with Everlight about LED trends, an article about the aspects of light quality by Osram, a piece on print optics from LUXeXcel, an analysis of retrofit LED lamps by the Turku University and an item about the mesopic photometry for streetlights from the Surya Technology & Innovation Center in India.

Of course the LED professional Symposium +Expo, the *LpS 2012* is also closely linked to this issue. It will be taking place in Bregenz, Austria from September 25th to 27th. The strategic goals of this event also serve the new orientation and innovated LED concepts for 2013 based on four strategic pillars: "Background Strategies", "Engineering Methodologies", "Technology Trends" and "Strategic Partnerships".

The amount of information and the dynamics in the area of LED lighting are currently very high. It is our goal to extract the highlights and/or the essence of this information so that you can use the various channels like our Homepage, the Magazine, the Newsletter, or the Event in Bregenz to find out the latest information. It is especially important that you have the right technological directions for new orientations in the coming year.

I wish you all the best and am looking forward to meeting you in person in Bregenz!

Yours Sincerely,

Siegfried Luger

Publisher, LED professional
Event Director, LpS 2012

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Peter Dehoff

Dipl. Ing. Peter Dehoff studied Applied Lighting Engineering at TU Karlsruhe, Germany and has been with Zumtobel Austria since 1987 in the Dept. of Strategic Applications. Here he finds and develops trends in modern lighting applications and tests them for the market. Mr. Dehoff is a member of numerous associations and standardization organizations (CIE, CEN, ASI, DIN, ZVEI, AK licht.de, LiTG, LTG, CELMA, FEEI).

His areas of expertise are quality of light, physiological aspects of lighting, energy efficiency and aspects of dynamic lighting.

IS THE LED FIT FOR LIGHTING SOLUTIONS?

Is the LED more suitable than other light sources? More energy efficient? Cheaper? Brighter? Does it have a longer life span? There is always an equal or better counterpart. There is the sodium lamp, the filament lamp, the metal-halide lamp and the long life fluorescent lamp. And yet we are all confident that with time, the LED will replace all other light sources.

Is the LED also better for implementation? Can better lighting solutions be created? Customers and planners alike are very interested in getting the answers to the many questions concerning LED lighting solutions, even when the answers can't explain just what the concrete advantages are. The only thing we know for sure is the fact that LED's are supposed to be very energy efficient and have a long life span.

Planners revert back to classic lighting solutions in order to reinforce concrete lighting requirements. Stipulations for the generation of norms are to reproduce the accepted status of technical regulations. When the EN 12464, the lighting of work places, was up for amendments, we all knew that we needed to keep solutions with LEDs at the back of our minds. At the same time it was clear that the norm had to be drawn up as technology independent. The main considerations were:

- Dot-shaped light sources create individual shadows. Every dot-shaped LED creates an individual, sharply confined shadow. Due to the fact that there are often numerous LEDs next to one another in order to guarantee the necessary luminous flux, multiple shadows are created which can make it irritating in the work place area.

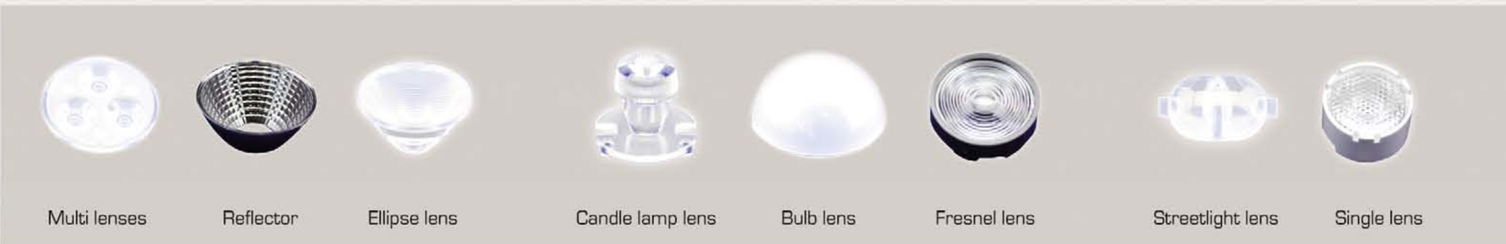
- Close boundaries of the radiation angle create sharp light-dark cross-overs. With this, the illumination of what is to be viewed has very precise edges, which would be the standard. This solution would decrease acceptance of the work place considerably. A light circumvallated area can guard against the reasons that a minimum brightness of walls and ceilings are required. Above all that, there is the danger that vertical areas don't receive enough light when an office is illuminated. The standard requires vertical and cylindrical illumination.

- Light colors can be created in higher numbers. It is important to pay attention to the fact that individual light colors can be seen slightly different from one another when they are next to each other.

- Color rendering is an important quality characteristic. The evaluation of glare has been limited to large scale light sources up until now. It is very important to evaluate the small, bright LED in the near future.

The LED as a light source enchants the present and will determine the future. But it will be tricky to implement them correctly. We want to have up-to-date standards in order to be able to support the planners and users in the best possible way. ■

P.D.


Multi lenses
Reflector
Ellipse lens
Candle lamp lens
Bulb lens
Fresnel lens
Streetlight lens
Single lens

Great Lighting Art for Great Sports

For a long time, luminaire expert, Zumtobel, has been involved in the areas of art and culture, supporting the lighting visions of renowned artists. Collaborating with internationally renowned artist Monica Bonvicini, Zumtobel has created a unique lighting installation to be admired in London this summer.

This summer, we witnessed athletic excellence in London. Zumtobel, the luminaire manufacturer, was represented in the city on the River Thames with an excellent performance as well. In collaboration with artist Monica Bonvicini, Zumtobel developed a huge permanent lighting sculpture titled “RUN”, which is on display at the London Olympic Park in front of the Handball Arena.

A total of 8464 high-power LEDs make the lighting installation shine at night

RUN comprises three nine-meter tall letters, each weighing about 15 tons, which have been installed slightly offset, one behind the other, on the elevated plaza in front of the new Copper Box Handball Arena. The giant letters consist of mirror-coated glass panels mounted on steel structures. Hence, in daylight, the entire surface produces a mirror effect, and these ever-changing reflections of its immediate surroundings – the sky, the park, people, buildings – make the sculpture virtually dissolve, so that it seems to merge with its environment in a surreal way. When night falls, the sculpture’s appearance changes: thanks to LED luminaires installed inside, along the outlines of the letters, and controlled by light sensors, the luminous letters clearly stand out against their environment. Convex mirrors installed on the inside, invisible in daylight, transform the individual LED strings into a scintillating mass. This conveys an unexpectedly strong, yet light-weight spatial presence to the structure. Indeed, both the “elegantly psychedelic effect at night” (Monica Bonvicini) and the dissolution due to the mirror effect by day form a striking contrast to the sheer size and massiveness of the letters.

In order to implement Bonvicini’s artwork, Zumtobel collaborated very closely with the artist, making every effort to turn her vision of the installation into reality. Completion of this unique task was facilitated by the years of experience and know-how Zumtobel has obtained in the field of LED technology. Moreover, the luminaire manufacturer has also been involved in the area of art and culture for years. In addition to unparalleled lighting solutions developed for museums and exhibitions, Zumtobel has, over the years, collaborated with renowned designers, architects and artists such as Zaha Hadid, Daniel Libeskind, Olafur Eliasson and Hani Rashid within the context of the Zumtobel Masterpieces range. The aim of these collaborations, and also of Monica Bonvicini’s “RUN” installation, is to put lighting ideas into practice and create unique luminous works of art. ■

Osram Offers DSL LED Module to Refurbish Historic Street Luminaires

Osram is now offering the Decorative Street Lighting (DSL) LED refurbishing module for historic street luminaires. The module can be used independently of manufacturer for a wide variety of luminaires and is prepared upon request so that fitting is as simple as replacing lamps or sockets. The DSL cuts energy consumption of luminaires previously operated with mercury vapor discharge lamps by at least 60 per cent, and upgrading costs less than half of a new LED installation. In total, street and park lighting are responsible for around 40% of overall energy costs for many municipal authorities.

The energetic refurbishment of street lighting is currently a hot topic for local authorities, and according to a recently published survey, street and park lighting consists of approximately 40% of total electricity costs for many municipalities. On the background of global hikes in energy prices and tight public budgets, LED is an important method of leverage in reducing such costs. In addition, the European Union’s Eco-Design guideline will, in the future, make sure that several lamp types are no longer available. The first choice when upgrading street lighting are LEDs. During operation these consume at least 60% less electricity than many light sources still in use and ensure especially long maintenance

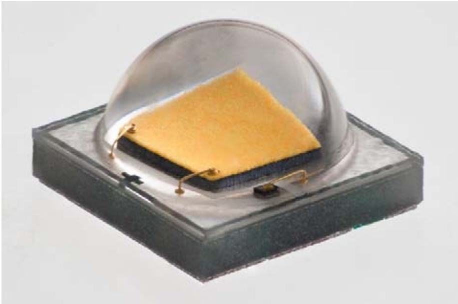
The luminaire (right) is easily installaed with hardly any tools. Decorative Street Lighting (DSL) LED refurbishing module (left) consumes up to 60% less energy than with originally fitted mercury vapour discharge lamps

intervals. Standardized refurbishment modules are available for many models that enable luminaires to be updated from classic technology to LED, but such standard solutions remain unavailable for heritage luminaires. It's here that the DSL provides support: the council sends a luminaire to Osram. The lighting experts adapt a construction kit consisting of an LED module and mounting plate specifically to the luminaire, and an employee from the town's works department is then able to install this on-site, simply and almost without use of tools.

The benefits of upgrading are obvious: with use of Oslon SSL, the latest generation of Osram LEDs, the DSL consumes at least 60% less energy than traditional lamps and is also more than twice as durable. The level of color rendering even satisfies the demands of office lighting, and the times of dimly-lit, pale roads are a thing of the past. DSL also enables more targeted control of light compared to classic lighting. If, for example, along a certain road section, the rear-illuminating third of the LEDs is done without, not only is energy saved but disturbing "light spill" behind the luminaires into the living rooms of residents need no longer be put up with. The integration of modern control units with intelligent light management ensures further energy savings. "AstroDIM", for example, enables luminaires to be dimmed completely self-sufficiently without the use of a corresponding control line. In this way, between midnight and the early morning hours, lighting can be adapted to lower volumes of traffic to achieve supplementary energy savings.

New XLamp® XP-G2 LEDs Deliver 20% Efficiency Increase in the XP Footprint

Cree, Inc. introduces the XLamp® XP-G2 LED to deliver luminaire manufacturers up to 20 percent more lumens per watt and 2.5 times the lumens-per-dollar over the original XP-G LED. The brighter, more efficient XP-G2 LED provides customers an immediate boost in performance and enables manufacturers to use fewer LEDs to get the same brightness at lower cost or increase brightness levels using the same LED count and power.



Cree's new XP-G2 LEDs are based on SC³ technology and combine high light output, reliability and efficacy to deliver up to 151 lpw @ 350 mA, 85°C

Characterized and binned at 85°C, the new XP-G2 LED leverages the same footprint (3.45mm x 3.45mm) and is compatible optically with the original XP-G LED – providing drop-in-ready performance enhancements to shorten the LED fixture design cycle and improve customer time to market. The XP-G2 LED can enable a broad range of high-lumen applications, from indoor and outdoor to portable and lamp retrofits.

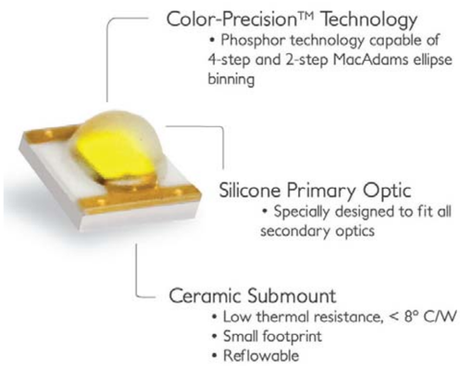
"We have many designs using Cree's XLamp XP-G LED," said William Weiss, partner and director of technology, MSi Solid State Lighting. "The new XP-G2 allows us to take full advantage of the benefits of Cree's latest technology without any significant design changes, improving time-to-market."

Built on the revolutionary SC^3 Technology Platform, the XP-G2 LEDs combine high light output, reliability and efficacy to deliver up to 151 lumens per watt at 350 mA, 85°C or 165 lumens per watt at 350 mA, 25°C in cool white (both at 6000K). In warm white (3000K), the XP-G2 LED delivers up to 133 lumens per watt at 350 mA, 85°C or 145 lumens per watt at 350 mA, 25°C. The SC^3 Technology Platform leverages Cree's advanced silicon carbide technology, features advancements in LED chip architecture and phosphor and showcases a new package design to deliver the most advanced lighting- class LED components in the industry.

Luminaire makers seeking ENERGY STAR® qualification will have access to specification and performance data, including LM-80 reports, which can speed time to market. XP-G2 LEDs are a "successor" product to the original XP-G LED for LM-80 data – accelerating qualification of luminaires using just 3000 hours of LM-80 data, instead of the normal 6000 hours. The XP-G2 LED is also UL-recognized and features a level 4 rating. ■

SemiLEDs Launches C35 LED Featuring Color-Precision™ Technology

SemiLEDs Corporation unveiled its new C35 LED emitter incorporating the new Enhanced Vertical (EVTM) LED chips. It features narrow binning, low thermal resistance and a special optical design. The C35 is SemiLEDs' first series of products to feature new Color-Precision™ technology, which will offer customers greater flexibility when making color choices. The C35 can yield consistent color within a single 7-step, 4-step or 2-step MacAdam ellipse centered in ANSI defined standard color spaces.



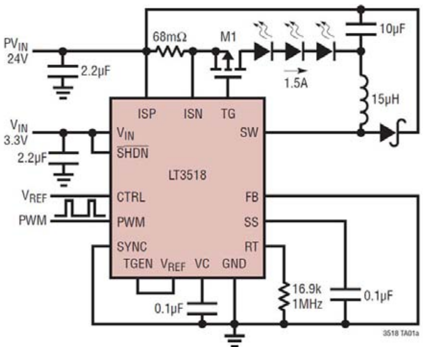
SemiLEDs' C35's Color-Precision™ technology gives users the choice of 7-step, 4-step and 2-step MacAdams ellipse binning

In addition, the C35 utilizes a ceramic sub mount which gives it low thermal resistance (Rth <8°C/W). Lower thermal resistance allows heat to be effectively driven from an LED's junction, both extending the lifetime of the LED and providing better light quality, and reliability. Luminaires will experience more stable lumen maintenance and consistent correlated color temperature (CCT) over time due to the C35 advantages in thermal management, making it ideal for general lighting applications.

Another key feature of the C35 is the special optical design that makes it easy to integrate with secondary optics. This design ensures light is distributed uniformly across the beam and diminishes the "yellow ring" effect typically found in white LEDs. ■

45V, 2.3A LED Driver for Boost, Buck or Buck-Boost High Current LED Applications

Linear Technology announces the H-grade version of the LT3518. The LT3518 is a 45V, high-side current sense DC/DC converter designed to drive high current LEDs at constant current. Its 3V to 30V input voltage range with transient protection to 40V makes the LT3518 ideal for a wide variety of applications, including automotive, industrial and architectural lighting.



1.5A buck mode LED driver schematics using Linear's LT3518H IC that can withstand a junction temperature of up to 150°C

Summary of LT3518H Features:

- 150°C Maximum Junction Temperature
- 3,000:1 True Color PWM™ Dimming Ratio
- 2.3 A, 45 V Internal Switch
- 100mV High-Side Current Sense
- Open LED Protection
- Adjustable Frequency: 250 kHz to 2.5 MHz
- Wide Input Voltage Range:
  - Operation from 3 V to 30 V
  - Transient Protection to 40 V
- For Boost, Buck & Buck-Boost Mode
- Gate Driver for PMOS LED Disconnect
- Constant-Current & Constant-Voltage Regulation
- CTRL Pin Provides 10:1 Analog Dimming
- Low Shutdown Current: <1µA

The H-grade version operates with a junction temperature up to 150°C, compared to the E- and I-grade versions' 125°C maximum junction temperature. All electrical specifications are identical for the E, I and H. The H-grade parts are tested and guaranteed to the maximum junction temperature of 150°C. They are ideal for automotive and industrial applications, which are subjected to high ambient temperatures.

The LT3518 can drive up to eight 300mA white LEDs from a nominal 12V input, making it well suited for applications such as automotive display backlighting. The LT3518 senses output current at the high side of the LED, enabling buck, buck-boost or boost configurations. It can deliver efficiencies up to 90% in boost mode from a 4mm x 4mm QFN package. The LT3518 offers True Color PWM™ dimming, delivering constant LED color with dimming ranges of up to 3,000:1. For less demanding dimming requirements, the CNTRL pin can be used to offer 10:1 analog dimming. Its fixed frequency, current-mode architecture ensures stable operation over a wide range of supply and output voltages. A frequency adjust pin enables the user to program the frequency between 250kHz and 2.5MHz to optimize efficiency while minimizing external component size. ■

Power Integrations Introduces 75 W Single-Stage LED Driver with Efficiency of up to over 92%

Power Integrations, maker of the world's most efficient, longest-lasting off-line LED driver ICs, today announced two new additions to its LinkSwitch™-PH IC family. The new devices allow commercial lighting applications up to 75 W to benefit from single-stage design, dramatically reducing BOM cost and enabling a smaller driver with very high efficiency.

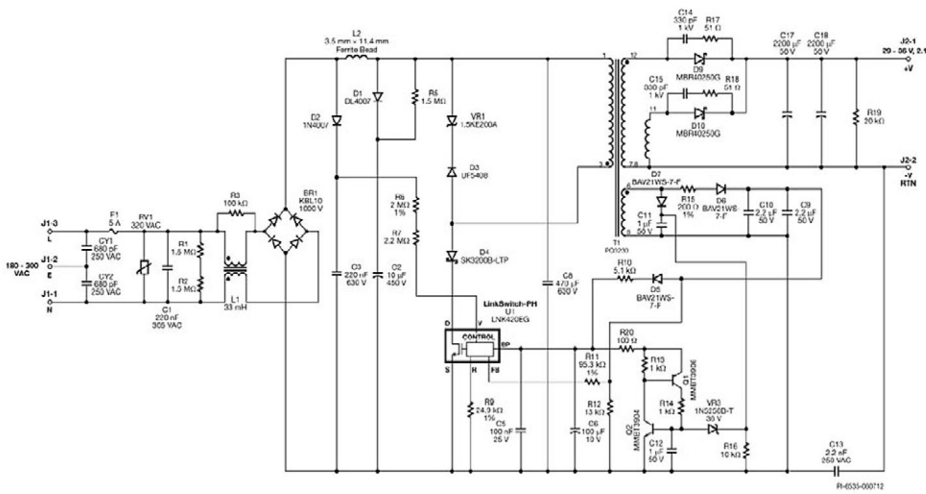
LNK410EG (dimming) and LNK420EG (non-dimming) provide a constant-current output with a PF-corrected and low THD input. The capabilities of the new devices are showcased in RDR-290, a reference design describing a single-output driver for high-bay lighting.

RDR-290 is 92.2% efficient at 230 VAC for a 75 W output design while easily meeting EN61000-3-2 class C limits. Power factor is above 0.95. No primary high-voltage electrolytic bulk capacitor is required, making lifetimes of 50,000 hours practical, even in challenging outdoor environments and at high ambient temperatures.

Comments Andrew Smith, product marketing manager at Power Integrations: "By greatly increasing the power capability of single-stage conversion, the efficiency and longevity benefits of the single-stage approach can now be applied to industrial and commercial LED lighting - the market that most needs those characteristics." ■

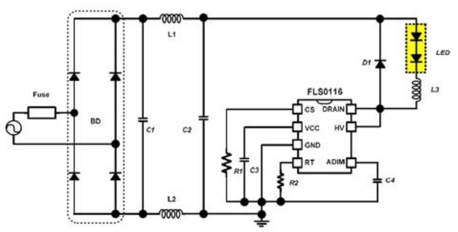
Fairchild's New Low-Power LED Drivers with Integrated MOSFETs Reduces Board Space

As the LED lighting market continues to grow, designers need solutions that meet limited circuit board footprints, meet circuit protection and system reliability demands, and simplify supply chain logistics, all while maintaining global energy regulation compliance.



Typical application schematic of Power Integrations' new drivers that allow for the reduction of BOM cost and enable a smaller driver with very high efficiency

To help designers meet these requirements, Fairchild Semiconductor expanded its LED lighting driver solutions portfolio to include an optimized low-power offering.



Typical application circuit for the FLS0116 that automatically detects AC and DC input voltage conditions, enabling and disabling PFC functions, analog dimming and soft-start functions

Features and Benefits:

FLS0116:

- Built-in MOSFET (1 A/550 V)
- Built-in HV supplying circuit for self biasing
- Low operating current of 0.85 mAa (typical)
- Current-sense pin open protection
- No transformer or electrolytic capacitor required for reduced component counts
- Digital PFC function (>0.9)
- Automatic, convertible AC-DC and DC-DC Inputs
- Analog dimming function
- Programmable LED current and frequency

FLS3217/FLS3247:

- Built-in MOSFET (FLS3217:1 A/700 V or FLS3247:4 A/700 V)
- Open/short LED protection
- Low operating current: 5 mA (typical)
- No input electrolytic capacitor required for reduced component counts
- High PF (>0.9)
- Low THD (Class C)
- Tight CC tolerance: <±5% in system

As a MOSFET technology leader, Fairchild continues to offer the latest in LED lamp drivers. The FLS0116, FLS3217 and FLS3247 with integrated MOSFET and power factor correction (PFC) are optimally designed for low-power LED applications. With the addition of the integrated power MOSFET, these devices help to minimize board space and overall component count while decreasing design time. Equipped with cycle-by-cycle current limiting and integrated protection features such as over temperature protection (OTP) and under-voltage lockout (UVLO) these devices help to significantly improve LED lamp system reliability.

The FLS0116 utilizes an “adopted digital” technique that automatically detects AC and DC input voltage conditions, enabling and disabling PFC functions while also offering programmable oscillation frequency and analog dimming and soft-start functions. The FLS3217 and FLS3247 with primary-side regulation (PSR) can support isolated flyback converter and non-isolated DC-DC converter applications. Additionally, the devices regulate accurate output current by using a precise constant-current control (CC) function and increase efficiency for an easier design with linear frequency control.

Fairchild’s complete LED solutions for low-, mid-, and high-power designs reduce external components to save space, provide high reliability, and enhance overall system efficiency. Featuring integrated components in a single IC, Fairchild utilizes proven, highly efficient and effective technologies to power ranges that are 1W and higher. With multiple topology offerings that provide energy efficient solutions, Fairchild helps designers achieve high power factor and low total harmonic distortion while meeting global energy regulations. Additionally, the company provides the system expertise and design resources needed to help designers get their LED IC-based products to market faster. ■

O2Micro Unveils Free Dimming™ Technology for LED Lighting

O2Micro® International Limited, a global leader in the design, development and marketing of high-performance integrated circuits and solutions, unveiled a new dimming architecture for the global LED lighting market.

O2Micro’s patented Free Dimming™ technology enables LED bulbs to dim using any on/off switch

O2Micro’s patented Free Dimming™ technology enables LED bulbs to dim using any on/off switch, thus eliminating the burden of installing expensive dimmers. O2Micro’s patented Free Dimming technology works with any on/off switch, including wall toggles, paddle switches, pull cords, rotary switches and other types of on/off switches commonly found on walls, extension cords and table/desk lamps.

According to industry estimates, there are roughly 150 million incandescent dimmers installed in the USA alone. In theory, LED bulbs are fully dimmable. However, chronic compatibility and performance issues include aesthetic problems such as flicker, audible hum, “jumpy” dimming, and poor turn-off performance. Others are various electrical issues such as inrush current, which stresses components in both the dimmer and LED bulb, shortening product lifetime and creating safety issues. Furthermore, support for legacy incandescent dimmers does not address the more than 85% of light bulbs that operate from non-dimming on/off switches.

O2Micro has the answer, the O2Micro’s Free Dimming LED driver product family.

For consumers, eliminating dimmer cost and installation makes LED bulbs that incorporate O2Micro’s Free Dimming LED driver easy to use and a great value.

For LED bulb manufacturers, O2Micro’s Free Dimming LED drivers shift dimming from a cost burden to a profit enhancer by enabling them to expand their addressable market by capturing dimmer revenue that would normally be served by dimmer manufacturers. O2Micro’s Free Dimming LED drivers offer the lowest BOM cost with the smallest footprint and have higher efficiency than incandescent dimming drivers by eliminating excess circuitry required to make LED bulbs work with incandescent dimmers.

The products in O2Micro’s Free Dimming LED driver product family, the pin-compatible OZ8022A and OZ8022B provide three-step dimming using any ordinary on/off switch. The LED drivers dim the LED bulb to one of three preset levels each time the on/off switch is toggled. For example, with each toggle action, the OZ8022A dims the LED bulb from 100% to 60% to 20% and then loops back to 100% full brightness, repeating the sequence.

Thermal Conductive Plastic Semi-Module

PAR30 PAR38 MR16 AR111 Bulb T8 Series

With the integration of thermal conductive plastic and aluminum part by insert molding, managing the thermal properly can be met . The heat generated from the LED is conducted rapidly from the insert aluminum part and then radiated via the plastic heat sink, so that the LED can be managed at most suitable condition!

Hybrid Lens

Reflector

Reflector Series

- Aluminum Reflector
- Electroplating Plastic Reflector

- LL01BR-TYRxxR34-P
  For BridgeLux
  ES ARRAY
  FWHM 24° 34° 55°
  D x H (mm) 40x20.1

- LL01BR-AJNxxR18
  FWHM 24° 38°
  D x H (mm) 75.8x20.1

- LL01CT-AJZxxR18
  FWHM 24° 38°
  D x H (mm) 50x19

- LL01SP-AJSxxR18
  FWHM 24° 38°
  D x H (mm) 50x30

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

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

- LL01ED-AKVxxR18
  FWHM 36°
  D x H (mm) 50.5x29.5

- LL01ED-ALAxxR18
  FWHM 24° 38°
  D x H (mm) 75x20.1

- LL01ED-AKAxxR18
  FWHM 60°
  D x H (mm) 85x23.4

- LL01ED-AKXxxR18
  FWHM 24° 38°
  D x H (mm) 116x32

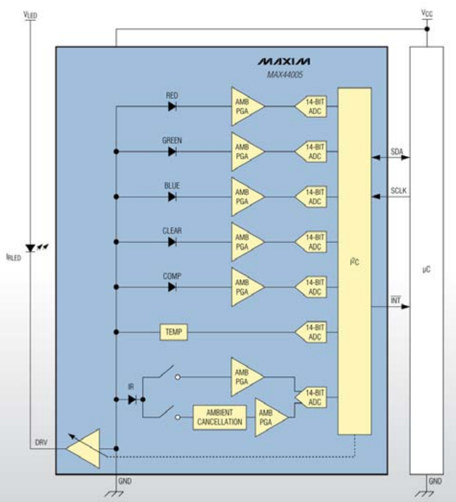
www.ledlink-optics.com E: ledprofessional@ledlink-optics.com T: +886-2-8227-6126

The OZ8022B operates in reverse, starting at 20% then increases brightness to 60% then 100% with each flick of the wall switch; imitating the operation of a traditional three-way incandescent light bulb and providing even more energy savings by starting at the lowest level.

The OZ8022 series supports universal 85 V to 265 V operation, enabling one LED bulb to address the global marketplace. High efficiency greater than 89% reduces energy consumption and thermal management complexity. Integrated over-temperature, over-voltage, cycle-by-cycle current limiting, and LED short circuit protection provides safe and reliable operation. Excellent LED current regulation ensures consistent lumen output, regardless of varying line input conditions. ■

Maxim's Digital, Highly Integrated Optical Sensors with up to Seven Sensors

Maxim Integrated Products announces four new digital optical sensors that advance analog integration with sensor fusion to measure RGB, ambient light, proximity motion, infrared, and temperature.



Maxim's new optical sensors provide higher levels of integration

The MAX44004/05/06/08 measure red/green/blue (RGB) light levels, ambient visible light (ALS), proximity to the sensor, ambient infrared (IR) levels, and temperature. As many as seven sensors are integrated into one compact optical package. The sensors provide robust and repeatable measurements and the MAX44005/MAX44006/MAX44008 all consume an industry-low 20 µA each. The high integration reduces system cost, eliminates several external components, and greatly simplifies design. These optical sensors can be used in a wide variety of applications such as smartphones, tablets, portable consumer devices, displays, digital light management, security systems, and medical devices.

Special features of the new types:

- The MAX44004 is a low-power ALS that consumes only 5 µA.
- The MAX44006/MAX44008 integrate RGB color sensors plus an ALS (clear), an ambient IR, and temperature sensors
- The MAX44005 includes an RGB color sensor plus an ALS (clear), ambient IR, IR proximity, and temperature sensors

Temperature range, packaging, and availability:

- The MAX44005/MAX44006/MAX44008 are guaranteed over the -40°C to +85°C temperature range.
- MAX44004 is guaranteed over the -40°C to +105°C temperature range.
- All sensors are available in a 2mm x 2mm x 0.6mm optical package.
- Pricing starts at $1.20 (1000-up, FOB USA).

"There is a progression of trends toward a world where everything is connected, where sensors become pervasive and technology virtually disappears," said Chae Lee, Senior Vice President of Maxim's Mobility Group. "Our goal is for these devices to be a natural extension of ourselves." ■

20 Watt Buck/Boost Driver Supplies High Power LEDs from Low Power Sources

Standard LED drivers (buck topology) require the input voltage be higher than the output voltage which can cause problems when working with the newest high power LEDs and powering them from low voltage sources like solar cells or batteries. Buck driver solutions, which must always have a higher input voltage than an output voltage, typically result in a design that requires multiple drivers for multiple led strings with lower forward voltages. This problem is solved with the introduction of RECOM Lightings buck/boost LED driver which can deliver high voltages (up to 40 V) from a low voltage source (as low as 8 V), simplifying the lighting system with the use of a single driver and a long single string of LEDs.

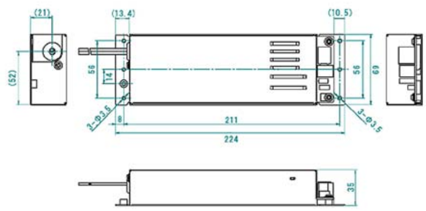
RECOM's RBD-12 series LED drivers are ideal for mobile, solar and battery driven LED-systems

The new RBD-12 series supplies LEDs from 3 to 20 watts with input voltages from 8 to 36 V providing constant currents of 350 mA or 500 mA. The output voltage can be above or below the supply voltage by a factor 2 (500 mA) or by a factor 3 (350 mA), within the range from 2 to 40 VDC. These new buck/boost models are digital (PWM + Remote On/Off) and analog dimmable and cover the temperature range -40°C to +75°C. Dimensions are 32.6 x 16.6 x 11.1mm (L x W x H), and weigh only 13 grams. Depending on the application the drivers can be supplied with wires or with standard pins for PCB mounting.

Buck/boost drivers such as the RBD-12 series are ideal for mobile, solar and battery driven LED-systems for transport and traffic applications (i.e. mobile homes, E-cars, street lighting, traffic signs, etc.) as well as for use in marine and air traffic lighting – that is wherever universal, long life LED-supplies are a must. They comply with all relevant safety standards such as EN/UL60950-1 and carry a 5 year warranty. ■

muRata Offers Standard Power Supplies for LED Lighting

Murata Manufacturing Co., Ltd. has launched mass production of standard power modules for LED lighting. The power modules comply with DALI (IEC62386) transmission standards for lighting and are the optimal choice for controlling BEMS and HEMS systems with multiple lighting devices.



Outer dimensions of muRata's new totally digital lighting controller for LED lighting systems

Features:

- Compatible with various types of dimming functions - Compatible with 3 types of dimmers: DALI dimmers, UART (Murata Manufacturing's dedicated wireless transmission module) dimmers and PWM dimmers.
- Worldwide input
  Compatible with 90-267 VAC; can be used anywhere in the world
- Insulated type
  North America: plan to acquire UL standard
  Europe: plan to acquire EN standard
- Reduced standby power - When not being used for extended periods, for example late at night, regular standalone lighting devices require AC OFF input to turn off. In many BEMS systems, lights are kept in standby mode even when turned off to enable wireless transmission. This power module helps save energy by reducing the standby power from 2 W to about 0.2 W.

<u>MPA1937 series:</u>

- MPA1937A (constant current: 700mA type)
- MPA1937B (constant current: 600mA type)
- MPA1937C (constant current: 500mA type)

Task & Ambient Lighting Systems are being used more and more when constructing new office buildings to optimize the environment and energy performance in the building. Task & Ambient Lighting Systems adjust personal (task) lighting and broad area (ambient) lighting to maintain sufficient brightness on the work surface while simultaneously lowering the intensity of base lighting to achieve a comfortable visual environment without waste. These systems are therefore optimal for BEMS and HEMS.

While task lighting devices are ordinarily outlet based, Task & Ambient Lighting Systems connect all lights wirelessly and control all task lights collectively. In contrast, wireless dimming and switching on and off of LED lighting devices requires the power supply circuit driving the LED devices to coordinate with the wireless circuit. Murata Manufacturing has thus begun mass production of a power supply module that can be directly coupled with the wireless transmission module as a standard module to help develop seamless lighting systems.

Murata Manufacturing used the DALI system for transmission for system control by power supply module. DALI sets a unique address for each power supply module and controls each lighting device individually to achieve both comfort and energy savings. The DALI standard is an IEC international standard, and complying with this standard means that many users can test and use the systems and devices for themselves. ■

30 Watt Constant Current AC/DC LED Power Supply

Green Watt Power announces the "GLC-30" Series of Constant Current AC/DC LED power supplies. The GLC-30 Series with universal / full range AC input voltage of 100 - 277 VAC, offers stable and reliable 30 W output power and is available in three different models of constant current output at 500 mA and 750 mA with self-adjusting output voltage from 30 VDC to 60 VDC range in the various models. All models are enclosed to IP67 standards in extruded aluminum metal case design and well-suited for virtually all LED lighting applications for indoor, outdoor, signage, refrigeration, thermally harsh and damp environments.

Green Watt Power's new 30 Watt constant current AC/DC LED power supply

The GLC-30 series has efficiencies in the 88% range with active Power Factor correction greater than 0.90 on every model. All units in the series have Over Voltage, Over Current, Over Temperature protection and are RoHS Compliant. All Green Watt Power LED power supplies are Safety Agency approval UL/CSA 8750 and 1310 class 2 or 1, depending upon the model.
All products are also CE approved. The product case dimension is 6.42"(L) x 1.73"(W) x 1.25"(H) with customer mounting provisions designed into the case. All products in the series are designed and built for consistent performance and high reliability and come with a 5 year warranty. ■

Lumiotec Ships Commercial Production OLED Panels with Ra93

Lumiotec Inc., a company specializing in organic light-emitting diode (OLED) lighting panels, began shipping commercially produced OLED lighting panels which achieve the world's highest color rendering index of Ra93*1 in August. The OLED panels are capable of high-level reproducibility of red and human skin colors, which has heretofore been an industry limitation. With a light output approximating natural light, the panel is capable of reproducing the original color of various materials, from fresh food and clothing, to human skin tones. The panels have won high acclaim from users, even at the sample production stage, thus, Lumiotec sees demand for applications in various fields and looks to expand its market.

The OLED panels being launched to market are the P06 Series (natural white) which have achieved high color rendering capability. The panels are available in five sizes, as were the previous commercial production panels (P3, P4 and P5 Series). The shipment prices of the P06 Series, with a luminescent efficiency of 28 lm/W (lumen/watt); an average color rendering index of Ra93 and, at the same time, red and human skin tones with a CRI over 90, significantly enhanced from previous models, will remain the same: prevailing market prices are about 13,000 yen to 40,000 yen, excluding sales tax.

Lumiotec's high-CRI OLEDs offer a CRI of 93 and are commercially available in five sizes

Lumiotec was the first in the world to begin marketing commercial OLED lighting panels (natural white and lamp color) in January 2011 and has continued to conduct marketing activities with the panels. Responding to requests from customers for high-efficiency, and high-rendering capability panels, Lumiotec began to sell the high-efficiency series (40lm/W, lamp color) in April of this year. The company now markets the P06 Series, a commercial production OLED panel, which achieves the world's highest color rendering capability. The color rendering index is a crucial factor for lighting equipment, along with efficiency and durability. In general, natural light is used as a criterion with the value of 100. Index numbers incrementally closer to 100 indicate higher color reproducibility.

The P06 Series has not only achieved a high color rendering index of Ra93 but has also realized high-level reproducibility for all colors, including red and human skin tones (Asian and European) color, which have been considered a limitation of this lighting technology.

OLED lighting panels offer qualities which neither conventional light sources, such as incandescent bulbs and fluorescent tubes, nor light-emitting diodes (LED) can provide:

- Lightweight and extremely thin
- Surface light emission, enabling uniform, soft non-glare light
- No ultraviolet or infrared rays, preventing damage to objects being lit
- No harmful substances such as mercury
- Low energy consumption, which reduces CO2 emissions

With their high color rendering capability, Lumiotec's OLED panels prevent differences in color impression of clothes in the fitting room versus outside lighting conditions. In exhibiting objects at museums, including art museums, as well as the illuminating of people, the original colors will be vividly reproduced. ■

GLT and ATD Develop 2 X 2 Foot High Bay Ceiling Light with 17,000 lm

Global Lighting Technologies (GLT) Inc. has utilized its advanced LED-based edge lighting technology in conjunction with Advanced Thermal Devices' (ATD) Loop Heat Pipe heat dissipation technology to develop a new high brightness luminaire for use in high bay recessed ceiling light applications.

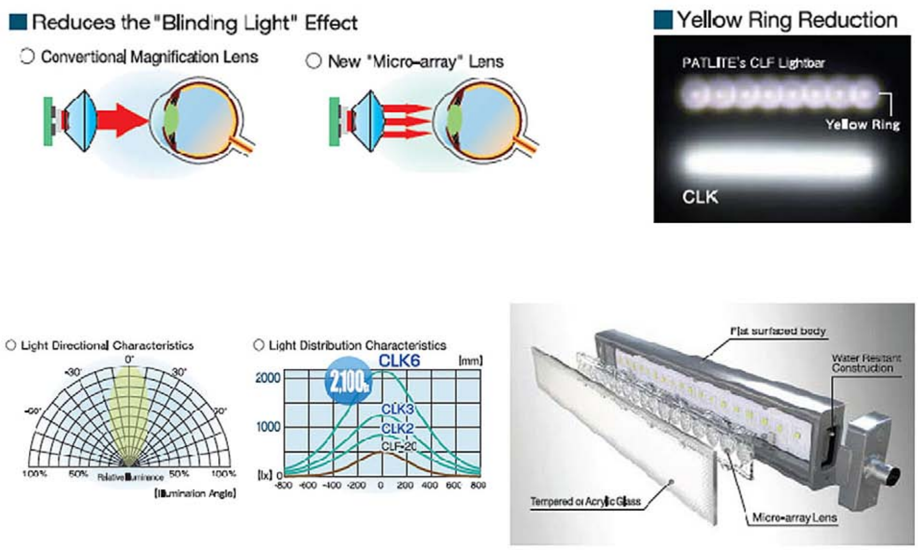
This new high bay ceiling light offers high brightness via a GLT edge-lit light guide plate (LGP), a slim profile and ATD's loop heat pipe (LHP) thermal management (inset)

The new ceiling light, ATD Model # SL-300-C7-NW, offers 17,000 usable lumens at a rated power of 300W and a color temperature of 4,000-5,000K. Slim and lightweight for a luminaire of its power and performance, it is ideal for a range of indoor applications such as theaters, auditoriums, convention centers, large open office spaces, parking garages and warehouses.

The luminaire measures 600 x 600 x 115 mm (23.6 x 23.6 x 4.5 inches) and weighs 17 Kg (37 lbs.), including adapter, and is waterproof. For illumination, it incorporates a light guide plate (LGP) from Global Lighting Technologies edge-lit by high brightness LEDs spaced along the edge of the LGP, which is only 5 mm (0.196 inches) thick, contributing to the slim profile, light weight and modularity of this easy-to-install unit.

Heat dissipation is addressed by ATD's Loop Heat Pipe (LHP), a passive, hermetic closed-loop heat-transfer device requiring no external power input that provides heat transport at distances up to several meters, high power (up to several hundred Watts), and utilizes flexible, bendable connecting pipe, maintaining high heat transfer capability in an anti-gravity direction. LHP can circularly transport waste heat and dissipate it to the surrounding environment by natural convection without extra power, effectively solving thermal problems and extending the lifetime of the LEDs. ■

Motion29's New Patlite Offering is a Welcome Sight for Sore Eyes



Motion29's new CLK luminaire is robust and with its special "micro-array-optics" photo biologically safe

Launched by Motion29, the new CLK is already becoming popular with the food, pharmaceutical, chemical and manufacturing industries, due to its tough aluminum or stainless steel body which resists water and oil or chemicals. It's not often you get a model with a 2,100 lx centre illumination which resists water and chemicals/oils but Motion29's new CLK LED from Patlite ticks all the boxes.

Features:

- Impervious to Water, Oil, and Chemicals
- Includes PATLITE's own 'Micro-array Lens" design to even out light distribution
- Available in lengths of 200, 300 and 600 mm
- Three different Body and Lens Material combinations available
- Uses the popular M12 Quick Disconnect
- Can connect in series with Daisy Links (using M12 Connectors)

In creating the CLK, Patlite has made use of 'micro-array lens' technology – designed to even out light refraction and cut out the 'yellow ring' effect which can be irritating and distracting at best. Conventional magnification lenses can cause a 'blinding light' effect but the new CLK design conforms to the photobiological safety of lamps and lamp systems and means that no immediate retina damage is done.

With a one-touch installation system as standard, the CLK is also available with an optional angle adjustment bracket and surface-mounting bracket for speedy and easy set up. Super slim with a side body angle designed to prevent dirt accumulation and water/oil pooling, the CLK is ideal for working environments where standard equipment just doesn't cut it. The LED lens has a simple flat-surface to ensure optimum lighting and to facilitate regular wipe-downs. ■

Lighting Science Group Launches Ultra-Efficient LED MR16 50-Watt Equivalent Bulb for Europe

Lighting Science Group, the world's premier LED lighting manufacturer, announced the European launch of a revolutionary high output 8-watt LED MR16 bulb that is a direct replacement for traditional MR16 50-watt halogen bulbs. Suited to a variety of applications that require directional lighting—such as track lighting, recessed ceiling lights, desk lamps, pendant fixtures and retail display lighting—the DEFINITY™ MR16 HO LED bulb will be the first of its kind introduced to the marketplace, and considered the best of its breed when evaluated by metrics of efficiency, lumen output and form factor.

Maintaining the ANSI form factor and just using 8W, LSG's new MR16 lamp challenges the luminous flux of 50W halogen lamps

The degree of difficulty involved in managing the MR16's discreet size and internal power supply and the intense requirements for brightness of a 50-watt equivalent renders its design and manufacture a complex challenge. Competitive attempts at reaching these high levels of performance have resulted in concessions that have been viewed as unacceptable to the market. No such sacrifice is required with the Definity MR16 HO Series.

At only 8 watts and a 25,000 hour life rating, the new DEFINITY™ MR16 HO LED bulb is up to 33% more efficient than competitive products while staying within the industry accepted form factor and not using any moving parts like fans to achieve its superior performance. Steve Marton, Interim Chief Executive Officer of the company, says: "We believe that our new MR16 HO, which couples unparalleled efficiency and incredible performance, is a significant advancement in the science of light and another step forward in the development of a more efficient, sustainable and brighter energy future." ■

Verbatim Unveils New Line-Up of Retrofit LED Lamps for Residential Application

From September 1st 2012, European Union legislation bans the manufacture and import of all incandescent bulbs. In anticipation to this, Verbatim has unveiled a complete family of cost effective retrofit LED lamps for households. They are designed to meet the growing demand for reliable, high quality and low energy lighting.

Verbatim's family of cost effective retrofit LED lamps for households

The LED lamps, which have a lifetime of up to 25 years, provide up to 85% energy savings over conventional types of comparable light output. They are designed as direct low cost replacements for incandescent bulbs, halogen lamps and compact fluorescent lamps (CFLs) in general purpose lighting.

Verbatim's new consumer product line-up comprises 13 products including LED lamps to replace 25 W to 60 W Classic A bulbs, 15 W to 25 W Classic B candle lamps, 25 W droplet bulbs and 20W spotlights for both MR16 GU5.3 and PAR16 fittings. Color temperatures range from 2700 K to 3000 K and each model has a minimum color rendering index (CRI) of 80. Packaged in distinctive green packaging, Verbatim's LED consumer range is available through the company's online store and through wholesalers and electrical retailers.

"LED technology is the best energy saving alternative available to replace conventional bulbs. Unlike compact fluorescent lamp bulbs, LED lamps typically deliver five times the operating life, turn on instantly and do not contain hazardous materials such as mercury," commented Jeanine Chrobak-Kando, Business Development Manager, LED EUMEA.

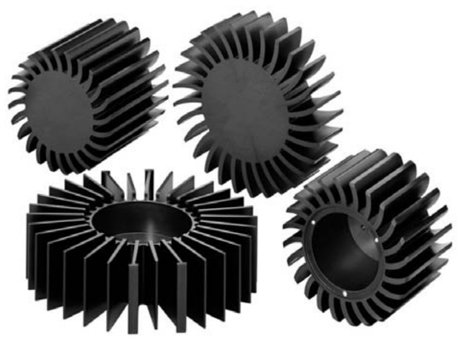
Five of the LED lamps in the new range are Classic A bulb replacements operating from a 220-240V grid supply. The LED lamps have power ratings between 4 W and 11 W and replace conventional bulbs rated from 25 W to 60 W. The 11 W model delivers a light output of 810 lumens and the 4 W model provides 250 lumens. All the lamps are available with either E27 (screw type) or B22 (bayonet) bases except a dimmable 9 W option made exclusively for E27 sockets.

The line-up includes two candle LEDs with E14 sockets to provide general and ambient lighting, particularly appropriate for bedside or tabletop use in the home. A transparent 3.5 W model will replace a traditional 15 W light bulb while a non-clear 4 W version serves as an alternative for a 25 W incandescent bulb. Two 4 W droplet LEDs with either E14 or E27 sockets are also available.

Consumers can choose between two MR16 spotlights fitting in GU5.3 sockets. The 4 W rated model has a beam angle of 20° while the 6 W version has a beam angle of 25°. Both spotlights are ideally suited to drawing attention to artwork in the living room or accent lighting in the bathroom. Ideal for accent lighting in the kitchen, bedroom or along the corridor, a 4 W PAR 16 GU10 LED replaces 20 W conventional bulbs and delivers 180 lumens of light output while a 4 W LED R50 with E14 fitting with the same output completes the line-up. ■

Fischer Elektronik Announces the Product Range Expansion of LED Star Coolers

Fischer Elektronik has expanded its product range of LED star coolers, which are specially matched, both thermally and mechanically, to the LED light engines (Zhaga compliant).



Fischer Elektronik's LED Star Coolers are now available for Zhaga compliant LED light engines

So-called LED light engines are being used ever more frequently in different sectors of the lighting industry due to their output performance. A significant advantage of this design is its modular construction, which ensures good interchange ability of the individual LED chips over several generations. A mounting ring, made of plastic and used for accepting the additional LED components, is simply fastened by means of screws to a cooling body. Further elementary components, such as the LED board and the matching optics, can be screwed without tools into the mounting holder provided.

Fischer Elektronik's newly developed LED star coolers have a massive internal diameter for accepting the LED light engines, while the LED modules can be directly integrated after the cooling body has been mechanically machined. ■

Ohmite Manufacturing Extends its FC4L Series of Resistors

Ohmite Manufacturing Company, a leading provider of thermal solutions and resistors for high current, high voltage and high energy applications, announces that it has expanded its FC4L Series of four terminal current sense resistors. This series, previously available in five watt package sizes, is now also available in two watt package sizes.

Ohmite Manufacturing now offers its FC4L series resistors also in a 2 W version

Employing a Ni-Cu-Mn resistive element, the FC4L Series features a built in four-terminal design with two larger electrodes for current management and two smaller electrodes for voltage measurement. This Kelvin type resistor is designed for automatic insertion and features a metal foil construction, ensuring a very stable temperature coefficient of resistance (TCR). In addition, it provides a tight tolerance (5% at 1 mΩ, 2% at 2 mΩ, and 1% at 3, 5, 10, 25, and 50 mΩ).

Available in industry standard sizes, the FC4L Series functions for both high heat resistant use and low heat electromotive use. Its four-wire connection improves measurement accuracy by directly sensing a voltage drop across the resistor. This eliminates inaccuracies caused by voltage drops across resistor leads and printed circuit board (PCB) traces.

These current sense resistors can be used in a variety of battery powered electronic devices to mitigate concerns with battery life, recharging frequency, and overcharging risks. ■

Thomas Research Products BSP3 Series Surge Protector Models Are Recognized to UL1449

Thomas Research Products has announced that a number of their BSP3 series Surge Protector models are now recognized to the UL1449 standard. Luminaire manufacturers can offer a new level of assurance with the safety they provide. TRP is a leading manufacturer of SSL power solutions.

TRP's Surge Protectors are particularly useful in avoiding costly problems in 24/7 outdoor applications

Thomas Research Products worked with UL to clarify the most appropriate utilization of the company's cost-effective BSP3 series Surge

Protectors. As a result, a number of models are now recognized to the stringent UL1449 standard for Surge Protective Devices.

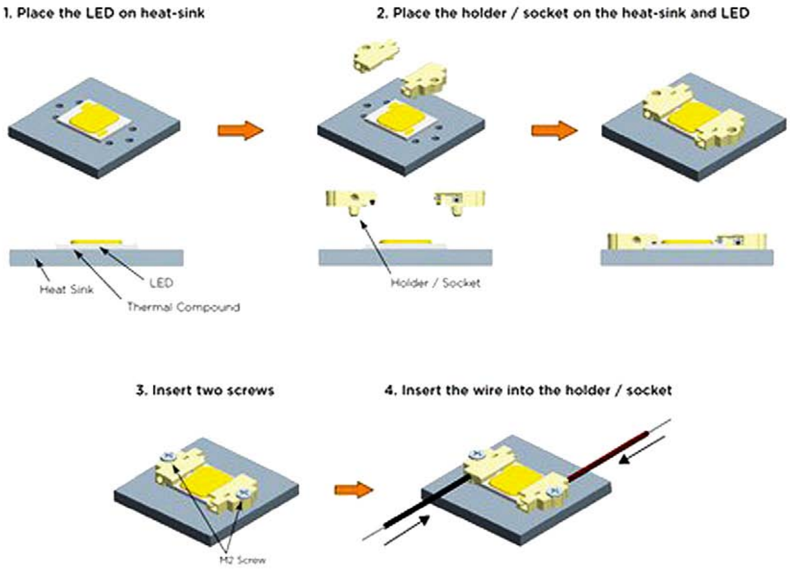
Standard BSP3 devices, which provide protection from surge currents up to 10,000 Amps, include the BSP3-277, BSP3-347, BSP3-480. LC series devices, providing the same protection with a smaller case profile, include the BSP3-347 (LC) and the BSP3-480 (LC). The higher rated BSP3-20K series devices, which provide protection up to 20,000 Amps, include the BSP3-277-20K and the BSP3-480-20K.

BSP3 Surge Protectors are utilized primarily in conjunction with LED drivers, to provide protection against dangerous power line disturbances in industrial and commercial outdoor applications. They also protect electronic FL and HID ballasts, and induction lighting ballasts. All BSP3 series devices are UL Recognized Components for the United States and Canada under UL935 and UL1029. Flame-proof plastic enclosures on all models provide 85°C surface temperature rating. IP65 rated.

TRP's Surge Protectors are particularly useful in avoiding costly problems in 24/7 outdoor applications, including street lighting, big-box retail, warehouses, parking garages, and transportation facilities. For OEM customers, TRP has 3D models of their Surge Protectors available at www.trpssl.com. Many of these items are available for immediate purchase from stocking distributor Digi-Key. ■

TE Connectivity´s New LED Socket Allows Direct Attachment of Sharp Mini Zenigata LEDs

TE Connectivity has expanded its solderless LED socket offering to include a version for SHARP's new Mini Zenigata LED. The SMIZ socket is precision engineered and designed specifically for the Mini Zenigata LED and offers customers a reliable "plug and play" complete solution. This new socket adds to TE's extensive portfolio of solderless LED sockets for a wide range of lighting applications. It underlines TE's commitment to the future of solid state lighting by providing solutions that add value for the customer.



Mounting process for the TE Solderless LED Socket, type SMIZ quick termination connector system for use with the Sharp Mini Zenigata LED

Product Features:
- Solderless termination to Sharp Mini Zenigata LED array series (GW5B)
- Locator posts on housing aid in positioning connector on heat sink
- Two-screw attachment to heat sink using M2 screws instead of soldering

Applications:
- LED replacement lamp for indoor and outdoor lighting
- Architectural illumination
- Spotlights
- Area and object lighting

"Advanced energy-efficient lighting systems are one of the primary focus markets of our Intelligent Buildings team. At TE, we strive to bring innovation and customer benefit to the lighting industry as we work to provide solutions that solve next-generation connectivity challenges," said Peter Lieffrig, General Manager of TE's Intelligent Buildings business unit.

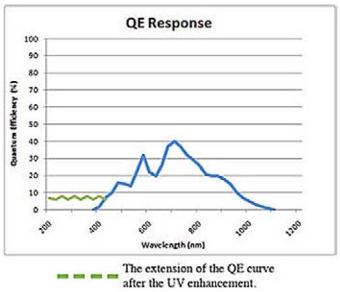
TE's SMIZ two-piece socket provides a mechanical and solderless electrical connection to the LED. Solderless connecting is not only very easy, but also very quick. Not soldering to chip-on-board LEDs enables uniformity and a reliable connection that can be made without special skills. It also reduces the risk of damaging the LED by the heat of the solder process or with solder flux spatters on the light emitting area. The socket holds the LED mechanically and firmly to the heat sink using M2 screws and locator posts on the housing to aid correct positioning.

The SMIZ socket is RoHS compliant and suitable for various applications such as:
- LED replacement lamp for indoor and outdoor lighting retrofit applications
- Architectural illumination
- Reading lamps
- Spotlights
- Pendant lights
- Mobile lighting
- Area and object lighting

Termination to the Mini Zenigata LED is simplified with locating features that position the LED into the socket during the assembly process. This socket allows the LED to be directly attached to the heatsink using two standard (M2) screws. ■

B&W Tek Provides a Quantum Leap in the Evolution of Miniature CCD Spectrometer Technology

B&W Tek, Inc., an advanced instrumentation company producing optical spectroscopy and laser systems, introduced the future of miniature spectrometers, that users are calling the first truly "smart" spectrometer. B&W Tek's Exemplar™ is the first miniature spectrometer to include an embedded processor to allow for effortless on-board data processing, including averaging, smoothing, and automatic dark subtraction.



B&W Tek calls its most recent spectrometer, Exemplar™, a "smart" spectrometer due to the built-in fast embedded processor

Applications:

- UV, Vis, and NIR: Spectroscopy / Spectroradiometry / Spectrophotometry
- Transmission, Reflection, Absorption
- Wavelength Identification
- OEM Systems Integration
- Multi-point Sampling
- Reflected Color

Features:

- On Board Data Processing, Including Averaging and Smoothing
- Temperature Compensation for Ultra-low Thermal Drift
- Ultra-low Trigger Delay (14ns) and Gate Jitter (+/-1 ns)
- Supports Up to 16 Simultaneous Channels
- 1ms Minimum Integration Time
- Automatic Dark Compensation
- UV - NIR (200 nm - 1050 nm)
- < 0.5 nm Spectral Resolution
- >2.0 MHz Readout Speed

In addition to these "smart" capabilities embedded directly into its compact form factor, the Exemplar embodies several other groundbreaking features that render it the only one of its class. Unprecedented speed, using "SuperSpeed" USB 3.0 communication provides data transfer of 900 spectra per second. Multichannel capabilities deliver an ultra-low trigger delay of 14 nanoseconds and a gate jitter of +/-1 nanosecond – specifications that are unmatched by any spectrometer currently on the market. The ability to control the CCD exposure time to within one microsecond allows the user to have unparalleled control over the spectra's signal-to-noise ratio.

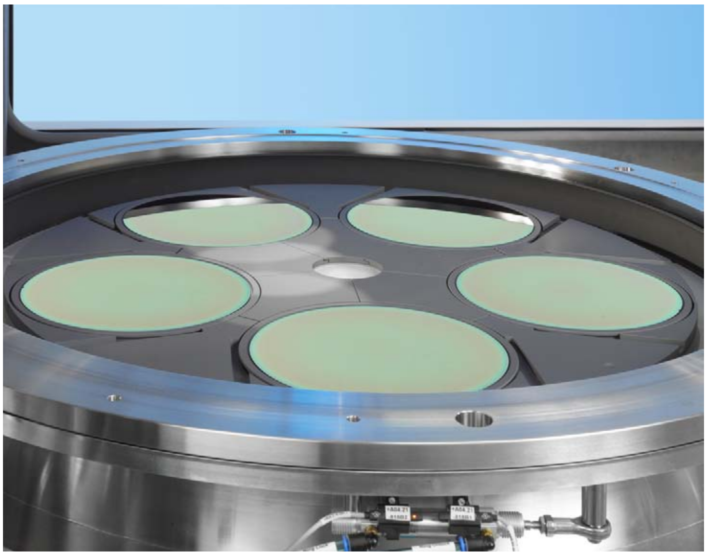
These advancements make this platform ideal for demanding applications such as high speed binning & sorting, reaction kinetics, and process monitoring. With the ability to support up to 16 simultaneous channels, the Exemplar is also the perfect solution for simultaneous multichannel analysis, such as multipoint sampling, and LIBS (laser induced breakdown spectroscopy).

"As part of our innovation strategy, we have developed a new class of modular spectrometers," says Dr. Mike Kayat, VP of Sales & Marketing for B&W Tek, Inc. "The Exemplar is a small, compact and smart multichannel spectrometer platform that can be configured for flexible, high speed spectral processing. Our end user and OEM customers can utilize the onboard data processing and scalable, multichannel configurations to achieve simultaneous analysis at nanosecond accuracies, allowing them to unlock new applications never before thought possible. This new development is just one of many innovations that you can expect from B&W Tek in the coming year."

The Exemplar is equipped with temperature compensation, a 2048 element detector, and built-in 16-bit digitizer with a >2.0 MHz readout speed. It is ideal for most UV, Vis, and NIR applications with spectral configurations from 200 nm to 1050 nm and resolutions between 0.5 nm and 4.0 nm. Custom configurations are available for OEM applications. ■

AIXTRON Introduces AIX G5+: 5 x 200 mm GaN-on-Si Technology for the AIX G5 Reactor

With its latest product, AIX G5+, AIXTRON SE has introduced a 5x200 mm GaN-on-Si (Gallium Nitride on Silicon) technology package for its AIX G5 Planetary Reactor® platform. Following a customer-focused development program, this technology was designed and created in AIXTRON's R&D laboratory and consists of specially designed reactor hardware and process capabilities. It is now available as a part of the AIX G5 product family and any existing G5 system can be upgraded to this latest version. Details of G5+ have already been disclosed to some of AIXTRON's key customers.



AIX G5+: fully rotationally symmetrical uniformity pattern on all five wafers

"GaN-on-Si technology is a hot topic for MOCVD users and manufacturers today", states Dr. Rainer Beccard, Vice President Marketing at AIXTRON. "It is the technology of choice for the emerging power electronics market segment, and also a very promising candidate for future high performance and low cost High Brightness LED manufacturing. The wafer size and material plays a crucial role when it comes to cost effective manufacturing processes, and thus the transition to 200 mm Standard Silicon wafers is a logical next step on the manufacturing roadmaps, as it offers unique economies of scale."

"Being convinced that uniformity and yield are the key success criteria in 200 mm GaN-on-Si processes, AIXTRON conducted a dedicated R&D program", adds Dr. Frank Wischmeyer, Vice President and Program Manager Power Electronics at AIXTRON. "We started the development process by conducting an extensive simulation program, which enabled us to design fundamentally new hardware components that provide unique process performance, while still being compatible with the well-proven AIX G5 reactor platform." The results are extremely stable processes, providing much better uniformity of material properties and enabling higher device yield than any other MOCVD platform, whilst offering a reactor capacity of 5x200 mm.

Some initial feedback from customers confirms the success of this technological development. Many of them have noted in particular that the fully rotationally symmetrical uniformity pattern on all five 200 mm wafers, the use of standard thickness silicon substrates and the controlled wafer bow behavior is exactly what they require for silicon-style manufacturing. "This uniformity pattern has been an inherent feature of our Planetary Reactor® technology, which we can now successfully obtain on the GaN-on-Si wafers", underlines Dr. Wischmeyer. ■

Labsphere illumia® lite - a World First in Portable Spectral Flux Analysis

Labsphere, Inc. has expanded its illumia LED and light measurement product range with the introduction of illumia® lite. The portable system packages the accuracy of sphere-based measurement in a cost-effective handheld device suitable for use on the production floor, in the lab or in the field.

Labsphere's illumia lite is a sphere-based flux and color measurements handheld unit

Features:

- 4 cm integrating sphere
- For LEDs and other sources up to 1 cm
- Wavelength range 380 nm – 820 nm
- Luminous flux range 0.1 – 5000 lumens
- Wavelength resolution < 5 nm
- Wavelength accuracy < 0.5 nm
- Dark correction capability via software
- Self-absorption correction via built-in auxiliary lamp
- Device calibration capability
- Handheld portable size and weight
- Ergonomic design
- USB connection to computer with easy-to-use software

The illumia lite overcomes the drawbacks inherent in other handhelds by incorporating a spectrometer calibrated for absolute spectral flux and employs an integrating sphere in its design. This combination delivers more complete spectral flux measurement capability than simple illuminance meters using near cosine receivers. The ergonomic handheld instrument measures both luminous flux and color of a device under test, including LEDs and other sources up to 1 cm in diameter. A built-in auxiliary lamp provides self-absorption correction for highly accurate results.

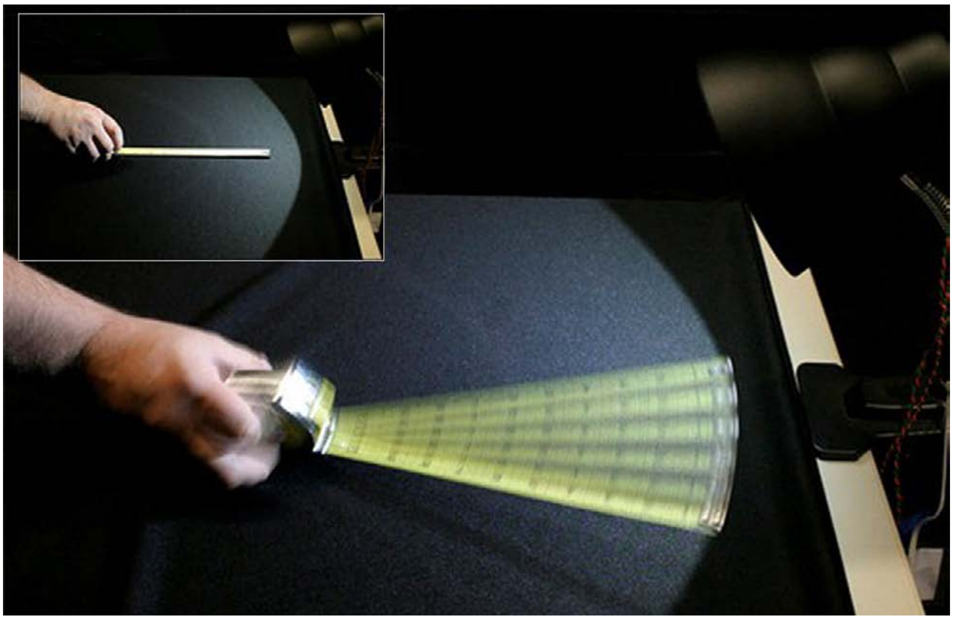
The luminous flux range of illumia lite is 0.1 lumens to 5000 lumens, with a wavelength resolution of <5nm and accuracy of <0.5 nm. Data is retrieved via USB connection to any laptop or PC and analyzed with Labsphere's easy-to-use MtrX-Spec software. The software calculates all industry standard color parameters such as x, y, CCT, CRI, and lumens, as well as spectral irradiance. ■

ASSIST Released Calculation Guidelines to Avoid Stroboscopic Effects in SSL Lighting

Flicker and stroboscopic effects have been a concern with solid-state lighting (SSL), and industry and the ENERGY STAR program have debated recently the effects of frequency and other driving modes on the perception and acceptability of flicker. To provide further data and guidance in this area, the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute has conducted human factors studies of flicker that were recently published in the Lighting Research and Technology journal. The studies, funded by the Alliance for Solid-State Illumination Systems and Technologies (ASSIST), will become the basis for future ASSIST recommends guidelines on flicker from SSL systems.

All electric light sources flicker, but the numerous ways in which LEDs can be driven creates the potential for a wide variety of flicker characteristics in SSL systems. These can be perceived directly if the flicker itself is visible, or indirectly through stroboscopic effects similar to the "wagon-wheel effect" where a spinning wheel appears to be moving slowly or be stationary under intermittent light. In early 2010, industry leaders from ASSIST asked the LRC to update the available research literature on perception of light source flicker through human factors studies. Previous research has shown at what frequencies direct flicker is perceptible, but ASSIST leaders expressed interest in identifying thresholds and acceptance levels for indirect perception of flicker and a means of predicting these levels for SSL and conventional light sources.

The studies, led by John Bullough, Ph.D., LRC senior research scientist, were designed to assess responses to flicker, specifically detection, acceptance and comfort. In the first published study, "Effects of flicker characteristics from solid-state lighting on detection, acceptability and comfort," a table lamp in a laboratory was fitted with LED sources to produce different flicker frequencies, modulation depths, duty cycles (duty cycle is defined as the percentage of time a modulating light source is "on"), waveform shapes and correlated color temperatures. Study participants reported whether they detected flicker effects and if so, how acceptable they were. They also rated their visual comfort under each condition.



In the small photo, the ruler is stationary and no stroboscopic effects are seen. In the other photo, multiple images are produced by each flicker cycle as the ruler moves across the scene. Both pictures were taken under a flickering light source (at 120 Hz) with an exposure time of 1/15th of a second

Dr. Bullough and colleagues found that although flicker was not directly visible at frequencies of 100 Hz or higher, indirect stroboscopic effects of flicker were perceptible even at 300 Hz. Lower modulation depths substantially reduced the perception of stroboscopic effects, and a higher duty cycle resulted in somewhat higher rated comfort than a lower duty cycle. Neither the shape of the flicker waveform nor the correlated color temperature of the light affected responses to flicker under the conditions studied.

"The results suggest that there is a tradeoff between the frequency and the modulation depth in the detection and acceptability of indirect flicker effects," said Dr. Bullough. Building on these results, ASSIST and the LRC performed a follow-up study to systematically evaluate this tradeoff and look more closely at the relationship between frequency and percent flicker. A second paper describing this study has been accepted recently for publication.

With the published findings, ASSIST is developing a set of recommendations for manufacturers under its ASSIST recommends publication series, noted Nadarajah Narendran, Ph.D., LRC director of research and ASSIST organizer. "Since 2002, ASSIST's leading industry stakeholders from both LED and traditional lighting have taken an active role in working with the LRC to solve technical and market problems through studies such as this," said Dr. Narendran. "The results of this research by ASSIST can be used to help LED lighting manufacturers in developing systems that minimize the effects of flicker." The recommendations will be made available for download later this year on the ASSIST website (http://www.lrc.rpi.edu/assist).

The first paper, "Effects of flicker characteristics from solid-state lighting on detection, acceptability and comfort," is published in the online early access section of Lighting Research and Technology at http://dx.doi.org/10.1177/1477153511401983. The second paper, "Detection and acceptability of stroboscopic effects from flicker," is forthcoming in the same journal. A project summary for both studies can be accessed at http://www.lrc.rpi.edu/programs/solidstate/assist/flicker.asp. ■

Guangzhou International Lighting Exhibition 2012 was Largest Ever in Show's History

The Guangzhou International Lighting Exhibition, Asia's most influential and comprehensive lighting and LED event, which was held 9 – 12 June at the China Import and Export Fair Complex, Guangzhou, has set new records for exhibitor and visitor attendance.

The 17th edition of the show was held concurrently with Guangzhou Electrical Building Technology which supports the electrical engineering and building and home automation industries and Building Solar China – Conference and Exhibition featuring integrated solar technologies and smart solutions for buildings. The Guangzhou International Lighting Exhibition and Guangzhou Electrical Building Technology were organised by Guangzhou Guangya Messe Frankfurt Co Ltd and Building Solar China – Conference and Exhibition was jointly organised by WIP Wirtschaft und Infrastruktur GmbH & Co Planungs-KG and Messe Frankfurt (HK) Ltd. Together the shows attracted 2,914 exhibitors showcasing their products in 21 halls covering 210,000 sqm.

Visitor numbers increased by ten percent compared to the 2011 shows with the final count being 110,406 from 111 countries and regions.

LED technology continues to be main area of interest Mr. Richard Li, Deputy General Manager of Messe Frankfurt in China said that the Guangzhou International Lighting Exhibition is now firmly established as Asia Pacific's major sourcing, networking and knowledge hub for the LED industry. "This year's record figures leave no doubt that the show has become the number one event for exhibitors and visitors wanting to gain a comprehensive global overview of what's happening in the fast moving LED industry," Mr. Li said. "Supporting the show's reputation is the fact that our exhibitors are major domestic and international players in the increasingly competitive LED market."

Altogether there were 1,900 exhibitors displaying LED products and technologies. For easy sourcing, the LED Asia theme zone was divided into different LED market sectors – retrofit lamps and lighting fixtures, raw material, manufacturing and processing equipment, manufacturing and inspection equipment, substrate and packaging materials; epitaxial wafers; chips and packaging; components and modules as well as drivers and controls.

The Guangzhou International Lighting Exhibition and Guangzhou Electrical Building Technology are part of Messe Frankfurt's architecture and technology shows, headed by the biennial Light+Building event in Frankfurt which will take place from 30 March – 4 April 2014. The next Guangzhou International Lighting Exhibition will be held 9 – 12 June 2013 at the China Import and Export Fair Complex, Guangzhou, China. ■

Guangzhou International Lighting Exhibition figures at a glance:

Total number of visitors	110,406
Local visitors	89,429, an increase of 11% compared to 2011
Overseas visitors	20,977, an increase of 5% compared to 2011
Number of represented countries and regions	111
Top 10 visiting countries and regions (in order of highest attendance)	Hong Kong, Taiwan, India, Korea, USA, Singapore, Japan, Thailand, Australia and Malaysia
Total number of exhibitors	2,653
Number of exhibitor countries and regions represented	27
Total m² (gross)	190,000

LpS 2012 – Strategic Background Behind the Event

Siegfried Luger, Event Director of the LpS 2012, explains the philosophy behind the annual international LED professional Symposium and Exhibition in Bregenz, Austria. He is confident that the strategic dimensions of technology paths is a key factor for doing successful lighting business in the future.

Over the past few years, the lighting sector has been strongly affected by LED technology. Unfortunately, it isn't an easy task for organizations in highly dynamic environments to find the right strategic directions.

Here we are especially talking about the dimensions of the technological orientation. How do we recognize, judge and combine the most diverse technology trends in the most varied disciplines?

In order to help, every year the LED professional Symposium and Exhibition in Bregenz, Austria, summarizes the important success factors in the area of lighting based on the following four strategic pillars: Background Strategies, Engineering Methodologies, Technology Trends and Strategic Partnerships.

In order to be able to understand the strategic approach of the LpS, it would be best to explain the four pillars in a little more detail:

The "Background Strategies" are the overriding drivers of the LED market. Market developments and regulatory factors play a big role here. This year this first pillar is made up of EU regulations, market developments in the industrial environment and implementation tendencies in real projects.

"Remarkable museum architecture calls for equivalently high-quality lighting technology. LED light sources lend themselves to provide for a pleasant and informative visual experience whilst avoiding damage due to light exposure. The lecture discusses lighting strategies design approaches and explains implemented lighting technologies in recently completed museums." Prof. DI Andreas Schulz, CEO LichtKunstLicht AG.

The second LpS 2012 pillar illustrates the "Engineering Methodologies". Technical systems don't change randomly, but rather,

follow clearly defined laws – the so-called Trends of Engineering System Evolution (TESE). This year the specially developed workshop with the title "Working Beyond Competition" is devoted to the topic of patent rights in connection with TESE.

"Successful high technology companies recognize that a comprehensive intellectual property portfolio can be of substantial value. One key component of the intellectual property portfolio is patents. In virtually every situation a patentee's interests are best served if the patentee follows a strategy focused on either circumventing competitive patents, or securing commercially valuable solutions or something else. The workshop concentrates on competitive patent circumvention techniques applying TRIZ, an innovation methodology used by GE, Siemens, Intel, Samsung, LG and other leading companies, worldwide. The approach will also enable the attendees to strengthen their own IP and to use trends of engineering system evolution for developing a "patent firewall" around your own patent." Prof. DDr. Sergei Ikovenko, MIT

The construction of the third pillar, "Technology Trends" is very elaborate and at the same time, challenging. The "Technology Trends" cover the "winning approaches" for luminaires, lamps and modules focusing on new system approaches, new components and the most up-to-date design techniques. The topics were chosen by the LpS 2012 Advisory Board, made up of international LED and lighting experts. They used a comprehensive and objective selection process and analyzed future trends – facilitating successful strategic technology decisions needed to be made by companies the world over.

The LpS will deliver the latest information about state-of-the-art technology and developments within the entire range of topics that Solid State Lighting encompasses. It starts with LED and light conversion technologies in the areas of research and practice, and goes on to optics, driver IC's and driver modules. Other topics that are covered are the corresponding production and material technology aspects, standardization, measurement and reliability. This year there is also one session dedicated to the application area "outdoor lighting". These LED lighting technologies have a big influence on the development of new lighting solutions and are applied in all areas of lighting.

Besides the 26 lectures, this year there will also be three Tech-Panels. These are meant to facilitate the exchange of expert knowledge through discussions with the participating attendees. The topics of this year's Tech-Panels are: OLED, Thermal Management and LED Lamp Technologies.

The fourth pillar stands under the concept of "Strategic Partnerships". It forms a very important network of leading research and industrial partners without whose support the strategic orientations would not be viable. These are the partnerships which, in the end, make new, common projects possible.

The strategic background and aspiration of the LpS is to provide the participants and visitors with the four dimensions of orientation towards "Background Strategies", Engineering Methodologies", "Technology Trends" and "Strategic Partnerships" on a yearly basis and to arm them technologically, help them derive the right conclusions and to establish partnerships in Bregenz.

If something new is to be created, whether it is innovations, new partnerships or new orientation impulses, the framework conditions should not be neglected. The environment is relevant and can be a decisive factor. This is one of the reasons that Bregenz was chosen as the site of the LpS. It was a strategic decision to make a place where many people enjoy their holidays, take pleasure in the arts and relax, the venue for this type of event. No big city. No conference centre. Just an inspiring place on a lake with explosive scenery to round off the strategic objectives of the LpS.

The whole event landscape, especially in the area of LED, has grown immensely, which imposes polar questions on the numerous organizers as well as the participants and exhibitors. The goal of the LpS event is to become the leading LED technology event in Europe using the above mentioned objectives – To EXPERIENCE innovations and strategic new orientations in Bregenz. ■

An LED Solution for Historic Monumental Electric Chandeliers

The Netherlands Institute for War Documentation (NIOD) is housed in a magnificent monumental late 19th century building at the Amsterdam Herengracht (the Netherlands). Recently, the unique brass chandeliers were provided with LED lamps, which were specially developed for this project by Ramselaar Light Solutions. Ron Ramselaar and M. Brouwers, advisor on behalf of the Government Buildings Agency (RGD), tell us about this extraordinary project.

Chandeliers with energy-efficient lamps. Can you imagine this? The Staff of the NIOD can because for years they have been working in a monumental building where the historic chandeliers were actually fitted with energy-efficient lamps (!). Recently this has changed. Although the NIOD is still housed in this beautiful former private house at the Herengracht 380-382 dating from 1890 and which was designed by the architect Gerlof Salm, the energy-efficient lamps have now been replaced by more appropriate lighting. "These low-energy light bulbs in the chandeliers really hurt me", says M. Brouwers, advisor on behalf of the Government Buildings Agency and as such closely involved with the replacement of the lighting in the NIOD building. "One of our jobs involved finding a new solution for the chandeliers. These historic fittings were technically worn but thanks to Ron Ramselaar we have been able to find a wonderful solution."

The Task

Mr. Brouwers has worked for the RGD for years and is specialized in the maintenance of monuments. In his opinion the lighting in this monument urgently needed to be replaced. The fittings no longer complied with the applicable NEN 1010 standard and so there was a need to replace the fittings immediately, but then he faced the question: "now what?" The RGD were not responsible for the lighting of the work areas of the NIOD employees because, contractually, this lighting was the responsibility of the user of the building – who, incidentally, had done an excellent job by using special desk lamps. So the focus was on the general lighting in the corridors, which was solved by using contemporary functional solutions. But because of the historic value of the building, Mr. Brouwers also wanted to retain the wonderful brass chandeliers in the building as lighting elements. So the question was how to do this.

The Challenge

There were several problems that needed to be addressed: the new lighting should capture the atmosphere of 1890 and also require as little maintenance as possible. In 1890, people of course used light bulbs, but today this is no longer possible due to the ban on the use of incandescent bulbs. But even apart from this prohibition, it was not wise to use this technology in this project. Light bulbs tend to fail and some of the chandeliers – especially the suspended ones in the stairwell (15 meters high) - are so difficult to reach that the use of light bulbs was not a realistic option from that point of view either.

The Solution

A specialist in the field of (custom-built) LED lighting, Ron Ramselaar was asked to develop a LED solution for the chandeliers in the NIOD building. He took up the challenge with both hands. Rob van Beek, architect of the Government Buildings Agency, requested if it would be possible to design a lamp equipped with LED technology but with the look and feel of an old-fashioned light bulb. The latter is very important because the lamps in the chandelier are in full sight; to retain the character of the chandeliers it was essential therefore to provide the lamps with a historic look and feel.

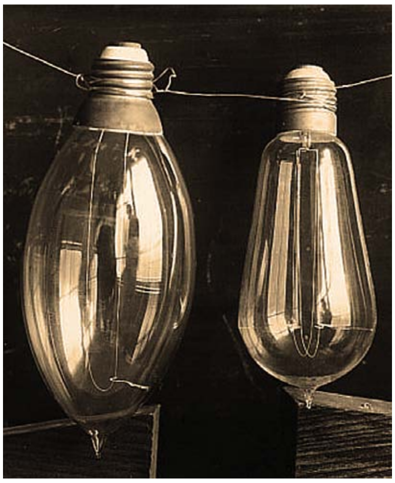


Figure 1: **One of these metal-filament lamps which were invented in 1889 by the Austrian inventor Carl Auer von Welsbach, or a carbon-filament lamp were very likely used at end of the 19th century (Credits © Bildarchiv d. ÖNB, Wien)**

Figure 2: **The simple but ingenious construction of the "bulb" results in a perfect simulation of an "historic" bulb**

Providing the authentic look and feel

The developed product for the NIOD project indeed looks like a light bulb: it is a transparent glass globe provided with a brass socket. Ramselaar assembled and developed the parts himself and had the glass globe made to measure in the Czech Republic. He also developed the electronics, because they had to fit in the selected brass socket. The light is emitted from two LEDs, which are housed back-to-back in the transparent glass globe.

In the first concept, the LEDs were placed horizontally in the bulb, connected with one or two wires to the driver. But that approach did not satisfy the ideas of the architect. Furthermore, at that time no white LEDs with a CCT of about 2.200 K were commercially available, which would have been the preferable color temperature due to the 1890 original light color. Rob Van Beek then suggested to place the LEDs vertically and brought up the idea to place a copper helix around the LEDs By that ingenious and simple measure two problems were solved: The overall design pleased the architect and, thanks to the yellow color of the copper wire, the LED light of 2,700 Kelvin acquires an even warmer quality. Moreover, the reflection of the light on the copper wire offers an even more uniform view of the lamp: even if you look at the two back-to-back LEDs from the side, the light exudes warmth and character. The chosen (multichip) LEDs, which use 0.36 Watts, are oblong in shape, suggesting an actual filament in the transparent glass globe, while the CRI of the used LEDs is 85.

Hiding the electronics

A total of approximately 250 LED solutions were used in the monumental NIOD building. The lamps operate on an external supply of 24 volts. So it is not a retrofit solution; retrofit lamps have the driver/supply in the lamp. In the case of a frosted lamp, this is easy because the supply can be concealed in the globe. But with a transparent glass globe, the electronics could only be housed in the brass socket. Obviously, this does not have enough space for an efficient 24 volt supply, while separating the LED, heatsink and driver or supply also ensures a longer life.

Historic Correctness

Every thinkable effort to make the solution as authentic as possible has been taken. This included a visit to the Electricity Museum in the town of Hoenderloo, where several old still working lamp bulbs can be admired, which allowed to measure the light intensity of original 19th century lamps. The lamps could not be too bright because the dazzle would hide the details of the chandeliers.

It can be assumed that in those days people were accustomed to candle light. The property at Herengracht 380-382 was one of the first buildings with electric light. The light intensity was very likely comparable to candle light. But one does not know that for sure. Strangely enough, relatively little is known about the nineteenth century. For a long time, this period was considered to be less interesting, architecturally. Today, at least the Government Buildings Agency thinks quite differently about this.

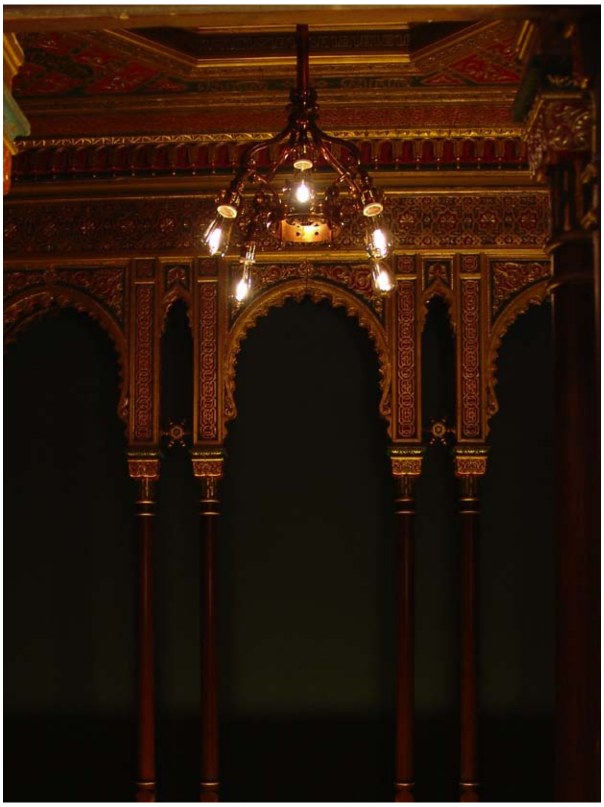
The Result

The special LED solutions in the NIOD building have eventually been provided with a light energy of 40 lux. - It is genuine atmospheric lighting. During a tour of the building it becomes clear what the RGD advisor means by this: the wonderful brass chandeliers in various sizes provide the imposing building with even more historic prestige, yet without the lighting compromising its functionality.

Since the LEDs work on 15 mA only (keeping the case temperature below 40 degrees), while 350 mA is permitted with good cooling, the LEDs easily last the default number of 50,000 burning hours. This means that only minimum maintenance is required. Several tests were conducted that showed that the solution opted for, may also be increased for higher light intensities. Although these tests are not relevant to the NIOD project, a similar solution could also be used in different circumstances.

Outlook

Ramselaar suspects that in the years to come he will often be asked whether there are any clear LED alternatives for the light bulb. Right now, he is busy developing a true-to-life LED alternative for the candle flame, without the flashing by the way.



Figures 3-5:
Equipped with this LED solution a touch of the historic look and feel is coming back to the Herengracht 380-382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Practical Results of a Gas Station Refurbishment with LED Luminaires

Perfect lighting at a gas station is very important for competitiveness. But a conventional lighting system is also a costly and energy demanding installation with high maintenance costs. Stelian Matei from the Electromagnetica SA Semiconductor Lighting Centre shows how a well-planned upgrade of conventional lighting to LED lighting lowers energy consumption and maintenance and, therefore, costs.

Good service is the key to a competitive gas station's selling point, which is simply comprised of the gas pumps in and around the station. The service station sells a combustible product 24 hours a day which makes artificial lighting an integral part of their operation. Safety is the most important aspect, yet designers seem to think that it is only a simple lighting project, and could never be a magnificent work. As if to emphasize energy conservation, then, they replace the traditional gas discharge lamps with LED luminaire tents. They not only have to comply with appropriate standards but their job is also to make customers feel relaxed and comfortable. If they succeed here, customers are bound to frequent this site again or visit the same brand name of gas station somewhere else. This article emphasizes this issue and analyses design aspects.

Introduction

Lately gas stations are showing rapidly changing trends in development, focussing on a number of issues like the different light effects, poor quality, and the visual differences. Specifically, the main differences between lighting at gas stations are in the following areas:

- Poor light efficiency: Most gas stations are still primarily using fluorescent lights, energy saving lamps, mercury vapour lamps, and mercury lamps which results in low luminous efficiency
- Poor quality: Low light flux; short life time, electrical quality compliance leading to frequent changes and some natural phenomenon caused by light
- Poor visual effects: There is too much glare (Figure 1), especially for the visual comfort of drivers that are not buying fuel

The new trends help to improve the poor visual image of gas stations which brings economic benefits. This also leaves competitors at a disadvantage.

Figure 1: **Example of an unpleasant illumination with high glare**

The current LED luminous flux technology has the ability to perform as required for this application. Therefore, the number of gas station lamps doesn't only resolve the flux problem but it also solves the problem of lighting quality.

LED Canopy Lighting

Lukoil and Bioromoil, both from Romania, are among the first companies to unveil their new LED lighting approach. The CIS Electromagnetica LED lighting solution as adopted shows the versatility which LEDs offer for internal as well as external applications. In addition, substantial energy efficient gains were achieved, without compromise to performance. Here we take a closer look at these projects.

The new LED lighting design encompasses the entire site from gas canopy and exterior, right through to inside of the shops and restrooms. The energy savings obtained is approximately 64% across the installation. The sites, as described, are the first in the country that are lit completely with LEDs which is a major breakthrough in filling station lighting. For canopies, the classical 250 W or 400 W metal halide fittings have been replaced with IP65 rated LED luminaires (Dorado 4M) using a high performance LED module (Figure 2).

The highly efficient and low maintenance solution offered makes a significant contribution to keeping lifetime costs down. Of equal importance is that profits achieved through energy efficiency are not made at the expense of good illumination. This is because the levels of illumination are almost the same as those achieved using conventional light sources. One of the projects is a small self-service "AutoMat", 2 pump gas station from BioRomOil. Initially, this site was lit by 6 luminaires containing 250 W metal halide lamps; two mounted on the canopy at a height of 4.5 m which caused a strong glare effect (Figure 1). This was replaced by a linear version (4 LED modules in a line) of the LED luminaire as shown in figure 2. Figure 3 shows the simulation in Dialux and figure 4 shows that the average level of luminance with an LED luminaire is 230 lx.

The illumination level measured with Metal Halide lamps indicates a level just over 200 lx nadir. After replacing them with LEDs the average illuminance level measured was 220 lx. The visual effect can be observed in figure 5. A similar lighting treatment,

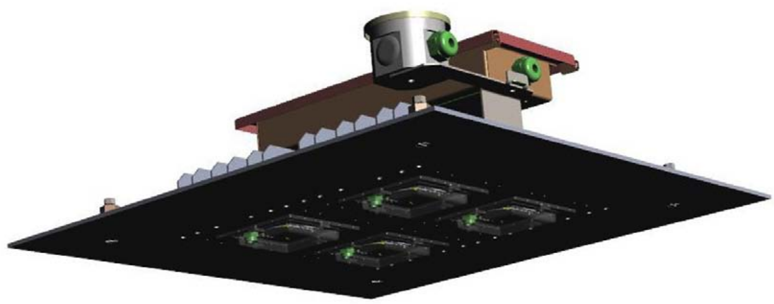
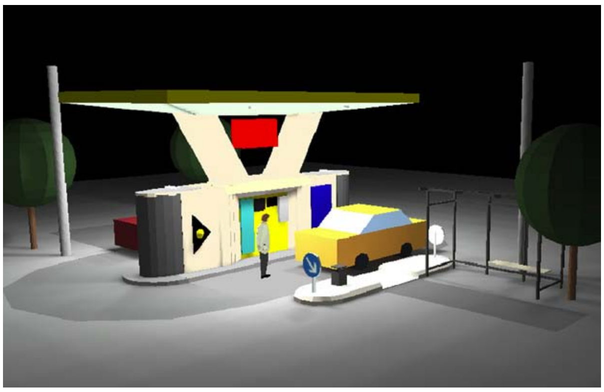


Figure 2: **LED luminaire - Dorado 4M with Luxeon LED**



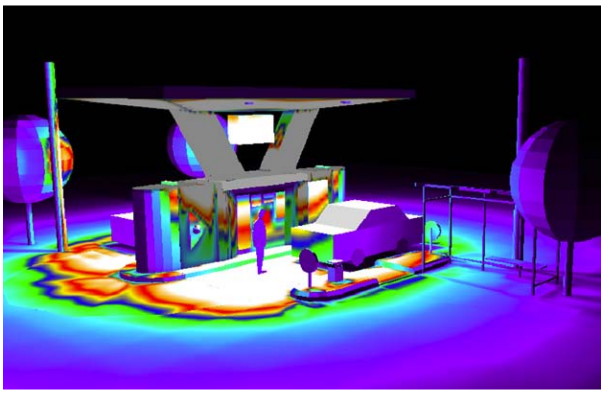


Figure 3 & 4: **"AutoMat", self-service gas station-simulation in Dialux (left). "AutoMat", illuminance level-simulation in Dialux - white equals 250 lx (right)**

Figure 5 & 6: **"AutoMat" gas station before (left) and after (right) installing LEDs**

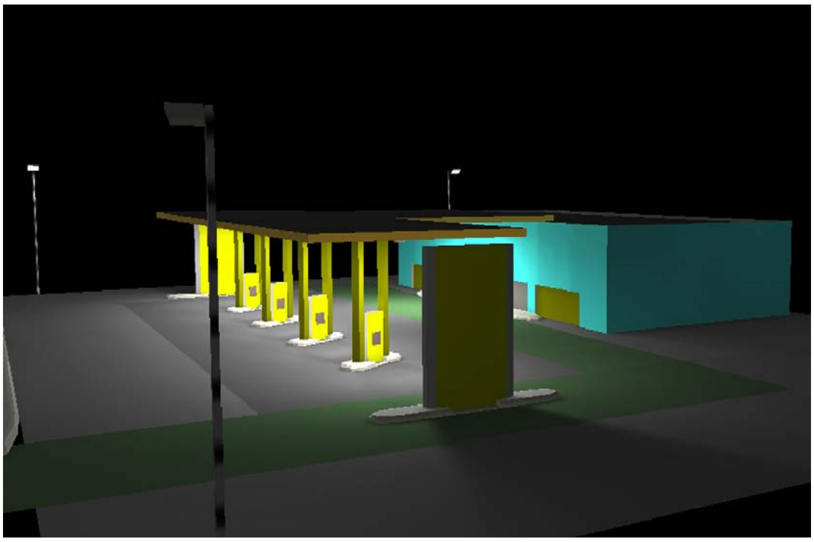


Figure 7:
Lukoil, gas station-simulation in Dialux

this time using symmetric Dorado 4M luminaires, was used for larger gas stations like the Lukoil sites. It should be mentioned here that in both cases (Bioromoil and Lukoil) the electrical installation was not changed except for those sites in which a motion sensor/ dimming system was implemented. At the site mentioned, a simulation in Dialux (Figure 6) was also performed prior to installation, which indicates that the average level of illuminance was 300 lx as shown in figure 7. With traditional light, the level measured was just over 100 lx. The visual effect can also be observed in figure 8. The gas station is lit with traditional lighting on the right side of the picture and with LEDs on the left side.

As can be observed, canopy lighting is a key feature in gas stations due to the sales of gas and other flammable material goods in this region. The goal is to acquire high brightness, have glare and shadow control and guide the driver easily over to the gas pumps in order to improve security. Unfortunately, many gas stations have lighting that glares because most of them use metal halide lamp's as a light emitting source.

The metal halide lighting glare caused by direct exposure to the location makes it necessary for the drivers making a pit stop to adapt their vision

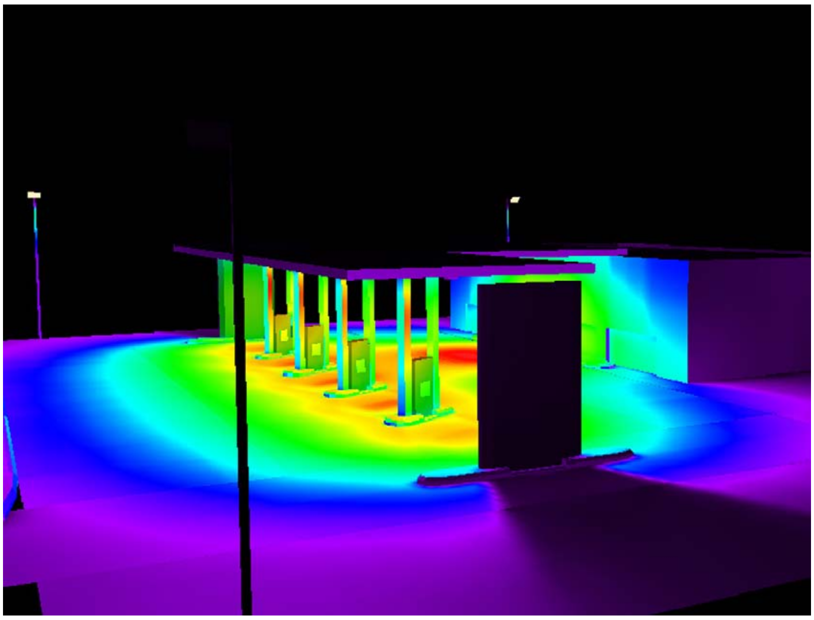


Figure 8:
Lukoil, gas station-illumination level (red 300 lx)

Figure 9:
Lukoil LED installation

quickly. The same problem may be encountered with LEDs if the light is not diffused. Once diffused, it will reduce risk and increase visual comfort. All LED luminaires as described above, use micro-lens light diffusers with a low grade of absorption below 20%.

Energy Saving

The emphasis of energy conservation is not just simply replacing the traditional discharge lamps with LEDs. Energy conservation is necessary but a lot depends on the location of the gas station. There is a difference if the gas station is in the city or on the highway. Because the cars drive fast on highways, drivers should be able to see the gas station's lights from a long distance away, especially in winter or when it is foggy. Current LED luminous flux technology has the fundamental ability to penetrate these elements as needed. Therefore, the problem of lighting quality does not depend on the number of lamps alone.

Compared with LEDs, metal halide electricity consumption as well as the speed of light output degradation is very high. Gas station lighting consists of gas station signage, refuelling area lighting, exit lighting square and the convenience store. In the table below the inventory of the traditional luminaire as used in a Lukoil gas station and the corresponding power consumption has been listed.

Listening to the needs of a gas station operation, the new LED lighting design encompasses the entire site from gas pump canopy right through to the shopping and coffee bar area.

Total installed power for traditional lighting was 6,680 W yet only 2,403 W when replaced with LEDs. This is almost 36% of traditional lighting energy consumption or, in other words, a 65% energy saving.

Conclusion

Gas station lighting has a direct impact on the staff's efficiency and physical health. In addition, gas filling stations are an important part of landscaping. With the requirements of modern cities it is not enough for gas stations to only meet lighting needs. Lukoil and Bioromoil is the first location to unveil their new LED lighting approach. The LED lighting solution adopted by them shows the versatility that LEDs offer for internal and external applications. Over and above that, it has allowed these companies to make substantial energy efficient gains without compromising performance. ■

Table 1: **Original traditional lighting products and power consumption**

Componet List				
No.	Qty	Type	Power consumption	Total Power
1	17	ELBA FIA-11-236	84 W	1428 W
2	5	ELBA FIA-11-218	34 W	420 W
3	22	ELBA FIA-11-518	84 W	1848 W
4	8	ELBA PREMIUM LUX I-250W HST	284 W	2272 W
6	6	ELBA-FIR-118	21 W	168 W
7	4	ELBA PREMIUM 125W	136 W	544 W
		Total	6680 W	
		Monthly energy consumption for a 100% utilization factor	4809.6 kWh	

Table 2: **New installed LED lighting products and power consumption**

LED Component List				
No.	Qty	Type	Power consumption	Total Power
1	39	ARIES 6 module	34 W	1376 W
2	5	NORMA 2 module	17 W	85 W
3	8	ELM 80-90	98 W	784 W
4	4	NORMA 80-30	35 W	140 W
5	6	ARIES M230	3 W	18 W
		Total	2403 W	
		Monthly energy consumption for a 100% utilization factor	1730.16 kWh	

Development Process for a Metal-Halide Replacement LED Module

Seen for the first time at this year's Light + Building, the TECOH® MHx, has provided specifiers and designers with a viable LED metal halide alternative. Talking about the issues surrounding such a development, Fred Bass, Managing Director of Neonlite International Ltd., the brand owner of MEGAMAN, shows how the module series has been developed and highlights its potential for metal halide replacement moving forward.

The pace of product development in LED lamp technology makes the sector exciting, yet also challenging for fixture manufacturers and designers alike. Already we can see that LED semi-retrofit and replaceable lamps will soon become as commonplace as traditional light sources.

In the professional specification sector, LED lamp alternatives are now commonly used for general lighting solutions with excellent results in terms of color characteristics, longevity and energy efficiency. Thanks to the company's unique approach of using axial mounted arrays, LED sources are able to imitate the point sources of tungsten halogen in reflector lamps. This provides the professional lighting sector with the intense beams and glare control of a halogen light source, but with the benefits conveyed by using low energy, accent lighting. The pace of change is so rapid that LED halogen equivalents can now perfectly match the light output of halogen reflectors up to 75W.

The challenge now is to move into metal halide territory of 20 W, 35 W and larger and create viable LED alternatives. This has had its challenges for LED light source manufacturers, as most metal halide solutions of this size do not use integral reflectors and have higher lumen packages. In addition, LED equivalents require careful thermal management. A successful LED replacement needs to outperform existing metal halide solutions in terms of longevity and light quality, be available in a range of color temperatures and needs to be of a similar size and shape to fit in existing and newly designed luminaires. Hence a sustainable, flexible LED alternative requires a range of technical challenges to be overcome.

The solution has come in the form of the TECOH® MHx module which provides designers with a practical alternative to metal halide capsules, with a similar sized unit. Creating a replacement metal halide solution is not without its challenges. The main hurdles that had to be overcome are:

- Creating a unique format, tubular shape with axial placed LED light emitting unit
- Boosting the output to higher lumen packages while dissipating the heat effectively
- Complying to SELV requirement when using 2 LED arrays in series
- Offering a sustainable solution where the unit can be upgraded, exchanged when required while ensuring good thermal management

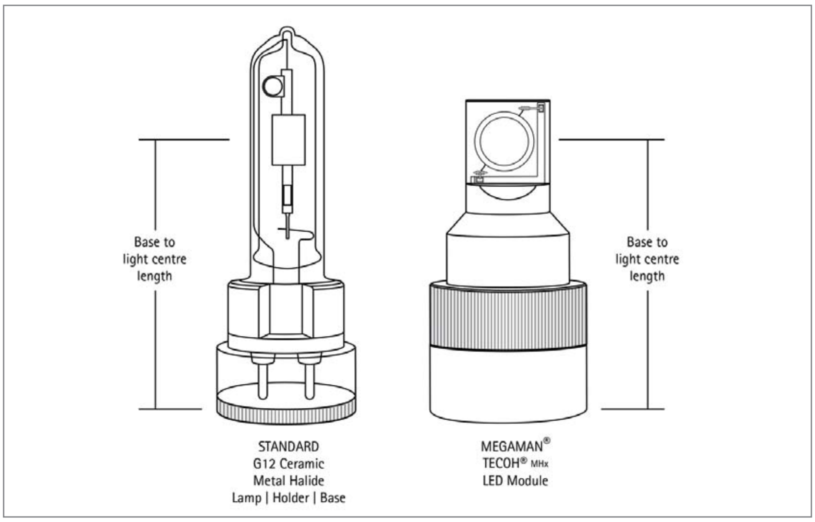


Figure 1: **Base to light centre of TECOH® MHx module similar to mounting surface to light centre of ceramic metal halide lamps**

The Approach

The principle behind the module is a "capsule" with 2 LED arrays axially mounted on a highly conductive metal substrate. Over the years, traditional lamps have proved that axially positioned light sources, combined with parabolic reflectors offer the most efficient method for directing light and optimizing the use of the lumen output. Through testing, the best light distribution for the MHx module was obtained when two LED arrays were placed back to back on a vertical construction, the so called 'capsule'.

The TECOH® MHx module is in essence an evolution of the company's AR111. The development team took the thermal conductive highway of the AR111 and the back to back chip mounting on the lamp's bridge and, after stripping away the AR111 reflector, sought to use these technologies as a basis on which to create a viable LED module.

During the development process, two 18 W LED arrays were placed in series. However this posed electrical challenges on top of the thermal management issues as the initial prototypes had a voltage Vf of 72 V (due to long term safety requirements for SELV, the maximum voltage for VDE certification is set at 60 V). With this in mind, a redesign of the array was required and optimization of both the module and driver were carried out to fulfill the SELV criteria.

Solving the Heat Dissipation Challenge

The major challenge during the product development of the module was to provide lumen packages to compete with ceramic metal halide, whilst ensuring sufficient heat was drained from the LED array in order to provide long life and high performance. After extracting the thermal conductive highway and back to back chip placement from the AR111, the product development team had to redevelop the lamp's thermal interface to accommodate the reduced dimensions of the LED module.

Although the module's product design was based on the company's patented Thermal Conductive Highway™ (TCH) Technology, which has proven its robust effectiveness in the company's reflector lamp series, a range of metals had to be tested to find the correct combination for the ultimate in heat dissipation for this specific construction.

Table 1: **Thermal conductivity for different materials**

Material	Thermal Conductivity (W/mK)
Iron	79.5
Aluminum (extruded)	140-200
Aluminum (die cast)	60-120
Copper	385
Air (@25°C)	0.024

A combination of metals was tested for the heat bridge, including a copper core with aluminum layers, to achieve the correct temperature distribution. The final module design uses a 'heat drain' across a highly conductive metal substrate, together with a unique combination of materials to dissipate the heat efficiently.

Throughout its product development it was decided to design the module as a 2-part, socketable solution for interchangeability reasons. However this poses another challenge as the thermal conductivity of such additional interfaces needs to be maximized in order reduce its impact on the heat drain from the LED arrays. With this in mind, the thermal conductivity between the base and capsule has been optimized by the use of a highly conductive Thermal Interface Material (TIM).

The heat finally needs to be dissipated away from the base. A heat sink which optimizes this dissipation and secures compliance with the maximum temperature requirements will ensure an excellent lumen maintenance and product life within the fixture. The TECOH® MHx has a long lamp life (L70) of up to 40,000 hours. This is more than double that of the most efficient ceramic metal halide lamps, which have maximum average lifespans of up to 20,000 hours.

In practice, when taking into account the installed luminous flux (survival rate x lumen maintenance) for the installation, the usable life span (when the overall light output has dropped 30%) for ceramic metal halide lamps becomes less than 2 years (3000 hrs/year), since other than the lumen drop of the individual products, a percentage of failures must also be taken into account. In comparison to this, the useful lifespan of the TECOH® MHx is expanded to 10 years.

AR111 lamps and the Thermal Conductive Highway™ technology

The patented Thermal Conductive Highway™ technology uses a unique design of 'heat drain' across the reflector to dissipate heat efficiently and prevent deterioration of the LED and other components. The technology also gives the lamps a longer life with lumen maintenance, resulting in 70% of initial lumens being available even at the end of the lamp life. Thanks to careful thermal

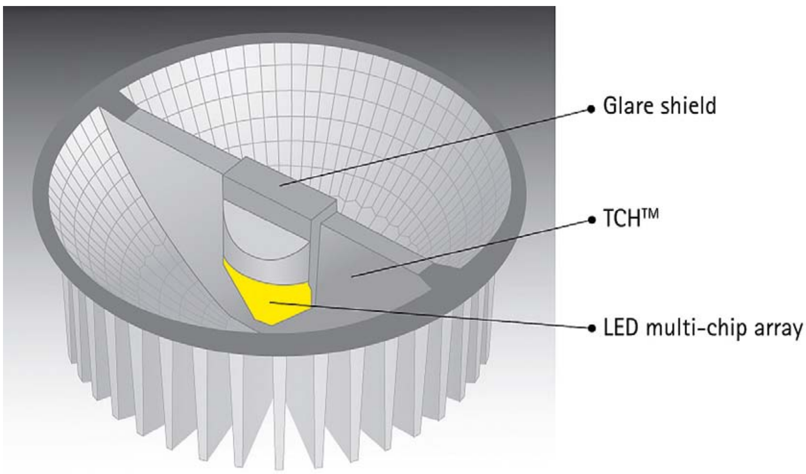


Figure 2: **The unique geometry allowing optimum thermal control with the TCH technology**

management, these LED's combine the higher efficiency, lifetime, and reliability benefits of LEDs, with the light output levels of many conventional light sources.

With the first AR111 LED reflector solutions the goal was to replace halogen and still achieve good quality accent lighting with a sustainable solution using LED for 80% energy saving and long life.

The technical challenge came from the need to use LED to approximate the axially mounted conventional incandescent tungsten halogen filaments. Sources mounted in this way allow the light to be controlled much more effectively by a parabolic reflector. Most of the light is then directed by the reflector minimizing uncontrolled direct light which leads to uncomfortable glare and poor beam quality. Thermal management of the resulting back to back LED arrays is extremely difficult but the breakthrough was the thermal conductive highway which provides a heat drain of sufficient capacity while still allowing the arrays to be close enough to approximate a point source. With the AR111 reflector lamp the heat sink is so efficient that the temperature difference between the centre of the bridge and the edges is only 5°C. The good approximation to a point source is demonstrated by the ability within the 111 mm footprint to produce intense beams as narrow as 8° with up to 20,000 cd, a power consumption of only 15 W and little stray light.

With this problem solved the move to separate the reflector from the source was a logical next step allowing the fixture maker to use their own expertise in reflector design and for the company to provide the first alternatives to metal halide capsules.

Table 2:
TECOH® series electrical characteristics and general data

Electrical data	
Wattage	36 W
System Wattage	41 W[1)]
Current	700 mA
Voltage	DC 48 V
General data	
Operating Temp.	-30°C to +40°C
Life - L70	40,000 hours with 70% lumen maintenance

[1)] **Data dependent on driver choice**

Addressing Light Quality over Lifetime

The secret to maximising light output and lumen maintenance lies in sound thermal management. As can be seen with the company's patented TCH technology, the efficient dissipation of heat has led to significant lumen maintenance over the module's considerable lamp life. However, the question of color consistency is always a key focus for end users and designers alike.

The key to creating an LED lighting scheme that looks good for years to come is in ensuring that, over their lifespan, all of the lamps are performing within an acceptable tolerance in terms of color deviation. The modules have high color uniformity, with a consistency of < 3 SDCM (Standard Deviation of Color Matching) initially and < 5 SDCM throughout the lamp's rated life. This high level of color consistency is thanks to the control of the phosphor/LED blend and the lamp's optimized control.

The color consistency of the module is superior to existing metal halide lamps, whose colour characteristics tend to change during their life (color and output of metal halide lamps is specified after the lamp has burned for 100 hours or 'seasoned', according to ANSI standards). This is even compared to newer metal halide lamps, which encompass a technology referred to as "Elite, Superia or Ultra", which have improved color rendering and more controlled kelvin variance of ±100 to 200 kelvins.

Thanks to the MHx modules excellent lumen maintenance and stable color, individual product replacements become feasible whereas with ceramic metal halide, individual replacements lead to different colors and intensity

Figure 3:
Color consistency

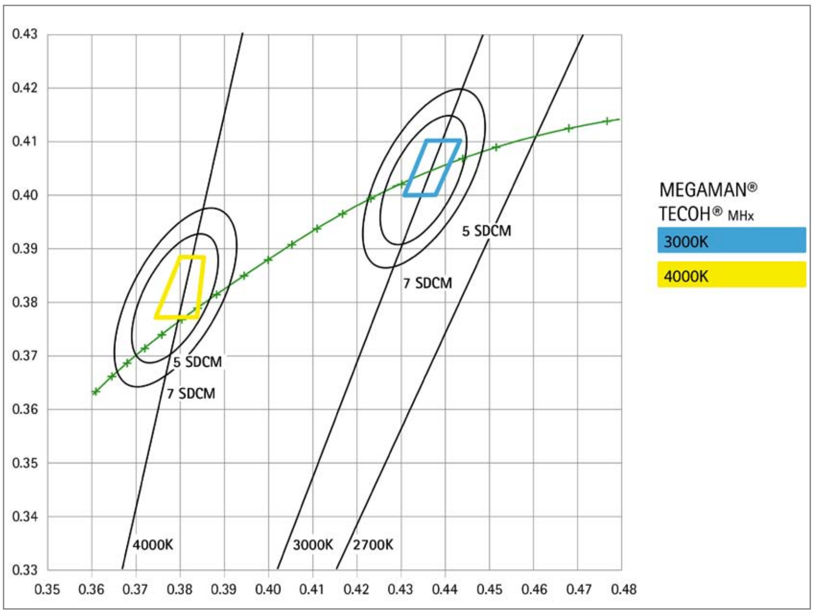


Table 3:
Photometrical characteristics

Photometrical data				
	MH0133/830-700mA	M 0133/840-700mA	MH0133R9/930-700mA	MH0133R9/940-700mA
Colour Temperature	3000K	4000K	3000K_R9	4000K_R9
Lumen Output	3000lm	3300lm	2460lm	2700lm
Efficacy Capsule	83 lm/W	92 lm/W	68 lm/W	75 lm/W
System	73 lm/W	80 lm/W	60 lm/W	66 lm/W
Color Consistency Initial Over life	< 3 SDCM < 5 SDCM	< 3 SDCM < 5 SDCM	< 3 SDCM < 5 SDCM	< 3 SDCM < 5 SDCM
CRI	82	85	92	92

impressions, resulting in unbalanced lighting. To avoid this, only group replacements are advised with metal halide products.

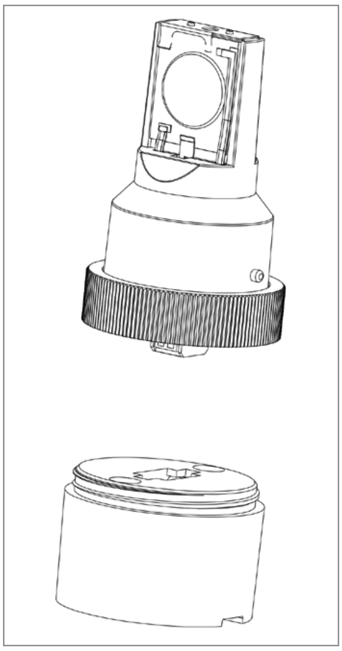


Figure 4: The TECHO® MHx modules allows for interchangeability

Provide Flexibility with Interchangeability

One of the primary aims when creating the module was interchangeability (for serviceability) to promote a more sustainable future for LED lamps and fixtures.

The 2-part base and head design of the module ensures that its head can be replaced when it comes to the end of its life or earlier if an upgrade is wanted for a more up-to-date version. This interchangeable design therefore offers intrinsically a more sustainable approach when compared to dedicated solutions.

The interchangeability of the module design allows for the late addition of the light source into the fixture and the desired color temperature to be put in as required for the specific application.

Next to the common 3000 K and 4000 K color options, the module is also offered in R9 technology. The R9 series is optimized for food illumination as it maximizes the visual impact of meat, fruit and vegetables by increasing the product's red rendition. The R9 modules not only have a high red color rendition value R9 of >75 (compared to the even for this application specially designed ceramic metal halide lamps having R9 values below 60), but also have high values for regular CRI and other 'saturated' colours R10 to R14.

Conclusion

The TECOH® MHx is the first LED solution that directly competes with ceramic metal halide lamps. With no UV and low maintenance costs, its better color characteristics, superb lumen maintenance throughout life, instant start/hot re-strike and dimming capabilities, the module's design brings the future of LED lamp technology to the high power accent lighting market. ■

LED Market and Development Trends from the Point of View of a Full-Range Trader in Lighting

In an interview with LED professional, Ms. Beate Jungwirth, Director of Marketing & Communications and PR at Everlight and Dr. Christopher Keusch, Senior Sales Manager at Everlight, talk about the market and development trends in the area of LEDs. The experts also discuss Everlight's focus at the LED professional Symposium +Expo 2012 which takes place in Bregenz, Austria from September 25th to 27th.

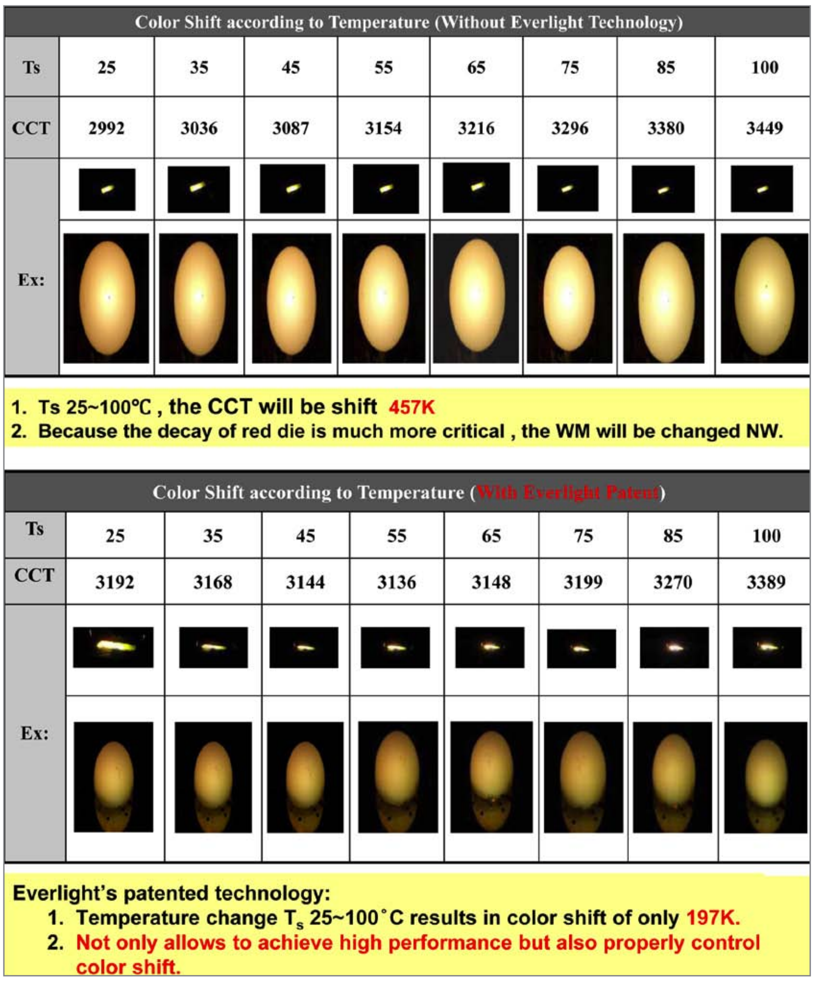


Figure 1: **Everlight's proprietary technology reduces the temperature dependent color shift of high CRI white array LEDs that use phosphor converted white LEDs combined with red LEDs. The max. color shift over temperature is 200 K within a T_s temperature range from 25°C to 100°C**

LED professional: Costs are still a deciding factor when it comes to market acceptance. How do you assess cost trends in the component business?

Everlight: The newest market trend in general lighting moves in the direction of a higher cost pressure for LED lamps. In connection with this is the appeal from lamp manufacturers for a cost reduction of LED components in order to meet the requirements for the cost pressure for the end product. As a consequence this will create greater market acceptance from the consumer.

The so-called mid-power LEDs with wattages between 0.4 W and 0.5 W are an inexpensive design between low power LEDs (0.06 W to 0.2 W) on the one side and high power LEDs and Chip-on-Board LEDs (COBs) on the other. They make the cost reduction trend possible in relation to a future-proof lamp design. The origin of the mid power LEDs is the backlighting applications for flat screens.

LED professional: Can you give us some examples of the main application areas for mid-power LEDs?

Everlight: Mid-power LEDs can be implemented very well in all non-directional retrofit solutions. They are predestined for linear LED applications. Traditional low-power LEDs with low wattage of up to 0.1 W and a power consumption of 20 mA are being used for tube light and strip light applications in order to recreate established fluorescent lamps with the required luminous flux and the desired homogeneous light emission. Tube light manufacturers are now looking for PLCC solutions in the mid-power segment with higher brightness and wattage. There are two reasons for this: First of all, requirements in regards to the brightness of the light source are generally increasing but the existing PCB layout and the mechanical dimensions of the semiconductor cannot be changed. Secondly, the number of LED components per tube light should be reduced while keeping a minimal light flux.

LED professional: Bulb replacement products still have the largest sales figures. What do you think about the market numbers and what are the arguments that speak for mid-power solutions?

Everlight: In 2013 there are supposed to be an estimated 257 million so-called A bulbs (LED-light bulb replacements) sold. With the continuous cost pressure, manufacturers of omni-directional (spherical beam) lamps also have the choice of replacing the high power LEDs with wattages of 1 W or more as well as COBs with the much cheaper mid power LEDs. These provide an excellent balance of luminous flux, power consumption and package dimensions. When assembled suitably on the PCB, optimal light distribution, light intensity and power dissipation is achieved.

LED professional: Cost pressure seems to be everywhere. From your point of view, what specific market and technology trends should be looked at right now?

Everlight: We see the main emphasis on PLCC LEDs with a high CRI value of >85 in the warm white color temperature area. This is a subject that is especially significant in Europe when it comes to interior lighting and has become even more important than efficiency!

LED professional: Everlight has developed a new system for color stabilization which you are planning to present at the LpS 2012. Could you explain the concept to us in a little more detail?

Everlight: The high efficiency COBs based on MCPCB have an intelligent color temperature stabilizer of absolute 200K over a wide temperature range of 25°C to 100°C (the so-called hot-cold factor). At the same time, underneath the phosphor layer, in addition to the blue LEDs, red LEDs have been inserted. Their emissions are regulated by temperature dependant resistors. This method provides for high color temperature stability of <200 K over a wide solder point temperature range of 25°C to 100°C. This temperature stabilization increases the color spectrum in the red range with a high CRI value of >80 is ensured.

LED professional: What deviations occur in LED systems without this compensation?

Everlight: The measurements with standard systems without color compensation have shown a deviation of the color temperature, the CCT, of about 450K over the same temperature range. The color changes in the direction of higher color temperature; from warm white to neutral white.

LED professional: Was the system comparison carried out on the basis of combined blue and red LEDs? There are also other methods where the red spectrum can be increased, like a 3-band phosphor. It would also be interesting to hear what influence the solution has on the CRI.

Everlight: The CRI value is more than 80 whereby the R9 value often shows the more important factor. The combination with a red LED offers a high R9 value and also yields a good balance between efficiency, CCT stability and the R9 value.

LED professional: What new products will Everlight be showing at the LpS 2012?

Everlight: In order to meet the requirements of the increasing demand for higher brightness and a wider range of PLCC housings, Everlight is going to present a large spectrum of new housing designs and wattages in the low and mid power segment in Bregenz. In Q3 and Q4 of 2012, the new products with the popular color temperature of 3000 K to 5700 K are going to go into

Beate Jungwirth

Ms. Jungwirth is director of marketing communications and PR. She joined Everlight Electronics in 2009 where she worked in their headquarters in Taiwan. She is now stationed in Germany.

Dr. Christopher Keusch

Dr. Keusch joined Everlight Electronics Europe GmbH in December 2010 as a Senior Technical Sales Manager EMEA. Before that he worked for Europe's leading photonics distributor, Laser 2000 GmbH.

mass production. The color temperature spectrum will then be gradually expanded to the entire ANSI range of from 2700 K to 6500 K.

The LEDs in the new 3020S series have a lower thermal resistance of only 50 K/W compared to the 3020 standard package and are therefore optimal for higher power applications. This version delivers a luminous flux of 9 lm to 14 lm (depending on the color temperature) at 30 mA and is especially suitable for light strips and panels. The 60 mA version, on the other hand, delivers a luminous flux of 15 lm to 27 lm and is also suitable for omni-directional or decorative lamps. The compact design of the 3020S allows for high packing density and small PCB measurements.

The same applies to the analog for the LEDs in the new 2323 series with a luminous flux of 45 lm to 52 lm.

LED professional: Everlight recently put the Shwo D series as a high power LED on the market. What developments have there been in the high power area?

Everlight: Everlight is going to present the new High Power LED from the Shwo D series on a ceramic substrate at 1 W at 350 mA with the popular dimensions of 3.5 x 3.5 mm in Bregenz. It is already in mass production with the color temperatures of 3000 K, 4000 K as well as 5700 K. Additional color temperatures in the ANSI range from 2700 K to 6500 K are going to be gradually added. Depending on the color temperature, the luminous flux ranges between 80 lm to 110 lm.

Typical applications for our high power Shwo D series are general industrial and commercial lighting, directional lamps (MR16, GU10, PAR) as well as spot lights.

LED professional: Do you offer products on a COB basis in this segment?

Everlight: Everlight presented the Chip-on-Board LEDs in the Ju series in May, 2012. They are based on a ceramic substrate with low thermal resistance from <1.8K/W. They have a power of 3.7 W and a luminous flux of up to 400 lm at color temperatures of 3000 K to 5700 K. With a CRI value of >80 and at the same time a higher efficiency of >100 lm/W, their overall performance is excellent. Additional 15 – 20W versions are being prepared for Q3/2012.

The COBs from the Ju series can (like all other COBs) be placed directly onto the heatsink using thermal conductive films without the SMT-process. This provides optimal heat dissipation, simple installation and reduced system costs. The COB Ju series provides a perfect light source for direct and decorative lighting for retrofits like MR16, GU10 or candle lamps.

Above all that, in Q4/2012 additional high performance COBs with performances of up to 40 W based on MCPCB will be presented. Like the versions from the ELCOB series that are already available, the 6.4 W and 8 W be equipped with color temperature stabilizers.

LED professional: Thank you for the interview.

Everlight: Thank you!

Energy Efficiency and Thermal Simulations of a Retrofit LED Light Bulb

Mika Maaspuro and Aulis Tuominen from the University of Turku investigated the energy efficiency of a LED driver mounted inside a retrofit light. The heat generation of the LEDs and the driver of the light bulb have been simulated and measured. A thermal model for the light bulb has been created and simulated using a Finite-Element-Method (FEM) software. Parameters of the model have been adjusted to match the temperature measurements which have been done with IR-camera and thermocouples.

Thermal management has a great influence on the reliability and on the life span of an LED light. The operational life of a LED light does not normally end suddenly but most likely the LED light encounters a steady reduction of light production at the end of its useful life span. Major decrease in light generation during theexpected normal lifetime of an LED is most likely caused by too high LED chip temperatures. This is a consequence of either failed thermal design or wrongly chosen ambient conditions of the light.

LEDs are not the only parts generating heat in LED lights. Some parts of the driver can reach high temperatures. Cooling them might not be as important as LEDs, but it makes sense to include these in the complete thermal model of an LED light.

There are numerous software tools for thermal and fluid dynamics simulations: ANSYS-CFX, Comsol Multiphysics, CoventorWare, FLUENT, STAR-CD, FEATFLOW (open-source) - just to name a few of them. Some of them solve complex fluid dynamics problems and some of them are FEM tools intended for solving various kinds of physical problems. In this study Comsol Multiphysics software and Heat Transfer Module were used. Comsol Multiphysics is a widely used FEM tool in universities and other educational institutes.

Thermal simulations can be an alternative to prototype building or to theoretical studies. Theoretical studies are normally limited to very simple structures and only for specific conditions. Theory of fluid dynamics is extremely complicated and design procedure to be used even for the simplest heatsinks become rather complicated. In general, the choices are either making simulations or building prototypes.

Simulations have some advantages when compared to prototyping.. Experimental methods can be too expensive or even impossible to make. Simulations can be used to discover the problematic parts in heat transfer from the LEDs or from the driver to ambient. Simulations make it possible optimize heat sink size, form and its material. Normally thermal interface materials are used to improve thermal conduction between adjacent components. Understanding of heat conduction, convection and radiation in the LED light can be expanded by simulations.

Thermal Model of the LED Lamp

The LED light bulb studied in this work is a commercial LED light rated at 9 W (110 VAC) or 10 W (220 VAC). The light bulb is rather large and heavy. Mass is 330 g, diameter 85 mm and length 160 mm. IP class is 30. Input voltage is specified for range 90 – 240 VAC. Color temperature 5700 K / 2850 K. Base type is E26/27. Light beam is 120°, and flux 570 lm. The number of LEDs is 14 and they do not have any lenses or diffusers directly above them. A shading dome covers all the LEDs.

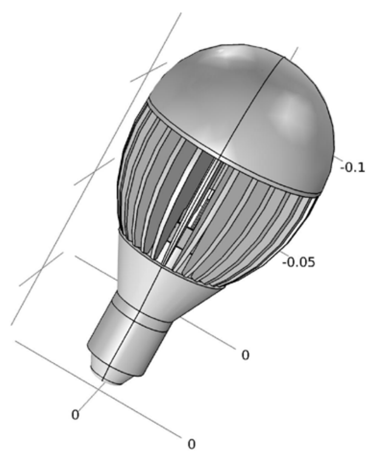


Figure 1: **The CAD model of the retrofit LED light bulb**

The 14 LED packages are on the thick (2 mm) aluminum MCPCB substrate plate. A thin insulator separates the conductive substrate and the copper layer. The aluminum substrate is

Figure 2:
The CAD model of the surface mounted LED

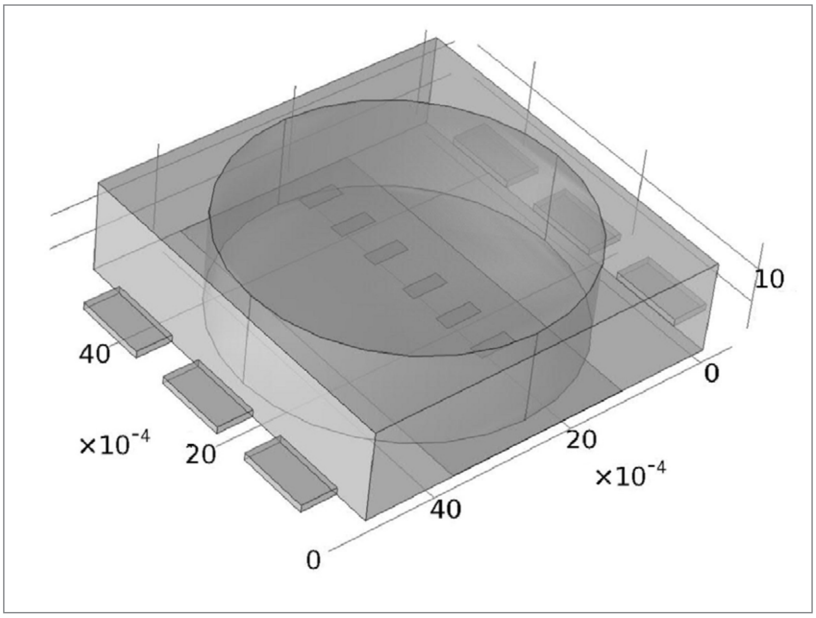


Figure 3:
The CAD model of the driver

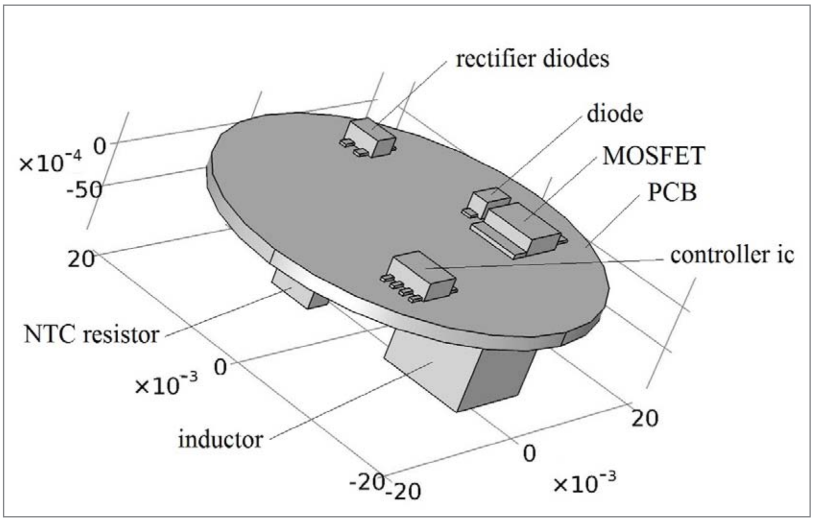
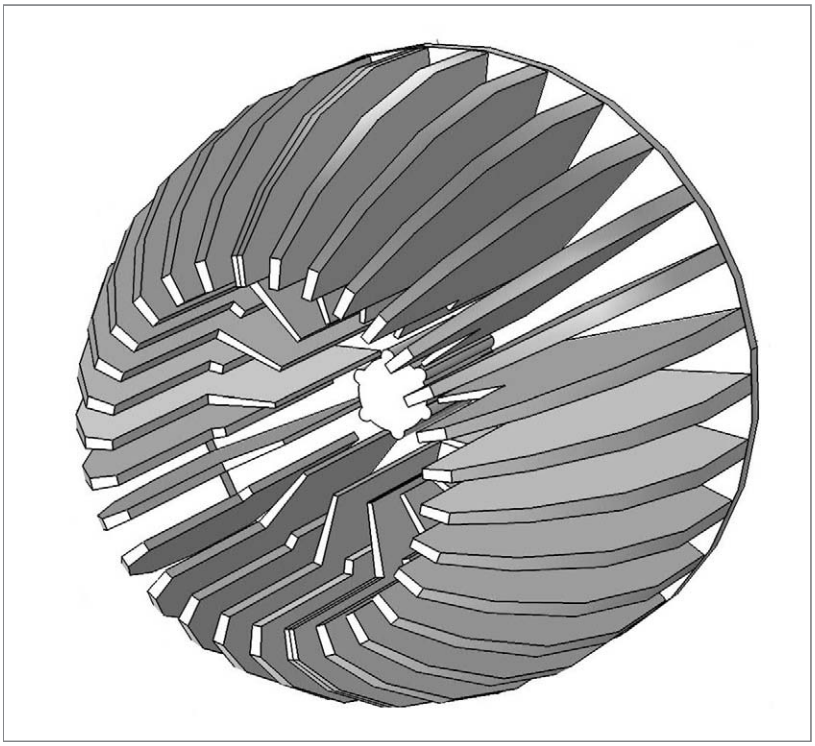


Figure 4:
The CAD model of the heatsink



mounted on the heatsink by using a thin layer of thermal grease between them. A polycarbonate dome covers the LED substrate plate. The driver is mounted inside the light base. Space around the driver is filled with thermal interface material. The same material is used to cover components mounted on top of the driver board.

The thermal resistance of the LED package can be found in a datasheet of the specific device. The FEM software uses a thermal conduction coefficient and this must be calculated from the thermal resistance. There is a following relationship between the thermal conduction and the thermal conduction coefficient.

$$R_{th} = \frac{\Delta T}{P_d} = \frac{d}{kA} \qquad (1)$$

ΔT = temperature difference between LED chip and the surface closest the LED package [K]
d = distance between LED chip and the surface closest the LED package [m]
A = area through the heat is transferred [m²]
k = thermal conduction coefficient [W/(m·K)]

If k is calculated using only the area of the thermal pad, it becomes underestimated. Some amount of heat is also transferred through other surfaces. In order to find the correct value for k a thermal simulation was carried out for a case of single LED mounted on an efficient thermal sink. Value k was varied until the simulated temperature difference equalled the value calculated by using the thermal resistance. For the LED used in this light bulb R_{th} is 15°C/W. In the simulations the thermal conduction coefficient k for the LED package becomes 4.45 W/(m·K).

The used surface mounted LED has a package size of approximately 2.5 x 2.5 x 1.3 mm. The component has six LEDs to be connected externally in parallel. Heat sources have been modeled as surface heats sources inside the package.

Table 1: **Material properties used for LED lamp simulations**

Material	Details	Density rho [kg/m³]	Thermal conductivity, k [W/m*K]	Specific heat Cp [J/kg*K]	Ref.
Aluminum		2699	237	900	
Aluminum casted		2640-2840	117-222	850-960	5
	alloy 6061	2700	180	896	
Copper		8960	401	385	
Solder	60Sn-40Pb	9000	50	150	3
Epoxy		1600-2000	0.495	970	
Polycarbonate		1100-1220	0.19-0.22	1200-1300	
ABS		1060-1080	0.17-0.188	1260-1675	
Printed circuit board	FR4	1900	0.3	1369	
Thermal interface material	silicone gel	2810	2.1	705	10
Thermal interface material	silicone grease	2810	4	705	9
Insulator of the MCPCB		1420	0.12	1090	
Air		1.176	0.026	101	

The main heat sources in the LED driver are the MOSFET, the freewheeling diode, the rectifier, the controller IC, the NTC resistor (used as a surge current limiter) and the inductor. Heat sources have been modeled either from surface sources inside a component package or volume sources.

The rather large and heavy heatsink has a form which is more spherical than conical. The size of every second fin has been reduced in order to give more airspace for heat flow from the center to out of the heatsink. In spite of this the center becomes the hottest point of the heatsink.

The CAD model differs from the real lamp in two details. In the real lamp, the heatsink fins are slightly curved to increase the surface area. In the model, the fins are straight ones. This limitation comes from the difficulty of generating such curved fins with the CAD tool. In the real lamp, the driver parts are surrounded with the thermal silicon. In the CAD model some parts of the driver are not entirely surrounded with the thermal silicon. This limitation comes from the difficulties of producing a mesh for such a structure. On the other hand, the CAD model is accurate enough in structural details.

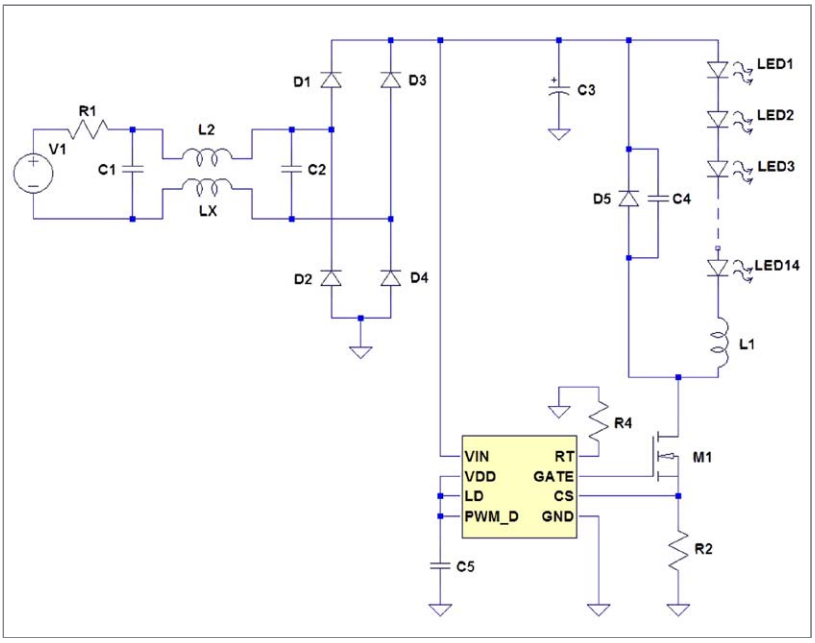


Figure 5: **The 10 W LED driver and the load of 14 LEDs**

Material Properties

A complete thermal model includes mechanical properties and material parameters. Material parameters need to be found in various sources. There can be some difference in parameters according to which reference is used. Especially properties of plastics can differ significantly depending on the exact concentrations of substances.

The dome of the light bulb is assumed to be polycarbonate plastics. The heatsink is cast aluminum alloy. One of the common materials used in heatsinks is alloy 6061 which is aluminum-magnesium-silicon alloy. The base of the light bulb is assumed to be ABS plastics, a common choice for LED light bulbs. The driver is mounted inside the base of the lamp. The remaining space is filled with thermally conductive gel. The gel should have suitable viscosity during LED lamp assembly. Afterwards it should feature high thermal conductivity, high volume resistivity, high dielectric strength, long term chemical stability and non-flammability. The typical thermal conductivity of silicone based gels is 0.8-2 W/(m·K) [10]. Thermally conducting grease is used between the LED substrate and the heatsink. The typical thermal conductivity of silicone based grease is 2-4 W/(m·K) [9].

Table 1 lists the main properties of the materials used in the LED light bulb. Density, thermal conductivity and specific heat are the most important ones. Emissivity factor will be defined entirely according to the surface finishing. Therefore it does not make sense to include emissivity factor in the table.

Energy Efficiency of the Driver

The most inexpensive retrofit LED light bulbs usually have a non-isolated buck-based LED driver [7]. An isolated driver typically has a transformer which output voltage is normally much lower than the input line voltage. A non-isolated driver has the input galvanically connected to the output. High input line voltage is present at the output. The typical efficiency of a LED driver is between 80-90 %. The buck converter has the smallest amount of components of any type of drivers and therefore it may feature the highest efficiency. Most inexpensive driver designs do not include power factor correction circuitry. Therefore such a driver has a low power factor. In this case only 42% (Vin is 220 VAC, 50 Hz).

Component values are: C1, C2 are 100 nF, L1 is 3 mH, common mode choke L2 is 1 mH, C3 is 10 uF (electrolyte cap.), C4, C5 are 100 nF, R2 is 0.75 Ω. Power dissipation in each component was calculated with Spice simulations. The results are listed in table 2. These values are used for heat sources defined in the thermal model. The controller circuit used in the driver is one of the most common driver ic's found in these kind of light bulbs. The MOSFET is rated for 0.9A drain current and for 600 V drain-source voltage. The $R_{ds,on}$ is relatively high (9.5 Ω) , but gate charge (5.9 nC) and C_{rss} are relatively small ones.

Component	P [W]
LED	0.571
MOSFET	0.332
Diode	0.185
Inductor	0.090
NTC resistor	0.060
Rectifier	0.059
Line filter	0.008
Sense resistor	0.005
Controller etc.	0.339

Table 2: Power dissipation. P_{in} is 9.064 W, P_{out} is 7.987 W, Efficiency is 88.1%

Thermal Simulations

Comsol Multiphysics software has a "Joule Heating" model which covers the most common thermal problems where heat is generated by an electromagnetic source like current flowing through an ohmic device [3]. The main objectives of thermal simulations are solving internal and surface temperatures in stationary thermal conditions. The time needed for reaching stationary conditions in a lamp may even be several hours. Time dependent simulations which could show temperatures changing towards the stationary condition would be interesting but exhaustive because of needed memory size and computing time.

Heat conduction can be simulated by including "Heat Transfer in Solids" model into the simulations. This model will be chosen for all solid domains in the model.

Heat convection will be simulated by defining a "Convective Cooling" model for all outer surfaces. There are alternatives of how the convection factor will be defined. By choosing natural external convection, air is supposed to surround the lamp and air movement is caused only by the heating of the lamp itself. External forced cooling can be modeled either by entering a convection coefficient or using the forced external convection model. This makes it possible to simulate the effect external air flow could have. When defining convection, the position of the lamp must be decided. Most likely this lamp would be used as a ceiling lamp which is emitting light downwards. Natural convection should in that case make heat flow towards the base of the lamp. As it was more convenient to test the lamp in a laboratory by setting the dome to point upwards all simulations have been made for that case as well.

Heat transfer in a gas filled domain is modeled by adding "Heat Transfer in Fluids" model into the simulation. This model is suitable for the gas (air) filled domain under the dome of the bulb. Gas pressure is expected to remain constant (isobaric process) although the heat generated by LEDs also heats the air and increases its volume. The sealing between the dome and the rest of the lamp is not gas-tight and extra air leaks out.

Radiation removes heat from the outer surfaces of the lamp. This can be modeled by including "Surface-to-Ambient Radiation" model into the simulation. The emissivity factor must be defined for all those materials which radiate heat from surface to ambient or from surface to other surfaces. Estimating roughly, about 20 % of the heat generated by the LEDs is radiated. The radiated heat can be modeled by selecting "Surface-to-Surface Radiation" in the "Joule Heating" model.

A domain with only a thin layer of some material causes difficulties in simulations. Mesh for such a domain has to be in dense comparison to other

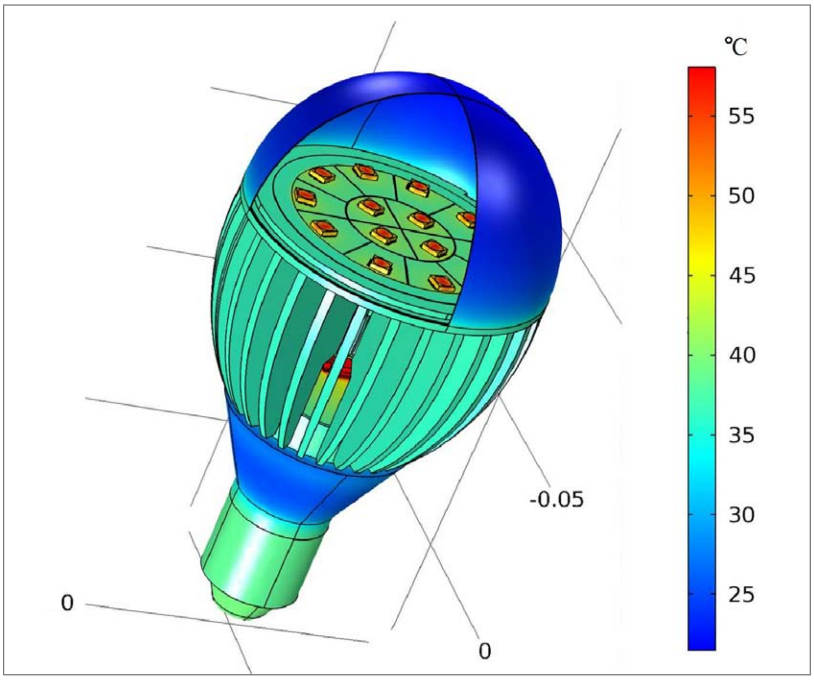


Figure 6: Simulated stationary surface temperature of 10 W retrofit LED light bulb. External natural convection. Ambient temperature is 20°C

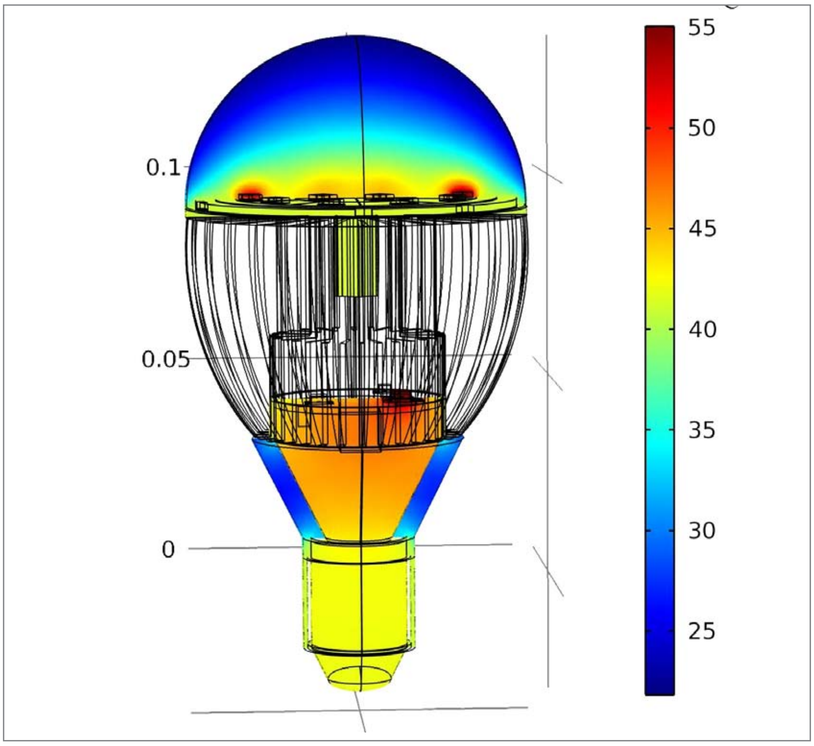


Figure 7: Simulated temperature of 10 W retrofit LED light bulb. (Cross section image. External natural convection. Ambient temperature is 20°C)

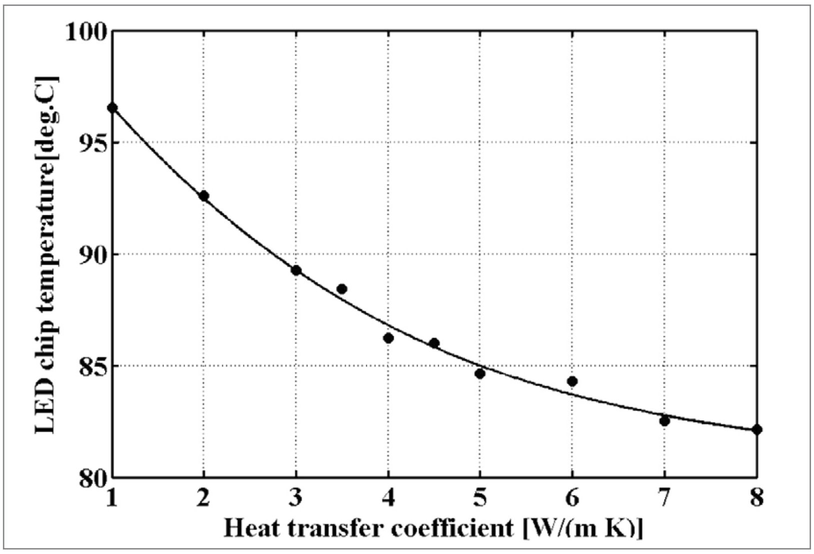


Figure 8: LED chip max. temperature vs. heat transfer coefficient of thermal convection

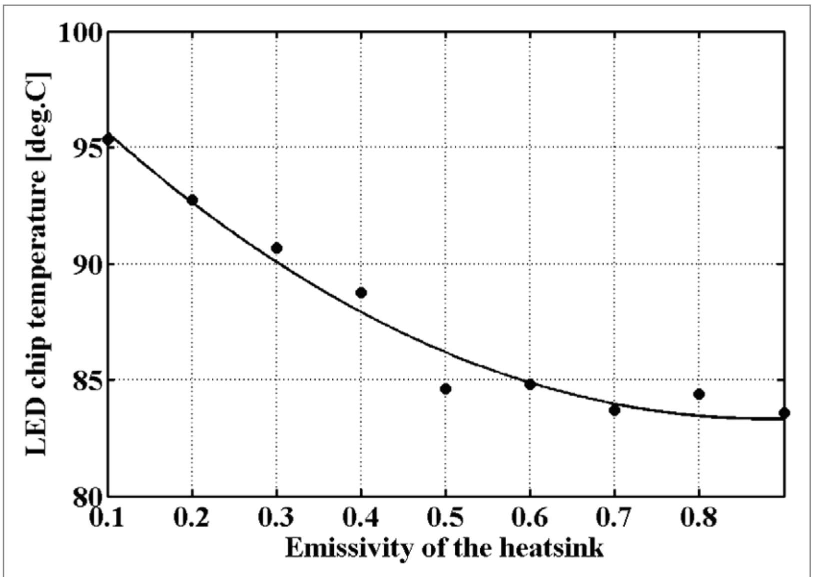


Figure 9: LED chip max. temperature vs. emissivity of the heatsink

domains. This consumes memory and slows down the simulation. The thermal crease domain below the LED substrate plate and the insulator domain between the copper layer and the substrate plate are the thinnest domains in the model. Thickness of 0.2 mm is the practical minimum for the model. Including these domains increased simulation time from approximately half an hour to several hours (PC with 64-bit operating system, dual core CPU, 2.33 GHz, 8 GB memory). The software offers partial relief for thin conductive domains with "Highly Conductive Layer" or "Thin Thermally Resistive Layer" options. "Highly Conductive Layer" option was used for the copper foil (< 100 um) which otherwise would have been impossible to include in the model.

Internal temperatures can be studied by taking a cross sectional view of the light bulb. Figure 7 shows that the conical domain inside the light base which is the thermal silicon filling has a temperature of approximately 45°C. Air just above the LEDs is also quite warm. The temperature of the MOSFET is distinctly more than 50 °C.

Studies [8] have indicated that convection coefficients of outer surfaces have significant effect on the junction temperature of a LED chip. It was also found that thermal conductivity of thermal grease has only a minor effect on the junction temperature. Another part of the study emphasizes the role thermal grease has in the cooling of a LED light [1].

External natural convection equals the situation where convection heat transfer coefficient h is approximately 5 W/(m^2·K). A higher value for h means forced external convection. A smaller value indicates natural convection is to some extent suppressed. Figure 8 shows the simulated maximum temperature of LED chip vs. the convection heat transfer coefficient. Emissivity factor of the heatsink is a parameter which is entirely defined by the surface finishing. If the emissivity factor is not known, it has to be estimated. Figure 9 offer the means for this and shows how the chip

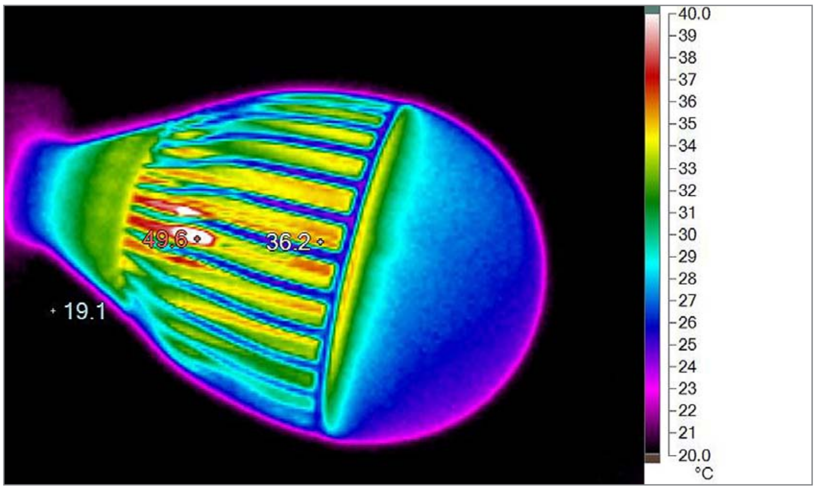


Figure 10: An IR image of the horizontally mounted LED light bulb: Heatsink 28-37°C, Dome 25-27°C, Hot spots of the driver up to 50°C. V_{in} is 220 VAC

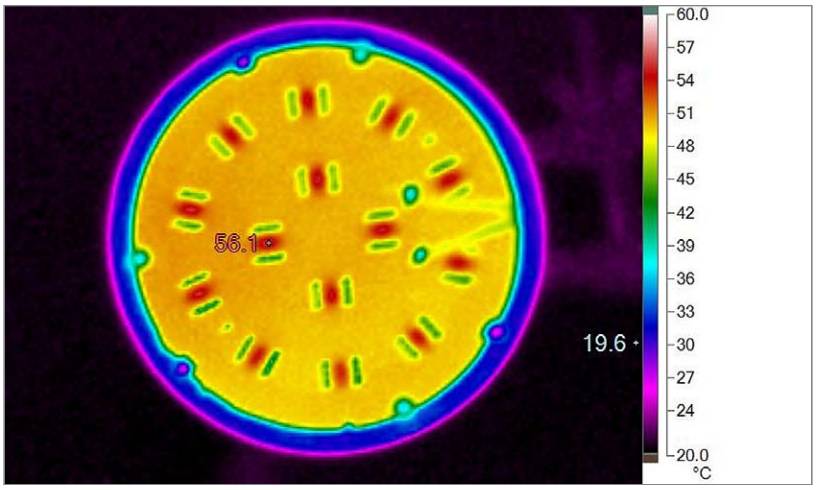


Figure 11: An IR image of the LEDs. Emissivity factor has been set to 0.6

temperature increases when the emissivity reduces. These simulations were made for conditions where natural external convection prevails. Table 3. lists temperatures in external natural convection.

Thermal Validation

Thermal validation was done by using IR imaging and temperature measurements with type K thermocouples.

Recording measurements was delayed by two hours to make sure the lamp had reached its steady-state condition. An IR camera can give erroneous (too low) temperatures when pointed towards a surface of a low emissivity factor. Therefore it was found necessary to check the temperatures also with thermocouples. During the measurements, the lamp was mounted on a lamp holder which was fixed on a statue. The lamp holder was thermally isolated from the statue. Ambient air space around the lamp was large and its temperature remained constant (20°C).

Table 3: **Measured and simulated temperatures. Emissivity set to 0.95 in the IR camera . V_{in} is 220 VAC. Ambient temperature is 20°C**

Part	Measured (IR)	Measured (therm.)	Simulated
	temp. [°C]	temp. [°C]	temp. [°C]
LED chip (max)			84.6
LED package/top	44	56	56.8
LED board/center	40	41	40.3
LED board/outer circle	39	38	36.7
Dome/top	25	27	21.6
Dome/surface	27	28	25.9
Heatsink/center	37	37	37.0
Heatsink/outer surface	28	35	36.3
Base of the lamp/outer surface	31		25.9

When measuring the LEDs, the dome had been removed. It was difficult to focus the IR camera carefully on the top of the LEDs as the camera had to be handled manually in front of the very bright LEDs.

The largest differences in results between IR images and thermocouple measurements were found for LED top surface temperatures. Thermocouple measurement resulted in almost the same values as the simulations. These values can be considered as the most reliable results. This indicates the emissivity factor which was automatically set to 0.95 in the camera is too high. In order to match the IR image to thermocouple measurement the emissivity factor was reduced from 0.95 to 0.6. Figure 11 shows the corrected image of the LEDs.

Conclusions

The studied retrofit LED light bulb was found to be thermally well designed. The simulated temperatures of LED chips were found to be less than 85°C in case line input voltage is 220 VAC and external natural heat convection conditions prevail. The simulated and measured temperatures match relatively well. The main results are how the chip temperature varies according to the convection heat transfer factor or to the emissivity factor of the heatsink. The thermal model can further be improved by defining the material parameters, the heat convection factors, the emissivity factors more accurately. The accuracy of the mesh in FEM can also be improved with the expense of increased computing time. The lamp has a simple non-isolated driver which has good energy efficiency but a relatively low power factor. Electrical isolating between the LED wiring and the heatsink was a bit frail and this caused some doubts about electrical safety. This lamp is manufactured and bought in Asia and it may not have been intended for sale in Europe. ■

Acknowledgments:

This work is part of the project ReLED, which is supported by TEKES, the Finnish Funding Agency for Technology and Innovations.

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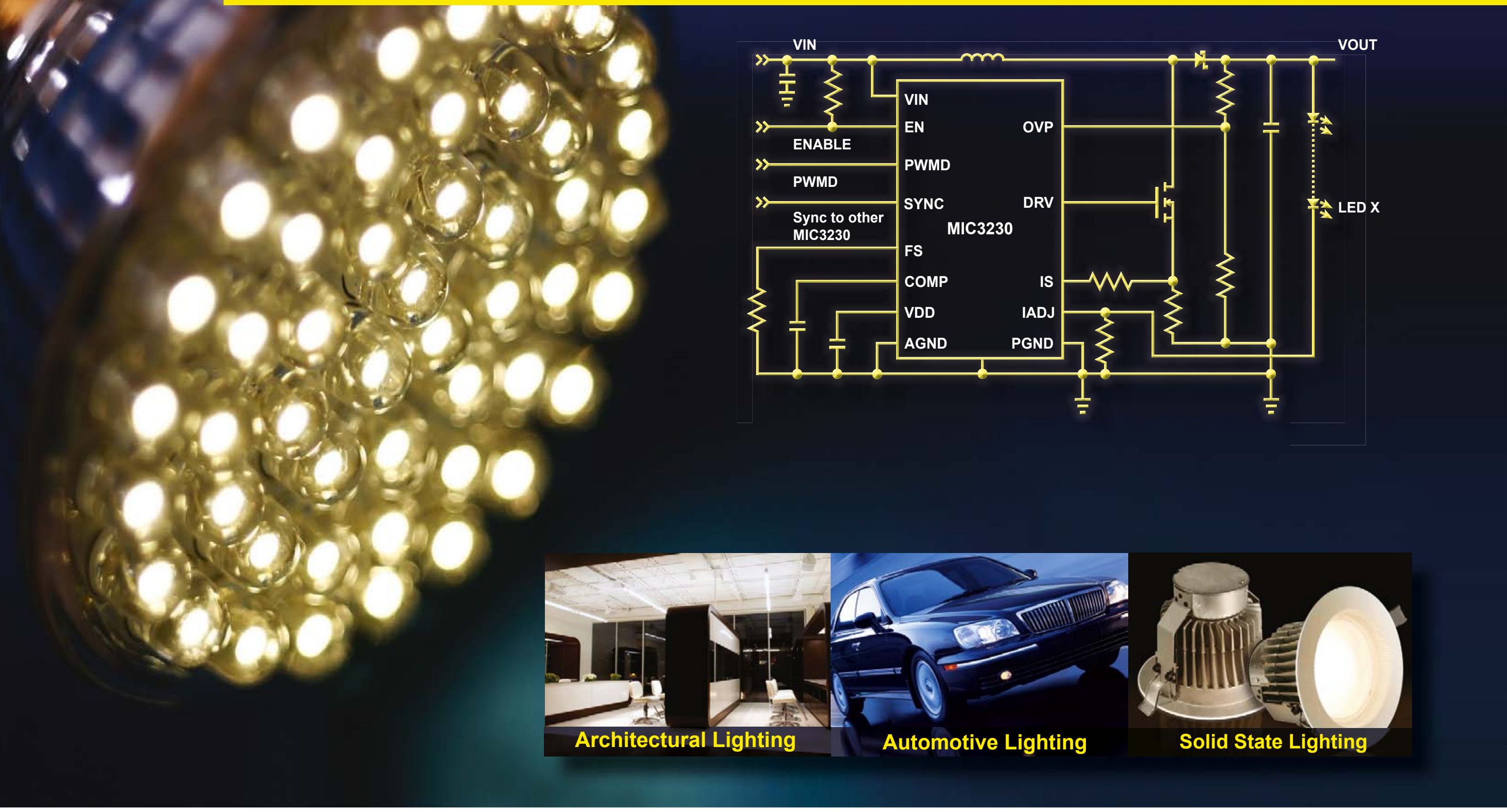

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Mesopic Photometry – An Accurate System of Road Lighting Evaluation

For a long time, photopic vision was the basis for all light measurement tasks, but today this approach is challenged. According to several research results, it seems that mesopic vision should be used as a basis to evaluate street lighting applications or other low level lighting applications. Prija Jain from the Executive Design and Development (Photometry & Optics) department of Surya Roshni Ltd. in India gives us an overview on the recent status of the discussion, explains it and shows the resulting consequences.

Today, while facing an insuperable challenge to meet the present needs of energy and an apprehension of energy crisis and global pollution in the future as well as the continuous evolution of technology, the world is striving to find solutions to leverage the resources available.

The major part of total global energy demand calls for electricity, an inevitable need of human kind, which in turn is being consumed by the end users for several applications together with a significant amount used for lighting (the electric eyes).

Undoubtedly, LED is the latest technology to supplant conventional light sources with several merits such as Energy Efficiency. This results in a reduced carbon footprint, longer life and a product free of mercury. As a consequence, it retards the rate of global pollution and takes a step towards a "greener" world.

For the last couple of years, the lighting industry has been promoting the LED lighting system by replacing conventional luminaire systems while maintaining equivalent performance of conventional light sources. However, the question of whether the lighting industry really understands the methodology for finding out the performance "equivalent" and if implementation is the same, arises.

About Photometry

First and foremost we should take a look at the need of lighting metrology i.e. photometry. "The measurement of light", although a very crude and non-technical definition, is a concept only known to a few people.

Precisely, photometry is the "measurement of light weighted by human eye response".

It is a branch of radiometry which focuses on the measurement of light limited to the visible spectrum only, (approx. 380 nm-780 nm) instead of total optical radiation as in the case of radiometry.

There are four basic parameters involved in the metrology of the lighting system. - Figure 1 shows how these parameters are linked with the practical application.

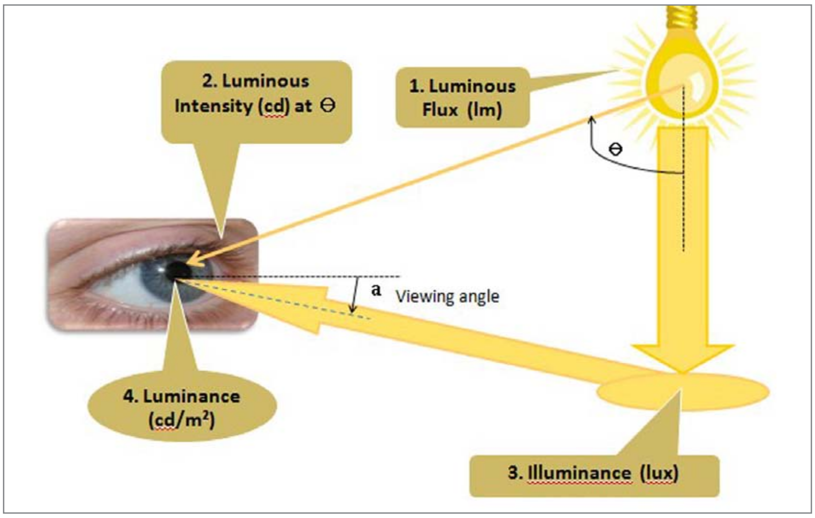


Figure 1: Photometric measurement parameters

1. The Luminous flux is the integrated total light output (in visible spectrum) emanating from the light source and weighted by human eye response. The unit of measurement is lumen (lm)
2. Luminous Intensity is the quantity of luminous flux in a specified direction (θ in figure 1) per solid angle (steradian).
3. Illuminance determines the amount of light falling upon the surface and is measured in terms of lux (lm/m^2) or foot-candle (lm/ft^2).
4. The eye is able to detect the object after perceiving the light reflected from it which is defined in terms of the luminance, intensity per square meter of light travelling in the given direction (viewing angle) a (Figure 1) and measured in terms of cd/m^2.

Although limited bandwidth of visible spectrum, it is difficult to understand its measurement as it involves a complex factor: The "HUMAN EYE" for which we are making the light.

Human Eye Vision

When light enters the eye it first passes the cornea, and goes through a circular hole called the "pupil", and is adjusted by the Iris diaphragm. The image is then focused on the retina with the help of the lens system. To a certain extent, this process resembles the way a camera works. However, the eye is an exquisite part of the human body and serves as a bridge between the brain and the visual world. It responds differently to varying light intensity conditions.

Figure 2:
Human eye

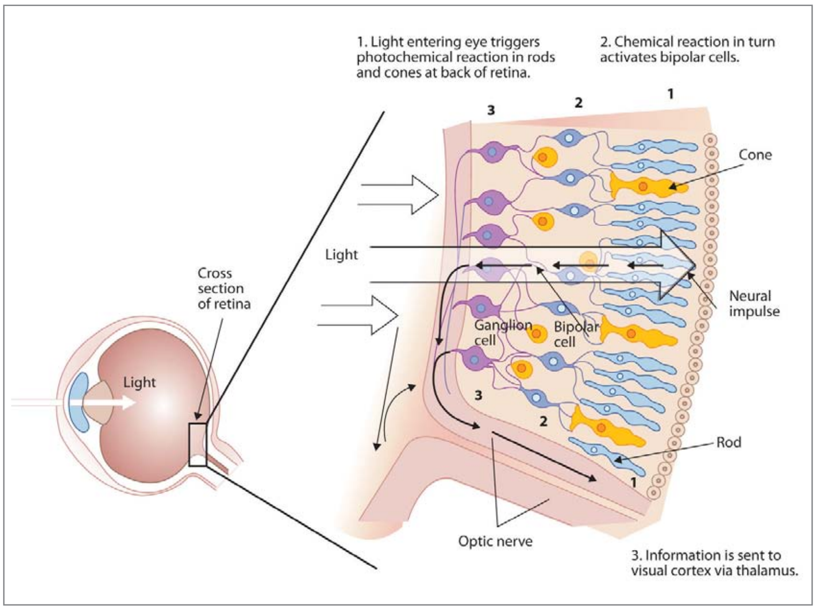
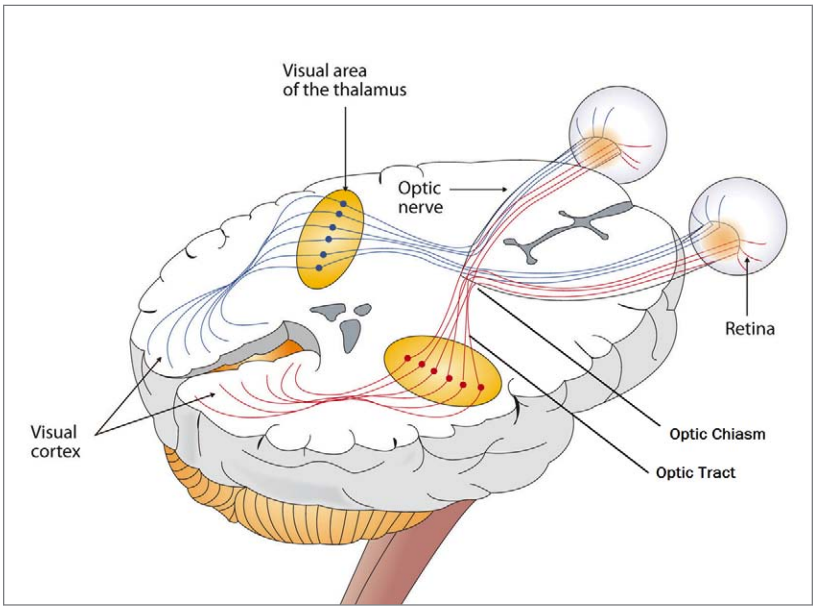


Figure 3:
Visual pathway



Within the eye, the surface of the retina is distributed with two types of photoreceptors (Figure 2), rod and cone cells. Up to 120 million numbers of rod cells are available in clusters and several rods are connected to the brain through a single fiber. This makes it difficult to transfer the information perceived by the individual rod cell and hence contributes only for motion and shape detection. The cones contribute to the perception of color since each cone cell is connected through a separate fiber to the brain.

Six to seven million cone cells are subdivided into the three primary color receptors red, green, and blue.

As mentioned above, the resolution of rods is inferior due to the input being merged from several rods before they reach the eye nerve. The result is increased sensitivity, at a price of lowered resolution. Cones, on the other hand, send individual input to the eye nerve, maximizing resolution, while partly sacrificing sensitivity.

Retinal ganglion cells send the processed signal from the retina to the brain via the optic nerve. The optic nerves from both the eyes unite and form the so called Optic Chiasma. From there, the visual information travels through the optic tract to the knee - shaped lateral geniculate nuclei, where the signals are distributed via the thalamus to the two visual cortices. After undergoing processing in the primary visual cortex, the nerve signals are transmitted to the associative optical cortex where these signals are interpreted and finally, the conscious person perceives images of what they are looking at. (Figure 3)

The Three Types of Vision

As photometric measurement is based on human eye response, the first and foremost prerequisite is to understand human eye behavior. A long journey of studies made on human eye vision found three different types of vision that the eye responds to:

- Scotopic Vision (very low or no light conditions approximately below 0.01 cd/m^2 luminance level),
- Mesopic Vision (low ambient light conditions, approximately between 0.01 cd/m^2 to 3 cd/m^2 luminance level),
- Photopic Vision (daylight or adequate ambient light conditions, approximately above 3 cd/m^2 luminance level).

The rods are incredibly efficient photoreceptors responsible for our dark adapted or scotopic vision also known as Peripheral vision of the human eye. More than one thousand times as sensitive as cones, they can reportedly be triggered by individual photons under optimal conditions. The optimum dark adapted vision is obtained only after a considerable period of darkness, say 30 minutes or longer, because the rod adaption process is much slower than that of cones. Under scotopic vision, say moonlight, our eye sensitivity peak occurs at 507 nm wavelength as per CIE luminous efficiency function i.e. V' (λ). This wavelength belongs to a greenish-blue color, making blue more prominent to the eye under scotopic vision.

When there is enough ambient light available, our eye's response jumps to photopic vision or Cone vision, also known as foveal vision (as cones are concentrated in the central foveal region on the retina), where the eye has sensitivity at 555 nm as per CIE Standard photopic luminous efficiency function i.e. V(λ), which belongs to a yellowish-green color.

There is a transitional state between scotopic and photopic vision called mesopic vision, like night time driving conditions, when both the rod and cone photoreceptors are partly active. The lower region of mesopic vision is dominated by rods whereas the upper region is dominated by cones.

The above thesis is sufficient enough to trigger the question- "which visual performance system (scotopic/ mesopic/photopic) should be preferred and when?"

Choosing the Right Vision Type

Basically, all photometric measurement systems employ photocell or photodiode calibrated for eye sensitivity functions obtained under photopic vision. These results have been directly applied in all types of lighting design calculations either internally or externally. Technically, though, they are not acceptable for applications involving low luminance levels falling in the region of mesopic vision, e.g. roadway lighting luminance calculations because under low light levels, the eye response is merely pertaining to mesopic vision. The yearning of all contenders of roadway lighting design calculations was fulfilled after the introduction of "CIE 191:2010 Recommended system for mesopic photometry based on visual performance".

Initially, to analyze the mesopic visual performance, USP System (Rea et al: 2004) was introduced, then the second proposed photometry system was the MOVE system (Elholma et al.-2005 and Goodman et al.-2007), to overcome the shortcomings of both of these systems. The third Intermediate system MES1 and MES2 was developed and finally the MES2 photometry system has been adapted to analyze mesopic photometry depending upon technical comparisons made among all of the systems proposed.

The significance of mesopic photometry only accounts for luminance (cd/m^2) calculations, keeping all other calculations unchanged.

Performance of LEDs and HPS Lamps under Mesopic Vision

For the mesopic photometric calculation, when HPS and LED streetlight installations were compared under the same installation conditions, the LED luminaire was found to be more effective for contributing better vision under night time driving conditions over the HPS luminaire.

Precisely, LED results in better visibility as compared to HPS under the same illumination level and less power consumption. In other words, "A low illumination level is required for LEDs as compared to HPS under the same visibility and comparatively low wattage".

This is due to a broad white spectrum of LED over HPS which improves its S/P ratio more than one (e.g. 2.07 at 5500 K) against S/P ratio for HPS which is less than one (e.g. 0.40 at 2000 K).

The S/P ratio less than one has a negative adjustment for luminance calculation under mesopic vision, meaning that the given photopic luminance will be effectively reduced under mesopic conditions. Conversely, S/P ratios greater than one have positive adjustment factors, meaning that the given photopic luminance will be effectively increased.

Hence, photopic luminance measured under LED streetlight converted to mesopic luminance results in increased value. Conversely, mesopic luminance value is always less than its respective photopic luminance for an HPS based luminaire.

Conclusions

The measurement system that has been applied for so many years for the field measurement and lighting design simulation software in roadway lighting calculations or other similar low illumination lighting applications, is based on the photopic photometry which is now required to be superseded by a new recommended system based on mesopic photometry so as to stop underestimating the LED over HPS lighting systems.

In conclusion, the LED is a better lighting solution, not only in terms of power consumption but in visual perception as well. It accomplishes the ultimate goal of making light for eyes which calls for the prerequisite need of proper guidance and systems to influence lighting to improve the economy, efficiency and more importantly, safety on roadways. ■

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Aspects of Light Quality in Solid State Lighting

For ages the quality of light has been one of the biggest topics for luminaire manufacturers. But since the introduction of LEDs in general lighting the definition of light quality has got a new dimension. Pros and cons of LED lighting quality are often very controversial. Alexander Wilm, Application Engineering Manager of OSRAM Opto Semiconductors, presents facts about LED lighting quality that provide a sound basis for discussions.

Light-emitting diodes (LED) are considered to be the technology of the future for all applications in the field of general lighting because of their numerous, superior advantages: In addition to an extremely long lamp life of up to 100,000 hours, LEDs display particularly high energy efficiency and luminosity. One LED with just one chip shines with a luminous efficacy of over 120 lm/W. Furthermore, on account of their small size, these tiny light sources can provide ideal lighting solutions on a small area. However, the light quality of LEDs has been questioned, mostly in relation to three main aspects. First is the damage potential: Can the light from these small diodes damage artworks or other sensitive objects? The second aspect refers to the photobiological safety of LED systems, while the last focusses on the color rendering quality of LED light. These three aspects are examined in detail in the sections below.

LED Lighting: High Blue Component in the Light

LEDs are penetrating an increasing number of segments in general lighting. But alongside their frequently mentioned advantages, such as high efficiency and long lamp life, they undoubtedly are associated with problematic aspects, particularly in museum lighting, such as their ability to render color and their potential to damage objects on exhibit. The high blue component in the LED light spectrum and the potential risk are issues that repeatedly give cause for discussion. This article objectively explores and evaluates the damage potential of LED lighting as compared to conventional lighting solutions.

White light is produced in LEDs primarily by combining a blue LED chip with a phosphor converter. The blue light of the chip is partially converted by the right phosphor mixture into light with a longer wavelength and a yellow color. This light, comprising blue and yellow wavelengths, is perceived by the human eye as white light with the desired color temperature. Figure 1 shows the contribution of the blue chip in the light spectrum as a pronounced deflection at about 450 nm.

Museum Lighting: Is LED Light a Risk?

From CIE 157:2004, a study of potential damage to museum objects by optical radiation, we know that short-wave optical radiation in particular displays an increasingly

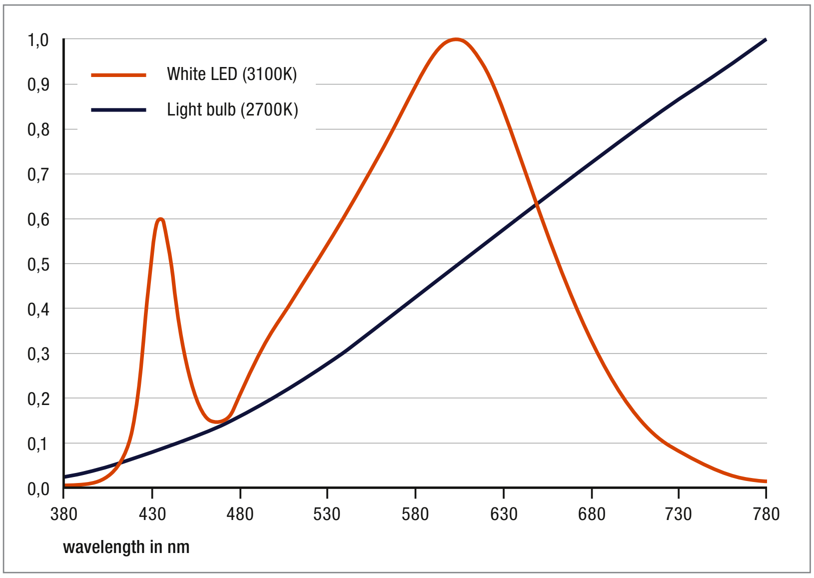


Figure 1: **Typical spectra of a white LED and an incandescent lamp**

higher damage potential. The superficial comparison of the spectra of a white LED and an incandescent lamp in figure 1 gives the impression that the white LED has a significantly higher blue component, making it appear more harmful than the incandescent lamp. However, this is only apparently so. To make a well-founded statement about the damage potential, the two spectra must be analyzed and compared on the basis of CIE 157:2004.

CIE 157:2004 describes a suitable method for evaluating and estimating the damage potential of optical radiation to museum objects. The core of the evaluation is the weighting of the spectrum of the light in terms of the relative spectral object sensitivity.

Together with the experimentally determined threshold radiation values, it is possible to estimate the damage potential of different spectra and light sources. The damage potential is the ratio of object-damaging irradiance to illuminance. As an example, object-damaging irradiation is calculated for the relative spectral object sensitivity of watercolor on paper (Figure 2). In the first step, several white LEDs with different color temperatures and phosphor mixtures are compared with the incandescent lamp mentioned above. As shown in the comparison with an incandescent lamp in figure 3, the damage potential of the white LED is even lower, depending on the color temperature, despite its high blue component. Consequently, illuminating museum objects with LED light is less damaging than with an unfiltered incandescent lamp.

Figure 2: **Relative spectral object sensitivities for different materials**

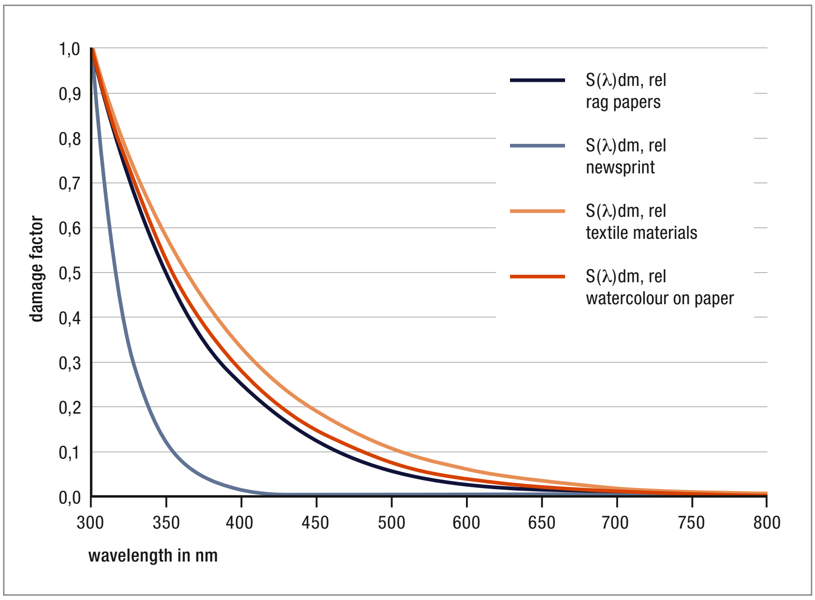


Figure 3: **Comparison of damage potential of different light sources**

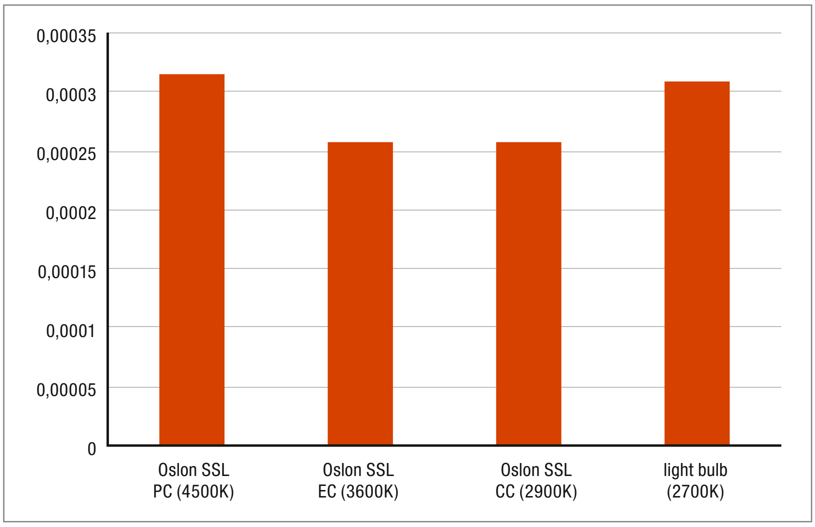


Figure 4: **Comparison of the damage potential of different lamps**

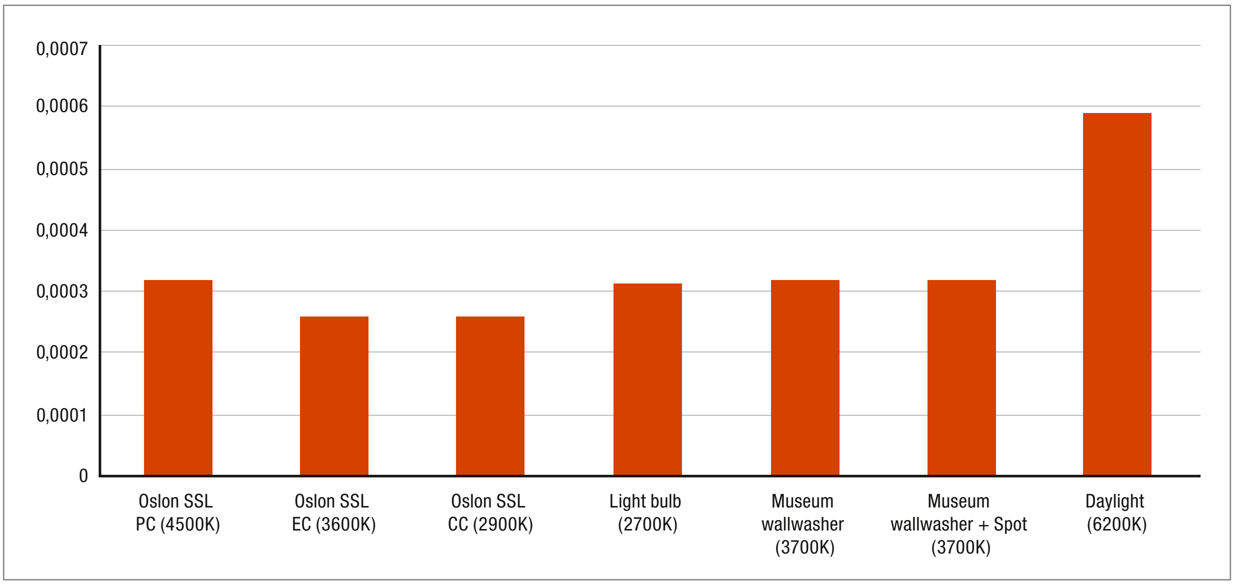
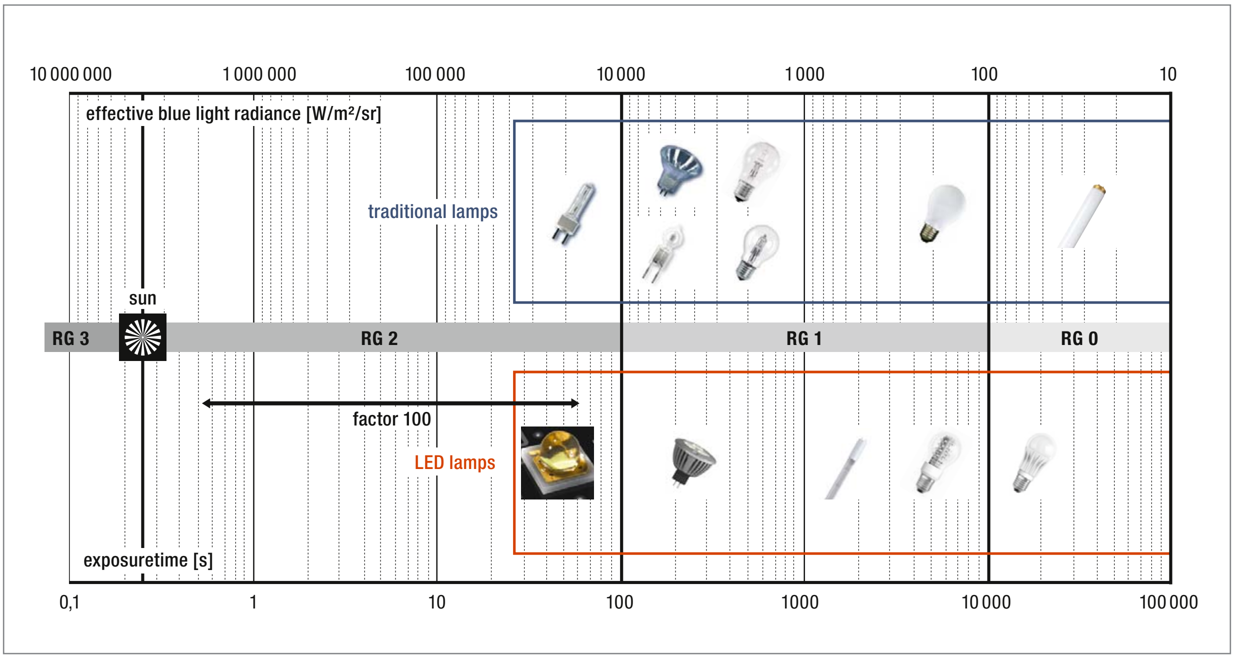


Figure 5:
Classification of conventional and LED lamps in risk groups to IEC 62471



LED: The Ideal Light Source for Museums

In museums, light sources often are equipped with special UV and infrared filters to minimize damage to the objects. To be able to classify the damage potential of LEDs in valid fashion, a representative lighting situation in a museum was evaluated. In the selected museum, the basic standard lighting consists of wall-washers and accent lighting provided by spotlights. The light source for the basic lighting is a fluorescent lamp; a halogen lamp is used for the spotlighting. Both are fitted with the standard museum UV and IR filters. For the study, this lighting was replaced by LED lighting. The spectra of both lighting solutions were scaled to an illuminance of 50 lux, and their damage potential on a watercolor painting on paper evaluated.

A comparison of the two lighting solutions in figure 4 shows that the damage potential of the LED lighting is similar to, or even lower than, that of the existing, high-quality museum lighting solution based on fluorescent and halogen lamps, given comparable color temperature. Daylight has the highest damage potential, which is why many museums attempt to ban it entirely from their exhibition spaces, so as to minimize as much as possible any impairment of the objects on display.

The study shows that modern light-emitting diodes are excellently suited as light sources for high-quality museum lighting. Although the obviously high blue component in the spectrum of white LEDs is deterring at first, closer consideration reveals that they pose no threat to the sensitive objects. Apart from the low damage potential, the high luminous efficacy combined with the long lamp life makes LEDs the perfect light source for the museum lighting segment.

IEC 62471 on Photobiological Safety

After examining the impact of LED radiation on objects, we turn now to its effect on the human eye. Lamp safety standard IEC 62471 defines safety guidelines for lamps and lamp systems, referred to as photobiological safety. The aim of this standard, accepted by lamp manufacturers, is to enable a standardized estimation of the magnitude of the risk to the human eye of potential radiation from lamps and lamp systems. IEC 62471 defines exposure limits, reference measurement categories and the classification scheme for the evaluation and control of photobiological hazards in the wavelength range from 200 to 3,000 nm. The defined numbers are applicable to most lamps and lamp systems, including luminaires: LEDs as well as incandescent, fluorescent, high-pressure discharge and other lamps can be evaluated, but not lasers. According to the IEC 62471 guidelines, both LED lamps and conventional light sources are classified in the same risk group, as shown in figure 5. Traditional lamps are in the upper part of the diagram, various LED lamps along the bottom. This shows that LEDs are just as safe as other conventional light sources and do not damage the human eye. In other words, nothing stands in the way of their use in the general lighting segment.

Color Rendering: A Challenge for Light Technologies

The greatest challenge for LEDs and other light technologies, however, is the adequate rendering of colors, as the following example illustrates. Every shopper has at some time faced the dilemma of wanting to buy a piece of clothing, but also wanting to first see it in daylight. The reason: Under the light in a store, colors often look different than they do at home or outdoors in daylight (Figure 6). The following section explains why color rendering differs so much, and which advantages and challenges exist, particularly for LEDs.

Figure 6:
The color of products in a store often looks entirely different at home

This is one of the reasons why colored objects, like clothing, look different under different light sources. To determine and predict how a colored object will appear based on the different spectral power distributions, the Commission Internationale de l'Éclairage (CIE) created the Color Rendering Index.

We are surrounded by any number of artificial light sources every day. We use primarily incandescent and halogen lamps at home, fluorescent lamps at work. Stores use spotlights fitted with high-pressure discharge lamps to illuminate their latest products, and xenon lamps in car headlights light up the roadway for us at night. But the LED also has established itself in recent years as an important light source in these fields. But all of these artificial light sources have different spectral power distributions. If a colored object is illuminated by different light sources, the color rendering can differ, and the object looks slightly different depending on the lighting.

If a colored object is illuminated with a specific light, for example an incandescent lamp, the illuminated object reflects some of the spectrum. The eye and brain of the observer then evaluate the reflected spectrum, which ultimately results in a specific color impression. If the same object is now illuminated with light of yet another spectral makeup, for example a fluorescent lamp, the colors of the object may look different again.

CRI – Standardization Method for the Color Rendering of Light Sources

As early as in 1974, CIE published the first detailed method that made it possible to express the rendering of colors under different lighting conditions as a number. For this purpose, CIE defined eight standard and six special samples as test colors. In this connection, the calculation of the CRI always involves a comparison of a test light source with a reference light source. If the correlated color temperature of the test light source is

Figure 7:
Example calculation of a Ra value of 62 using the color rendering index (CRI)

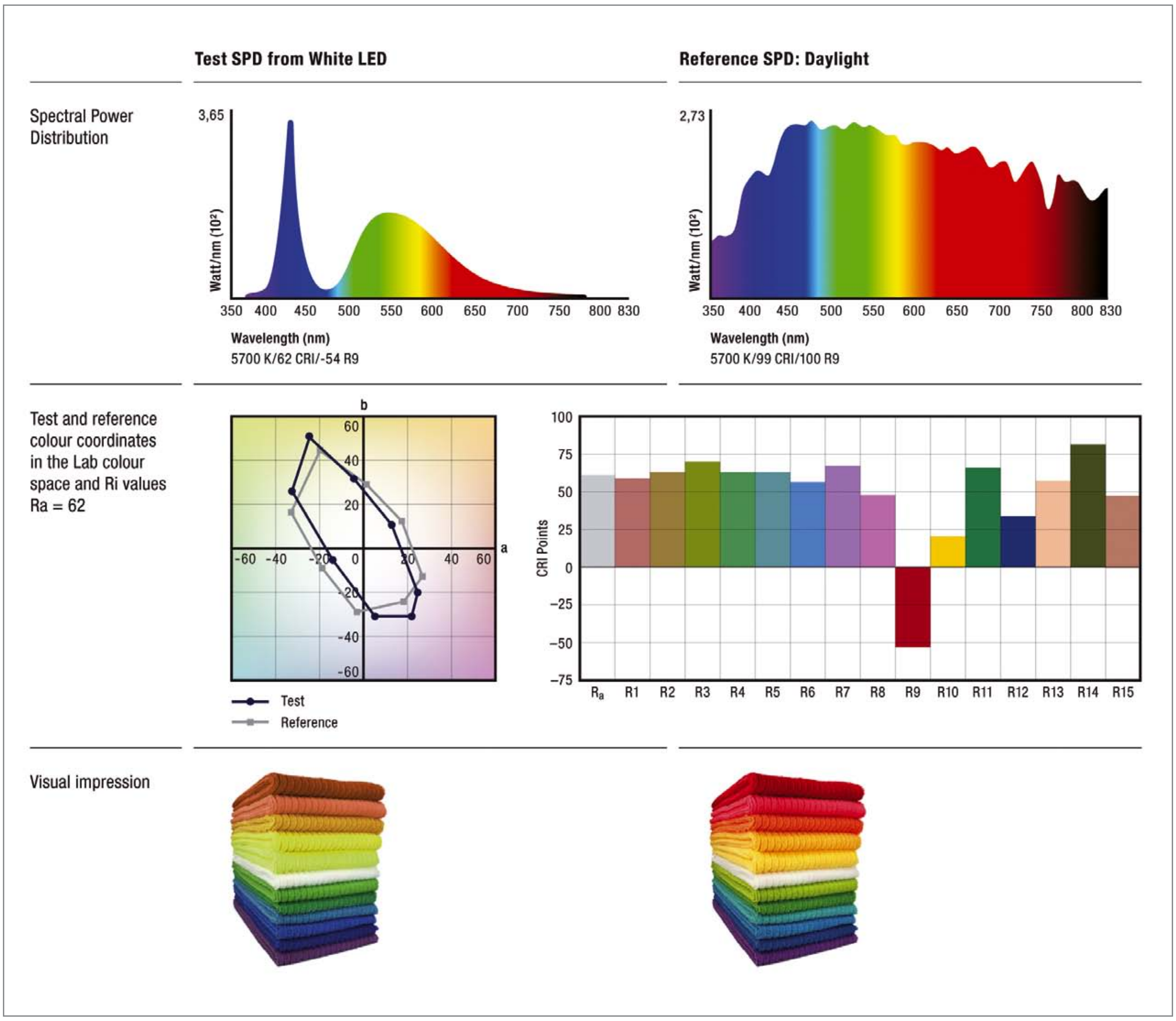
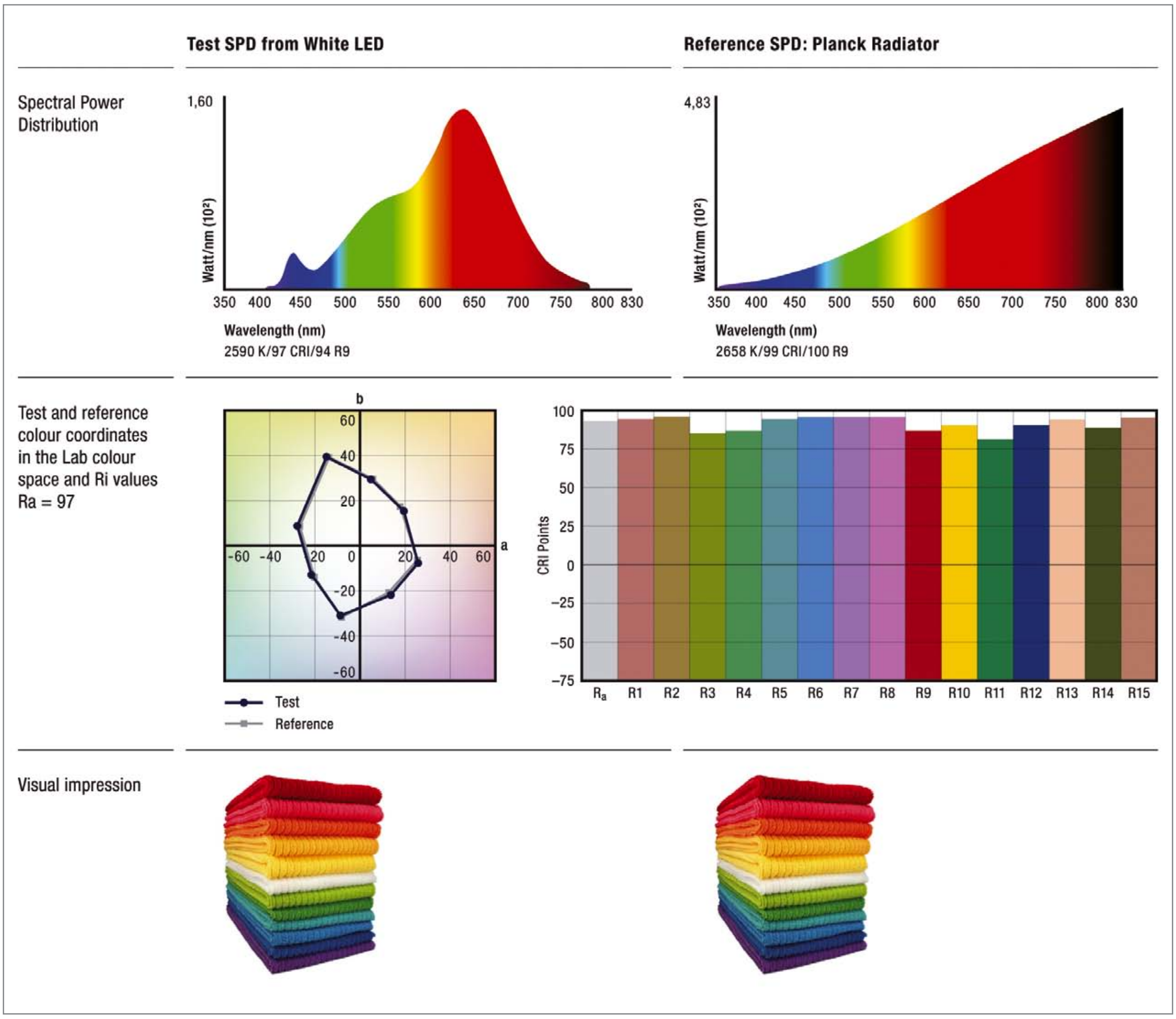


Figure 8: **Example calculation of a Ra value of 97 using the color rendering index (CRI)**



under 5,000 kelvin, the reference light source is a Planckian radiator with the same correlated color temperature. At a color temperature of over 5,000 K, a spectrum close to daylight is selected as a reference.

The test colors are then illuminated virtually by the test light source and the reference. The resulting tristimulus values X Y Z are derived and converted to the U*V*W* color space. Chromatic adaptation is carried out using a von Kries-type chromatic adaptation transform. The chromacity difference for each test color in the U*V*W* color space can then be calculated.
The 8+6 color rendering indices Ri are calculated based on the chromacity difference Ri = 100 – 4.6ΔEi. The general color rendering index is the average of the first eight individual indices: Ra = 1/8 ∑ Ri.

CRI 100 – The Optimum in Color Rendition

In the example calculation in figure 7, the color rendering index is calculated for a white LED with a high correlated color temperature of about 5,700 K. Because the color temperature exceeds the value of 5,000 K, daylight is used as a reference light source. The test color samples are illuminated by both the white LED and the reference light source (daylight), whose spectra differ significantly, as the top section of the figure shows.

The different color coordinates resulting from the lighting are represented in the Lab color space diagram, where the test lighting is shown by the blue line, the reference by the gray. In the diagram, the blue and gray points and lines differ significantly, because the resulting color coordinates of the test colors differ. The rule in this case: The greater the distance in between, the lower the Rx values. Therefore, the red R9 color field can also be negative on account of the general scaling of the color rendering index. In the visual impression of color difference based on the stack of colored towels, the difference in color rendering is clearly noticeable at a Ra value of 62 for the test and reference light sources.

To achieve very good color rendering close to the optimum value of 100, the color coordinates of the test and reference light sources must be as similar as possible or even identical. In this case, color perception is not distorted and color rendering accordingly good. If we now compare a warm white LED with 2,600 K, optimized for high CRI, with a Planckian radiator of the same CRI, the test colors look very similar (Figure 8).

The points and lines in the Lab color space then match more or less, which indicates Rx values that lie close to optimum color rendering, e.g. in this case 97.

Establishing a Precedent: Color Fidelity Versus Color Preference

However, a high color rendering value can be achieved even with a very different spectral power distribution between the test and reference spectra, so that colors look very similar. In what is known as the Brilliant Mix Concept, the light from a greenish-white and a red LED is mixed. The color points in the Lab color space resulting from the test and reference light sources are very close together. With a small deviation, a value of 91 can be calculated for the color rendering index. However, the color coordinates of the Brilliant Mix lighting are always on or outside the reference light source in this case. As a result, the colors are slightly changed and appear more brilliant, saturated and glossy, although the color rendering index is not at 100. This effect is also referred to as color preference: It describes how strongly the saturation of a color is increased by the spectrum of the lighting. Within certain limits, relatively high saturation is even preferred. However, color preference has not yet been incorporated in the existing color rendering index definition.

These considerations show that the color rendering index in its current form has reached its limitations in some areas. For this reason, work on revising it is already underway: CIE is discussing what possible routes can be taken to calculate and define the color rendering index. It must be accepted, however, that compromises will always have to be made between color fidelity, color preference, custom spectral power distribution and efficiency. Furthermore, some fields of application, such as street lighting, do not require a high color rendering value. Fortunately, the spectrum of LED light can be modified in many directions, meaning that the optimum LED can be selected for every lighting requirement.

Conclusions

Closer examination shows that in addition to possessing the advantages described in the opening paragraphs, current LEDs are in no way inferior to conventional light sources when it comes to light quality and color rendering. What is more, research and development in the field of LED technology is extremely fast-paced and efficient, leading to the continuous optimization of these miniature light sources. In view of these results, LEDs are justifiably referred to as the light technology of the future. ■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Additive Manufacture of Optics Goes Digital

With a new technology for additive manufacturing, optics fabrication has gone digital, making more product innovation and variety affordable by eliminating the expense of molds and tooling, enabling just-in-time manufacturing and bringing a new freedom for optics and lighting designers. Marco de Visser, Business Development Manager at LUXeXceL B.V. gives an update on this technology and its new opportunities.

Not long ago, CDs were the way we all bought and enjoyed music. Then the computer industry, most notably Apple, digitized the music retail supply chain with handheld devices and online music stores. Listeners gained exponentially more choices and a more convenient way of finding and buying music. Stacks of physical CDs were replaced by databases of digital music files. Digital production and inventory revolutionized a massive industry in only a few years.

In the global lighting industry, there is another digital revolution beginning, catching the wave of the rapid shift to LEDs. The impact is on luminaire makers and their suppliers rather than on end customers. A new mode of digital production, digital inventory, and just-in-time supply chain efficiency is now available for the optical components of light fixtures. Arguably, after the light source itself, optics are the most critical determinant of a fixture's style and function, and also the industry's chronic, debilitating "bottle neck" of design, sourcing, and manufacturing.

Additive Manufacturing – The Third Industrial Revolution

Along with many other products, optics can now be produced by "Additive Manufacturing" - a set of technologies for making physical products directly from digital Computer Aided Design (CAD) files in only one step. With the traditional "subtractive" methods of milling, turning, grinding and polishing, material is cut away to achieve the desired form, either of the products directly or for making molds and tooling. In contrast, Additive Manufacturing, also referred to as "3D printing" or "rapid prototyping", builds products by progressive computer-controlled deposition of material, in a process that resembles printing, taking multiple passes over the work until the desired 3D form is achieved. In recent months, nearly all of the leading business publications have featured articles about how Additive Manufacturing ("AM") will streamline product development and accelerate the supply chain for many industries.

Extrusion and injection molding are the dominant way of making lighting optics today. Additive Manufacturing in the lighting industry is sometimes used to prototype new fixture casing designs, but not, until very recently, to make optics. The few AM systems which could print with clear materials could only offer parts good enough to test the form, but not the function of an optic.

In March 2012, the authoritative "Wohler's Report 2012," by Wohlers Associates, an independent consulting firm focused on Additive Manufacturing, cited "printoptical technology" as one of five new "Emerging Developments". The principal author, Terry Wohlers, explained this further in his keynote address at Rapid 2012 in Atlanta, USA, highlighting that this is the first ever AM process capable of producing a complex optical quality surface. It is also among the very few AM processes capable of making precise full color textures. Most remarkably, it is also among the first AM processes ready for economical higher volume manufacturing, not just for low volume rapid prototyping.

In August 2012, printoptical technology was honored by Frost & Sullivan with their prestigious "2012 European Enabling Technology Award in Advanced Optics for LED Lighting", commenting "Lack of optics flexibility, high costs, and long manufacturing lead-times have been the major challenges faced by LED system integrators. Frost & Sullivan appreciates the fact that LUXeXceL, with its innovative Printoptical Technology, has eliminated most of these challenges by combining 3D printing and optics".

What is Printoptical – How Does it Work

The printoptical process 3D prints optical structures using modified wide-format industrial inkjet equipment, engineered for high volume printing. Droplets of a transparent UV-curable polymer "ink" are jetted onto a translucent substrate and then cured by UV-lamps which are attached to the print head. The droplets are deposited in several passes until the desired form is built. The results are geometric or free-form shapes which may incorporate prisms or lenses, as well as full color graphics and textures. Even though the polymer ink is deposited in discrete drops, the final surfaces are optically smooth and fully functional. This is accomplished by allowing time for the droplets to join and flow into the desired shape before curing. By precise control of flow and using the natural mechanism of surface tension, optical quality surfaces are achieved with no further processing.

The use of clear inks for optics along with optional colored inks for tinting or for full color printing enables the creation of a broad spectrum of optical structures and design treatments, like troffers, diffusers, fresnel lenses, micro-optical surfaces, etc., along with colored and textured adjacent surfaces, optionally as an integrated single part. By adapting commercially available industrial inkjet printers, their reliability, speed, and precision are inherited and put to a new use.

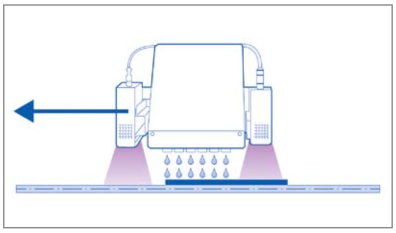
Geometrical Specifications and Materials

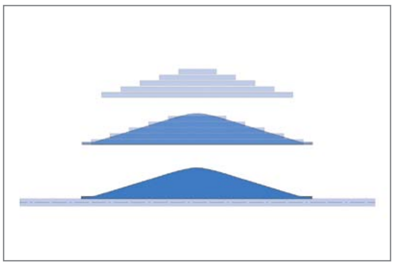
Instead of printing on paper, a sheet of translucent material is used as a substrate. Most frequently, sheets of Acrylic (PMMA) or polycarbonate are used, but films of Poly-Ethylene terephthalate glycol (PET-G) or polycarbonate, and many other substrate materials are available.

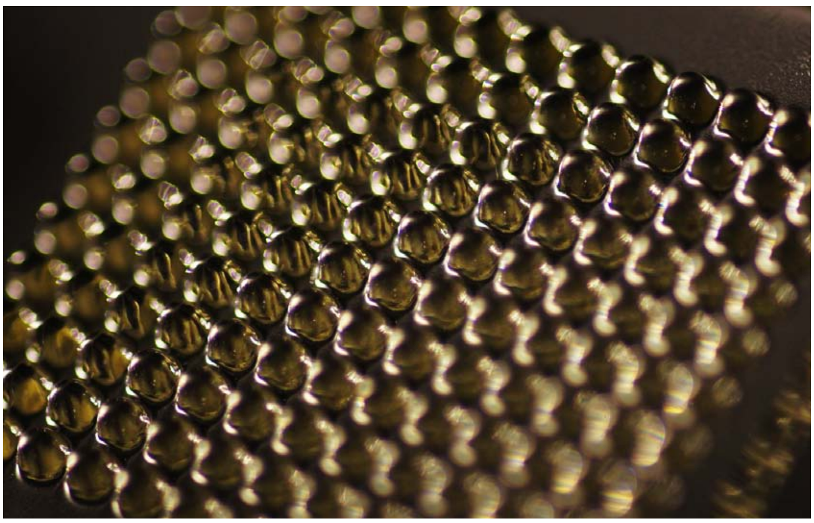
Thickness of the substrates used is typically from 0.3 mm to 8 mm, with thicker materials also possible. The design of the equipment means that printed optic can be any size up to the total available print area of 1280 x 2000 mm. More typically, many small lenses are produced on each sheet of substrate. After printing, the substrate sheet may be left as a single optic, or cut into smaller arrays or individual lenses.

Optics Manufacturing – Time to Evolve

A major obstacle to the introduction of new lighting fixtures is the current slow process for prototyping and commencing production of custom optics. Fixture manufacturers are impeded by the limitations and expense of injection molding. Meanwhile, the higher efficiency but more intense light of LEDs is making optics design more important than ever.







Figures 1 to 3: **Deposition of droplets by UV print head onto substrate material (left-top). Droplets of polymer are allowed to "flow" under surface tension before curing with UV light, giving smooth surfaces needed for optics (left-bottom). Array of micro-optic lenses (right)**

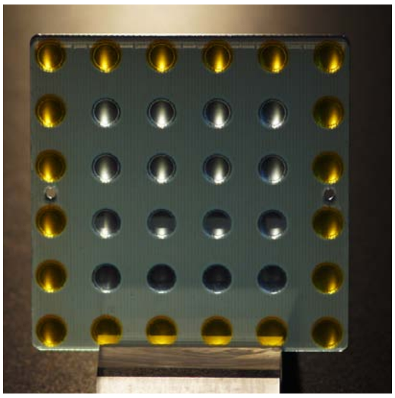
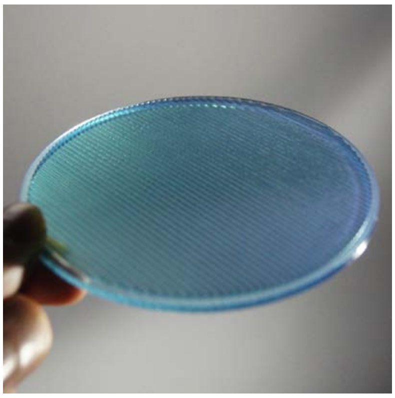



Figure 4: **Lens Array with dual lens coloring, integrated in an opaque textured panel (left)**

Figure 5: **Interchangeable prism lens with blue tint (right)**


Figure 6: **A multi-functional lens sample in wood grain - matte structure (left)**

Figure 7: **Functional lenses integrated in wood grain texture (right)**

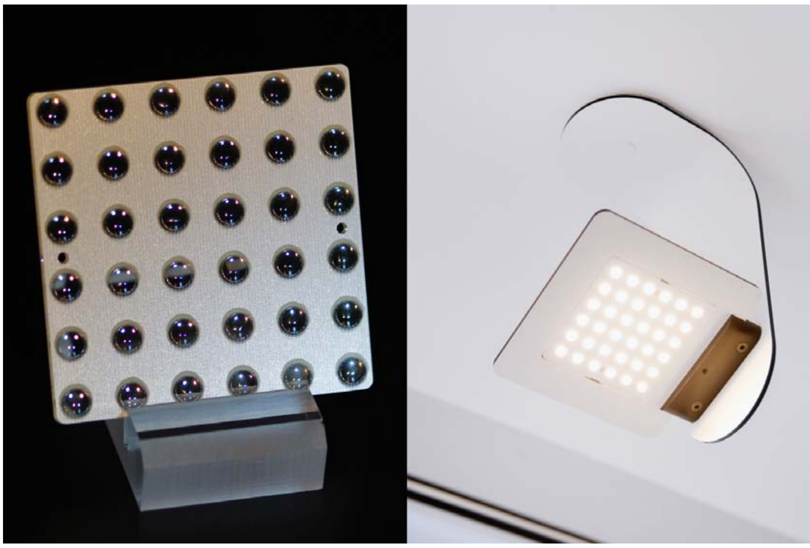


Figure 8: **Printoptical Lens Array including white surface texture (left) and its application (right)**

"Direct Digital Manufacture" of optics is the solution and Printoptical Technology is the leading approach. Instead of the expense and time for the tooling of a metal mold, now "the mold is digital", with only the CAD file needed to fully describe the optic and initiate its manufacture. Optics can be printed "on demand" with no minimum order quantity issues. Lead times from order to delivery are measured in days, not weeks or months. Limitations of tooling and molding are eliminated and new designs can flow from the imagination of designers with only a few limits on what is "printable," with these limits rapidly advancing.

Adapting optics designs:

CAD systems have long enabled optics designers to rapidly adapt designs to new requirements. With AM, short-run, custom manufacturing has become equally feasible. Optic designs can be modified and produced in new shapes, sizes and configurations, quickly adapting to changes in availability of other components, including the LEDs themselves, or to shifts in market demand.

Optics arrays:

Arrays of multiple lenses can be printed all as one part to eliminate assembly and reduce costs. Individual optics within a printoptical array need not be identical and may vary parametrically across a fixture. Textured and colored backgrounds or other decorative effects, frames and adjacent parts can be incorporated and printed in a single process.

New illumination patterns:

Due to the design limitations and trade-offs necessitated by traditional optics manufacturing, the current catalog of available luminaires is dominated by designs which use optics based on linear (extruded) or circular (turned) symmetric geometry. The resulting light-directing functionality has tended to be simple diffusion, sending light in all directions, or simple spot illumination, sending light in a conical beam. With printoptical technology, illumination patterns can just as easily be rectangular, trapezoidal, asymmetric or complex. Many surfaces we want to illuminate tend to be rectangular - rooms, desks, kitchen counters, tables, showcases, building facades, or parking lots. Optics designers and customers no longer need to accept the mismatch of a round spot with a rectangular painting, or streets that are alternately over- and under-illuminated due to the overlapping circular patterns of light from the lamp poles.

Even illumination:

Within the projected light pattern, AM optics can help make the level of illumination more even from edge to edge, or conformed to whatever gradient is desired. The prime targets for improvement are wall washers, streetlights, stage lighting, sports facilities, or anywhere that there is an irregular or oblique target space or where the placements of luminaires are problematic.

Colors and textures:

The printoptical process evolved from color graphics printing and so inherited its high resolution color capabilities. Color tints can be printed within the optic itself to adjust the color temperature of the light from an LED or for decorative effects.

Color mixing:

For luminaires using multiple colors of LEDs – e.g. RGB arrays – complex micro-optics can be designed and made using printoptical Technology which mix the colors to make a smooth white light distribution with uniform color balance from all angles.

Rapid, Low-Cost Prototyping Encourages Experimentation

In combination, these new capabilities open many new options and directions for optics design and novel, eye-catching and functional fixture designs. printoptical technology is both a prototyping and a production process. The low cost and speed of turn-around allow iteration, and the prototypes are fully functional and have the same performance as the final manufactured parts.

Complexity is for free:

Within the ever expanding bounds of what is “printable” there is no penalty for complexity. Costs for a complex mold can be prohibitive, but the complexity of the CAD file has minimal impact on the printoptical process.

Modular design options:

A lighting company might have one lighting fixture with many available optics. These could either be installed as a final fixture manufacture assembly step or offered to lighting designers and installers to allow them to install or change the optics themselves to match their needs, much as a professional photographer might fit different lenses to an SLR camera to match each photographic assignment.

Interestingly, we are starting to see novel luminaire designs that are only possible because of the printoptical technology. One noteworthy example is from a leading German Design and LED technology company, using an array of 36 micro-lenses printed in one pass as a finished assembly to produce this fixture, including the visual cover plate.

Commercially Available Now and Continuing to Advance

From a research and development effort in 2009 and 2010 to a 'very promising' technology in 2011, printoptical technology evolved into an award-winning commercial service offering in early 2012, with full production capability now available for non-imaging optics applications targeted to meet the requirements of the lighting industry.

Some limitations remain but future enhancements expected to further extend the printoptical process include:

Double sided lenses:

Using both sides of the substrate material to build the lens structure will take advantage of the improved precision of higher performance printers and a laser alignment process has been adopted to enable a continuously improving accuracy of the ink deposition onto the substrate.

Enhanced lens coloring and filtering:

Unfortunately, many of the light sources used today emit a spectrum of visible light which is less than ideal for popular applications. This can be adjusted through blending inks with color and additives. Although lens tinting is already a part of the printoptical capability portfolio, further measurement and calibration improvements are under development to deliver more accurate color correction.

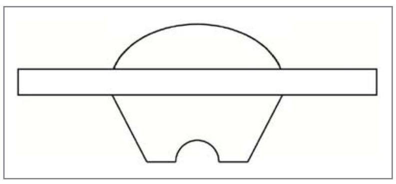


Figure 9: Substrate including double sided lens structure

Increased print precision:

Pitch diameters, the distance between the single structures or elements – are now limited to 1 mm for prism, fresnel and micro-optics made on current standard equipment with a resolution of 1,440 dpi and minimum droplet size of 7 picoliters. This limit will be pushed further to well below 1 mm with the adoption of equipment capable of higher dpi and smaller droplet size. Printers are commercially available with up to 9,600 dpi and minimum droplet size below 1 picoliter.

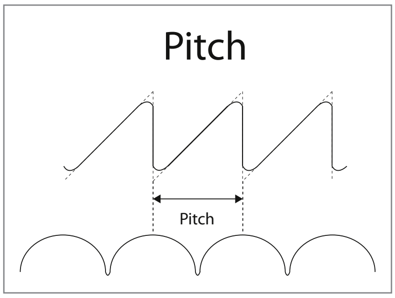


Figure 10: Prism and micro-optics pitch

Improved form factors:

Although the current 4 mm maximum total thickness of printed material covers much of optical market demand, there is room for further improvements. In the category of taller Total Internal Reflection (TIR) based lens designs, significant advances will be offered by the end of the year.

Economics

With the ascendance of LEDs, optics design and manufacture is becoming a more critical determinant of product development success and final profitability of luminaire makers. Direct Digital Manufacture of optics introduces the ability to produce fully functional prototypes, identical to proposed production optics, and being able to test market reaction, iterate the design if needed, place a small order to start and have finished units to customers – and new product

	"ANALOG"	"DIGITAL"
Optics Manufacturing	• Metal molds • Injection molded optics • Long lead times • Large minimum order quantities • Optics designs limited by molding & mold-making capabilities	• No mold – "the mold is digital", a CAD file • Printed optics • Short/no lead times – optics "on demand" • No minimums - Order one or 10,000 • Optics limited by digital process and designer's imagination
Resulting Economics	• Large investment per optic design • Large inventory of optics • Large write-off costs if availability of components, or customer/market needs change	• Low investment per optic design • Minimal Inventory – reorder as/when needed ("Just-in-time optics") • Free working capital to invest in new designs; write-offs not a drag on profits
Impact on Optic & Product Design	• High barriers to change & innovation • High barriers to testing new product variants or ideas • Limited product differentiation	• Low/minimal barriers to experimentation and testing of new concepts • Low barriers to testing new optics for existing fixtures. Reduced cost and time for new fixture designs and introduction • Product range can grow to serve customer's needs, address new segments, respond to Custom Lighting enquires, test new ideas, new forms, new approaches

Table 1: The impact on lighting fixture and optic economics

revenues – in a few weeks. Instead of trying to make forecasts of market demands months in advance and committing to large minimum order quantities, orders can be placed on an “on demand” and “as needed” basis.

The impact of “Just-in-time” supply seen in many other manufacturing processes can now allow optics stocks to be dramatically reduced. Instead of changes in LED availability, customer demand or market needs making forecasts obsolete and requiring the write-off of inventories, lighting companies can reduce their optics inventories and reorder stock only as needed creating an immediate saving in working capital and ongoing reductions in financial write-offs.

Custom Lighting groups often have the opportunity to respond to smaller run, high margin leads to meet lighting goals set by forward-thinking architects, lighting or interior designers. Often only the optic need be changed in an existing lighting fixture to meet these needs – perhaps a different beam angle or different light distribution pattern is required. With AM optics a revised CAD file is sent to the Printoptical service provider and fully working prototypes can be shown to the customer, often in time to win a bid from slower-moving competitors with paper designs and simulations, instead of working prototypes. When the project is won, as many optics as needed can be ordered. Faster time to market can mean more bids won on higher-margin orders, with little extra engineering time needed and no inventory risk.

When new lighting fixture ranges are being designed, fully working prototype optics can be ordered to be tested in prototype mechanical fixtures. Customer reaction can be gauged, changes made, designs improved. The difference between a slow, expensive prototyping process and a fast, inexpensive one isn’t subtle, it’s radically better. It has recently become known that Apple used 3D printing as part of its prototyping process and that over 40 designs were tried before the final design of the iPhone was selected. This change allows more design alternatives to be tried, more risky experiments made. Low cost risk taking can make innovation happen on a regular basis. Printoptical technology has already helped its customers to create product variations and cutting-edge products, taking immediate advantage of new LED chips and modules.

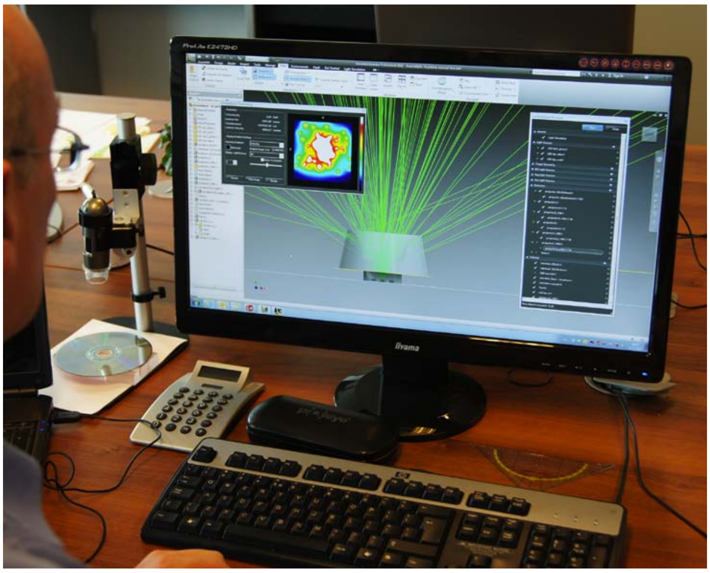


Figure 11: New optic designs can be created and visualized on CAD systems before being sent for manufacturing directly from a CAD file

Outsourced Manufacturing

Most lighting fixture companies already outsource the manufacture of optics. For them, using printoptical technology will be a very familiar process of discussion with the supplier and usually submission of a CAD file of the optics design in any of several common CAD file formats.

Currently CAD files from SolidWorks (.SLDPRT and .SLDASM file formats), Inventor (.IPT and .IAM), AutoCAD (.DWG and .DXF), and Photopia (.RAY) can be used directly as well designs from other CAD systems using common interchange file formats (incl. .STP, .STE, .STEP, .STL and .IGES).

What changes most is the up-front cost and lead times. For prototypes, turnaround in 1-2 weeks or a rush order in a few days is the new norm, instead of waiting weeks for molded prototypes. The prototype optics are made on the same machines and are identical to subsequent production pieces. The digitally-made prototypes are returned quickly and are commonly an order of magnitude cheaper than comparable alternatives.

If a lighting company is ready to commit to ordering huge numbers of identical optics, the expense of production tooling for injection molding may still be warranted. The upfront cost for molds can be amortized as a small per unit component of cost compared to the cost of materials and the machine-time to make each piece. However, the economics of printoptical manufacture is clearly advantageous for smaller volumes, from one piece up to 50,000 – 100,000 pieces, depending on the complexity of the optic. In fact, many luminaire makers might consider splitting their larger optics orders into smaller separate commitments, possibly with variations of design, keeping their options open and avoiding the heavy working capital and inventory risk.

Optics Designers Can Lead the Way to Increased Profitability

With AM, optics can shift from being the bottleneck that slows down the process of new product introductions to being a powerful competitive weapon. Optics designers are finding that prototypes made with Printoptical Technology are typically not just much faster and cheaper than molded prototypes but also lead to better fixtures. Given that most designers have an optic prototype manufacturing budget already, they find that they can easily test the claims of this new process for themselves on their designs and their CAD files. The recognition by Wohlers Associates and Frost & Sullivan are strong validation, and the description here above should answer some questions. But the really convincing test is to see an actual prototype optic, made from your CAD file or design, produced in only a few days. Fortunately, it is not necessary to buy expensive equipment or learn to use new software. printoptical manufacture is available as a service with no minimum order quantities and very affordable pricing.

Once printoptical technology is experienced in-house by optics and fixture designers, more applications and benefits will be discovered. The technology is still new, but Additive Manufacturing of optics already appears to provide an important new core technology for lighting industry and deserves to be evaluated by every maker of luminaires. ■

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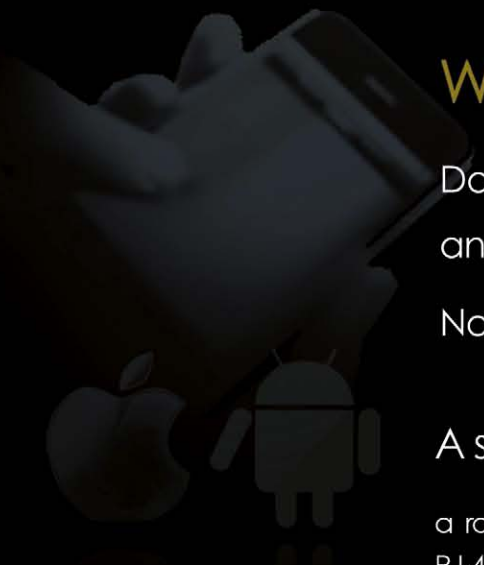

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Content

Introduction to Zhaga and Zhaga's Spotlight Specification

Menno Treffers from Philips Lighting, and Zhaga's Secretary General gives background information about Zhaga and explains why the selected articles are relevant for better understanding the aims of Books One and Three.

The lighting industry has always worked with standard light sources. Conventional light sources, such as fluorescent tubes, are available from different manufacturers, and when a fluorescent tube from another supplier is used, the luminaire need not be modified. Conventional light sources are interchangeable. LED retrofit lamps are also interchangeable, but LED retrofit lamps cannot unlock the full potential of the LED revolution.

Making LED Light Sources Interchangeable

The industry uses LED modules with new form factors and optimized thermal design in high performance LED spotlighting applications. LED modules, unfortunately, are not interchangeable. At least not until today.

LED modules are offered in many different shapes and light distributions, and many lighting companies make their own mutually incompatible LED modules. All these variations are useful in the early stages of a technology, when we experiment with product architectures and system solutions, but by now the lack of standardization is becoming a limiting factor in mass market adoption of LED in general lighting.

The R&D cost of LED lighting systems will remain high without interchangeable light sources. The rapid improvement in LED technology makes it necessary to constantly upgrade the LED light source: new LEDs, new drivers, and frequent testing for certification marks such as UL, CE, or ENEC.

And, even more important, the business risks of developing and selling LED lighting systems remain high without interchangeable light sources because the supply of components is uncertain, stock levels must be high to hedge that uncertainty, and the risk of obsolescence and write-offs is high.

The Zhaga Consortium was established with the goal to make LED light sources interchangeable. This will benefit luminaire manufacturers because it lowers their R&D costs and business risks, and it benefits the manufactures of LED modules because they can supply a larger and faster growing market with lower selling expenses and reduced risk of obsolescence.

What Is an Interchangeable Light Source?

In this context we consider two light sources interchangeable when one light source can replace the other light source without any change in the luminaire. We are not only talking about end-user replaceable light sources, but also about LED modules (PCBs) that are integrated into the luminaire and can be sealed for life. In the latter case, interchangeability means that the manufacturer can switch from one supplier to another without modification in the manufacturing process of the luminaire.

In Zhaga we use the term "LED light engine" when we talk about interchangeable light sources. We use this term to identify the combination of an LED module and its associated current source. As with many conventional light sources, the LED light engine is not necessarily integrated in a single housing: the driver or ECG that supplies a stable current to the LEDs may be separate from the LED module from which the light is emitted.

To achieve interchangeability, the luminaire must "know" what to expect from an LED light engine:

1. The maximum size (the mechanical outline)
2. The fixation method (e.g. screws at fixed positions, or a holder)
3. The amount of heat generated by the LED light engine as well as the maximum operating temperature
4. The location and size of the light emitting surface, in relation to the luminaire's reflector
5. The distribution, uniformity, and other photometric properties of the light emitted by the LED light engine
6. The electrical characteristics (e.g. mains voltage requirements, control methods)

Note that "interchangeable" does not imply "identical". "Interchangeable" means that the differences are acceptable in the context of a particular lighting application. It is not necessary that light engines are identical. If we ask that light sources become identical it would limit innovation, it would limit the possibility to differentiate lighting products, and it would make it more difficult to target applications with special requirements.

What Is an Interface Specification?

Zhaga specifies the interface between an LED luminaire and an LED light engine. A good interface specification defines only the interaction between luminaire and light engine. It should not unnecessarily restrict the design of the light engine, or the design of the luminaire. A good interface specification allows innovation inside the light engine while keeping the interaction with the luminaire stable.

Zhaga specifications have requirements for products on both sides of the interface: the LED luminaire has to provide the proper environment for the LED light engine, and the light engine has to fit inside the luminaire.

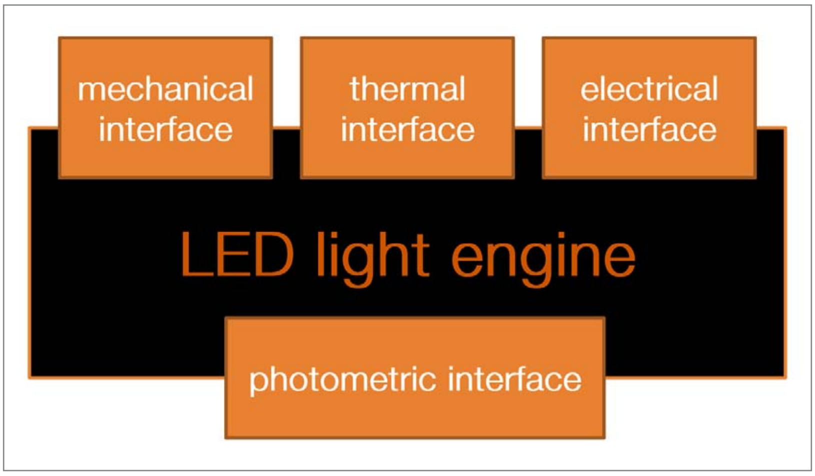


Figure 1: Zhaga specifications define the interaction between light source and luminaire without restricting innovation in the technology inside the light engine

Zhaga specifications describe test procedures for luminaires and test procedures for light engines. These test procedures help the product developer to determine whether their product complies with all the Zhaga requirements. The test procedures are meant to be complete and sufficient. Ideally, an LED light engine that passed all tests will fit in all luminaires that passed the tests, and the behavior of the lighting system (the combination of luminaire and light engine) is fully predictable. In practice it is difficult to specify the test procedures 100% complete. The Zhaga members deal with this challenge by building prototypes and testing them before the specification is released. That way it is possible to identify ambiguities and inconsistencies, and revise and improve the specifications. By the time the first products arrive on the market the test specifications are mature and give sufficient coverage.

Book 3 - the Interface Specification for a Spotlight Engine

Spotlight engines are the first products in the market that use a Zhaga specification. This Zhaga specification is called "Book 3: Spot LED Light Engine with Separate Electronic Control Gear". It defines a 50 mm round LED module.

Figure 2: Impression of a Zhaga spotlight engine

The Zhaga members who developed Book 3 faced many engineering challenges. Some of these challenges are described in articles that are published together with this introductory paper.

1. How the mechanical dimensions and optics contact area (OCA) are used to fix the LED spotlight module to the heat sink and to accurately position the reflector.
2. How the position of the Light Emitting Surface (LES) influences beam angle and center intensity.
3. How non-uniformity of the emission from the LES is characterized, and what deviations from an ideal Lambertian source can be tolerated in an LED spotlight module.
4. How an optional locking ring makes it possible to replace an LED spotlight module without using screws and special tools.
5. How the thermal properties of luminaire and light engine are determined and how the system behavior can be derived from the test result of the components.
6. How to measure the heat dissipation by the light engine at the interface with the luminaire. This is a new type of thermal test that was developed to avoid over-dimensioned heat sinks when matching LED light engines with luminaires.
7. How the specification of the mechanical dimensions of Electronic Control Gear (ECG), makes it possible to easily interchange the ECG when the manufacturer chooses a different LED spot light module for the luminaire.

Book 1 – a Special Specification

Several test procedures and aspects of the Book 3 specification are not unique to the Book 3 spotlight engine. The thermal test methods, for example, apply equally well to Zhaga's Book 2, Book 4, Book 5 and Book 6. The mechanical dimensions of ECG housings apply to all Zhaga light engines that have a separate electronic control gear.

The Zhaga members have collected these common specifications in Book 1 "Overview and Common Information". Whereas this book does not specify a light engine and you will find that the other Zhaga books reference Book 1 quite often. ■

Definitions and References:

LED Luminaire: A lighting fixture which provides an appropriate environment for one or more LED light engines.

LED Light Engine: A combination of on ECG (Electronic Control Gear) and one or more LED modules.

LED Module: A light source that is supplied as a single unit. In addition to one or more LEDs, their mechanical support and their electrical connection, it may contain components to improve its photometric, thermal, mechanical and electrical properties, but it does not include the electronic control gear.

Book 1: A specification that provide a set of requirements and tests which are considered to be generally applicable to most types of LED light engines and corresponding luminaires.
See also: http://www.zhagastandard.org/specifications/book-1.html

Book 3: The interface specification for a spotlight LED light engine, consisting of an LED module and an electronic control gear in separate housings.
See also: http://www.zhagastandard.org/specifications/book-3.html

Electronic Control Gear or ECG:
A unit that is located between the external power and one or more LED modules to provide the LED module(s) with an appropriate voltage or current. It may consist of one or more separate components, and may include additional functionality, such as means for dimming, power factor correction, and radio interference suppression.

Key Facts on the Mechanical Properties of Book 3 Modules

Ralph Bertram from Osram and Martin Creusen from Philips Lighting present the mechanical properties of Zhaga compliant modules of the "Book 3 - Spot LED Light Engine with Separate Electronic Control Gear".

To enable interchangeability of LED light sources, the Zhaga consortium has created several interface specifications for LED light engines covering different general lighting applications. One of these interface specifications is called "Book 3: Spot LED Light Engine with Separate Electronic Control Gear". This Book defines the interface between a luminaire and a LED light source consisting of a round ø50 mm LED module and its associated electronic control gear (driver) in separate housings.

LED light sources that comply with "Book 3" are interchangeable. That means that a luminaire manufacturer can replace the light source with another Book 3 compliant light source without any change in the mechanical, thermal, and photometric components of the luminaire.

In this article we explain how the outlines of the LED module are defined and which freedom both the LED module and the luminaire manufacturer still have when designing their products. We will also discuss why the mechanical dimensions are specified in this way and how it stimulates interchangeability of LED light sources.

Zhaga Defines Mechanical Outlines for the LED Module

The first and most obvious task when creating an interchangeability specification is to define the mechanical dimensions of the exchangeable part. Zhaga interface specifications provide sufficient freedom to manufacturers to create their own designs, while ensuring interchangeability between modules of different manufacturers.

As an optimum trade-off between module compactness versus proper thermal management, Zhaga has decided to use 50 mm as a typical module diameter and allow a module height of maximum 7.2 mm. To provide good thermal contact, the module is intended to be screwed to the heatsink base of a luminaire by an (OEM) luminaire manufacturer. Extensive thermal investigations have shown that two M3 screws at a distance of 35 mm are sufficient. Exact size and position of screw holes and screw head supports are prescribed in the specification.

Light is emitted from an area in the center of the module, called the Light Emitting Surface (LES). Zhaga does not limit the technology for light generation, as clearly shown by the prototypes that were developed to test the specifications (Figure 1). Regarding the LES specification, the light emission height is variable and sufficient space is foreseen for elements like outcoupling domes, optical mixing elements or electrical safety barriers around and above the LES itself.

The LED modules specified in Zhaga Book 3 are expected to be used primarily with reflector optics provided by the luminaire manufacturer. Consequently, to allow a reflector to be mounted close to the LES in the center of the module, Zhaga defined a recessed reference surface for attachment of the reflector (Optics Contact Area – OCA / Figure 2). This OCA has a defined height of 4 mm, so a luminaire construction can rely on a mechanical support and make sure that no light is escaping

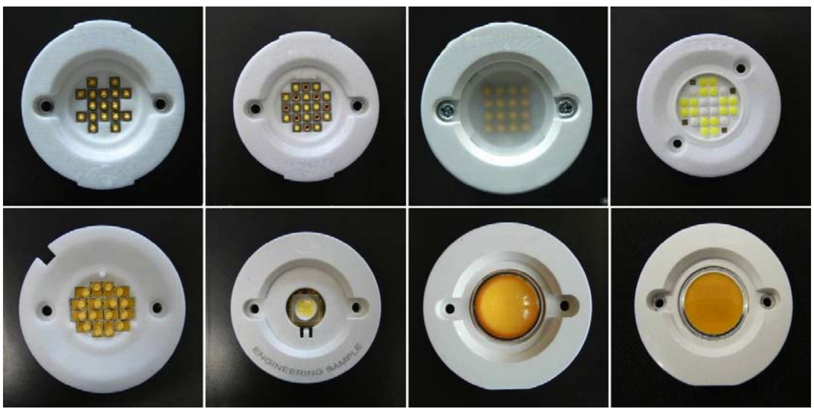


Figure 1: **Spot module prototypes made by different Zhaga members to test the Book 3 specification**

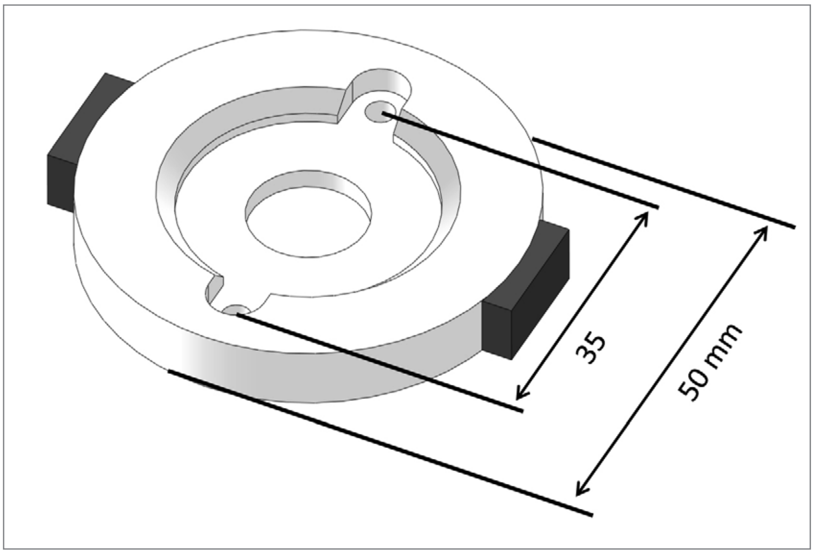


Figure 2:
Module maximum outlines

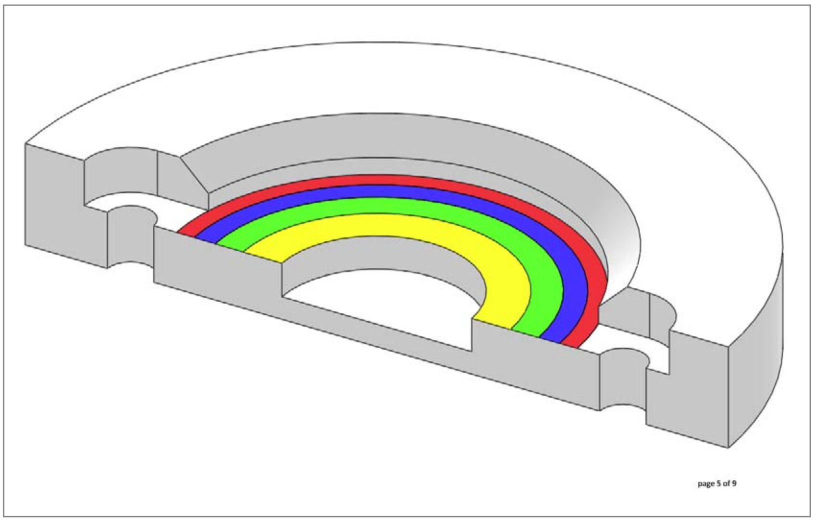


Figure 3:
Four Optical Contact Area (OCA) categories defining a mechanical reference plane positioning different (external) reflector geometries

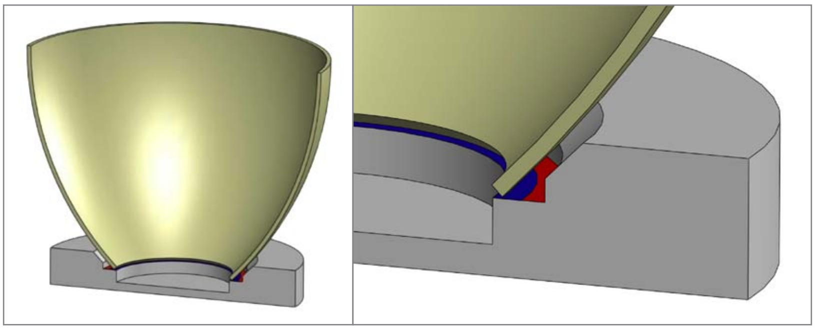


Figure 4:
Different reflector designs and materials can be accommodated by the Zhaga spot module design (drawings by P. Sachsenweger)

below the reflector. The OCA outer dimension has a defined diameter for all modules. The inner dimension depends on the LES size and is classified in 4 OCA categories (Figure 3). This categorization enables consistent design of different reflector geometries.

Except the OCA height, the rest of the module shape is defined as a maximum outline only. Thus, LED module manufacturers may decide to reduce the module height or even completely change the shape of the resulting module, as long as the module is smaller or equal to the maximum module outline indicated in figure 2. On the other hand, the luminaire designer exactly knows the maximum space that may be occupied by the module and can design his luminaire such that every Zhaga certified module will mechanically fit into the fixture. Furthermore, Zhaga carefully designed the module outline to accommodate typical reflector materials and shapes, as can be seen in figure 4.

For connecting the LED module to the Electronic Control Gear (ECG) or to interconnect another LED module, space for electrical (inter)connection should be foreseen as indicated in the grey area in figure 2.

Summarizing, Zhaga has brought together luminaire and LED module designers and defined the mechanical interface of LED modules to facilitate both module and luminaire design enabling interchangeability of LED light sources. ■

Definitions and References:

LED Light Engine: A combination of one ECG (Electronic Control Gear) and one or more LED modules.

LED Module: A light source that is supplied as a single unit. In addition to one or more LEDs, their mechanical support and their electrical connection, it may contain components to improve its photometric, thermal, mechanical and electrical properties, but it does not include the electronic control gear.

Book 3: The interface specification for a spotlight LED light engine, consisting of an LED module and an electronic control gear in separate housings. See also: http://www.zhagastandard.org/specifications/book-3.html

Electronic Control Gear or ECG: A unit that is located between the external power and one or more LED modules to provide the LED module(s) with an appropriate voltage or current. It may consist of one or more separate components, and may include additional functionality, such as means for dimming, power factor correction, and radio interference suppression.

Zhaga's Light Emitting Surface (LES) Concept and its Impact on the Light Distribution

Stefan Lorenz from Osram gives a detailed explanation how the Light Emitting Surface (LES) of Book 3 modules is defined and how various sizes of the LES enable different beam angles.

To enable interchangeability of LED light sources, the Zhaga consortium has created several interface specifications for LED light engines covering different general lighting applications. One of these interface specifications is called "Book 3: Spot LED Light Engine with Separate Electronic Control Gear". This Book defines the interface between a luminaire and a LED light source consisting of a round, 50 mm diameter, LED module with a central light emission and its associated electronic control gear (driver) in separate housings.

LED light sources that comply with "Book 3" are interchangeable. That means that a luminaire manufacturer can replace the light source with another Book 3 compliant light source without any change in the mechanical, thermal, and photometric components of the luminaire.

This article explains how the optical emissive area of the LED module is defined, and how design freedom for luminaire optics as well as interchangeability for different LED light engines is ensured by this definition.

The Light Emitting Surface LES

Zhaga Book 3 LED Light Engines are expected to be used mainly in combination with collimating optics like reflectors within a luminaire. The Zhaga specification uses a generalized description of the optical interface between LED light engine and luminaire optics, called Light Emitting Surface (LES). This generalization enables comparison and categorization of LED light engines without referring to specific LED technologies or LED layouts, thus providing design freedom for the LED Light Engine while at the same time ensuring similar optical properties. For the luminaire optics design, on the other hand, it is sufficient to use the abstract LES description as optical reference, and not a specific LED light engine.

The Light Emitting Surface (LES) in Zhaga Book 3 is a round plane from which ideally the light of the LED module should be emitted. It covers all light emitting parts of a given LED module. Zhaga Book 3 defines four LES size categories, depending on the LES diameter.

The Zhaga Specification includes instructions on how to determine the actual LES diameter as well as the LES category of a given LED light engine. Both values are included in the product data set of each Zhaga LED module or LED light engine, so that optical interchangeability can easily be checked by comparing the individual LES categories.

Apart from the LES diameter, also the allowed LES height is also specified within Zhaga Book 3. The range of possible heights depends on the LES category, being smaller for small nominal LES diameters. The categorization of LES diameter and LES height is introduced to ensure that LED light engines within the same category will have similar optical performance in a luminaire optics with regard to beam angle. The category sizes were chosen

Table 1: **LES categories, including nominal, maximal and minimal LES diameters**

LES category name	LES category nominal diameter [mm]	LES maximum diameter [mm]	LES minimum diameter [mm]
LES 9	9.0	9.0	>6.3
LES 13.5	13.5	13.5	>9.0
LES 19	19.0	19.0	>13.5
LES 23	23.0	23.0	>19.0

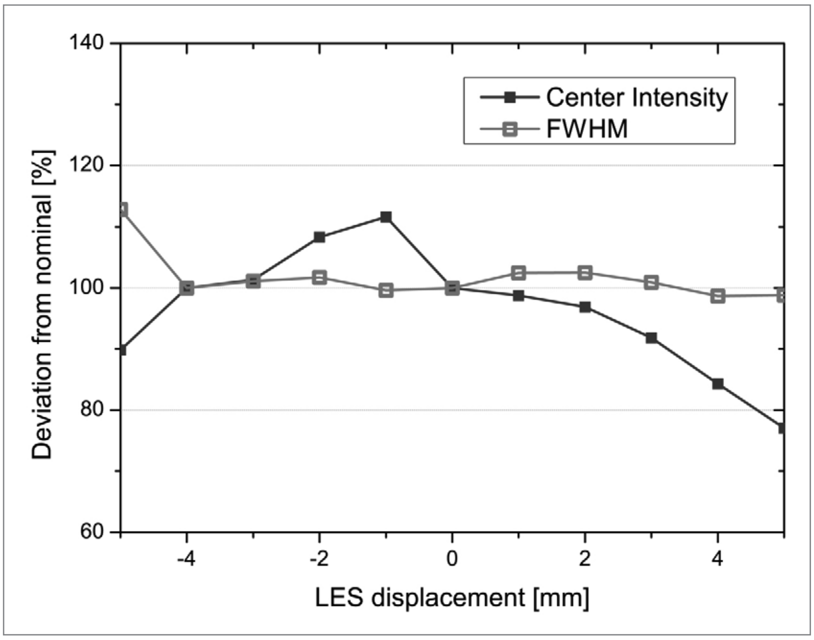


Figure 2:
Variation of beam angle and center intensity with different LES height, shown with a sample LES of 16mm diameter (i.e. LES category 19) in a typical reflector

The same is true for LES height. The LES height range associated with each LES category ensures that optical performance with typical reflectors is not altered when exchanging different LED light engines from one category. A sample calculation with a typical reflector is shown in figure 1, where FWHM and center beam intensity are shown versus LES displacement from nominal 4,0 mm height. Note that for LES category 19 as in this example, the allowed deviation would be -4,0 up to +2,4, as defined in Zhaga Book 3. It is clearly visible that within the category limits, the variation of LES height has negligible impact on optical output.

such that beam angle of a given optical system will not vary by more than 12,5% when using LED light engines from the same LES category.

For the design of luminaire optics, e.g. reflectors, it is sufficient to use the LES category as a reference. The nominal LES diameters are given in table 1, the nominal LES height is always 4,0 mm. This coincides with the height of the Optical Contact Area (OCA), which is the mechanical reference surface for reflector attachment in Zhaga Book 3 LED light engines. An optical system, which is designed for a given LES category, can be used optically with all LED light engines which have the same LES category.

Impact of LES Position and Category on Optical Luminaire Performance

The LES category spacing has been chosen so that a few categories can cover a large range of actual diameters, while still ensuring that beam angles don't exceed a certain variation band. In most reflector designs, the beam angle decreases with decreasing LES diameter. As long as a LED light engine is exchanged with another one from the same category, the beam angle variation stays sufficiently small. If a LED light engine is exchanged with another one from a different category, significant changes in beam angle can be the result.

Summary

To summarize, the LES concept allows luminaires to be constructed independently of a certain LED light engine. By having a luminaire optics which is suited for one LES category, all Zhaga Book 3 LED light engines which fall into this category can be used for this luminaire, regardless of their LED type or layout, and will produce comparable optical output.

Definitions and References:

LED Light Engine: A combination of on ECG (Electronic Control Gear) and one or more LED modules.

LED Module: A light source that is supplied as a single unit. In addition to one or more LEDs, their mechanical support and their electrical connection, it may contain components to improve its photometric, thermal, mechanical and electrical properties, but it does not include the electronic control gear.

Book 3: The interface specification for a spotlight LED light engine, consisting of an LED module and an electronic control gear in separate housings. See also: http://www.zhagastandard.org/specifications/book-3.html

Electronic Control Gear or ECG: A unit that is located between the external power and one or more LED modules to provide the LED module(s) with an appropriate voltage or current. It may consist of one or more separate components, and may include additional functionality, such as means for dimming, power factor correction, and radio interference suppression.

Light Emitting Surface or LES: A physical or virtual plane on the LED module or LED Light Engine which characterizes the light emission in a simplified and generalized way. Its shape, size, and position allow to group the LED Light Engines into different categories which are optically interchangeable, and enable Luminaire Optics design without referencing to a specific LED Light Engine.

Luminaire Optics: A set of one or more optical elements, which shape the light output of the LED Light Engine, not being part of the LED Light Engine itself.

Criteria of the Photometric Interface of a Zhaga Compatible LED Light Engine

Horst Rudolph, from Trilux, explains criteria of the photometric interface of a Zhaga compatible LED Light Engine based on "Book 3 - Spot LED Light Engine with Separate Electronic Control Gear".

The Zhaga Specifications (called Zhaga Books) define LED Light Engines ("LLE") consisting of one or more LED modules and an electronic control gear. The LED module is to be mounted to or into a Luminaire by an OEM luminaire manufacturer. The luminaire may incorporate optical elements ("luminaire optics"), which shape the light output of the LED module to a specific light distribution which is required in the application for which the luminaire is designed for. In that case the light output of the LED module itself has a general distribution which is defined in the respective book.

The photometric interface of the Zhaga compatible LED light engine is specified in such a way that using suitable luminaire optics (reflectors, lenses, prisms, etc.), similar luminaire performance is to be expected using different LLEs with the same photometric interface. The specifications have been carefully evaluated to yield as much "similar" performance as possible without either restricting the inner structure of the LED module or the LED technology used inside. This has been done to leave as much room as possible for technical innovation in this field.

For spot light applications, for example, the definition of the photometric interface has been developed aiming at a maximum deviation in both beam angle and center beam intensity of luminaires with reflectors of +/- 12,5 % from sample average. Testing of the standard with reference parts has shown that these criteria could be met. However, it cannot be guaranteed for any combination of luminaire optics and LED light engines.

This article explains some criteria of the photometric interface of a Zhaga compatible LED light engine and its interaction with the luminaire optics.

Luminous Intensity Distribution ("light distribution")

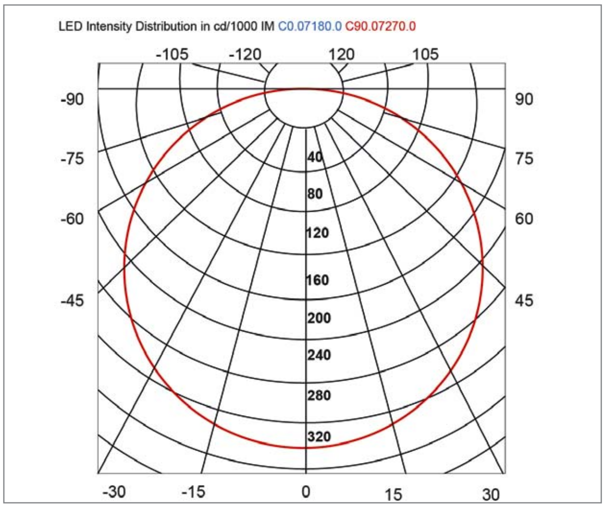
In the case that the LED module is co-operating with luminaire optics, the general light distribution of the LED module itself shall be Lambertian-like as shown in figure 1. A way to describe such a light distribution in more detail is to divide this curve into several parts and calculate the relative luminous flux that is emitted in each part. The CIE has developed such a principle, which is well known and broadly used to define the so called "CIE flux codes" of light sources.

Zhaga uses the same principle to describe Lambertian-like light distributions in more detail and restrict deviations from the ideal Lambertian-like light distribution (Figure 2). Deviations will occur because Zhaga LED light engines from different manufacturers will not be identical in any detail, even when they are designed to meet all specifications of the same Zhaga standard. For example, the height of some LED modules outlines are just defined as maximum values, resulting in different shielding angles between LEDs and module outline.

The luminous intensity distribution of the LED module is divided into 4 parts, where each of them covers the same solid angle of $\omega = \pi/2$. The relative luminous flux fractions of an ideal Lambertian-like light source are shown in table 1. Many tests and photometric calculations with different luminaire optics have shown that LED modules for spot light applications may deviate from the relative luminous flux fractions as also shown in table 1, and still lead to comparable photometric results in the application. There will be other minimum and maximum restrictions for other LED light engines, depending on the application they are designed for.

Figure 1 (left): Lambertian-like light distribution

Figure 2 (right): CIE zones to calculate flux fractions



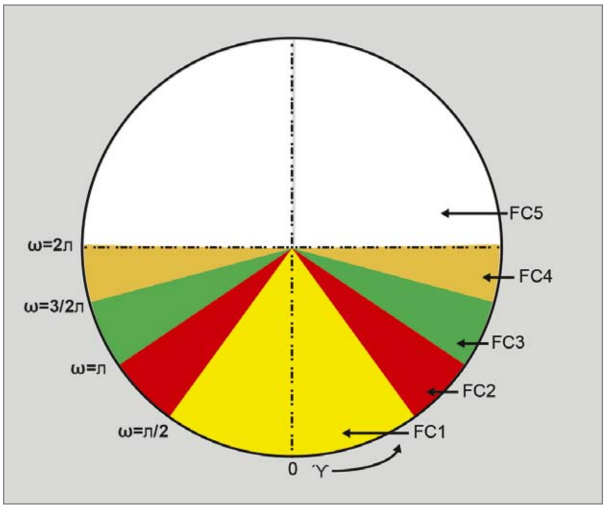


Table 1: Relative partial luminous flux

		Relative Partial Luminous Flux		
Flux zone	γ-angles (all C-planes)	Ideal Lambertian-like light source	Minimum value of spot light LLE	Maximum value of spot light LLE
FC1	0° - 41.4°	43%	39%	56%
FC2 – FC1	41.4° - 60°	32%	31%	37%
FC3 – FC2	60° - 75.5°	18%	11%	22%
FC4 – FC3	75.5° - 90°	7%	0%	7%

Luminance Properties

It is also very important to specify the near field light distribution in the Light Emitting Surface ("LES") to achieve similar light beams when luminaire optics are attached to the LED module. Otherwise, the illuminated task area may show bright spots or dark regions instead of the desired homogeneous appearance. Therefore, the light emitting surface is divided into several areas of the same size with which the luminance characteristics are calculated (Figure 3).

These areas allow the calculation of symmetry factors (horizontal, vertical or rotational symmetry) without counting the single LEDs which may be placed in an arbitrary variety inside the light emitting surface (Figure 4). It is also possible to calculate the center balance of the light emitting surface by taking the luminances of the inner and outer areas into account. For some Zhaga compatible LED light engines some or all luminance properties may be reported in the datasheet because they affect the light distribution of the appropriate luminaire via the luminaire optics.

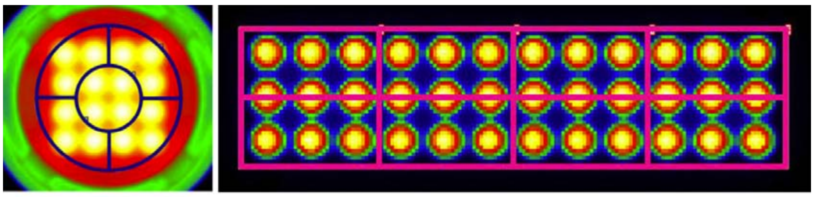


Figure 3: The light emitting surface of LED modules for spotlight applications is divided into 5 areas (left) and for streetlight applications it is divided in 8 areas (right) for luminance characterization

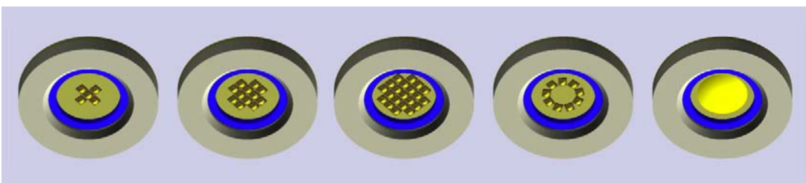


Figure 4: Arbitrary variety of LED arrangements inside a circular shaped Light Emitting Surface

For some LED modules additionally a more detailed evaluation of the uniformity parameter is also necessary to ensure a similar performance of the appropriate luminaire in the application. After testing different mathematical principles and comparing their results with visible effects on task areas which were illuminated with a huge variety of different LED modules attached to luminaire optics, the following principle was chosen to achieve the LES uniformity value:

Measure the luminance distribution of the light emitting surface with an imaging luminance measuring device. Calculate the average luminance L_{avg} and the RMS (Root Mean Square) of the luminances L_j of every pixel j inside the light emitting surface with $RMS = \sqrt{(\sum L_j^2 / N)}$. The number of pixels N shall not be less than 500. The uniformity parameter shall be calculated $U = L_{avg} / RMS$.

More specifications for all technical interfaces of LED light engines are defined in detail in the respective Zhaga Books to make electronic light sources interchangeable. ■

The Optional Locking Ring – A Quick Connection for Zhaga's Book 3 Modules

Matteo Raimondi from A.A.G. Stucchi demonstrates the Locking Ring option specified in the Zhaga Book 3 "Spot LED Light Engine with Separate Electronic Control Gear"; requirements, specification and benefits.

The Zhaga consortium has created several interface specifications for LED light sources. One of these interface specifications is called "Book 3: Spot LED Light Engine with Separate Electronic Control Gear". Book 3 defines the interface between a luminaire and an LED light source consisting of a round, 50 mm diameter, LED module and its associated electronic control gear (driver) in separate housings.

LED light sources that comply with "Book 3" are interchangeable. That means that a luminaire manufacturer can replace the light source with another Book 3-compliant light source without any change in the mechanical, thermal, and photometric components of the luminaire.

The so-called "Locking Ring" system is an optional component developed for the Book 3 spotlight engine. In this article we explain what the locking is and what requirements it places on the LED module.

Figure 1: Overview of the single components of the Zhaga "Locking Ring" system for Book 3 modules and the attached system

The Locking Ring

The locking ring is a module holder that, when used together with its matching ring, eliminates the need to screw the LED module onto the heat sink. The locking ring has been inserted in the Zhaga Book 3 as an alternative to the screw-fixing for LED spot modules.

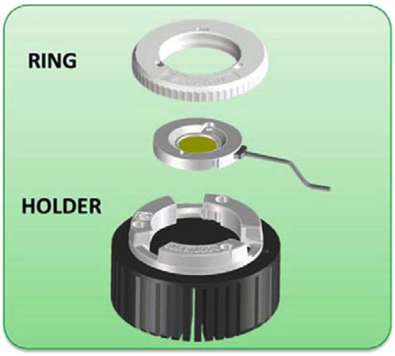


Figure 2: The Locking Ring consists of two components: one holder and one ring

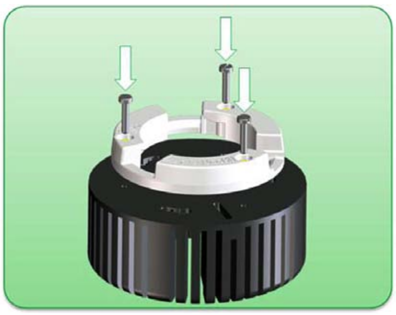


Figure 3: The holder is fixed to the heat sink

Figure 4:
When the module is positioned inside the holder, the rotation of the ring gives the required pressure to the module against the heat sink and fixes the module in the correct position

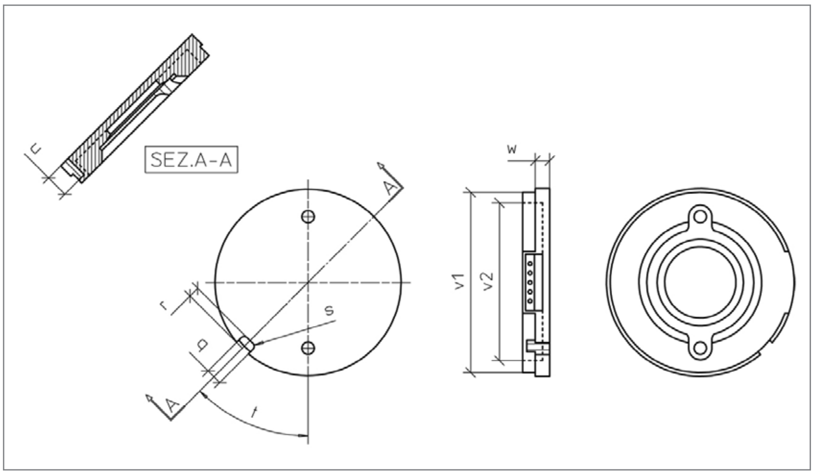


Figure 5:
Drawing of the optional features that are necessary for a locking ring system

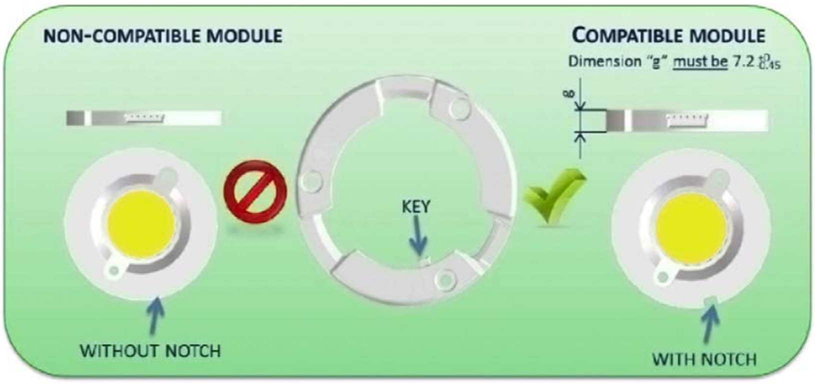


Figure 6:
Differences between modules that are compatible and non-compatible to the locking ring system

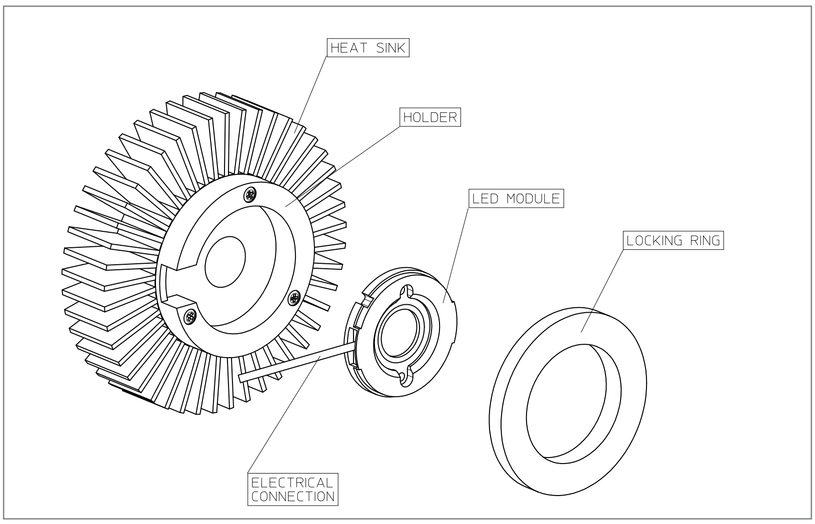


Figure 7:
Functional drawing of the locking ring interface and the module

The Requirements for the Locking Ring in Zhaga

In Book 3, the requirements for the locking ring system are described in Chapter 3 “Mechanical Interface”.

In paragraph 3.8 “Optional Locking Ring Feature”, some extra-requirements for the module are specified, while in paragraph 3.12 “Optional Locking Ring System (LRS)” the mechanical interface between the holder and the module is described.

Paragraph 3.8 “Optional locking ring feature”

Zhaga Book3 allows two different designs for the spot module that could be named “Normal” and “Locking Ring” configuration.

In the **“Normal” configuration,** the maximum outline of the spot module is

- Circular diameter of 50 mm
- Minimum height “g” not defined

In this case the module is NOT COMPATIBLE with the locking ring, meaning that it can be fixed only by screws.

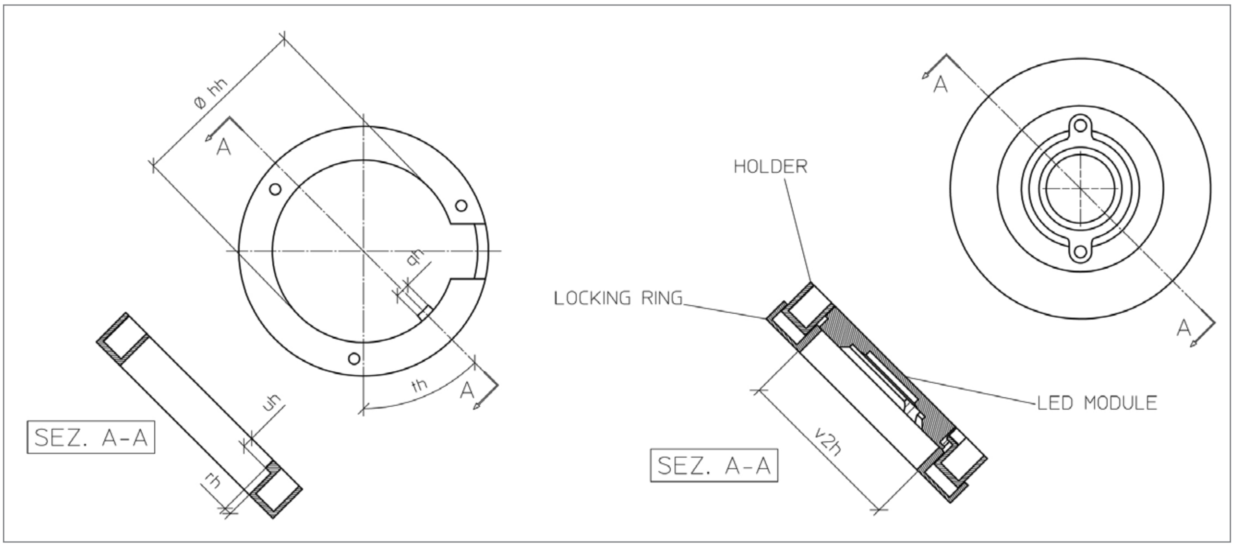
In the **“Locking Ring” configuration** the module shall fulfil the following characteristics:

- A notch positioned on the outer diameter of the module (as described in Figure 5)
- Minimum height “g” of 6.75 mm
- The module can withstand 50 N of force by the holder

In this case the module is COMPATIBLE with the locking ring. In other words, the notch prevents installation of non-compatible LED modules.

Modules designed with the notch and with a thickness from 6.75 mm to 7.2 mm are suitable for locking ring.

Figure 8:
Mechanical drawing of the locking ring interface and the module



The Mechanical Interface of the Locking Ring

The mechanical interface between the holder and the module is described in Book 3, section 3.12. The interface has the following requirements:

- A suitable thermal interface material shall be used, preferably attached to the LED module: it is recommended that the TIM material is easily removable when using the locking ring system.
- The holder shall provide a homogeneous pressure between 25 and 50 N to the rim of the LED module
- The anti-rotation notch shall be used by a suitable pin in the holder to prevent rotation.

The notch on the module together with the key on the holder avoid any rotation of the module during locking. In this way any deformation of the TIM is avoided.

Locking Ring Benefits for the Luminaire Manufacturer

The main benefits for the luminaire manufacturers using the locking rings are:

- Simplification of the production process as no TIM material is to be handled in the production line and tightening the holder screws is less critical than fixing the module directly to the heat sink.
- More flexible products and reduction of stocks as the desired LED module is chosen, purchased and mounted just before the delivery.
- Reduction of the luminaires part numbers: the “standard fittings” can be stocked without an LED module allowing a significant reduction of the number of different end products to be stocked.

Locking Ring Benefits for the Module Lifetime

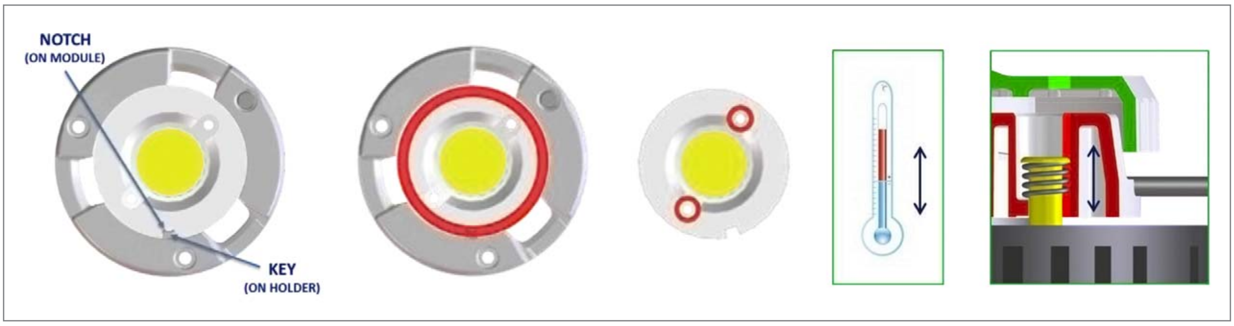
Thanks to the springs mounted inside the holder, the locking ring assures homogeneous homogeneous pressure on the TIM. In fact the pressure is applied by the ring to the complete circular surface of the module and not only in two positions around the screws.

Moreover, any thermal expansion of the module and compression of the TIM material during lifetime of the module is compensated by the holder springs.

Locking Ring Benefits for the End User

The locking ring allows a more “user friendly” insertion and removal of the module. In this way, installation is much more “future proof” and the module can be easily upgraded to a new product generations. ■

Figure 9:
Advantages of the locking ring from left to right - secure placement, homogeneous pressure on the TIM, compensation of the thermal expansion during lifetime due to the springs of the holder



Proper Thermal Interface Calculation for an Optimized Heatsink Design

Jan de Graaf from Philips Lighting, Uli Mathis from Tridonic and Evans Thompson from Cooper Lighting explain how to calculate the thermal resistance of Zhaga compliant modules properly to optimize the thermal system.

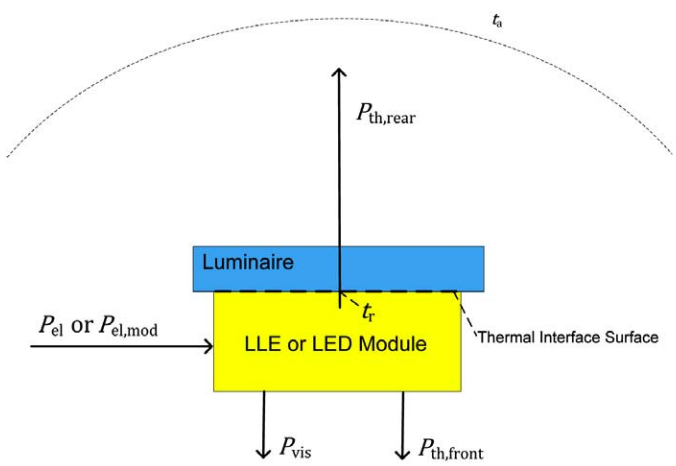


Figure 1: **Thermal model of a LLE-luminaire combination**

To enable interchangeability of LED light sources, the Zhaga consortium has created several interface specifications for LED light engines covering different general lighting applications. One of these interface specifications is called "Book 3: Spot LED Light Engine with Separate Electronic Control Gear". This Book defines the interface between a luminaire and a LED light source consisting of a round ø50 mm LED module and its associated electronic control gear (driver) in separate housings.

LED light sources that comply with "Book 3" are interchangeable. That means that a luminaire manufacturer can replace the light source with another Book 3 - compliant light source without any change in the mechanical, thermal, and photometric components of the luminaire.

In this article we explain the thermal interface of the LED module-luminaire system and we show which thermal design freedom both the LED module and the luminaire manufacturer still have when designing their products. We will also discuss why the thermal interface is specified in this way and how it stimulates interchangeability of LED light engines.

Thermal Resistance as Key Parameter of the Thermal Interface

One of the main interfaces that need to be defined to ensure interchangeability between LED light engines is the thermal interface of the LED module–luminaire system. Zhaga interface specifications provide sufficient thermal design freedom to manufacturers to create their own designs, while ensuring thermal interchangeability between LED light engines of different manufacturers.

Specification of the maximum thermal resistance, suitable for the LED light engine

A proper thermal interface between a LED module and luminaire ensures that the thermal power, $P_{th,rear}$ (W) that is generated in the module is dissipated to the ambient via the luminaire heat sink without exceeding the maximum temperature that the LED module can tolerate for its proper functioning (Figure 1). In Zhaga, the LED module manufacturer specifies the maximum temperature at the thermal interface ($t_{r,max}$) that the module can tolerate. The maximum thermal resistance of the luminaire heat sink that is suitable for this LED module is given by:

$$R_{th,max} = \frac{t_{r,max} - t_a}{P_{th,rear}} \qquad (1)$$

with t_a being the ambient temperature around the luminaire. The LED module manufacturer has the freedom to design the LED module with any $t_{r,max}$ and $P_{th,rear}$ values.

Measurement of the thermal resistance of the actual luminaire

In Zhaga, the thermal resistance of a luminaire is measured with a thermal test engine. For each type of LED light engine an appropriate thermal test engine has been defined. This test engine contains power resistors that dissipate heat equal to the thermal power $P_{th,rear}$ of the light engine. The temperature at the thermal interface (t_r) of the test engine and the luminaire is measured as a function of the thermal power that is applied to the thermal test engine (Figure 2). The thermal resistance of the luminaire heatsink is given by:

$$R_{th} = \frac{t_r - t_a}{P_{th,rear}} \quad (2)$$

The luminaire manufacturer has the freedom to design a luminaire with any R_{th} value.

Thermal compatibility check

In order to check whether a specific LED light engine is compatible with a specific luminaire, a comparison is made between the $R_{th,max}$ and R_{th} values of respectively the LED module and the luminaire:

$$R_{th} \leq R_{th,max} \quad (3)$$

If this condition is met, the temperature of the module will not be exceeded.

Thermal spreading resistance

One important prerequisite for comparing the thermal resistance values of both LED module and luminaire heatsink as stated above in the thermal compatibility check is that the thermal spreading resistance of the LED light engine – heatsink combination, $R_{th,sp}$ is similar to the thermal spreading resistance of the thermal test engine – heatsink combination (Figure 3 and equation).

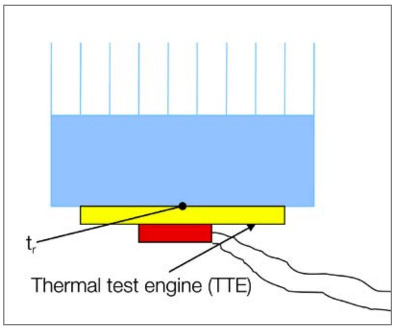
$$R_{th,sp} = \frac{t_r - t_{i,min}}{P_{th,rear}} \quad (4)$$

In order to deal with this situation, a reference heatsink has been defined in Zhaga to measure the thermal spreading resistance of thermal test engine-reference heatsink – and LED module – reference heatsink combinations. In Book 3, any deviation in thermal spreading resistance of the LED light engine to the thermal test engine can be accounted for in the value of $R_{th,max}$ of the LED light engine.

Thermal power at the thermal interface surface

The total thermal power, P_{th} (W), that is generated in a LED module is partly directly transferred to the ambient via radiation and convection and the large remaining part $P_{th,rear}$ is transferred to the ambient via the heat sink over the thermal interface surface (Figure 1). In Zhaga this $P_{th,rear}$ value is measured with a heat flux setup. The use of the $P_{th,rear}$ value instead of the P_{th} value allows for an optimised heatsink design with smaller dimensions and cost.

Summarizing, Zhaga brings together luminaire and LED module designers by defining the thermal interface. This facilitates both module and luminaire design enabling interchangeability of LED light sources.



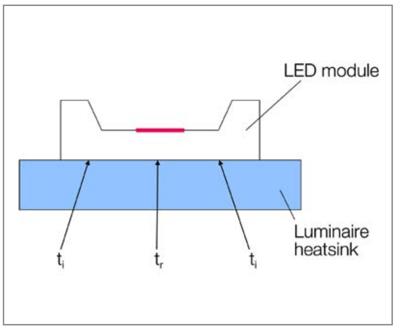


Figure 2: Measurement of the thermal resistance of the actual luminaire (left)
Figure 3: Thermal interface between LED module and heatsink with interface temperatures (right)

Definitions and References:

LED Light Engine: A combination of on ECG (Electronic Control Gear) and one or more LED modules.

LED Module: A light source that is supplied as a single unit. In addition to one or more LEDs, their mechanical support and their electrical connection, it may contain components to improve its photometric, thermal, mechanical and electrical properties, but it does not include the electronic control gear.

Book 3: The interface specification for a spotlight LED light engine, consisting of an LED module and an electronic control gear in separate housings. See also: http://www.zhagastandard.org/specifications/book-3.html

Electronic Control Gear or ECG: A unit that is located between the external power and one or more LED modules to provide the LED module(s) with an appropriate voltage or current. It may consist of one or more separate components, and may include additional functionality, such as means for dimming, power factor correction, and radio interference suppression.

Testing the Thermal Interface Power of Zhaga Book 3 Modules Correctly

Jan de Graaf from Philips Lighting, Uli Mathis from Tridonic and Evans Thompson from Cooper Lighting demonstrate a correct setup and procedure to measure Zhaga compliant modules properly.

To enable interchangeability of LED light engines, the Zhaga consortium has specifications for LED light engines covering several interfaces: mechanical, photometric, thermal, electrical and control. For different general lighting applications the requirements with respect to these interfaces are defined in different Zhaga books. In addition to these specifications, Book 1 has been written containing specifications that are common in multiple Zhaga interface specifications such as:

- Common definitions and conventions
- General system aspects and general aspects of the mechanical, photometric, electrical, thermal and control interface
- The mechanical interface of separated electronic control gear
- Common test procedures
- One of the key common thermal tests in Zhaga is the determination of the thermal power at the thermal interface surface of the LED light engine-luminaire system. In this article we explain the use and the application of this thermal test procedure

Thermal Power Affects the Heatsink Size

A key part in the LED light engine–luminaire system is the heatsink that is needed to dissipate the heat generated in the LED light engine to the ambient. The required size and thus cost of this heatsink depends on the maximum temperature that the LED light engine can tolerate and the thermal power that needs to be dissipated from the LED light engine through the heatsink to the ambient.

Thermal power that is dissipated through the heatsink, $P_{th,\ rear}$

The electrical power consumed by the LED light engines is transformed into light (P_{vis}) and heat, i.e. thermal power P_{th} (Figure 1). This thermal power needs to be dissipated to the ambient. Part of this power is dissipated to the front of the LED light engine by convection and radiation ($P_{th,front}$). The main part of this thermal power is dissipated through the rear of the LED light engine through the heat sink of the luminaire as $P_{th,rear}$ (Figure 2).

For the thermal design of the heatsink the $P_{th,rear}$ needs to be known. Using P_{th} instead would lead to an overdesign of heat sinks in terms of volume and cost.

The Test equipment for measuring $P_{th,\ rear}$

Zhaga specifies equipment and a measuring method for measuring the thermal power at the thermal interface surface of the LED light engine–luminaire system. The equipment and method were developed by the company Hukseflux, Delft, in the Netherlands. Figure 3 shows a sketch of the measurement equipment.

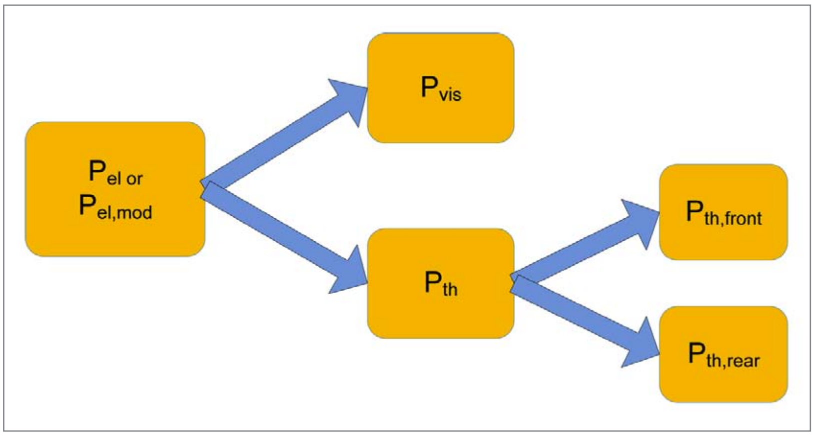


Figure 1: Power conversion

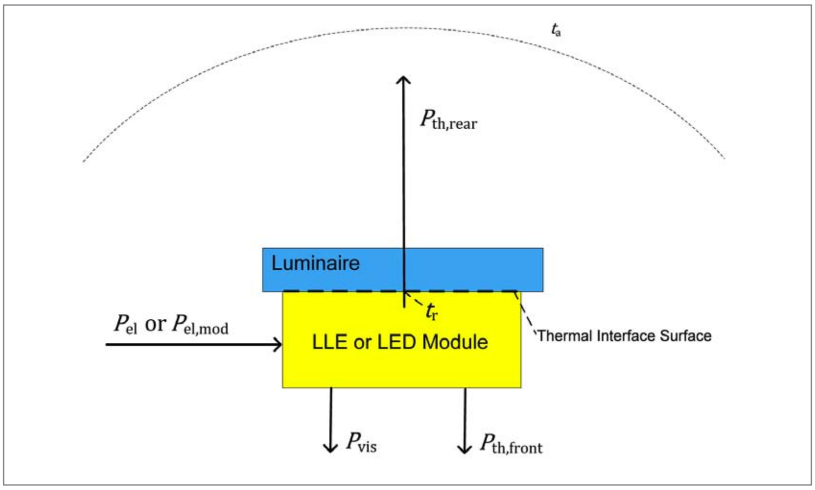


Figure 2: Thermal model of a LLE- luminaire combination

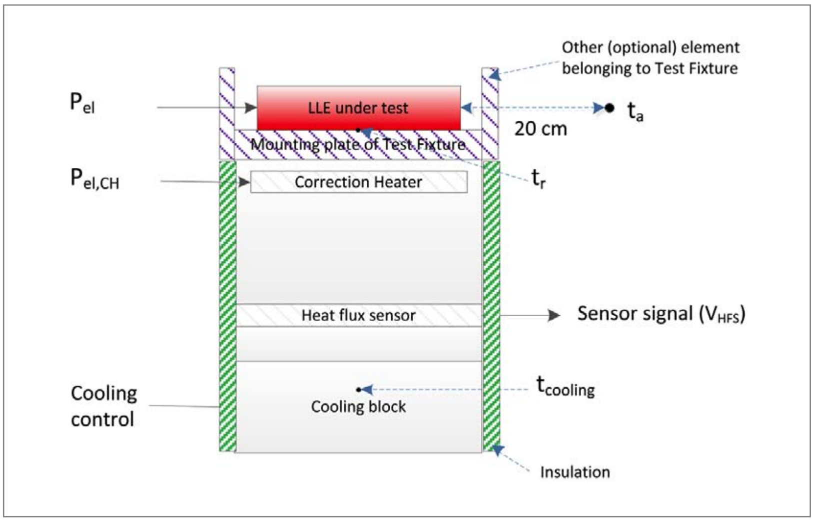


Figure 3: Model of the thermal power test fixture (TPTF)

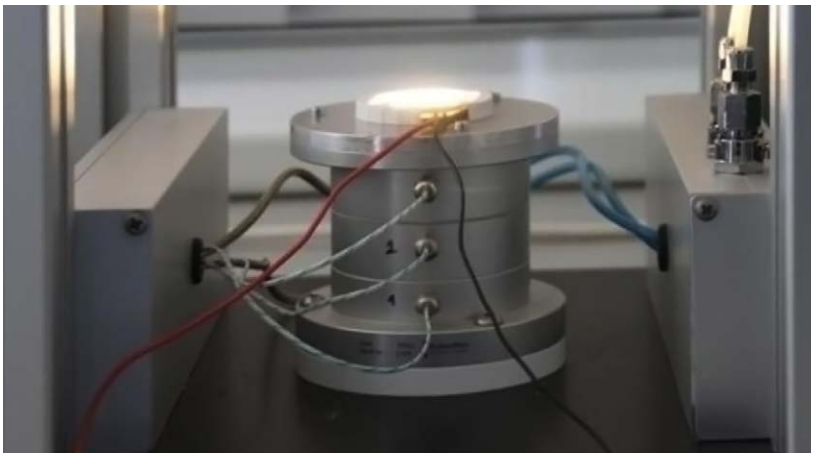


Figure 4: The thermal power test fixture (TPTF) without insulation

The Test procedure for measuring $P_{th,rear}$

The Thermal Power Test Fixture (TPTF) is a one-dimensional heat flux measuring device which measures the amount of heat traveling from the rear of the LLE into the luminaire.

The first step in measuring $P_{th,rear}$ of the LLE will be calibrating the TPTF with the LLE attached.

While keeping the cooling block set to 25°C, the correction heater is configured to consume an electrical power P1 as specified in the different books. After the stabilization of the reference temperature t_r the average of six measurements of heat flux sensor voltage V_{HFS} shall be recorded. Additional V_{HFS} are to be taken at different values (P_2...P_n) of correction heater input power. The results for the different V_{HFS} measurements will be plotted as a curve.

Once the TPTF has been calibrated, $P_{th,rear}$ can now be measured. With the LLE attached to the TPTF, apply power to the LLE using the appropriate control gear. Wait for the stabilization of t_r. By controlling the power on the internal correction heater the temperature on t_r is kept at the value $t_{r,max}$. $P_{th,rear}$ is determined from the measured value V_{HFS} and the previously developed response curve.

Summarizing, Zhaga enables luminaire designers to obtain optimum heat sink designs in terms of volume and cost by defining a test method and procedure for the measurement of the thermal power at the thermal interface surface of the LED light engine – luminaire system. ■

Definitions and References:

LED Light Engine: A combination of on ECG (Electronic Control Gear) and one or more LED modules.

LED Module: A light source that is supplied as a single unit. In addition to one or more LEDs, their mechanical support and their electrical connection, it may contain components to improve its photometric, thermal, mechanical and electrical properties, but it does not include the electronic control gear.

Book 1: This book contain specifications that are common in multiple Zhaga interface specifications, such as: common definitions, the mechanical interface of separated electronic control gear, the generic aspects of the thermal interface. See also: http://www.zhagastandard.org/specifications/book-1.html

Electronic Control Gear or ECG: A unit that is located between the external power and one or more LED modules to provide the LED module(s) with an appropriate voltage or current. It may consist of one or more separate components, and may include additional functionality, such as means for dimming, power factor correction, and radio interference suppression.

Zhaga's New Housing Strategy Simplifies Interchangeability of Electronic Control Gear

Norbert Wittig, Panasonic Lighting Europe, describes the mechanical outlines of electronic control gear (ECG) and the Zhaga "New Housing Strategy" using the example of a spot LED light engine according to "Book 3 - Spot LED Light Engine with Separate Electronic Control Gear".

The Zhaga consortium has created several interface specifications for LED light sources. One of these interface specifications is called "Book 3: Spot LED Light Engine with Separate Electronic Control Gear". Book 3 defines the interface between a luminaire and an LED light source consisting of a round, 50 mm diameter, LED module and its associated electronic control gear (driver) in separate housings.

LED light sources that comply with "Book 3" are interchangeable. That means that a luminaire manufacturer can replace the light source with another Book 3-compliant light source without any change in the mechanical, thermal, and photometric components of the luminaire.

This article explains the background and the general understanding in Zhaga for the interchangeability of separate ECG used in combination with LED modules which are described in Book 1.

Interchangeability of Electronic Control Gear for Traditional Light Sources

For more than 30 years electronic control gear has been used with traditional light sources like fluorescent or high intensity discharge lamps. So far the safety and performance aspects are standardized but standardization or specification of the dimensions of ECGs under the aspect of inter-changeability are not realized. Over the years hundreds of different housings with different housing design principles (region-dependent) are created around the world. With this undefined interchangeability the freedom of actions for the luminaire manufacturer is restricted.

Interchangeability of Electronic Control Gear - Zhaga Target

Zhaga makes LED Light Engines (LLE = combination of ECG and LED module) inter-changeable. This statement includes also electronic control gear which is separated from the LED modules. In principle the combination of the ECG and the LED module could be realized in two different ways - as one unit or within separate units for the ECG and the (one or more) LED modules.

Figure 1 shows the two different concepts of LLEs. Figure A is the example for a LLE in one unit. Here the interchangeability is realized with the description of the Zhaga Interface requirements in the related Zhaga Specification for the LLE, while figure B is an example for a LLE consisting of a separate electronic control gear and one LED module. Here the interchangeability is realized with the description of the Zhaga Interface requirements in the related Zhaga specification for the LED module linked with the requirements for the separate electronic control gear specified in Zhaga Book 1.

The interchangeability for a separate electronic control gear is given when the mechanical outlines of the used ECG meet the Zhaga specifications. That ensures that the luminaire manufacturer could also use electronic control gear in the future with the same specified dimensions.

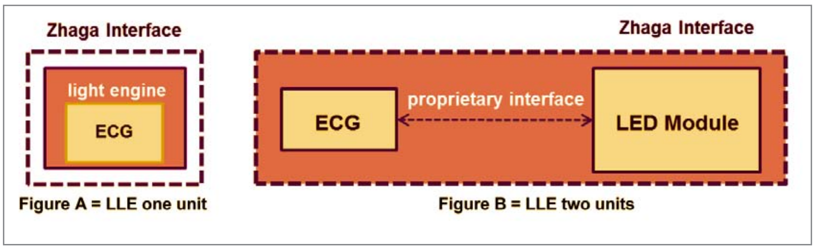


Figure 1: **Figure A shows the Zhaga LLE concept with an integrated ECG, while Figure B shows an LLE with separate ECG**

Special features are the electrical connections from the electronic control gear to the LED modules (so called "proprietary interface" see Figure B). This proprietary interface is not specified within Zhaga because a lot of functions and information (firmware) could be exchanged between the ECG and the LED module. Therefore, if it is necessary to change a LED module in a luminaire, the electronic control gear may also be changed to accommodate the different firmware requirements of the new LED module. With this background it makes sense not to specify the electrical properties of the electronic control gear.

The mechanical interchangeability of separate electronic control gear is realized in a two step strategy. The first step is called "Existing Common Practice" and the second step "New Zhaga Specification". The two step strategy is necessary for producing Zhaga compliant luminaires in a short period of time and giving the industry time to develop electronic control gear related to the second step dimensions.

Existing Common Practice Dimensions of ECG

For the first step "Existing Common Practice" Zhaga selected the most widely used electronic control gear sizes from the different regions and listed this dimension in four different tables.

In Zhaga Book 1, the tables are divided into "compact" and "stretched" sizes, both for "built-in" and "independent" electronic control gear:

Table C-1: Designation and dimensions for compact built-in ECGs
Table C-2: Designation and dimensions for stretched built-in ECGs
Table C-3: Designation and dimensions for compact independent ECGs
Table C-4: Designation and dimensions for stretched independent ECGs

ECG Designation	A max. (mm)	B (mm)	C max. (mm)	D (mm)	E (mm)	F (mm)	G (mm)	H max. (mm)	J	Min. screw hole size for:	Stud Size [1]	Type
AS1	103	94	67	58	-	-	-	31	-	M4	-	Type 1
AS3	93	83,5	58	48,5	-	-	-	29	-	M4	-	Type 1
AS5	70	60	95	85	-	-	-	32	-	M4	-	Type 1
AS6	97	87	77	67	-	-	-	30	-	M4	-	Type 1
AS7	98	88,3	44	34,3	-	-	-	32	-	M4	-	Type 2
AS8	102	98	33	15,5	-	-	-	30	-	M4	-	Type 5
AS9	102	-	34	-	-	50,8	-	35	-	-	8-32	Type 3
AM1	110	99	75	64	-	-	-	33	-	M4	-	Type 2
AM2	113	101	79	63	-	-	-	30	-	M3	-	Type 1
AM3	123	111	79	67	-	-	-	33	-	M4	-	Type 1
AM4	126	117	76	15	35	51	28	26	41	M4	8-32	Type 3
AM5	125	116	75	18,5	-	-	-	35	-	M6	-	Type 3
AM6	127	117	70	0	-	-	-	31	-	M4	-	Type 3
AM7	126	116	74	18,5	-	-	-	35	-	M6	-	Type 5
AM8	128	117	76	18,5	29	50,8	29	35	29	M4	8-32	Type 3
AM9	118	113	34	13,5	-	-	-	30		M4		Type 1
AL1	133	122	77	0	-	-	-	48	-	M4	-	Type 1
AL2	135	124	104	85	-	-	-	34	-	M3	-	Type 1
AL3	141	129	75	64	-	-	-	33	-	M4	-	Type 2
AL4	205	188	96	85	-	-	-	51	-	M3	-	Type 1
AL5	215	204	165	150	-	-	-	50	-	M5	-	Type 8
AL6	250	225	122	112	-	-	-	51	-	M3	-	Type 1
AL7	170	150	105	0	-	-	-	40	-	M4	-	Type 1
AL8	150	130	90	0	-	-	-	40	-	M4	-	Type 1
AL9	161	152	92	73	-	-	-	40	-	M4	-	Type 9
AL10	165	155	70	50	-	-	-	40	-	M4	-	Type 9
AL11	165	153	94	80	-	-	-	35	-	M4	-	Type 2

Table 1: Exemplary extract of the original Zhaga Book 1 Table C-1 - designation and dimensions for compact built-in ECGs. Here the type number starts with A – in Table C-2 the type number with B etc. ([1] designation of stud size is according to [ANSI B1.1])

Figure 2:
A reference drawing as it is used for the tables in the Zhaga Books

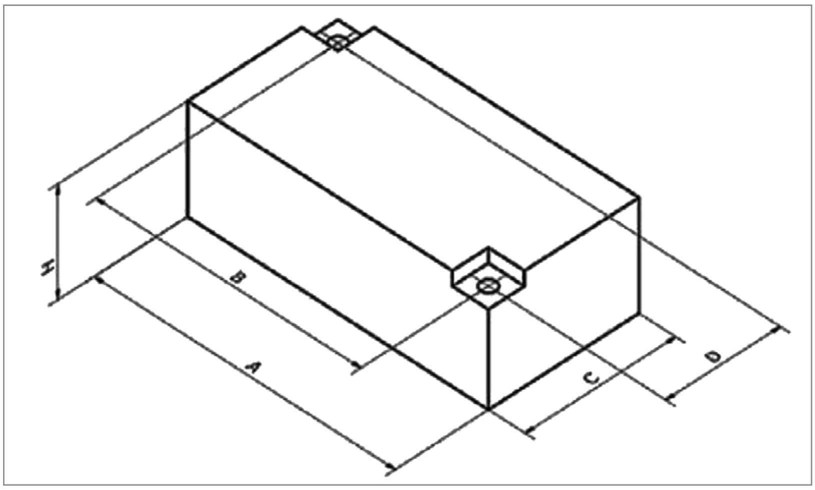
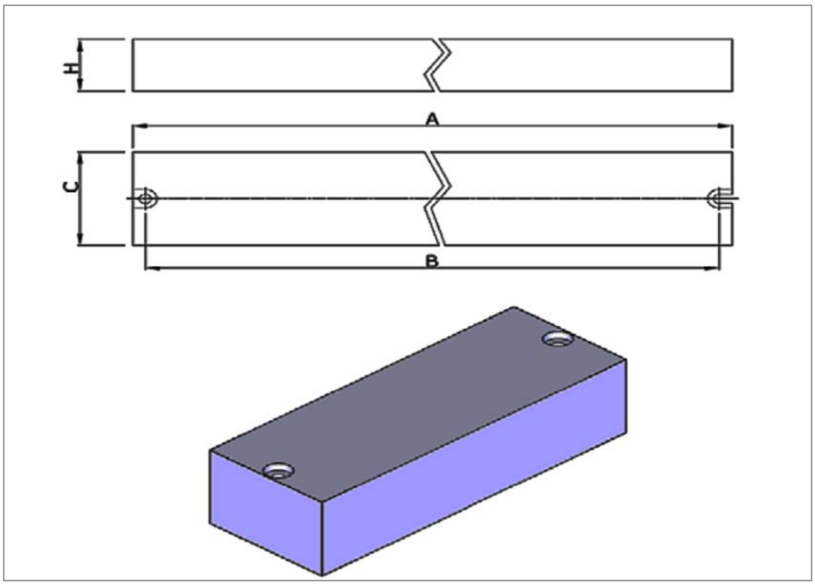


Figure 3:
Example of an ECG designation



The tables contain the maximum dimensions for the length, the height and the width as well as the place and the distances of the fixing holes with the definition of the screw size for the electronic control gear.

The definition of the mechanical interface is described in a reference drawing as indicated in the tables.

For each data set a type number (reference) with max. 4 digits is assigned – ECG designation (extract of Table C-1).

Electronic control gear defined in the tables could have either connectors or flying leads to fulfill the regional performance requirements.

Table 3:
The designation of the ECG housing example

	ZHAGA	Compact / Stretched	Size	Height	Height	Connec-tions: Double / Single
Possible entries	Z	C	1	H	1	D
		S	2		2	S
			3		3	
			4		4	
			5		5	
			6		6	
			7		7	
			8		8	
			9		9	

The Electronic control gear of the table “Existing common practice” is not allowed to carry the Zhaga Logo. The Zhaga certification of electronic control gear is only possible for ECG of step two.

New Zhaga Specification of Electronic Control Gear

The second step of the Zhaga ECG Housing strategy is the “New Zhaga Specification”. There are only two tables “compact” (Table C-5) and “stretched” (Table C-6) defined. Zhaga selected the housing dimensions for the “New Zhaga Specification” in the view of two aspects. First the calculations of the space for the necessary components of ECG power classes and second a logical scheme to reduce the number of ECG housings.

The designation of the ECG housing is defined with max. 6 digits (Table 3).

Example - ZS9 H7 D:

Z	Zhaga specified ECG housing
S9	Stretched housing with data set 9
H5	Indication of the housing height that is rasterized in 5 mm steps
D	Terminals or flying leads on both ends of the housing

Alternative option:

S	Terminals or flying leads on one end of the housing

For independent, potted or IP-Protected (higher than IP 20) electronic control gear the same dimensions scheme shall be used.

The following Table C-6 gives a view to the complete ECG designation of stretched electronic control gear under the “New Zhaga Specification”.

At this time only the height indications H3 = 20 mm, H4 = 25 mm, H5 = 30 mm, H6 = 35 mm and H7 = 40 mm are used (in Table C-6) – therefore, there is space for additional heights if needed in the future.

For Table C-5 additionally H8 = 50 mm is used.

ECG Designation	A max. (mm)	B (mm)	C max. (mm)	D (mm)	H max. (mm)	Min. screw hole size for:	Reference drawing
ZS1 H3 D	100	90	50	0	20	M4	Type 4
ZS1 H5 D	100	90	50	0	30	M4	Type 4
ZS2 H4 D	150	140	50	0	25	M4	Type 4
ZS2 H6 D	150	140	50	0	35	M4	Type 4
ZS3 H5 D	200	190	50	0	25	M4	Type 4
ZS3 H6 D	200	190	50	0	35	M4	Type 4
ZS4 H5 D	245	235	50	0	30	M4	Type 4
ZS4 H7 D	245	235	50	0	40	M4	Type 4
ZS5 H5 D	280	270	40	0	30	M4	Type 4
ZS5 H7 D	280	270	40	0	40	M4	Type 4
ZS7 H5 D	360	350	40	0	30	M4	Type 4
ZS7 H7 D	360	350	40	0	40	M4	Type 4
ZS9 H5 D	425	415	40	0	30	M4	Type 4
ZS9 H7 D	425	415	40	0	40	M4	Type 4

Table 3: **Type 4 example of table C-6 - designation and dimensions for stretched ECGs of "New Zhaga Specification"**

The table C-5 and C-6 containing the maximum dimensions for the lengths, the height and the width as well the place and the distances of the fixing holes with the definition of the screw size for the electronic control gear as well as defined in the tables of the first step.

The definition of the mechanical interface is described in a reference drawing as indicated in the tables (here Type 4 / Figure 3).

Electronic control gear defined in the tables C-5 and C-6 could have either connectors or flying leads to fulfill the regional performance requirements.

Electronic control gear with the ECG-Dimensions listed in the tables "New Zhaga Specification" (C-5 and C-6) and fulfilling the other Zhaga compliance criteria can obtain Zhaga certification and may carry the Zhaga logo.

Definitions and References:

LED Light Engine: A combination of on ECG (Electronic Control Gear) and one or more LED modules.

LED Module: A light source that is supplied as a single unit. In addition to one or more LEDs, their mechanical support and their electrical connection, it may contain components to improve its photometric, thermal, mechanical and electrical properties, but it does not include the electronic control gear.

Electronic Control Gear or ECG: A unit that is located between the external power and one or more LED modules to provide the LED module(s) with an appropriate voltage or current. It may consist of one or more separate components, and may include additional functionality, such as means for dimming, power factor correction, and radio interference suppression.

Book 1: This book contain specifications that are common in multiple Zhaga interface specifications, such as: common definitions, the mechanical interface of separated electronic control gear, the generic aspects of the thermal interface. See also: http://www.zhagastandard.org/specifications/book-1.html

Book 3: The interface specification for a spotlight LED light engine, consisting of an LED module and an electronic control gear in separate housings. See also: http://www.zhagastandard.org/specifications/book-3.html

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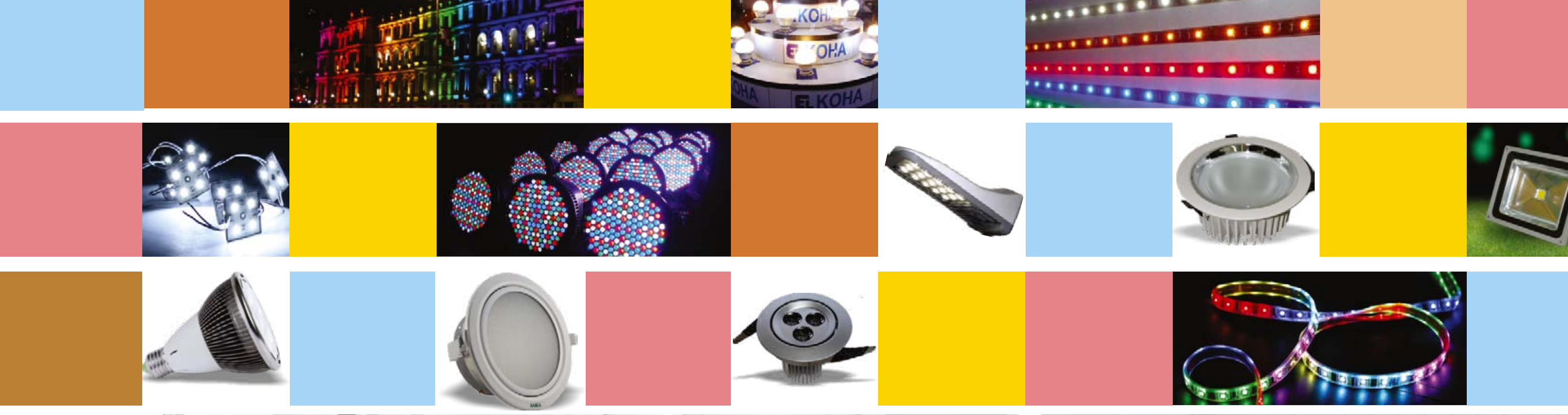

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Imprint

LED professional Review (LpR), ISSN 1993-890X

Publisher
Luger Research e.U.
Institute for Innovation & Technology — phone +43 5572 394 489
LED professional Dept. — fax +43 5572 394 489-90
Moosmahdstrasse 30 — email editors@led-professional.com
A 6850 Dornbirn, Austria / Europe — web www.led-professional.com

Publisher
Siegfried Luger — phone +43 5572 394 489
email s.luger@led-professional.com

Editor-in-Chief
Arno Grabher-Meyer — phone +43 5572 394 489-18
email a.g-m@led-professional.com

Int. Account Manager
Theresa Koenig — phone +43 5572 394 489-20
email theresa.koenig@led-professional.com

Promotion & Sales Mgr.
Gerlinde Graf — phone +43 5572 394 489-43
email gerlinde.graf@led-professional.com

Cover-page
Image: Arno Grabher-Meyer, LED professional; Seoul Semiconductor Z7-F
Artwork: Thomas Klobassa, ©LED professional 2012

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