JULY/AUGUST 2010

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LEDs MAGAZINE®

TECHNOLOGY AND APPLICATIONS OF LIGHT EMITTING DIODES

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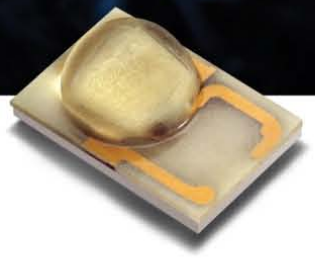

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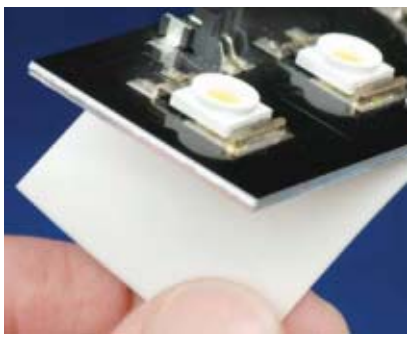

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Cover Story

Accent and cove lighting in the Red Rock Casino in Las Vegas has utilized AC-LED lamps from Lynk Labs, which are a simple retrofit for the 12 VAC infrastructure. See page 12.

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columns/departments

commentary

European and global efforts promote SSL

In past issues of LEDs Magazine we have written at great length about various solid-state lighting (SSL) activities in North America, such as government-funded programs and the development of standards. In case anyone should think that not much is going on in Europe, we are happy to redress the balance. The European lighting industry, represented by CELMA for luminaires and components, and by the ELC for lamps, recently held an LED forum that described various ongoing activities, discussed the development of standards, and made a series of recommendations to the European Commission (EC) for future legislation. EC representatives were also present at what turned out to be a very thorough and informative event (page 29). Several CELMA and ELC representatives, including ELC president Jan Denneman, will participate in the SIL Europe conference in September (www.ledsmagazine.com/features/7/7/1).

One thing I learned at the forum was that a European LED Quality Charter is now in development. Also, it was announced that the EC intends to support a series of large-scale pilot installations to evaluate the benefits of solid-state lighting (page 21). The projects will start at the end of 2011 after a competition in the first half of the year.

Ultimately, it will be desirable and necessary to bring together the various country-specific and regional activities into a globally-coordinated framework. With this in mind, the International Energy Agency (IEA) has launched a new program, or Annex, that will tackle quality concerns in solid-state lighting as part of its Efficient Electrical End-use Equipment (4E) program (www.iea-4e.org). The IEA says that SSL is "fast emerging as a key technology with potential to tackle climate change, however many [participants] share concerns that poor products may damage the market and set back acceptance of LED lighting." The new Annex has been initiated by France, the United States and Japan, and will provide guidance on appropriate test methods and performance levels that can be used to identify high-quality SSL products, and to remove poorer-performing products from the market before consumer credibility is lost.

One issue that has caused some debate recently is the impact that artificial light at night may, or may not, have on human health. Our article (page 25) concludes that more research is certainly needed. Even outside of the health issues, groups such as the International Dark-sky Association (IDA) are seeking to limit light pollution. "We look at LEDs as having promise and peril," says Peter Strasser, IDA managing director. He applauds the way LED fixtures control light patterns. But he attributes that control to the fact that LED fixture makers "can't waste a lumen" because the efficiency of the products today are barely effective in street-lighting applications. He worries about what will happen as LED brightness and efficiency continue to escalate, warning that less-precise designs may cause further light pollution.

Another area of debate is color quality of white-light sources. Various alternatives have been suggested to the ubiquitous color-rendering index (CRI), which is seen to have various flaws when applied to LEDs (page 59). The options are being evaluated by the International Commission on Illumination (CIE), which is based in Europe but has the necessary input from organizations across the world.

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Web Exclusive Articles

Lighting industry at the edge of the unknown

Everyone involved with the LED world is involved in a massive industry transformation, which has parallels with the changes that were seen in another industry, explains Ankush Chopra.

www.ledsmagazine.com/features/7/7/2

US International Trade Commission offers potential forum of choice for patent litigants in SSL industry

An investigation by the ITC can prove to be the quickest way to reach an early resolution to patent disputes in the fast-moving LED lighting space, says Darren Jiron of Finnegan.

www.ledsmagazine.com/features/7/7/5

Working group pursues LED and induction street-light retrofits

www.ledsmagazine.com/features/7/7/7

Schréder LED fixtures utilize HSMtec printed board technology

www.ledsmagazine.com/features/7/7/6

Swiss department store chooses energy-saving LED lighting solution

www.ledsmagazine.com/features/7/7/3

COMPANY PROFILE: Docter Optics

www.ledsmagazine.com/features/7/7/4

FEATURED *events*

Strategies in Light Europe 2010

Strategies in Light Europe
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September 27-29, 2010
Frankfurt, Germany
The conference schedule has been announced for SIL Europe, which has the theme of "Accelerating the Market Adoption of LED Lighting."
See www.ledsmagazine.com/features/7/7/1 for full details.

LED Japan – Strategies in Light

LED JAPAN Conference & Expo
Strategies in Light

September 28-October 01, 2010
Yokohama, Japan
MORE: www.sil-ledjapan.com/index.html

Intelligent Transport Lighting 2010
August 24-26, 2010
Hamburg, Germany

China International Optoelectronic Exposition (CIOE)
September 6-9, 2010
Shenzhen, China

PLASA
September 12-15, 2010
London, UK

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135˚×40˚

27W

EMPx-A61xxxG-24Kx

Specifications

LED Emitter : Edixeon
Watt : 27W
Available CCT(Typ.) : 6,000K
4,000K and 3,000K
Field Angle : 135˚×75˚

27W

EMPW-A36700G-241L

Specifications

LED Emitter : Federal
Watt : 27W
Available CCT(Typ.) : 6,000K
Field Angle : 135˚×75˚

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news views

ARCHITECTURE

LED light for World Cup arenas

LED lighting featured in several World Cup soccer stadiums in South Africa, as well as in other infrastructure projects as the host country sought to minimize the event's carbon footprint.

Cape Town's Green Point Stadium (right) was torn down and rebuilt as a larger and more modern structure that made full use of LED lighting technology to accentuate the building's architecture. LEDbeam luminaires supplied by BEKA (Pty) Ltd, a member of the Schréder Group GIE, were built using Osram LEDs. "Because of their limited dimensions and particular light distribution, LEDs were the only luminaires we would consider, as we were able to construct a particularly slim light installation with them," said Daniel Kasper of BEKA (Pty) Ltd. "This »page 10

Source: BEKA (Pty) Ltd

Durban stadium and Arch

PATENTS

Cree and Philips sign LED licensing agreement

Cree, Inc. and Philips have signed a comprehensive, worldwide patent cross-license agreement that is "designed to further accelerate the growth of the LED lighting market," according to a joint press release. The agreement covers patents from both parties in the fields of blue LED chip technology, white LEDs and phosphors (including remote phosphors), control systems, LED luminaires and lamps. It also covers LED backlighting of LCDs, and patents in the Philips LED Luminaire Licensing Program. Several other companies, including Osram, Zumtobel and Acuity Brands, have already joined Philips' licensing program.

Rudy Provoost, CEO of Philips Lighting, said that the "wide-ranging IP portfolios" of Philips and Cree reflect the "significant investment in innovation" that the companies have made in LED lighting. "We wish to see the accelerated adoption of LED lighting, and are therefore delighted that Cree will be joining our LED Luminaire Licensing Program," added Provoost. ◄

MORE: www.ledsmagazine.com/news/7/7/3

MANUFACTURING

TMG suppliers increase capacity to serve LED market

As LED demand continues to grow, materials suppliers are keeping pace by adding more capacity for vital chemicals such as trimethyl gallium (TMG). Metalorganic precursors such as TMG are used in metalorganic chemical-vapor deposition (MOCVD) systems to grow layers of different semiconductor materials in a process known as epitaxy. The properties of the epitaxial materials largely determine the performance of the LED chips that are fabricated from these layer stacks.

One supplier, Dow Electronic Materials, said that it would add significant TMG capacity at its plant in North Andover, MA to address short-term demand as quickly as possible (www.ledsmagazine.com/news/7/6/10). In addition, to create capacity for long-term demand, Dow will build a new manufacturing plant in Cheonan, Korea, which is expected »page 10

news+views

TMG from page 9

to begin operating in early 2011. Total additional TMG capacity resulting from the multi-phase plan is expected to be 60 metric tons per year.

In May of this year, AkzoNobel said that it would double production capacity for TMG at its plant in LaPorte, Texas, USA during the summer of 2010 (www.akzonobel.com/hpmo). The company's High Purity Metalorganics (HPMO) business cited the growing market for LEDs in "backlight units for computer screens and the new generation of LED-TVs" as well as general lighting and many other applications.

In March 2010, SAFC Hitech, a division of the Sigma-Aldrich Group, announced plans to invest $2 million to expand production of TMG at its manufacturing plant in Bromborough, UK (www.ledsmagazine.com/press/21520).

"Demand for TMG today is being driven by explosive growth in LED backlighting of LCD TVs with the potential of future growth of LEDs in the general lighting market," said Dow's James Fahey. "The LED market is growing rapidly, particularly in Korea, Taiwan and other countries in the Asia-Pacific region where there is a large display manufacturing base, and semiconductor manufacturers are building and converting capacity to manufacture LEDs."

Likewise, SAFC Hitech cited the "growing demand for [TMG] in the production of high-brightness LEDs for applications such as backlighting in flat-panel television sets and energy-efficient lighting." ◄

World Cup from page 9

means light is focused only on relevant areas without scattering losses."

A total of 432 luminaires, each 1.8m in length, were fitted to the stadium's upper outer ring and a balustrade beneath it. These form two light strips around the stadium, which are separated by distances varying between two and 12 m, producing a wave-like effect to "embrace the natural wave elements of the adjacent Atlantic Ocean." A narrow color distribution was required to produce uniform white around the ground.

Meanwhile, over 12,000 Golden Dragon Plus LEDs from Osram were used in the Moses Mabhida Stadium in Durban, to light the giant illuminated Arch, which is 350 meters long, 2,600 metric tonnes in weight and 30 stories high. This application also used LEDbeam luminaires from BEKA. ◄

LIFETIME

DOE recommends new approach to LED luminaire lifetime ratings

The DOE has published a new recommendation for testing and reporting LED luminaire lifetime that accounts both for failure attributable to declining light output (i.e. lumen maintenance), and to catastrophic failure of the luminaire.

The "LED Luminaire Lifetime: Recommendations for Testing and Reporting" guide recommends that luminaire makers specify an F rating for catastrophic failures – for example F10 at 30,000 hours would imply that 10% of the luminaires in a given population will have failed catastrophically by 30,000 hours of usage.

Both LED manufacturers and luminaire makers need a way to accurately define lifetime. Moreover, buyers need accurate information to justify SSL purchases and calculate accurate payback windows.

The new recommendation builds on the L and B ratings that originated with Philips Lumileds. First lumen maintenance was defined with a figure such as L70 at 50,000 hours implying that an SSL product would decline to 70% of its initial light output after 50,000 hours of usage. The B figure was added such that L70/B50 at 50,000 hours implies that 50% of the population reaches the L70 point in 50,000 hours.


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However, catastrophic failure also needs to be considered. The DOE recommendation identifies 12 reliability considerations that could contribute to a catastrophic-failure lifetime rating, including electrical connections, printed circuit boards, thermal elements, the drive electronics and more. The F rating is intended to account for all of these considerations. ◄

MORE: www.ledsmagazine.com/news/7/5/21

AC-LEDS

Lynk Labs AC-LED Festoon lamps light up Red Rock Casino

Lynk Labs has provided accent and cove lighting for the Red Rock Casino in Las Vegas using 15,000 GeoLite AC-LED Festoon replacement lamps. "This 0.5 watt AC-LED lamp was a simple and seamless retrofit solution for us in the existing low-voltage 12VAC embedded infrastructure throughout the casino," said Curtis Saunders of Nedco Supply, which managed the project.

"These AC-LED lamps were easily installed into the existing lamp sockets, operate with the existing 12VAC transformers and dim on the existing dimmers in the casino," said Curtis. "The return on investment for this retrofit was under 12 months on energy alone (75 kW reducing to 7.5 kW). If you included man hours and lamp replacement cost, the retrofit paid for itself as soon as it was completed!" Curtis added. ◄

MORE: www.ledsmagazine.com/news/7/7/10

PROGRAMS

EPA clarifies Energy Star SSL test accreditation requirements

The EPA recently contacted its stakeholders to answer a number of questions about the current and near-future Energy Star testing requirements for lumen maintenance of solid-state lighting (SSL) products. The existing Energy Star Solid-State Lighting Luminaires v1.1 specification (SSL v1.1), which references the IES LM-80-08 standard, remains in effect until the new Energy Star Luminaires v1.0 specification replaces it in the summer of 2011. The Luminaires v1.0 specification is going through a period of

comments and re-drafting during the summer of 2010 (see *LEDs Magazine* May/June 2010, p.19).

The LM-80 standard describes methods for measuring lumen maintenance. As of March 31, 2010, the EPA is only accepting data collected in compliance with LM-80. Data collected prior to publication of LM-80, and not performed in compliance with the standard, will not be accepted for Energy Star qualification of SSL products.

As of September 30, 2010 the current SSL v1.1 specification requires that LM-80 test data come from a laboratory accredited by NVLAP, the National Voluntary Laboratory Accreditation Program. However, EPA says that no labs have yet achieved this accreditation for LM-80 testing, so it is putting in place an interim accreditation scheme.

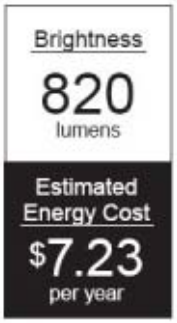
LM-80 does not include lumen-maintenance projections, which are covered by current protocols outlined in the SSL v1.1 specification and the "Manufacturers Guide for Qualifying Solid State Lighting Luminaires" document (www.energystar.gov/index.cfm?c=ssl_res.pt_ssl). These remain in effect until Luminaires v1.0 becomes effective in summer 2011. Under Luminaires v1.0, lumen-maintenance projections using data collected in accordance with LM-80 will be governed by the forthcoming IES technical memorandum TM-21-11. ◄

MORE: www.energystar.gov/luminaires

LAMPS

FTC lamp labels emphasize lumens, not watts

Starting in mid-2011, the US Federal Trade Commission (FTC) will require that all light bulbs carry new labeling on the packaging that is designed to help consumers choose among the different types of bulbs on the market. The FTC proposed new output-based labels for light bulbs in November 2009 (www.ledsmagazine.com/news/6/11/26), and says that the new regulations will come into force around the middle of 2011. Under direction from Congress to re-examine the current labels, the FTC has devised new labels for light-bulb packages that are intended to enable consumers to save money by selecting the most efficient lamps that best fit their lighting needs.



Front

The label on the front of the package will emphasize the lamp's brightness as measured in lumens, rather than quoting watts. The FTC says that the "focus on brightness in lumens will help consumers make purchasing decisions as they transition to more energy-efficient types of bulbs." The use of lumens is valid when comparing lamps with similar sizes and shapes. However, the

Back

lumen is the unit of luminous flux (effectively the total light output), while brightness or luminance is the luminous intensity per unit emitting area, and is actually measured in candela/m^2 or nit.

The new front-of-package labels also will include the estimated energy cost (in $/year, based on 3 hours' use per day and electricity costs of $0.114/kWh). Meanwhile, the back of each package of light bulbs will have a "Lighting Facts" label modeled after the "Nutrition Facts" label that is currently on food packages. As well as the brightness (lm) and energy cost ($/yr), this will list the the bulb's life expectancy in years (based on 3 hours per day), the color appearance (on a scale ranging from warm to cool ,with a value for CCT), the energy consumption in watts, and a disclosure if the bulb contains mercury. ◄

MORE: www.ledsmagazine.com/news/7/6/18

EVENTS

Strategies in Light China announced for May 2011

Strategies in Light China will take place at the Kowloon Shangri-La Hotel in Kowloon, Hong Kong on May 10-12, 2011. The event is the latest in the Strategies in Light franchise of conferences and exhibitions covering the global LED and lighting industry, and joining events in the USA, Japan and Germany. Strategies in Light China will focus on the LED industry supply chain. China has a robust LED device manufacturing environment, ranging from conventional and high-brightness chips to a wide variety of packaging types. On the applications side, there are thousands of companies supplying systems ranging from outdoor signage to display backlights to solid-state lighting. Moreover, all elements of the HB-LED vertical supply chain are represented in China, ranging from substrates, to process materials and chemicals, to manufacturing equipment. Also, the government has become a key player in the development of China's LED industry. ◄

Strategies in Light China

MORE: www.sil-ledchina.com

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PUBLICATIONS

Outdoor LED Lighting newsletter and Japanese version of LEDs Magazine

LEDs Magazine is adding two new publications to its repertoire. The Outdoor LED Lighting newsletter was launched in July (http://newsletters.pennnet.com/leds_enl/98321659.html) and, as the name suggests, the focus is on exterior illumination applications using LEDs and other advanced lighting technologies.

LEDs MAGAZINE JAPAN

Meanwhile, the first issue of LEDs Magazine Japan will be published in September 2010, in time for the LED Japan 2010/Strategies in Light conference & expo. The Japanese edition will provide in-depth information in Japanese about leading-edge technologies and up-to-date news about the global market, replicating the focus of the flagship publication LEDs Magazine. The advertising deadline for the premier issue is August 20. ◄

MORE: www.led-japan.com/mag.html

LEDS

Osram improves red, green LED performance

Osram Opto Semiconductors has claimed a new performance record for prototype red LEDs. The InGaAlP thin-film devices have an efficacy of 119 lm/W at an operating current of 350 mA, and 136 lm/W at 70 mA. This represents a 30% improvement over current-generation devices. The device is a 1-mm^2 thin-film InGaAlP chip, emitting at a dominant wavelength of 615 nm. The prototype chip was tested in a Golden Dragon Plus package. The overall efficiency is 44% at 350 mA and 49% at 70mA. The value exceeds 50% for a wavelength of 642 nm.

"This will benefit all applications that use high-efficiency red, particularly projection applications," said Wolfgang Schmid, who is responsible for developing this chip technology at Osram Opto Semiconductors. "We expect to start equipping LED products with the new thin-film chips in about a year's time."

Wolfgang Lex, Head of the LED business unit at Osram Opto Semiconductors, told LEDs Magazine that the improvements were the result of a focused internal project to improve the performance of red LEDs. "The project looked for barriers," said Lex, "and resulted in an improved epitaxial process."

Another consequence is that the new prototype red LEDs have a reduced temperature dependence. "For InGaAlP LEDs there is usually a very quick drop-off of light output when hot, much more so than for InGaN LEDs," said Lex. This can be particularly important for automotive applications, for example.

While the improvements to Osram's red LEDs came about as a result of a planned research project, green LED performance experienced a great leap forward when a blue LED chip was combined with a phosphor developed by 3M (www.ledsmagazine.com/news/6/11/24). Unfortunately, says Lex, the phosphor contains cadmium, which creates environmental issues, and also lacks stability with temperature. However, he said, the discovery had "opened the door" and Osram has now developed a Cd-free phosphor with much better temperature stability.

The performance improvements for both red and green LEDs, coupled with high-performance blue LEDs already in production, should open up new markets. In projection, for example, these devices can enable efficient projectors embedded in mobile hand-

see the light

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LIGHTING

GE licenses Rambus technology

GE Lighting and Rambus Inc., a technology licensing company, have signed a broad licensing agreement covering GE's use of Rambus' patented lighting innovations, including its product reference designs and manufacturing process know-how. The initial focus will be to create a flat-panel LED lighting system for architectural and commercial lighting. In December 2009, Rambus acquired patents and technology from Global Lighting Technologies (GLT). These include LED edge-lit optical designs, MicroLens light distribution features, and high-volume, low-cost light guide panel and multi-function film manufacturing technologies. Although the technologies were originally developed for backlighting applications, GE evidently intends to exploit their benefits in general lighting products, for example by using fewer or lower-cost LEDs while delivering high light quality and output. ◄

MORE: www.ledsmagazine.com/news/7/6/19

BUSINESS

Everlight and Epistar involved in joint ventures, mergers

LED-packaging specialist Everlight Electronics is to launch a new company focused on LEDs for TV backlights with partners LG Display and Amtran Technology (www.ledsmagazine.com/news/7/5/23). Korea-based LG Display is one of the leading manufacturers of LCD panels, while Amtran is a contract manufacturer of computer monitors and TVs based in Taipei, Taiwan. The joint venture will be capitalized with $30 million, and will be based in WeJiang City, JiangSu Province, China. Mass production is expected to start by the end of the year.

Everlight is also involved in a new collaboration with TPV Technology Limited, a leading manufacturer of PC monitors and LCD TVs, and Epistar, the largest LED chip manufacturer in Taiwan (www.ledsmagazine.com/news/7/6/9). The focus is on LED packages and light bars for the ramping TV and display backlight segment. The partners will capitalize the new venture with $30 million and base its operations in Fujian Province, China.

In more Epistar news, the company recently announced plans to take a 47.88% stake in Huga Optotech, the second-largest LED-chip manufacturer in Taiwan (www.ledsmagazine.com/news/7/5/26). Win Semiconductor, a gallium-arsenide (GaAs) foundry specialist, will also invest in Huga. ◄

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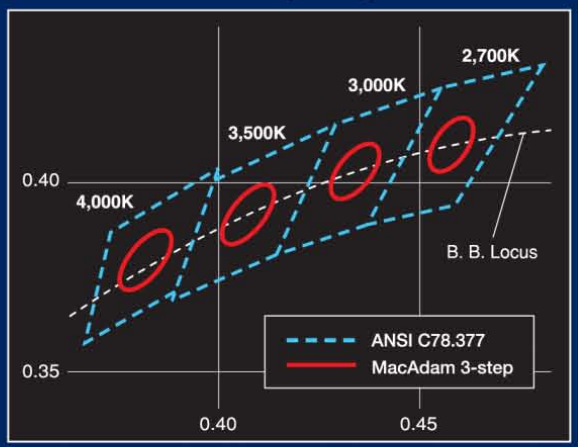

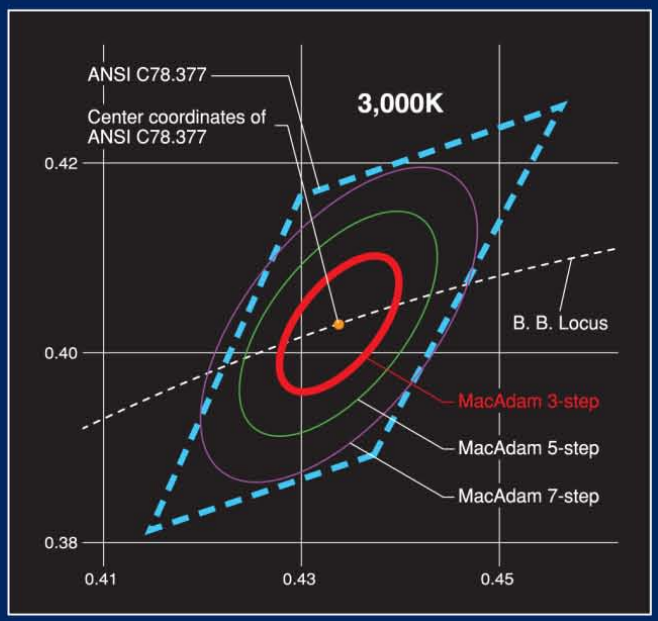

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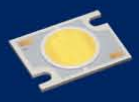

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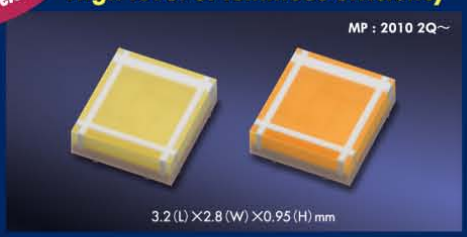

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funding + programs

GE retrofit LED lamp wins UK Energy Saving Trust approval

A 4-watt GU10 LED lamp from GE Lighting has become the first retrofit LED lamp to gain approval by the UK's Energy Saving Trust (EST) Recommended product certification scheme. The lamp is now permitted to carry a Recommended label, which enables costumers to recognize energy-efficient products.

LED luminaires have also been approved; certain models of the alphaLED Universal Open luminaire from Projection Lighting are also allowed to use the Recommended certification mark.

The GE lamp has the same 36-degree beam angle as 20W GU10 halogen lamps, with 12% higher candela, according to GE's brochure. It produces warm-white light at 3100K with CRI >80, and has a rated lifetime of 15,000 hours (to 70% lumen output). The lamp has been shown to meet a variety of stringent criteria set by the EST relating to properties including beam angle, candela, color rendering, power factor, color temperature and physical size and shape. The EST has published separate criteria for LED lamps and LED luminaires (see www.ledsmagazine.com/news/7/5/25).

The EST Recommended scheme's objective is to certify the best performing energy-efficient products and make them easily identifiable to consumers. All products have to be verified by third-party test laboratories to gain EST Recommended approval. Mike Barrett, Commercial Director, UK & Nordic Region at GE Lighting told *LEDs Magazine* that, in order to be considered for approval, LED products have to submit third-party test data after 2000 hours of life testing (approximately 12 weeks). "The testing therefore would typically take between 3 and 4 months. The actual submission process for the GU10 lamp was completed in a couple of weeks," he explained.

Barrett said that all the EST criteria are achievable individually, but the challenge is getting them all to happen simultaneously. "Other manufacturers end up optimising one criterion but at the expense of others," he said. "For example, there are lamps on the market with higher lumen values than ours but these are bigger in size where achieving higher output is desirable. However these lamps are not suitable for retrofitting consumer applications -- as consumers want to be sure the lamps will fit their fittings, so the prospect for real energy savings is much less." According to Barrett, the two differentiating fac-

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EC to support LED lighting demonstrations

The European Commission (EC) is to support a series of large-scale pilot installations in order to evaluate the benefits of solid-state lighting, and will also produce a Green Paper on SSL. Speaking at an LED forum at Light+Building (see p.29), John Magan, Deputy Head of the EC's Photonics unit, said that the pilot actions on SSL technology deployment and demonstration are expected to be published in the Competitiveness and Innovation Programme (CIP) for 2011. "The Call for proposals is planned to open around January 2011 and close around June 2011, with the first projects starting by the end of the year," he said.

The catalyst for this work is the Digital Agenda for Europe, which was published in May 2010 as one of the flagship initiatives of the EU2020 strategy (http://ec.europa.eu/eu2020). Two concrete actions on lighting were included as part of the Digital Agenda, said Magan:

- In 2011, the Commission will publish a Green Paper on SSL to explore the barriers and to put forward policy suggestions. It will in parallel support demonstration projects via the CIP.
- By 2012, Member States should include specifications for total lifetime costs (rather than initial purchase costs) for all public procurement of lighting installations.

Magan says that the EC's Photonics unit has been holding meetings and dialogue with stakeholders such as CELMA, the ELC, and Photonics21 (www.photonics21.com), a voluntary association of industrial enterprises and other stakeholders in the field of photonics in Europe. Details of the CIP work program will be published on the Photonics unit website at http://cordis.europa.eu/fp7/ict/photonics/home_en.html. ◄

funding + programs

Gateway projects continue LED evaluation

The US Department of Energy (DOE) has made various announcements related to Gateway demonstration projects, which evaluate LED lighting in various commercial and residential applications.

In Washington, DC, the DOE has acted in cooperation with the Department of Labor (DOL) to install 19 LED luminaires in the DOL's Frances Perkins Building parking garage. Preliminary tests show an energy saving of more than 75% relative to the prior garage lighting system, due to the LED lighting and also to motion sensors that can automatically dim or extinguish the lights when no cars are present. The DOE also proclaimed that the new system offers "greatly improved illumination quality i.e. more uniform light and a heightened ability to discern colors." The project utilized VizorLED luminaires from Philips Wide-Lite (pictured), a Best In Class winner in the 2009 Next Generation Luminaires competition.

Parking-lot LED lighting installation using VizorLED luminaires by Philips Wide-Lite.

Presidential orders have compelled the federal government to reduce its energy usage. Roland Risser, Building Technologies Program Manager at DOE, said, "Federal agencies must lead by example, and DOE will continue to guide government-industry collaborations to implement high-performance LED products in appropriate applications."

T.J.Maxx LED parking-lot lighting

Two recent Gateway reports have focused on results from a parking lot in a Manchester, NH shopping plaza, as well as from a street-lighting demonstration in Palo Alto, CA. The parking-lot demo at the T.J.Maxx store in Manchester revealed a 58% energy saving attributable to LEDs along with light-output controls triggered by occupancy sensors. A total of 25 LED luminaires from BetaLED replaced 22 high-pressure sodium (HPS) luminaires and 6 metal-halide luminaires. The estimated payback time is 3 years, although this might be longer in regions were electricity is less expensive.

The integrated occupancy sensors are able to reduce the LED light output when cars are not present, so that the average light level is reduced by 47% compared to the previous installation. The controls and the LEDs delivered the reduction in average light levels while still meeting IES recommendations for minimum horizontal illuminance.

Palo Alto street-lighting report

In Palo Alto, three groups of HPS streetlights were replaced — four with one type of LED luminaire, three with another type of LED luminaire, and three with induction luminaires — allowing comparisons between the three groups as well as to the existing technology.

In addition, two LED and two induction luminaires were installed on a commercial street in the center of Palo Alto to test a remote street-light monitoring system. These luminaires were equipped with Echelon communication hardware that can be remotely controlled through a desktop or laptop personal computer. These luminaires were programmed to turn on and off on a schedule similar to that of the street-light luminaires controlled by a photocell but then were dimmed by 25% of full power for 5 hours each evening.

Among the key findings were that, of the three roadway lighting systems (induction, HPS and LED), LED used the least energy (44% reduction compared to the baseline HPS) and provided comparable average illuminance on the street. Also, LED luminaires produced more-uniform light output than HPS or induction luminaires, and had better cutoff on the curbside, resulting in significantly reduced light trespass onto residential properties. However, simple payback for retrofitting a 70-watt (nominal) HPS with an LED luminaire was estimated to be around 12 years, improving to about 10 years in a new construction scenario.

Community feedback showed a marked preference for LED lights over induction lights. However, two common concerns related to LED lights were excessive glare and the perceived blue/cold color of the LED light output. These issues will have to be resolved prior to a mass rollout of LED streetlights for Palo Alto. The LED luminaires tested in the demonstration have a correlated color temperature (CCT) of 6000K; by comparison, the CCT for the induction and HPS streetlights were 5000K and 2100K, respectively. ◄

MORE: www.ssl.energy.gov/gatewaydemos.html

UK government selects six companies for lighting research

The UK government's Technology Strategy Board (TSB) in collaboration with the Department for Environment, Food and Rural Affairs (Defra) has taken the next step in its GBP 1.2 million Ultra-Efficient Lighting (UEL) competition, which was announced back in January (www.ledsmagazine.com/news/7/1/30). The agencies have now selected six Phase 1 winners: Cambridge Consultants Ltd, Juice Technology Ltd, Marl International Ltd, PhotonStar LED Ltd, Tridonic Atco (UK) Ltd, and Zeta Controls Ltd. Each will get GBP 40,000 to develop a feasibility study of their proposed SSL concepts. The TSB and Defra will review the studies and select the most promising to receive additional Phase 2 funding of up to GBP 450,000 to develop and evaluate prototypes or demonstration units.

The goal of the UEL program is to help the companies become leaders in energy-efficient lighting and also to ultimately contribute to reduced energy consumption in homes.

Cambridge Consultants intends to use the funds for a feasibility study to design a low-cost, ultra-efficient lamp that can be made anywhere in the world, says the company, adding "By making that design available to multiple manufacturers, we can encourage a cost-competitive manufacturing environment to supply lamps in high volumes at the lowest commercial cost to the UK." ◄

MORE: www.ledsmagazine.com/news/7/7/9

funding + programs

DOE announces funding opportunity for SSL manufacturing

The US Department of Energy (DOE) has announced an SSL funding opportunity which constitutes round 2 of the R&D program area for US Manufacturing Support (www.ledsmagazine.com/news/7/6/17). Recipients of Round 1 funding for US Manufacturing Support were announced in January 2010.

Up to $15 million will be available in total for Round 2, and between two and eight projects will be funded. DOE is soliciting SSL manufacturing R&D projects that will achieve significant cost reductions through improvements in manufacturing equipment, processes, or monitoring techniques. Projects should address the technical challenges that must be overcome before prices fall to a level where SSL will become competitive with existing lighting on a first-cost basis. By advancing these activities, DOE believes it can accelerate progress toward creating a US-led market for high-efficiency light sources. However, foreign companies are allowed to apply as part of a project team.

The DOE has also published the 2010 edition of the SSL Manufacturing R&D Roadmap, which is intended to guide the manufacturing R&D program and help direct funding solicitations. It also provides guidance for equipment and material suppliers, based on industry consensus on the expected evolution of SSL manufacturing, thereby reducing risk, improving quality, increasing yields, and lowering costs. ◄

MORE: www.ssl.energy.gov

>>GE Retrofit LED Lamp from page 21

tors between GE's lamp and its competitors are probably beam angle and power factor. The GE lamp has a wide-flood, 36-degree beam that replicates a halogen GU10. "Most competitor lamps have narrower beams, which are OK for accent lighting but are poor for general household lighting," said Barrett.

Also, the GE lamp has a very high power factor of greater than 90%, while competitive LED GU10 lamps are down in the 50-60% region or sometimes even lower, said Barrett. "Power factor is becoming a hot topic in the UK because a lower power factor means that more of the grid capacity is used for a given energy consumption. With many power stations reaching the end of their life, grid capacity is still a potential problem even if energy usage drops. So the Energy Saving Trust is increasingly insisting on minimum standards for power factor in their specifications," he said. ◄

MORE: www.energysavingtrust.org.uk

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Debate continues over the impact of light at night on human health

Advocacy groups such as the International Dark-sky Association (IDA) have claimed that blue-spectrum wavelengths found in sources such as LED-based solid-state lighting (SSL) can disrupt circadian rhythms and potentially cause other health maladies such as cancer. Meanwhile, the Alliance for Solid-State Illumination and Technologies (ASSIST) has published a technical paper developed by the Lighting Research Center (LRC) that examines the impact of artificial light at night on humans. The report concludes that realistic night-lighting scenarios have small-to-no impact on humans, as measured by melatonin suppression (see Sidebar).

Over the course of the past year, the debate over artificial light at night and its impact on circadian rhythms and human health has intensified. Back in October, IDA published a statement that began, "The rapidly expanding use of bluish-white outdoor lighting threatens visibility at night and jeopardizes the nocturnal environment worldwide." The not-for profit organization, which is dedicated to protecting the night-time environment, suggested that lights with a correlated color temperature (CCT) above 3000K should no longer be used outdoors (www.ledsmagazine.com/news/6/10/8).

IDA's stated goals range from safeguarding scientific opportunities such as astronomy to protecting human health and saving energy wasted on excessive lighting. But the organization has latched on to health concerns as a hot-button topic that might have considerable impact on the night lighting debate (www.ledsmagazine.com/features/6/8/9).

MAURY WRIGHT *is the Senior Technical Editor of LEDs Magazine.*

The short-wavelength problem

There are probably more unknown issues than known ones on the topic at present, but it's scientifically accepted that short-wavelength light has an impact on circadian rhythms. The ASSIST report notes that both the circadian and vision systems in humans are sensitive to short wavelengths in the 400-500-nm range. Many LED-based lights—especially those with the highest efficacy—have a major spectral component at such wavelengths. According to ASSIST, the circadian system is blind to longer-wavelength light above 600 nm.

At present no exhaustive research exists on the real health impact of short-wavelength or bluish light. Still, the American Medical Association (AMA) adopted a resolution last year advocating that energy-efficient luminaires be used for all outdoor lighting. The resolution specifically mentions wasted energy and carbon emissions as a goal of such lighting installations. It also specifically targets better roadway safety via the reduction of glare associated with legacy street lights.

The AMA resolution doesn't mention wavelengths and seems more focused on controlling light pollution in general. But one of the dozen justifications of the resolution is related to circadian issues. The document states, "Light trespass has been implicated in disruption of the human and animal circadian rhythm, and strongly suspected as an etiology [cause] of suppressed melatonin production, depressed immune systems, and increases in cancer rates such as breast cancers."

Measuring the circadian impact

The ASSIST report entitled "The potential of outdoor lighting for stimulating the human circadian system" doesn't attempt to address the potential health issues, but instead focuses on whether the circadian system is stimulated in test cases (www.ledsmagazine.com/news/7/6/15). The research looked at the impact of light on the levels of melatonin. Darkness causes the pineal gland in the brain to secrete melatonin into the blood, while exposure to light can suppress the nocturnal melatonin level.

Circadian rhythms and melatonin

The circadian rhythm is essentially the 24-hour physiological cycle that controls wake and sleep patterns in humans and animals. Disruption of the rhythm has been proven to cause various sleep disorders and can also impact alertness when a person is awake. The circadian rhythm is largely controlled by the body's level of the hormone melatonin, which promotes sleepiness (among other effects). Production of melatonin is inhibited by daylight and permitted by darkness. ◄

LRC relied on an established model that accounts for the spectral composition of light (including short-wavelength content), the absolute magnitude of the light, the spatial distribution of the light on the cornea, and the duration of exposure.

LRC studied the potential circadian impact of four light sources: two commercially-available, cool-white LED luminaires, a metal-halide lamp, and a high-pressure sodium (HPS) lamp. The report presents a reference case supported by prior controlled-laboratory research in which pupils representative of a 20-year-old human are exposed for one hour to a light source. The reference case is the equivalent of a person looking up from

directly under a street light with illuminance of 95 lux (lm/m^2) on the cornea.

The research then presents two more-realistic scenarios. Scenario 1 is the equivalent of a person standing 3m from the light pole looking down the road. This produces a maximum illuminance of 27 lux at the cornea. Scenario 2 is the equivalent of a person standing 10m away from the pole looking directly at the luminaire, resulting in 18 lux illuminance at the cornea.

Melatonin suppression is expressed as a percentage impact on normal nocturnal melatonin levels. In the reference case all of the sources resulted in some level of suppression, ranging from 6% for the HPS source to 30% for the LED source with the highest CCT of 6900K. In Scenarios 1 and 2, only the 6900K source caused suppression ranging from 3%-10%.

Interpreting the results

A quick glance at the data suggests that cool-white LED sources won't impact circadian rhythms in typical scenarios. But LRC director Mark Rea won't go that far. The report points out that prior research has revealed that nocturnal melatonin suppression levels must be greater than 15% to be measured reliably. That doesn't mean that a suppression level below 15% is a guarantee that no problems exist. Rea stated, "15% reflects the uncertainty of the measurement."

Of course, the other question is whether a one-hour test is in any way typical. Since exposure time factors into the study, one might assume that a person walking briefly at night is far more typical and therefore far less likely to have suppression. Asked that question, Rea said, "I think that's a rational inference."

Not everyone agrees that one hour is an atypical exposure, and in fact Peter Strasser, the IDA Managing Director, suggest even longer exposures are typical. Talking about a residence in an urban area, Strasser said, "The second-story window is often better lit than the street."

Also, it's easy to find far worse night-lighting scenarios than street lights, such as those faced by night-shift workers. And if there is a real health risk, those scenarios should perhaps be at the forefront of the discussion. Rea said, "You can talk about home lighting as a problem."

Rea believes that further study needs to consider the full day. He said, "It's the full 24-hour cycle that's important. The circadian system integrates over a full 24 hours. The impact would be different if your only exposure to light was from a street light."

Rea also wants to make sure that people understand the goals of the LRC research, saying, "We're not trying to say lighting isn't a problem. We're simply trying to provide analytical tools for people trying to make rational decisions."

Rea and Strasser do agree on one thing – that more research is required. Strasser stated, "More testing needs to be done before recommendations can be made."

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CELMA and ELC joint forum represents views of European lighting industry

A recent seminar highlighted the ongoing efforts of the European lighting industry to deliver high-quality, energy-efficient LED lighting solutions, writes **TIM WHITAKER**.

With so many people in Frankfurt for the Light+Building trade-show earlier this year, two industry organizations took the opportunity to hold a joint LED forum, sharing views representing the "European Lighting Industry." At the European level in Brussels, Belgium (the location of the European Commission), the lighting industry is represented by CELMA for luminaires and components, and by the ELC for lamps (see Sidebar).

Andreas Ludwig, CELMA President at the time of the event, explained that the objectives of the European lighting industry, as represented by CELMA and ELC, are to increase the market opportunities for CELMA & ELC members to sell high-quality LED lighting products and systems, and to ensure satisfaction of consumers and end-users. Three key methods to achieve this are by speeding up and increasing the adoption of LED products and luminaires; by driving standards and certification in favor of high-quality solutions; and by educating the market.

Ludwig also stated that "the European Lighting Industry welcomes the arrival of EU Regulations on EcoDesign (EuP)" which include the phasing out of energy-inefficient lighting products (sometimes referred to rather inaccurately as "Ban the Bulb" legislation). He noted that the continued improvement in LED technology will enable a major contribution towards the EU's "20/20/20" energy-saving objectives. By 2020, these objectives call for a 20% reduction in greenhouse-gas emissions, a 20% increase in energy savings and a 20% contribution from renewable energy sources.

As Ludwig noted, the market for LED lighting is growing fast, and there is an urgent need for minimum product requirements, including quality aspects. He stated that the European lighting industry would warmly welcome the arrival of new EU-wide Lighting System Legislation (LSL) to improve the light quality, as well as the energy efficiency, of lighting installations. While the EcoDesign Regulations deal with the energy efficiency of lighting products, LSL will focus on lighting systems and installations, explained Ludwig. "LSL will challenge existing inefficient lighting installations, and will triple the benefits of EcoDesign Regulations," he claimed.

Quality and EcoDesign

Having set the scene, Ludwig was followed by two representatives from the European Commission (EC). Paolo Bertoldi of the DG Joint Research Center (JRC) Institute for Energy spoke about quality, saying that there is "a need to make sure consumers accept LED technology and will not feel cheated by poor light quality, short lifetime, and other possible problems." With extensive experience relating to CFL quality, JRC is now in the process of developing a European LED Quality Charter, which will aim to harmonize criteria and test methods on an international basis. Such criteria are necessary, for example, to allow products to qualify for incentives.

Next, András Tóth of the Directorate-General for Energy, Unit C3, spoke about the status of LED lighting in EcoDesign (EuP) legislation. He explained the key elements to promote energy-efficient appliances are EuP, which removes the poorest-performing products, and energy labeling, which promotes the best-performing products. These are complemented by public procurement and other incentives, which are set mainly by the EU member states.

The EcoDesign of Energy-Related Products (2009/125/EC) directive is not only concerned with energy efficiency but also looks at the "cradle to grave" environmental impact, explained Tóth. With regard to lighting, EC Regulation 244/2009 covers non-directional (or "omni-directional") household lamps and has set out a timetable

TIM WHITAKER *is the Editor of* LEDs *Magazine.*

CELMA and ELC

CELMA (www.celma.org) is the Federation of National Manufacturers Associations for Luminaires and Electrotechnical Components for Luminaires in the European Union. It has 19 member associations in 13 countries, and together these associations represent more than 1000 small- and medium-sized enterprises which have more than 100,000 employees in the EU, and a total annual turnover of EUR 15 billion.

ELC (www.elcfed.org) is the European Lamp Companies Federation and has 8 member companies with more than 50,000 employees in the EU and a EUR 5 billion annual turnover. Members are Aura Light, BLV Licht-und Vakuumtechnik, GE Lighting, NARVA Lichtquellen, Osram, Philips Lighting, Havells Sylvania and Toshiba.

Both CELMA and ELC, along with the UK-based Lighting Association, are Supporting Organizations for the inaugural Strategies in Light Europe conference (www.sileurope.com), which takes place in Frankfurt, Germany on September 27-29, 2010. ◄

Claimed equivalent incandescent lamp power (W)	Rated lamp luminous flux (lm)		
	LED and other lamps	CFL	Halogen
25	249	229	217
40	470	432	410
60	806	741	702
75	1055	970	920
100	1521	1398	1326

TABLE 1. Lumen equivalency requirements for non-directional lamps (partial list) from EcoDesign (EuP) regulation no. 244/2009.

to phase-out incandescent lamps, while setting functionality requirements for remaining lamps. Less well known is EC Regulation 245/2009, covering "tertiary sector" lighting products typically used in office and street lighting, such as linear fluorescent lamps, high-intensity discharge lamps, and related ballasts and luminaires.

The 244/2009 regulation sets targets for energy efficiency that go beyond simply eliminating incandescent bulbs. As well as functional requirements, 244/2009 sets requirements to display product information on the packaging of lamps, including LED lamps. From September 2010, packaging must display information to allow fair comparison between different lamp technologies. Lumen information should be more prominent than watts (similar rules are also being introduced in the USA: see page 14), and any equivalence claims will be subject to defined conditions. As Table 1 shows, for example, a non-directional LED lamp that claims to be equivalent to a 60W incandescent must have an output of at least 806 lm.

Further EcoDesign legislation is already at the draft stage, with adoption expected in the first half of 2011. This will cover the efficiency, functionality and product information requirements for directional lamps (including LEDs), as well as the functionality requirements for non-directional LED lamps. It will also include efficiency requirements for LED drivers, and if necessary it will make the scope of EcoDesign legislation more specific to LED retrofit lamps, LED modules and LED luminaires.

In the same timeframe, the EC is reviewing the Energy Labeling of Lamps (Commission Directive 98/11/EC) to specifically include LEDs, to enlarge the scope to directional lamps, and to review label classes. Finally, Tóth directed attendees to the multi-language EC website on lighting at www.e-lumen.eu.

Design guidance and standards

CELMA has produced a Guide for OEMs and Producers of LED-based Luminaires (available on the organization's website), which discusses the specific know-how and competences necessary to build such products. As described by Steffen Holtz of Schréder R-Tech, who will also discuss the Guide at the SIL Europe conference in September, the first fundamental decision is whether one has sufficient experience and resources to develop an LED-based luminaire, or whether one should find a partner who is an expert in LEDs, associated components and electronics. The second decision is whether to integrate a standard LED module, or use a customized LED solution. This decision, said Holtz, is based around the company's core competency, its resources, and the desired time to market.

Key factors discussed in the Guide, and also by Holtz with reference to the example of an outdoor luminaire, include the desired light level, color temperature and color rendering; thermal management and temperature considerations; standards; efficacy; lifetime and reliability; drivers and electrical isolation; and optics.

Also in its Guide, CELMA has made a proposal for the presentation of photometric data for LED luminaires, and this was discussed by Tommy Govén of Fagerhult. "Photometric data is essential for good lighting design with LEDs," said Govén, "and allows comparison with other approaches and compliance with lighting requirements."

The CELMA proposal is necessary because existing CEN (European Committee for Standardization) standards for measurements and presentation of photometric data of lamps and luminaires are not completely applicable for LED luminaires. Specifically these are EN 13032 Part 1 "Measurements and file format" and EN 13032 Part 2 "Presentation of indoor and outdoor workplaces." Revised CEN standards are expected by 2012 at the earliest, said Govén.

Franco Rusnati of Assil presented an overview of standards for LED products, as summarized in Table 2. A draft performance standard for LED modules is expected soon, and similar standards for self-ballasted lamps and for luminaires are also being developed. Global standards are issued by IEC (www.iec.ch), explained Rusnati, while CENELEC (www.cenelec.eu), the European Committee for Electrotechnical Standardization, develops standards at the European level.

James Hooker of Havells-Sylvania discussed the challenges of standardizing a

Product type	Safety standard	Performance standard
LED drivers	IEC 61347-2-13. Published 2006.	IEC 62384. Published 2006.
LED modules	IEC 62031. Published 2008.	IEC/PAS expected in 2010.
LED self-ballasted lamps (>50V)	IEC 62560. Publication expected 2010.	IEC/PAS 62612 published 2009. Publication of IEC 62612 standard expected 2011.
LED luminaires	IEC 60598-1. Published 2008.	IEC/PAS expected in 2010.
Definitions	IEC TS 62504 "Terms and definitions for LEDs and LED modules in general lighting." Publication expected 2010.	

TABLE 2. Standards published and in preparation, from the Joint CELMA/ELC Guide on LED-Related Standards.

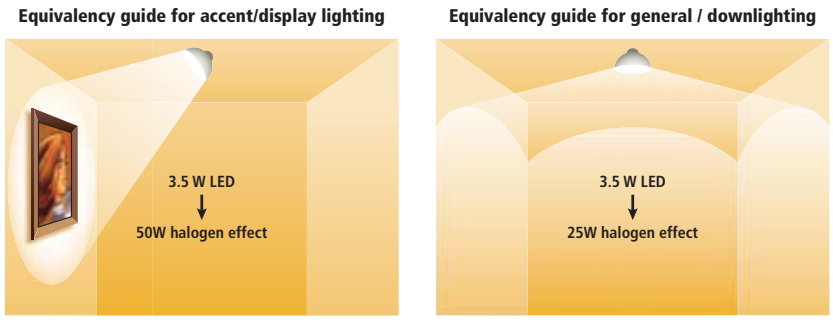

FIG. 1. For accent and display lighting using directional lamps, the most important factor is the luminous intensity (cd) in the central spot. However, for general- and down-lighting applications the total luminous flux is the key feature when trying to determine equivalence between different lamp types.

breakthrough technology, looking at LED lamps as retrofits for halogen-reflector lamps. Hooker said that the industry does not want to standardize LED packages, since this might impede development, and that the focus should be on end products. "The purpose of standardizing is to protect the end consumer, who should receive what he is expecting," said Hooker, adding that claims of equivalence require both standards and adequate market surveillance and enforcement.

Halogen lamps are sold by a candela figure for a given beam angle, and the luminous flux (lm) is generally not published. Because LED is an optically more efficient light source than halogen, LED retrofits can achieve similar peak intensities with far fewer total lumens. For example, a 3.5W LED lamp can produce 1200 cd in a 20-degree beam with 150 lm. In comparison, a 50W halogen might produce 1200 cd in a 25-degree beam, but the total luminous flux is 300 lm. For accent and display applications, the luminous intensity (cd) is most important, and in this example the 3.5W LED lamp could be claimed to be equivalent to the 50W halogen. However, when the same lamps are used for general- and down-lighting applications, the luminous flux is the most important factor, and in this case the 3.5W LED lamp is roughly equivalent to a 25W halogen (see Fig. 1).

For these reasons, said Hooker, the ELC has proposed a new measure of "Luminous flux in a 90-degree cone." This favors lamps having superior optical control and less stray light (i.e. LEDs), but would also still provide enough lumens to meet expectations in general- and down-lighting applications. ELC is actively lobbying the European Commission to embody this and other recommendations in the future EcoDesign Regulation on Directional Lamps.

> "The purpose of standardizing is to protect the end consumer, who should receive what he is expecting" —JAMES HOOKER

Calls for action

Closing the forum, Jan Denneman, ELC President (and a Keynote speaker at SIL Europe in September) said that the European Lighting Industry is seeking support from the EU and Member States on several issues. One is strong EU legislation, introduced rapidly, to ensure only good-quality LED products can reach EU consumers. These should have review periods in line with rapid technology evolution. Also, there is a crucial need for active and effective market surveillance across the EU, since this is the only way that regulations and standards are meaningful.

Denneman also called for harmonized initiatives (including financial) to promote good quality LED products & systems, as well as the inclusion of LED technology in the EU "New Industrial Policy" Framework and the 8th EU Framework Programme for Research. Finally, he said, there should be increased global cooperation and exchange of information, to prevent the need for national initiatives which may simply duplicate work that has already been carried out.

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- Power consumption : 21.2W
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WTH - 6 series

5W

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14W WTL – 14 series 14(w) × 14(H) × 550(L)mm

21W WTL – 21 series 14(w) × 14(H) × 820(L)mm

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[IC] [OPTO] [LED] [LCD] [RF]

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Tighter collaboration is essential for driving the high-brightness LED industry roadmap

The lack of standards in LED manufacturing makes it difficult for LED makers to change their process flows, while equipment suppliers are required to supply highly-customized tools, says **THORSTEN MATTHIAS**.

The high-brightness LED (HB-LED) market is continuing to grow at a rapid pace thanks to the rising number of applications that can take advantage of the low energy consumption and other benefits of LED devices. Although applications such as backlighting in computer displays and televisions, as well as automotive lighting (headlamps and interior lighting), are already seeing adoption of HB-LEDs, the general lighting market represents one of the greatest—and as of yet mostly untapped—opportunities for HB-LEDs.

Today, approximately 20 percent of the electricity produced worldwide is used for general lighting—equal to the amount produced from all of the world's nuclear power plants. Traditional (incandescent) lighting technology can now achieve single-digit or low-double-digit energy efficiency, with most of the remaining energy going to waste as heat. Replacing all incandescent lighting with LED systems at current levels of efficiency could reduce total energy consumption for general lighting to about 2 percent—nearly a 10-fold reduction. The key to driving adoption of HB-LEDs is two-fold—reducing costs and increasing light efficiency or light extraction.

These twin drivers are similar to those in the mainstream IC industry, where manufacturers are driven by the need to increase performance while lowering manufacturing costs. However, the cost equation is different for LED manufacturers, who face lower yield rates and higher risk of fab downtime due to less mature manufacturing processes than those of IC makers. Whereas IC makers are mostly concerned with increasing yield and equipment utilization rates to achieve lower cost of ownership or lower cost per wafer, LED makers are more concerned today with keeping down their initial capital expenditures.

Another key difference between the IC and LED industries today is that LED manufacturing currently has little standardization. In a sense, the LED industry is much like the IC industry was many years ago. There is no equivalent in the LED industry of SEMATECH or the Semiconductor Industry Association to develop an industry roadmap and guide manufacturers toward a common goal. Nor are there established standards in process equipment (e.g. interfaces or automation) yet.

Lack of standardization

A key reason for this lack of standardization is that there are so many potential applications for LEDs across many different markets. To effectively compete, LED makers rely upon highly proprietary and customizable manufacturing processes. In addition, LED manufacturers rarely build new fabs or add new process lines. Instead, they often add to existing process lines. This creates significant "jury rigging" of process flows, using a variety of different tools (often for the same process) and requires continuous incremental improvements to the process flow in order to realize minor gains in cost reduction and improved light efficiency.

The lack of a standardized process flow has major implications for LED manufacturers and equipment suppliers alike. LED manufacturers are limited in their ability to make major changes to their process flow to address new and emerging technical challenges that arise in their manufacturing processes, since they lack a baseline or benchmark for making process improvements. For equipment suppliers, tools must be highly customizable in order to address each customer's unique needs. This in turn drives the need for closer collaborations between suppliers and their customers, in order to maximize the capabilities of OEM solutions for each customer and address specific manufacturing challenges.

An example of where this is currently taking place is the NILCom Consortium, where companies and research organizations throughout the nano-imprint lithography (NIL) supply chain are working together to build the infrastructure needed for photonic crystal production—a key ingredient in achieving significant improvements in LED light efficiency. A collaborative effort similar to NILCom, covering key aspects of the manufacturing supply chain—including process equipment, materials, metrology, qualifica-

THORSTEN MATTHIAS *is the Business Development Director of EV Group.*

tion and assimilation—could lead to successful cost reduction and performance improvement for all LED manufacturers.

Common areas of focus

Although LED manufacturing processes are highly differentiated among device makers, there are several common areas on which LED device manufacturers and their equipment suppliers can focus to address cost and light efficiency—in some cases, leveraging technologies and experiences gained in the IC and MEMS industries. These areas are at the substrate level, at the device level, and at the packaging level.

At the substrate level, for example, nanoimprint lithography enables patterning of sapphire substrates, which increases light extraction. Wafer bonding allows the transfer of epitaxial (epi) layers that are grown from sapphire wafers to other substrates with better thermal properties. Wafer bonding can also be used to bond a thin seed layer (e.g. GaN) to the substrate template prior to epi-layer growth in order to facilitate the growth of the LED layers.

At the device level, several improvements can be made to optimize the light efficiency of LEDs. The most promising approach to improve light extraction from the diode is by employing nano-imprint lithography to create three-dimensional photonic crystals within the top layer of the LED.

Packaging accounts for the majority (approximately 50 percent) of LED manufacturing costs. Moving from die-level to wafer-level packaging is seen as a key step for reducing costs—especially for larger wafer sizes. For example, silicon interposers based on surface and bulk micromachining offer superior thermal properties, and also enable integration of the driver IC and optical elements to minimize form factor. The implementation of through-silicon vias (TSVs) can also enable further reductions in form factor and maximize the density of individual LEDs in the final device.

Next steps

Looking to the future, more standardization within the LED industry will be essential for enabling device manufacturers and equipment and materials suppliers alike to push the envelope of their respective technology roadmaps and mutually reap maximum return from their investments. As noted earlier, the standardization of processes will allow device manufacturers to more readily make changes in their manufacturing line to address existing, emerging and new technical challenges as they arise.

In addition, standardization will even the playing field among vendors and allow LED manufacturers to choose from a variety of equipment and materials suppliers for their needs, as opposed to being limited to a single supplier due to their highly-configured production flow. This in turn will help spur innovation among vendors, which will ultimately create greater value-add and further drive down costs for LED manufacturers.

Lightfair shows latest in LE

Were one to have walked into the Lightfair International (LFI) exhibit hall on May 12 with no prior knowledge about the event, the impression would have clearly been that the show was focused on LEDs. Indeed the event featured the latest LED technology ranging from LED chips to the latest in LED-based luminaires.

The expectations for LED-based solid-state lighting (SSL) are huge. In a keynote address, US Department of Energy (DOE) Lighting Program Manager Jim Brodrick succinctly summarized the opportunity and the challenge. Brodrick said, "The potential for solid state lighting simply put is about $120 billion worth of savings over the next 20 years… We can reduce the energy that is used for lighting by one fourth… This is one of the few technologies that I've seen for 20 years at the department that can actually turn the consumption curve down."

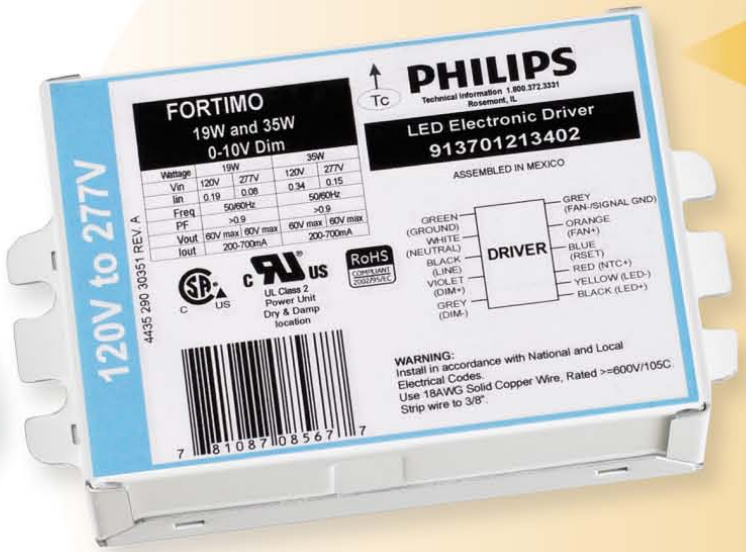
Brodrick also set expectations high, saying, "SSL has the most potential of any light source for high efficacy. The program that I'm managing is going for 250 lm/W… You need to think today that we are about where Thomas Edison was in 1890…You are going to be making history in the next 10 years in the world of lighting."

The exhibition and attendance clearly indicated a surging market. There were more than 22,000 registered attendees and almost 1600 booths. Most telling was 72 first-time exhibitors and it's a safe bet that most were LED focused. Moreover LED-related products took three of the four top spots in the LFI Innovation Awards program (www.ledsmagazine.com/news/7/5/8).

We've already provided a significant amount of LFI-oriented coverage. Check out the editorial column "Vegas' brightest lights shined at Lightfair" from our June issue that you can download in digital form (www.ledsmagazine.com/magazine/toc/1006). That same issue included a review of LED-based replacement lamps that were introduced at the show (www.ledsmagazine.com/features/7/6/12). And during LFI we offered up a show daily five consecutive mornings (www.ledsmagazine.com/features/7/5).

In the following pages, we'll showcase other notable products seen in the LFI exhibit hall.

Ds



Philips Lighting expanded its Fortimo LED module family at Lightfair as well as introducing a number of retrofit lamps. The biggest news in retrofit lamps was a 60W replacement lamp that will only dissipate 12W (www.ledsmagazine.com/features/7/6/12). The lamp is similar in design to the L-Prize candidate lamp and will come to market late this year. The Fortimo products include models for indoor and outdoor applications along with drivers. The pictured SLM Module and Driver targets spot- and accent-lighting applications as an alternative to halogen and ceramic-discharge-metal-halide lamps. Other models include the DLM with integrated driver for general illumination and the LLM 4500 for outdoor applications including residential and park lighting.

Cree's Lightfair booth was all about bright – bright LEDs and bright luminaires. The company announced a new member of the LR6 downlight family — the LR6-DR1000 — that offers 70% more light output than the prior version. The 12.5W fixture delivers 1000 lm with an efficacy of 84 lm/W. The new downlight uses Cree's XLamp XP-G LEDs to deliver better brightness and efficacy where the original LR6 used XR-E LEDs. Cree also announced the CR6 downlight for residential and light-commercial applications. The Energy-Star-qualified luminaire delivers 575 lm and is expected to retail for under $60. On the LED side, Cree announced that the XLamp MX-6 now can handle higher drive current and deliver 160% more light. At 1A drive current, the new LEDs deliver 300 lm in cool white and 245 lm in warm white. Cree Director of Marketing Paul Thieken said, "By qualifying our XLamp MX-6 LEDs at higher drive currents we are giving customers additional design flexibility."

Traxon and e:cue featured numerous examples of LED-based lighting for architectural and decorative applications. For example, Traxon and AGC Glass are partnering to produce fully-transparent glass panels that have monochrome or RGB LEDs embedded within the glass. These Glassiled panels include base and cover layers of glass that sandwich the LEDs in a resin layer along with a fully-transparent conductive layer that drives the LEDs. Designers will be able to customize the Glassiled panels and use Traxon's control technology to add a dynamic sparkling element to applications such as retail shop shelves, facades, and even mirrors.

The EnOcean Alliance had a Lightfair booth dedicated to the ultra-low-power wireless communication scheme championed by the Alliance for green applications such as controllable LED lighting. Consider the pictured products from Illumra. The solar-powered light sensor can operate indefinitely by harvesting light sporadically – including either sunlight or light from a luminaire – and storing energy in a supercapacitor. The sensor can communicate wirelessly using the EnOcean Protocol with the dimmable LED controller pictured and can dim or brighten the luminaire output on sensed light conditions. Members of the Alliance also offer self-powered light switches that can use energy generated when a person pushes a light switch to wirelessly transmit commands to a controller mated to a luminaire.

Sharp and Toshiba both announced entry into the global lighting market after many years supplying lighting products strictly for the Japanese market. Both will focus on LED lighting going forward. Sharp's first product will be a PAR 38 replacement lamp. Over the course of a few months the company expects to announce A-lamp replacements and solar-powered lighting. In the Sharp LFI exhibit, a remote-controlled A-lamp replacement (pictured) received the most attention. The product is shipping in Japan and each lamp comes with a small remote control that uses infrared technology that allows consumers to dim or brighten the lamp or even change color temperature. Sharp indicated that the product may come to the US in the fall.

Outdoor and area lighting

Outdoor and area lighting is proving to be a ready market for LEDs because applications such as street-lights greatly benefit from the long life and low maintenance costs associated with SSL. LEDs can also reduce energy costs relative to high-pressure sodium (HPS) and other legacy lighting types. And LED-based luminaires are proving adept at controlling the beam pattern and the illuminated area, cutting down on light pollution.

Everbrite launched the PSL125 LED luminaire for parking structures quite a different attern. The t the optics d in a square small array of h side of the elies on a reflector lls iDV (in-Direct am pattern. One of a luminaire that arking structure Manager Jeff he design allows r high-power LEDs le light output inaire designs.

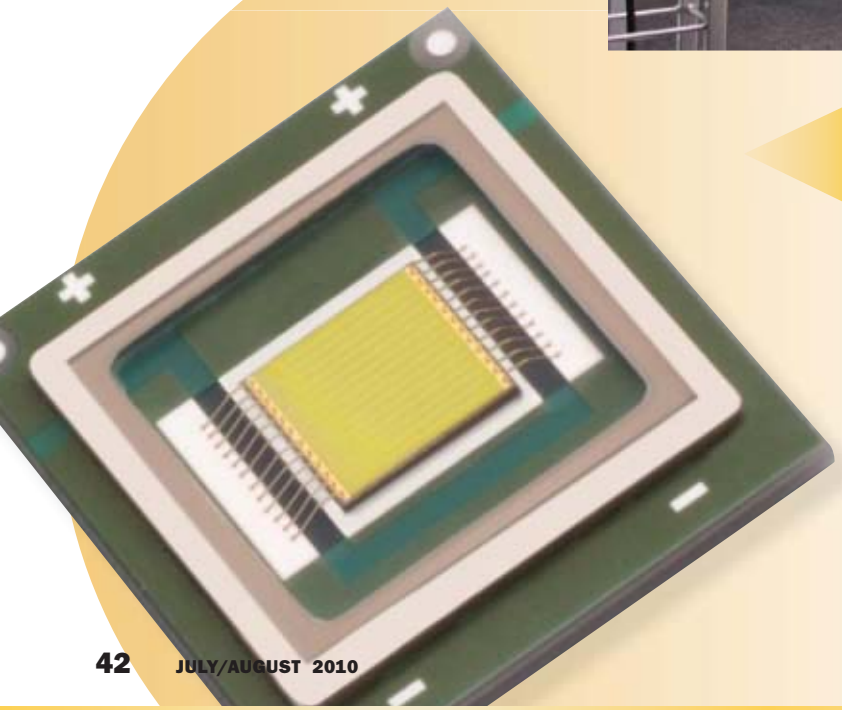
BetaLED uses an optic that it calls Nan beam pattern on its o lighting products. Earl company announced the 304 Series that broke the 100 lm/W mark (www.ledsmagazine.com/news/7/1/20). At Lightfair the company had several new products including the FP-90 street and area luminaire pictured. BetaLED classifies the luminaire as a designer series product and in fact had the Ferrara Palladino lighting design house in Milan, Italy handle the design. Pietro Palladino, Ferrara Palladino founder and engineer, said, "I believe fixtures should not exist just to execute a function, they should be nice to look at. We wanted something that was simple and easy to install and maintain." The FP-90 is available with 40 to 90 LEDs.

ss a spectrum of s a planar array of Marketing and has an individual e light into the target zone." Those individual optics called AccuLED control the beam pattern and can even direct light primarily in one direction – for instance reducing glare to oncoming drivers traveling in a one-way lane in a parking garage. The Lumark Ridgeview luminaire shown along with the LightBar targets parking-lot and perimeter-security-lighting applications.

LEDs

One would be hard pressed to find more variety in a Lightfair booth than Osram offered up. Demonstrations ran the gamut from individual LEDs to OLEDs to an LED-based retrofit lamp that also serves as an MP3 music speaker system – called MusicLite. Products such as an iPod can use a small wireless transmitter to stream music to a speaker integrated along with LEDs in the MusicLite luminaire. Osram hasn't formally announce the pictured MusicLite product, but expect such an announcement later this year. Meanwhile, LED demonstrations included the Golden Dragon Oval Plus. The oval lens on the LED spreads the beam pattern in a near-rectangular fashion simplifying the design of luminaires with beam-pattern requirements for street and area-lighting applications.

Seoul Semiconductor added to both its Acriche and Z-Power LED families at Lightfair. In the AC-powered Acriche line, the company launched 1W A6 and 4W A7 products that are smaller than existing Acriche products. The A7, for instance, measures 8x8 mm compared to existing 18x12-mm Acriche LEDs. The cool-white 75-lm A6 and 290-lm A7 target general lighting fixtures and streetlights. In the Z-Power series, the new Z5 comes in 3000K or 6300K CCT and offers a CRI of 90. The Z6 is an RGB model for decorative and architectural lighting. And the Z7 integrates four individually addressable LEDs in one package.



Continuing along their chosen path of producing big, bright LEDs, Luminus Devices announced the SBT-90 PhlatLight LED at Lightfair for entertainment, display, medical, and automotive applications. The LED is specifically applicable in applications that don't have a secondary optic such as a dome lens. Luminus designed the package expecting that the LED would emit light directly. Director of Global Product Marketing Chuck DeMilo said, "The SBT-90 contains a single 9mm^2 chip so the optical brightness can't be matched by tiled arrays of traditional 1W LEDs." The LED outputs 1800 lm with a 6500K CCT and a CRI of 70. Luminus also exhibited luminaires from a number of partners. Perhaps the most notable was the Almeco Vega street light that uses a single Luminus CSM-360 PhlatLight.

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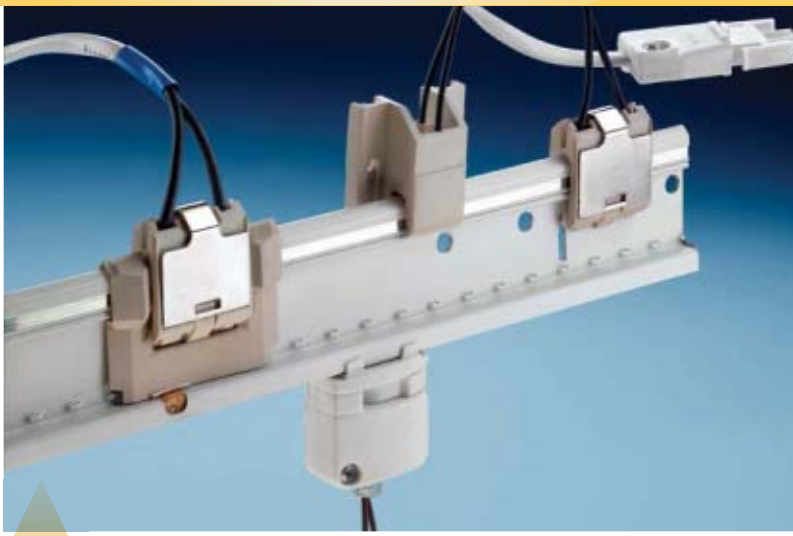
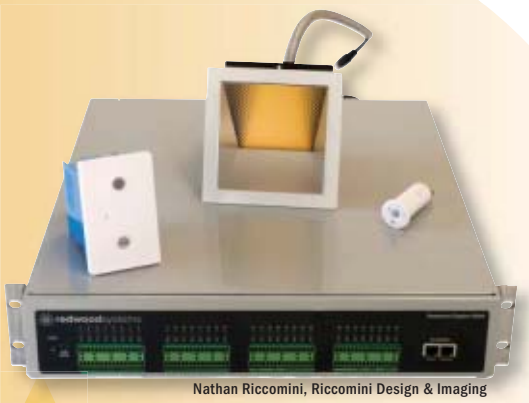
DC Power distribution



The concept of DC power distribution for LED lighting was prevalent at Lightfair with the EMerge Alliance pushing its standard (www.ledsmagazine.com/press/22355). The California Lighting Technology Center is also championing the technology. The Alliance claims that LED lighting driven by the DC scheme can offer an additional 10-15% efficiency gain relative to typical LED lighting with AC/DC drivers. On the show floor, demonstrations of the technology took place in the Tyco, Osram, and Lunera Lighting booths. Tyco has developed a grid interconnect scheme that supports the low-voltage DC standard for use in commercial interior applications. The interconnect relies on a bus bar to carry the DC current. The system offers the flexibility of allowing modification or addition of lighting fixtures without any rewiring. Tyco offers Universal Mate-N-Lock connectors for use with the grid.

Lunera Lighting demonstrated a number of their LED-based planar lights at Lightfair including models that can be driven by EMerge-Alliance-compliant power sources. The 4-ft linear suspended luminaire (pictured) outputs 1700 lm and consumes 30W. Lunera offers multiple color temperature options ranging as high as 5000K. The suspended luminaires also come in an 8-ft version. Other Lunera fixture models can be installed directly in suspended ceilings and serve as replacements for 2x4-ft fluorescent troffers in commercial applications.



Nathan Riccomini, Riccomini Design & Imaging

Redwood Systems formally launched its network-based lighting power and control platform at Lightfair. The platform includes both a DC-based power distribution scheme and an engine that controls the luminaires and offers network support for remote monitoring and control (www.ledsmagazine.com/news/7/3/7). The Redwood approach is proprietary but does work with LED luminaires from major manufactures such as Acuity Brands Lighting, Cree LED Lighting, Intense Lighting, Lunera Lighting, GE Lighting, and Philips Lightolier. The engine is accompanied in the picture by a Calculite wall washer from Lightolier.

The EMerge Alliance

demonstrations on the show floor all relied on a power supply from Nextek Power Systems called the Power Server Module. The power supply takes a 208-240V AC input and provides sixteen 24V DC output channels. Optionally, the supply can also operate from DC sources such as solar or fuel-cell systems. The system also includes a Zigbee wireless network for remote control and monitoring. Typical installations will mount the Power Server Module in a suspended ceiling to drive a number of luminaires. The system can also connect to occupancy and other sensors to automatically control lighting and maximize energy efficiency.

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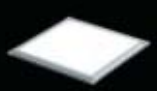
90Lm
550Lux

35°/60°

MX50L
5W
12V
300Lm
520Lux



DFL-V0606N
64W
AC90-245V
4300Lm
1440Lux

3 Color Mode
Q-200
10W
12V
1400Lux

15°/25°/40°/60°

GA3022S
18W
AC90-245V
540Lm
4200Lux

IX060B
7.5W
AC90 - 245V
440Lm
130Lux

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drivers | RELIABILITY

Well-designed LED drivers are no longer the weakest link in the chain

When correctly designed, LED drivers deliver strength and value to the entire LED lighting ecosystem, as **ARYE SCHREIBER** and **JOHN DALY** explain.

LED power supplies, or drivers, are the great enablers — a little-known, barely-understood yet vital part of the LED lighting value chain. The drivers are crucial in determining how much power will go into the LEDs, whether and how they can be dimmed, whether additional controls and sensors can be added and used, and even how robust the fixture will be and where it can be located. Most importantly perhaps, drivers can give value to the entire LED value chain by being reliable and durable, or destroy the value of the entire LED ecosystem by failing hard and fast.

The great promise of LED lighting comes from the three Es: Economics i.e. saving money; Ergonomics i.e. greater performance, and Efficiency i.e. reducing the energy footprint. In order for LED lighting to deliver on its promise it needs to deliver in each of these three areas, and each of these is in turn facilitated by LED driver technology. Let's look at each in turn.

Economics

LED lighting is supposed to be more economical than competing technologies. These savings come from several areas. First, there's the durability of LED lighting. LEDs are typically rated for 35,000 or even 50,000 hours or more. This means that it could be years before a fixture needs to be changed or replaced, representing savings on maintenance and parts. How is this relevant to drivers?

Well, historically drivers were considered the weak link in the LED reliability chain. That's because they include electrolytic capacitors (e-caps) that eventually dry out. However, there is a lot that a driver manufacturer can do to ensure that the e-caps last at least as long as the LEDs themselves. At Lightech, for example, we use the highest quality e-caps, but also design the driver to draw heat away from the capacitor so that it runs cooler and therefore lasts longer. Our lab tests show that many of our drivers would last for more than 10 years at full-on and we have 7 years of LED drivers installed in which the e-caps are still not dried out. Calculating the lifetime of the e-caps gives us confidence to offer a 5-year warranty, which means that, in most cases, it is not the driver but the LEDs that are the weak link in the chain.

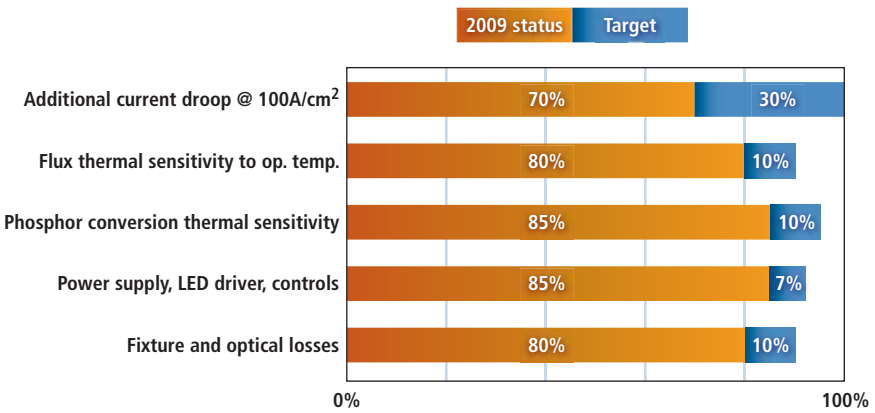

FIG. 1. Sources of loss in a phosphor-converted (PC) LED luminaire, showing 2009 status and targets for 2020. Source: DOE SSL R&D Multi-Year Program Plan, March 2010, www.ssl.energy.gov/techroadmaps.html.

Ergonomics

Another area in which LED lighting delivers extraordinary value is in its performance, convenience and comfort, also known as ergonomics. LEDs are inherently capable of being dimmed, and they consume proportionately less energy as they are dimmed—as well as ultimately lasting longer. This is in contrast to other technologies, notably fluorescent lighting, which is not typically dimmable. LEDs can also be switched on and off interminably, without suffering negative side-effects. They can also be created in almost any color temperature, and can be used to great effect for color mixing applications. Yet in this case too, the great potential of LEDs can only be capitalized with a driver suited to the purpose. Drivers need to be designed in order to enable the LEDs to deliver these various advantages. Chief amongst these is dimming, which used to be a luxury, but is fast becoming standard in the LED world. Let's look at dimming.

Dimming

How does a driver deliver dimming capability? Essentially, the driver takes a signal from the dimmer, and dims the LED

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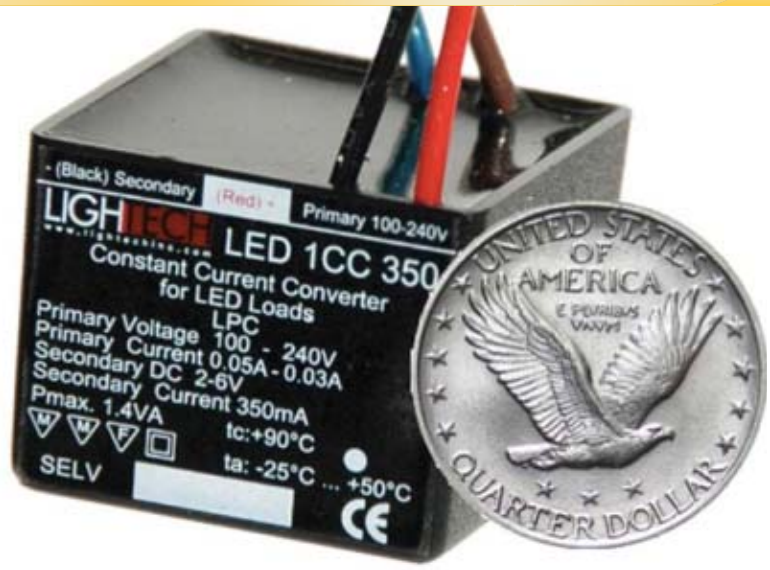

FIG. 3. Lightech drivers, available from 1W to 150W, have a 5-year warranty.

appropriately. Sounds simple enough, but there are several different ways to dim LEDs and none of them is simple. Firstly, the driver must take a signal from the dimmer. In many dimming technologies, that involves a separate control wire that must connect the dimmer and driver. That is how 1-10V dimming works, for example, and Lightech provides 1-10V dimming drivers for this exact purpose.

However, in a TRIAC dimming system the dimming signal is sent on the power line. In that case, there is no third wire to be pulled from the dimmer to the driver. This has an enormous advantage for retrofit markets (as opposed to new construction) since existing infrastructure can be leveraged to provide a dimmable LED solution.

Another way the driver adds value is by being compatible with as many dimming topologies as possible. Another is in dimming smoothly, without flickering. Another is that dimming drivers are trimmed so that several fixtures can be dimmed - and will dim to the same extent and level, even if they run off different drivers. Finally, and perhaps most importantly, dimming is a very subjective experience. The relationship between actual dimming (light output reduction) and perceived dimming (how the human eye/mind perceives it) is logarithmic. So greater dimming range enhances the user experience considerably, and a narrow dimming range barely affects the perceived performance at all. Dimming to just 20% of the original light output is perceived as just over 50% dimming and so forth. Lightech has patented technologies around dimming drivers that enable dimming well below 1%, and is continuing to develop drivers with extreme dimming capabilities.

Efficiency

Energy efficiency has become a key component in LED adoption. Of course, this is in large part driven by economics – energy is expensive and energy savings make LED lighting more valuable and therefore easier to adopt. LED manufacturers go to great lengths to improve the efficiency of LEDs—i.e. more lumens/watt—but the "low-hanging fruit" of efficiency are in the driver.

Beware driver manufacturers that wax lyrical about tradeoffs; we've heard it claimed that voltage-out (Vout) range is traded off against efficiency; that voltage-in (Vin) range is traded off against efficiency, and more. To be sure, there are tradeoffs, but good drivers can reach impressive driver efficiencies without compromising such critical metrics as Vout and Vin (there will be some tradeoffs, including good quality components that cost money).

Another important metric we often hear "traded-off" for better efficiency is in-rush current. This is particularly important for large installations, and we hear of customers being told by driver manufacturers that a low in-rush current would force down efficiencies. Don't fall for that nonsense. Sure, a cheap and easy way to reduce in-rush current could come at the expense of efficiency, but it needn't be that way. Properly designed drivers will not trade-off efficiency for a low in-rush current. At Lightech we show efficiencies of just under 90% with a tiny in-rush current of well under 1A.

FIG. 2. Lightech drivers were used in this installation at the Field Museum in Chicago, which features LumeLEX LED fixtures from Lighting Services Inc. that incorporate Xicato LEDs (www.ledsmagazine.com/press/20284).

Weak link grows stronger

The LED value chain is only as strong as its weakest link. There is a general perception in the market that the driver is the weakest link, but it isn't necessarily that way. Lightech's product development has proven that drivers can be more reliable

and long-lived that the LEDs. Further, they can add great value to the entire fixture, and even to the installation, by providing outstanding capabilities in everything from Vout range, in-rush current and ripple to dimming and efficiency.

As the LED lighting market matures, the capabilities and value-add moves from the LEDs to the drivers. LEDs and their commonly-projected supply surplus and pricing pressure will increasingly become commoditized; drivers in the meantime are becoming increasingly differentiated by their reliability, durability, controllability and performance.

Sure, the light engine provides the light, but the driver is taking its place in the driver's seat. This will increasingly add value to the LED lighting paradigm, as the driver is centrally located between controls and light engines. Drivers are the crucial intermediary between users' expectations and their experience. Drivers connect the human input into a system with the human enjoyment of that system. Drivers connect inputs and controls – switches, dimmers, sensors, and even electricity bills – and make the LEDs respond in line with users' expectations. For the user, the driver is the invisible enabler, delivering on the promise of the entire LED value chain.

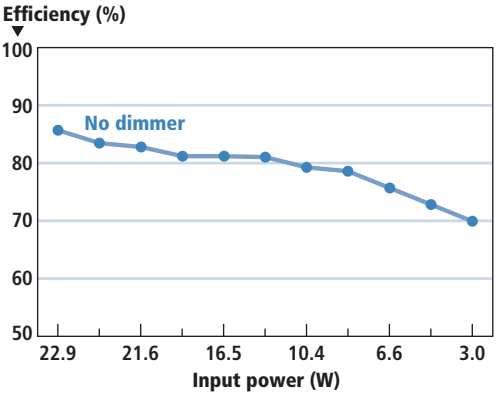

FIG. 4. Efficiency of Lightech driver with dimmer attached. Efficiency remains high through the full range of dimming.

LED drivers have become reliable and robust enough that not only are they not the weakest link, but they even deliver value to the entire LED lighting ecosystem. Looking forward, optimized solutions incorporating LED drivers matched with LED modules on one side and lighting controls on the other will increasingly become the staple deliverable to fixture manufacturers.

By delivering the entire technology value-chain, in which each part complements and enables the other, the LED driver, module and controls segments can provide the best technology and value, enabling the OEMs to focus on the fixture, and creating the optimal experience for the ultimate user.

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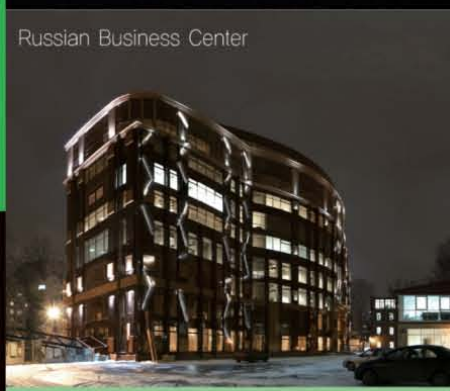

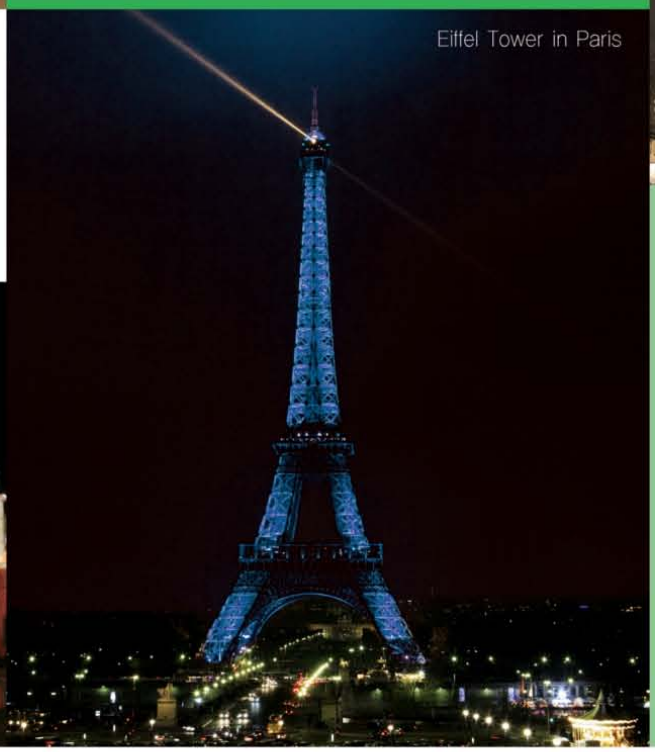

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Accurate third-party testing improves consumer confidence in Energy Star program

Improvements in goniophotometer engineering can increase the throughput of solid-state lighting test laboratories without compromising the accuracy of measurements, writes **JENNIFER LEWIN**.

The IES-LM-79 standard definitively states that lumen output and thermal issues in solid-state lighting (SSL) are best managed by requiring SSL performance testing to use absolute photometry on a Type C goniophotometer. The organizations that run programs such as Caliper and Energy Star have therefore charged their performance-testing laboratories to use absolute photometry on a Type C goniophotometer for luminaire output, efficacy, intensity distribution and zonal lumen density measurements.

Due to LED manufacturing processes, individual LEDs vary in lumen output. When placed into a luminaire and/or an array, the sum of the individual LED lumens (as modified by the luminaire components) becomes the cumulative light output of that luminaire. Relative photometry prorates test results against self-certified bare-lamp rated lumens. It uses mathematical calculations to remove the differences in the output of the bare lamp(s). Absolute photometry records the actual intensity levels during the test, such that the manufactured differences among LEDs are tested as they performed on the day of testing, in the sample fixture.

In most instances, an LED cannot be removed from the fixture in order to test it as a bare lamp. Even when this is possible, the production of LEDs results in a wide range of lumen outputs among the individual LEDs. Therefore, absolute testing is required to determine whether or not the cumulative light output of the luminaire is qualified for the Energy Star label.

It is additionally critical that the temperature of the array remains stable throughout the test so the light output levels do not shift. If the luminaire is moved or tilted during testing, then the temperature and the accompanying result (i.e. lumen output levels) will vary. With a Type A goniophotometer, typically used for measuring automotive incandescent lights, the luminaire is repeatedly tilted to different angles during testing. For SSL products, these tilts cause significant thermal instability that renders the entire test inaccurate. A Type C goniophotometer holds the luminaire steady, while (on most of today's models) a mirror moves around the luminaire.

For the above reasons, the Illuminating Engineering Society (IES) determined that the only accurate form of performance testing for SSL is absolute photometry on a Type C goniophotometer, so it is worthwhile to discuss the procedural implications of this type of performance testing.

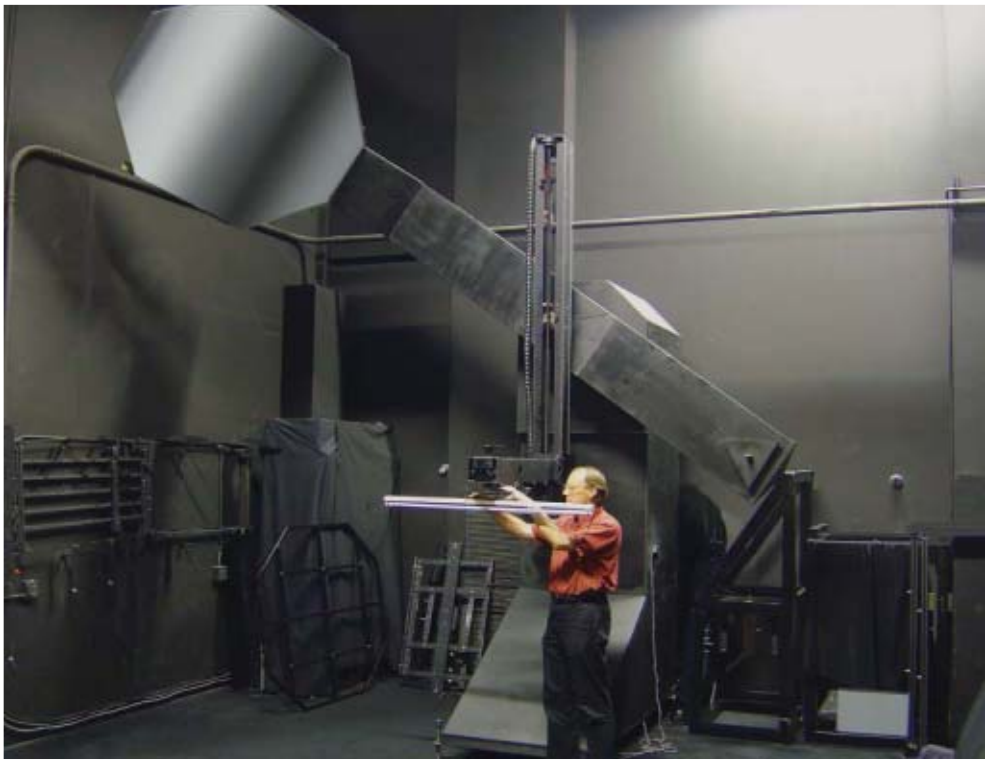

FIG. 1. LSI goniophotometer in the testing laboratory.

JENNIFER LEWIN *is the Director of Marketing of Lighting Sciences Inc., a lighting technology laboratory that provides third-party photometric testing services and supplies photometric and electrical test equipment. (www.lightingsciences.com).*

Consumer confidence in Energy Star labels

Absolute testing reports the performance of the tested package of the luminaire and its LEDs. If the lamps, i.e. the LEDs, are producing a lower lumen output than the manufacturer had expected, absolute photometry will show this. Relative photometry would hide this effect in the prorating to rated lamp lumens, but consumers could find that, at the end of the day, their lighting product does not perform as they had expected based on its labeling.

Customers need to be confident enough in the Energy Star for SSL label that they don't have to understand each IES file at the moment of sale. They must be able to rest assured that an Energy Star-labeled SSL product will perform at the lumen output and color levels stated. Above all other considerations, the lighting industry must ensure that each luminaire actually performs as the Energy Star label states it will.

The IES Testing Procedures Committee (which includes Lighting Sciences Inc. staff) has time and again chosen accuracy over expediency. IES-LM-79 very thoroughly states that LED-based products must be tested on a Type C goniophotometer using absolute testing procedures.

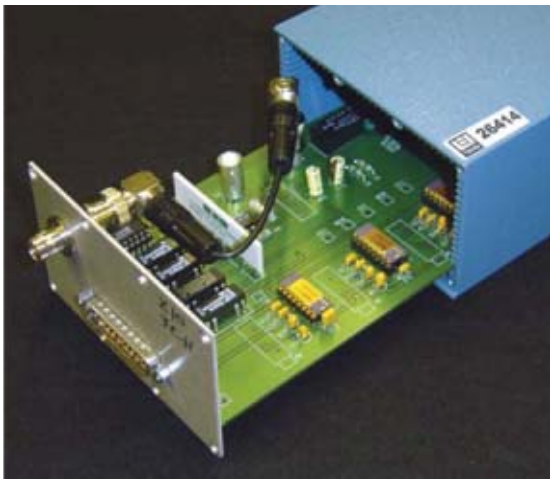

FIG. 2. Detail of the Series 6400T amplifier.

Self-certification in Energy Star

Non-lighting Energy Star programs commonly use self-certification practices during the application process, and certain areas of Energy Star for SSL (within IES-LM-80, specifically) also allow self-certification. Self-certification means that the program accepts data captured at the manufacturer's or component supplier's laboratory, whether of foreign or domestic origin.

Testing luminaires just prior to Energy Star application ensures that every single component in an SSL fixture is effectively measured by absolute photometry methods, to determine the real performance of the fixture as a whole. While it is possible that self-certified data may be acceptably accurate, the inherent variations in cumulative lumen output created by LED manufacturing itself means that self-certification is a greater risk for SSL than for non-lighting Energy Star programs.

Third-party testing

Moving away from self-certification and always toward actual intensity value readings (absolute testing) means certain shifts in procedure for the industry as it approaches Energy Star for SSL qualification. Rather than attempt to monitor the technical accuracy of every global manufacturer and all lighting component suppliers, the EPA/DOE uses US-based third-party goniophotometer laboratories for its Caliper program for evaluating SSL performance. The delivery time required for absolute testing is based on discrete methodologies set by the IES, which must be followed by the Caliper laboratories for each test.

Testing via a third-party laboratory also increases both the manufacturers' and the Energy Star program's credibility with the consumer audience. Many potential product issues can be identified by independent testing that otherwise could have slipped through without identification, until the unfortunate consumer discovered the issue in application.

Third-party testing is necessary to assure consumers that the Energy Star label means the very highest standards of lighting performance. Lighting manufacturers need the entire Energy Star for SSL application process to move swiftly, opening up the greater consumer market the label offers. In a fast-moving industry such as lighting, it does little good to tout the value of accuracy if that accuracy takes too long to record. What amount of time is "too long" is a matter of debate, meaning that the specific testing methodologies are the subject of intense technical discussions. The IES published the procedures to be used for Energy Star for SSL (IES-LM-79) testing despite the on-going nature of the debates.

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Faster testing procedures

Performing IES-LM-79 tests on a typical Type C goniophotometer requires sample fixture warm-up and stabilization and, during the test itself, manual management of the amplifier sensitivity. Third-party laboratories maintain warm-up/stabilization chambers so the fixtures are pre-warmed prior to placing on the goniophotometer. Once the long period of warm-up has completed in an adjacent area of the laboratory, the luminaire is quickly switched to a goniophotometer.

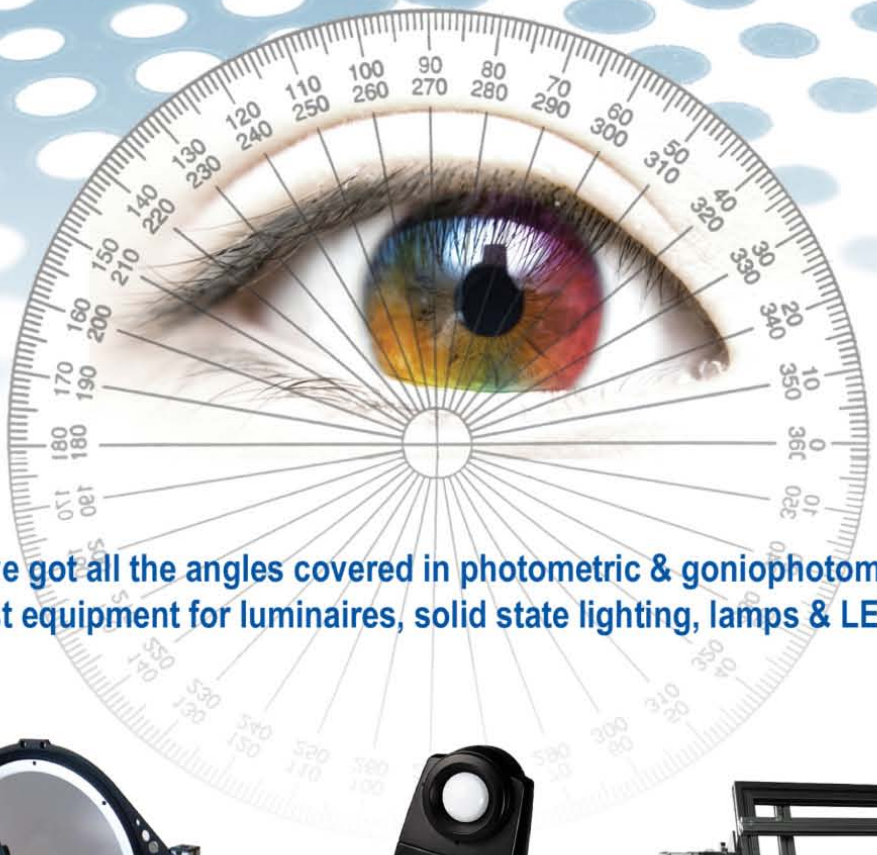
Despite the ability to reduce warm-up and stabilization times to a minimum, certain aspects of the test still require discrete amounts of time. One of these is setting the amplifier sensitivity level. With the luminaire stabilized, the mirror runs once to determine the luminaire's maximum intensity. The technician then sets the amplifier level for that maximum, so the intensity levels do not saturate, and the entire test is run with the amplifier on that setting. This leads to less accurate results at the lower ends of the intensity range, so if the test requires high accuracy at the low end, the amplifier needs to be reset and the fixture tested again. In practice, this is an unusual workaround; for most tests the lower-end intensity levels are simply accepted even if they are less accurate. The choice is either to accept the less-accurate readings at the lower levels, or to reset the amplifier sensitivity multiple times during test; neither solution is ideal.

Automatic amplifier sensitivity

To address this issue, Lighting Sciences Inc. (LSI) developed a new generation of Type C moving-mirror goniophotometer that effectively reduces the time required for testing. The LSI Moving Mirror Goniophotometer Series 6400T is the first on the market to offer multiple amplifier and electronic channels. The triple amplifier in the Series 6400T automatically optimizes amplifier sensitivity for all different intensity ranges during a test. Data collection occurs at a rate of 18,000 readings per second, allowing the mirror to rotate at 4 rotations per minute (RPM) or faster throughout the entire test.

An entire indoor photometric test now takes three minutes because all different intensity scales are read automatically and simultaneously by the goniophotometer. (Outdoor tests take a few minutes longer.) This has increased the throughput of LSI's goniophotometry laboratories. Previously, all Caliper laboratories had been bound to follow similar working procedures that required a similar amount of turnaround time for Energy Star testing. LSI is now using the Series 6400T to perform IES-LM-79 testing, and now averages fewer than 8 working days from receipt of fixture to emailing the IES file. The new goniophotometer allows delivery of test results to manufacturers more quickly, while fully supporting the IES, the EPA and the DOE in their missions to communicate comparable, accurate photometric data.

Total Light Measurement



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Search continues for replacement for Color Rendering Index

Color-rendering index (CRI) is widely used as a standard for assessing the color quality of white-light sources. However, due to various shortcomings with this 40-year-old metric, particularly with regard to white LEDs, various alternatives are being discussed and promoted.

The US-based National Institute of Standards and Technology (NIST) has developed the Color Quality Scale (CQS), as described in a paper by Yoshi Ohno and Wendy Davis of NIST which was published on the DOE's website (www.ssl.energy.gov/articles.html) in June 2010. The authors say that the purpose of the article is "to solicit comments from the SSL industry on the CQS," and such comments can be emailed to ohno@nist.gov.

The CQS is being discussed as one of the proposals in the Technical Committee (TC) 1-69 of the Commission on Illumination (CIE), which is evaluating new metrics for the color rendering of white-light sources. "Since the SSL industry is not well represented in the TC, we hope to convey the opinions of the SSL industry to the committee members," the paper says.

The authors note that a spreadsheet that calculates CQS has been distributed to many users in the SSL industry, and that CQS continues to gain support in the USA. But the authors believe that CQS is not gaining good support in TC 1-69, and that the TC is leaning toward a different metric which is "a pure fidelity metric very similar to CRI."

The NIST authors say that the lighting industry has long known of various shortcomings in the use of CRI. (The terms "CRI" and "CRI score" are used here and in NIST's paper to refer to the Ra score). "The CRI score does not correlate well with visual evaluation in many cases," say Ohno and Davis, "while CQS should work well for both traditional lighting technologies and SSL sources."

CRI assesses the color fidelity (i.e. the accuracy or faithfulness with which colors can be rendered under the light source) by calculating the color differences of a set of pre-defined test samples under illumination by the source under test and by a reference illuminant. It has long been known that color fidelity cannot serve as a sole indicator of color quality of white light, and CQS seeks to address this and other important aspects.

> "TC 1-69 of the CIE is evaluating new metrics for color rendering of white-light sources."

One problem with CRI is that it can give fairly high scores to sources that render some saturated object colors very poorly. An example is given in the NIST paper of an RGB-LED source which has a high CRI (Ra) of 80 but renders some colors, especially skin tones, very poorly due to a negative R9 value.

CQS also uses reference color samples, which comprise a total of 15 saturated colors. The CQS score (Qa) is notably reduced if one or two colors appear very poorly even when all other colors are rendered well (as in the case of the RGB-LED source above).

ASSIST promotes GAI metric

Shortly after the NIST paper was published, the Alliance for Solid-State Illumination Systems and Technologies (ASSIST) published the latest in their "recommends" series (www.lrc.rpi.edu/programs/solidstate/assist/recommends.asp), based on research conducted by the Lighting Research Center (LRC). Volume 8 in the series focuses on light-source color for retail merchandising, and includes a new metric that augments CRI in such applications.

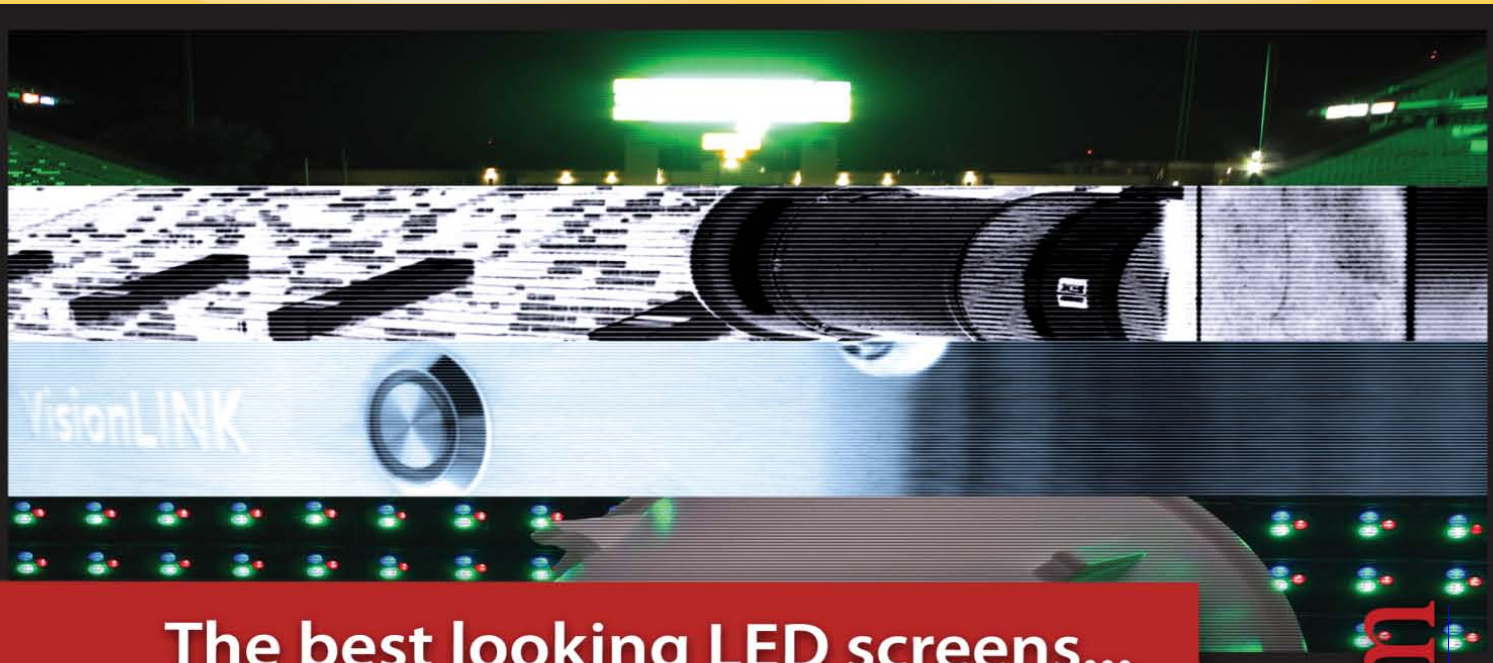
The new "recommends" volume includes two issues entitled "Guide to light and color in retail merchandising" and "Recommendations for specifying color properties of light sources for retail merchandising." The first provides a background on CCT and CRI including the advantages and drawbacks of each and how they can be augmented for retail applications. The second recommends a new two-metric approach for specifying light sources.

To achieve good color rendering, ASSIST recommends using CRI along with a new metric called GAI (gamut area index). GAI targets the relative separation of the colors in an illuminated object. A higher GAI equates to greater saturation or vividness of object colors.

Mark Rea, director of the LRC, said, "Broadly speaking, CRI is a measure of how 'natural' an object appears, and GAI is a measure of how 'vivid' the colors appear. LRC experiments show that light sources which balance both CRI and GAI are generally preferred over ones that have only high CRI or only high GAI."

The ASSIST publications include a step-by-step methodology to the two-metric approach, with the goal of achieving consistent lighting results. Rea said, "The rationale and new methods provided in this ASSIST volume should lead to a light-source specification that most closely represents a designer's intentions."

TIM WHITAKER *is the Editor of LEDs Magazine.*



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lighting | CONTROLS

Adaptive controls add to LED efficiency

LEDs may offer a path to more efficient lighting in many different applications, and adaptive control technology significantly stretches the efficiency gain, says Maury Wright.

As municipalities and commercial enterprises look to LED-based solid-state lighting (SSL) as a way to make major reductions in energy usage, the LED evaluation should include adaptive controls in the equation. Two recent research reports highly recommend that controls are part of commercial lighting upgrades, and an industry street-lighting expert has made the same claim. Controls that dim—or even extinguish—lights based on ambient light conditions and activity can slash electricity usage.

Reports from both Cleantech Approach (CTA) and Lux Research address SSL in commercial applications. The CTA report states that lighting comprises as much as 38% of the electricity expense in a commercial building, and that's clearly a target for reduction.

With the title of "Lighting Controls: Savings, Solutions, Payback, and Vendor Profiles," CTA's report puts a target on SSL savings in the 35-55% range (www.ledsmagazine.com/news/7/5/12). CTA goes so far as to recommend that companies first adopt a lighting control system when trying to cut energy usage, because control systems carry little of the technology risk associated with new lighting technologies such as SSL. Moreover, CTA expects a control system installed today to be compatible with new SSL technology in the future.

The CTA report calculates savings and the investment payback periods based on a range of costs for a lighting upgrade combined with their estimates for the energy-saving potential. In the worst-case scenario, a project would cost $2.50 per square foot and only save 35% in energy expenses, resulting in a 10.7-year payback. In the best-case scenario, a project would cost $1.00 per square foot and save 55% in energy expenses, resulting in a 2.7-year payback.

Aiming for 60% electricity reduction

Lux Research has also identified lighting as a target for energy savings, although the company's report "The Future is so bright: Energy, carbon, and cost savings through better lighting" puts lighting at only 20% of electricity use in a commercial building (www.ledsmagazine.com/news/7/7/6). Still, Lux estimates that by 2020 automated control technologies combined with SSL and higher-efficiency fluorescent lamps can reduce lighting electricity usage by 60%.

"With the potential cost savings afforded by new technologies like LEDs, advanced building illumination is on track for rapid and sizeable adoption, which spells opportunities across markets," said Michael LoCascio, a Senior Analyst for Lux Research. "If you want to improve a building's energy efficiency, lighting is the first thing you should look at because it's comparatively easy and inexpensive to update."

Lighting efficiency is especially important given the ramp in commercial building space, which Lux estimates is being added in the developed world at a rate of 11.3 billion square feet per year. The company believes that the annual cost of electricity for lighting is $174 billion globally, but that this can drop to $119 billion by 2020 even with the ramp in building space.

Lux projects that LEDs will "explode onto the scene in 2014," and that SSL will begin to supplant T8 fluorescent lamp in 2014 despite the fact that today's LED-based T8s generally do not perform well (see www.ledsmagazine.com/features/7/6/6). The company says that by 2020, LEDs will provide 60% of the light in commercial buildings and 42% of the light in the residential market.

Lux does warn that the early deployments of more-efficient lighting may ironically slow adoption later on. This is because electrical rates could stagnate or drop as lighting efficiency improves over the next decade. In turn, that would lengthen the payback period associated with efficient lighting deployment and actually slow the momentum.

Controls add street-light savings

In the outdoor lighting area, the concept of adaptive controls and dimming in street lights has long been part of the energy-saving discussion. It moved

MAURY WRIGHT *is the Senior Technical Editor of LEDs Magazine.*

LED street-lighting from ewo has been installed in Calcinate, Italy (see www.ledsmagazine.com/features/7/7/8).

Lighting manufacturer Schréder has incorporated HSMtec printed-board technology from Häusermann GmbH in the development of new street-lighting fixtures (see www.ledsmagazine.com/features/7/7/6).

to the forefront recently when Ed Smalley, director of the DOE Municipal Solid-State Street Lighting Consortium, addressed the topic in an interview with LEDs Magazine.

Smalley pointed out that municipalities will be able to save even more energy by never operating the lights at maximum output early in their service life. He stated that, for new LED street light designs and deployments, "you are designing for a time in the future." The point is that LED street lights must be designed so that the light output after 50,000 hours' usage (perhaps 11 to 12 years in the future) is still acceptable. The design must account for the projected decline in light output that all LED lighting products exhibit over time.

Smalley suggests that at install time, "You are putting out 30% more light than is required." So a street light with a controller could cut back the drive current by 30% in the period just after installation, both saving energy and potentially lengthening the service life of the LEDs and the drive electronics. Smalley stated, "We can save at least another 20% in energy."

In the past, most of the discussion of controls and energy reduction has primarily focused on dimming street lights late at night when there is little automotive or pedestrian traffic. LEDs offer a significant advantage in dimming capability compared to alternatives such as high-pressure sodium (HPS) or metal-halide lamps.

The concept of operating LED street lights at a reduced power level, and raising that level over time as light output declines, does introduce logistical problems. A networked installation of lights would allow for remote control of drive current and light output, but at significant added cost. Of course, municipalities could manually check the light output sporadically and adjust the lights, but that goes against the selling point of little-to-no maintenance of LED luminaires.

Asked whether municipalities might use networks or manual adjustment techniques, Smalley replied "All of the above." Smalley pointed out that the city of Los Angeles is in a multiyear street light upgrade program and is using the Roam remote monitoring system to monitor and control the lights.

Smalley also pointed out that Virginia Tech has developed a mobile unit that uses a camera to accurately measure light output without stopping traffic. Presumably, a municipality could survey street light performance on an annual or periodic basis and only make manual adjustments when required.

Both Smalley and DOE Lighting Program Manager Jim Brodrick have noted that zero maintenance is not a realistic expectation. In his keynote presentation at the Lightfair tradeshow, Brodrick noted that dirty lenses could be just as problematic in an outdoor lighting application as LEDs with depreciated light output. So municipalities may have to perform periodic preventative maintenance in any event.

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SMT assembly process requirements dictate choice of interconnects for LED-based PCBs

Assembling LED-based PCBs for solid-state lighting applications requires careful choice of interconnect technology so that the products are compatible with automated SMT processes, explains **LUKAS MUTH**.

The increasing luminance of HB-LEDs is opening up more and more areas for solid-state lighting (SSL). But HB-LEDs generate a lot of heat, requiring a robust cooling scheme, and for this reason HB-LEDs are often mounted on metal-core printed circuit boards (PCBs) to improve cooling. The metal core provides efficient cooling, but is not compatible with conventional through-hole connectors that ensure fast and easy wiring of the LED boards. Design teams need an interconnect scheme that is compatible with automated surface-mount technology (SMT) PCB manufacturing and assembly processes.

Miniature push-in PCB terminal blocks can solve the interconnect problem. Design teams need to choose products that are capable of quick wiring, and that meet the mechanical and thermal requirements of SMT assembly lines. This article investigates the requirements placed on SMT-capable PCB terminal blocks.

SMT processes

In SMT processes, components are automatically fed to the pick-and-place equipment for automatic mounting on the PCB. After all the components have been mounted, the PCB module is soldered in the reflow oven and is then subsequently inspected. These processes require all components to be capable of certain requirements (such as withstanding high temperatures).

The industry has generally adopted the tape-on-reel component-packaging scheme and conveyor system for the automatic feed of components to the pick-and-place equipment. The tapes, with standard widths of 24, 32, 44, 56, and 72 mm, are supplied wound on reels. They are then inserted into the feeder unit of the pick-and-place machines. Feeder table space is generally quite restricted, and widths of between 24 and 56 mm are the preferred choice. As a consequence, the tape width essentially defines the maximum length of the PCB terminals. This means that the components should be packaged in the narrowest possible standard tape width. Together with the other components of the LED PCB, they are then used in a standard feeder. Narrow widths ensure that commonly-used placing routines, such as "chaotic" placing, can still be used without any restrictions.

Placing and soldering

Depending on the particular pick-and-place machine, a free-placing height of approximately 25 mm is typically available. Generally, the free-placing height is even smaller for pick-and-place machines equipped with turret heads. The PCB terminal block height should then be as low as possible so that it can be used in as many pick-and-place machines as possible. This eliminates the need to program specific sequences, which is a complex procedure.

In order for the picking head of the pick-and-place machine to "pick" the PCB terminal from the tape, it must also have a smooth and adequately large suction surface. This means that the component can then be picked off the tape using a standard vacuum pipette; costly grippers or special pipettes are not required.

FIG. 1. The small dimensions of the PTSM Mini push-in terminals permit straightforward placing and processing.

The ability to briefly tolerate high temperatures is the first and foremost property that is specified for plastics used in SMT production processes. Depending on the particular requirement, polyamide (PA 4.6) or liquid-crystal polymer (LCP) are used. The requirement for high temperature stability has significantly increased with the changeover to lead-free processes. For many components, the upper temperature limit lies between

LUKAS MUTH *is with the Combicon Product Marketing department of Phoenix Contact GmbH & Co.KG (www.phoenixcontact.com), based in Blomberg, Germany.*

255°C and 260°C.

The process capability of a component manufactured from a specific high-temperature material must be qualified according to the IPC/JEDEC J-STD-020D standard. This standard focuses on the basic absorption of moisture in plastics, which can lead to destruction in the form of blistering, delamination, or deformation of the component itself when subjected to the high temperatures of the soldering process.

The standard defines threshold values for the moisture sensitive level (MSL) that determines the type of packaging as well as the processing relative to common SMT processes. A component whose plastic absorbs a lot of moisture (MSL 6) must therefore be dried and placed in an airtight package. After the packaging has been opened in the SMT production environment, the sensitive components must be processed within a certain time period. Maintaining the so-called "open time" ties up resources and requires time-consuming checking in the SMT environment. It is simpler to process components that have an unlimited "open time" (MSL 1), because then it is not necessary to observe when the packaging was opened.

SMT PCB terminals

Like all surface-mountable components, the solder contact surfaces of PCB terminals used in SMT processes must also comply with certain requirements. In this case, good solderability on the surface of the PCB is especially important. Most specifications stipulate a solder surface coplanarity of between 100 and 200 µm. This applies to the solder surfaces of anchor metals as well as to the contact solder pins, since the component is connected to the PCB through both of these surfaces. PCB terminals transmit electrical power or signals and, when the conductor is being connected (terminated), are subject to a mechanical load. When designing a PCB terminal block, it must be ensured that the block can withstand all of the mechanical forces while continuing to provide adequate electrical-connection reliability at the solder contact area.

Additional requirements arise from how the terminal is actually handled and used. Several options are available for implementing spring-cage connection systems.

Process requirements	Features of mini PCB terminal
Process: Feed and placing	
Short width to use the standard tape packaging	The maximum component width for 8 terminal points lies below 25 mm, which means that a standard tape width is used
Short height due to less free placing height; suction is suitable for a standard pipette	The height is only 5 mm the suction point is at the center of gravity of the terminal
Process: Soldering in reflow ovens	
High-temperature plastic with an unlimited open time	An LCP material with an unlimited "open time" (MSL 1) is used
Good solderability on the PCB surface	The solder surfaces are coplanar (100 µm) with respect to one another
Process: Operation/function of the terminal	
Mechanical forces are transmitted to the PCB surface	Strong connection between the anchor at the housing and the PCB
User-friendly connection system (simple to use, conductor can be released)	Direct plug technology for quick operation; can be released using a screwdriver
Reliable conductor clamping	Conductors from 26 to 20 AWG rigid/flexible are clamped
Power can be transferred	Approved for 5 Amps up to 150 volts UL

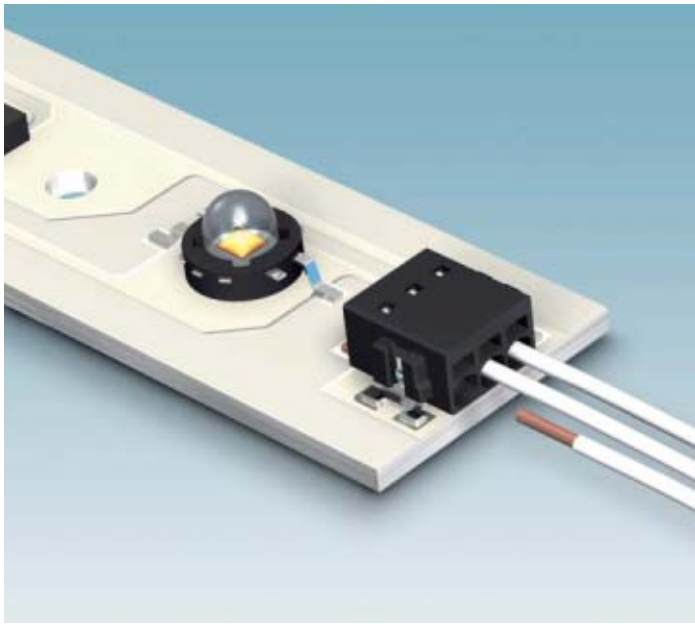

FIG. 2. The PTSM Mini push in terminal is suitable for use in LED lighting modules as a result of its compact size.

One connection method is the push-in spring technology. This type of contact is extremely compact and allows conductors to be quickly connected as the pre-prepared wire is directly inserted. The terminal point has to be actuated with a screwdriver only when connecting finely-stranded conductors without ferrules, as well as when releasing the conductor. Taking into account all of the requirements from a processing-related perspective (Table), the ideal PCB terminal block has the same features as established SMT components such as SMT LEDs.

This means that hardware development engineers now have the option of producing connection systems and modules in just one SMT process at a favorable cost. Also, when it comes to subsequently connecting the conductors, users will not be able to identify any differences to a through-hole technology (THT) PCB terminal. These push-in PCB terminals (Fig. 1) can save users a lot of time when connecting multiple wires, making the terminal especially suitable for PCBs used in LED lighting technology (Fig. 2). In spite of the low height of just 5 mm, the rugged spring-cage connection allows conductors of up to 20 AWG to be inserted and removed conveniently.

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Active PFC driver design enables dimmable retrofit lamps

Designers of LED-based solid-state lighting (SSL) retrofit lamps face thermal and power challenges as well as the need to work with legacy dimmers, but new driver topologies enable reliable designs says **PIERO BIANCO** of Maxim.

Halogen and incandescent lamps, although popular, present some key concerns in today's power conscious, green world. The lamps consume a lot of power and typically burn out after a few thousand hours of use. The latest high-brightness LEDs (HB-LEDs) offer a great alternative – they use a lot less power and can last about ten times as long. However, designing LED-based solid-state lighting (SSL) replacements for popular halogen and incandescent lamps such as the MR16, PAR20, A19, and others presents several design challenges. The retrofit lamps must work with legacy triac dimmers and the driver electronics must fit in a tight space. But new driver designs with active PFC stages are enabling reliable and dimmable SSL retrofit lamps.

The primary challenges of designing an LED retrofit lamp include:

- The retrofit lamps must fit in the same socket as the lamp they replace, and that means they should have the same form factor;
- They have to manage the high amount of power generated by the LEDs, by having proper heat sinking, but also by working at high temperature while keeping high reliability and long lifetime;
- They must be electrically compatible with the existing lighting infrastructure (wiring, dimmers, etc.).

Previous-generation LED drivers could implement retrofit LED lamps that meet the first challenge, but most of the drivers don't have the circuitry to meet the third challenge when a cut-angle (triac or trailing edge) dimmer is present, and can have problems delivering long lifetime at high operating temperature, due to the lifetime limitations of electrolytic capacitors. However, the latest–generation drivers, such as the solutions offered by Maxim, incorporate additional circuitry to handle dimming functions and provide workalike functionality to halogen and incandescent lamps, while delivering what is probably the most important advantage of LED technology today, which is the very long lifetime of the lamps and, as a consequence, low lamp replacement costs.

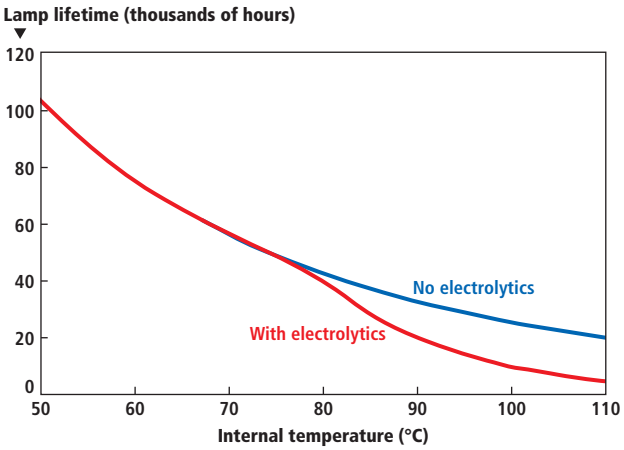

FIG. 1. As the internal temperature of the lamp increases, its operating lifetime decreases. Lamps that employ electrolytic capacitors in their driver boards (red line) have shorter lifetimes than lamps that don't have electrolytics (blue line).

Fitting in the existing form factor

The existing form factor imposes both a physical limitation (i.e., the driver board has to be small enough) and a thermal limitation on a retrofit lamp. Both limitations are particularly challenging for MR16 and GU10 form factors, but they pose a challenge for the design of any replacement lamp including PAR, R, and A19 form factors.

While size is important for a retrofit, thermal limitation is often more critical. LEDs emit only visible light; they do not irradiate energy at infrared wavelengths like other technologies. Thus, while LEDs are more energy efficient than incandescent or halogen lamps, they dissipate much more heat through thermal conduction in the lamp.

Thermal dissipation is also the main limiting factor for the amount of light that a lamp can produce. Today's LED technology in retrofit lamps can just barely achieve a level of brightness that is acceptable for the mainstream market. Pushing the limits of brightness and thermal management is essential for designing a commercially successful product.

PIERO BIANCO *joined Maxim Integrated Products in 2008 as Business Manager for High Brightness LED Driver products. Previously, he held positions of senior IC design engineer and field applications engineer at STMicroelectronics from 2005 to 2008, and before that he was an IC design engineer at Agilent Technologies and iTerra Communications LLC.*

A corollary issue to the thermal dissipation is the lifetime of the driver board. To emit more light, the lamp must work at a fairly high temperature -- often 80°C to 100°C. At this temperature, the lifetime of the driver board can limit the lifetime of the whole lamp. Electrolytic capacitors are, in particular, the biggest challenge. Since they dry quickly at those temperatures, the lifetime of those capacitors is limited to little more than 10,000 hours, and this becomes the limiting factor for the lifetime of the whole lamp.

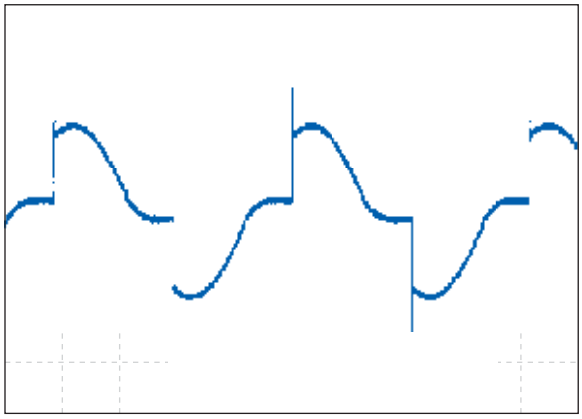

FIG. 2. Typical output voltage (vertical axis) against time (horizontal) for a triac dimmer.

The graph in Figure 1 shows an example of LED lamp lifetime degradation (B50/L70 lifetime, i.e. when 50% of the LEDs have lost at least 30% of their brightness) as a function of the lamp's internal operating temperature. As you can see, at about 80°C the lifetime shortens for lamps that use electrolytic capacitors vs lamps that don't use the electrolytics. At 100°C, the lifetime with electrolytic capacitors is much shorter.

Long lifetime is a major selling point for LED lamps, and probably the main reason why businesses are switching to LED lighting today—long lifetime means much lower lamp replacement costs, which can more than offset the considerably higher sticker price of LED lamps. For this reason, lamp makers need to provide more than 10,000 hours lifetime if they want to make a successful product.

Matching the electrical infrastructure

Retrofit LED lamps must work correctly in infrastructures that can include cut-angle (triac or trailing-edge) dimmers and electronic transformers.

Triac dimmers reduce the amount of light produced by a lamp connected as their load by keeping the lamp off for the initial part of each AC supply voltage cycle. The dimmer is off for an amount of time which is adjustable, and then turns on, and latches on for the rest of the half cycle. The effect is that the voltage applied to the lamp looks like the waveform in Figure 2.

Triac dimmers are designed to work with incandescent and halogen lamps, which are purely resistive loads. In fact, they have some requirements for their load current, which are fulfilled by a resistive load.

During the off part of the voltage half cycle, the dimmer cannot have an open circuit as their load, but instead needs a resistive load. Dimmers in general have a RC network that times the off time, and the load (the lamp) is the only return path for the current flowing through this RC network.

After the end of the off portion of the cycle, dimmers latch on. In order to remain latched on during the remaining part of the voltage half cycle they need to have at least a certain amount of load current. If the current falls below this amount, dimmers unlatch and turn off inappropriately, and as a consequence the light of the lamp flickers. High transient spikes in the load current can also be a problem, because they can cause the load current to fall below this minimum level.

LED lamps that are not designed to be dimmable do not work well with triac dimmers. The internal driver circuits

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typically include a rectifier, which converts the input AC voltage to DC, and a buck or flyback converter. The input current of such a driver consists of short, high spikes at each half cycle of the input voltage. Such an input current is not compatible with a triac dimmer. In fact, such lamps do not turn on at all when used with triac dimmers.

The electrical infrastructure is even more complicated for 12VAC input lamps because an electronic transformer and dimmer can be connected at the lamp's input.

Electronic transformers typically include an oscillating circuit that modulates the input 50/60Hz AC voltage with a frequency around 40kHz. The resulting higher frequency passes through a transformer that provides isolation and converts the input 120/230VAC to the output 12VAC. By modulating the input voltage with a higher frequency, it is possible to have a much smaller transformer, thus reducing size, weight and cost.

Similar to triac dimmers, electronic transformers need a certain amount of load current to remain on for the full cycle of the input voltage. If the load current is not sufficient, or has high spikes, the transformer can turn off, causing the light to flicker. For the same reason stated above, a traditional AC/DC converter driver can be incompatible with the transformer and dimmer, and cause the light to flicker.

Active power factor correction for dimmable LED lamps

Let's now consider a dimmable driver design for offline 120VAC lamps, and many of the same considerations apply to 230VAC input lamps.

As described above, dimmability of LED lamps, and compatibility with electronic transformers, both have a lot to do with shaping the input current of the lamp appropriately.

Another typical requirement for LED lamps that has to do with the shape of the input current as well is power factor correction. For LED lamps, a power factor of at least 0.7 is needed for most residential applications, and a power factor of at least 0.9 is needed for most commercial ones.

As the problems of dimmability and power factor correction are similar, it is likely that a single solution can solve both challenges. In this article in particular, we propose active power factor correction as the best solution for those challenges. There are numerous reasons why active power factor correction is superior to passive power factor correction in this case:

- With active power factor correction, a power factor of 0.9 is easily achievable; with passive power factor correction, a power factor of 0.7 is fairly easily achievable, but 0.9 is a much bigger challenge;
- Active power factor correction allows a very fine control of the input current, and therefore it can keep the input current above the level required for the dimmer to work properly for the whole cycle of the input voltage. With passive (or valley fill) PFC, the input current remains zero or close to zero for a certain part of the input voltage cycle, and/or is phase shifted with respect to the input voltage;
- Passive PFC, in particular if done with a valley fill circuit, causes spikes in the input current, which can cause flicker of the lamp as mentioned above. With active PFC, it is possible to reduce the amplitude of those spikes.

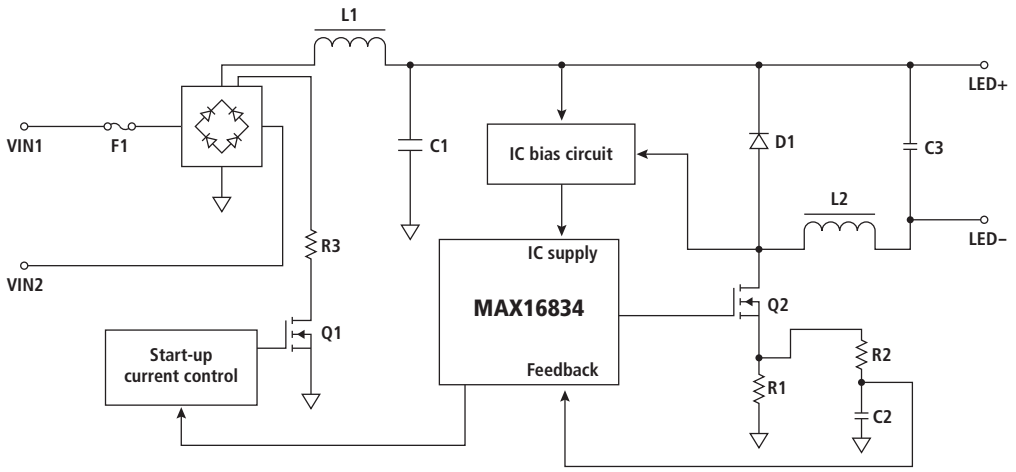

FIG. 3. Block diagram of the electrolytic-free LED driver

Fixed and variable frequency options

The designer also faces the choices between a fixed-frequency switching regulator topology and a variable frequency topology such as a transition-mode scheme, and between continuous conduction mode and discontinuous or transition mode.

Fixed frequency offers an advantage for the management of EMI issues. With a fixed frequency solution, the designer must only filter EMI noise at that particular frequency, while with a variable frequency design (e.g. a transition mode design) the switching frequency varies along the cycle of the input voltage, so it causes noise over a wide frequency range, which can be more difficult to filter.

The continuous conduction mode alternative offers the advantage of keeping the peak current lower, thus reducing conduction losses that increase as the square of the currents. With discontinuous or transition mode, the switching losses are lower because the MOSFET turns on at zero inductor/transformer current. But the gains in conduction losses in continuous conduction mode are often greater than the difference in switching losses.

The solution shown in Figure 3 uses a single-stage conversion, to minimize size and cost, to drive LEDs in a replacement lamp. It uses active PFC, and works at a fixed frequency in continuous conduction mode.

In this solution, the input current is shaped as a square wave at the » page 75

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same frequency as the input voltage. The current shape maximizes its value over the whole cycle of the input AC voltage, in order to fulfill the requirements of triac dimmers. The square input current is obtained by controlling its average value, and keeping it constant throughout the cycle of the rectified input voltage. Resistor R1 senses the MOSFET current, which is basically the same as the input current, and components R2 and C2 extract the average of this value, and feed this information to the MAX16834 which keeps it constant with its control loop.

As we mentioned before, an LED driver compatible with triac dimmers needs to behave like a resistive load for the dimmer during the off part of the input voltage cycle. In this design, components R3, Q1 and the Start-up Current Control block perform this function, by providing an input resistance whenever the input current of the driver falls below a certain level.

The IC Bias Circuit block provides a 15V supply for the MAX16834 IC. At start-up, a linear regulator circuit generates this voltage from the AC supply. Once the IC starts switching, a second circuit generates this voltage with a level translator supplied by the switching node, and overrides the linear regulator. This second supply circuit allows for an increase in efficiency of the solution, because it avoids the power dissipation that takes place in a linear regulator.

"Retrofit lamps must work with legacy triac dimmers, and the driver electronics must fit in a tight space."

This design uses a non-isolated buck topology composed of inductor L2, diode D1 and MOSFET Q2. It is possible to design a similar solution that uses a flyback isolated topology. So this solution works no matter if the safety isolation of the LED lamp from the input voltage is done in the driver, or in the enclosure of the lamp.

Option to avoid electrolytic capacitors

The electrolytic output capacitor C3 is optional. If it is included, the LED current has a small amount of ripple at twice the input voltage frequency. If a smaller value ceramic capacitor is present, the LED current is a rectified sinusoid at twice the input frequency, as mentioned above, but the lifetime of the lamp can extend to 50,000 hours or more, since there are no electrolytic capacitors in the circuit.

The circuit in the schematic above has been tested on a demo board, with a 120VAC/60Hz input, and 9 LEDs at the output with a total power of 12W. It has been tested to work with a wide range of triac dimmers from leading manufacturers including Lutron, Panasonic, Leviton, Cooper, and GE.

With output electrolytic capacitors, this driver dims to zero light intensity with no flicker. Without electrolytic capacitors, it can dim to about 5% of the maximum light intensity without flicker. The observed efficiency is 83%, and the input power factor is 0.93.

Designing LED retrofit lamps is a big challenge. They have to fit into a physical and electrical infrastructure that was made for incandescent and halogen lamps, which have very different requirements and limitations. Lamp makers can overcome the challenge with a driver based on an active PFC stage and offer triac dimming. The lamp maker can make the choice of dimming performance relative to the output capacitor selection and optimize the design for longer life or better low-light dimming.

last word

Don't put all your eggs in one basket: LEDs not all they're cracked up to be?

Although LED lighting is proving to be useful in many applications, **RON DAVIS,** a marketing consultant with **VU1 CORPORATION,** believes the industry should continue to consider other lighting options.

Many years ago, I was assigned the task of establishing a beachhead of mini-computers in a large Fortune 50 company that had been operating under an "IBM only" buying mandate. I was working for the second largest computer company in the world, Digital Equipment Corporation (DEC). To set the expectations of the 22-person DEC sales team calling on this account I brought them into the customer's primary data center. I walked them into a 50,000 square foot "glass house" packed with huge IBM mainframe computers and said "here's your challenge". As someone involved with a new lighting technology that is not LED based, I felt the same "challenge" as I walked into this year's Lightfair. I mentioned on the Vu1 Corporation blog (vu1corp.blogspot.com) that one was hard pressed to find even a CFL at this year's Lightfair, and that the name should have been changed to "LED Fair."

This all leads me to suggest that the lighting industry should not be "putting all of its eggs in one basket." LEDs will likely prove to be great solutions in many applications. They are already showing promise in automotive lighting, street lights, traffic signals, and retail and display applications. Unfortunately, some of the basic characteristics of LEDs may keep them from being the best solution in general lighting. Concerns regarding brightness, spectrum, glare, dissipation, CRI and cost are issues that may not have easy solutions. Recent articles by leading US Department of Energy SSL representatives are confirming that LED general illumination products are too often over promising and under delivering.

Another consideration often overlooked is the total cost of ownership (TCO) for LEDs over a reasonable period of time such as 5-6 years. An LED value proposition that is based on 30-50k hours does not hold up when you consider the actual time a homeowner will stay in their current home—an average of 6 years according to the National Association of Realtors. A light bulb needs to reach break-even in less than 2 years and start generating measurable savings. It will be a long while before a true direct-replacement LED-based R30 or A19 bulb will come close to offering a compelling 5-6 year TCO.

Lastly, the environmentally-focused consumer will start to look at the cradle-to-grave environmental cost of LED lighting solutions. When one considers materials (especially heat sinking), manufacturing processes and—the real show stopper—transportation costs (consider the weight of an LED versus a CFL or incandescent), the LED may end up being a losing proposition.

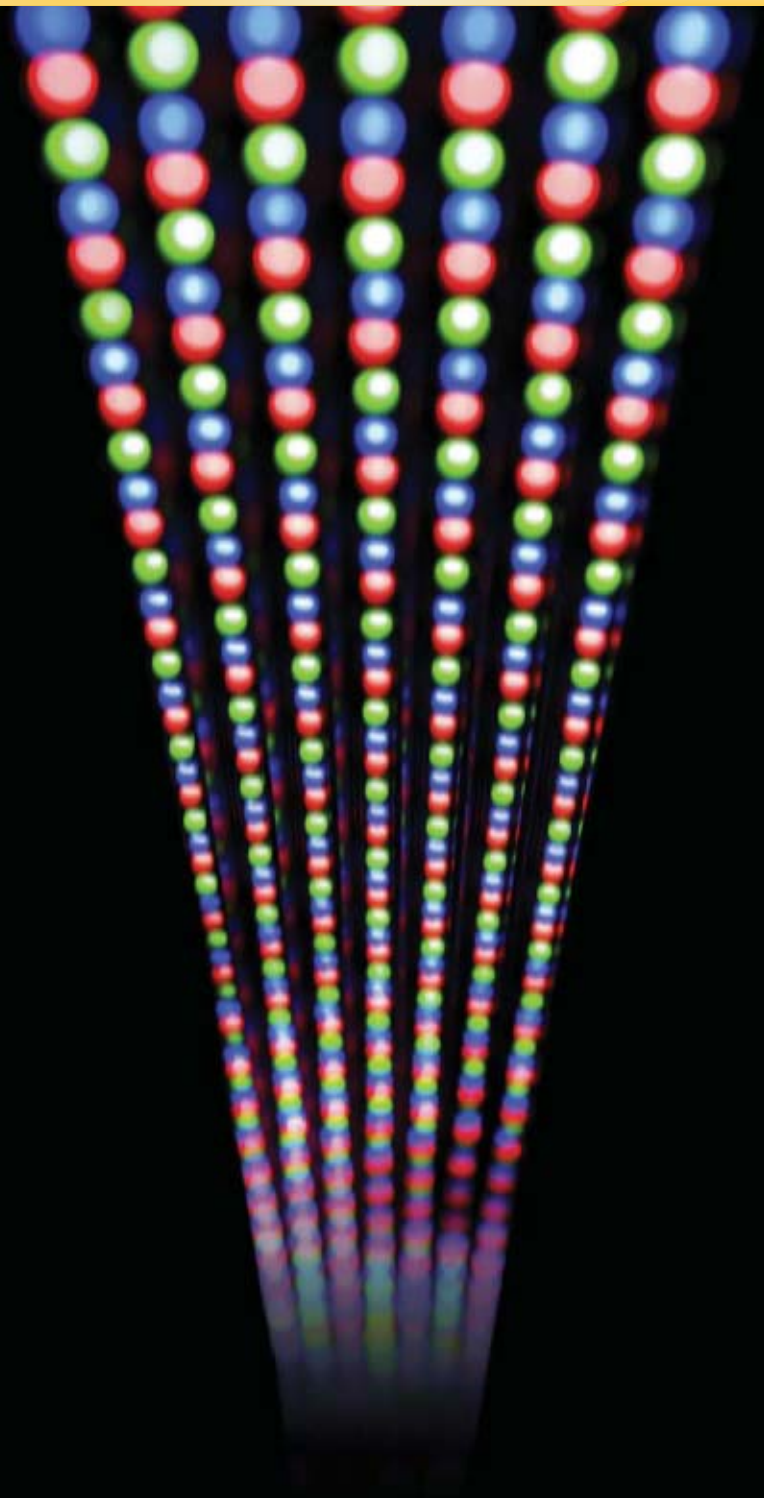
The CFL industry is currently in a losing battle as they try to down play down their environmental Achilles Heel i.e. the mercury issue. If the "small amount of mercury" in the CFL bulbs sold in America over the last 5 years were to end up in landfills, potentially gaining exposure to soil and water, it will represent enough mercury to contaminate every lake, river and stream in North America. The EPA predicts that—best case—only 25% of CFLs will be recycled. The rest will end up in landfills.

There are several energy-efficient technologies for general illumination that should be considered and supported by industry and governments; halogen infrared reflecting (HIR), photoluminescent nanofibers (PLNs), induction and of course my favorite, electron-stimulated luminescent (ESL).

Vu1 has been working to apply electron physics in a way never before used in general illumination to create a product that essentially duplicates the incandescent light spectrum while being fully dimmable, instant on, trash-bin disposable and similar in price and life to a CFL. Vu1 is hoping that industry and governments will want to hedge their bets and not put all their eggs in one basket.

By the way, what happened to DEC? They went out of business after 40 years. Why? Because they bet the farm on the mini-computer and refused to acknowledge that there could be a better technology on the way (the personal computer). Their eggs were all in one basket. **MORE**: www.vu1.com

• In mid-July 2010, Vu1 announced that the US Patent and Trademark Office had issued a Notice of Allowance for a patent application for its ESL lighting technology. More at www.ledsmagazine.com/press/23930.



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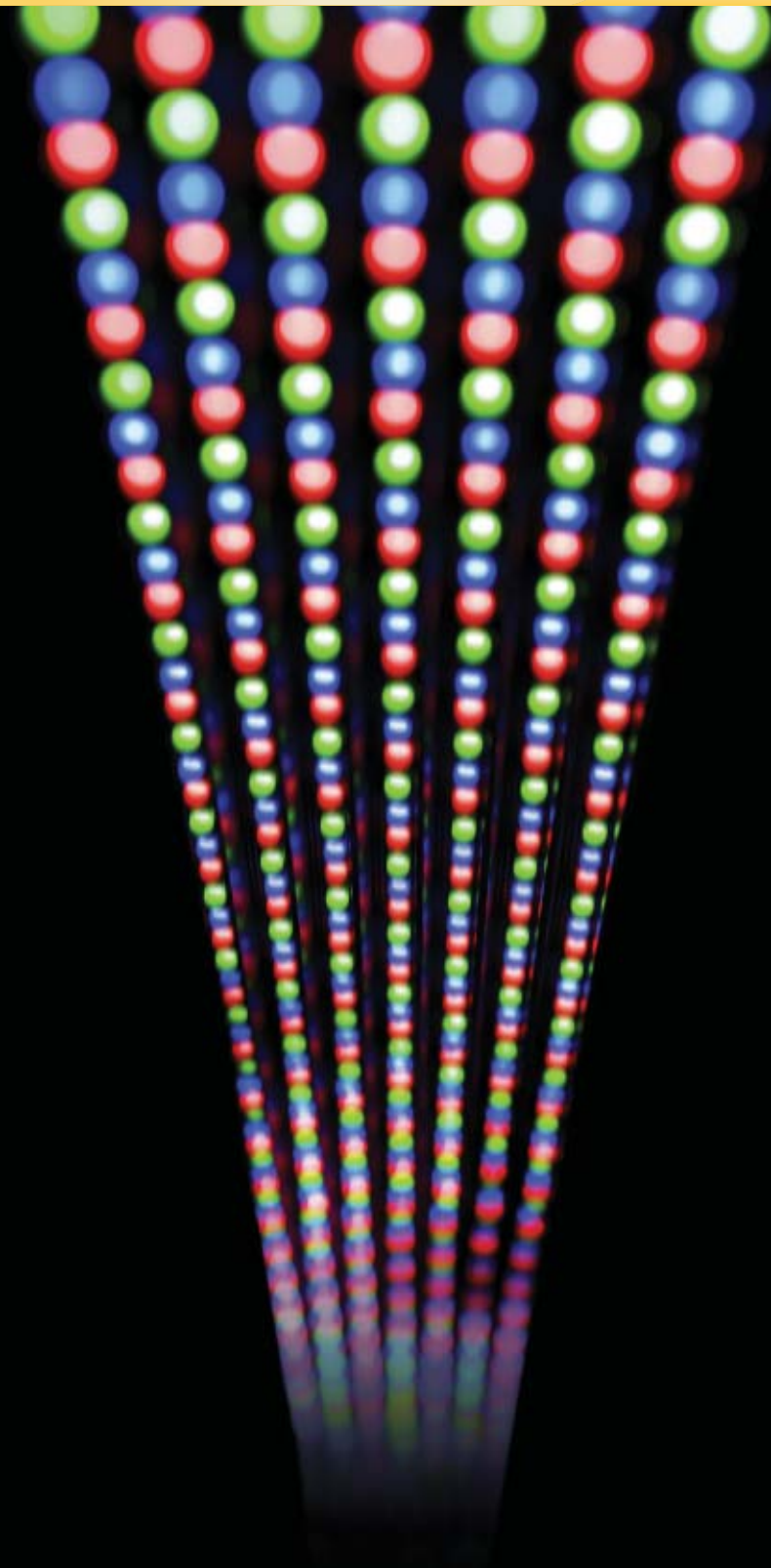

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Martin Goetzeler, President & CEO of OSRAM GmbH

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EVENT TIMETABLE

Monday 27 September

Workshops	10:30 – 15:00
Keynote Session	15:30 – 17:00
Welcome Reception & Exhibition (Sponsored by: OSRAM OPTO SEMICONDUCTORS GMBH)	17:00 – 19:00

OSRAM Opto Semiconductors

Tuesday 28 September

Conference Sessions & Exhibition	08:30 – 17:00
Networking Reception (Sponsored by: GRAFTECH INTERNATIONAL)	17:00 – 19:00

GRAFTech International

Wednesday 29 September

Conference Sessions & Exhibition	08:30 – 15:00

WORKSHOPS

Monday 27 September, 10:30–15:00

Workshop A

Standards for LED Lighting: What's the Current Status and Where Are the Gaps

Standards are playing an essential role in the growth of the LED lighting market and the rate of adoption of LED lighting in various applications. Without standards, performance comparisons can be difficult or impossible, and specifications cannot be traced to a meaningful reference. This can make customers and specifiers uneasy about using LED lighting for their projects. With standards in place, such issues can be alleviated. Various standards have already been issued, relating to both performance and safety of LED-containing products. This Workshop reviews the existing standards that are in place both internationally and in North America, and looks at the ongoing work to create new standards. Initiatives such as the Zhaga consortium will be discussed, as well as the different photometric measurements that are called for by various standards.

Workshop B

Building the Perfect Luminaire: Essential Considerations When Designing Effective LED Lighting

Due to the nature of LED light sources, the design of high-quality LED-based lighting fixtures requires specific design competences. OEMs and producers of LED-based luminaires must decide whether they have sufficient in-house expertise and resources, or if they need to select a partner with the appropriate knowledge in LEDs, electronics and associated components. These and other considerations are discussed in the "CELMA Guide for OEMs and Producer of LED-Based Luminaires," which will be presented during the Workshop. Further presentations will then focus in more detail on three specific technical areas that are all essential parts of a well-designed LED-based luminaire, namely optics, drivers and thermal management.

CONFERENCE PROGRAMME

Monday 27 September, 15:30–17:00

KEYNOTE SESSION

Shaping the future of light
Martin Goetzeler, President & CEO, OSRAM GmbH

European lighting industry efforts to promote quality led lighting
Jan Denneman, President, European Lamp Companies Federation (ELC)

European directives and LED lighting products
Speaker to be announced

Keynote Session is free of charge and open to visitors, delegates and exhibitors of SIL Europe.

MAIN CONFERENCE SESSIONS

Tuesday 28 September
SESSION 1 08:30–10:00

Market overview and forecast for HB-LEDS and LED lighting
Vrinda Bhandarkar, Analyst, LED Practice Strategies Unlimited, USA

Lighting designers and specifiers: how are their requirements being met by LED lighting?
Mike Simpson, Technical and Design Director, Philips Lighting, UK

Quality of LED lamps & modules: recommendations for EU regulation
Peter Besting, CELMA & ELC

SESSION 2 10:30–12:00

LED and OLED: the complementary light sources of the future
Markus Klein, Director, Solid State Lighting, OSRAM Opto Semiconductors GmbH, Germany

The future LED value chain
Dominik Wee, Associate Principal McKinsey & Company, Germany

China's strategies on SSL technology and industry
Wu Ling, General Secretary China SSL Alliance, China

SESSION 3 13:30–15:00

Driving for greater efficiency and performance
Gordon Routledge, UK Business Development eldoLED, The Netherlands

From enthusiasm to economy: precision optical design is a key to making LED street lamps cost-efficient
Andreas Timinger, Optical Designer OEC AG, Germany

AC LED – the infrastructure solution
Bob Kottritsch, Vice President, Lynk Labs Inc

SESSION 4 15:30–17:00

As strong as the weakest link: reliability from the LED system perspective
Rudi Hechfellner, Director of Applications, Philips Lumileds Lighting Company, USA

LED industry shifting from technology-driven to application-driven market
Tom van den Bussche, European Marketing Director ,Bridgelux Inc, USA

Lighting industry requirements from an LED manufacturer's perspective: LED performance, uniformity, reliability, form factor and other key areas
Tom Salter, Worldwide Business Development Manager, Cree, USA

Wednesday 29 September
SESSION 5 08:30–12:00

How many governments does it take to change a light bulb?
Roy Burton, Group Chief Executive , Dialight plc, UK

The new technology landscape of lighting - from challenges to solutions
Guo Qi Zhang, Fellow and Open Innovation Program Manager, SSL Philips, The Netherlands

LED backlighting: utilizing BLU technology for general lighting
Uwe Hock, Manager, Lighting Business , Sharp Microelectronics Europe, Germany

SESSION 6 10:30–12:00

High efficacy linear lighting fixtures – market demand, technical trends, competitive technologies, design approaches and manufacturer's experience
Michael Kramer, CEO, LED Linear GmbH, Germany

Modular spot- and down-lights beyond 1000 lumens with minimized supply chain complexity
Stefan Gianordoli, Leader LED Components , Ledon Lighting, Austria

Impact of video-based LED lighting in architectural projects
Carl Rijsbrack, Director, Product Management, Video & Lighting Solutions, Barco, Belgium

SESSION 7 13:00–15:00

Development of LED retrofits
Moritz Engl, Head of Department - Development SSL Consumer Lighting Europe, OSRAM GmbH, Germany

2010: The year of the LED module
Andy Davies, Product General Manager, LED Solutions, EMEA GE Lighting, UK

What it takes to bring 2.5 Million LED lamps to consumers' homes
Martijn Dekker, CTO, Lemnis Lighting, The Netherlands

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❑ 06 LED chip manufacturer
❑ 07 Lighting Fixture or display manufacturer
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❑ 09 Optics and Optical design
❑ 10 Drivers and Power supplies
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❑ 05 Signs and Displays
❑ 06 Mobile Appliances
❑ 07 Industry and medical
❑ 08 Architect/Lighting Designer/Specifier
❑ 09 Other, please specify
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