JULY/AUGUST 2011

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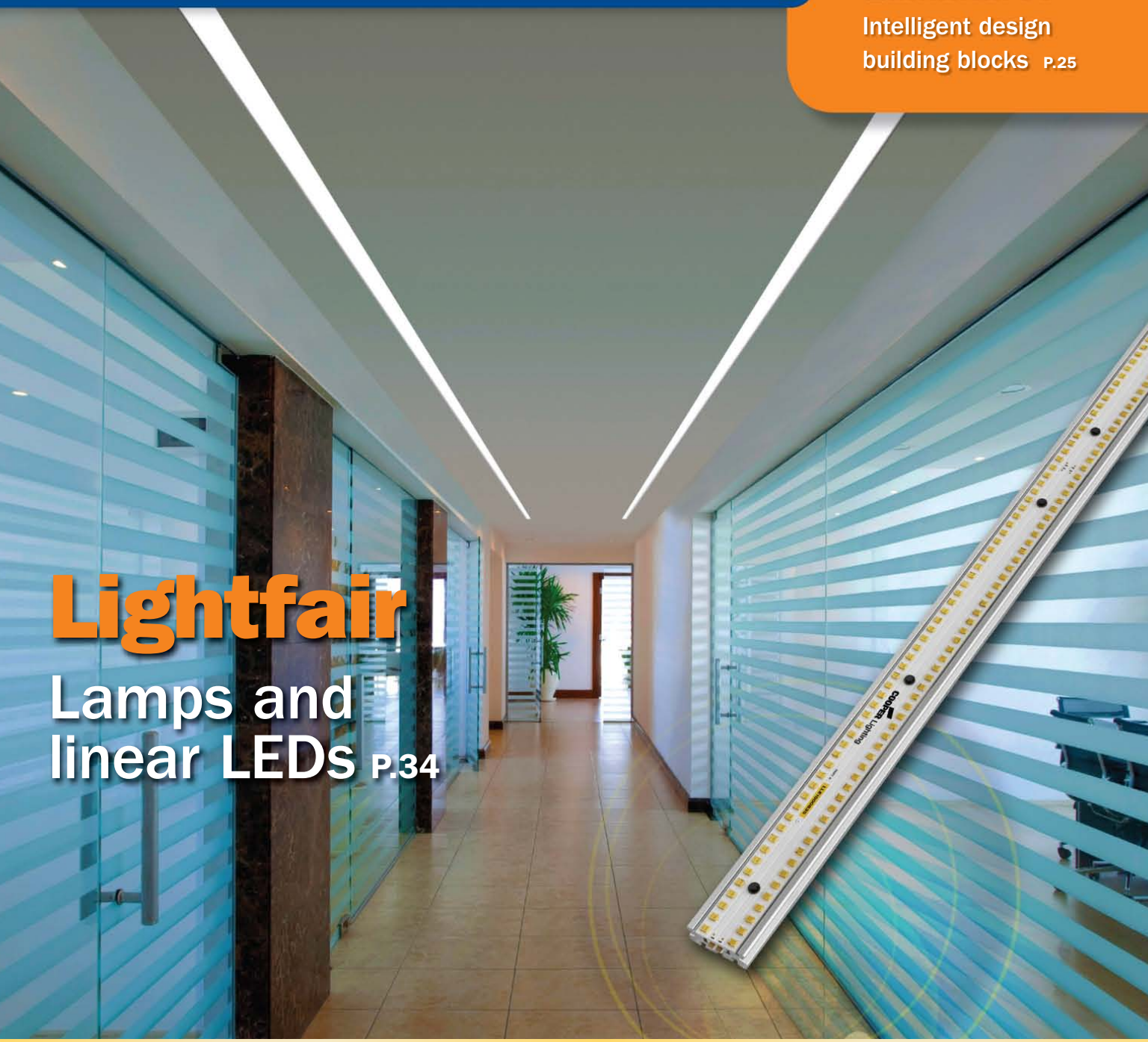

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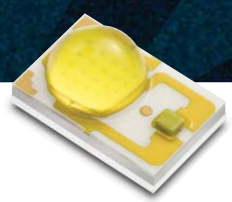

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ISSUE 44

july/august 2011

Cover Story

Lightfair 2011 delivered LED-based lighting innovation in many forms (page 34). Cooper incorporated its LED-based ALM module into various fixtures, including the Direct Recessed LED model from its Neo-Ray line.

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commentary

LED lamps may solve Japan's energy woes

With Japan's power-generating capacity hit by the closure of nuclear reactors in the aftermath of the earthquake and tsunamis, could LED lamps provide the most cost-effective solution? Japan's utilities are looking at ways to install new capacity to meet the shortfall, and in the short term this could lead to huge spending on solar power and other renewables. But what if energy demand can be cut, both rapidly and substantially? It's been suggested in some quarters that LED lamps could provide the answer.

A study in Japan (see page 22) has attempted to quantify the potential benefits of replacing all the country's lighting with LED equivalents. There are some big numbers involved: 1.6 billion lights to be replaced in total, which could result in savings of 92.2 TWh of electricity, equivalent to the generating capacity of 13 nuclear reactors.

Of course, the upfront cost is enormous, at 15.7 trillion yen (around $194 billion). But compared to installing new solar-power capacity, this could prove to be relatively cheap. The study quantified the cost to achieve electricity savings, calculated as the initial cost of LED replacements divided by the total electricity savings over an average usage of 40,000 hours. The result was an average of 9.2 ¥/kWh for replacing all lamp types, and only 1.3 ¥/kWh for replacing incandescents with LED lamps. In comparison, said the study, the cost of photovoltaic power generation is 40-50 ¥/kWh.

But what about the upfront cost? As the article on page 21 explains, the now-completed Eco-Point Program to promote energy efficiency in Japan had mixed results. It encouraged lots of people to buy large-screen digital TVs, which actually increased energy usage. But many people used their eco-point rewards to buy LED lamps, which provided a huge boost for the domestic market and demonstrated that LED lamps are popular (at least in Japan) if the initial cost can be offset in some way.

Several different but related models have been suggested to promote the widespread adoption of LEDs. These usually involve government-sponsored loans or subsidies that would provide LED lamps to end users at low or zero upfront cost. The energy-cost savings experienced by the end user would be used in part to pay for the LED lamps over time. For example, a utility could distribute LED lamps and then recoup its costs via regular utility bills.

The theory sounds good, but there's also the practical aspect of being able to supply sufficient quantities of LED lamps to meet market demand. But there's every reason to assume that Japanese LED makers and lamp manufacturers alike will be keen to rise to the challenge.

Still on the subject of replacement LED lamps, GE Lighting in collaboration with Cree has announced that it plans to throw its hat into the ring and compete for the valuable L Prize, organized by the US Department of Energy (page 10). While the requirements for 60W-replacement lamps are very stringent, the DOE must be wishing it had received more than 1 entry and 2 letters of intent in the 3 years since the L Prize was launched.

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July 26-27, 2011
Las Vegas, NV, United States

SPIE Optics + Photonics Exhibition
August 22-24, 2011
San Diego, CA, United States

China Int'l Optoelectronic Exposition
September 06-09, 2011
Shenzhen, China

Plasa 2011
September 11-14, 2011
Earls Court, London, UK

IES Street & Area Lighting Conf.
September 18-21, 2011
New Orleans, United States

OLEDs World Summit 2011
September 26-28, 2011
San Francisco, CA, United States

LED Japan / Strategies in Light
September 28-30, 2011
Yokohama, Japan

SIL Europe
October 4-6, 2011
Milan, Italy

Professional Lighting Design Convention
October 19-22, 2011
Madrid, Spain

4th International LED Forum Moscow
November 9-10, 2011
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OUTDOOR LIGHTING

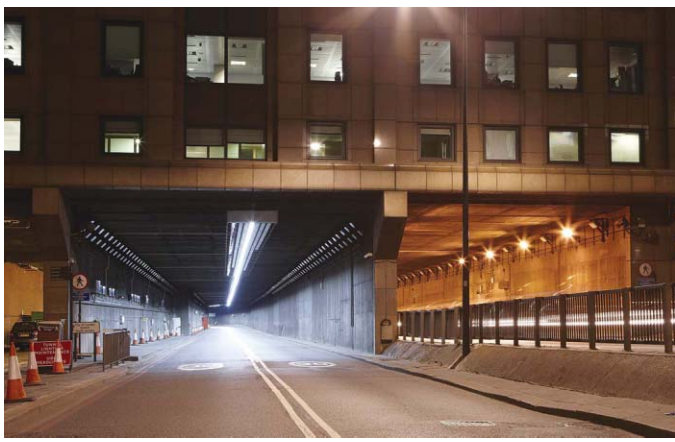
Philips to acquire LED outdoor-lighting specialist Indal

Royal Philips Electronics has entered into an agreement to acquire Indal, a Spain-based luminaire manufacturer which is well known for its expertise in LED outdoor lighting. Indal claims it has established a position as "the market leader of LED exterior lighting products" during the past three years.

Headquartered in Valladolid, Spain, Indal employs approximately 1,000 people in 11 countries, with sales of EUR 156 million in 2010. Financial details of the deal were not disclosed, and the agreement is subject to EU competition authorities' approval, which is expected to take up to nine months.

"Indal's capabilities in delivering lighting solutions make it a natural fit with Philips, further strengthening our ability to offer our customers integrated and high-value options for professional lighting," said Marc de Jong, Philips Lighting's general manager of Professional Luminaires, the group that Indal will eventually join.

Indal has been particularly active in LED-based outdoor lighting in the UK through its subsidiary Indal WRTL, which is the sole supplier to the very large project to install LED street lights to the city of Birmingham. Indal WRTL has also supplied linear LED lighting to a road tunnel in London (see photo). The company says that its Stela LED luminaire has been adopted by more than 100 local authorities, with more than 60,000 units currently installed. ◄



A linear LED lighting system supplied by Indal WRTL was recently installed in the westbound Upper Thames Street tunnel (left) in central London, contrasting with the legacy lighting in the eastbound tunnel at right (www.ledsmagazine.com/news/8/6/16).

MORE: www.ledsmagazine.com/news/8/6/29

PATENTS

Osram targets Samsung and LG with LED patent litigation

In early June, Osram, the Germany-based lighting manufacturer, filed LED patent infringement lawsuits against two rival Korea-based LED makers and consumer-electronics giants, Samsung and LG (www.ledsmagazine.com/news/8/6/2). Osram said it had filed legal actions against Samsung group companies and LG group companies in the US and Germany, and also targeted LG in Japan and China. Osram is claiming infringement of patents covering technologies related to electrical and thermal-connection structures as well as to the phosphor-based conversion technology used to make white LEDs.

Both Samsung and LG are leading LED manufacturers. For 2010, Strategies Unlimited placed Samsung LED as #2 and LG Innotek as #6 equal, while Osram Opto Semiconductors was ranked #3. White LEDs are used extensively for display backlighting for TV sets and monitors, both of which product categories are also manufactured by Samsung and LG.

Since a number of LED makers have signed royalty- » page 10

CONFERENCE

Program unveiled for Strategies in Light Europe 2011

After a successful launch in September 2010, the Strategies in Light Europe conference and exhibition moves to Milan, Italy, where the event will take place on October 4-6, 2011. The theme of this year's event is "Enhancing the Quality and Performance of LED Lighting", and the conference program (www.ledsmagazine.com/features/8/6/13) will address key issues surrounding the evolution and transformation of the lighting market, and the ongoing development of higher-quality, higher-performance LED lighting.

Speakers at Strategies in Light Europe 2011 will focus on issues such as critical challenges and barriers to adoption; case studies and user feedback; regulatory issues and standards; government support » page 10

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Patents from page 9 bearing licenses to use Osram's patents on conversion technology, it is reasonable to assume that this option was offered to Samsung and LG before the legal actions were initiated.

Shortly afterwards, Samsung LED stated its official position with regard to the Osram lawsuits, claiming that it has "never infringed" Osram's LED lighting patents (www.ledsmagazine.com/news/8/6/9). The Korean company described itself as "the leading company in the area of [packaged LEDs] and [LED backlighting units] for LCD display" and said that it has been "assiduous in developing its own core technologies and in protecting its own intellectual properties."

Perhaps predictably, Samsung LED Co., Ltd. then filed a patent infringement lawsuit against Osram Korea Co., Ltd. and two other defendants at the Seoul Central District Court. The eight patents cited relate to LED chip and package technology used in LED light lenses and high-power applications. In response to the news of Samsung LED's lawsuit, Osram said it was "relaxed about the move by the counter claimant" which it described as "a typical counter attack of a defendant." ◄

DRIVER ICs

LED driver IC market booms

LED driver IC sales will increase from nearly $2 billion in 2010 to nearly $3.5 billion in 2015, a compound annual growth rate (CAGR) of 12%. This is one of the results described by Mountain View, CA-based market research firm Strategies Unlimited in its new report "LED Driver ICs – 2011."

With its acquisition of National Semiconductor, Texas Instruments is now strongly positioned as the number one supplier of LED driver ICs. The top 10 LED driver IC suppliers hold more than 55% of revenues, with about 30 IC suppliers and captive manufacturers sharing the remainder. Winners will be those who can keep delivering innovative products at competitive prices. Also, fabrication with leading-edge, high-voltage processes will play a key role.

Growth will be driven by applications in LCD backlighting for edge-lit TVs and monitors, while LED lighting will be the "next big thing," beginning with LED replacement bulbs. However, LED driver IC revenues are threatened by continued integration into fewer ICs, as well as by competition from OLEDs, CFLs, and other technologies. Severe price erosion for driver ICs will limit the revenue growth as volumes increase, but new, higher-priced ICs are appearing that reduce the overall bill of materials and also help maintain the average price of the ICs. Also, AC-LED products minimize the driver and some eliminate the driver IC, but this will not have a significant impact on overall revenues through the period, and may even help accelerate adoption of LED lighting.

Revenues from LED drivers for lighting will see strong 40% CAGR through the period. Innovations in driver design will help take LED lighting mainstream, but the market will quickly shake out those who cannot meet strict goals for dimming, efficiency, power factor, and price. Also, industry and government are moving toward more-standardized specifications that will reduce manufacturing costs and accelerate adoption of LED lighting. ◄

MORE: www.ledsmagazine.com/news/8/6/22

LED LAMPS

GE collaborates with Cree on L Prize submission

GE Lighting says that it plans to submit a 60W-equivalent LED lamp to the Bright Tomorrow Lighting Prize (L Prize) competition, which is organized by the US Department of Energy (DOE) and targets solid-state lighting (SSL) replacements for inefficient legacy lights.

GE has collaborated with Cree on the planned submission, and says that Cree has designed a "custom LED component that features Cree TrueWhite technology to deliver superior efficacy and light quality." The technology mixes red LEDs with phosphor-converted white LEDs to deliver warm-white light. This will allow GE lamp designers to avoid the use of a remote phosphor, which appears yellow in an unlit state. The lamp submitted to the L Prize by Philips over 18 months ago, and which is currently undergo-

SIL from page 9 and funding; technology updates and roadmaps; the manufacturing supply chain; quality and reliability; and the competitive landscape.

One noticeable enhancement to the 2011 conference program is the addition of a second, parallel track. Following the opening Keynote session (Tuesday 4th October, 15:30–17:00) and the Plenary session

Strategies in Light China launched in May 2011. The next SIL China takes place on May 22-24 in Shenzhen (www.sil-ledchina.com).

(Wednesday 5th October, 08:30–10:30), the conference splits into two tracks, one on Market Transformation and the other on Technology.

The Market Transformation Track will look at some of the Europe-wide initiatives relating to solid-state lighting (SSL), for example the development of an EU quality charter, as well as a project that aims to establish a European metrology infrastructure capable of measuring SSL effectively. Other sessions will discuss the ongoing work to develop standards, and market-development issues such as financing. The Market Transformation Track will also discuss applications, focusing on the challenges and potential benefits of using SSL in different lighting environments. The last session will focus on outdoor lighting.

In parallel, the Technology Track will feature sessions on luminaire and system design; drivers and dimming; networks and control; retrofit lamps; optical materials and packaging; and finally optics.

The conference program provides a comprehensive update on the current status of the LED lighting industry, and offers valuable insights into future directions and strategies for business success. ◄

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ing extensive testing, uses the remote phosphor approach (www.ledsmagazine.com/news/6/9/24). GE clearly thinks that customers will want a lamp that looks similar to standard incandescents, and says it believes its solution will "more closely match consumer preference for an incandescent look and feel."

GE has only submitted a letter of intent to the DOE, and will need to provide 2000 lamp samples for the actual entry, along with a commercial manufacturing plan and detailed technical specs. Lighting Science Group also announced its intent to enter the L Prize in March this year (www.ledsmagazine.com/news/8/3/7) but has not yet submitted the required lamps and other collateral (at the time of writing).

The stringent 60W-replacement L Prize

40W-equivalent Energy Smart LED lamp.

requirements include an output of more than 900 lm with under 10W power consumption (i.e. >90 lm/W), plus a CRI of 90 or more, color temperature between 2700K and 3000K, and projected lifetime of greater than 25,000 hours. ◄

MORE: www.ledsmagazine.com/news/8/7/1

OUTDOOR LIGHTING

Hella and Hubbell collaborate

Automotive electronics and lighting supplier Hella has formed a strategic partnership with US-based lighting manufacturer Hubbell Lighting to develop and market a non-automotive application of Hella's LED lighting technology in North America. The two companies intend to form

a cross-branding relationship in which Hella will design, develop and manufacture LED modules (or light engines), while Hubbell Lighting will market and distribute roadway lighting fixtures into municipal markets.

The Hella LED light engine, which is designed for installation into existing cobra-head style roadway fixtures, will be manufactured at Hella's facilities in Flora, Illinois. The 48-LED module has a power consumption of 75W and produces 5850 lm, at an efficacy of 78 lm/W. The standard color temperature is 4800K and the stated power factor is 0.95. The module provides a Type II or Type III lighting distribution.

Around two years ago, Hella, which is at the forefront of developing LED lighting for automotive applications including headlights, introduced LED street lights in its native Germany. The Hella LED module will be integrated into Hubbell's RM series roadway fixture at the company's plant in Christiansburg, VA. It will also be marketed as a retrofit kit for existing roadway luminaires. The product is intended to replace 150W high-pressure sodium (HPS) and 175W mercury lamps and fixtures. ◄

MORE: www.ledsmagazine.com/news/8/6/19

REPLACEMENT LAMPS

LED lamps at Sears, Macy's

Two major retailers, Sears in Canada and Macy's in the US, are both undergoing major LED retrofit programs. Sears Canada plans to replace 130,000 incandescent spotlights with LED lighting in all Sears Home and full-line Sears stores across Canada. The retrofit, which the company described as one of the largest replacements of inefficient lighting ever completed internationally, will reduce the company's electricity use by more than 16 million kWh per year. Sears Canada is also banning the sale of inefficient incandescent and halogen lighting, becoming the first Canadian retailer to do so. James Gray-Donald, sustainability leader and associate VP, Sears Canada, said: "Replacing inefficient lighting products with LED and CFL options is a major move to save customers energy and money, while empowering them to take sustainable steps at home."

Meanwhile, in the US, replacement LED lamp manufacturer MSi says that Macy's, a national department-store chain, is continuing its retrofit program announced last December. As part of a wide-ranging program to reduce energy consumption and waste, Macy's is replacing halogen lighting with LED lamps, including iPAR lamps from MSi. Last year Macy's replaced over 130,000 60-watt halogens, and in 2011 another 280,000 LED lights will be installed in over 200 stores. ◄

GOVERNMENT PROGRAMS

India provides incentives for LEDs

The Indian government is set to provide incentives to the country's emerging energy-efficiency industry, including LED lighting, under the National Mission for Enhanced Energy Efficiency (NMEEE), according to an article in the Hindustan Times.

Two funds have been set up under the mission to provide financial incentives necessary to kick start a new industry. "Both these instruments [will provide] public money towards energy efficiency," said Ajay Mathur, Director General of the Bureau of Energy Efficiency (BEE). "Many banks are not ready to pay loans for companies in the energy-efficiency sector because the risk has not been evaluated."

In addition the BEE has asked the government to reduce excise duty on energy-efficient appliances including LED lights. "We are looking at making LED cost-effective in the next two years through market intervention and a labeling regime," Mathur said.

The article says that a 40W LED light that used to cost Rs 1,200 (around $27) a year ago now sells at around Rs 500 (around $11). The BEE believes that prices will go down further in the next two years as demand rises. Already, municipal bodies in Kolkata, Bho-

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pal and Gwalior are using LED streetlights, and others are expected to follow suit.

Also, the Bureau of Indian Standards (BIS) has introduced specifications for LED lights, and the government has created a testing facility at the Central Power Research Institute (CPRI) to examine LED-based lighting products. ◄

MORE: www.ledsmagazine.com/news/8/6/25

SAPPHIRE WAFERS

GT Solar, Rubicon expand sapphire production

GT Solar, a sapphire-crystal manufacturer which acquired Crystal Systems a year ago, has completed a $27 million project to create a high-volume production facility in Salem, MA (see photo). The expansion project, which began in the fall of 2010, has tripled the company's sapphire production capacity. "We've leveraged forty years of crystal growth expertise from Crystal Systems

and combined it with GT's successful track record of rapid scale-up of commercial crystalline growth technology to create a new state-of-the-art sapphire manufacturing facility capable of producing predictable and repeatable high-quality sapphire crystal run after run," said Tom Gutierrez, GT Solar's president and CEO.

Meanwhile, rival sapphire-wafer manufacturer Rubicon Technology has announced it is moving into volume production of 6-inch polished sapphire wafers at its facility in Penang, Malaysia, based on its recently-completed qualification by a key customer. The facility is also capable of processing and polishing 8-inch wafers to customers in R&D volumes. Typically, LED producers must re-qualify new wafer-manufacturing facilities by successfully producing LED chips on the wafers and testing the chips in specific applications. Existing Rubicon customers who previously purchased 6-inch wafers from its US facility in Batavia, IL have been re-qualifying the Malaysia facility. Rubicon's press release also stated that the Malaysia facility has successfully completed ISO 90001:2008 certification. ◄

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funding + programs

DOE provides $14.8 million in new funding for SSL R&D

The US Department of Energy (DOE) has announced its latest round of funding for solid-state lighting (SSL) core technology research ($4.3m), product development ($3.6m), and manufacturing ($6.9m) projects. Announced by US Energy Secretary Steven Chu, the latest funding round for LED and OLED R&D will distribute $14.8m across eight projects, and those funds will be augmented with an additional $4.2m in funds from the private sector. This is the 7th round of funding for core SSL R&D and the 2nd round of funding for manufacturing projects.

"These next-generation lighting technologies have the potential to transform the way we light our homes and businesses and generate enormous energy and cost savings for families and businesses across the country," said Chu. "These investments in cutting-edge lighting technologies will support American innovation, create new manufacturing jobs for US workers, and help ensure that the US leads the world in this rapidly-evolving industry."

Arizona State University ($0.66m), Research Triangle Institute ($1.70m), Soraa Inc. ($0.68m), and the University of Rochester ($1.25m) received funds in the core technology research area. In general, core research is focused on solving problems that are delaying widespread deployment of LED and OLED technology in general-illumination applications.

The two universities will both focus on OLED research. Rochester will investigate the use of an internal scattering layer to improve light extraction. Arizona State is researching a single-emitter approach to white OLEDs that could reduce costs.

Soraa will seek to improve packaged-LED efficacy by developing devices that can operate at higher current levels. The Research Triangle Institute will research methodologies for predicting the reliability and lifetime of LED-based luminaires.

The product development funds were split between LED manufacturers Cree ($1.61m) and Philips Lumileds ($1.99m). Product-development projects focus on reducing the cost and ramping-up the performance of SSL materials, devices, and systems.

Lumileds will focus on high-voltage, low-current LED designs in order to simplify driver requirements, improve driver efficiency and reduce system cost. Cree will investigate various design tradeoffs in LED package design and fabrication. Both companies are aiming for warm-white LEDs with efficacies around the 130 lm/W mark.

Moser Baer Technologies ($2.91m) and Veeco Instruments ($4.00m) will receive funding for SSL manufacturing projects, which are intended to achieve the manufacturing cost reductions needed to make LED and OLED lighting cost-competitive with other light sources.

Veeco will explore the use of an aluminum-nitride (AIN) buffer layer that could enable LED manufacturing on silicon substrates.

Moser Baer's project will focus on improved processing techniques that can reduce the cost of OLED lighting panels. The pilot OLED manufacturing line in Canandaigua, NY, will be used to demonstrate the improvements. ◄

MORE: www.ledsmagazine.com/news/8/6/7

EPA postpones date for Energy Star Luminaires spec

The US Environmental Protection Agency (EPA) has announced its intention to postpone the effective date for the Energy Star Luminaires Version 1.0 specification from October 1, 2011 to April 1, 2012.

EPA believes that postponing the effective date will allow Energy Star manufacturing partners and EPA-recognized Certification Bodies (CBs) and Laboratories the necessary time to appropriately apply the technical requirements contained in the new specification, while in the interim maintaining a sufficient selection of Energy Star-qualified fixtures for consumers.

The new date by which CBs will be asked to stop certifying new product models under the existing Energy Star Residential Light Fixture v4.2 and Solid State Lighting v1.3 specifications will be September 15, 2011 (formerly June 15, 2011).

In its postponement announcement (www.ledsmagazine.com/news/8/5/23), EPA also explained how manufacturers should deal with the uncertainty around two standards – IES TM-21-11 and IES LM-82-11 – which are referenced in the Energy Star specification but which are not yet published.

In related news (www.ledsmagazine.com/news/8/6/20), EPA is developing guidance related to lumen-maintenance performance data used to support the Energy Star qualification of LED-based lamps and luminaires. Specifically this relates to test reports, generated according to IES LM-80-08, for LED packages, LED arrays and LED modules. The most commonly-employed approach to fulfilling Energy Star lumen-maintenance performance requirements for lamps and luminaires is through projections based upon such LM-80 test reports.

EPA says that the objective of the guidance document is to "facilitate robust testing which...helps maintain confidence in Energy-Star-qualified lighting products." ◄

funding + programs

UL adds component certification program for packaged LEDs

Underwriters Laboratories (UL) is best known for safety certifications of end products sold in the consumer space, but increasingly the certification body is also developing recognition programs for enabling technologies. The company recently announced the LED Package Recognition program that will certify key operational characteristics of packaged LED components to UL 8750.

The LED package certification will fall under the Category Control Number OOQL2 in the US and OOQL8 in Canada (www.ledsmagazine.com/press/31604). The certification will verify the following characteristics:

– Input type
– Maximum junction temperature
– Environmental location suitability
– Enclosure considerations
– Maximum operating voltage.

A packaged LED might seem to be inconsequential in terms of safety testing. UL principle engineer for solid-state and LED lighting Bahram Barzideh admits that "People think of an LED as a low-voltage, low-current device." But from the UL perspective, he said, "This is the building block of the light source."

For example, Barzideh says that maximum operating voltage becomes a safety issue, especially with packages that integrate multiple emitters and arrays where the stack voltage gets quite high. Moreover, Barzideh said that in a street-light design based on a 400V input "a single fault could leave that voltage present across an LED package," depending on the particular luminaire design.

The UL test will verify factors such as anode-to-cathode spacing in a packaged LED and certify that the device can safely withstand the specified operational environment. While Barzideh admits that the operational characteristics don't look at first glance to be safety related, he said, "All of the concerns go back to UL 8750, which is a safety standard."

Mathew Sallee, head of global business innovation for solid-state and LED lighting at UL, relates that the LED vendors asked UL to develop the new LED package certification. According to Sallee, LED makers said, "We need a way to record a set of attributes relative to safety criteria."

UL has already recognized components in other categories, such as optical isolators, so LEDs are not unique in this respect.

While the initial emphasis behind the LED package program is safety, down the road we can expect UL to add performance guidance into the database of information it stores in relation to LED families. For example, UL already has test capability for the LM-80 standard. Sallee suggested that UL could verify and record component performance to LM-80 and other standards such as ANSI RP-27 and IEC 62471 that focus on photobiological safety.

Sallee foresees that end-product manufacturers will use UL's LED package database to carry out parametric searches in the component selection process. This capability already exists in other UL databases. Sallee said, "We currently do this with our plastics database for materials and enclosures." In the plastics case, he said searchers can utilize parameters including thermal ratings and electrical power ratings.

While UL has only recently announced the LED package program, there is one certification already in the database for the Samsung SPHWHTL3D30 family of LEDs. To search the database, go to the certifications section of the UL website and enter the OOQL2 code in the UL Category Code box. You will find the Samsung listing along with an information guide to the new program.

According to Sallee, other unnamed LED manufacturers already have products undergoing the certification process. He said the certification process will take four to six weeks generally, depending on the exact criteria that manufacturers choose to test. For example, some tests could be run with an aging angle, and that would require test times approaching 1000 hours. If UL adds LM-80 to the mix that would require longer testing based on the 6000 hours listed in the specification. ◄

Model Lighting Ordinance guides outdoor practices

In the Model Lighting Ordinance (MLO), municipalities have a new tool to help them prescribe outdoor-lighting practices that ensure a safe environment while minimizing light pollution. Nancy Clanton of lighting firm Clanton & Associates used Lightfair as a stage to unveil details of the MLO, which has been jointly developed by the IES and the International Dark-Sky Association (IDA). The MLO was released publicly on June 14 and is generally meant to specify criteria for lighting on private property.

Clanton said the MLO development focused on lighting first rather than energy. It is meant to apply to lighting applications such as monuments, signs, water features, and seasonal, landscape, emergency, and temporary lighting. The MLO could also be adopted by small communities that lack the engineering resources to create their own street-light regulations.

Some have seen the IES and IDA as having dueling goals, but Clanton said, "There really was a cohesive common goal." She added that the organizations were seeking to minimize excessive light to save energy, improve the enjoyment of the night sky, and minimize the impact on bio-cycles of people and animals.

The MLO defines light levels and sets limits on light spill based on five zones that are designated LZ0 through LZ4. Clanton said LZ4 is for places like Las Vegas or Times Square and "is not recommended for most cities." Conversely, LZ0 prescribes an absence of constant ambient light and the use of motion sensors.

Ultimately the success of the MLO will depend on city planners that make the right decision in choosing the appropriate zones and enforcing the MLO. Clanton said that Plymouth, MN and Anchorage, AK would be the first cities to adopt the MLO. ◄

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Japan's Eco-point Program transforms market for LED lamps

A government-sponsored program in Japan could serve as a model for other countries seeking to transform their domestic retail market for LED lamps, explains **PHILIP JESSUP.**

The superior performance of a new technology is no guarantee of market success. Potential adopters can gain experience with innovative technologies by trying them out first, but after new products pass this initial hurdle they often face an even more nagging barrier – higher cost.

In its recent survey of municipal-lighting asset managers across Canada, for example, the Toronto Atmospheric Fund found that 66% of the respondents were using LED lighting in some way and were well aware of its benefits. However, 86% of the respondents said that the high cost of LED technology is the leading barrier to adoption.

Governments employ a variety of policies to reduce the cost of new technologies to speed their market adoption. Feed-in tariffs jump-started the European market for wind and solar generation technologies. China's Green Light Program, which began in 1996, provided robust subsidies to accelerate adoption of CFL lamps across the country. Chinese companies now dominate this manufacturing sector globally. Meanwhile, the US DOE's SSL Manufacturing Roadmap has added a new pathway to the agency's strategy to accelerate SSL adoption, namely R&D funding that will reduce manufacturing costs while enhancing product quality.

Out of Japan comes another approach that has stimulated rapid market uptake of LED lighting – the Eco-point Program. In April 2009, then Prime Minister Taro Aso of Japan announced a large economic-stimulus package that included the $10.9 billion Eco-point Program to stimulate consumer purchases of energy-efficient air conditioners, refrigerators, and televisions. In addition to stimulating the economy, the program sought to reduce greenhouse-gas emissions and hasten digital broadcasting across Japan.

Here is how the program worked. After purchasing an energy-efficient appliance or TV, a consumer received from the government eco-points worth 5-10% of the value of the purchase – with each eco-point worth ¥1. The consumer then redeemed these points for a variety of 271 so-called green goods and services listed in a catalog sponsored by the government. These ranged from travel to hamburgers. Eco-points could also be redeemed for gift certificates for family and friends. Indeed, 85% of redemptions were eventually gifts.

	Number of lights	Annual energy consumption (billion kWh)		Annual savings (billion kWh)
		Existing lamps	LED lamps only	
Households	870 million	38.2	14.1	24.1
Offices & commercial buildings	580 million	89.1	34.6	54.5
Industrial sector	160 million	23.3	9.7	13.6
Total	1.6 billion	150.6	58.4	92.2

FIG. 1. Replacing all the incandescent and fluorescent lamps in Japan with LED alternatives could have a significant impact on energy consumption, but would have an upfront cost of ¥15.7 trillion, says the Institute of Energy Economics (see sidebar on p.22 for more details).

LED lamps join Eco-point Program

In December 2009, the government added LED lamps to the list of redeemable products. From April 2010 onward, consumers were allowed to exchange their eco-points for LED lamps at twice their value. For example, only 2,000 eco-points (instead of 4,000 previously) were needed to redeem an LED lamp priced at ¥4,000 (around $50).

The impact of the program on LED lighting products was profound. According to GfK Marketing Services, Inc., by June 2010 consumer sales of LED lamps had surged to 19% of total light-bulb sales by volume, and 60% by total value. Domestic shipments were expected to reach 20 million units in 2010, despite the cost of products ranging from ¥3,500 to ¥3,800 ($43-47). Meanwhile, the average cost of LED lamps fell by about 25%, the result of increasing economies of scale and intense competition among Japanese manufacturers.

In May 2011, the government reported that a total of 450,000 consumer applications had been processed to redeem eco-points for LED lamps (batteries were also included in this category) worth a total of ¥3.8 billion or $46 million.

The double value of eco-points for LED lamps no doubt attracted consumers to these products. Cultural factors also played a role, however. The Japanese love gadgets and are notorious energy savers. Even electric tea kettles boast energy-saving features! So the novelty of LED lamps held

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strong appeal.

By April 2011, individuals had submitted 44 million eco-point applications to the government, which were worth ¥621 billion ($7.7 billion) in redeemable eco-points. Despite the popularity of the program, critics maintain it did not save much energy. It's true that 82% of consumer purchases were for energy-hogging flat-screen TVs. Energy-efficient air conditioners and refrigerators accounted for only 19% of the eligible purchases.

The large proportion of large-screen TV purchases was not a surprise. The government plans to end analog broadcasting by July 2011, and the eco-point program was designed in part to ease consumers into the new system.

The Ministry of Economy, Trade and Industry had been expected to revive the program in the Tohoku and Kanto districts that were hit hardest by the March 2011 tsunami, in order to reduce electricity demand and avoid rolling blackouts in the Tokyo Electric Power Co. service area. But the government finally decided not to reinstate eco-points after determining it would not save enough energy.

Energy-saving potential of LEDs

However, with 7% of its electricity generation now out of commission due to the failure of the Fukushima Dai-ichi nuclear power plant, Japan needs electricity conservation more than ever. A recent report issued by Japan's Institute of Energy Economics (IEEJ) highlighted the opportunities afforded by LED lighting (see Fig. 1 and sidebar, below).

Lighting accounts for 16% of Japan's electricity consumption. According to the IEEJ, if all lighting in Japan were switched to LEDs, Japan's electricity consumption could be reduced by 9%. The residential sector presents a prime opportunity, where incandescent lamps account for 29% of the lighting load.

The government of Japan is now reportedly drafting comprehensive energy-saving measures to address the electricity crisis caused by failing nuclear plants. By design, eco-points targeted flat-screen TV purchases that eventually increased household electricity use. However, the LED component of the program demonstrated that significant energy savings and rapid market transformation for home-grown technologies could be achieved by significantly lowering the initial cost of products in a way that appealed to the public's values.

In sum, in a remarkably short period, Japan's Eco-point Program quickly built market share for LED lamps, while stimulating the economy and boosting Japan's LED manufacturing sector. Despite its cultural biases, the Eco-point Program could serve as a model for other national governments seeking to rapidly transform their domestic retail markets for LED lighting.

Report estimates energy-saving potential of LED lamps in Japan

TIM WHITAKER

The Institute of Energy Economics, Japan (http://eneken.ieej.or.jp/en) recently published a report on the electricity-saving potential of LED lighting and concluded that if all lighting in Japan was switched to LEDs, the total potential savings would amount to 92.2 TWh/year. This figure is equivalent to 9% of Japan's current total energy consumption. Fig. 1 (previous page) breaks down the savings by sector, and shows that the greatest potential exists in offices and commercial buildings.

The report says that the switch would cost ¥15.7 trillion (around $197 billion), due to the current high cost of LED lamps compared with ¥100 for incandescent bulbs and ¥1000-1500 for CFLs. However, as Fig. 2 shows, the cost of replacing all the 340 million incandescent lamps would be ¥800 billion (around $9.9 billion). Such a move would lead to very significant savings of 27.3 TWh/year, as well as by far the shortest payback period.

The report also says that the cost of achieving the electricity savings shown in Fig. 2 would be ¥1.3/kWh for incandescent lamps, based on a 40,000-hour lifetime. The figure is ¥14-17/kWh for replacing other technologies, and ¥9.2/kWh on average. In comparison, the cost of photovoltaic power generation is ¥40-50/kWh.

The report notes that households are highly sensitive to initial cost, so eco-point and other discounting measures are likely to be effective in promoting the spread of LED lamps. Meanwhile, businesses may require energy-conversation tax incentives and other subsidies to reduce the burden of up-front investment.

	Total lamps (million)	Price per replacement LED lamp (¥)	Total initial cost (trillion ¥)	Payback period	Electricity savings (TWh/yr)
Incandescent lamps	340	2000-3000	0.8	1 yr 5 mo	27.3
Fluorescent lamps (straight tube)	690	10,000-25,000*	9.6	9 yr 11 mo	49.7
Fluorescent lamps (circular lamps)	350	7000-15,000	3.5	18 yr 6 mo	6.8
HID lamps	20	100,000*	1.8	10 yr 11 mo	8.4
Total	1600		15.7		92.2

FIG. 2. Cost and payback periods for replacing different lamp types with LED lamps. (*Includes possible infrastructure and labor costs required to make the changes.)

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Building blocks of intelligent lighting design help create successful LED products

Engineers working on LED-based designs need to make the right decisions when faced with some basic building-block questions to yield successful, intelligent SSL products, explains **GAVIN HESSE**.

The long-awaited hockey-stick expansion of the LED-based lighting marketplace is beginning to take shape as more replacement fixtures are entering the consumer and industrial landscape. The market potential is leading more product-development teams to attempt their own solid-state-lighting (SSL) designs, whether the product is a small MR16 or a larger PAR lamp. Yet herein lies the issue. LEDs are powerful semiconductor devices, and so allow product developers to deliver a whole new world of differentiation with their designs, such as intelligent lights with sensors and dimming capabilities. Lamp and luminaire designers are no longer defining LED fixtures only in terms of basic lux and color requirements.

In this still-maturing technology segment, many product designers are still coming up to speed on the language necessary to understand how to build any of this potential intelligence into their lighting system. This puts them at a disadvantage when it comes to discussions with potential vendors and partners. The developers, trying to grasp a changing and maturing technology landscape, need an understanding of the basics – the building blocks of intelligent lighting design.

These essential questions can help a developer understand not only how to correctly define a project, but also how to choose appropriate partners, design-service providers and vendors.

Building Block #1: Do you require dimming?

The dimming question is tougher than it appears at face value. A "yes" answer sets off a daisy chain of follow-up questions including three major issues: input voltage, the dimming scheme, and dimming quality/performance.

Let's first consider the input voltage. Low-voltage fixtures such as MR16 lamps that have inputs of 12 VAC or 24 VAC make it more difficult to develop a driver that can operate with the majority of the TRIAC dimmers installed in the existing infrastructure. Companies such as Cypress and Zetex are creating such drivers at this time. For standard line-voltage applications, there are many more available drivers that support TRIAC dimming. At the high end, there are a small number of 277V dimmers that are available for high-bay lighting, although the requirement for this feature is trending upward.

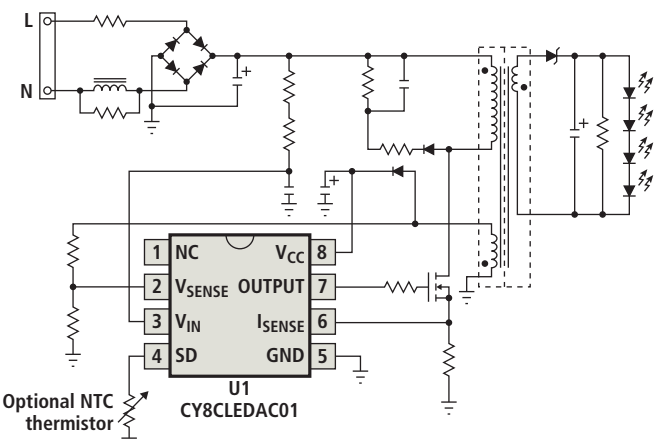

FIG. 1. Even in an isolated topology where a transformer drives the LED load, the driver can use feedback from a tertiary winding at the bottom of the transformer (dashed box) to adjust the drive signal based on operational characteristics.

The second issue is the type of dimming-control required (see page 49 for more information on dimming-control scenarios). TRIACs were not designed to interface with LED systems but are broadly installed. Your new favorite dimmable AC/DC LED driver may only work with half the TRIAC dimmers installed in typical application scenarios. A driver also may be unable to correctly read the low and high end of the TRIAC and so will only offer about a 20-40% dimming range without introducing flicker, especially on the low-voltage side of the range.

If the dimming control comes from a microcontroller, the power from the AC line needs to be appropriately managed. Standard AC/DC drivers from companies such as Advanced Transformer are not made to power a microcontroller that has a 5V input rail. The microcontroller will also require an input signal to control the modification of the output dimming waveform, which can even introduce the complexity of supporting a communication network to carry the dimming information.

The final issue is the quality of the dimming waveform itself, because all dimming circuits are not equal. Dimming is nominally done via a pulse-width modulation (PWM) signal, a digital waveform used to control power (usually current) to the load based on the PWM duty cycle (from 0-100%). But the PWM signal can introduce complications via EMI noise that can result in LED flicker and create obstacles in the regulatory approval process.

GAVIN HESSE *is a product marketing engineer at Cypress Semiconductor (www.cypress.com).*

The details of PWM signal control are beyond our scope here, but product designers should look for low-noise implementations. Some drivers use pseudo-random control of the PWM signal to greatly reduce noise.

Dimming performance can also suffer in terms of how smoothly a light dims if the control comes from a digital output. An 8-bit PWM waveform only has 256 possible steps that can dim a string of white LEDs. Especially at the low-end of the dimming range, those individual step changes become visible to the user. However, a 16-bit PWM has over 65,000 steps, allowing for a much smoother dimming curve.

Building Block #2: Do you require feedback?

The notion of actually being able to adjust the operation of a light engine on the fly, based on input from sensors and operating characteristics such as temperature, is an advantage that LEDs afford. Yet the concept is new both to product developers working on lighting and to lighting designers.

In the case of LED lighting, sensing and control can yield more robust products from a lifetime standpoint. In part this is due to proactively preventing potentially-damaging operating conditions. Any LED system should be able to appropriately track different conditions such as overvoltage, undervoltage, short circuit, open circuit, and thermal runaway. Let's consider how monitoring these conditions can be leveraged using Fig. 1. While this is an example using a Cypress Semiconductor driver, other IC vendors support similar sensing in simple white-light applications.

The circuit relies on a transformer (in dotted lines) to create an isolated topology, which makes it easier to pass UL certification. However, the circuit itself is able to sense what is happening at the load through the tertiary winding of the transformer (at the bottom of the transformer), and as such is able to recreate the waveform internally and adjust how it drives the LEDs.

The circuit also includes a temperature sensor and will shut down if the temperature rises above a set threshold. Temperature is the bane of the existence of LED lighting design engineers, since LEDs conduct all their heat through the base. This puts the engineers into an uncomfortable position of having to work as much on thermal design as on electrical design. This ensures that temperatures do not rise beyond datasheet junction temperatures of the components on the PCB board and cause a failure. Also, it's widely known that temperature dramatically affects the flux and color output of the LEDs themselves, which can make the visual appearance of a row of fixtures appear to be different in color or brightness.

A system with added intelligence and driven by a microcontroller can implement an improved temperature-compensation algorithm using a simple and cheap thermistor placed near the LEDs themselves. After reading the board temperature, a well-known equation is used to calculate the junction temperature of the LEDs. Junction temperature is equal to the temperature measured on the board plus the product of the thermal resistance of the board, the constant current of the LEDs, and the forward voltage of the LEDs. These are all easily-discoverable values. The calculated temperature can then be used to derive any adjustments to the drive current or voltage in order to keep the flux output (or the color output of an RGB series of LEDs) inside the visible limit.

Building Block #3: How do you want to drive the LEDs?

This is another simple question that becomes more complex the moment you bring a power engineer to the table. When faced with the omnipresent cost question, most engineers will quickly turn to a linear implementation, which can cost half of the switching alternative. Unfortunately, the tradeoff for using a linear drive system is about a 50% hit in the overall system efficiency, and that tends to counteract the green energy-efficiency advantage of LED lighting.

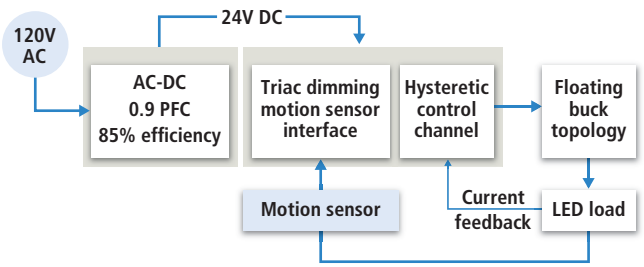

FIG. 2. The block diagram model of a prototype LED retrofit lamp demonstrates how features such as motion sensing can add value.

Switching implementations typically use either a step-down buck or step-up boost topology. There is a wide range of suitable driver ICs on the market that support such topologies. But product developers should keep a critical eye on a few operational features that can crucially impact performance.

The first is switching frequency. For example, if a driver is able to switch at 1.5 MHz rather than 1.0 MHz it will reduce the size of the inductor needed for the circuit, which in turn helps solve the inevitable board-space crunch in most retrofit applications.

A second key specification is a resistance value called RDSon, which is associated with the high-voltage MOSFET that switches the output and in some cases is integrated in the driver IC. If that RDSon value is too high, over 1 ohm for example, then the power dissipation will suffer, again killing the efficiency of the system.

The final key concern is the driver efficiency specification. A decent switching regulator can get up to 95% efficiency, which can differentiate a lighting system effectively in this competitive marketplace.

Building Block #4: What's going to set your product apart from the competition?

To be frank, this final question is about the sum of the parts of a lighting-system design that truly differentiate a product – or the lack of differentiating features. There is a veritable crush of companies seeking to carve out a space in this burgeoning LED retrofit market. Many will simply decide to create a non-dimmable or TRIAC-dimmable LED fixture or lamp and try to win in the market based on low cost. These companies will rise and fall based on the commodity pricing of basic components, not on the quality of their overall system.

Companies who instead desire to push forward with a combination of simple differentiating techniques will carve out unique and stand-alone spaces for themselves. Many lighting engineers simply don't know enough of what's available in the semiconductor market to take advantage of simple solutions. These techniques include some features in LED retrofit bulbs and fixtures, and other features in complete lighting system designs. Fig. 2 depicts some examples.

The block diagram shows a potential retrofit bulb. It takes the AC/DC line voltage such as 120 VAC, and then drops the voltage to drive a microcontroller which handles the TRIAC dimming of the LEDs. This is a similar approach to creating the PWM signal that we discussed earlier. However, this example also interfaces with a motion sensor that is a relatively low-cost external device that might be implemented in a lighting system. The sensor detects the presence of an individual in a room, causing the intelligent light to turn on automatically. A sensor that can be in the sub-$0.10 range can result in a product that is easily differentiated from the competition.

Consider as a second example a table lamp. In the simplest fashion it takes an offline signal and drives a set of white LEDs with no dimming. Again, there are multiple vendors in the market designing this lamp. However, the development team can differentiate the product with the addition of a capacitive touch-sensitive slider on the lamp to both turn the light on and off and to adjust the dimming level. Adding a capacitive slider to a design that already includes a microcontroller can cost as little as a line of copper on a circuit board. In other words, it is not expensive but yet again provides a unique advantage.

As a final example, consider outdoor backlights, such as those used behind restaurant signs. To save energy, the restaurant will want to drive the sign at different levels in the day or at night. But the simplest version of an SSL design will not allow such control.

There are driver ICs that allow software control of the constant current used to drive the LEDs. For example, the level might be software-adjustable from 350 mA to 700 mA – significantly changing the brightness. Such an LED backlight design can offer even more energy savings to the potential customer, maximizing efficiency during the entire day.

There are far more examples of features the lighting-product developer will encounter as LED technology continues to mature. Examples include additional communication interfaces, control mechanisms or thermal platforms. Differentiating a product in this market is not an onerous process, does not have to be costly, and can ultimately help a company position itself effectively. The building blocks discussed here are obviously not the only questions necessary to create an intelligent lighting fixture, but they offer an excellent starting point to successful products.

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standards | UPDATE

ANSI evaluates revisions to SSL chromaticity standard

A working group within ANSI is evaluating ways to improve an existing standard that defines how to communicate the chromaticity of white-light SSL products to end users, explains **JIANZHONG JIAO**.

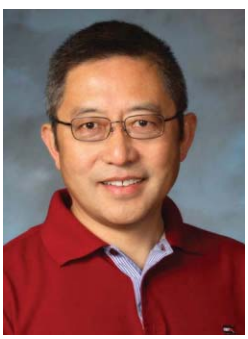
In early 2008, the American National Standards Institute (ANSI) published its Solid State Lighting (SSL) color standard, ANSI C78.377-2008, entitled "Specifications for the Chromaticity of Solid State Lighting Products" (available at www.nema.org/stds/ANSI-ANSLG-C78-377.cfm). For manufacturers, this standard defines how to communicate the chromaticity of white-light SSL products to end users.

After two years of practice using this standard, the industry recognized the need for improvements in its accuracy and the need to make the standard more user-friendly. In fall 2010, the ANSI Technical Committee TC78, Working Group of SSL Light Source WG09, formed an *ad hoc* task force to define the appropriate revisions to the document, focusing primarily on making improvements without requiring major thematic changes.

Similar to other lamp-color standards, this specification will provide recommendations on the white-color-variation ranges when SSL products are used for indoor lighting applications. The white-light chromaticity specified in the standard may deviate from "perceived" white, but are generally acceptable to most users.

Variations of white

The variations of white are primarily described in four so-called directions. These are yellowish (or warm) white; blueish (or cool) white; greenish white, and pinkish white. The variation from yellowish to blueish white occurs in the direction of the correlated color temperature (CCT), where the CCT ranges from lower temperatures (warm white) to higher temperatures (cool white), and the change is measured in delta T. Meanwhile, the variation from greenish to pinkish occurs as a deviation from the Plankian locus or blackbody curve, and is measured in delta uv (Duv). The Duv value on the curve equals zero, while the direction towards greenish color has a positive Duv, and conversely the direction toward pinkish color has a negative Duv value.



The CCT range and Duv range together form white-color boundaries that are detailed in the ANSI SSL chromaticity standard. Using this specification, a manufacturer of SSL products and the users of these products can achieve a common understanding of how any given white color will appear on the chromaticity diagram where the color point of the product fits within (or outside of) these color boundaries.

The ANSI standard does not imply that the whites that fit within the color boundaries are the "good" whites, or that those outside of the color boundaries are inferior. This is because the perceived whiteness of a light source is not directly related to its color rendering capabilities, or to personal preferences. Interestingly, if products' color variations or tolerance fall within these ranges, they will not necessarily be consistent for observers. In other words, the specified color tolerance in the ANSI standard is large enough that color inconsistency from the same CCT products can be detected.

Chromaticity and product yield

During the development of the ANSI SSL color standard, two basic aspects were considered and the results are reflected in the current version of the document. The first aspect was the chromaticity specifications for existing technologies i.e. linear fluorescent and compact fluorescent lamps. In the SSL color standard, the centers of the defined color range, or the nominal CCTs, as well as the color variations or tolerances, are very similar to those of fluorescent lamps.

The other consideration in the standard was LED product yields. Instead of using ellipses, as is the case for the fluorescent lamp standards, the SSL color standard uses quadrangles so the LEDs in the gaps between ellipses can be used. The outlines of these quadrangles are defined as the overall color range or color boundaries for the SSL products. The ANSI standard recommends eight selected nominal CCTs and the flexible nominal CCTs from 2700K to 6500K with 100K for each increment. In other words, if a manufacturer or user chooses an SSL product claimed at 4200K, a close match to natural moon light, this product will meet the ANSI specification. With these nominal

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CCTs, the ANSI standard specifies the tolerances in CCT direction, or delta T, and in the perpendicular-to-CCT direction, or Duv. When the current version of the document was developed, the center points of the eight selected nominal CCTs were similar to the fluorescent lamp standards. However, five of the eight center points of the selected nominal CCTs are not on the blackbody curve.

For a given nominal CCT, the standard lists its center-point location with a chromaticity value (xy), as well as the tolerances for delta T and Duv. In the current version, the center points of the CCTs were approximated up to the third decimal of the Duv value. Because of the approximation used for the center-point values of Duv, the upper and lower color boundaries (positive and negative Duv) for the eight quadrangles are not continuous, rather they appear to follow a zigzag shape.

Issues and revisions

This may create two possible issues or inconveniences. One is the correlation between selected nominal CCTs and flexible nominal CCTs. Because both are nominal CCTs in principal, the tolerances for one or the other should be inclusive without conflict. For example, if a nominal CCT of 3800K is chosen, the upper or lower boundaries of the quadrangle should overlap some portion of the quadrangles for 3500K as well as for 4000K as both are selected nominal CCTs. However, in the current version of the standard, that is not the case.

Another inconvenience arises when SSL product manufacturers (LED package manufacturers in particular) divide the quadrangles into finer bins. The LED bins located near the zigzag points can lead to uncertainty or a lack of clarity for the users.

The revisions proposed by the ANSI *ad hoc* group are primarily focused on fixing these two issues in the current version. The revised technical matter is less complicated but the results can be more accurate. Instead of using three decimals for Duv values for the center points of the nominal CCTs, a fourth decimal is introduced. In addition, a new and more accurate mathematical expression for the Duv tolerance calculation is now presented. With this new expression, the Duv tolerance (+/- 0.006) is unchanged, but the derived upper and lower color boundaries for all the nominal CCTs now become continuous without zigzags. This change will make the tolerances of selected and flexible nominal CCTs more consistent with the hope of making the corresponding LED package binning simpler.

Other proposed revisions in the new version include adding more updated CIE chromaticity, or u'v' coordinates, into the specification.

Other proposed revisions in the new version include adding more updated CIE chromaticity, or u'v' coordinates, into the specification. This is part of the continuous effort within ANSI to seek harmonization of international standards. Additionally, users have previously raised the question of how to convert given CCT and Duv values to chromaticity values xy or u'v'. The proposed revision will provide detailed explanations in one of the annexes for calculating these conversions. Technically, for the corner values of each defined quadrangle in xy or u'v', the connecting lines between the two upper corners and the two lower corners are not straight, but have some curvature similar to the blackbody curve. The new calculation method provided in the revision will explain how to derive any point on these curves. This will also serve to give a more accurate description when SSL products are to be certified for specific CCT values.

Unanswered questions

Two larger questions with no clear answers remain that are not addressed in this revision. The first is: what is "perceived" white, or where should the center points or curve be located for a white light source? Another question is: what will be the acceptable deviations from the center curve of the perceived white for observers? Ideally the color range or color boundaries specified in the ANSI standards should be based on the answers to these two questions.

When the ANSI SSL color standard was initially developed, some information was unavailable and certain assumptions were made, which is not unusual in standards development. Currently two studies are being conducted by research organizations in the US to better understand the relationship between these two questions. Like any other research into human factors, these studies may need to involve reasonably-adequate sample sizes and may not be completely conclusive. Human observers are often subjective, particularly when dealing with color-related questions. White light as well as its associated acceptable deviation to one group of observers may not be the same to another group of observers.

To add more complexity, convoluted answers can arise from observing the whiteness of a light source and then relating that whiteness to the color rendering of illuminated objects with a variety of colors. Hopefully the results from these studies may provide references or rationale to the standards community. Without convincing evidence or arguments, it is difficult to make further changes to any existing standards.

LINKS

ANSI C78.377-2008: www.nema.org/stds/ANSI-ANSLG-C78-377.cfm

LED safety standard UL 8750 requires further clarification
LEDs Magazine Apr/May 2011, p69: www.ledsmagazine.com/features/8/4/11

TM-21 seeks method for lumen-maintenance prediction
LEDs Magazine Feb 2011, p37: www.ledsmagazine.com/features/8/2/10

Non-directional luminaires require new testing procedures for LED light engines
LEDs Magazine Nov/Dec 2010, p47: www.ledsmagazine.com/features/7/11/8

LED lighting community benefits from ongoing standardization efforts
LEDs Magazine April 2010, p59: www.ledsmagazine.com/features/7/4/7

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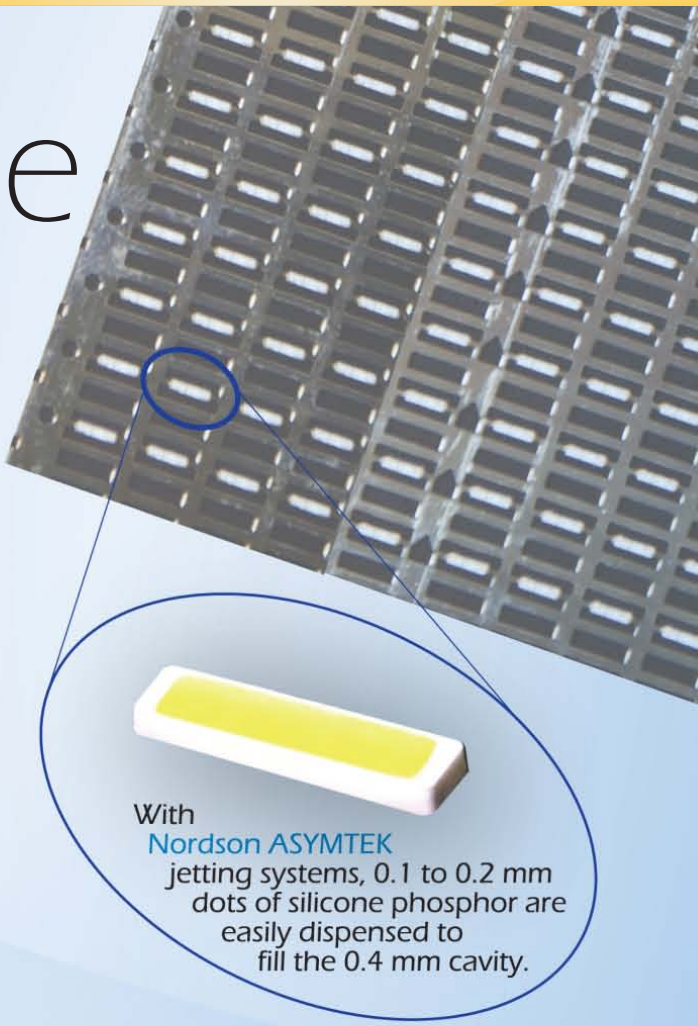

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Linear and A-lamp LED products dominate LFI

Lightfair 2011 delivered LED-based lighting innovation in many forms. A-lamp and linear products took center stage, while new outdoor-lighting fixtures and modular SSL products also emerged. Impressive general-illumination OLED products were again on display although aren't yet shipping in volume, while other approaches to planar lighting appear close to fruition, reports **MAURY WRIGHT**.

LEDs again stole the show at the annual Lightfair International (LFI) tradeshow. While you could find plenty of conventional lighting on the exhibit floor, it was solid-state lighting (SSL) products that were prominent in most booths, ranging from A-lamp retrofits to decorative and architectural lighting. Purpose-built LED-based linear lighting that might replace fluorescent fixtures was arguably the biggest story. There was little new on the OLED lighting front at LFI, but other planar technologies are coming to market. There were both new players and new looks in outdoor SSL. And adaptive-control technology for sensing and controlling light levels is headed into the mainstream – despite the lack of broadly-accepted industry standards.

LFI continues to surge in popularity and surely LED lighting is partially responsible. Despite some concern in the industry about moving LFI to Philadelphia due to construction issues at the New York venue, registered attendance hit 23,709 – up slightly from last year's Las Vegas show.

Again this year SSL dominated the LFI Innovation Awards (www.ledsmagazine.com/news/8/5/16). The Most Innovative Product of the Year award went to the Revel OLED luminaire from Acuity Brands. The Design Excellence Award went to Tech-Generation Brands for a low-voltage LED-based wall washer. Philips Lumileds took the Technical Innovation Award for its Luxeon A LED that the company is hot-testing at typical operating temperatures of 85°C. LED-based products also dominated the product-category awards, with winners including Cooper Lighting, Visa Lighting, and Lumenpulse.

Ironically, LEDs were an afterthought in the keynote presentations this year. But the conference sessions included plenty of LED-centric content.

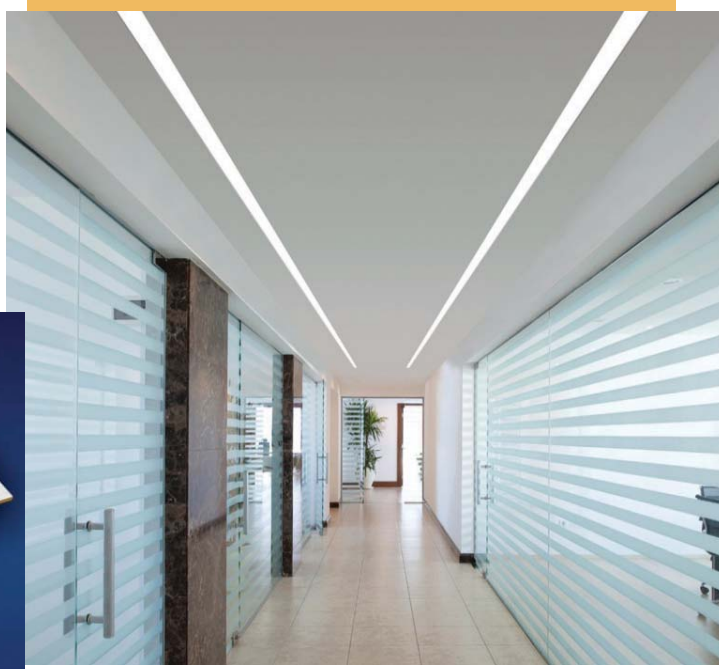
We've already provided quite a lot of LFI product coverage on our website. See the three summary articles for links to the coverage (www.ledsmagazine.com/news/8/5/19, www.ledsmagazine.com/news/8/5/21, and www.ledsmagazine.com/news/8/5/24).

In the following pages, we'll present what we saw as the most-compelling product announcements and demonstrations in OLED and planar lighting, linear LED lighting, LED retrofit lamps, modular SSL products, LED technology, outdoor lighting, and other areas.

Linear LED lighting

Lithonia Lighting (an Acuity Brand) was out in front of the purpose-built, LED, linear-fixture trend by announcing the RTLED product at LFI last year, and showcasing the family in its 2011 LFI exhibit. The product also integrates support for Acuity's lighting-control technology that relies on wired links between fixtures using Cat-5 (computer-network) cables. Moreover the products implement what the company calls lumen management where the LED driver produces less output early in the fixture life and increases the output over time to combat lumen depreciation. Lithonia also demonstrated square surface fixtures called TLED, and square recessed ACLED coffer fixtures, both of which use an array of LEDs and feature integrated controls.

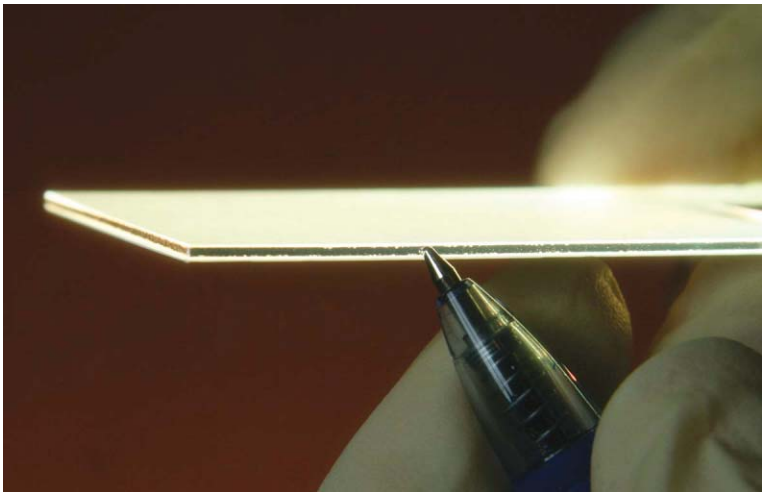
At LFI a year ago, LED-based lamps designed to replace T8 linear fluorescent tubes were in the headlines as many companies sought to deliver an SSL retrofit for what is the largest installed base of office and industrial lighting. But as we reported after the show (www.ledsmagazine.com/features/7/6/6), LED tubes haven't delivered equitable performance. This year the focus was more on purpose-designed LED-based fixtures that can serve in place of fluorescent troffers. That's not to say there weren't LED tubes on display. In fact, Cree showed a T8 tube reference design that product marketing manager Paul Scheidt said "addresses all of the shortcomings that the US Department of Energy (DOE) has documented about LED T8s." Still, the bigger fluorescent-replacement news in the Cree booth was the CR fixture (www.ledsmagazine.com/news/8/4/19) that the company launched prior to the show.



Osram Sylvania introduced an LED module for linear fixtures that it will both sell to others and use in its own luminaires. The LED Distributed Array integrates 48 LEDs on a 2x9-in circuit board. Luminaire designers can utilize multiple modules to create fixtures of almost any size. The company states that the module design produces uniform diffused light with no apparent bright or dark areas associated with LED location. Just after LFI, Sylvania's sister business unit Osram Opto Semiconductors announced the Duris E3 LED designed with a wide beam angle to produce uniform light in linear fixtures (www.ledsmagazine.com/news/8/5/28).

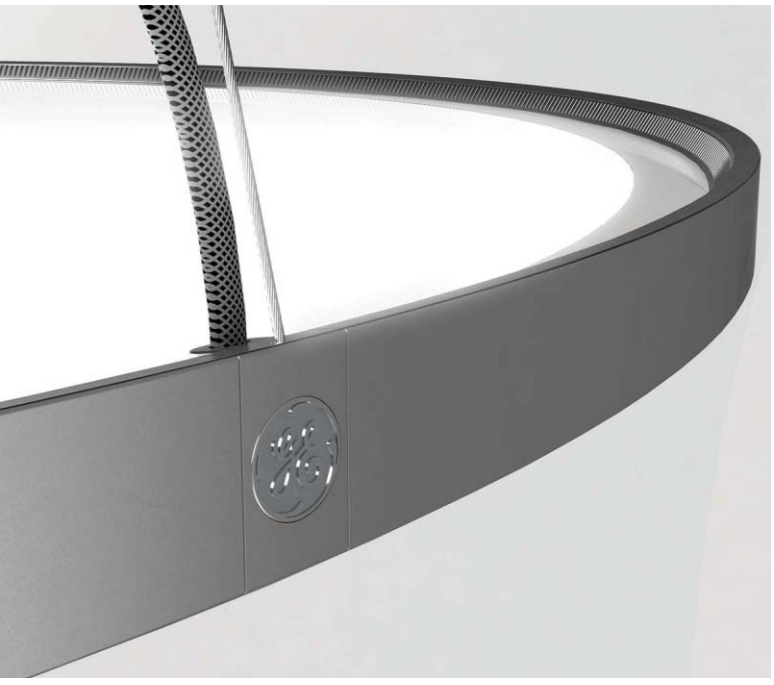
Cooper Lighting launched an LED module called the ALM that the company will use as a technology base for linear lighting, and also unveiled 32 luminaires across Cooper brands that will utilize the new module (www.ledsmagazine.com/press/31564). The module design is based on a dense array of relatively low-power (0.25W) LEDs, and the design only drives the LEDs at half the rated power. The scheme optimizes efficacy, according to Cooper, and will yield products that last 50,000 hours. The company asserts that its linear products will match or exceed fluorescent systems in optical performance with a 15-20% reduction in power density.

OLED and planar lighting



Acuity Brands took the top LFI Innovation Award with its Revel OLED luminaire, and actually announced two OLED products at LFI. The ceiling-mounted Revel (pictured) is more decorative in nature although the individual OLED modules can be positioned to direct light where it is needed. The Kindred is a stylish ambient light designed to be suspended from the ceiling. The Kindred integrates more OLED panels and produces more than 3000 lm in aggregate. Acuity termed the LFI announcement a commercial launch, but the products will not be available until the first quarter of 2012.

Oree and **Future Lighting Solutions** have partnered hoping to commercialize Oree's LightCell planar LED-based technology. At LFI, the partners conducted private demonstrations of tunable white panels whereas much of Oree's earlier efforts have been focused on color panels (www.ledsmagazine.com/press/31500). As shown in the picture, the panels are relatively small, but Oree believes they can be combined to construct much larger fixtures. Each small panel includes built-in LED emitters. Future plans to have a demonstration platform available for sale by the end of the summer, allowing product designers to experiment with the technology and start luminaire designs. Separately, Future announced an intelligent lighting platform based on a partnership with Synapse Wireless.



GE Lighting made LFI news with LED-based planar luminaires based on technology licensed from Rambus. Rambus's edge-lit Pentelic technology relies on etching a substrate layer to control the ray angle of light to provide uniform distribution over a panel (www.ledsmagazine.com/products/31517). The company has said that the technology delivers 92-95% optical efficiency. GE demonstrated the Pentelic-based Edge family of luminaires at LFI including a ceiling troffer, a circular suspended pendant (pictured) and a suspended rectangular luminaire (www.ledsmagazine.com/products/31506). GE plans to ship the troffer this year and the others in the first half of 2012. All of the products will support adaptive controls and dimming for maximum energy savings.

LIGHTING showcase

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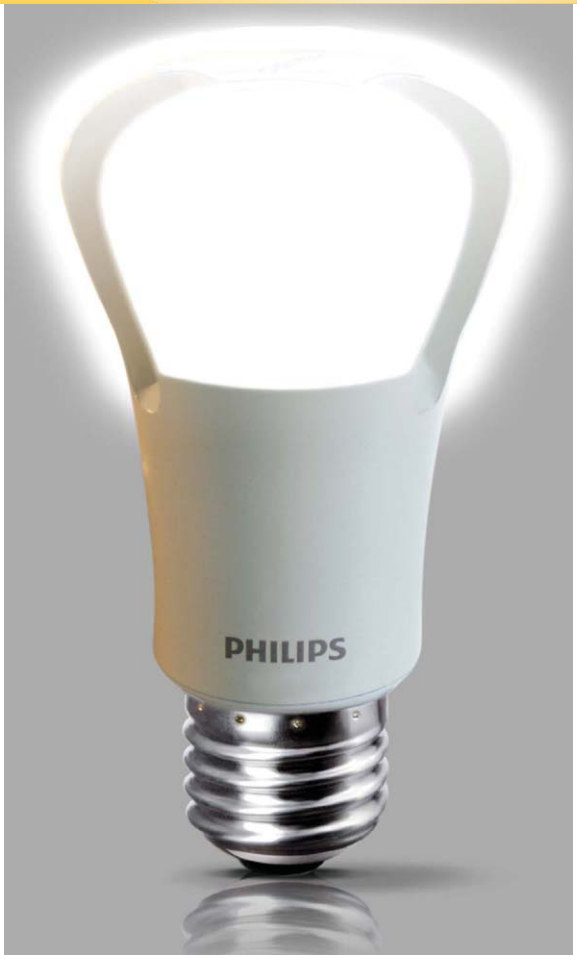


Retrofit lamps

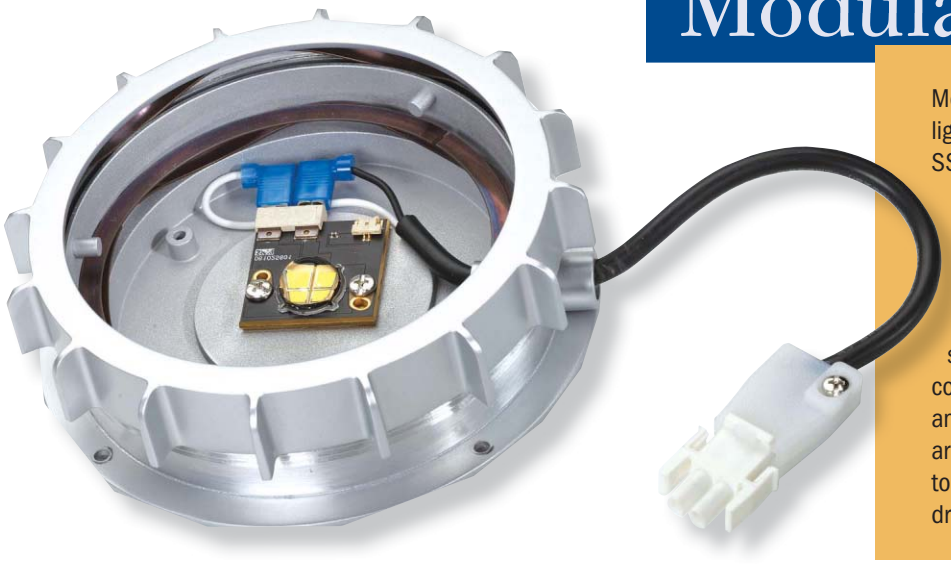
We get the most out of LEDs in terms of energy efficiency and lighting performance from purpose-built fixtures. But the lure of existing sockets continues to bring players into the retrofit lamp market. LFI witnessed a number of demonstrations of LED lamps targeted at replacing 100W incandescent bulbs and 75W-equivalent lamps that are ready for market (www.ledsmagazine.com/news/8/5/25). There were also new LED-based lamps in the PAR, MR, and AR form factors.

Phillips Lighting didn't make the boldest claims at LFI about retrofit lamps but the company's announcement of a 75W-equivalent lamp may carry more credence than others given the company's success in the 60W-equivalent space. Philips showed the new EnduraLED A21 lamp that dissipates 17W while delivering 1100 lm. The lamp is rated for 25,000 hours of life and features a 2700K color temperature and a CRI of 80. The new $40-$45 lamp is due in stores late this year. Philips said that the lamp would soon undergo Energy Star testing and the lamp is based on a design similar to the 12.5W design that was the first 60W-equivalent product to win an Energy Star rating. Philips also demonstrated its Ledalite Jump luminaire that would be at home in our section on linear lighting.

Lighting Science Group (LSG), Osram Sylvania, GE Lighting, Samsung LED, and Acuity Brands all showed new retrofit products. **LSG** demonstrated a roadmap to lighter brighter lamps achieved via active MEMS-based cooling and remote phosphors. **GE** showed a 60W-equivalent lamp, while **Samsung LED** entered the US market for LED-retrofit lamps (www.ledsmagazine.com/news/8/5/18). **Acuity** introduced its first retrofit products via the new Acculamp family including PAR16/20/30/38, MR16, and AR111 lamps (www.ledsmagazine.com/news/8/5/15). **Sylvania** added omnidirectional A-lamps (pictured) to its Ultra retrofit line with 40W and 60W-equivalent lamps due this summer and the 75W equivalent due in the fall (www.ledsmagazine.com/press/31552). Moreover, the company demonstrated a 100W-equivalent lamp (www.ledsmagazine.com/press/31550).

Switch Lighting entered the retrofit market just before LFI with the introduction of a 75W-equivalent lamp (www.ledsmagazine.com/news/8/4/17) and followed with demonstration of a 100W-equivalent on the exhibit floor. Switch allowed the public to experiment with the lamps in their booth. The lamps are noticeably heavier than other LED-based lamps due to the inert liquid in the globe used for cooling. When presented side by side behind a screen simulating a light shade, 100W incandescent and Switch retrofit lamps were tough to distinguish at full power.

Modular SSL



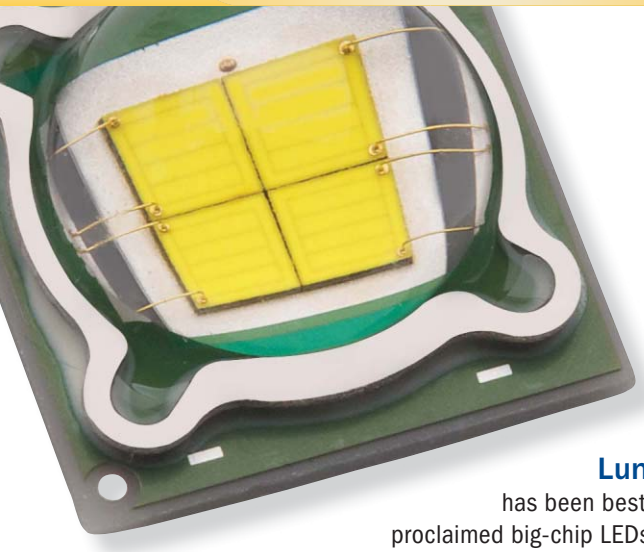
Modular approaches to luminaire design allow lighting companies to more easily enter the SSL market, and that will become even more true as multi-vendor standards emerge. The Zhaga Consortium is closing in on standards for about a half-dozen different LED light-engine modules. There was a module in the TE Connectivity LFI booth that looked suspiciously like some Zhaga photos, but company spokespeople refused to comment on any Zhaga work. Meanwhile other companies are moving forward on different approaches to modules – for example some with inclusive drivers and others without.

T-Opto and Luminus Devices have partnered on the SoloLux module for what they call high-lumen, general-lighting applications. T-Opto (a division of Toyota Tsusho America) will manufacture the module using a single Luminus CSM-360 LED. Field upgradability is a key attribute of the module. T-Opto general manager Michael Handerhan said, "As LED performance continues to improve, fixture performance can be upgraded by replacing the chip-on-board LED with a standard screwdriver." The companies say the module will replace 175W metal-halide lamps. The SoloLux requires an external driver that will figure into system power consumption, but at 6500 lm the LED module will dissipate around 85W.

Modular SSL

Bridgelux, **Molex** and **GE Lighting** all demonstrated new versions of existing modular products at LFI. Molex and Bridgelux launched the second-generation of the Helieon module family that they jointly launched in March 2010. Whereas the original products required an external driver, the new models integrate the driver and directly operate from AC line voltage (www.ledsmagazine.com/products/31409). Integrating the driver will further simplify luminaire development projects. GE lighting showed new versions of its Infusion LED modules for the first time in the US after launching the products in Europe a few months back (www.ledsmagazine.com/news/8/3/27). The family now spans 1000-3000 lm, and all use the simple twist-lock mechanism allowing easy replacement.

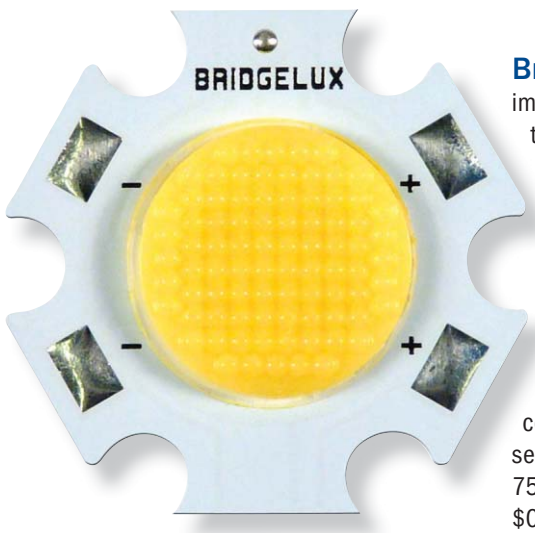
Cree continues to break brightness barriers in LEDs, achieving 231 lm/W in the lab just before LFI, and a bright module highlighted its LFI exhibit. The LMR4 module is based on Cree XM-L LEDs and delivers a choice of 700 or 1000 lm with better than 90 CRI. The brighter version consumes only 16W yet the company says that it can serve as a replacement for 100W incandescent down lights. Cree offers the products with a choice of 2700K, 3000K, 3500K, and 4000K color temperatures. Cree's Paul Scheidt said that system cost for a luminaire using the module would be in the $100 range.



LED technology

The LED technology that underlies innovative SSL products was also on full display at LFI. As mentioned previously, Philips won an LFI Innovation award with its Luxeon A family. Perhaps the most notable LED trend is the combination of red or amber LEDs with white LEDs to more-efficiently produce warm-white light. In its TrueWhite-based lighting products, Cree has used sensors to monitor the white and red emitters to detect differences in lumen **depreciation and adjust drive current accordingly. The company has now decided that the sensor is not needed, eliminating it in the previously mentioned CR linear fixture. Cree's VP of research and development Paul Pickard said, "Our longevity data indicates similar depreciation rates in both colors of LEDs used in Cree TrueWhite technology. This allows us to design fixtures that maintain their specs, over their lifetime, with no adjustments."**

Luminus Devices has been best known for its self-proclaimed big-chip LEDs, but at LFI moved to a smaller emitting area with the launch of the 1600-lm SSM-80 LED (www.ledsmagazine.com/products/31595). The new LED offers a tighter beam and will target applications such a spotlights used to illuminate retail merchandise. Luminus' Chuck DeMilo said customers can more easily design drive circuits for the new LED. The device actually uses four emitters in series yielding a 12V stack that requires 1A in drive current. That's more in line with LEDs from other vendors whereas the Luminus SST-90 product, for example, requires 3.2V and 3.2A.



Bridgelux continues to ride improvements in its LED technology to offer brighter products in smaller packages, announcing the third generation of the LS, ES, and RS LED-array families at LFI (www.ledsmagazine.com/products/31467). The benefit according to VP of global marketing Jason Posselt is better efficacy and lower cost. Generally, Posselt said the second-generation products offered 75 lm/W in luminous efficacy at $0.013-$0.015 per lm. The new products take efficacy to 90 lm/W and cost under $0.01 per lm. As to how the gains were made, Posselt said, "It's a sum of epi, chip design and packaging." He noted that a close examination of the LEDs would reveal that "we've added some extraction features to the silicone-coated phosphor on the arrays."

Osram Opto Semiconductors launched its own Brilliant-Mix technology at LFI, utilizing white and amber Oslon SSL LEDs to generate warm-white light (www.ledsmagazine.com/news/8/5/11). Osram is advocating the use of a sensor to monitor the different LEDs, thereby ensuring consistent brightness and color. Brian Terao, director of SSL, believes that customers will relish the choice of optimizing a design for efficacy or cost. He said the Brilliant-Mix will yield better efficacy, although the sensor will make it more expensive. Osram said Brilliant-Mix will deliver 110 lm/W in luminous efficacy – 30% higher than can be achieved using warm-white LEDs with similar CRI and CCT.

Outdoor lighting

The established players in LED-based outdoor-area lighting were all present at LFI, most of whom utilize relatively-small LEDs mounted on a circuit board in an array, and total-internal-reflection (TIR) optics on each LED to form a beam pattern. It's generally been considered problematic to control the light from larger LED sources although such sources could offer advantages in outdoor lighting since many such applications require significant light output. LFI witnessed more luminaire makers using larger sources. For example, Eagle Eye Lighting demonstrated lights that use its retrofit module based on larger Bridgelux arrays and reflectors that form the desired beam pattern (www.ledsmagazine.com/news/8/5/26).

GE Lighting is the one established player in street and area lighting that has utilized reflector technology broadly in its outdoor LED product line. The Evolve family typically includes one or more closely-grouped arrays of LEDs mounted within circular or rectangular reflector structures. At LFI, GE announced new Evolve series luminaires for area-light, flood-light, garage-light, post-top, and roadway-light applications. The Contemporary Conical luminaire pictured is designed for post-top use and offers a 60% reduction in energy consumption compared with typical HID lights, according to GE.

BetaLED stuck with smaller emitters in the new LEDway SLM and LEDway SLM IP66 products launched at LFI. If a street light can be called elegant in terms of looks, then the SLM is the one. SLM stands for single light module and as the nearby photo shows the fixtures are rather sleek-looking relative to the more typical rectangular or cobrahead lights. BetaLED says that the products can replace 70-250W high-pressure-sodium lights. Certainly the development of the SLM products was enabled by significant industry gains in LED brightness.

Eye Lighting has boldly entered the market with its KiaroLED area light that is the first product to use a TIR approach with larger LED sources. The product is based on Luminus Devices' SST-90 LEDs. To eliminate light losses caused by the Etendue effect, the TIR must be quite a lot bigger than the source resulting in a 0.75-in-diameter TIR according to Eye Lighting VP of lighting Rob Freitag. The luminaires use 6 to 9 LEDs in linear or rectangular arrays depending on the prescribed beam pattern, whereas outdoor lights based on smaller emitters often use 20-60 LEDs.

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LED lighting enables economical cruising for giant passenger ships

LEDs for lighting solutions are gaining increasing importance in the shipping industry, based on their energy-saving potential and long service life. But the application places stringent demands on the quality of LED lighting, writes **UWE HOCK**.

On modern cruise ships, lighting systems account for up to 25% of the total energy consumption which is not used for propulsion. This means that any reduction in electricity consumption for lighting leads to a positive impact on the ship's operating costs, as well as reducing the environmental impact. Lighting providers such as LED Linear, Bluleu LED Solutions and Navalimpianti are already working with leading shipyards throughout Europe to develop efficient LED lighting solutions for cruise ships, including the giant Celebrity Equinox.

© Bluleu LED Solutions and Celebrity Cruises.

FIG. 1. The Celebrity Equinox pool deck: Bluleu LED Solutions delivered the illumination of the stairs, whirlpool border and the stages. The products use warm-white (2900K) LEDs in an aluminum profile, and are waterproof-molded in clear polyurethane.

Demanding applications

In the shipping business, there are strict and demanding requirements when it comes to lighting. These include color rendering index (CRI) values of at least 80, light/color homogeneity, efficacy of at least 60 lm/W, warm white light of 3000K or less, and a long service life. Excellent weather resistance is also required, particularly for outdoor lighting. In addition, easy assembly and replaceability are required as well as standard sizing, in order to meet relevant standards and regulations.

High color homogeneity is extremely important, particularly for the illumination of long axes of vision, for example along railings, or to illuminate large rooms with several thousand built-in lights. A deviation of only a few Kelvin can be perceived by the human eye as a color difference which is not acceptable, particularly in area or strip lighting.

Light quality and efficiency are two sides of the same coin. For customers, high CRI values together with high efficiency and a warm color temperature are fundamental criteria for the selection of LEDs. However, this is a challenge for LED manufacturers, since high CRI values, combined with a warm color temperature, reduce the efficiency of the lamps.

The service life of LEDs is another important factor for customers, and is influenced heavily by the operating and ambient temperatures. Optimum heat management for LED lights can save costs by drastically extending the service intervals for difficult-to-access lighting solutions.

Celebrity Equinox

Built by the Meyer shipyard, the Celebrity Equinox (Figs. 1 & 3) is a 315m-long luxury cruise liner for 2,500 passengers that is designed to be particularly environmentally friendly. As well as photovoltaic installations, the ship features LED lighting solutions from LED Linear (www.led-linear.com) and Bluleu LED Solutions (www.bluleu.de). The use of LEDs for lighting enables weight

UWE HOCK *is the Manager, Lighting Business with Sharp Microelectronics Europe in Hamburg, Germany. Email: info.sme@sharp.eu.*

savings of up to 30%, which means the overall weight can be reduced by up to eight tonnes. For a cruise ship with 50,000 light sources, the use of LED solutions can allow a reduction of CO_2 emissions of up to 3,000 tonnes per year and an annual cost saving of up to EUR 200,000.

Bluleu LED Solutions and LED Linear supplied the Celebrity Equinox with more than 1,200m of water-tight LED strips in the VarioLED Flex ATON IP67 and VarioLED Flex Venus product series (Fig. 2). These were used for the railing lighting (Fig. 3) as well as for complete ready-to-plug systems for installation in stairways. The encapsulated luminaires with protection classes up to IP68 are extremely weather-resistant and protected against yellowing and salt water thanks to high-quality sealing.

The illuminants used by LED Linear include SAE and Double Dome LEDs from Sharp, mounted on thermally-enhanced flexible circuit boards that are easy to install and can be laid in any shape. With a power consumption of just 7.6 W/m at a supply voltage of 24V, they achieve a luminous efficiency of 75 lm/W for a length of up to 7.5m.

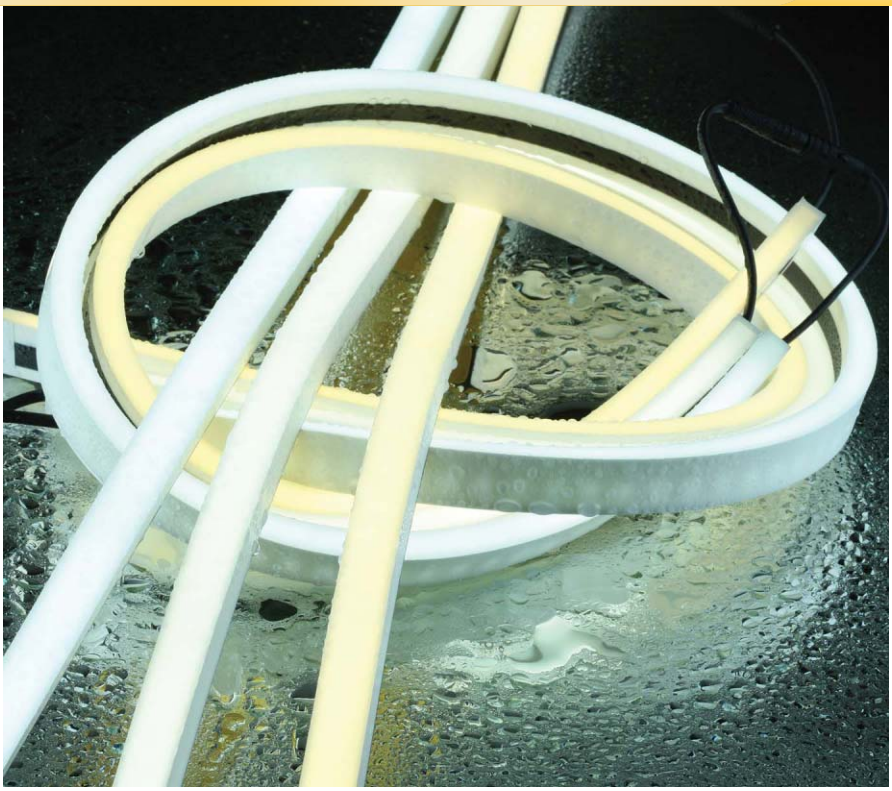


FIG. 2. VarioLED Flex Venus products with different color temperatures from LED Linear.

Navalimpianti and Powergiant 2

Another lighting supplier, Italy-based Navalimpianti (www.navim.com), has developed the Powergiant 2 range of recessed luminaires for lighting the interior of vessels. Based on Sharp Zenigata LEDs, these products can directly replace conventional lighting systems and thus can provide an enormous savings potential for existing ships.

A typical cruise ship for 2,800 passengers weighing 92,000 tonnes, with 16 decks and 1,150 cabins, is illuminated in public areas (lobbies, restaurants etc) with just under 8,000 halogen lamps. About one fifth have an output of 35W, while the output of most of the rest lies in the region of 50W – all in all around 370 kW for the public areas alone.

In this example, replacing all traditional halogen lighting with Powergiant 2 recessed lights would reduce power consumption by almost 300 kW. Based on 12-24 hours of operation each day, the LED lighting would save 7,100 kWh in energy and 1.5 tonnes of fuel, resulting in a total daily saving of around EUR 550.

Thanks to the service life of 50,000 hours, further savings are possible due to lower maintenance costs. With an average use of 10 hours a day, a Powergiant 2 will remain

operational for over eight years until it has lost 30% of its initial brightness. The service life of a high-quality halogen lamp is only 6 to 7 months. Usually the service life of halogen lamps is even lower due to the vibrations when the engines are running, while this strain does not affect LED technology.

The Powergiant 2 LED recessed luminaires ensure very natural color rendering of illuminated objects with a CRI value of 80. The light output is 60 lm/W with a power consumption of just 9W. This leads to a very low surface temperature compared to halogen lamps, drastically reducing the risk of fire on board.

Powergiant2 lights are dimmable and fully compatible with the Helvar Lighting dimming system or other IGBT phase-cut dimmers, which are often used on ships. As a result, Powergiant products can replace existing halogen solutions without the need for extensive changes to cabling and electric circuitry.

FIG. 3. The Celebrity Equinox at the fitting-out quay of the Meyer Werft in Papenburg, Germany. Bluleu LED Solutions delivered the railing illumination.

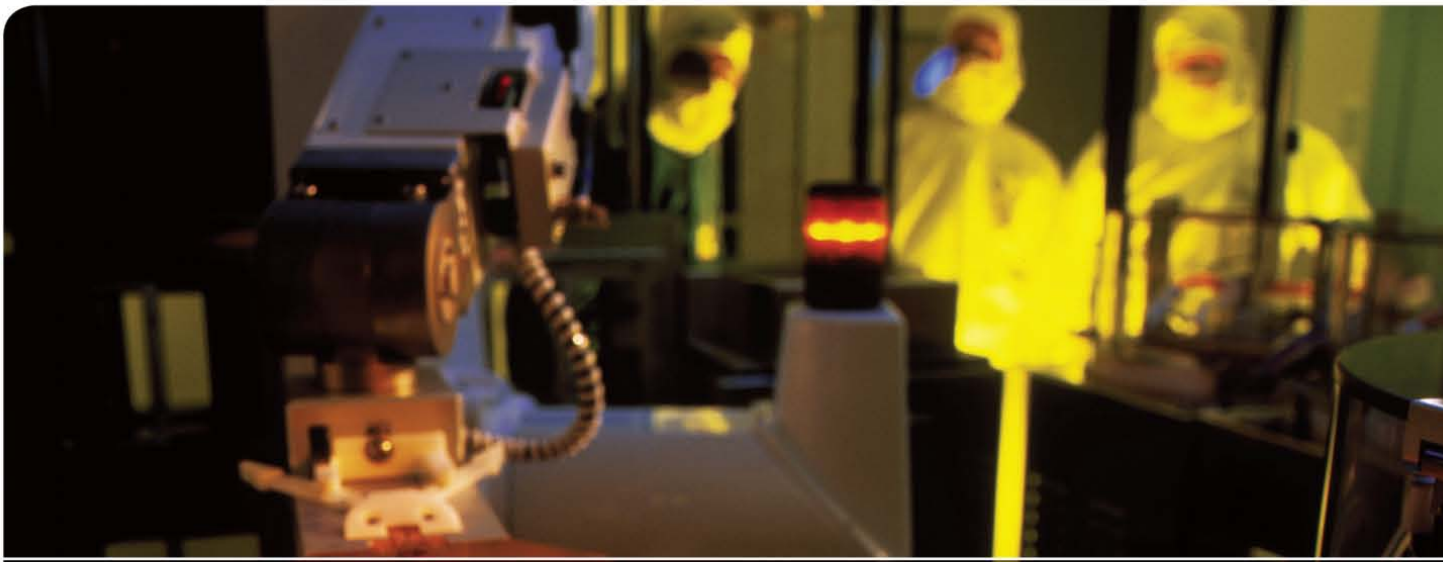
LED supplier requirements

The high demands placed by shipbuilders on their lighting suppliers explain why companies such as LED Linear and Navalimpianti attach great importance to quality in the selection of LEDs.

Homogeneity is a great challenge in LED production, requiring a defined color temperature which is as uniform as possible in each component, in all production batches. Many manufacturers accept a certain fluctuation margin in LED production and subsequently place the LEDs into different bins in accordance with defined deviations from the original color. Sharp, on the other hand, has already optimized the manufacturing process of its LED arrays so that the fluctuation margin of the color temperature is so small that it cannot be perceived by the human eye. LEDs from one series can hardly be distinguished from one another optically, even if they come from different production batches.

A second important selection criterion is CRI. Sharp uses different mixtures of red and green phosphor, so that all its white LED components, for all color temperatures, have a CRI value of at least 80. The Zenigata and Mega Zenigata series have a CRI value as high as 94.

The third important criterion for shipbuilders is long service life which, in the case of LEDs, depends on how efficiently the heat can be dissipated. As an LED substrate, Sharp uses a ceramic plate with silicone sealing instead of conventional plastic materials. This design allows for efficient and homogeneous heat dissipation as well as good thermal and mechanical resistance. This helps to keep the required cooling element small, but also to guarantee the service life of 50,000 hours (at a substrate temperature of up to 80°C, depending on the module). These concerns were a further reason why LED Linear and Navalimpianti chose Sharp as a strategic partner for the supply of LED components.



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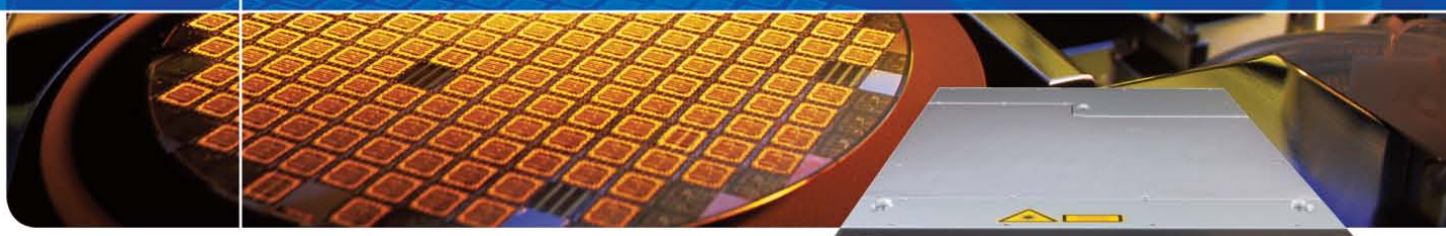

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Wired and wireless interfaces convey dimming settings to luminaires

Wireless networks such as Zigbee, wired digital standards such as DALI and DMX, and analog 0-10V dimming can all contribute to energy efficiency and better lighting, says **DAVID COOPER**.

LED-based solid-state lighting (SSL) is inherently controllable affording advantages ranging from lower energy consumption to more elaborate control scenarios that deliver the right amount of light when and where it is needed. But product designers face the dual problems of how to design dimming circuits, and how dimming information gets conveyed to the luminaire. In the June issue of LEDs Magazine (p.47), we covered basic dimming technologies and control scenarios that utilize existing AC wiring (www.ledsmagazine.com/features/8/6/9). Now let's consider other methods of implementing dimming control through dedicated analog, digital or wireless interfaces, and the type of dimming technology that's compatible with each.

Dimming interface	Advantages	Disadvantages
AC wiring (phase-cut)	No control wiring required Can use existing phase-cut dimmers	Cannot dim smoothly to zero Some dimmers require minimum load May exhibit flickering Difficult to cover wide AC voltage range
AC wiring (voltage)	No control wiring needed	Only suitable for dedicated applications
Analog (0-10V)	Can use existing 0-10V lighting controls Can dim smoothly down to zero Simple implementation in driver	Added cost of control wiring Requires controller
Digital (DALI)	Standard for control of multiple luminaires Can include luminaire monitoring capability	Added cost of control wiring Requires controller
Digital (DMX)	Standard focused on theatre/stage lighting Can offer comprehensive control – pan, tilt, zoom, colour, image effects	Added cost of control wiring Requires controller No monitoring capability
Wireless (Zigbee)	No control wiring required Can offer comprehensive features	Driver and controller are more complex Wireless signals have limited range

As we discussed in the last issue, there are two basic alternatives that can be used to reduce the light output of the LEDs: analog dimming and pulse-width modulation (PWM). Whichever method is used, some form of signal is needed to convey the dimming information to the luminaire.

This signal can be carried through the AC wiring, an analog input, a digital input or through a wireless interface (the Table summarizes the scenarios). Each of these options has some advantages and some drawbacks, and different options are appropriate for different applications. In general the formats of the dimming signals are common to any lighting technology – they are not specific to LED lighting. The majority of LED luminaires will be retrofitted into existing installations and they must be able to interact with the existing lighting controls.

DAVID COOPER *is the North American Applications Engineering Manager at AEG Power Solutions (www.aegps.com)*

Analog (0-10V)

Analog dimming, often called 0-10V dimming, is defined in the IEC 60929 (Annexe E) standard, and uses a control wire separate from the AC input to provide the 0-10V dimming signal. The dimmer control – a dedicated 0-10V wall dimmer or a circuit in a control system – acts as a current sink, allowing one signal to control several luminaires/ballasts in parallel. When the dimming input is 10V the output is full brightness, with a linear reduction to zero as shown in Fig. 1. If the dimming input in a luminaire is not used it can simply be left open-circuit and is internally pulled up to 10V.

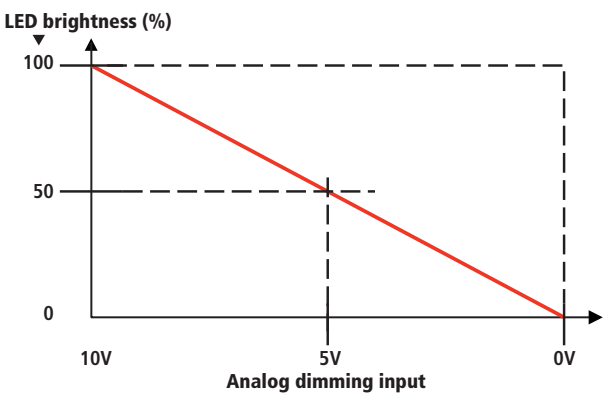

FIG. 1. In analog 0-10V dimming, a 10V input equates to full brightness while a 0V input equates to lights turned off or operated at the lowest possible dimming level.

In a 0-10V scenario, a luminaire can use either a linear control of the output current or a variable PWM output to dim the LEDs. Fig.

2 shows a block diagram of a power supply and driver with linear output dimming. Note that the 0-10V signal controls the LED driver current, not the power supply output voltage which remains constant (24V in this example).

Fig. 3 shows a block diagram of a power supply with analog control that relies on a PWM output for dimming. In this case the 0-10V signal is input to a PWM controller in the power supply that provides a constant-voltage variable-pulse-width output via a MOSFET switch. An LED driver (not shown in Fig. 3) would convert the pulses to constant current and drive the LEDs. A PWM frequency of 200Hz avoids any noticeable flicker of the light output.

DALI digital controls

Moving on to digital interfaces, the digital addressable lighting interface (DALI) standard is also defined in IEC 60929, Annexe E. The main application for DALI is the control of multiple light fixtures in commercial applications such as conference rooms, offices and public buildings. One DALI interface can control up to 64 devices. All devices on a DALI network are controlled by an electronic control device (ECD), which can also include an Ethernet interface to allow the network to be administered from a PC.

DALI provides comprehensive dimming capabilities based on stored information for different brightness configurations, referred to as scenes. The DALI protocol allows control of brightness and of dimming speed within each luminaire, to coordinate all luminaires on a network and ensure they all react simultaneously. DALI also allows for status reporting from each device to the controller on request, including brightness setting as well as power status, fault information, etc.

For LED lighting in a DALI network, the dimming itself can be achieved through normal PWM control of the LED drive current. The same microcontroller that provides the DALI interface functionality can also provide the PWM signal to the LED driver.

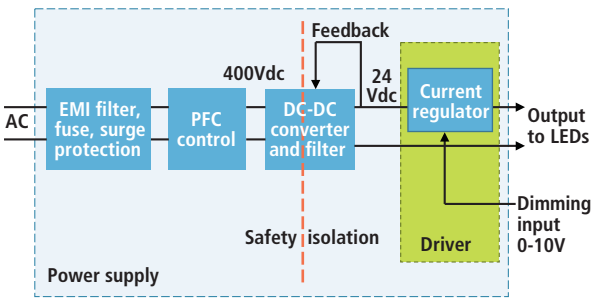

FIG. 2. The analog-control scenario is easily applied using linear-dimming technology, which supplies a continuous constant current at the prescribed level.

DMX512

The DMX512 (digital multiplex) standard is defined in ANSI E1.11-2004. Its main use is to control theatre stage lighting, and it can support multiple functions such as pan, tilt, zoom, color and image effects in addition to dimming. A maximum of 32 devices can be connected on one DMX512 line. DMX data flow is unidirectional and does not include any provision for status reporting.

Dimming is normally implemented in one of two ways. The first method uses a specific DMX dimmer unit (called a dimmer pack) that provides several AC outputs into which lights are plugged. Each of the outputs has an internal phase-cut dimmer, controlled through the DMX signals. The second method uses a multi-channel DMX-to-analog converter that provides analog 0-10V outputs for each channel rather than AC outlets. These analog outputs are used to control lighting that can accept a 0-10V dimming input.

Control of LED lighting through DMX could use either method for dimming, but the 0-10V analog method is simpler and allows more complete control.

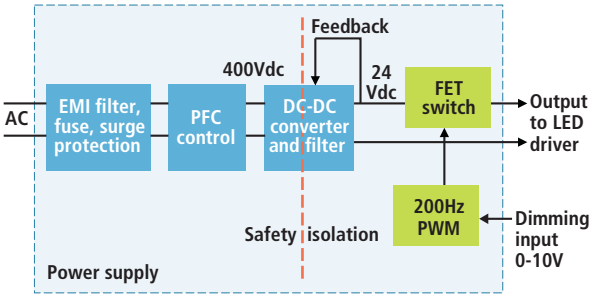

FIG. 3. PWM dimming is also applicable in 0-10V control scenarios, but requires a PWM controller to drive the output MOSFET switch of a power supply that in turn feeds a constant-current LED driver.

Zigbee wireless networks

Zigbee is a digital wireless mesh networking standard based on IEEE 802.15.4-2003. It is intended for applications such as building automation, smart energy and lighting control. One of the advantages of using Zigbee to control lighting is that no additional wiring is needed apart from the AC power. This can be particularly attractive for LED street lighting applications where the intention is to retrofit existing luminaires. A Zigbee network can support dimming during off-peak hours, multi-level dimming integrated with motion sensors, and other intelligent-lighting scenarios. It can also support status monitoring from the luminaire to provide warning of damage or failure, operating temperature, power consumption, indication of brightness level, and other operational characteristics.

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Thick-film technology with aluminum substrates optimizes LED assembly

Thick-film insulation in combination with aluminum substrates provides a low-cost method of LED circuit assembly with good thermal management, says **ANITA LAFOND**.

As the LED market grows, companies that assemble LED-based products are looking for methods to make them more efficient and reliable, thus making them more cost-effective for the consumer. To guarantee high-quality performance from an LED, efficient heat dissipation is crucial. LEDs convert only 20-30% of their electric power into visible light; the rest converts into heat that must be conducted from the LED to the atmosphere. This excess heat reduces the LED's efficiency and reliability, resulting in a shorter lifespan. Thermal management, therefore, is essential for maximum performance.

In the standard method of LED assembly, the LED component is soldered to a metal-core printed circuit board (MC-PCB), a thermally-enhanced PCB or a ceramic substrate, which is then bonded to a heat sink. While such a configuration is currently popular in the industry, it does not manage heat conduction well and is expensive to produce. Consequently, many manufacturers are interested in mounting LED components directly on aluminum substrates. Although aluminum offers excellent thermal conductivity and is less expensive than ceramic or metal, it requires an insulation layer on the substrate.

Thick-film substrates

For one LED assembler, Norbitech AS, finding an insulation system for aluminum substrates was important in meeting their customers' requirements. Norbitech, headquartered in Roros, Norway, is a supplier of electronic manufacturing services to the international market. The company executes SMT and high-level assembly, and is well-known in the industry for its thick-film production techniques.

ANITA LAFOND *is Senior Editorial Manager with Constructive Communication, Inc.*

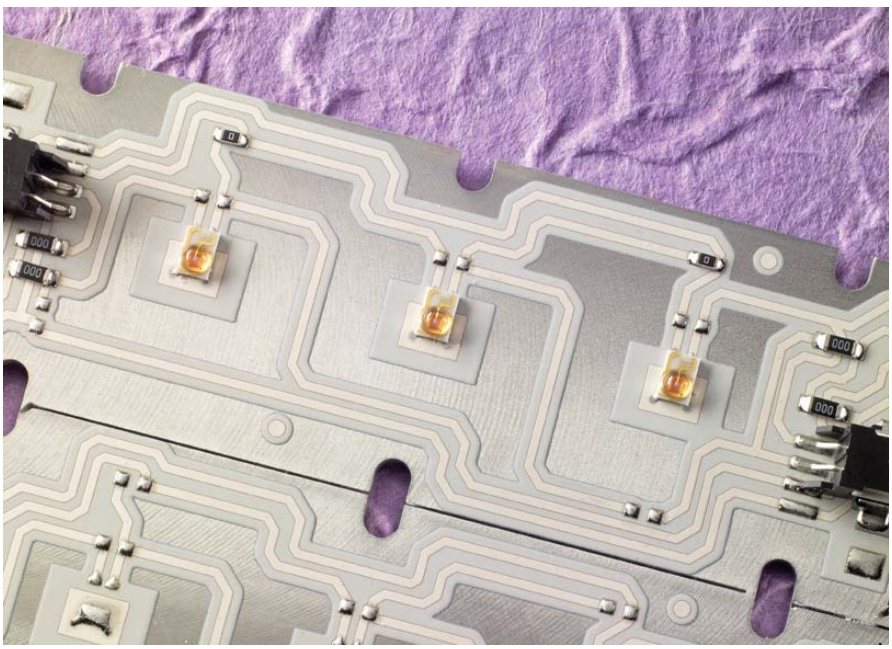

FIG. 1. Insulated Aluminum Materials System (IAMS) pastes from Heraeus have permitted Norbitech to print directly on aluminum, a less expensive base material than ceramics.

"We use thick-film technology to manufacture hybrid circuits with inorganic substrate materials," says Roar Sundt, Sales and Project Manager for Norbitech. "Typically, the circuit-manufacturing procedure entails the deposition of several successive layers (resistive, conductive or dielectric) onto an electrically-insulating substrate using a screen-printing process."

Although the most common substrate material is ceramic plate, thick-film pastes can be printed on special steel alloy plate or aluminum alloy plate. Thick-film pastes offer a highly reliable solution for many purposes such as automotive, high-frequency applications, and high-power/high-voltage electronics.

Fig. 2. shows the stages in a typical thick-film process. Thick-film substrates can be assembled with all types of SMT electronic components by using soldering, gluing or wire-bonding processes. With these methods, thick-film technology has several benefits, which are also shown in Fig. 2.

Manufacturing challenges

Working with high-power LEDs and ceramic substrates can present challenges, says Sundt. "In 2005, we started working with high-power LEDs using standard thick-film material," he says. "At that time, this was a good solution since thermal conductivity was acceptable (28 W/mK) with ceramic plates (alumina) compared to similar PCBs. However, the mechanical strength

of ceramic substrates is fragile, making the ceramics prone to cracking. Mounting to the heatsink was becoming a challenge for our customers."

Norbitech needed to find a solution to the mechanical problems, and they found their answer in Heraeus Materials Technology's Insulated Aluminum Materials System (IAMS). Heraeus, a supplier of products for thermal-management applications, developed IAMS as a low-temperature firing (less than 600°C), thick-film insulating system that can be printed and fired on aluminum substrates. The IAMS material set consists of dielectric pastes, conductors, solder masks, and resistors.

According to Mitsuru Kondo, Global LED Project Manager for Heraeus' Thick Film Division, IAMS was designed to be compatible with aluminum processing conditions. "The IAMS technology allows the LED circuit design to be screen-printed directly onto the aluminum substrate," explains Kondo. "Because the IAMS pastes can be fired at less than 600°C, the problems of cracking and bowing are eliminated."

Solving the problem

Heraeus' paste system permitted Norbitech to print directly onto aluminum, allowing them to take advantage of all the benefits aluminum has to offer. "Aluminum is a less-expensive base material than ceramics," notes Sundt. "Since a lot of today's high-power LEDs

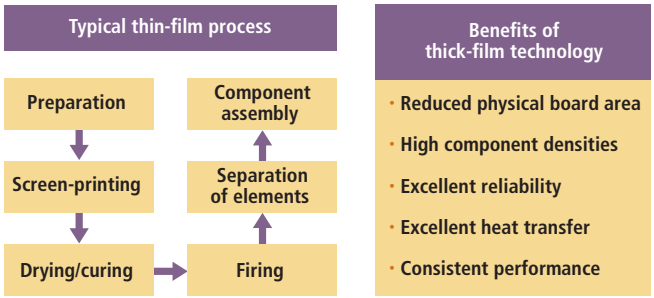

FIG. 2. Stages in a typical thick-film process, a technology which offers a range of benefits.

are electrically insulated at the heat slug, IAMS allowed us to print directly between the LED and the aluminum. The heat transfer from the die to the substrate is excellent."

Another advantage to using IAMS pastes is minimal material waste, resulting in lower production costs compared to etched MCPCBs and thermally-enhanced PCBs, where sheets of copper are chemically etched to create the circuit.

"IAMS is an additive process with selective deposition capability," says Kondo. "The conductor paste is deposited only where the circuit is located. Thermal vias connect easily to the aluminum substrate."

Norbitech used several of the IAMS products including IP6075 Lead-Free Dielectric Paste, an insulating paste that produces an extremely dense, grey, hermetic-fired film; C8829B Low-Temperature Silver Conductor, a low-firing, lead- and cadmium-free, silver-conductor paste; and PD5200 White Epoxy Insulator, a screen-printable, single-component, fast-curing, modified-epoxy coating for circuit protection.

Successful cooperation

In past experiences, Norbitech was not able to find a standard paste system that would exactly fit the application needs of its customers. By working closely with its customers and Heraeus, Norbitech was able to fine-tune the quality and the functionality of its customers' products to fit the application.

"IAMS minimizes thermal resistance by reducing the number of interfaces or layers required in an LED module," explains Kondo. "It allows low-cost design changes, offers the ability to use less expensive substrates, increases conductivity, and lengthens the LED's life span."

All IAMS pastes also meet RoHS requirements, which are especially important to Norbitech, since all the products they produce must meet these standards. Norbitech has held ISO 14001 environmental certification since 2004, and Heraeus has been in the forefront of developing RoHS paste systems.

To ensure that IAMS can provide the thermal management properties that are so crucial to LED manufacturers, the system has undergone extensive independent testing.

"The test results concluded that LEDs soldered with IAMS paste operated at cooler temperatures than the LEDs that were soldered on MC-PCBs," notes Kondo. "The measured thermal resistance between the LED active junction and the board's bottom was up to 10-percent lower with IAMS than in the MC-PCBs."

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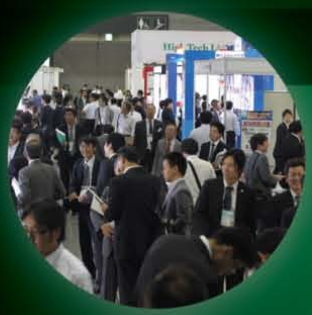

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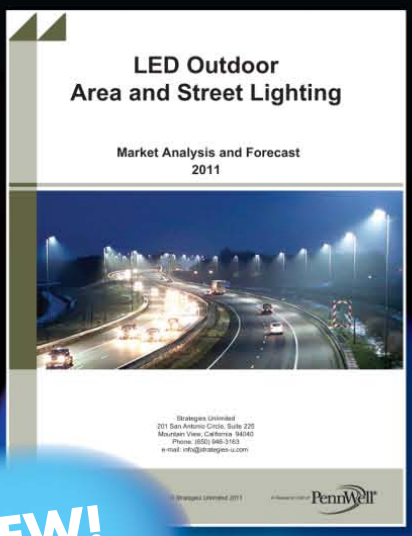

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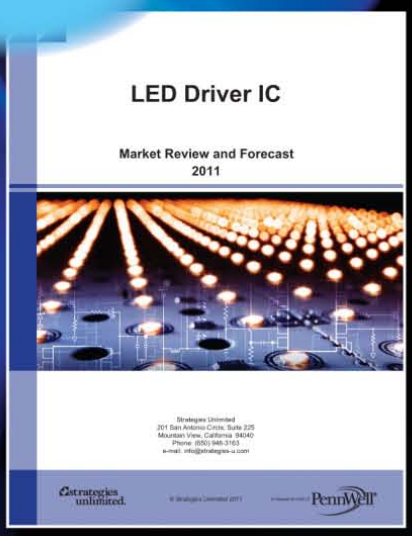

Uncertainty abounds about the current state of outdoor area and street lighting market. What will happen post-stimulus? How will the evaluation of LED streetlight installations in China affect the market there? Are growth rates in LED area lighting segments sustainable? What drives the market for LED area lighting luminaires?

Find these answers and more in the new *LED Outdoor Area and Street Lighting – Market Analysis and Forecast 2011* report from Strategies Unlimited.

The new and completely revised *LED Driver IC – Market Review and Forecast 2011 is also available.*

This new report from Strategies Unlimited takes a fresh look at the LED driver electronics market, with over 200 pages of detail on technology and application trends. It is a complete revision of an earlier report, with perspectives on the LED applications, the LEDs, requirements on the drivers and driver ICs, and findings on suppliers and market shares. It provides unit, price, and revenue forecasts to 2015 for all of the LED driver segments, and findings on suppliers and market shares. The forecast builds on Strategies Unlimited's 2011 LED forecast with new information and perspectives on driver electronics.

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LED-based poster-box reference design overcomes optical and cost challenges

LEDs can be used to replace fluorescent tubes in advertising poster boxes, offering long-term savings in energy and maintenance costs, which are set against the higher up-front cost of the LED system, explains **MATTHIAS SCHMIDER**.

The lightbox, widely used for advertising displays and in decorative lighting, is simple, relatively cost-effective and easy to design and manufacture. Traditionally, the focus of poster-box manufacturers' engineering efforts has been on producing metal frames in various shapes and sizes. The light source was an apparently trivial issue: conventional poster boxes use T5 or T8 fluorescent tubes, which have the advantage of being both inexpensive and technically simple. The main challenge is to produce an evenly-illuminated surface: this is a matter of adjusting the depth of the metal frame to allow sufficient room for light diffusion.

So is there scope for innovation and new technology to add value to the humble poster box? An LED-based reference design developed by Philips Lumileds provides a model for imaginative poster-box manufacturers to follow. This article outlines the key technical issues that manufacturers will need to address in implementing an LED-based poster box. A range of tools are available to guide the optical, electrical and thermal design decisions that manufacturers must make.

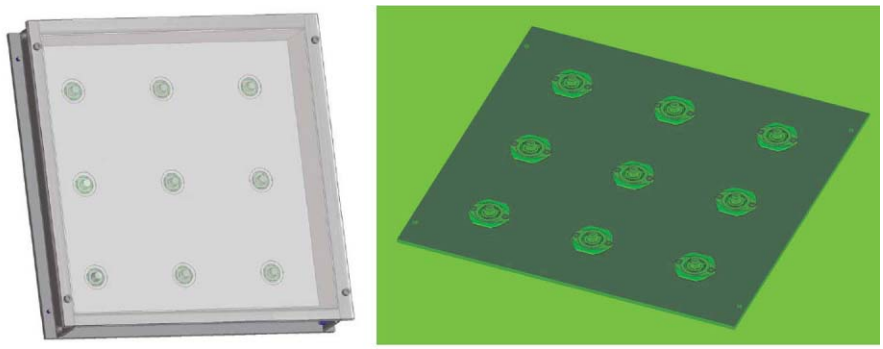

FIG. 1. Nine LEDs are spaced evenly across the plane beneath a diffuser sheet.

Why use LEDs?

By implementing an LED-based design, the poster-box manufacturer can offer customers important environmental, performance and financial benefits. A comparison of fluorescent tubes with advanced power LEDs, such as the Luxeon Rebel range of devices from Philips Lumileds, will show that an LED array uses less power (meaning a reduced carbon footprint) and has a longer operating life than fluorescent tubes producing equivalent luminance.

LED-based lighting also performs better in cold conditions, while fluorescent tubes perform poorly in the cold. Overall, LED-based poster boxes promise lower energy costs, lower repair and maintenance costs, and less downtime. This last point is particularly important for advertising applications – a poster box with a failed or flickering fluorescent tube is of no value to an advertiser.

And while end-of-life disposal of fluorescent tubes is problematic, because they contain hazardous materials, the materials in LED systems are much more environmentally benign (although subject to the provisions of various waste directives).

Every manufacturer will of course make their own economic calculation to determine the value of switching to LED technology. However, the combination of more reliable operation, lower maintenance costs and lower energy costs certainly has the potential to outweigh the higher initial bill-of-materials (BoM) cost of an LED system.

Changing the light source

In approaching the design of an LED-based poster box for the first time, the most important step is to understand the important differences between an LED and a fluorescent tube.

First, LEDs emit light from a point, and towards the front, whereas a fluorescent tube emits light along the whole length of the tube and from the full 360° circumference. So while a fluorescent tube wastes some of the light it produces, because it cannot all be reflected to the front of the box, an LED's light can be efficiently collected and directed where it is needed. In other words, LEDs need to generate fewer lumens to produce the same luminance (in cd/m^2) as a T5/T8 tube.

On the other hand, since LEDs are point sources of light, a larger part of the design effort must go towards diffusing the light evenly across the surface than is the case with fluorescent tubes.

There are also mechanical differences between LEDs and tubes: an LED is an electronic component and must be mounted on

MATTHIAS SCHMIDER *is a Product Marketing Engineer with Future Lighting Solutions, Germany (www.futurelightingsolutions.com).*

a printed circuit board (PCB) together with other components such as a driver chip. A fluorescent tube simply needs to be mounted on electrical terminals.

The third issue to consider is that both types of light source generate waste heat: the tube heats the air inside the box, while an LED generates a hot spot at its rear. This heat must be dissipated to avoid damage to the LED, and to optimize performance and operating life. In a poster-box design, the box itself can function as a heatsink and the LEDs can be placed directly on the metal casing.

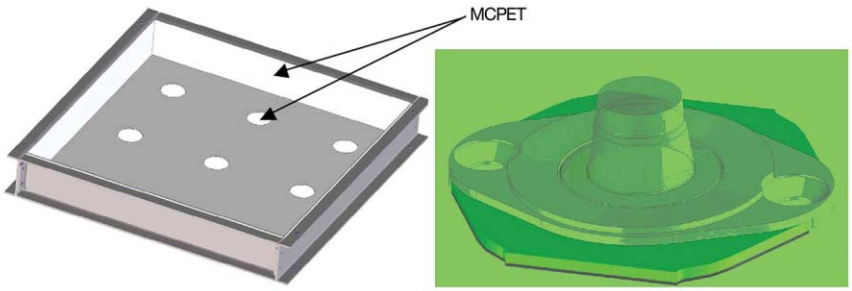

FIG. 2. A secondary optic bends the LED's light to the side.

Philips Lumileds reference design

Creating an LED-based poster box design, then, requires careful handling of trade-offs. The key decision concerns the number of LEDs to use. In general, an LED is more efficient and lasts longer when it is driven at a low current, though it will emit less light than an LED driven at a higher current. In addition, a system with a lower number of dimmer point sources can achieve even diffusion of light in a thinner box than a system with the same luminance provided by fewer, brighter points.

At the same time, a system that uses fewer LEDs has a lower BoM cost. So the design must find the optimal balance between cost and performance. The Philips Lumileds reference design illustrates the way to manage these trade-offs.

The basic mechanical design of Philips Lumileds' demonstration model is a simple metal-frame box with an outline dimension of 230 × 230 × 37 mm. The inner dimensions are 210 × 210 × 30 mm. The PCB carries nine Luxeon Rebel LEDs (part number LXML-PWN1-0100) evenly spaced in a square configuration (see Fig. 1). This design, however, is completely scalable: the width and length of the poster box can be changed at will. An applications engineer from Future Lighting Solutions can work with the poster-box manufacturer to calculate the number and spacing of LEDs and their drive current for any given box dimensions.

The power circuit drives the LEDs at 350 mA to produce a 700-lm output, and efficacy of 71.3 lm/W. Of course, different driver and LED configurations will produce different efficacy values.

An LED has a much lower profile than a fluorescent tube, so it is possible to make the poster box thinner – there is just a 30-mm gap between the LEDs and the diffuser sheet. Normally it would not be possible to illuminate the diffuser sheet evenly at such a short distance from the light source. The reference design solves this problem by use of a secondary optic (Fraen lens F360L-3-RE-OS) in conjunction with a highly-reflective material (MCPET) in the sides and back of the poster box, together with a diffuser sheet on top (Fig. 2).

The lens emits most light at around a 70-degree angle, so instead of being directed at the diffuser sheet the light bounces inside the box before being reflected back out by the MCPET material. This design has the dual advantages of mixing the light – which makes the poster box tolerant of color-temperature variations between LEDs from different bins – and diffusing it evenly across the entire surface of the box.

The system achieves a high standard of efficiency because LEDs are inherently frugal consumers of power, and because the optical design wastes little of the LEDs' light output.

Comparing solutions

Making a definitive comparison between this LED design and a fluorescent tube-based poster box is difficult, however, as various aspects of the design can have an impact on total power consumption. Nevertheless, poster-box designers should take account of the following factors in relation to the efficiency of LED systems:

- Systems using fluorescent tubes commonly over-specify the tubes to compensate for the decline in light output from a tube over time. Such over-specification is not required in the case of LEDs, which offer superior lumen maintenance and longer replacement cycles, giving a more stable light output over time.
- The efficiency of tubes at lower temperatures drops significantly, and tubes are also prone to flickering in the cold. LED performance, on the other hand, is not affected by the cold, and this is an advantage in outdoor applications.
- LEDs can be dimmed and controlled. With LEDs, it is possible to adjust the brightness of a poster box in response to changes in the ambient light level, and thus to generate further energy savings.
- Brightness control also enhances contrast while reducing discomfort from glare. This helps reduce light pollution, which is a growing concern in city centers.

Tools facilitate system design

Sophisticated tools are now available that enable manufacturers to develop virtual prototypes and experiment with various parameters in order to produce an optimized design.

At a high level, the SSL Designer tool from Future Lighting Solutions (http://bit.ly/jsP-gtc) takes the designer's goals for the poster box – light output and efficacy – and generates a basic specification, in terms of number and type of LEDs and drive current, to best meet the goals. It also provides a financial analysis and break-even calculation, showing whether it makes financial sense to switch from a traditional system to an LED system.

Having established a basic system specification, the Usable Light Tool (also from Future Lighting Solutions) provides a precise calculation of expected lumen output under real operating conditions (such as ambient temperature, thermal resistance and drive current). This allows the simulation of variations in thermal management, board material, power supply and so on in order to find the best combination.

Finally, technical support staff at Future Lighting Solutions can help poster-box manufacturers to model specific design variations and box dimensions based on the reference design, to estimate the effect of using different numbers of LEDs, different drive currents and different LED spacings.

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LED lighting and control systems evolve for optimal efficacy

New SSL system designs and control architectures will allow LED-based lighting to better realize the efficacy potential of the technology, explains **JOE DENICHOLAS**.

For multiple fiscal and environmental reasons, lighting efficacy – defined loosely as light only when, where, and how it is needed – should be given the utmost consideration when we deploy lighting systems. From an energy-consumption standpoint, LED-based lighting represents the most important advancement in lighting in decades. LEDs as light sources are inherently efficient and LEDs can be configured in systems that are much more intelligent in terms of both controllability and adaptability than traditional fluorescent and HID technologies. Indeed LED-based solid-state lighting (SSL) can provide an advantage in efficacy from many angles, but luminaire and control-system architectures must evolve to deliver truly optimal efficacy.

From a system perspective, lighting efficacy is comprised of several elements, all of which are of first-order importance. Several are outlined in Table 1. Light source efficacy is not enough. Truly efficient lighting also requires efficient electronics, fixtures that don't waste light, and control systems that further reduce wasted light.

Based on efficacy advantages, LED-based fixtures appear to be either in the lead or quickly approaching the lead in many applications such as high-bay lighting, street lighting, indoor downlighting and even fluorescent troffer replacement. Still, we need to rethink proper light levels, focus on lighting only where it is required, and push deployment of control schemes to maximize energy savings and eliminate light pollution in the environment.

The lighting industry still has work to do in determining proper light levels. For example, regulatory bodies in North America do not currently take into consideration the differences between photopic (day), mesopic (dusk), and scotopic (night) human visual systems. Our visual system has evolved to account for the differences in lighting between day and night. During bright sunlit days, our eyes are more excited by warmer CCTs (correlated color temperatures) than during dim nights when our eye sensitivity shifts toward the colder, more-bluish moonlight. Mesopic lumen output describes a situation in between photopic and scotopic and is generally considered the most appropriate measure for street lighting.

JOE DENICHOLAS *is the director of National Semiconductor's lighting business unit.*

Efficacy and eye sensitivity

The differences in efficacy can be dramatic when considered relative to photopic, mesopic, and scotopic sensitivity. This is shown in Table 2, which compares a low-CCT high-pressure-sodium (HPS) source to a much-higher -CCT, metal-halide (MH) source. High-CCT sources such as MH and LED are not necessarily given proper credit for exciting the eye in an optimal way for given environmental conditions. Given the data in the table, it's no surprise that many people involved with case studies report that LED street lights with a lower total lumen output appear brighter than higher-total-lumen HPS street lights. Note that this statement refers to the brightness of the target area and not the fixture itself which may (falsely) appear brighter due to glare effects. We need standards that ensure safety without wasting light and energy.

Likewise, some regulations and guidelines don't consider the CRI (color rendering index) of a light source even though it has recently been proven to have an effect in some applications (again, like street lighting) where small-target visibility is critical. Both CCT and CRI are critical because the required lumen output of a lamp varies greatly based on these factors. That said, their importance is still being debated and as recently as 2007, CIE's stated position in CIE 180:2007 is that, "Colour rendering is not highly important for roadway lighting, except in sensitive urban centres and/or areas with large numbers of pedestrians."

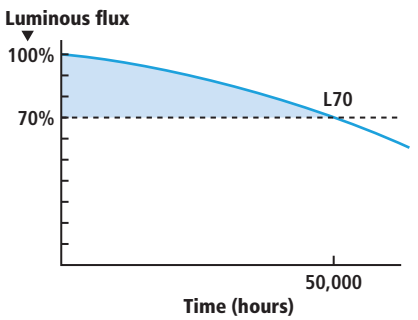

FIG. 1. Many LED luminaires waste energy (represented by the shaded area) because they initially produce more light than required to account for lumen depreciation and ensure a long L70 life.

Utilization factor

Now let's discuss utilization factor. The first three efficacy elements in Table 1 are static, at least within a relatively short timeframe of days or weeks. This is not the case with the fourth element that addresses the difference between the light supplied relative to the light needed. Utilization factor is a combination of the percentage of time that the lights are on and, when lights are on, the intensity of the light compared to what's required or being utilized. Optimized lighting controls are essential to improving utilization factor and thereby reducing energy costs. LED lights present a new opportunity for controls

as they are easy to regulate using various dimming methods, sensor interfaces, and communication infrastructures that allow the light to be modulated based on environmental conditions.

Lighting systems can perform occupancy detection to control on and off states. Several technologies can detect occupancy including passive infrared (PIR) or ultrasonic motion sensors, capacitive- or MEMS-based microphones, and digital cameras that perform image processing. Motion sensors are relatively inexpensive and are used most often although a combination of a motion sensor and another occupancy-detection method can yield superior performance. Multi-technology sensors decrease the likelihood of erroneous behavior, thus maximizing precision and decreasing energy usage.

Controlling fixtures and dimming lights to produce the appropriate amount of artificial light based on ambient light conditions is critical to both energy efficiency and user experience. Dual-loop sensors are now able to differentiate between light provided by the sun and artificial lighting systems so that fixtures can maintain a consistent light level on a target area. LED-based lamps have the advantage that deep dimming is easy to do and actually increases lamp life, in contrast with competing technologies.

Table 1. Elements of lighting efficacy

Efficacy element	Description	Units
Source efficacy	Ability to convert electricity to visible light. May or may not take into account photopic, mesopic, and/or scotopic human visual system response, and even Color Rendering Index (CRI)	Lumens per watt (lm/W)
Power supply efficiency	Power source to load conversion	Percent (%)
Fixture efficacy / light distribution efficacy	Light directed to target relative to wasted light, and distribution uniformity as portions of the target area may need to be over-lit to achieve minimum required levels elsewhere in the pattern	Lumens per watt (lm/W) as calculated according to Fitted Target Efficiency
Utilization factor/ supply vs. need	Over-lit conditions, due to lack of occupancy sensors or user preference waste energy with little to no incremental user benefit and sometimes user detriment	Percent (%)

Leveraging lumen depreciation

SSL also affords the potential of further energy savings in luminaire designs that accurately account for lumen depreciation in regulating light output. Light-output regulation is very important to LED-based lighting because of the technology's extremely long lifetime. If properly protected and driven, LEDs shouldn't burn out. Instead, the LED light output decreases over time based on a phenomenon called lumen depreciation. L70 is a parameter that describes the point in time at which the light output has decreased 30% from its initial value, and is typically on the order of 35,000 to 100,000 hours for LED lamps, as shown in Fig. 1.

To maintain a minimum amount of light output over the lifetime of a fixture, say 750 lm for a 65W replacement lamp or 6,000 lm for a parking-lot light, many fixture designs initially output 30% more light than is required. This represents a significant waste of electricity in that the target area is being over-lit for virtually the entire lifetime of the fixture.

Intelligent fixtures can regulate the light output to a lower level initially and increase the output over the fixture life. Ancillary benefits include consistency of light inten-

sity and color, lower overall energy expenditure, and lower total thermal load. Lowering the total thermal load is extremely beneficial as it leads to longer lifetimes for all electronic components, especially the LEDs and power electronics.

Though beneficial, light-output regulation provides a significant technical challenge. One could use a predictive algorithm that estimates LED efficacy or output based on hours of operation and temperature measurements. But LED performance over time and temperature may not be all that predictable. For several families of LEDs from various suppliers, the actual lumen-depreciation curves have been shown to be significantly shallower than those predicated by accelerated, high-temperature testing.

Alternatively, a fixture design could add a sensor to measure the lumen output during operation, but there are challenges here as well. First, achieving proper mechanical placement of the sensor to measure overall- or average-lumen output may be difficult or even impossible. Second, dirt can can prevent photons from getting out of the fixture and

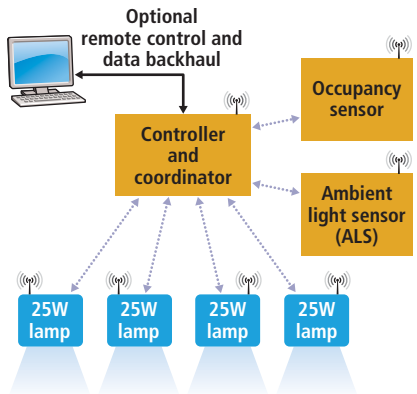

FIG. 2. In this relatively-expensive intelligent lighting system, each downlight includes an AC/DC power supply and wireless network.

may even redirect them towards the sensor, thus corrupting the measurement. Third, sensor aging and temperature drift could complicate matters even further.

In lighting systems, external sensors could measure the light output and communicate the data to the fixture. Such a system could be cumbersome, costly, and have its own set of technical issues. The right answer is likely a combination of approaches, and light-output regulation appears to be one area that is ripe for innovation.

Table 2. Comparison of high-pressure sodium (HPS) and metal halide (MH) source efficacies.

Source	Photopic efficacy (lm/W)	Mesopic efficacy (lm/W)	Scotopic efficacy (lm/W)
HPS (low CCT)	125	97	78
MH (high CCT)	107	155	175

Microcontrollers and networks

Clearly the industry must move toward intelligent lighting platforms to maximize energy savings via sensors, programmatic controls, and communications links between fixtures. Such intelligent luminaires rely on driver modules that integrate a microcontroller for interfacing to sensors and for control of the dimming profile. The smart fixtures enable managed-lighting systems with wired- or wireless-communications capabilities.

The communications infrastructure allows lights to communicate with each other, with remote sensors, and with centralized control and data-collection points. Such control systems have existed for some time but have not been widely deployed, having an estimated market share at 2% to 4%. Cost and complexity have hampered deployments. Moreover, the lighting industry focused first on more efficient sources such as fluorescent and HID that weren't inherently controllable.

With LED sources, it's time for broader deployment of control networks although the technology landscape is fragmented.

Wired communications options include 0-10V dimming, DALI (Digital Addressable Lighting Interface), DMX (Digital Multiplex) or power-line communications. Wireless personal area network (PAN) options include Zigbee, Z-Wave, 6LoWPAN, or even Google's new Android lighting platform. All may find usage although the market will likely pick the winners.

New lighting system topology

The trend is clearly toward systems that integrate the control strategies and intelligence directly into the ballast or driver. But, the overall power-supply and control architectures of these systems will likely change to take full advantage of LED technology. For example, consider a space lit by four 25W downlights, as shown in Fig. 2.

The lamps are controlled by remote occupancy and ambient-light sensors over a wireless PAN. A wired configuration could just as easily have been shown. Regardless, each fixture operates from line voltage and includes significant intelligence and therefore requires:

- 25W AC/DC converter
- 25W DC/LED constant-current converter
- Radio for the wireless PAN
- A relatively expensive microcontroller including flash memory for the PAN protocol stack
- Energy meter
- Optional sensors (temperature, light output, or color).

As shown in Fig. 2, data gathered by the MCU could be backhauled to a central location that records energy usage. Such a system could also be under remote control in addition to being able to interface to local sensors. This system, while perfectly functional, is expensive to implement and does not take into account the simple but significant fact that we now have a light source that is easy to power remotely. An alternative approach is shown in Fig. 3.

In this case, the 100W power supply incorporates the room controller/coordinator and is therefore capable of communicating directly with the sensors and the remote-control/data-backhaul interface. In this case, each fixture contains:

- 25W DC/LED constant-current converter
- A relatively inexpensive microcontroller
- Optional sensors (temperature, light output, or color).

From a power-supply standpoint, one 100W AC/DC converter is both more electrically efficient and less expensive than four 25W AC/DC converters. Energy metering is performed at the centralized power supply instead of at each lamp. The lamps communicate with the 100W supply over an extremely simple and inexpensive wired interface and therefore contain a less-expensive microcontroller, lighter communications-protocol stack, and no radio. Finally, if the optional local sensors aren't needed, then no electronics are required locally inside the lamp – the 100W power supply could send a constant current directly to the lamp.

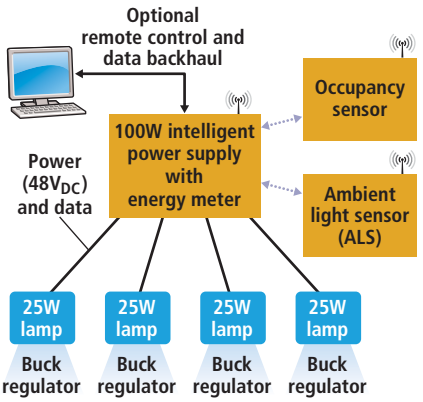

FIG. 3. A centralized power supply and simple wired control scheme within a room results in a lower-cost intelligent lighting system.

Our proposed system lies somewhere in the spectrum between 100% local power supplies and intelligence and 100% remote power supplies and intelligence (something akin to Redwood Systems' technology). The market must decide on the best solution.

Finally, artificial-intelligence or fuzzy-logic technology will enable these systems to become more efficient by enabling active learning – prediction of occupancy and even a user's desired light level. Such systems could also greatly simplify and possibly even eliminate the commissioning process. This is obviously yet another area begging for innovative solutions.

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last word

The time for intelligent LED-based lighting systems is now

LED–based light sources are uniquely controllable, and intelligent SSL systems with adaptive controls can greatly enhance energy savings, so what are we waiting for, asks **MAURY WRIGHT**?

We have the technology pieces that are required to broadly deploy intelligent LED-based lighting systems. Sure there are issues to be resolved such as the multiple wired or wireless interconnects that we might use to network a lighting system. But workable networks exist, mainstream LED-based luminaires support dimming and control, and intelligence is the key to really delivering the energy-saving potential of solid-state lighting (SSL).

You will find intelligent lighting as a recurring theme throughout this issue of LEDs Magazine, shared by contributed features on pages 25, 49, and 63.

Intelligent SSL technology was also a recurring theme in the Lightfair International (LFI) educational program. The "Incorporating lighting technologies of today with buildings of tomorrow" session yielded insight into intelligent lighting and perhaps afforded a view at the direction some industry leaders will take. Speakers included Osram Sylvania executives Makarand Chipalkatti and Karl Jessen; Mark Bauserman, executive director of engineering at Paramount Pictures; and Nadarajah Narendran, associate professor at the Lighting Research Center (LRC).

The crowd was sparse at the early-Sunday session and Chipalkatti used that fact to make a key point about the energy-saving potential of LEDs. Noting the two empty rows in front, Chipalkatti suggested that an efficient intelligent-lighting system would reduce the CRI of the lights that were directed at those empty rows and hence drop the energy those lights used by 25%, without affecting the attendee experience. It's not just output level that's controllable in SSL.

Still, first-level savings should come from supplying light only where it is required. Narendran stressed that efficient light sources alone aren't sufficient saying, "Light source efficacy does not tell you whether you are going to save energy." Narendran stressed the need for using sensors, and leveraging daylight to minimize the need for artificial light.

Bauserman provided insight from the user side of the equation. He said that when Paramount upgraded lighting with dimmable fluorescent lamps with a CRI of 85, he found that the lights could be set at lower output levels yet workers perceived an improvement in the lighting. And he believes that workers will save energy given the option. He said, "If you give an occupant the ability to control light in their space, normally they are going to save energy."

Financial story is paramount

Bauserman is planning a major lighting retrofit across the 64-acre Paramount campus. His focus is both saving money and improving light quality. Discussing the pitch he will make to management, he said, "I have to tell the story financially, or there is no story to tell." But he also added that the lighting must maximize worker productivity and mitigate any worker health impact.

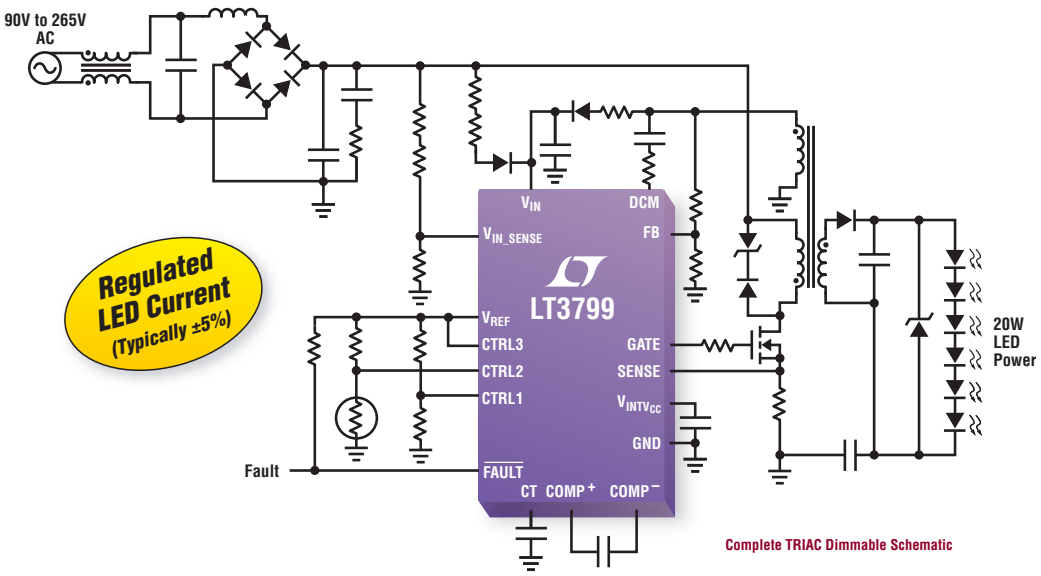
For new lighting, Bauserman is looking for bidirectional communications so that he can automatically detect failures and monitor operations. Other goals include a lighting system that is easy to install and commission, as well as long life, and low total cost of ownership.

It turns out that reading between the lines there was a reason the four speakers teamed on the session. Osram Sylvania's Jessen revealed that his company would be working with Paramount on a case study this fall involving 2x2-ft SSL luminaires with wireless connectivity. Moreover the test will use a DC grid and Class 2 cable to carry power, eliminating the need for an electrician to install the luminaires. Jessen did not say whether the installation will use the Emerge Alliance's DC technology, but Osram is a member.

The speakers were careful not to provide too many details, but Narendran earlier had mentioned research that the LRC had done with a technology called Future Tiles in which the researchers used LED-based tiles in the walls and ceilings of a room. Jessen also mentioned "LEDs integrated into things like building materials" as a next phase in SSL. It appears we will have a compelling case study to cover later this year, although the speakers declined to provide more details at LFI.

Every retrofit or new lighting installation in commercial applications should include intelligence going forward. Not every case needs the type of technology that we may see from the Paramount installation, but sensing and controls should be universal requirements and LED sources deliver the best user experience and maximum energy savings.

Isolated LED Current Control with Active PFC



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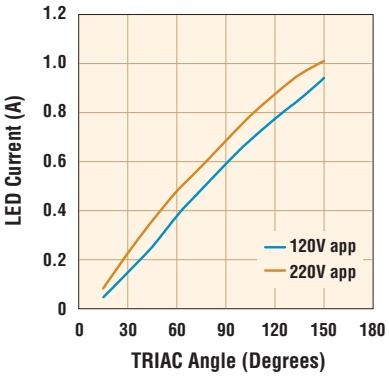
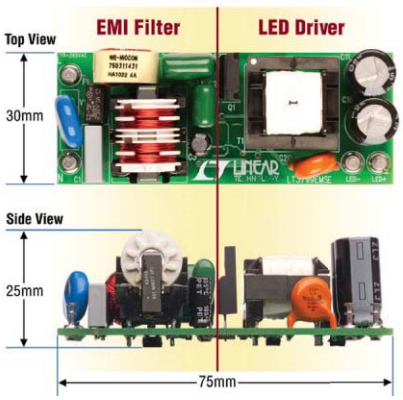
LED Current vs TRIAC Angle



LT3799 Demo Board (25W)



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Strategies in Light® Europe

4 - 6 October 2011
Conference & Exhibition
Crowne Plaza Milan Linate
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ENHANCING THE QUALITY AND PERFORMANCE OF LED LIGHTING

PRE-SHOW GUIDE

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Pre-register as a visitor before 31st August 2011 for FREE admittance into the exhibition.

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REGISTRATION FORM

Please turn to the back page of this pre-show guide for the registration form. Simply complete the form and fax it to: +1 918 831 9161.

Alternatively please mail your completed form to us at: Conferences and Exhibitions Registration, PO Box 973059, Dallas, TX 75397-3059, USA

REGISTER ONLINE

Online registration via the Strategies in Light Europe website is a straightforward and simple process. Just logon to the event website **www.sileurope.com** and click the online registration link.

WELCOME TO STRATEGIES IN LIGHT EUROPE 2011

ENHANCING THE QUALITY AND PERFORMANCE OF LED LIGHTING

Dear Colleague,

After a successful launch in September 2010, the Strategies in Light Europe conference and exhibition moves to Milan, Italy, where the event will take place on 4th-6th October 2011.

The theme of this year's event is "Enhancing the Quality and Performance of LED Lighting", and the conference programme will address key issues surrounding the evolution and transformation of the lighting market, and the ongoing development of higher-quality, higher-performance LED lighting.

Speakers at Strategies in Light Europe 2011 with focus on issues such as critical challenges & barriers to adoption; case studies and user feedback; regulatory issues & standards; government support & funding; technology updates & roadmaps; the manufacturing supply chain; quality & reliability; and the competitive landscape.

One noticeable enhancement for our 2011 conference is the addition of a second, parallel track. Following the opening Keynote Session (Tuesday 4th October, 15:30–17.00) and the Plenary Session (Wednesday 5th October, 08:30–10.00), the conference splits into two tracks, one on "Market Transformation" and the other on "Technology".

The Market Transformation Track will look at some of the Europe-wide initiatives relating to solid-state lighting (SSL), for example the development of an EU quality charter, as well as a project that aims to establish a European metrology infrastructure capable of measuring SSL effectively. Other sessions will discuss the ongoing work to develop standards, and market-development issues such as financing.

The Market Transformation Track will also discuss applications, focusing on the challenges and potential benefits of using SSL in different lighting environments. The last session will look specifically at outdoor lighting applications.

In parallel, the Technology Track will feature sessions on luminaire and system design; drivers and dimming; networks & control; retrofit lamps; optical materials and packaging; and finally optics.

On behalf of the Advisory Board of Strategies in Light Europe I would like to thank all those who submitted papers for consideration. While we were not able to accommodate all these submissions, we believe we have assembled a conference programme that provides an excellent and comprehensive update on the current status of the LED lighting industry, and that will offer valuable insights into future directions and strategies for business success.

We look forward to seeing you in Milan in October.

Tim Whitaker
Conference Director, Strategies in Light Europe
Editor-in-Chief, LEDs Magazine

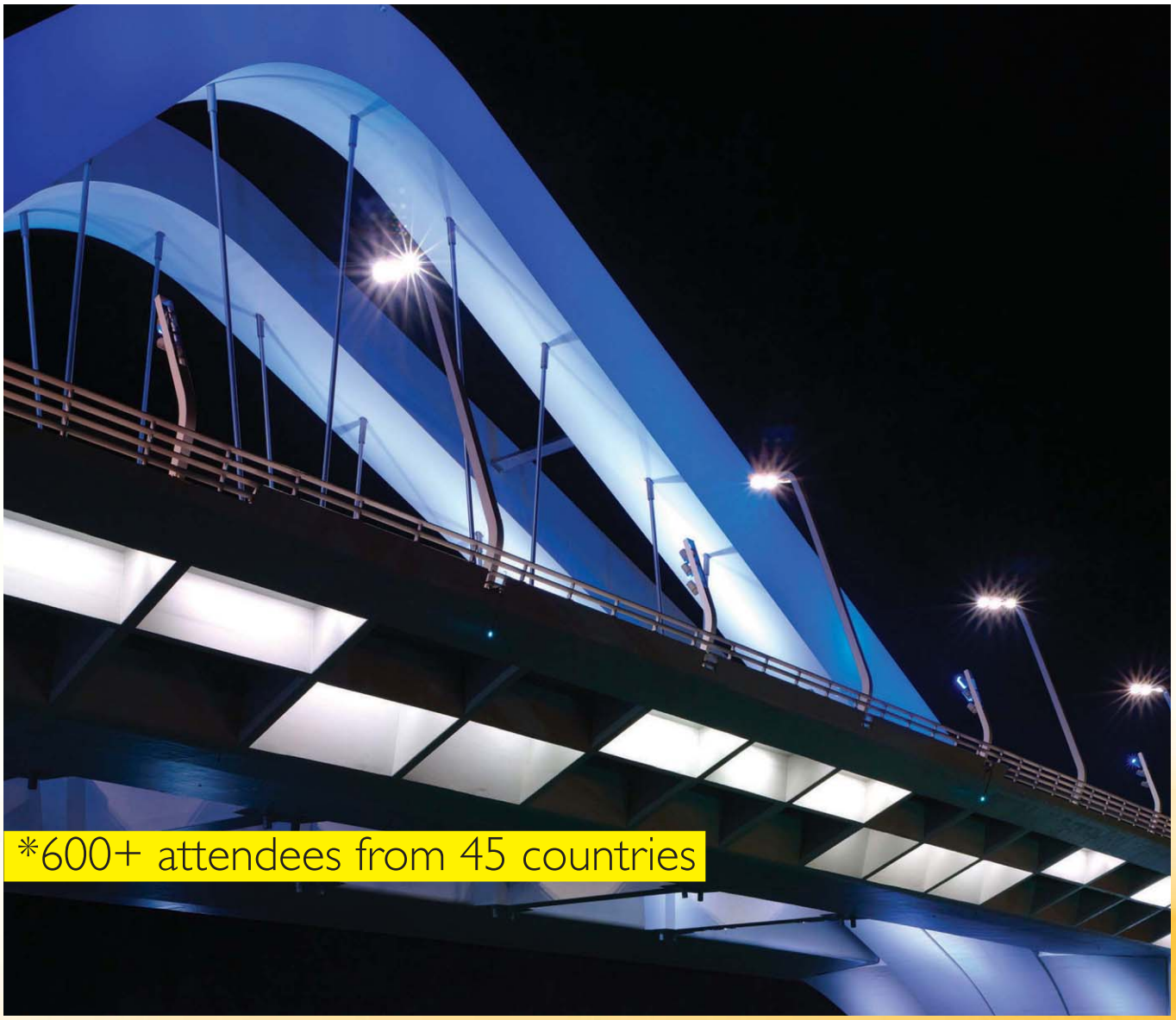
ABOUT STRATEGIES IN LIGHT EUROPE

Strategies in Light Europe enjoyed its inaugural event in 2010, with over 600 attendees from 45 countries. There was strong industry support for an event that provided a platform to share knowledge and experiences and to discuss the latest technologies.

Focusing on the European and broader worldwide market for high-brightness LEDs, including lighting fixtures and lamps as well as LED components and modules, Strategies in Light Europe brings together companies from throughout the industry supply chain, including designers, architects and other end-users of LED lighting technology.

The LED market at the component level is expected to grow to over $9 billion in 2010, and will be double that figure in 2014. At the application level, LED illumination is expected to demonstrate a compound annual growth rate of 48% from 2009 to 2014.

Strategies in Light Europe 2011 will address current LED and lighting industry issues and future potential, providing a forum for debate and bringing together key industry players under one roof to find the solutions they need.



* Data taken from Strategies in Light Europe 2010 Conference & Exhibition.

SCHEDULE OF EVENTS

TUESDAY 4 OCTOBER

08:30 - 18:30	-	Registration
09:00 - 15:00	-	Solid-State Lighting Investor Forum
09:00 - 12:00	-	Workshop A
12:00 - 13:00	-	Lunch
12:30 - 15:00	-	Workshop B
15:00 - 15:30	-	Delegate Coffee Break
15:30 - 17:00	-	Main Conference – Keynote Session
17:00 - 19:00	-	Welcome Reception
17:00 - 19:00	-	Exhibition Floor Open

WEDNESDAY 5 OCTOBER

07:30 - 18:30	-	Registration
08:30 - 10:30	-	Conference Session 1
10:30 - 11:00	-	Delegate Coffee Break
11:00 - 12:00	-	Conference Session 2
12:00 - 13:30	-	Lunch
13:30 - 15:00	-	Conference Session 3
15:00 - 15:30	-	Delegate Coffee Break
15:30 - 17:00	-	Conference Session 4
17:00 - 19:00	-	Networking Reception
08:30 - 19:00	-	Exhibition Floor Open

THURSDAY 6 OCTOBER

08:00 - 15:00	-	Registration
08:30 - 10:00	-	Conference Session 5
10:00 - 10:30	-	Delegate Coffee break
10:30 - 12:00	-	Conference Session 6
12:00 - 13:00	-	Lunch
13:00 - 15:00	-	Conference Session 7
08:30 - 15:00	-	Exhibition Floor Open

CONFERENCE AT A GLANCE

STRATEGIES IN LIGHT EUROPE 2011 PROGRAMME GRID			
Day 1 - Tuesday 4th October 2011			
Tuesday 4th October 2011	09:00 - 12:00	WORKSHOP A - Thermal Management for LEDs & Solid-State Lighting	Solid-State Lighting Investor Forum
	12:00 - 13:00	Delegate Lunch	
	13:00 - 15:00	WORKSHOP B - Light Measurement for Solid-State Lighting	Solid-State Lighting Investor Forum
	15:00 - 15:30	Delegate Coffee Break	
	15:30 - 17:00	Opening Keynote Session	
	17:00 - 19:00	Welcome Reception	
Day 2 - Wednesday 5th October 2011			
Wednesday 5th October 2011	08:30 - 10:30	SESSION 1 - Plenary	
		Market Transformation Track	**Technology Track**
	10:30 - 11:00	Delegate Coffee Break	
	11:00 - 12:00	SESSION 2 - European Initiatives #1	SESSION 2 - Luminaire/System Design
	12:00 - 13:30	Delegate Lunch	
	13:30 - 15:00	SESSION 3 - European Initiatives #2	SESSION 3 - Drivers & Dimming
	15:00 - 15:30	Delegate Coffee Break	
	15:30 - 17:00	SESSION 4 - Standards	SESSION 4 - Networks & Control
	17:00 - 19:00	Networking Reception	
Day 3 - Thursday 6th October 2011			
Thursday 6th October 2011	08:30 - 10:00	SESSION 5 - Market Development	SESSION 5 - Retrofit Lamps
	10:00 - 10:30	Delegate Coffee Break	
	10:30 - 12:00	SESSION 6 - Outdoor Lighting	SESSION 6 - Optical Materials & Packaging
	12:00 - 13:00	Delegate Lunch	
	13:00 - 15:00	SESSION 7 - Lighting Applications	SESSION 7 - Optics

*80% of attendees stated that the event met or exceeded expectations

* Data taken from Strategies in Light Europe 2010 Conference & Exhibition.

SOLID-STATE LIGHTING INVESTOR FORUM

DAY 1 - TUESDAY 4TH OCTOBER 2011

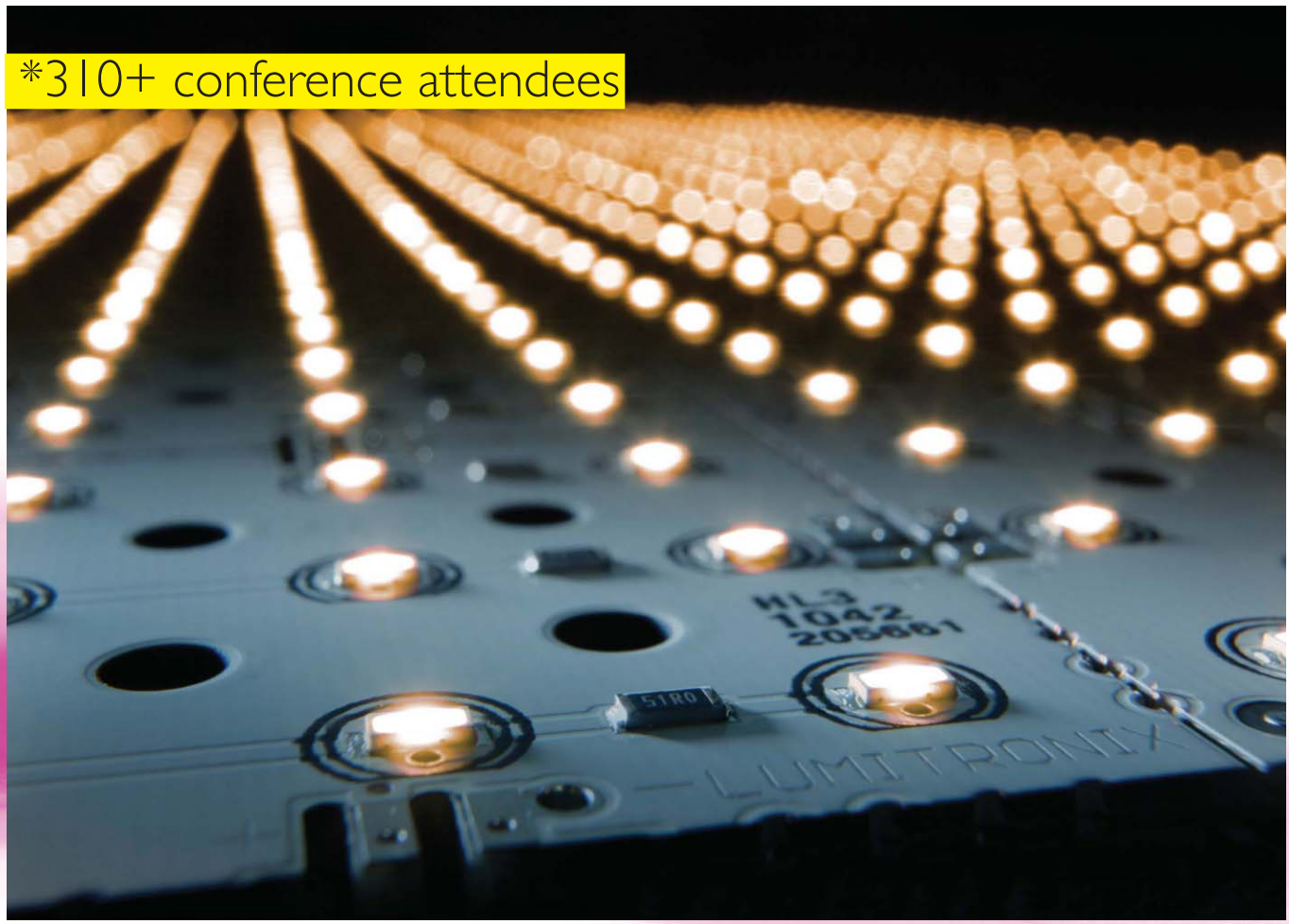
09:00 - 15:00 (incl. one-hour break for lunch)

The lighting market is evolving rapidly, driven to a large extent by the adoption of LEDs and solid-state lighting (SSL) into various application segments. While this creates opportunities for investors, the rate of change can also create uncertainty.

The SSL Investor Forum, held for the first time at Strategies in Light Europe 2011, aims to address the principal questions being asked by investors. Organised in association with Berenberg Bank, the Forum will discuss issues such as the pace of adoption of LEDs in lighting, the longer-term growth potential of the market, and opportunities to invest in different levels of the lighting value-chain. Other factors for discussion include the effects of regulations and government subsidies, and the penetration of consumer-electronics manufacturers into the lighting space.

Speakers from major publicly-quoted companies in the LED and lighting markets will share their expertise and insight. The SSL Investor Forum is specifically designed for current and potential investors, and will provide valuable information and excellent networking opportunities.

Sponsored by Berenberg Bank



* Data taken from Strategies in Light Europe 2010 Conference & Exhibition.

WORKSHOPS

DAY 1 - TUESDAY 4TH OCTOBER 2011

WORKSHOP A

THERMAL MANAGEMENT FOR LEDS & SOLID-STATE LIGHTING

09:00 – 12:00

Thermal management is a critically important factor influencing the success or failure of LED-based lamps and luminaires. Temperature has a direct affect on the performance and long-term reliability of LED-based fixtures, meaning that appropriate steps must be taken to protect the LEDs from unwanted heating situations. This workshop will discuss such issues in detail, looking at ways in which different LEDs, materials and designs can influence heat transport and junction temperature. Speakers will discuss the role of metal-core PCB substrates; the use of flexible graphite as a thermal-interface material and as a heat spreader; and the use of technologies such as stamped circuit boards and nanoceramic aluminium substrates. The various applications of thermally-conductive plastics will also be described. Participants will have the opportunity to discuss these technologies in detail and see practical, hands-on demonstrations.

WORKSHOP B

LIGHT MEASUREMENT FOR SOLID-STATE LIGHTING

12:30 – 15:00

As LED-based lamps and luminaires continue to replace conventional light-source technologies in a range of general-illumination applications, particular attention is now being paid to light quality, including issues such as uniformity and binning. Besides the basics of light measurement, this workshop will discuss the optical properties of LEDs, and how these properties can be measured in line with existing and developing standards (CIE127, DIN5032). It will explain the different types of equipment needed for accurate optical measurements in the lab and in the production line. Furthermore, aspects of colour quality such as colour temperature and colour-rendering index will be discussed. Participants can expect to learn how to evaluate the optical performance of LEDs and LED assemblies, as needed for the successful development of LED-based fixtures and luminaires

CONFERENCE PROGRAMME

DAY 1 - TUESDAY 4TH OCTOBER 2011

JOINT OPENING KEYNOTE SESSION

15:30 – 17:00

The Global LED Trend Barometer
Dominik Wee & Arthur Jaunich, LED Competence Center, McKinsey & Company, Germany

LED Lighting Evolution and Global Market Opportunities
Vrinda Bhandarkar, Director of Research, LED Lighting, Strategies Unlimited, USA

Designing with LEDs and Redefining the Lit Environment
Simon Fisher, General Manager EMEA, Indoor Luminaire Solutions, GE Lighting, UK

17:00 – 19:00 WELCOME RECEPTION

CONFERENCE PROGRAMME

DAY 2 - WEDNESDAY 5TH OCTOBER 2011

SESSION 1 – JOINT PLENARY

08:30 – 10:30

LED Lighting in the EU: Status Update*
Paolo Bertoldi, European Commission DG JRC, Italy

The Next Phase in LED Illumination
Geert van der Meer, Senior Director, Global Product Marketing GBU LED Systems, Philips Lighting

International Cooperation for Quality Assurance of SSL products: Results from the International Energy Agency Annex on SSL
Marc Fontoynont, Operating Agent, Annex on Solid State Lighting 2010-2014, International Energy Agency

OLEDs for General Lighting Applications
Bernhard Stapp, Senior Vice President, Solid State Lighting, Osram Opto Semiconductors

10:30 – 11:00 DELEGATE COFFEE BREAK

MARKET TRANSFORMATION TRACK

SESSION 2 - European Initiatives #1

11:00 - 12:00

EU LED Quaility Charter
Casper Kofod, Director, Energy Piano, Denmark

An Overview of the Russian LED Industry*
Eugene Dolin, CEO, Russian LED Makers Association

*Invited

TECHNOLOGY TRACK

SESSION 2 - Luminaire/System Design

11:00 - 12:00

The Holistic System Approach to Lighting Fixture Design
Gordon Routledge, Consultant, Dialight, UK

Integration of Thermal Management with Optical Systems for Improved Performance and Cost
Ian Turner, CEO, Juice Technology Limited, UK
Co-Author:
Phil Rimmer, CTO, Juice Technology Limited, UK

12:00 – 13:30 DELEGATE LUNCH

CONFERENCE PROGRAMME

DAY 2 - WEDNESDAY 5TH OCTOBER 2011

MARKET TRANSFORMATION TRACK

SESSION 3 - European Initiatives #2
13:30 - 15:00

Requirements on a Future Lamp - Luminaire System: the European EnLight Project
Thomas Noll, Senior Director, OSRAM, Germany

Is There a Need for a LED Performance Label?
Jacob Nuesink, Account Manager, DEKRA Certification B.V., The Netherlands
Co-Author:
Herman te Lindert, Project Manager, DEKRA Certification B.V., The Netherlands

Metrology for Solid State Lighting- The European Metrology Research Project
Simon Hall, Senior Research Scientist, National Physical Laboratory, UK
Co-Author:
Paul Miller, Higher Research Scientist, National Physical Laboratory, UK

TECHNOLOGY TRACK

SESSION 3 - Drivers & Dimming
13:30 - 15:00

Dimmed Efficiency of LED, HID and CFL Lighting Systems
John McDonnell, Managing Director, Harvard Engineering, UK

LED Lighting System Level Impacts of Driver Electronics
Nick Holland, Strategic Marketing Lighting Power Products, Texas Instruments, Germany

A Practical Guide to Designing for High Reliability in SSL Systems
Steve Roberts, Technical Manager, Recom, Austria

15:00 – 15:30 DELEGATE COFFEE BREAK

SESSION 4 - Standards
15:30 - 17:00

LED Modules and Zhaga Standards*
Andy Davies, Product General Manager, LED Solutions, EMEA

Better Quality SSL by Performance Testing
Fabrizio Allavena, EU Marketing Manager, Intertek, Italy
Co-Authors:
Carl Bloomfield, Global Director of Business Services - Energy Efficiency & Lighting, Intertek, USA

LED Standards in the European and Global Markets*
Speaker to be confirmed

*Invited

SESSION 4 - Networks & Control
15:30 - 17:00

Are DC Power Distribution Networks the Way Forward for LED Lighting Systems?
Marc Ottolini, CEO, iSotera Ltd, United Kingdom
Co-Author:
Phil Rimmer, Chief Scientist, iSotera Ltd, UK

TCP/IP as a Control Protocol for an LED Lighting
Meinrad Braun, Director Sales, dilitronics GmbH, Germany

Wireless DALI – The Right Complement to LED Luminaires
Yariv Oren, CEO, Virtual Extension, Israel
Co-Author:
Marius Gafen, VP Marketing, Virtual Extension, Israel

17:00 – 19:00 NETWORKING RECEPTION

CONFERENCE PROGRAMME

DAY 3 - THURSDAY 6TH OCTOBER 2011

MARKET TRANSFORMATION TRACK

SESSION 5 - Market Development
08:30 - 10:00

What Makes an LED Company Attractive to Investors
Marco Toja, Director, Luckygar, Monaco

Enabling Fast Adoption of LED Lighting by Luminaire Manufactures Through a Different Market Approach
Markus Zeiler, General Manager Global Sales & Marketing, Optogan GmbH, Germany

Zero Energy Building : a Great Opportunity for LED Lighting
Franco Bruno, Aerospace Engineer, Tecnid SpA, Italy

TECHNOLOGY TRACK

SESSION 5 - Retrofits Lamps
08:30 - 10:00

Omni-Directional LED Lamps
Markus Hofmann, Senior Development Engineer, OSRAM GmbH, Germany

How to Design a Perfect LED Bulb
Kamal Najmi, Power Design Engineer for Lighting, National Semiconductor, Germany

Creating the Price Breakthrough in the Consumer Market of LED Lighting
Martijn Dekker, CTO, Lemnis Lighting, The Netherlands
Co-Author:
Jurgen Hornman, COO, Lemnis Lighting, The Netherlands

10:00 – 10:30 DELEGATE COFFEE BREAK

SESSION 6 - Outdoor Lighting
10:30 - 12:00

Requirements for Wide Area Communications with LED Street Lights – Learning from One of Europe's Largest LED Telemanagement Deployments
Will Gibson, Director, Telensa Ltd., UK

Solid-State Lighting for the Bridges of Dublin: a Decade Later
Duilio Passariello, Lighting Consultant, DPLD, Spain

SESSION 6 - Optical Materials & Packaging
10:30 - 12:00

How Can Plastics Support LEDs in Lighting?
Klaus S. Reinartz, Director of Global LED Program, Bayer MaterialScience AG, Germany

Silicone Technology: Creating Value and Opening New Possibilities for the New Lighting
Hugo Ferreira da Silva, Global Market Manager, Dow Corning, Belgium

UV LED Package: An Hermetic and Non-organic Solution
Frank Gindele, Product Developer, Schott EP, Germany

12:00 – 13:00 DELEGATE LUNCH

CONFERENCE PROGRAMME

DAY 3 - THURSDAY 6TH OCTOBER 2011

MARKET TRANSFORMATION TRACK

SESSION 7 - Lighting Applications

13:00 - 15:00

***Solid State Lighting: Opportunities for Luminaire Manufacturers**
Christian Hochfilzer, Technical Director, Regent Lighting, Switzerland

Enabling Adoption of LEDs in the High Bay Lighting Market
Shawn Keeney, Applications Engineer, Cree, USA

Reducing Wasted Light
Fenella Frost, Marketing Director, PhotonStar LED Ltd., UK
Co-Authors:
Majd Zoorob, Director and CTO, PhotonStar LED, UK
James Mckenzie, CEO, PhotonStar LED, UK

*Invited

TECHNOLOGY TRACK

SESSION 7 - Optics

13:00 - 15:00

Ergonomic and Efficient Reflectors with High Power LED Arrays
Hans Laschefski, Consultant Business Development MIRO, Alanod Aluminium-Veredlung GmbH & Co. KG, Germany
Co-Authors:
Matthias Weigert, Manager Lighting Technologies, Alanod Aluminium-Veredlung GmbH & Co. KG, Germany
Detlef Düe, Head of Business Development and Marketing, Alanod Aluminium-Veredlung GmbH & Co. KG, Germany

MR16 LED-Optic Design: Hitting the Sweet Spot
Mike Bean, Head of Design, Carclo Technical Plastics, UK

Use of Light Guides in LED Lighting for Concentrators
Meir Ben-Levy, CTO, Magic Lighting Optics, Israel

The Visual Barrier: Designing the Night Appearance of a LED Product.
Giorgia Tordini, Optical Designer, Philips, France

WELCOME RECEPTION

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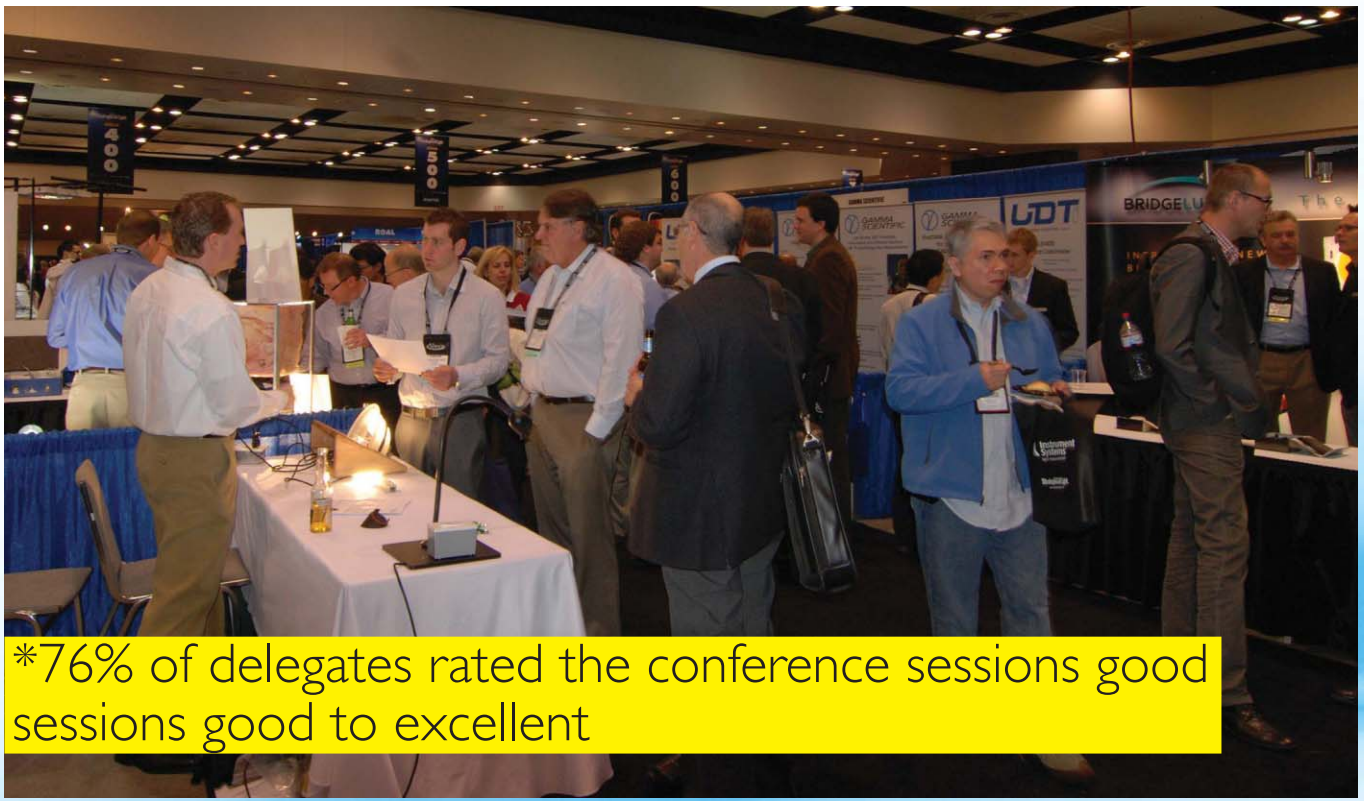
Time: 17:00 – 19:00
Date: Tuesday 4th October 2011
Location: Exhibit Floor

We will be holding the Strategies in Light Europe Welcome Reception on the exhibit floor straight after the Keynote Session. Take the opportunity to network with highly influential decision makers from the LED and Lighting industry while enjoying our complimentary drinks and appetisers generously sponsored by Styron.

NETWORKING RECEPTION

Time: 17:00 – 19:00
Date: Wednesday 5th October 2011
Location: Exhibit Floor

Join us for the 2011 Strategies in Light Europe Networking Reception with complimentary appetisers and drinks provided. Don't miss this important networking event that will attract all attendees and provide an excellent opportunity to engage face-to-face with potential customers.



*76% of delegates rated the conference sessions good sessions good to excellent

* Data taken from Strategies in Light Europe 2010 Conference & Exhibition.

WHY EXHIBIT

Strategies in Light Europe 2011, combines a first class conference programme and an exhibition that showcases the latest technological advances. The conference will address current LED & Lighting industry issues and provide a forum for debate, attracting key industry players and decision makers interested in learning about the latest developments in the industry.

Book exhibition space at Strategies in Light Europe to ensure you get to meet high level decision makers face to face and promote your company's technology and solutions.

REASONS TO EXHIBIT:

- Network with an international audience of high level decision makers
- Meet existing customers face to face
- Make contact with new customers
- Increase product and services awareness
- Launch new products and services
- Raise brand awareness in the market place

PROFESSIONALS FROM ALL AREAS OF THE LED & LIGHTING INDUSTRY WILL ATTEND INCLUDING:

- The LED manufacturing supply chain
- Members of the lighting industry
- The lighting design community
- Policy makers
- Standards organisations and other key stakeholders

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Make more of your attendance at Strategies in Light Europe. Sponsorship opportunities offer a great way to enhance the profile and greater raise the awareness of your company - before, during and after the event.

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To reserve one of the last remaining booths and to discuss sponsorship opportunities contact

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HOTEL INFORMATION

HOTEL

If you are attending Strategies in Light Europe 2011 and require hotel accommodation in the Milan area please log on to the website: www.sileurope.com.

Click the 'Hotels' button on the home page. This will take you to the Hotel Booking link which is a fast and user friendly online hotel booking system. You will find a full list of available hotels & rates, a hotel map, as well as options for all your other travel needs.

Special rates for attending Strategies in Light Europe are available from 1st October 2011 through to 8th October 2011. Please note that Events in Focus cannot guarantee special rates beyond these dates, however they will make every effort to accommodate your request.

Events in Focus is a market leader in accommodation, travel and on-site management for worldwide events. Offering competitive rates at a wide range of hotels including transfers, meet and greet, organising private functions and dinners during this event.

For reservations, questions or concerns please contact:

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REGISTRATION FORM

PRIORITY CODE

Early Bird Discount
Register before 31st August 2011

Strategies in Light Europe

Conference and Exhibition
4 - 6 October 2011

Crowne Plaza Milan, Linate
Milan | Italy

PLEASE PRINT CLEARLY

First Name _____

Family Name _____

Position _____

Organization/Company _____

Complete Mailing Address _____

_____

Postal Code: _____ Country: _____

Telephone (+) _____ Fax (+) _____

E-mail _____

CONFIRMATIONS WILL BE EMAILED IF A UNIQUE E-MAIL IS PROVIDED.

4 Ways To Register

1. Online: Visit www.sileurope.com

2. By Fax: Fax your completed reg form to: +1 918 831 9161 or toll free (US only): +1 888 299 8057

3. By Mail: SIL Europe Conference & Exhibition Registration, P.O. Box 973059, Dallas, TX 75397-3059

4. By email: Scan in your completed registration form and email to Registration@pennwell.com

www.sileurope.com

CONFERENCE FEES:

Total Access Package – Includes Workshops or Investment Forum (4th October) Conference (4th, 5th & 6th October) Conference/Workshops/Investors Forum Proceedings, Keynote Presentation, Exhibition, Welcome Reception, Network Reception, Coffee Breaks and Lunches:

Paid Before 31st August ☑ €950 individual
Paid on or after 31st August ☑ €1110 individual

Individual Full Conference – Conference, Conference/Workshop Proceedings, Keynote Presentation, Exhibition, Welcome Reception, Network Reception, Coffee Breaks and Lunches:

Paid Before 31st August 2011 ☑ €700 Individual
Paid on or after 31st August 2011 ☑ €750 Individual

Individual Day Delegate (Single Day Registration) – Includes Conference access only for the specific date registered for* Conference Proceedings, Exhibition, Coffee Breaks and Lunches only for the specific date registered for:

☑ Tuesday 4th October 2011
☑ Wednesday 5th October 2011
☑ Thursday 6th October 2011

Paid Before 31st August 2011 ☑ €455 Individual
Paid on or after 31st August 2011 ☑ €495 Individual

Exhibitor Full Conference - (Must be Exhibiting Company) Includes Conference, Conference Proceedings, Keynote, Exhibition, Networking Reception, Coffee Breaks and Lunches:

☑ €360.00

Workshop – Includes access to 1 x Workshop, Exhibition, Welcome Reception

☑ Workshop A –
☑ Workshop B –

Paid Before 31st August 2011 ☑ €105 Individual
Paid on or after 31st August 2011 ☑ €165 Individual

Investment Forum: Includes access to the investment forum (4th October), Exhibition, lunch on that day and the Welcome Reception ☑ €105 Individual

Exhibition – Includes access to Keynote, Exhibition Floor, Coffee Breaks, Welcome Reception and Networking Reception only

☑ Free if you pre-register before 30 September 2011
☑ Register Onsite in Milan - €30

Conference Proceedings Only: Download the presentations post show from www.sileurope.com
☑ €105

Payment must be received by published date in order to receive early discount registrations. Registration without payment will not be processed. Company checks must be issued to PennWell/SIL Europe Conference & Exhibition 2011. Credit card payments require card number, expiration date and signature.

Confirmation and Cancellation Policy: No attendee will be admitted into the conference without payment by check, cash or credit card. Any individual, sponsor, or corporate registrations cancelled before August 31, 2011 will receive refund of registration fee less a €100 service charge. After August 31, 2011 no refunds will be permitted. Proceedings will be sent to cancellations made after August 31, 2011. All cancellations must be received in writing. Please note: non-payment does not constitute cancellation. Substitutions may be made at any time by contacting registration office in writing.

PLEASE COMPLETE THE FOLLOWING SECTIONS:

1. TYPE OF COMPANY OR ORGANIZATION: (SELECT ONE)
❑ 01 Designer/Specifier/Installer/End-User
❑ 02 LED module/Sub-system manufacturer
❑ 03 LED Equipment and Instrument Supplier
❑ 04 LED Material and Chemical Supplier
❑ 05 Test & measurement/Standards
❑ 06 LED chip manufacturer
❑ 07 Lighting Fixture or display manufacturer
❑ 08 LED packager
❑ 09 Optics and Optical design
❑ 10 Drivers and Power supplies
❑ 11 Equipment/Materials supply for chip manufacturing
❑ 12 Distribution/Sales representation
❑ 13 Financial and Consulting
❑ 14 Academic or Government research
❑ 15 Media and PR
❑ 16 Other, please specify

2. JOB FUNCTION: (SELECT ONE)
❑ 01 Mgt (CEO, President, GM, VP)
❑ 02 Engineering/Product/Technical Manager
❑ 03 Design Engineer
❑ 04 Architect Lighting Designer
❑ 05 Product Eng & Manufacturing
❑ 06 Corp R&D
❑ 07 Distribution and Sales
❑ 08 Purchasing
❑ 09 Consulting
❑ 10 Investment/Financial
❑ 11 Other, please specify

3. APPLICATIONS AREAS OF INTEREST: (CHECK ALL THAT APPLY)
❑ 01 General Lighting
❑ 02 Entertainment and decorative lighting
❑ 03 Vehicles
❑ 04 Signals
❑ 05 Signs and Displays
❑ 06 Mobile Appliances
❑ 07 Industry and medical
❑ 08 Architect/Lighting Designer/Specifier
❑ 09 Other, please specify

4. WHAT PRODUCTS DO YOU PURCHASE OR SPECIFY? (CHECK ALL THAT APPLY)
❑ 01 LED chips
❑ 02 LED Manufacturing Equipment
❑ 03 Materials and Chemicals for LED Manufacturing
❑ 04 LED modules and subsystems
❑ 05 Packaged LEDs
❑ 06 Chip-on boards
❑ 07 Driver ICs
❑ 08 Drivers and control equipment
❑ 09 Optical design software & services
❑ 10 Test and Measurement equipment
❑ 11 Optics, lenses, diffusers, etc.
❑ 12 Packing materials, heat sinks
❑ 13 Displays
❑ 14 Lighting fixtures
❑ 15 Other, please specify

5. WHAT PUBLICATIONS DO YOU READ TO OBTAIN INFORMATION ON HB LEDS? (CHECK ALL THAT APPLY)
❑ 01 Compound Semiconductor Magazine
❑ 02 LEDs Magazine
❑ 03 CompoundSemiOnline/ SolidStateLighting.net/LIGHTimes
❑ 04 Lighting Design + Application Magazine
❑ 05 LED Journal
❑ 06 Other, please specify

6. PURCHASING ROLE: (CHECK ALL THAT APPLY)
❑ 01 Specify
❑ 02 Recommend
❑ 03 Approve
❑ 04 None

METHOD OF PAYMENT:

Credit card, wire transfer or make cheques payable to PennWell/SIL Europe Conference & Exhibition. Payment must be received prior admittance to the conference.

Please add all selections and total here: € _____

Add 20% Italian VAT: € _____

TOTAL DUE: € _____

☑ Cheque enclosed (€)
☑ Wire Transfer (Wiring infomation provided on invoice)

Credit Card:

☑ Amex ☑ MasterCard ☑ Visa

Card number: _____

Exp date: _____

Name on Card: _____

Signature: _____

Date: _____

I understand that my signature authorizes PennWell to charge the above amount to my credit card

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