JANUARY/FEBRUARY 2009

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LEDs MAGAZINE®

TECHNOLOGY AND APPLICATIONS OF LIGHT EMITTING DIODES

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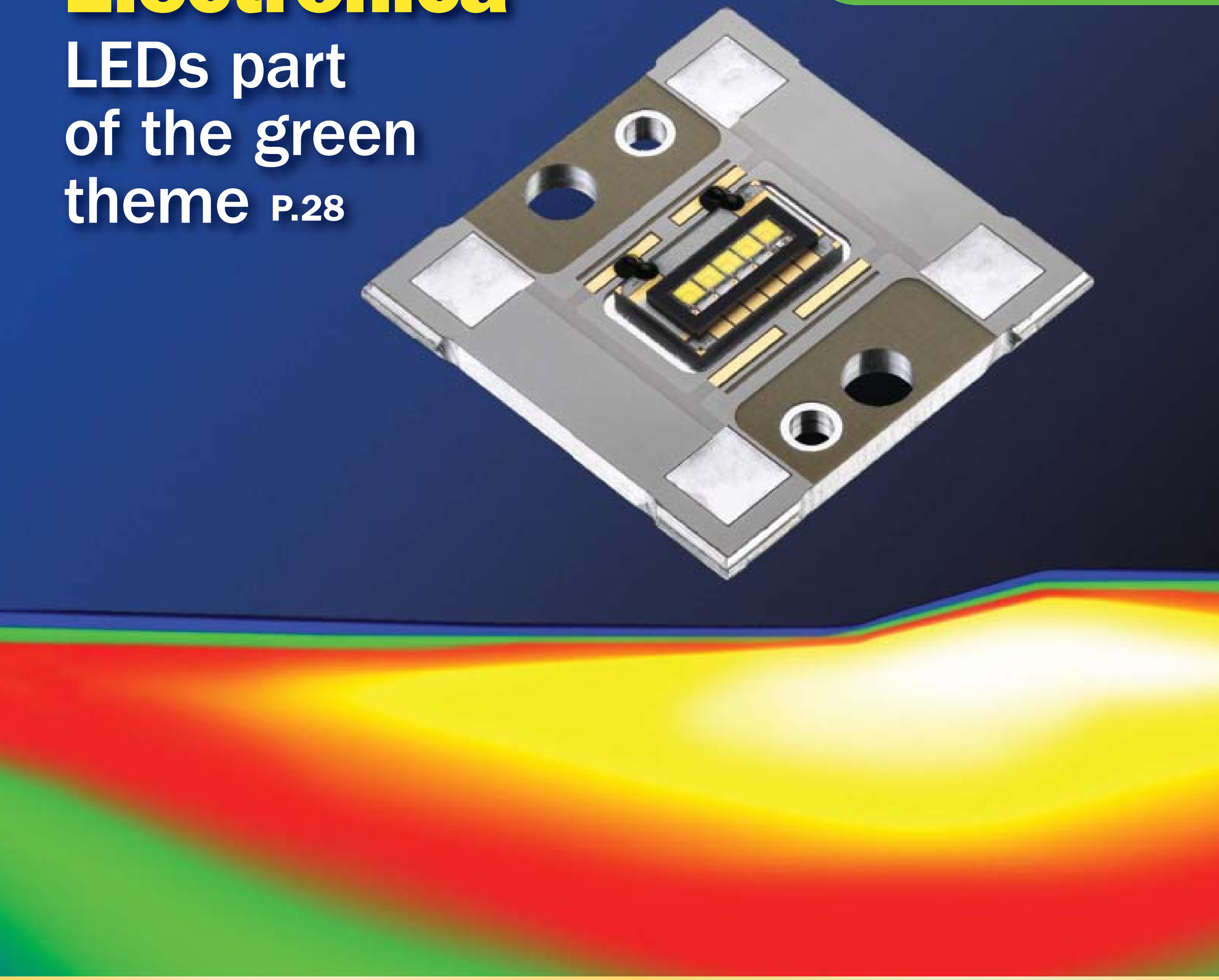

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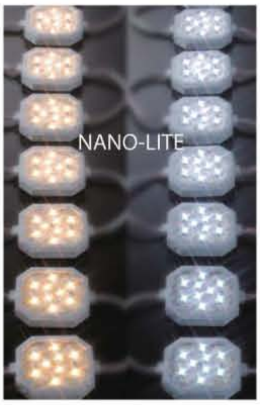

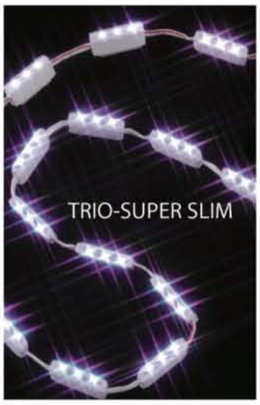

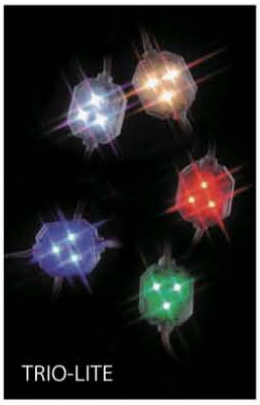

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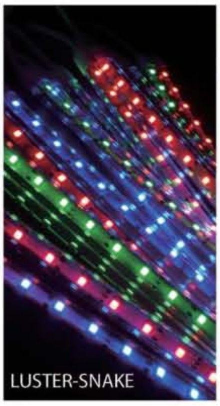

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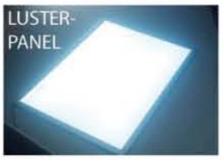

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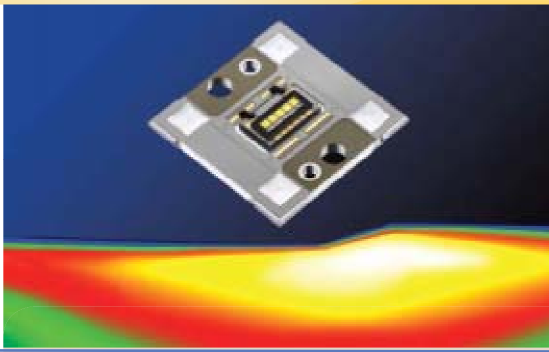

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january/february 2009

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New LEDs for car headlights were among the products launched by Osram Opto Semiconductors at the Electronica trade show (see pages 21 and 28).

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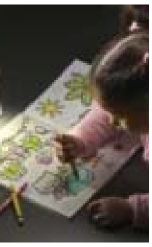

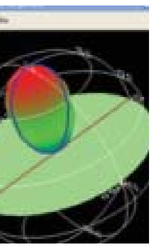

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commentary

LEDs for lighting, but only if it makes sense

While I was away in December, enjoying the delights of New Zealand, Europe moved a step closer to banning the energy-hungry incandescent lamp. Legislation has yet to be ratified and will need to be approved on a country by country basis, but the clear intention is to remove from sale the most inefficient lamps, in a tiered manner, so that before too long it won't be possible to buy most types of incandescent lamp. See page 17 for more details. Whether or not you think this is a good idea depends on your viewpoint. Purely based on energy consumption, it certainly sounds sensible – but only if you believe the numbers concerning relative energy consumption of incandescent lamps versus CFLs. Clearly, the mercury content of CFLs should be a concern, but apparently not to European legislators. Other groups point out that CFLs are totally unsuitable for certain applications. Their light quality can leave a lot to be desired, and can even cause problems for people with poor vision.

So, does this open the door for LEDs in domestic applications? In short, no. The European Union points to the future potential of LEDs, but it is clear at present that in many applications LEDs cannot hit the required price-performance point. You can get very good LED lamps with high light quality and long lifetime (subject to certain conditions, such as not using them in poorly ventilated fixtures) but they are expensive to buy. For the average consumer, price is a huge factor. Conversely, if you buy cheap and end up with an LED lamp that fails to meet your expectations, it could be a long time before you buy anything labeled "LED" again.

Rather than promoting LEDs as the ultimate and immediate alternative to CFLs and incandescents, the LED industry should continue to penetrate the applications where LEDs make most sense. For Philips Lighting UK, one such area is professional indoor luminaires. The company will stop selling non-LED products in this category, although business will continue as normal in other market sectors (see page 9).

Elsewhere in Europe, the biennial Electronica tradeshow was a lively event with lots of interest in LED products and technology (see page 28). However, the electronics industry is now seeing the effects of the economic slump, and the LED sector won't escape unscathed. US-based LED maker Cree said that, in the first calendar quarter of 2009, it expects that lower demand for products in consumer, mobile and automotive applications will be partially offset by growth in LED sales for commercial lighting applications. Bob Steele of Strategies in Light will unveil his 2009 market forecast at the Strategies in Light meeting in mid-February, but preliminary estimates suggest the high-brightness LED market will show an overall decline of around 10% during the coming year. While some non-illumination markets still show promise (see page 21), lighting will be the main area of focus for many LED companies in 2009.

Tim Whitaker, EDITOR
twhitaker@pennwell.com

LEDs MAGAZINE®

EDITOR Tim Whitaker
twhitaker@pennwell.com
Tel. +44(0)117 946 7262

MANAGING EDITOR Julie MacShane
juliem@pennwell.com
Tel. +1 603 891 9221

SALES MANAGER (EUROPE & ASIA) Joanna Hook
joannah@pennwell.com
Tel. +44(0)117 946 7262

SALES MANAGER (USA) Mary Donnelly
maryd@pennwell.com
Tel. +1 603 891 9398

PUBLISHER Shannon Alo-Mendosa
shannona@pennwell.com
Tel. +1 603 891 9137

PRODUCTION DIRECTOR Mari Rodriguez

ART DIRECTOR Cindy Chamberlin

ILLUSTRATOR Christopher Hipp

MARKETING COMM. MANAGER Carol Fronduto

CIRCULATION MANAGER Debbie Bouley
debbieb@pennwell.com

TECHNOLOGY GROUP SENIOR VICE PRESIDENT & PUBLISHING DIRECTOR Christine A. Shaw
cshaw@pennwell.com
Tel. +1 603 891 9178

VP OF AUDIENCE DEVELOPMENT Gloria S. Adams

CORPORATE OFFICERS
CHAIRMAN Frank T. Lauinger

PRESIDENT AND CEO Robert F. Biolchini

CHIEF FINANCIAL OFFICER Mark C. Wilmoth

PennWell®

LEDS MAGAZINE IS PUBLISHED BY: PennWell Technology Group
98 Spit Brook Rd, Nashua,
NH 03062, USA
Email: leds@pennwell.com

SUBSCRIPTIONS: LEDs magazine is available by paid subscription. Price includes 6 print issues per year plus the LED Suppliers Directory. The electronic (PDF) version is available free of charge from our website. Visit www.ledsmagazine.com/subscribe.
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Hybrid OLEDs combine vapor deposition with solution processing
www.ledsmagazine.com/features/5/12/5

Water jet-guided laser improves LED efficiency
www.ledsmagazine.com/features/5/12/2

Webcasts

Thermal Design for Enhanced LED Performance

ORIGINALLY BROADCAST: November 2008

PRESENTATIONS FROM: Mentor Graphics and The Bergquist Company

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Featured Companies & Profiles

The following have recently been added to the LEDs Magazine website as Featured Companies (see www.ledsmagazine.com/buyers/featured):

Alliance Optotek Corp. • Ecomaa Lighting • Edison Opto Corp. ProLight Opto Technology Corp. • UPEC Electronics Corp.

Company Profiles have also been added for the following (see www.ledsmagazine.com/Profiles):

Edison Opto Corp. • Docter Optics

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FEATURED *event*

Guangzhou International Lighting Exhibition

June 9-12, 2009
Guangzhou, China

Guangzhou International Lighting Exhibition 广州国际照明展览会

GILE is focusing more on LEDs this year by adding a second dedicated hall. Organizers say the LED booths were very popular last year, due in part to the expanding LED market in China. The exhibition showcases a comprehensive range of technical and exterior lighting, decorative lighting, professional lights, accessories and components for architects, building planners, lighting retailers and wholesalers. Last year there were 1,539 exhibitors from 21 countries. *More details: www.ledsmagazine.com/news/6/1/9*

LED lighting today: tales or facts?
March 13, 2009
Naples, Italy

Green Lighting Event
March 24-26, 2009
Frankfurt, Germany

Phosphor Global Summit
March 24-26, 2009
Miami, Florida, United States

LUMEN
March 25-26, 2009
Milan, Italy

LED Asia 2009
March 31-April 02, 2009
Kowloon, Hong Kong

Electric Lighting International Exhibition
April 08-11, 2009
Bucharest, Romania

LED/OLED Lighting Technology Expo
April 15-17, 2009
Tokyo, Japan

Euroluce
April 22-27, 2009
Milan, Italy

Lux Pacifica 2009
April 23-25, 2009
Khabarovsk, Russia

See www.ledsmagazine.com/events for event reports, latest updates and related news.

news+views

PATENTS

Sharp, Nichia in cross-licensing deal

Two Japanese companies, the electronics giant Sharp Corporation and LED maker Nichia, have entered into a patent cross-licensing agreement covering LEDs and laser diodes. The deal grants each other the right to use inventions related to LEDs and laser diodes covered by the vast number of patents owned by the respective companies in Japan and other major countries. The companies say they will aim to create even higher performance LEDs and laser diodes, enabling them to respond to rapidly expanding market demand. The companies are expecting to see growing demand for gallium nitride (GaN)-based LEDs in general illumination, LCD TV backlighting and automotive lighting. Meanwhile, blue-violet GaN-based laser diodes are required in Blu-ray Disc recorders and players. By working toward development of a vertically integrated business model including both LED lighting and Blu-ray Disc recorders, Sharp says it is aiming to create unique, one-of-a-kind products in the future that feature both devices at their core. ◂

ENERGY EFICIENCY

Smart LEDs illuminate parking lot

Courtesy: Cree Inc.

The California Lighting Technology Center (CLTC) at the University of California at Davis and industry partners have developed an energy-efficient LED parking lot light with a motion sensor that triggers increased brightness. After two years of development and field testing, the college placed the fixtures in its South Entry Parking Structure. The 50 LED light fixtures, developed by Ruud Lighting/BetaLED using Cree LEDs, feature activity-sensing technology, provide enhanced nighttime visibility, and reduce energy consumption by up to 80% compared with the metal-halide fixtures that were replaced, according to UC Davis.

Safety can be improved with the two-level activity-sensing system. When motion is detected and the higher light-level mode is activated, the change in the visual environment alerts people nearby. Drivers, pedestrians and security agents now have an indicator when there is activity in the area. "Even at half power, the LED fixtures are delivering plenty of light to the space. We may be able to cut levels further, saving even more electricity and lengthening fixture lifetimes," said Michael Siminovitch, director of UC Davis' CLTC and a professor in UC Davis' Design Program. PG&E offered incentives as part of a University of California system-wide energy initiative and supplied partial funding based on demonstrated energy savings and Watt Stopper/Legrand of Santa Clara, CA supplied the occupancy sensors. ◂

MORE DETAILS: www.ledsmagazine.com/news/6/1/13

LIGHTING

Philips UK focuses on LEDs for professional indoor luminaires

Philips Lighting UK has announced that it intends to concentrate its professional indoor luminaire activities on LED-based solutions. This means that, in the UK market, the company will cease selling non-LED products to all its professional indoor customers, such as architects and specifiers.

This strategic move will not affect Philips Lighting UK's activities in its other major market segments, namely outdoor luminaires, consumer luminaires and lighting controls. Outside of the luminaire business, the company's businesses selling existing lamps and control gear are unaffected by this new strategy.

The company believes it is "extremely well positioned" to compete in the "new landscape" of LED lighting, and says that it is convinced that this repositioning towards LED solutions will "allow it to meet the current and future needs of its customers, bringing them the full economic, environmental and design benefits of this new technology."

Philips says that it has held the view for some time that LEDs are "the future of illumination". The company has established strong expertise throughout the industry supply chain, based on the development of a strong IP portfolio and various acquisitions such as those of Lumileds, Color Kinetics, TIR Systems and PLI.

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news+views

Philips from page 9

According to Paul Coggins, Director of Philips Lighting Solutions UK, the switch to LEDs for the professional indoor market allows the company to focus on areas where it can add most value. "In the UK the general luminaire market is saturated," says Coggins. "By focusing just on LED products, we can add value for early adopters, and we can also accelerate the uptake of the technology."

While Philips feels the time is right to focus on LEDs for professional indoor applications, this is clearly not the case for consumer or outdoor luminaires. "LEDs are not the right option for every project," says Peter Maskell, Chairman & Managing Director of Philips Electronics UK Ltd. "But, we are very comfortable with LED technology for the applications where it works."

This is not to say that Philips is ignoring the domestic or outdoor luminaires markets. The company has worked extensively on street lighting applications, and one of the main reasons for acquiring the Belgian company PLI was to accelerate the use of energy-efficient lamps and luminaires, including LEDs, in the domestic market.

Many of today's applications for LED lighting are in areas such as outdoor floodlighting or entertainment lighting, often using colored LEDs. However, says Coggins, LEDs are now increasing capable of addressing more traditional lighting segments such as high-output downlights or office lighting. "The market is at a crossroads," he says. "In particular, the development of viable 2700K white products is allowing much greater penetration."

Philips acknowledges that upfront cost is often an issue when specifying LEDs. "However, the cost of ownership story invariably stacks up," says Maskell. The move to LED products will allow Philips to work with a narrower range of luminaires and control gear, making product support easier and also simplifying the specification process. The new strategy will also help to bring standardized products to the market. "By leading the move away from traditional lighting technologies to LEDs, Philips can become the recognized expert in this field," concludes Coggins. ◂

LIGHTING

Hubbell snaps up Varon

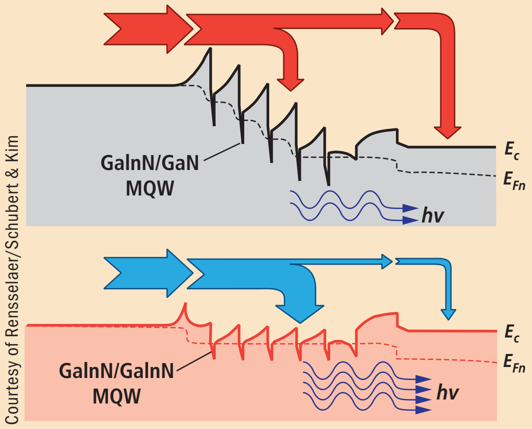
Hubbell Inc., one of the largest US-based lighting manufacturers, has acquired the Varon Lighting Group, LLC. Financial terms were not disclosed. Varon will join Hubbell's Lighting business, which includes lighting brands such as Kim Lighting, Architectural Area Lighting, Kurt Versen, Columbia Lighting, Progress Lighting and Prescolite. Based in Chicago, Illinois, Varon manufactures energy-efficient lighting fixtures and controls designed for indoor commercial and industrial lighting retrofits, as well as outdoor new and retrofit pedestrian-scale lighting applications. "This very large retrofit market is an attractive complement to our existing lighting business, which emphasizes new construction," said Timothy Powers, CEO of Hubbell Inc. The Varon Group's four primary brands include: Precision Lighting, Paragon Lighting, Beacon Products and Thomas Research Products. Precision and Paragon focus on commercial and industrial facilities, while Beacon specializes in outdoor and public spaces, and has an extensive portfolio of LED fixtures. Beacon's LED street lights use an indirect lighting approach to reduce glare and improve uniformity. The company has manufacturing operations in California, Florida, and Wisconsin, and a R&D facility in Illinois.

Varon was advised on the sale by ThinkEquity, an investment banking company. ThinkEquity's Mike Burton told *LEDs Magazine* that his team spoke to more than 50 lighting companies regarding the sale. "We think there is a window at the moment for lighting companies to make platform investments in technology," said Burton. "Varon gives Hubbell access to the retrofit market, but their LED technology was also important; this includes Beacon's LED streetlights and Thomas Research's driver technology." ◂

CHIP DESIGN

RPI researchers tackle droop

Researchers at Rensselaer Polytechnic Institute (RPI) have published a paper (*Applied Physics Letters 94*, 011113, 2009) describing a new type of LED with significantly improved lighting performance and energy efficiency. The new polarization-matched LED, developed in collaboration with Samsung Electro-Mechanics, exhibits an 18% increase in light output and a 22% increase in wall-plug efficiency. The LED achieves a notable reduction in "efficiency droop," a phenomenon where LEDs are most efficient when driven at low current density, but then lose efficiency at higher current density. "This droop is under the spotlight since today's high-brightness LEDs are operated at current densities far beyond where efficiency peaks," said RPI project leader Fred Schubert. "Our new LED, however, which has a radically re-designed active region, namely a polarization-matched active region, tackles this issue and brings LEDs closer to being able to operate efficiently at high current densities."



Band diagram of conventional GaInN/GaN active region (top) and new polarization-matched GaInN/GaInN active region (bottom) of an LED.

Schubert's team discovered that the active region of gallium indium nitride (InGaN)-based LEDs contains materials with mismatched polarization. The researchers discovered that the mismatch can be strongly reduced by introducing a new quantum-barrier design, and replaced the conventional GaInN/GaN layer of the LED active region with GaInN/GaInN. This substitution allows the layers of the active region to have a better matched polarization, and in turn reduces both electron leakage and efficiency droop. ◄

MORE DETAILS: www.ledsmagazine.com/news/6/1/11 news+views

METROLOGY

NIST tweaks LED test methods

A new, economical method to allow LED and lighting manufacturers to obtain accurate, reproducible, and comparable measurements of LED brightness and color has been proposed in a recent paper by researchers at the National Institute of Standards and Technology (NIST).

To speed production, LED manufacturers typically use a high-speed pulsed test at ambient temperature to measure the color and brightness of their products. However, pulsed measurements do not give the LED chip time to warm to its normal operating temperature, so the results are different from the output in actual lighting products. The lighting industry uses steady-state DC measurements that involve turning the light on, letting it warm up, and measuring the characteristics of the light produced. Although time-consuming, DC measurement provides a more realistic test of how the lighting product will perform in a consumer's living room.

NIST scientists Yuqin Zong and Yoshi Ohno have created a standard high-power LED measurement method that leverages the fact that the optical and electrical characteristics of an LED are interrelated, and are a function of the LED's junction temperature. The method entails mounting the LED on a temperature-controlled heat sink set to the desired LED junction temperature between 10 and 100°C. After applying a pulse of electricity through the LED and measuring the voltage across the junction, scientists turn on the DC power to the LED and adjust the temperature of the heat sink to ensure the voltage has the same value as for the pulsed measurement. The measurement results can be reproducible regardless of pulse or DC operation, or type of heat sink. The new method also allows the measurement of heat flow in and out of the LED, enabling LED and lighting manufacturers to improve the design of the LED and the thermal management system of the associated lighting product. ◄

MORE DETAILS: LEDsmagazine.com/news/5/11/28

BUSINESS

Osram, Traxon form joint venture

Osram has set up a joint venture with Traxon Technologies Ltd, a Hong Kong-based company that serves the professional LED lighting market with a focus on architectural, hospitality and shop lighting. The new company, in which Osram has the majority shareholding, will operate under the name "Traxon Technologies – An Osram Company". The purchase price was undisclosed. Osram CEO Martin Goetzeler said that the joint venture will act as "a powerful driving force for the continuing innovative development of Osram's components business. We intend to create an integrated offering across the entire LED spectrum, which will be marketed through the joint worldwide partner and sales network." The Traxon group also includes e:cue Lighting Controls, which supplies light management and control software. Osram was also attracted by Traxon's contacts with architects and lighting designers in the worldwide project business. The joint venture will continue to operate from Traxon's head office in Hong Kong while its R&D activities will remain in Paderborn, Germany, and Hong Kong. The company employs around 135 people and had sales of around EUR 17 million ($22 million) in fiscal 2008. ◄

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PRODUCTION

From Russia with LEDs

OptoGaN, a supplier of high brightness LEDs based in Espoo, Finland, has been acquired by Onexim, a Russian financial group. OptoGaN's Finnish and German operations have become part of the OptoGaN Group, a joint venture established by Onexim, the Russian Corporation of Nanotechnologies (RUSNANO), and the Ural Optical and Mechanical Plant (UOMP). The JV is aimed at creating a production company in Russia for next-generation lighting based on gallium nitride (GaN) chips. Products will include LED chips, lamps, and lighting systems. Industrial production of GaN chips will take place within the special economic zone in St. Petersburg, Russia, while the assembly of LED lamps and lighting systems will be performed in Yekaterinburg, Russia, at newly built production facilities next to UOMP. OptoGaN's management considers the deal a significant step towards commercializing its GaN technology and establishing itself as a mass-production LED company. ◄

LITIGATION

Cree settles with Bridgelux

The patent dispute between rival US-based LED makers Cree and Bridgelux has ended after Boston University and Cree agreed with Bridgelux to settle the parties' patent infringement litigation and to dismiss all claims and counterclaims in the suits. As part of the settlement, Cree granted Bridgelux a license to the Cree and Boston University patents at issue in the litigation (US patents #6,885,036, #6,614,056, #6,657,236, and #5,686,738), and Bridgelux agreed to pay a license fee and royalties. In addition, the two companies have entered into a supply agreement under which Cree will become a significant supplier to Bridgelux. Mark Swoboda, Bridgelux CEO, said that the agreement affirms the commitment of both companies to the protection of intellectual property, adding "Cree will become an important technology and manufacturing partner for Bridgelux, supporting our efforts to enable the mass adoption of solid-state lighting." ◄

OLEDs

Europe targets OLED production

A new facility has been opened by Fraunhofer IPMS in Dresden, Germany for R&D and pilot production of organic LEDs and solar cells based on small-molecule technology. The Federal Government of Germany, the Free State of Saxony and the European Union have invested a total of EUR 25 million in the Center for Organic Materials and Electronic Devices Dresden. The primary purpose of the center is to develop economically viable and

production-oriented processes for organic semiconductor devices such as OLEDs and organic solar cells, and to secure a manufacturing industry in Europe. ◄

MORE DETAILS: www.ledsmagazine.com/OLEDs

PATENTS

Seoul, Tridonic cross-license

Korean LED maker Seoul Semiconductor has entered into a cross-licensing agreement with Tridonic Optoelectronics and its patent partners. The agreement relates to white LEDs using silicate-based phosphors. Tridonic, part of the Zumtobel Group, is an established supplier of chip-on-board LEDs and modules, and a joint venture partner with Toyoda Gosei in Lexedis Lighting. Tridonic, Toyoda Gosei and other partners are joint owners of patents related to silicate-based phosphors. Under the cross-licensing agreement, SSC says that it is now in "a very strong position to manufacture and sell its own white LEDs using silicate system phosphors" as well as to expand and accelerate relevant R&D activities. ◄

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• Over Voltage Protection	✓	✓	✓	✓
• Over Temperature Protection	✓	✓		
• Adjustable Output Voltage / Current	✓(150W)	✓	✓	
• Optional Dimming Function			✓	
• Protection Level	IP65 / IP67	IP64	IP64	IP67
• UL 1310 Class 2 Compliant	✓(60/100W)	✓	✓	✓
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European regulations outlaw inefficient incandescent lamps

On December 8, 2008, experts from European Union member states endorsed the European Commission's proposals for a regulation that will lead to the progressive phase-out of incandescent lamps starting in 2009 and finishing at the end of 2012 (see www.ledsmagazine.com/news/6/1/15). The regulation (scheduled for formal adoption by the Commission in March 2009) targets lamps typically used in households - in particular incandescent lamps, halogen lamps and compact fluorescent lamps (CFLs) - by setting minimum energy efficiency and functionality requirements.

Beginning in September 2009, all non-clear (frosted) incandescent lamps and all clear incandescent lamps at 100W and above will effectively be prohibited from sale. The staged phase-out process will then remove lower-power incandescents from the market as well. (The regulation doesn't target specific lamp types, but it does set minimum efficiency/performance levels that certain lamp types will fail to achieve.)

An EU Technical Briefing document says the regulation is the result of a desire to prohibit "the sale of the worst-performing domestic lighting products from 2010, where alternatives exist, while avoiding any risk of disruption of supply to the internal market or loss of functionality from the user perspective." The same document describes LEDs as "a fast-emerging technology, whose efficacy competes with that of CFLs. However, LEDs for room illumination are today only in the first phase of commercialization, and rare are those that fulfill all the expectations of the consumers in terms of light output and other functionalities. They are likely to become true alternatives to CFLs very rapidly." In the meantime, however, CFLs are the forefront the EU's plans to enhance the adoption of energy-efficient lighting. The Professional Lighting Designers Association (PLDA) is one of many groups that feel a ban on incandescents is not warranted, given the inherent problems with CFLs and their unsuitability for many applications. In an open letter (www.ledsmagazine.com/news/6/1/12), the PLDA's Director of Sustainability Kevan Shaw said the EU's action was "entirely led by a desire to appear to be making progress with climate change issues, rather than by a fully thought-through and effective policy." Indeed, the EU's own technical briefing document brushes aside the problem of mercury content, and the effect that CFLs can have on people with various diseases or ailments related to light sensitivity.

How the EU's decision will affect the LED market is yet to be determined; it could accelerate the adoption of LED lamps, but experience with CFLs shows it would be a mistake to try to push inferior or expensive products into the market. ◄

LED eye-safety testing is essential, says Orb

LED-based lighting products have been shown to exceed the "blue light hazard" limits for risk group category RG-1 as defined by the ANSI/IESNA RP-27.3-07 standard "Recommended Practice for Photobiological Safety for Lamps, Risk Group Classification and Labeling." David Jenkins, president of Orb Optronix, says, "It is clear from our testing that [some] SSL products exist that exceed the ANSI standard's limits." These products would fall into the RG-2 categorization, which cautions against direct viewing of light sources with the human eye. RP-27 describes the "blue light photobiological hazard" as the "potential for a photochemically induced retinal injury resulting from radiation exposure primarily between 400 nm and 500 nm."

The hazard levels defined in the standard are specific to the operating conditions and system, so LED component makers cannot provide conclusive eye safety information specific to the end product implementation of their parts. For this and other reasons, it is critical that product manufacturers incorporating LEDs properly test and label their products for their intended system application.

Orb Optronix offers product evaluation to the various standards, and also works closely with medical physicist David Sliney, an expert in photo-biological safety.

Until recently, there was confusion among manufacturers about the use of proper classification standards in differing markets. For instance, in some countries, products containing LEDs required a classification under IEC 60825-1, a product standard intended for lasers, not LEDs. Fortunately, the recently published second edition of this laser product standard no longer includes LEDs in its scope. IEC 62471 replaces IEC 60825-1 internationally for LEDs and provides methods to assess the risk of LEDs by classifying their risk group (i.e., Exempt, RG-1, RG-2, RG-3) and is a "dual-logo" standard with CIE S009. ◄

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DOE revises Energy Star requirements for SSL

The U.S. Department of Energy (DOE) has unveiled version 1.1 of its Energy Star requirements for solid-state lighting to start February 1, 2009. The new version includes various revisions, and some Category A applications have been postponed for more comment. In version 1.1, references to industry standards have been updated to reflect current status. For example, the Lumen Maintenance Qualification (p16 of the 1.1 document) was updated to explain the required 6,000 hour lumen maintenance minimum thresholds, based on the new LM-80-08 test procedure.

Several new category A applications have been added (see www.ledsmagazine.com/news/5/12/16). The original category A applications that require further time to finalize criteria are: outdoor pole/arm-mounted area and roadway luminaires; outdoor wall-mounted area luminaires ("wall packs"); circular or square parking garage luminaires; and cove lighting with asymmetric distribution. DOE plans to issue revised draft criteria for these applications early in 2009, providing for a second stakeholder review and comment period before finalizing these criteria.

Since the requirements for the original Category A applications were published in September 2007, LED light output, efficacy, and other performance attributes have improved significantly, and new applications and products have appeared on the market. To keep pace with changing technology, and consistent with Energy Star program objectives, minimum luminaire efficacy requirements for the Category A additions are higher than requirements for the original Category A applications. ◄

Draft criteria for integral LED lamps

The DOE has released the first draft of Energy Star criteria for integral LED lamps (those with LEDs, an integrated LED driver, and an ANSI-standardized base) and is inviting comment by February 27, 2009.

The criteria include integral LED lamps intended to replace standard general service incandescent lamps of ≥25 W; decorative (candelabra style) lamps and standard reflector lamps of ≥20 W; and non-standard lamps. The criteria are not applicable to LED lamps intended to replace linear fluorescent or high-intensity discharge (HID) lamps.

DOE is especially interested in comments on dimming, non-standard lamps, low-voltage MR16s, and reliability testing. See www.ledsmagazine.com/news/6/1/20 for links and contact information. ◄

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Life beyond lighting: LED market shows growth in other areas

Although lighting is the fastest-growing and most exciting application for LEDs, there is plenty of activity and technical development in other market sectors, as Wolfgang Lex of Osram Opto Semiconductors explains to TIM WHITAKER.

As a major LED manufacturer with a parent in the top two of global lighting companies, Osram Opto Semiconductors has a strong interest in developing LED products for lighting applications. However, as Wolfgang Lex, vice president LED, explained when we met at the Electronica trade fair recently, there is definitely life outside of general illumination. The non-illumination LED markets remain very important, not least because they are substantially larger than the current market for lighting with LEDs.

Wolfgang Lex

"Some non-lighting customers see lots of communications and press coverage about LEDs for illumination and express their concern that we might be focusing only on lighting. It makes them nervous," says Lex. "However, we have strong obligations and commitments to existing customers and markets. This is especially the case in the automotive market, which requires long-term supply commitments; suppliers can't just jump in and out of the business."

In fact, says Lex, there is strong synergy between existing markets and the emerging lighting market. Technology and design innovations that are developed in areas such as automotive forward lighting and high-end consumer products will filter through to the lighting market. Conversely, lighting is a high-volume market that will require competitive pricing through efficient production, which in turn helps LEDs to remain competitive in other markets.

Lex says that Osram Opto Semiconductors participates in markets where it can leverage its strengths in advanced technology. The company is not involved directly in low-end consumer applications, for example blue keypad backlights, where the market is saturated and technology developments are limited. However, Lex notes that while Osram does not push this market, its distributor partners serve the market indirectly.

Automotive applications

Interior automotive applications are very well penetrated by LEDs, and the trend is now to optimize the design and reduce the number of LEDs. However, this is offset by an increase in the number of applications for LEDs such as internal mirror lights, reading lights, car ceiling lights, and foot-space illumination. Car makers are also starting to work with infrared (IR) illumination for safety-related applications, for example to detect if a driver is showing fatigue. Other systems combining an IR emitter with a camera can be used to measure the size and position of the passenger, and adjust the airbag deployment strength accordingly. IR emitters use the same thin-film technology as Osram's visible products, says Lex. Another example is a ten-chip Ostar Observation package, which can be used as the IR source for external night-vision systems. The device yields 4.3 W of optical power, and one device per headlamp can illuminate the required range of 200m.

On car exteriors, LED-based rear combination lights are well-established, but there is still room for further penetration, says Lex. "The decision to use LEDs is often related to brand appearance, while the cost of implementing LEDs becomes a less and less significant consideration in comparison with the overall energy savings available."

Unique phosphor combinations enable unusual LED colors, and give drivers the flexibility to chose the color of their instrument panel.

Recent European legislation mandating daytime running lights (DRLs) in new vehicles does not specifically require LEDs. "However, this will be a great opportunity for increased LED usage, as designers take advantage of the unique features of LEDs," says Lex. "The feasibility of full-LED headlamps has now been proven, and these will penetrate the market in the coming years." In general, the use of LEDs will be supported by energy savings targets for the total automotive fleet of a car manufacturer. LEDs can help here to achieve a minimum power budget for lighting applications, at least.

Infrared thin-film emitters in small packages provide sufficient power at short distances to enable proximity sensing; if the handset is held close to the face, the display can be switched off or the loudspeaker volume can be reduced.

As we are all aware, car sales have been badly hit by current global economic conditions. However, the impact on the LED market has yet to become clear. To stimulate sales, car makers often include features that previously were paid-for extras. In past downturns, this has seen car radios and climate control become standard in all vehicles. Additional lighting using LEDs may be one such feature, leading to increased penetration, and offsetting the decline in car sales to some extent.

Professional consumer

A growing area in the mobile handset sector is power flash; in-built cameras with increasingly large numbers of pixels require more powerful flash units, in competition with xenon. LEDs require more time to produce the same illumination (lux) levels as xenon, and this requires complex power management. "As with automotive headlights, it's not simply a matter of replacing the previous light source with an LED," says Lex. "This is an area that requires detailed understanding of advanced technology, making it ideal for Osram. Also, the substitution rate is high, with better cameras being introduced, so that continuing LED developments are required."

Minaiture projectors, either embedded into phones or as accessories, could be a growth area for LEDs, but at this stage it is not clear whether phone makers will chose to introduce this technology into their flagship models, primarily for business customers. Typically a technology such as this might take 2-3 years to migrate from high-end phones into widespread use. Larger so-called pocket projectors are seeing a surge in interest, at least on the part of OEMs. "We've never seen so much interest, and our customers think there is growing demand from consumers," says Lex. "The feasibility has been demonstrated of producing more than 50 lumens from a battery-powered device, and even larger, non portable projectors could potentially be equipped with LEDs. Our thin-film technology is optimized for projection applications, and this is an area where we have been involved for more than 5 years, starting with head-up displays in cars."

Notebooks have emerged as the first real high-volume application for LED backlights in larger LCD panels. This takes advantage of the special features of LEDs: environmental aspects such as absence of mercury and lead, as well as long lifetime, thinness, and the most important parameter — extended battery life. The monitor segment, for areas such as medical and desktop publishing, is mainly driven by the need for better colour gamut as well as by environmental concerns.

The TV backlight market is potentially the largest for LEDs, but also the most challenging, and is driven mainly by cost competition from the incumbent CCFL technology. "The original idea to simply exchange CCFLs for LEDs was not so successful," says Lex. "The new trend is to make best use of the unique features of LED technology, benefiting from the form factor of the package, the individually addressable nature of the LEDs, and their long lifetime. This leads to the trend of very flat LCD TVs (< 20mm thick) with large diagonal."

Industrial applications

LED lighting offers multiple functions for the illumination of white goods such as freezers, fridge, ovens etc. New design capabilities, long lifetime and the ability to use colors for different product presentations are the main drivers for this growing market.

Meanwhile, the existing market for LED signs will see a trend from radial LEDs towards SMT solutions. Performance is increasing as the individual LEDs are optimized for this application, and also the reduction of power consumption will be a key driver. Market development will be strongly related to general economical situations and major global events, such as the Olympics Games or world soccer championships.

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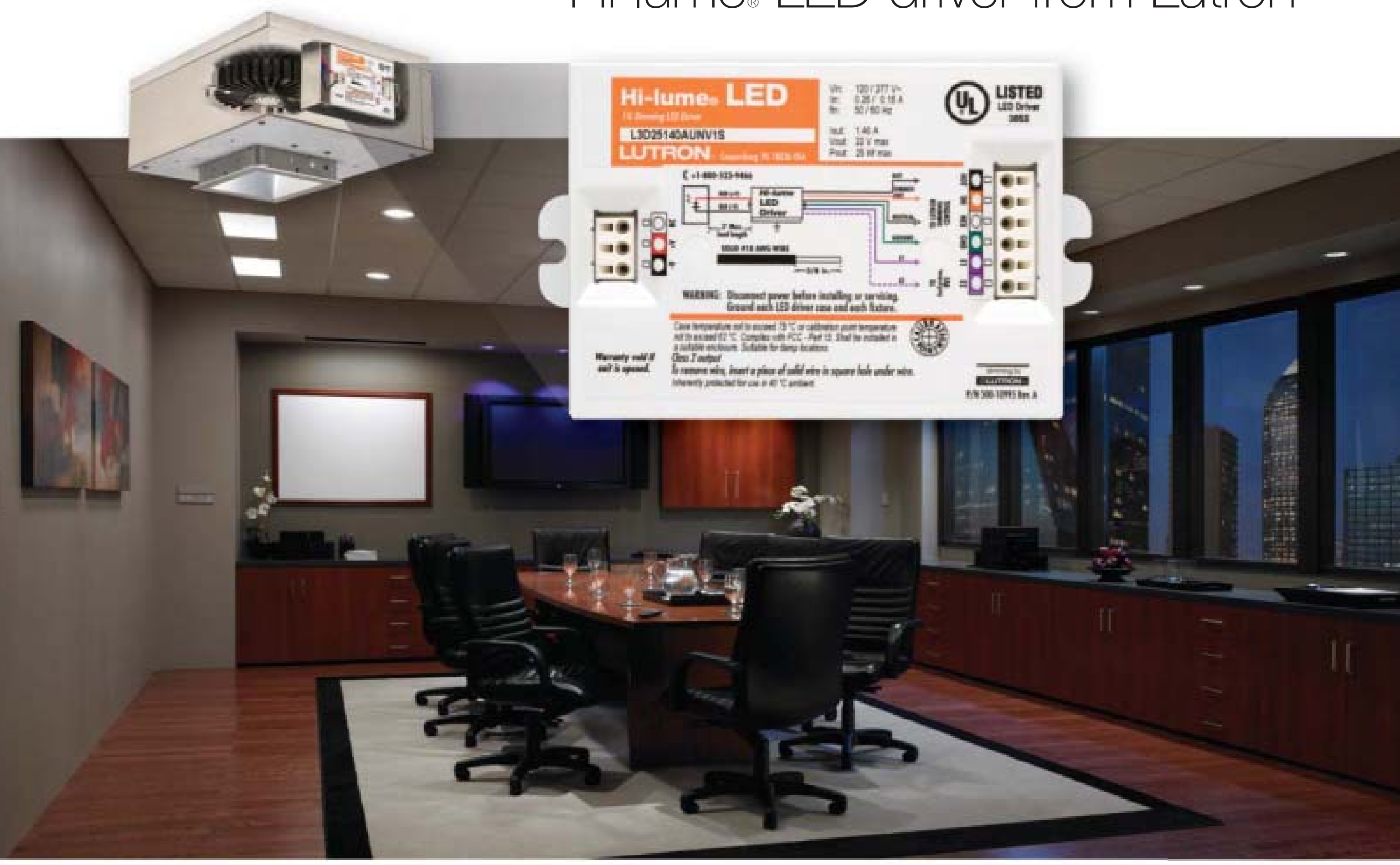

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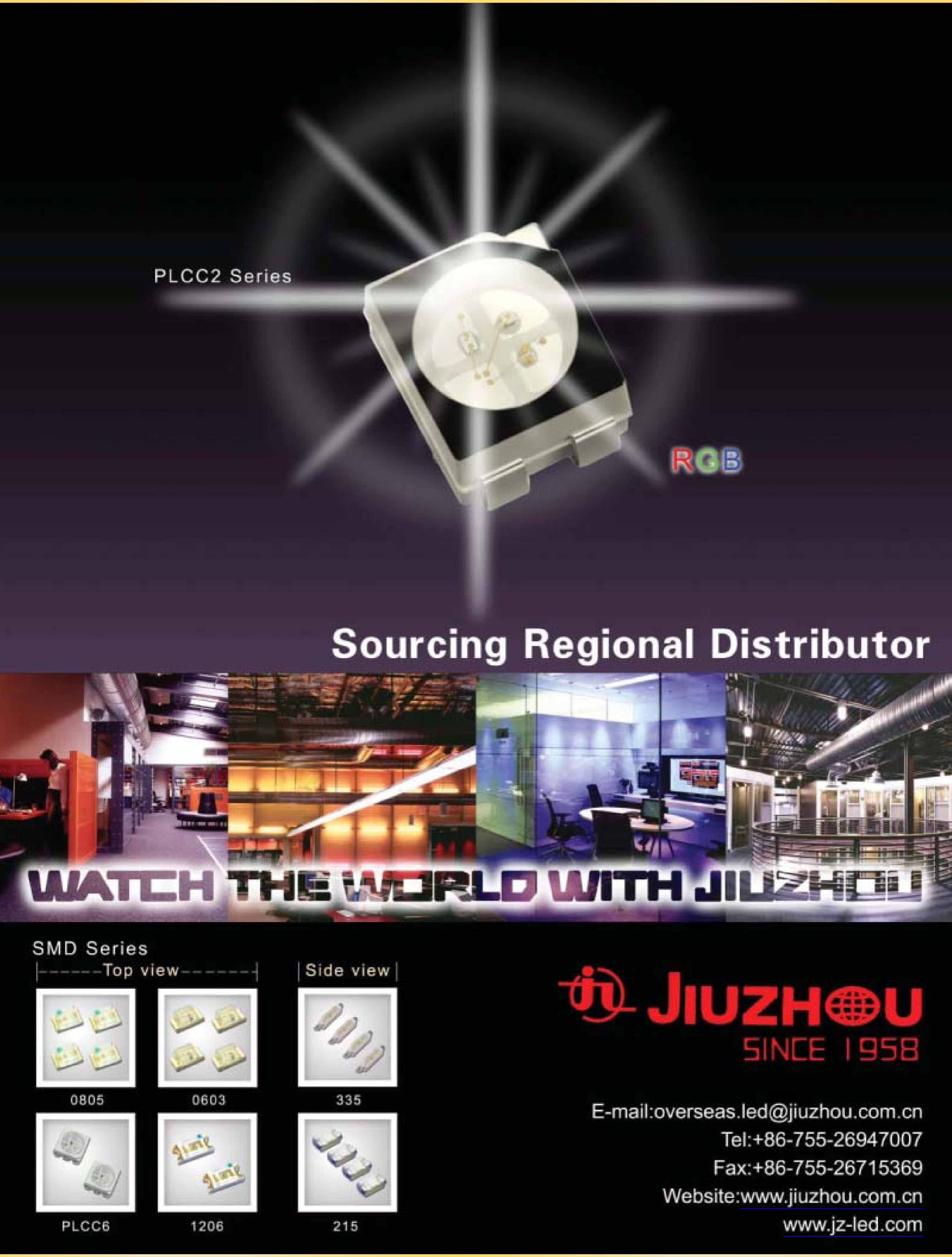
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Time to stop ignoring light losses from residential fixtures

Luminaire efficacy testing will help buyers and builders choose efficient residential lighting fixtures and accelerate the rate of energy savings achieved, writes **JAMES BRODRICK.**

The arrival of LED products in the general illumination market has provoked a great deal of discussion about how the lighting industry measures energy efficiency, particularly for residential fixtures. There is great debate about the merits of the old approach (measuring source efficacy) and the new approach (measuring luminaire efficacy). At issue is the notion that luminaire efficacy measurements provide a much truer picture of potential energy savings than do source efficacy measurements. See "Definitions" at right to learn more about the difference between these approaches.

The real question is: can we continue to ignore light loss within residential fixtures, as most residential lighting energy efficiency programs have to date? Answering that question requires a brief look back at the market introduction of compact fluorescent lamps (CFLs), and a look forward at our nation's energy and environmental future.

A look back

The North American market introduction of CFLs in the late 1980s created an enormous opportunity for reducing residential lighting energy use in the US. At the time, almost all residential fixtures used incandescent sources. Being three to four times more efficient than the incandescent lamps they replaced, CFLs presented a simple and compelling opportunity: by replacing an incandescent lamp with a CFL, energy savings of 60% to 75% were achievable.

Both consumers and residential fixture manufacturers, however, proved reluctant to transition to CFLs. Despite the promise of longer product life and reduced electricity costs, consumer interest and purchases remained small. Seeing little consumer interest in CFL equipped fixtures, manufacturers remained focused on making fixtures designed for incandescent lamps, and demonstrated an unwillingness to design fixtures specifically for CFLs. To help jumpstart this early market, electric utilities provided substantial financial incentives to consumers. Utility-funded rebates of $10 to $15 for CFLs were not uncommon in the 1990s.

Approximately 1.5 billion light bulbs were sold each year in the 1990s, and only about 2% were CFLs. Concerned that consumers would switch back to incandescent bulbs after trial runs with CFLs, many energy efficiency programs — including the newly launched Energy Star Residential Lighting Fixture program — began to promote residential fixtures using pin-based CFLs (these fixtures couldn't accept incandescent sources). These programs focused their technical requirements on the source efficacy of the CFL lamp, and chose to ignore light losses that occur when that lamp is placed in a fixture. Regardless of how much useful light the fixture produced, a fixture could qualify for these programs so long as its light source was deemed efficient.

Given consumer and manufacturer reluctance to adopt CFLs, using an approach that only considered the efficacy of the light source (not the entire fixture) made a lot of sense at the time. This approach made it relatively easy for fixture manufacturers to qualify products for most programs. All they had to do was select a lamp/ballast combination from an approved list of products that met minimum technical requirements, and then assemble their fixtures with the approved components.

They needn't concern themselves with minimizing light losses. Fixtures did not require redesign for maximum energy efficiency, nor did manufacturers have to undertake photometric testing, used to measure how much light actually escapes the fixture. Energy savings of 60% or more could be achieved without asking manufacturers to go through the more expensive and complicated steps of addressing how efficiently they could extract light from a fixture. For the most part, fixture manufacturers retrofitted existing designs to accept CFLs.

Definitions

Source efficacy measures the efficacy of the light source, separate from the fixture. It is calculated by measuring the total light output of a lamp/power supply system, and then dividing it by the power drawn by that system. (It does not account for losses caused when that system is installed in a fixture/luminaire.) It is expressed in lumens per watt.

Luminaire efficacy measures the efficacy of the complete luminaire, taking into account the optics, thermal design, and other design factors that impact efficacy. It is calculated by measuring the total light output of a luminaire, and then dividing that by the amount of power drawn by that luminaire. It is expressed in lumens per watt. ◂

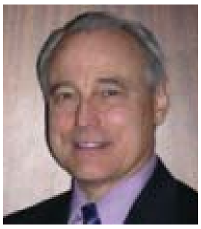
JAMES BRODRICK *manages the US Department of Energy's Solid State Lighting program (www.netl.doe.gov/ssl).*

Times have changed

Today there is growing concern about energy security, greenhouse gas emissions, and environmental sustainability. While energy efficiency specialists were once the loneliest guys at the party, they are now among the most popular. America's newly elected president has made it clear that energy will be among his top priorities, with energy efficiency and greenhouse gas emission reductions among the key components of his new energy policies.

Large corporations are racing to adopt sustainability and clean energy practices and policies. After decades of relative dormancy, CFL sales have exploded, with Wal-Mart alone selling more than 100 million per year. It is no longer difficult to persuade a large number of fixture manufacturers to develop and offer for sale fixtures using efficient light sources. They, like a wide range of companies across our economy, are aggressively trying to position themselves as purveyors of efficient, sustainable products.

Further, US law regarding residential lighting has changed. The Energy Independence and Security Act of 2007 requires DOE to establish minimum efficiency standards for general lighting service (GLS) bulbs to start taking effect three years from now (January 2012). While the first standards will likely be met by advanced incandescent lamps (such as halogen IR, which use about 30% less energy than conventional incandescent lamps), the Tier 2 standards required eight years later will likely be met by CFLs or LEDs. Countries accounting for at least half of the GLS sales throughout the world have adopted similar new policies to phase out standard incandescent lamps. As a result of these policies, the average residential fixture will soon be using a light source whose efficiency is equivalent to CFLs.



> Can we continue to ignore light loss within residential fixtures, as most residential lighting energy efficiency programs have to date? – JIM BRODRICK

Soon, a program approach that focuses solely on the efficiency of the light source will become obsolete. Coupled with the possibility of new national policy to reduce greenhouse gas emissions, energy efficiency program sponsors will need to look beyond the lighting energy savings that can be achieved by focusing solely on light source efficacy, and turn their attention to new types of luminaires that will achieve maximum energy savings. Lighting controls, daylighting solutions, and more efficient light fixtures will all be part of the solution.

By basing their programs on luminaire efficacy, efficiency program sponsors can reward fixture manufacturers who carefully design their fixtures to maximize energy efficiency and minimize light loss, and steer buyers toward fixtures that could potentially consume as little as 10% as much energy as today's incandescent fixtures. True, residential fixtures have not historically been photometered to calculate luminaire efficacy. But times have changed, and a wide range of products including ceiling fans, televisions, and other consumer electronics are now being tested for energy efficiency.

> It's time to begin photometric testing of residential fixtures.

More importantly, recent photometric testing of residential fluorescent fixtures (conducted through the US Department of Energy's CALiPER program) has revealed that many of the fixtures are often inefficient. Test results show that a large fraction of the light produced by the source is trapped and therefore wasted — more than 50% in some products.

A look to the future

The arrival of LEDs in the general illumination market makes the shift toward luminaire efficacy even more attractive. LEDs are directional sources of light, emitting light in narrow to wide beams in one direction, as opposed to the omni-directional output of incandescent and fluorescent lamps. Directional output allows fixture manufacturers to minimize and sometimes eliminate the reflective surfaces, lenses and diffusers used to guide light out of fixtures into intended directions. Each of those components absorbs some fraction of the light emitted by the source, reducing the overall efficacy of the fixture.

If LEDs are transplanted into fixtures that were originally designed for incandescent lamp use, as has been done with CFLs, much of the efficiency advantage of LEDs is surrendered. Lighting programs based only on source efficacy do not reward manufacturers for making efficient fixtures, and won't guide consumers to higher performing products.

It's time to look to the future, to begin photometric testing of residential fixtures, and to begin making the information produced from those tests available to buyers and builders so they can choose truly efficient lighting fixtures, not just fixtures with efficient light sources. Doing so will allow us to accelerate the rate of energy savings achieved in residential lighting and to make deeper reductions in greenhouse gas emissions. Early automobile manufacturers installed internal combustion engines in modified horse buggies, compromising the potential of the new power source. Let's not make the same mistake.

LEDs part of the green th

Green electronics and LED lighting were major themes at the biennial Electronica tradeshow in Munich, reports **TIM WHITAKER**.

As a major event for the European electronics industry, last November's Electronica trade fair attracted around 2800 exhibitors and around 73,000 trade visitors to Munich, Germany. Green electronics was a key theme, and Ruediger Mueller, CEO of Osram Opto Semiconductors, was one of several participants in a debate on "The Contribution of the Semiconductor Industry to Climate Protection". This is not a show for lighting companies, but many LED makers were present, some represented by distributors, and others such as Nichia were notable by their absence. All the major semiconductor makers were present and many (Texas Instruments being a good example) had demonstrations of drivers for lighting, LCD backlighting and other applications. The show also attracted LCD makers, with the majority showing demonstrations of LED backlighting.

Like other exhibitors, Future Lighting Solutions illuminated its booth with LED lights. As a demonstration of the advances in LED performance, FLS said that its booth at the last Electronica in 2006 was lit with more than 150 LED light fittings, while this year the company's slightly larger booth was illuminated with just 53 units. These were downlights from UK manufacturer IST, each containing 18 Luxeon Rebel LEDs and producing the equivalent light output to a GU10 halogen lamp (more details: www.ledsmagazine.com/press/16785). LEDs Magazine had an interesting discussion with the head of FLS, Jamie Singerman, who has authored the Last Word column on page 56 of this issue. We also had a preview of the newest FLS software tool, which will sit alongside the LED Reliability and Usable Light tools, and will enable designers to model multicolor mixing and CRI for different configurations.

Osram Opto Semiconductors announced a series of new LED products for automotive headlighting, video displays and camera phone flash (see www.ledsmagazine.com/news/5/11/12). The company is involved in a wide range of LED markets outside of the relatively small general illumination area, as discussed in our article on page 21. The Ostar Headlamp LED, illustrated on the cover of this issue, can be equipped with between one and five chips, and is fitted with a glass cover that has an integrated shutter to create the desired beam pattern on the road. At the show we saw a Sony LCD panel using Advanced Power TopLed Plus devices from Osram for backlighting. The red, green and blue devices have special outcoupling optics enabling high optical efficiency and homogenous direct backlighting. Also, Osram has developed software can be used to select the correct combination of R-G-G-B LEDs across the whole display, meaning that all the LEDs of the same color do not need to come from the same bin.

Using a contrasting approach, backlighting specialist GLT demonstrated a 42-inch panel lit by 160 white LEDs on the top and bottom edges. Cross-display uniformity of 85%is

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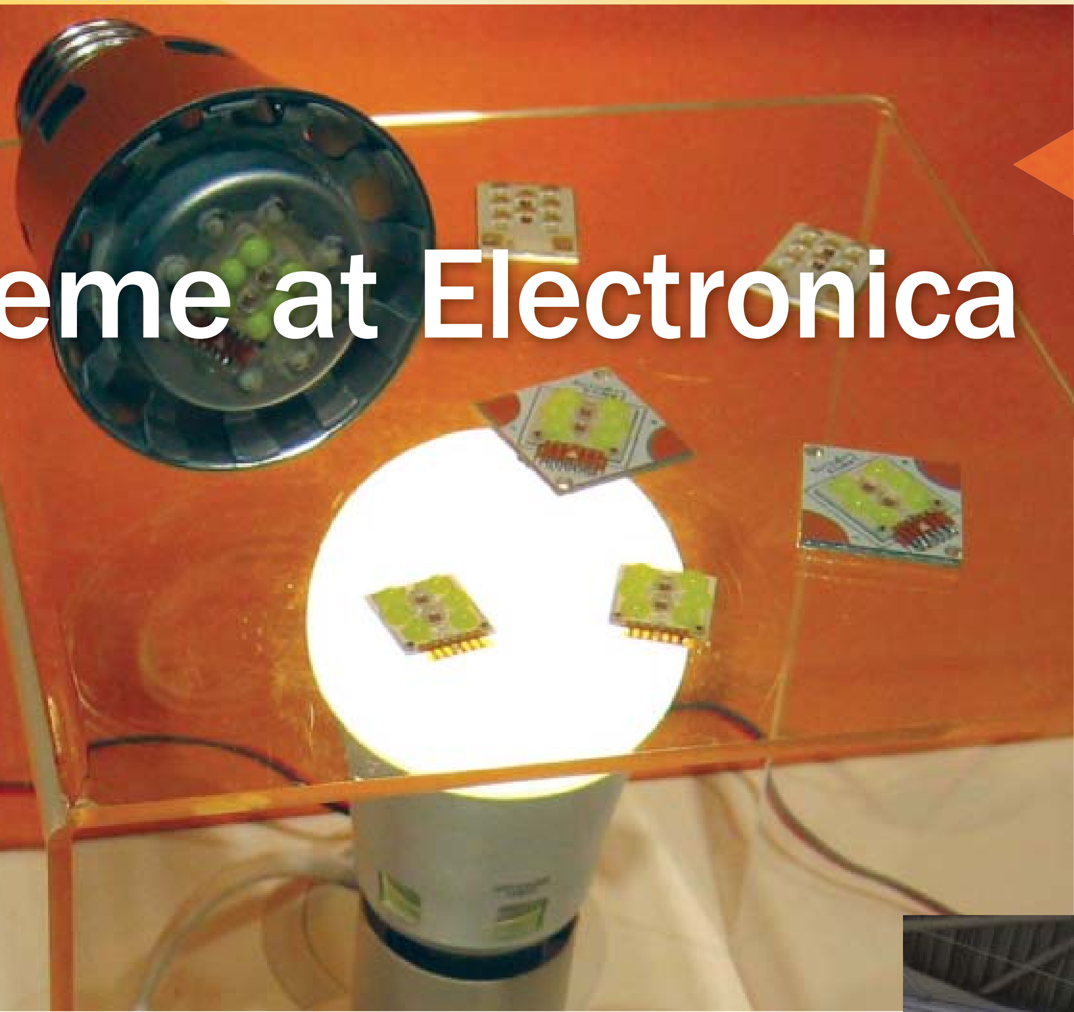

Texim Europe, a distributor, showcased a new light source from Lemnis Lighting, the manufacturer of the Pharox LED lightbulb. Lemnis is now offering the Pharox's LED light source as a separate OEM product. The chip-on-board array has 6 white LEDs and 2 red chips, to produce warm white light with color temperature of 2900K. The CRI is 86 and the luminous flux is 235lm for a power consumption of 4.0 W (350 mA and 11.6 V), corresponding to an efficacy of 58 lm/W. Several OEM modules are also available, and Lemnis plans to introduce a greenish-white light source, suitable for street lighting, in the near future.

attained using the company's MicroLens light extraction technology. White Lumileds Rebel LEDs with a red and green phosphor mix were used to achieve a color gamut of 100% of NTSC. The thickness of the light guide and the backlighting unit were 5mm and 12mm, respectively. The power consumption was 185 W. GLT said that it expected to reduce the number of LEDs to 120.

Among the exhibits on Rohm Semiconductor's stand was a new LED driver IC for LCD backlighting that is intended to provide optimized viewing with low power consumption (see www.ledsmagazine.com/press/17316). The company also had an interesting poster on ZnO LEDs and ultraviolet photodetectors. As UV emitters, ZnO LEDs can be used for fluorescent excitation, sterilization or TiO2 catalyst excitation.

CeramTec showed a range of applications for its CeramCool ceramic heat-sink technology, in which the LED can be bonded directly to metalized pads on the heat-sink surface. The company announced a heat sink design with optimized geometry to enable the operation of a 4W LED at a maximum temperature of 60°C (see www.ledsmagazine.com/products/17344). The company can form its ceramic material into a wide variety of shapes, including a GU10 LED spot, where the LED is bonded directly to the ceramic (see www.ledsmagazine.com/products/17776). CeramTec also demonstrated a heat sink with conduits suitable for liquid cooling.

TAOS Inc. demonstrated its TCS3404 and TCS3414 Digital Color Light Sensors with inte-

LINKS

Additional photos from the 2008 show: www.ledsmagazine.com/features/6/2/1

Crowds flock to Electronica 2006: www.ledsmagazine.com/features/3/12/10

Electronica 2010 takes place November 9-12 in Munich: www.electronica.de/en grated red, green and blue (RGB) filters. These can derive the color chromaticity and illuminance (intensity) of ambient light with 16-bits of resolution for managing LED and CCFL display backlighting. Applications include RGB backlighting, industrial and commercial signage, architectural lighting, embedded display calibration and medical diagnostics. Both devices have a six-lead chipscale package, providing a very small footprint of 2.095 x 1.875 mm with a height of only 0.685 mm. The chipscale package includes an internal infrared-blocking filter that eliminates the error resulting from the infrared spectral component of the light source while measuring light intensity and color as the human eye sees it without the need for an external filter.

Stanley Electric showed a variety of LEDs for lighting, at color temperatures of 5000K and 3300K, with a focus on very high CRI – not surprising, given the company's close relationship with Nichia, which is also strong in this area. At a drive current of 300 mA, and power consumption of 1W, Stanley's cool- and warm-white LEDs have a flux 70 lm and 60 lm respectively, with a very high CRI of 95. A cool white device with CRI of 70 has an efficacy of 100 lm/W. Stanley's roadmap includes the development of cool white LEDs with efficacy of 150 lm/W at 1W by 2010, and 5W devices operating at 100 lm/W by 2009. The company also had a striking visual display of twisted light-guides and reflectors illuminated with pastel-colored LEDs to demonstrate the company's optical design technology developed for applications such as automotive headlighting, LCD backlighting and amusement machines.

Sharp had a major presence, showcasing its LED modules and lamps, LED lighting fixtures, and LCD displays, including the world's largest, a 108-inch model on which visitors could play a Nintendo Wii tennis game against a life-size opponent. The company has a wide range of LCD panels for industrial applications that feature LED backlights, from 3.5 to 15 inches in diameter. While CCFL backlights require a high-voltage inverter, LEDs operate at low voltages and avoid the risk of sparks and explosions in hazardous areas. Sharp has also designed the LCD housing to provide adequate heat management, enabling operation from -30°C to 80°C.
Sharp's Zenigata LED modules contain multiple LED dies, and are available in high color-rendering versions (CRI of 90) as well as standard versions. "Normal white" 5000K modules produce either 540 or 280 lm at 360 mA, equivalent to 80 lm/W. Warm white (2800K) versions produce 400 and 190 lm, respectively. The more powerful modules contain 48 LED die in 16 parallel-switched series of 3, while there are 30 die in the less-powerful versions. The modules all use an 18 x 18 x 1.5 mm aluminum-ceramic plate as the substrate, pre-drilled with holes for mounting to a suitable cooling element.

Avago introduced a full series of single- and dual-digit, seven-segment displays for use in a wide range of consumer and industrial applications (www.ledsmagazine.com/press/17282). Crucially, these very small devices can be surface-mounted directly to a PCB, with a maximum reflow soldering temperature of 260°C. Avago also unveiled 3W warm- and cool-white Moonstone LEDs (www.ledsmagazine.com/press/17281). These two-chip LEDs are in the same package as the 1W version. For cool white, the luminous flux is typically 145 lm at 700 mA, with a maximum of 165 lm. The warm white version has a typical output of 130 lm.

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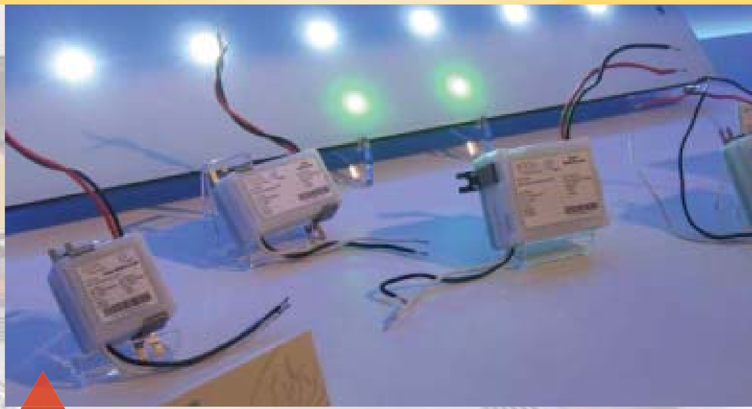
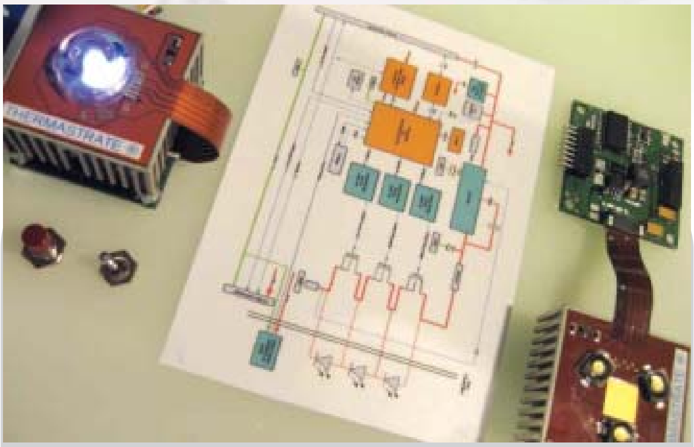
As well as a Surefire flashlight and several downlights built using their LEDs, Seoul Semiconductor showed a headtorch manufactured by Petzl, containing a single Seoul P4 LED at 6300K, which produces 80 lm. The company also unveiled its new ultrathin Z-Power LED Z1 series, in a ceramic package measuring 5 x 6 mm by only 1.2 mm thick (www.ledsmagazine.com/press/17343). The LED contains six chips, and has a viewing angle of 120°. The pure white version (6300K) has a CRI of 68 and an output of 105 lm typical at 400 mA, with a forward voltage of 4.2 V (equivalent to 1.68 W, and 62.5 lm/W). The maximum output is 120 lm (equivalent to 71 lm/W). The warm white version (3000K) has a CRI of 80 and a typical output of 80 lm at 400 mA.

Several manufacturers such as Piciesse, Huntsman and AB Mikroelektronik showcased circuit boards for automotive LED lighting applications. Freudenberg Mektec had several examples of lamps using flexible printed-circuit boards, including the daytime running light (DRL) for the new Audi R8. The photo shows a flexible strip sitting on top of the DRL unit. Freudenberg says that the flexible PCB's free formability allows electrical connections to be made into a third dimension and, therefore, to connect contact points on different levels in the simplest possible way.

IC maker Microchip demonstrated its automotive electronics products using a model car fitted with a number of LED-illuminated icons (www.ledsmagazine.com/products/17770). Touching an icon triggered a PC presentation of Microchip's offering in the chosen application. The icons combined capacitive-based touch sensors with printed lightguide technology from Design LED Products. Each icon contains four hexagonal panels, shown in the photo; at left is the panel containing the pattern to be illuminated; next is the mesh light guide that distributes the LED light across the panel; next is the circuit board; and at right is the board with the capacitive switch in the center and the LEDs at the top and bottom.



ROAL Electronics previewed a new range of drivers that will be launched in early 2009, aimed specifically at the lighting market. Output powers for the different series will range from 15W to 240 W. The Tropo series is aimed at retrofit commercial and residential markets and are compatible with most standard triac-based wall dimmers. The Strato series is aimed at new-build markets and is optimized for size, efficiency and cost. The Spectra series is for architectural and entertainment lighting and is intended to drastically reduce design cycle times for color-mixing LED fixtures.



National Semiconductor (NSC) demonstrated an LED light engine, using flexible thermal circuit material from Thermastrate Ltd. Nick Atkinson of Thermastrate said his company had been working with NSC and their other partners (Aavid, Avago, EBV, Fairchild) on the Mood Lighting project, culminating with the demonstrator unit at electronica. "This application of our Flexitherm technology is an excellent practical demonstration of what can be achieved with our new Direct-to-Heatsink construction," said Atkinson. "It fulfills the criteria given to us by NSC, which was to provide a solution that thermally out-performs conventional MC-PCBs, while adding functionality and reducing solder interconnects." One or more LEDs are mounted onto the Flexitherm circuit which in turn is mounted directly onto the heat sink, with a flexible tail connecting to the control PCB. "The construction of the Flexitherm circuit relies on our best-in-class ceramic insulating layer," continues Atkinson, "which achieves good electrical isolation, while optimising thermal conductivity. The ceramic layer is typically 35 microns thick, has a thermal conductivity of over 6W/mK and produces an isolation voltage of over 1,000 Vdc between the copper circuit and aluminum heatsink. More details: www.ledsmagazine.com/press/17451.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Atlanta TEL : +1-201-956-3609 / E-mail : jason@acriche.com

LED retrofits offer clear and effective benefits

LED replacements for fluorescent tubes provide energy savings without costly infrastructure changes, writes **DAVE SIMON.**

In the long term, the ultimately proper and successful implementation of LEDs as the predominant technology in general illumination will be through the use of fixtures and infrastructure specifically designed to take advantage of the unique properties of LEDs. Many elements of LED optical, thermal, and electrical characteristics are at odds with today's lighting infrastructure.

In the short to medium term, however, there are very good reasons to pursue a strategy to retrofit structures with LED products. Although using existing fixtures for LED products is an imperfect solution, it is nonetheless the solution offering the quickest path to the greatest energy savings over the shortest period of time. As the payback period for retrofit lamps falls steadily below five years, even for fluorescent replacements, the pure dollar impact of a lamp-to-lamp replacement will be attractive enough to entice facility owners toward energy-efficient LED solutions, given that they do not have to incur additional infrastructure changes.

One argument against a lamp replacement is that the added efficiency and light-quality benefits of infrastructure changes can also be quantified on short timelines. This may be true, but the additional outlay of capital may be onerous enough to prevent that from happening, even if additional savings are on the table. Moreover, there is a sense of comfort among facility managers that, if LEDs somehow cause a problem, they can swap backwards to current products or upgrade to newer LEDs in the same form factor. Custom installations don't allow this lamp source flexibility.

DAVE SIMON *is president of ilumisys (www.ilumisys.com), located in Troy, Michigan, USA.*

Another argument against infrastructure changes is the overall inconvenience and environmental footprint inherent to demolition and disposal, as well as manufacturing and installation of new fixtures.

ilumisys offers two versions of its T8 and T12 replacement tubes. The MK1 runs with standard T8 fluorescent ballasts, while the MK2 is powered by 120V and 277V building current, bypassing the ballast. The MK2 approach provides a clear advantage in terms of eliminating the ballast from the circuit as a failure and power-draw point. Yet, the MK1 remains a popular option because the task of simply swapping out tubes is quicker and easier than digging in behind fixtures to wire around modern T8 electronic ballasts, which may in fact be very efficient and long lived.

ilumisys installation of first-generation MK1 tubes in the Escanaba, Michigan, State Office Building.

The gains from an easy implementation today are deemed "good enough" by many users to offset the incremental advantages from a more labor-intensive swap. On the other hand, when presented with inefficient T12 ballasts, the equation shifts quickly to bypassing the old ballast as a preferred option.

As part of its public/private partnership with the State of Michigan, ilumisys installed first-generation MK1 tubes in the Escanaba State Office Building, with an agreement to perform two subsequent upgrades. (It should be noted that the LED lights have been so well accepted that the Escanaba staff have decided to keep them, and to simply use later generations to fit out more of the building.) The swap-out of 200 tubes was accomplished in a couple of hours by a small team of people. Had the conversion to LED lighting required a significant tear-up of ceilings and disruption to the working environment, it is unlikely that this project would have moved as rapidly or with such immediate acceptance as a low-risk way of going forward.

The definition of short, medium, and long-term is of course of paramount interest. Given the long life-cycles for buildings, it seems reasonable to expect the need for retrofit technologies in significant numbers for at least the next 20 years, after which the lighting infrastructure can be expected to have cycled through to new, LED-specific designs.

For the reasons listed, a case can be made that retrofitting existing lighting fixtures provides a clear and effective benefit to the end-user, while reducing extensive capital costs at the budding stages of the LED development movement.

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Software predicts performance of phosphor down-converted white LED designs

Predictive modeling benefits from sophisticated algorithms and accurately measured data inputs, writes **CHAO-HSI TSAO**, **EDWARD FRENIERE** and **LINDA SMITH.**

The use of white LEDs for solid-state lighting to address applications in the automotive, architectural and general illumination markets is just emerging. LEDs promise greater energy efficiency and lower maintenance costs. However, there is a significant amount of design and cost optimization to be done while companies continue to improve semiconductor manufacturing processes and begin to apply more efficient and better color rendering luminescent materials such as phosphor and quantum dot nanomaterials.

In the last decade, accurate and predictive opto-mechanical software modeling has enabled adherence to performance, consistency, cost and aesthetic criteria without the cost and time associated with iterative hardware prototyping. More sophisticated models that include simulation of optical phenomenon, such as luminescence, promise to yield designs that are more predictive — giving design engineers and materials scientists more control over the design process to quickly reach optimum performance, manufacturability and cost criteria.

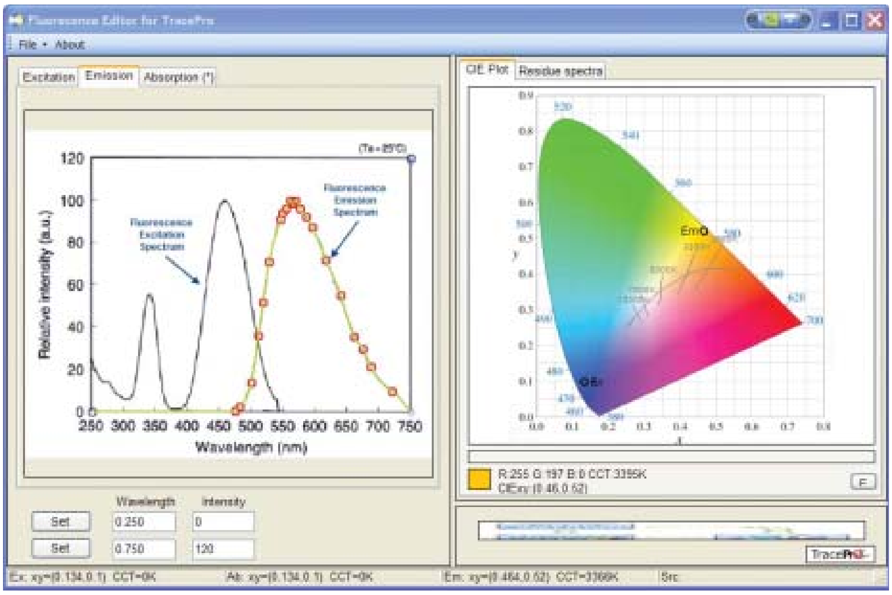

FIG. 1. Relative emission spectrum of YAG:Ce mapped to chromaticity coordinates.

White LED designs

There are generally two types of white LED design forms:

1) luminescent materials including phosphors or quantum dots mounted on an LED and
2) three LEDs of primary colors combined.

The TracePro Fluorescence Property Editor Utility was developed to facilitate selection of the phosphor formulation and excitation LED in design form 1) above. The earliest and most common commercially available design of this form is a blue LED chip exciting a yellow YAG:Ce phosphor. Other designs of this type include red and green phosphors applied to a blue LED, a combination of two or more phosphors spanning blue to red applied to a UV or violet LED, and luminescent quantum dots applied to LEDs.

Performance criteria include luminous flux, relative spectral power distribution, angular intensity distribution and viewing angle. Color criteria include CIE chromaticity coordinates (x, y) and correlated color temperature (CCT). Used to specify white light, CCT is a comparison of chromaticity coordinates with that of a black body. It is the temperature that corresponds to the blackbody whose chromaticity is represented by the point where the iso-temperature line from the white LED source point intersects the black body curve. Representative CCT values for commercially available white LEDs are 4500-10,000 K for cool white, 3500-4500K for neutral white, and 2670-3500K for warm white.

Optimum phosphor downconversion

As a simple example, consider a YAG:Ce phosphor excited by a blue LED. The formulation of the specific down-converting phosphor materials and selection of the excitation LED may be modeled and analyzed for desired color criteria using software such as TracePro's Fluorescence Property Utility.

Most often, the optical properties of existing phosphor luminescent material formulations are proprietary. However, with the goal of discovering an optimum formulation for a particular application, the user can directly import specifications from a phosphor manufacturer's datasheet to the software as a

CHAO-HSI TSAO *is the general manager and* EDWARD FRENIERE *is the president of Lambda Research Corp. (www.lambdares.com), Littleton, MA, and* LINDA SMITH *is the principal of Ceres (www.cerescom.net), Needham, MA, USA.*

starting design point. Phosphor manufacturers specify relative excitation, absorption and emission spectra for the luminescent material. Figure 1 is representative imported data for a YAG:Ce phosphor [1].

The chromaticity coordinates of the phosphor material's emission, absorption and excitation energy are determined by its relative emission, absorption and excitation spectra. In this example, the emission of the YAG:Ce phosphor has chromaticity coordinates (xem, yem) of (0.464, 0.520).

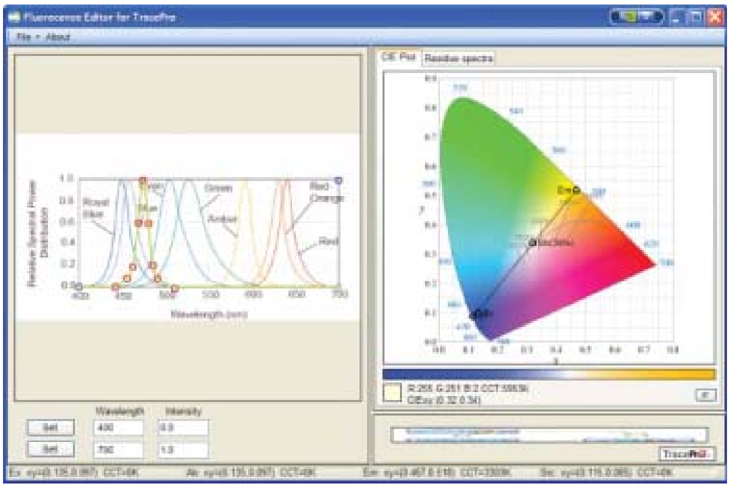

FIG. 2. Relative spectral power distribution of blue LED mapped to chromaticity coordinates, resulting in a mix of white light.

The chromaticity coordinates of the excitation source are determined by the excitation LED's relative spectral power distribution. Similarly, this data can be retrieved from the LED manufacturer. Figure 2 is an example that includes a blue LED as the excitation source where (xsource, ysource) = (0.115, 0.085).

White light may result when the blue excitation energy mixes with the yellow luminescence of the phosphor. It is dependent on the chromaticity coordinates of each as well as the conversion efficiency of the phosphor. The straight line between (xsource, ysource) and (xem, yem) represents the locus of points that result from mixing the blue excitation source energy with the yellow luminescence of the phosphor with different conversion efficiencies. The color bar below the CIE plot graphically displays the color along the straight line between (xsource, ysource) and (xem, yem). In Fig. 2, the CCT of the resulting white light with 61% conversion efficiency is shown on the CIE plot at the point, "Mix (39%)". In Fig.3, a conversion efficiency of 61% yields a cool white with CCT of 6136K and chromaticity of (0.319, 0.338).

Predictive white LED modeling

A white LED may be modeled in software and its adherence to design criteria may be analyzed. The opto-mechanical model is created by importing the 3-D geometry from mechanical CAD files or by directly creating the geometry in TracePro. The user can model the complete packaged LED by creating or importing the geometry for the LED cup, LED lens, and LED die and then applying optical material and surface properties to the geometry. For higher system-level modeling of systems including luminaires and displays, the user can simply incorporate additional optics and mechanics to the packaged LED models.

An optimized phosphor formulation, like that created above, may be directly exported to the opto-mechanical model. The parameters specified for optimizing phosphor formulation above are directly exported to the opto-mechanical model from the TracePro utility. In Fig. 4, the YAG:Ce phosphor in epoxy material is further characterized by its quantum efficiency of 0.921, peak molar extinction coefficient and molar concentration. Its bulk scatter properties are characterized by wavelength dependent scatter coefficients, anisotropy and its bulk absorption coefficient.

Additional material properties of the phosphor formulation may be incorporated in the model for more accurate simulation. The designer is able to include temperature dependent data for all properties and bulk scatter characteristics for the epoxy and phosphor formulation in the model. The ray trace of this model in TracePro then simulates the phosphor formulation's luminescence effects alongside the absorption, reflection, transmission, and scatter effects of the phosphor formulation and other components in the model. The accurate simulation of scatter and luminescence is particularly useful in remote phosphor down-conversion designs where backscattered light is extracted from the phosphor layer.

In the simple design form above, the excitation source, a blue LED, is characterized by its relative spectral power distribution and angular intensity distribution. In Fig. 5, using TracePro's Surface Source Utility, spectral and angular excitation LED characteristics from manufacturers' binned data are quickly and accurately exported and applied to the excitation LED

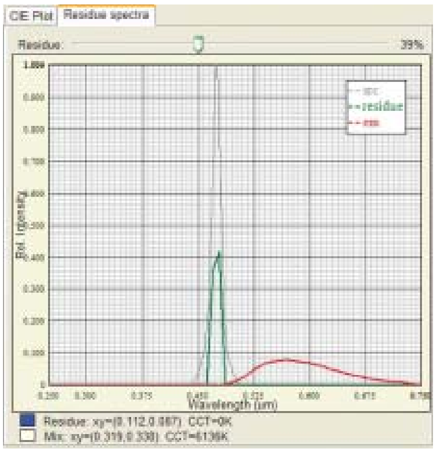

FIG. 3. White light resulting from 39% residual excitation energy.

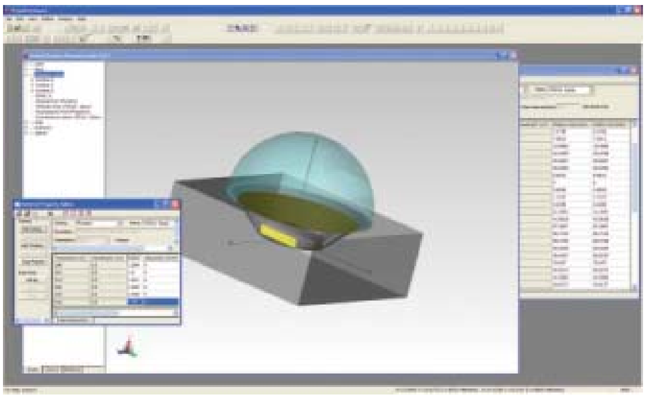

FIG. 4. Remote phosphor white LED model.

chip surface in the white LED model.

The blue LED excitation and yellow luminescence rays are then propagated through the 3-D model with portions of the flux of each ray allocated for absorption, specular reflection and transmission, luminescence and scatter. From the ray traced model, it is possible to analyze lumens exiting, absorbing and incident at the component and system levels, as well as candela distributions, optical efficiency, luminance and radiance metrics.

Luminescence simulation

To simulate luminescence, TracePro traces rays from the LED excitation source to the phosphor. It calculates excitation efficiency, bulk absorption, path length, absorbance and absorption at the phosphor material. The flux in each ray is spectrally weighted as the area ratio of the emission curve. The ratio is the integral under emission curve within the spectral band divided by the integral under the entire emission curve. The resulting emission rays are then traced throughout the LED model.

Discrepancies between phosphor down-conversion white LED models and experimental data will arise if luminescence simulations do not account accurately for path length-related absorbance and absorption, and the phosphor's particle size and particle density. The models described herein account for particle size and density in their excitation and emission spectra and for particle density in molar concentration. Given these inputs, algorithms in the software calculate path length-dependent absorbance and absorption. The measured bulk scatter property of the phosphor formulation that is integrated into the model also accounts for the phosphor's particle size and density.

Analysis

From the white LED model, it is possible to analyze luminous flux, relative spectral power distribution, angular intensity distribution

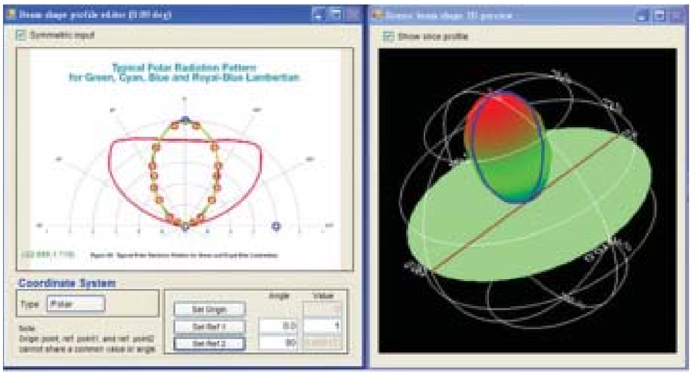

FIG. 5. Relative angular polar radiation pattern of blue LED source.

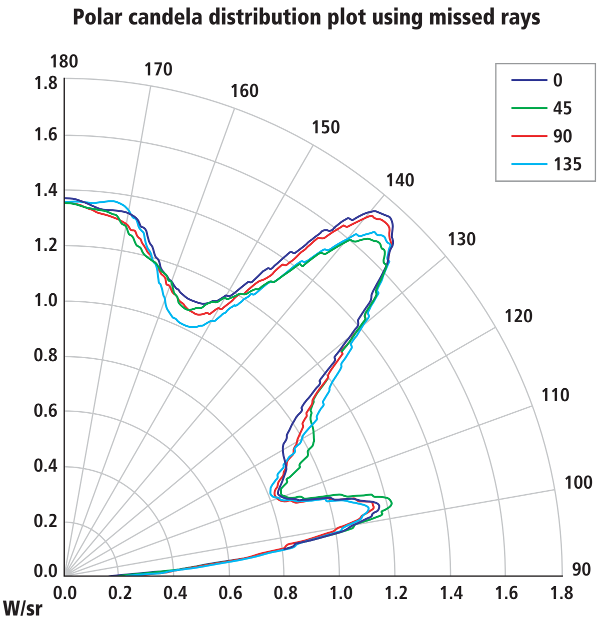

FIG. 6. Polar candela distribution plot of a blue chip:YAG white LED.

and viewing angle at a defined plane in the model. It also possible to analyze color criteria includes CIE chromaticity coordinates (x, y) and the CCT at any defined plane in the model. In Fig. 6, TracePro's Candela plot displays the luminous intensity or flux per solid angle.

Summary

Opto-mechanical Monte Carlo ray-trace simulation has been instrumental in the continuous improvements in efficiency, flux, maintenance and cost of white LEDs. How closely the software model predicts the actual device, however, remains dependent on the validity, accuracy and precision of the assumptions and optical property values attributed to each component in the system. For this reason, it is critical that the design software's user interface calls for accurately measured data inputs that are readily available to the designer.

Furthermore, in the case of the phosphor down-conversion white LED design forms, accuracy of results is also dependent on the fundamental algorithms used to simulate luminescence. More sophisticated simulation algorithms, combined with the capability to include accurately measured data inputs, give engineers and materials scientists more control over the design process to quickly reach best performance and lowest cost.

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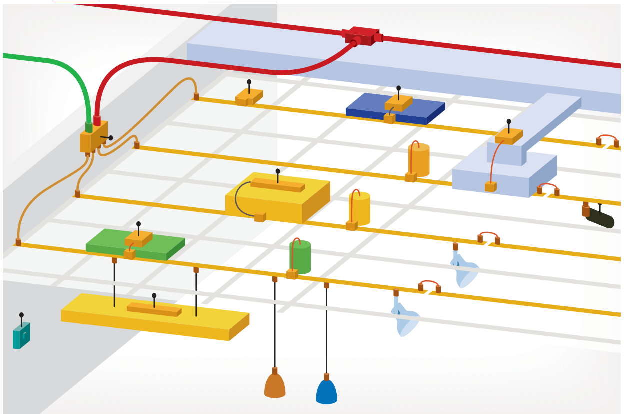
DC power distribution favors LED lighting

A low-voltage DC power standard could accelerate the conversion to LED lighting and create an enabling infrastructure for the workplace, write **BRIAN PATTERSON** and **PAULA ZIEGENBEIN**.



Schematic of a typical ceiling-based plug-and-play DC system. Picture courtesy of Armstrong World Industries and the EMerge Alliance Corp.

Many opportunities to save energy exist in the commercial building environment. Besides the offer of high efficacy, extended operating life and reduced maintenance, significantly reduced power consumption favors the eventual conversion of most lighting uses to solid-state sources, most particularly LEDs. To underscore this contention, after three years of relatively slow growth, the market use of LEDs has virtually exploded into double-digit growth in the past two years, particularly in fixed position applications like architectural lighting. The U.S. Department of Energy estimates that if LEDs become standard technology in indoor white-light niche market applications, 108 TWh of electricity could be saved per year, which is equivalent to 1.1% of total annual primary energy consumption and 13% of electrical energy consumption for lighting in the U.S. in 2007 [1].

However, one of the subtle obstacles facing LEDs, despite their otherwise compelling benefits, is that driver circuits for these devices must include power conversion capability to transform alternating-current (AC) branch distribution voltages (typically 277 V AC) to low-voltage direct-current (DC) power. While this process is fairly simple, it adds cost and can reduce the otherwise extraordinary power conversion efficiency of the LEDs themselves. It is like putting a brick wall in front of each device or light engine. Given today's typical building AC power distribution infrastructure, there is not much choice.

Of course, LEDs are not the first devices to run into this brick wall; all digital devices used in commercial buildings have the same issue – they are DC devices trying to exist in an AC environment. This problem includes computers, printers, cell phone chargers and assorted other personal use devices, as well as basic building controls, sensors, HVAC actuators, security systems and A/V systems. It is the latter part of this list that increasingly has become a larger portion of the fixed building infrastructure's use of power. Even state-of-the-art high efficiency fluorescent lighting systems take an efficiency hit because all electronic ballasts have a front end that converts AC input voltage to DC voltage. Electronic ballasts require DC voltage to efficiently drive fluorescent lamps at high frequency as well as to facilitate dimming, programmed starts and assorted other digitally managed tasks. Typical AC to DC conversion efficiencies range between 85% and 92%.

Power generation dilemma

The situation is not much different on the power generation side when site-based photovoltaic (solar), wind or other alternative generation is put into play. The native DC power generated by these increasingly efficient sources must be converted and synchronized with the utility-based AC power – meaning it typically is converted to 60Hz AC power. This comes at a higher initial investment cost for inverters, isolation, controls and noise filters, and a significant operating efficiency loss.

Making matters worse is the sometimes necessary use of a UPS battery-based backup system, which nearly doubles the initial loss, as DC power is converted to AC two times before making contact with the devices. To put this in perspective, because of accumulated conversion losses, a typical device in a building data center will only see half the power that was first measured and paid for at the utility power meter. This statistic does not even take into account any power used in cooling to compensate for any waste heat that can escape back into the occupied environment.

Society has been headed for a digital, DC-powered world at break-neck speed, while powered by an analog, AC-powered infrastructure that has not changed much in more than 100 years. And if you're not yet convinced, look at the statistics concerning the use of external power supplies [2].

In 2008 alone, 3.2 billion external power supplies will be manufactured worldwide. Also in 2008, 737 million external power supplies will be shipped to the U.S. and 434 million external power supplies will be retired in the U.S. alone. Only 12.6% of them will be recycled, resulting in 379 million external power supplies going into landfills.

BRIAN PATTERSON *is chairman of the EMerge Alliance (www.emergealliance.org) and GM, Business Development, Armstrong World Industries.* PAULA ZIEGENBEIN *is an application marketing manager with Osram Sylvania.*

These statistics do not include transformers inside ballasts and other internal power conversion devices. A conservative estimate would easily double the numbers if it counted all the AC to DC power conversions made each year, and added a double-digit compound average annual growth rate on top of that figure.

Adding a hybrid distribution layer

One solution to this dilemma, however, particularly favors the use of solid-state devices like LED light engines and lighting fixtures. Taking the form of a hybrid distribution layer of low-voltage (typically 24 V DC) power, it does not replace AC in a building, but complements it. After all, there are still some high-current loads that favor the use of AC power. The goal is to efficiently aggregate or eliminate multiple AC to DC conversions, thereby making devices simpler, safer and more flexible in use.

Why add DC? Two reasons:

Efficiency: Both alternative power generation and device consumption becomes more efficient with the consolidation or elimination of poor and highly fractionated power conversion.

Cost: More and more devices, like LEDs, are native users of DC power, and therefore can be easier to build and smaller when directly connected to DC power.

Why low-voltage? Two reasons:

Safety: Low-voltage power allows use of greatly simplified and less expensive class-2 wiring [3] and device protection, greatly reduces spark and fire hazards and eliminates shock/startle hazards.

Flexibility: Low-voltage power allows for 'hot-swap' plug-and-play connectivity that essentially can be embedded into existing building structure and elements, i.e. suspended ceiling grid, modular furniture, etc.

A typical ceiling-based plug-and-play DC system might look like the figure on p. 43.

Safety, flexibility, efficiency, and cost

Couple these basic benefits with the enormous capability offered by either digital RF or power line carrier (PLC) device controls, and the result is a system with the promise to deliver near-wireless capability all around (power and signal), eliminating the need for battery-powered switches, sensors and controls.

By providing convenient direct access to safe power (low-voltage, DC), such a system could:

1. Make it easier and less expensive to install lighting fixtures, sensors and other devices and simpler to repurpose and reconfigure future renovations without building or device re-wiring so buildings can resume operation sooner.
2. Help dramatically reduce technology upgrade costs for new technologies such as LED lighting, while reducing energy consumption via state-of-the-art device control and digitally integrated load and source management that can enable higher resolution control, metering and demand response
3. Promote sustainability with simpler system devices that have fewer materials without AC to DC conversion components and through use and reuse of system devices with interoperable plug-and-play mobility and simplicity.
4. Facilitate the direct connection and efficient use of energy from solar, wind, or other native DC alternative energy sources.
5. Allow facility technicians to quickly and safely move or re-install lighting fixtures and other low-voltage devices without the need to shut down branch power lines or otherwise significantly interrupt area occupants.

New commercial DC power standard

In a move aimed at addressing existing problems and increasing the flexibility, efficiency and sustainability of commercial buildings, a group of visionary companies recently announced in November 2008 the creation of an organization called the EMerge Alliance™. The Alliance is leading the creation and deployment of a new power, control and device-level technology standard for commercial interiors, developed around the use of safe, low-voltage DC power.

Founding members of the Alliance at the Governing level include Armstrong World Industries, Johnson Controls, Nextek Power Systems, Osram Sylvania and Wave. Having worked behind the scenes on this concept for the last several years, the alliance officially launched in November 2008 and currently has council and membership representing over 25 well-known companies, agencies and industry experts in the following fields: architecture/design; electrical and mechanical engineering; sustainability consultants; energy providers; building owners/developers; government; code and industry groups; product manufacturers in lighting, power supplies, electrical systems, cabling, HVAC sensors and controls; and A/V and security, building automation, and interior systems (ceilings, walls, and furniture).

Membership in the alliance is open, with tiered rights and privileges. Representation is given at the organization level with one vote per organization, depending upon membership type. The alliance hopes to draw from a broad and deep pool of industry leaders involved in the design, construction and management of commercial buildings to create an enabling infrastructure that prepares the workplace for the future of DC power.

A step in the right direction

The central features of the proposed EMerge standard include the selective and scaleable distribution of low-voltage DC power within common infrastructures already present in commercial interiors, as well as improvements in the optional use of on-site alternative energy through providing a means of direct and more efficient connection between these new energy sources and interior electrical loads, such as lighting and controls.

The belief is that this new commercial technology standard will also provide a platform for innovation to create even more energy efficient and individually controllable devices for the future, including new forms of LED or other solid-state general lighting devices. In essence, the alliance is focused on the nexus of today's top priorities for building owners – energy savings and adaptability. Sustainability-minded building owners are looking for leading-edge technologies that can provide a faster return on their investment in clean energy. This new standard is a deliberate and empowering step in that direction.

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Novel lighting technologies offer a future alternative to LEDs

A broad and exciting diversity of emerging illumination technologies is a natural and healthy response to current lighting challenges, writes **HASSAUN JONES-BEY**.

No one disputes the obviously bright future of LED technology in the emerging 21st century marketplace for general illumination. The brightness of that future, however, can blind the unwary to the broader context of competing and complementary lighting technologies emerging to share the same future.

"We get a lot of inquiries about the coming of LEDs as the lighting savior of energy efficiency and brilliance," quipped Kelly Cunningham, outreach coordinator of the California Lighting Technology Center (CLTC; Davis, CA). "One of the things we usually tell people right away is that we are a research lab. We are technology agnostic or neutral and position ourselves to look at a broad technology spectrum."

The broad spectrum at the CLTC includes daylighting, luminaire technologies, compact and electrodeless fluorescents, LEDs, metal halides and other emerging technologies. CLTC advisors find a combination of technologies most beneficial in many scenarios. They also increasingly combine lighting technologies with control technologies to, for instance, dim the light in a parking garage by 50% when no occupants are detected.

The technology agnostic approach is not unique to the CLTC or even to research labs for that matter, as indicated by discussions with representatives of commercial, university and government organizations concerned with lighting technology. So although diode fundamentalists may cry "heresy," most folks actually view the broad and exciting diversity of emerging illumination technologies as a natural and healthy response to current illumination challenges.

Replacing the light bulb

The electron stimulated luminescence (ESL) light bulb under development at Vu1 (Seattle, WA) looks like and is actually made from the same glass that makes incandescent bulbs (see Fig. 1). But instead of a tungsten filament, the ESL bulb contains an electron source that projects a uniformly distributed pattern of accelerated electrons onto a luminescent coating on the inside of the bulb. A plastic sleeve in the neck of the bulb houses electronics that drive the system.

FIG. 1. Similar appearance, different technology: the Vu1 bulb uses electron stimulated luminescence instead of a tungsten filament.

Ron Davis, chief marketing officer at Vu1, expects to enter the market in a matter of months, initially with replacements for the conventional, incandescent R30 65-W reflector bulbs, typically installed in home ceilings. Those 65-W bulbs produce on average 600 to 650 lumens and the ESL bulb will match that luminance at only 19 W energy usage, shooting to eventually get below 15 W through optimization of the bulb electronics, Davis said. He expects the product to be price- and lifetime-competitive with the 65-W reflector-bulb-shaped $12-$17 compact fluorescents, but with incandescent light qualities that CFLs lack, such as a CRI of 93, a color temperature of 2800K and instant-on, fully dimmable operation from 100 to 0%.

ESL bulbs also generate only half as much heat as incandescent bulbs, and unlike compact fluorescents, are non-toxic enough to meet Title 24 California standards for disposal in recycling bins. Currently Vu1 is ramping up manufacturing capabilities to move from the current prototype bulbs to the first actual mass producible versions of their bulb. The company completed a $5 million financing round in December 2008.

Group IV Semiconductor (Ottawa, Ontario, Canada) is targeting the traditional light bulb market also, but with filaments made of light-emitting, doped silicon oxide thin films that would essentially replace the tungsten in an incandescent bulb. Stephen Naor, CEO of Group IV, projects that, in volume, the costs of these light-emitting elements will be low enough to enable manufacture and sale of high quality 1200 lumen (100W incandescent equivalent) light bulbs for $4 a piece.

The thin-film, doped silicon oxide emitters

HASSAUN JONES-BEY *(hassaun@gmail.com) is a technology writer based in California.*

currently sit on silicon wafers and draw their power directly from AC line voltages. Group IV is staffed largely by former Nortel and JDS Uniphase employees who have experience developing lasers, also based on doped oxides, Naor said. The Group IV technology generates red, green and blue light independently on the same chip, which mixes spontaneously on leaving the chip to produce white light.

The company expects to field a product prototype in late 2010. In the meantime, they've established a joint development relationship with Applied Materials (Santa Clara, CA) to adapt a standard semiconductor-industry production tool for the fine process control required to fabricate devices that will meet Group IV's performance targets.

Interestingly, since Group IV technology is based on a thin film, it might also provide area lighting similar to OLED technology, Naor said. The company's focus at present, however, is on light bulbs.

Complementary technology

The naturally distributed light from OLEDs offers a complementary lighting technology, not just to point-source LEDs but to the vast majority of existing light sources as well, potentially opening up numerous applications such as light partitions, mood lighting and canopies of light, as well as windows, skylights and other daytime lighting structures that could become light sources themselves after the sun goes down.

OLEDs are still very much at the R&D stage, however. Commercially competitive brightness levels have already been achieved in the laboratory and good progress is being made in terms of general lighting requirements. But the development of manufacturing processes still present major hurdles. To develop cost-effective processes for volume production of organic LEDs, the European Union is funding the CombOLED project (www.comboled-project.eu), coordinated by Osram Opto Semiconductors (Regensburg, Germany), as well as OLED100.eu and other projects.

In the U.S., about 40% of the $15 to $20 million annual Department of Energy (DOE) funding for solid-state lighting projects goes for work on OLEDs and the rest goes for work

FIG. 2. Eden Park Illumination has developed a microplasma nano-technology for area lighting. (Courtesy: Calello Photography)

FIGURE 3. Pemco Lighting Products has developed a prototype fixture for street lighting using Luxim's LIFI(R) STA-40-01 source (inset).

on LEDs, according to James Brodrick, lighting programs manager at the DOE. The money is usually spread over between 40 and 60 companies, working on projects of about three years in duration.

As with LEDs, however, competitive technologies and products are being developed by folks who hope to deliver the general illumination promise of OLEDs before OLEDs can. For example, Eden Park Illumination (Somerset, NJ) has developed a microplasma nano-technology for area lighting (see Fig. 2). An anodized aluminum mesh creates the thin dielectric barrier structure for a two-dimensional array of 500-micron-diameter cavities. These are filled with non-mercury-based emissive material and sandwiched between an aluminum electrode layer at the bottom and a transparent window at the top.

Application of an electric field between the bottom electrode layer and aluminum electrodes in the dielectric barrier layer creates a microplasma light source in each microcavity with color determined by the emissive materials and also by phosphor coatings (if used to produce white light for instance) on the transparent window layer.

"These flat light sources give a homogenous white light output with brightness on

the order of 13,000 candelas/m2, even in early demos," said CEO Philip Warner. "And we expect to get considerably brighter. In terms of efficiency, we're looking at 30 lm/W right now with an aggressive roadmap towards 100 lm/W." The company is now in the industrialization phase, which, by the end of 2010, is expected to result in a low-cost and environmentally recyclable product, manufactured on the same type of equipment that is used to create plasma display panels.

The first thing to go

Induction lighting, provided by Osram and several other lighting companies, uses various methods (magnetic coils outside of the fluorescent tube in Osram's product), instead of electrodes within the tube, to directly couple energy through the glass enclosure and into the mercury vapor. Since electrodes are often the first things to go in fluorescent bulbs, induction lighting achieves lifetimes up to 100,000 hours, while offering luminous efficiencies in excess of 70 lm/W. CLTC often recommends them for large industrial or institutional settings, such as parking garages and prisons.

Electrodeless plasma lighting, which has recently begun to emerge onto the market is similar to induction lighting in that no electrodes are used, but the energy is transmitted using radiofrequency radiation, rather than magnetic induction. One product based on this technology is already offering almost twice the luminous efficiency of traditional induction lighting at brightness levels suitable for an entirely different range of applications now served primarily by 400W metal halide lamps. The bulb in these plasma devices contains a gas, which is transformed into plasma by radio-frequency (RF) energy, and metal halide salts that are vaporized by the gas plasma to give off white light. The actual frequency of the RF power source can vary, depending on the manufacturer, from hundreds of MHz in the case of Luxim (Sunnyvale, CA) to microwave in the case of Ceravision (Milton Keynes, England).

Luxim's flagship product, the LIFI STA 40, was launched last November for sale to fixture manufacturers, said Julian Carey, VP of marketing (see Fig. 3). The product provides about 20,000 lumens and targets applications such as street, façade and entertainment lighting, and Luxim is ramping up production. The technology for the company's solid-state 400 and 800 MHz RF amplifier system comes from the cellular communications industry.

The 20,000 lumen LIFI light source operates at 275 W to provide the same illumination as the 460-W metal halide bulb it is replacing and offers a directional source, as do LEDs, providing efficiencies within fixture designs on the order of 90%. While pricing varies with volume, the LIFI product costs roughly three times more at initial purchase than the metal halide competition, but pays back the difference in about 3 years, Carey said.

Luxim is not considering residential lighting at this time. Ceravision, however, with electrodeless plasma technology based on microwave energy, is (according to its web site) developing product solutions for a range of potential markets, including residential and automotive.

LINKS

Ceravision: www.ceravision.com
CLTC: cltc.ucdavis.edu
Eden Park Illumination: www.edenpark.com
Group IV Semiconductor: www.groupivsemi.com
Luxim: www.luxim.com
Vu1 Corporation: www.Vu1.com
OLEDs: www.ledsmagazine.com/OLEDs

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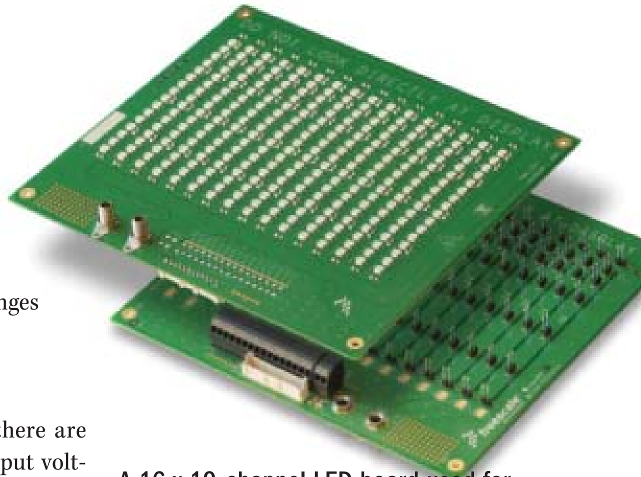
Driver IC design ensures optimum performance of LED backlighting

LED backlight drivers are the "wizards behind the curtain" that ensure a display's visual performance will remain as specified regardless of the operating conditions, says **MICHAEL JENNINGS**.



A 16 x 10-channel LED board used for evaluating LED backlight driver ICs.

LEDs had their first backlighting successes in small, battery-powered devices, such as mobile phone handsets, thanks to their brightness and high efficiency. Now these and other performance characteristics are likely to make them successful for backlighting computer displays and televisions as well, where they may ultimately replace cold cathode fluorescent lamps (CCFLs) that currently serve this purpose.

The potential advantages LEDs have over CCFLs are formidable: they consume less power, last about five times longer, are more efficient, can reduce display thickness, are dimmable in fine steps, use low-voltage drivers and do not contain mercury and other hazardous substances as do CCFLs. However, it's important to remember that behind every successful LED-enabled backlighting application are driver ICs that optimize the performance of the LEDs, protect them from a wide range of potentially damaging scenarios and ensure consistent visual quality over the life of the display.

Understanding the many functions performed by driver ICs and how they affect display performance enables designers to potentially reduce subsystem size and cost by closely matching the driver to its application.

Although CCFLs age faster and have a shorter operating life than LEDs, the effects of aging, in which LED characteristics change over time, can still be a major challenge for LED backlighting designers. Whereas aging is not a primary issue in applications using only white LEDs, it can be a significant problem with RGB (red, green, blue) LEDs, since they age at different rates. To help maintain display uniformity, which can also be affected by differing materials and manufacturing variations, the backlighting driver IC compensates for LED changes that develop over time.

Voltage and current specs

Among backlighting driver ICs, there are wide variations in the range of input voltages they can accept. Those with a narrow voltage range will be limited in the applications for which they are suited and may be unable to withstand the broad input voltage swings and other transient conditions that occur in service.

The driver's maximum output voltage is also a key parameter because the number of LEDs a driver can support is determined by its maximum output voltage as well as the number of channels. Driving more LEDs in series can reduce cost and require fewer channels, but since each LED can produce a voltage drop of 1 V to 4 V, the driver IC must have sufficient output to compensate by handling the voltage drop that occurs among all the LEDs in the array.

The maximum current a driver can deliver per channel is important. This current must be matched to the requirements of each design, with emphasis on the employed LED type. For example, LEDs specified in most portable applications draw 20 to 30 mA, while monitors and TVs typically use LEDs that consume 40 to 120 mA. Some applications, however, use LEDs that draw up to 350 mA.

The number of channels offered by today's driver ICs ranges from just a few to 16 or more. A 16-channel driver with lower output may support only five LEDs in series (80 LEDs), while a 10-channel driver with higher output voltage may drive up to 16 LEDs in series (160 LEDs). The goal in each case is to satisfy the needs of the backlighting system using as few drivers as possible in order to reduce cost and complexity. For both output voltage and output current, higher values are generally better, but it is important to keep in mind that drivers with high voltage and high current cost more than their less powerful siblings.

Maintaining system performance by using driver ICs to control and compensate variations in LED characteristics becomes a more daunting task as display sizes increase. For example, the number of LEDs a panel employs can vary from 30 in a 10-inch computer display to more than 1,000 in a large TV. As the light output of these LEDs is dependant on the current, it is very important that the current for all LEDs be tightly matched to compensate for device-to-device variations. Failure to minimize these variations will cause percep-

MICHAEL JENNINGS *is market segment manager with the Analog, Mixed Signal and Power Division of Freescale Semiconductor (www.freescale.com), based in Tempe, Arizona, USA.*

tible differences in lighting uniformity across the display. The driver's ability to maintain a tight tolerance over current variation is dictated by its current-matching specification. A good figure of merit is +/-2% or better for notebook computer and monitor applications and +/-1% for TVs.

Pulse-width modulation considerations

Some LED properties vary with LED current, so it is desirable to perform the dimming function using a pulse width modulation (PWM) control scheme that maintains a constant current in the "on" state. Some notebook computers use direct PWM control while other systems use an external PWM control signal. Choosing a driver with an onboard PWM generator simplifies overall system design. Some driver ICs have internal PWM generators but also support external ones.

Another driver IC consideration is avoiding audible noise that can arise when backlighting applications employ PWM frequencies below 1 kHz and use low-cost ceramic capacitors (most of today's systems use 200 Hz to 1 kHz). The noise is often caused by slower drivers that do not provide a good range at higher frequencies. This problem can be avoided by choosing a device like Freescale's MC34844 10-channel LED backlight driver that supports a wide range of PWM frequencies, including those above the audible range. Some drivers can also synchronize themselves with other devices or an external source to remove certain visual artifacts as well as the possibility of noise caused by beat frequencies and harmonics resulting from device interaction.

The granularity, or precision, with which a driver can dim an LED depends on its number of bits and its speed. The greater the number of bits, the finer the increments into which the PWM signal can be "sliced," which makes dimming control more precise. For example, the MC34844 has eight bits, which allows LEDs to be dimmed to any of 256 levels and makes it suitable for notebook computers and monitors.

To ensure a precise square-wave output pulse, even with very low duty cycles, and tighter current matching and a more linear dimming range, transition time between low and high PWM states should be short (on the order of 50 ns). Drivers that provide linear dimming down to one least significant bit (LSB) at a high PWM rate, such as 25 kHz, provide the best performance. However, transition time should not be too short because higher frequencies can cause ringing and other forms of electromagnetic interference. Speeds of about 50 ns satisfy this requirement and optimize efficiency.

A communications interface is desirable when the driver is employed in backlighting applications, but it's essential when the device has an on-board PWM generator. The most common interface is the inter-integrated circuit (I^2C) type. For systems requiring high-speed update, the low voltage differential signal (LVDS) scheme is becoming popular.

Boost converters

Drivers with integrated boost converters eliminate the need to implement this function externally. An integrated switch is preferred because it eliminates the potential for EMI caused by board interconnects, reduces the bill-of-materials, saves PCB board space, and removes the need for the designer to specify a transistor that is well matched to the driver. Boost frequencies vary widely and are sometimes programmable. Higher frequencies, such as 1.2 MHz, have the advantage of using smaller inductors and capacitors.

A dynamic headroom control scheme, also essential, measures the forward voltage of all LED strings connected to the boost converter and automatically adjusts the output voltage to the minimum value required to drive them. The result is less voltage drop across the linear drivers in the current mirrors and lower driver power dissipation, which increases overall efficiency.

If a driver IC has optical loop control, it provides the ability to use an optical sensor to compensate for LED temperature and aging variations. Optical sensors can also be used to adjust backlight brightness in response to changes in ambient conditions, such as dimming the display in dark environments. Thermal sensors may abe used to compensate for temperature-related effects.

One of the most important functions a driver IC can provide is the ability to protect both itself and the LEDs. Short and open protection for the LEDs allows backlighting to continue when an LED or LED string fails. Over-voltage, over-current, and over-temperature protection guard both the driver and the LEDs. Under-voltage lockout ensures that the driver does not operate outside of its specified range, which can lead to incorrect operation of the device.

In summary, a driver IC is a stabilizing force that ensures a system's visual performance will remain as specified under all operating conditions, allowing the LEDs to deliver superior image quality and efficiency.

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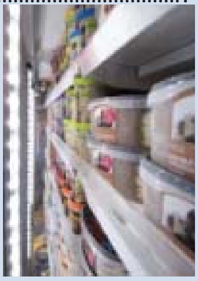
Nualight reduces M&S energy costs



Marks & Spencer, a leading UK-based food retailer, has used LED lighting from Nualight to help reduce the energy footprint of some of its stores. Nualight embedded its Vantium Porto LED luminaires into refrigerated display cabinets from SPG, replacing fluorescent case lighting that consumed 384W with LEDs consuming 174W. Positive customer reactions are another important advantage, as explained in the case study at www.ledsmagazine.com/features/6/1/5.

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last word

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tive for high-volume general lighting applications that will support a rich ecosystem of commercial off-the-shelf suppliers. Modules that provide standardised combinations of LEDs, drive and control electronics, heat-sinks and optics can help reduce the cost of many high-volume lighting applications and accelerate lighting manufacturers' time-to-money. We expect to see many developments in this arena in the coming months.

Every step that makes the design and development of solid-state lighting applications quicker and simpler will ease the culture of caution that affects LEDs in the mainstream lighting industry. Ultimately, every participant in the solid-state lighting value chain has their part to play in helping lighting industry decision-makers understand the benefits to their businesses and how this unstoppable migration will benefit their customers.

Traditionally, electronics distributors focus their customer service efforts on product designers and manufacturing engineers. That's not enough. We need to reach the decision-makers who will help steer lighting businesses to completely appreciate the risks and benefits of implementing solid-state lighting.

If I had to sum up what's required in one sentence, it would be that we must make LED lighting solutions simple — indeed, we have made this our mission. In time, the efforts I have described will produce a greater acceptance of LED technology, and this in turn will lead to the mass adoption of solid-state lighting. A concerted industry effort in this direction will deliver the continued growth that we all want to see. This could very well be the brightest light in a difficult economy.

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Reconfiguring LED distribution to meet the needs of lighting manufacturers

Driving LEDs into general lighting will require extended distribution models, says **JAMIE SINGERMAN**, worldwide corporate vice-president, **FUTURE LIGHTING SOLUTIONS**.

A well-established component distribution model has served the electronics industry for many years, supporting OEMs with technical information and engineering resources, as well as providing global logistics and inventory services that streamline the manufacturing process.

For over 40 years now, Future Electronics — the parent company of Future Lighting Solutions — has been at the forefront of electronics distribution. Helping the lighting industry bring LEDs into the mainstream, however, requires extending this model. Distributors must take additional measures such as investing in more in-depth technical and commercial support and enabling the proliferation of easy-to-use solutions in order to accelerate adoption.

The early adopters who developed the first LED-based lighting had to build new, custom-engineered light engines and luminaires from the ground up. They experimented with different combinations of LEDs, optics, and control electronics. The traditional strength of electronics component distributors — supplying and supporting a wide variety of components to systems designers — played well in this first phase of the industry's development.

I believe, though, that growth will plateau if we do not extend the model beyond service and supply. The mass adoption of LEDs, which we are all so eager to see, will come when LED-based light sources are the de-facto preferred and optimal solution for many applications.

The technological advances in the design and manufacture of LEDs, as well as complementary technology, have enabled us to get to where we are today. We still have a huge role to play in overcoming the last of the barriers to mass adoption.

The barriers that remain are of three kinds: technical, commercial and cultural:

1) Technically, a skills gap diminishes the ability of the lighting industry to implement LED-based luminaires quickly and easily. Accustomed to using the incandescent lamp as its light source, the industry lacks widespread familiarity with engineering concepts such as drive and control electronics, thermal management and optics.

2) For many years, luminaire manufacturers have worked with standards: for systems and light sources. While standards for solid-state lighting-based systems are being worked on, their absence has created a challenge to adoption for companies who are taking a wait-and-see approach. Yet, this is a market opportunity for first-movers!

3) Culturally, mainstream lighting companies are most at home in the incandescent world. Many aspects of solid-state lighting — how they cast light, how they are integrated into equipment, how long they last, how much they cost — are unfamiliar, and so it is not always obvious to lighting companies how to make decisions about investing in this new technology.

All of these barriers can be overcome in time. Indeed, many of the initiatives implemented or in development by Future Lighting Solutions already address them. While Future Lighting Solutions has some of the answers, it will be the creativity and determination of all the key players in the solid-state lighting industry that will lead to the eventual achievement of mass adoption.

In relation to the technical barriers to adoption, it is clear that distributors can do much to bridge the gap for lighting industry customers. In truth, this requires significant expertise in engineering. And this expertise, in many cases, can only be gained after a considerable amount of investment and time. Our engineers can help customers overcome technical implementation issues while they develop in-house expertise. Customers who leverage our Lighting Resource Centres in Montreal, Shenzhen and (in the near future) Europe will receive exactly this kind of much needed support.

We are also well positioned to develop tools to accelerate and simplify the design cycle for solid-state lighting applications. Every day we see the issues our customers are grappling with. In this regard, Future Lighting Solutions has developed unique tools that, for instance, simplify the processes of calculating the actual light output from any combination of LED, drive current, ambient temperature and heatsink, and calculating the expected lifetime of an LED system under the same conditions. Design automation provides the solution for easing the solid-state lighting development process.

Commercially, the environment is becoming more favourable for suppliers of off-the-shelf luminaire modules. Now, as never before, LEDs are a viable alterna- » page 54

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0.98" / 25mm
diameter

L-Dot Pico by eldoLED: 15 Watt, DMX-compatible RGBW LED driver/controller for 350mA – 700mA high-power LEDs in a 25mm diameter package – the ideal choice for in-fixture spot applications. Pico offers 15-bit resolution per channel allowing accurate dimming and colour mixing. Pico is available in a 1-, 2-, 3- and 4-channel version, all equipped with an NTC interface for robust thermal control.

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For North America please contact : eldoLED Inc. | NAsales@eldoLED.com or +1 408 451 9333 (San Jose, USA)
For other countries please contact : eldoLED B.V. | sales@eldoLED.com or +31 40 2054050 (Eindhoven, The Netherlands)