MAY/JUNE 2010

LEDs MAGAZINE

LEDsmagazine.com

TECHNOLOGY AND APPLICATIONS OF LIGHT EMITTING DIODES

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Replacement lamp updates P.14 & P.51

Reliability
Specifying luminaire lifetime P.25

Manufacturing
Reducing the cost of LED production P.61

Light+ Building

LED lights add sophistication

P.32


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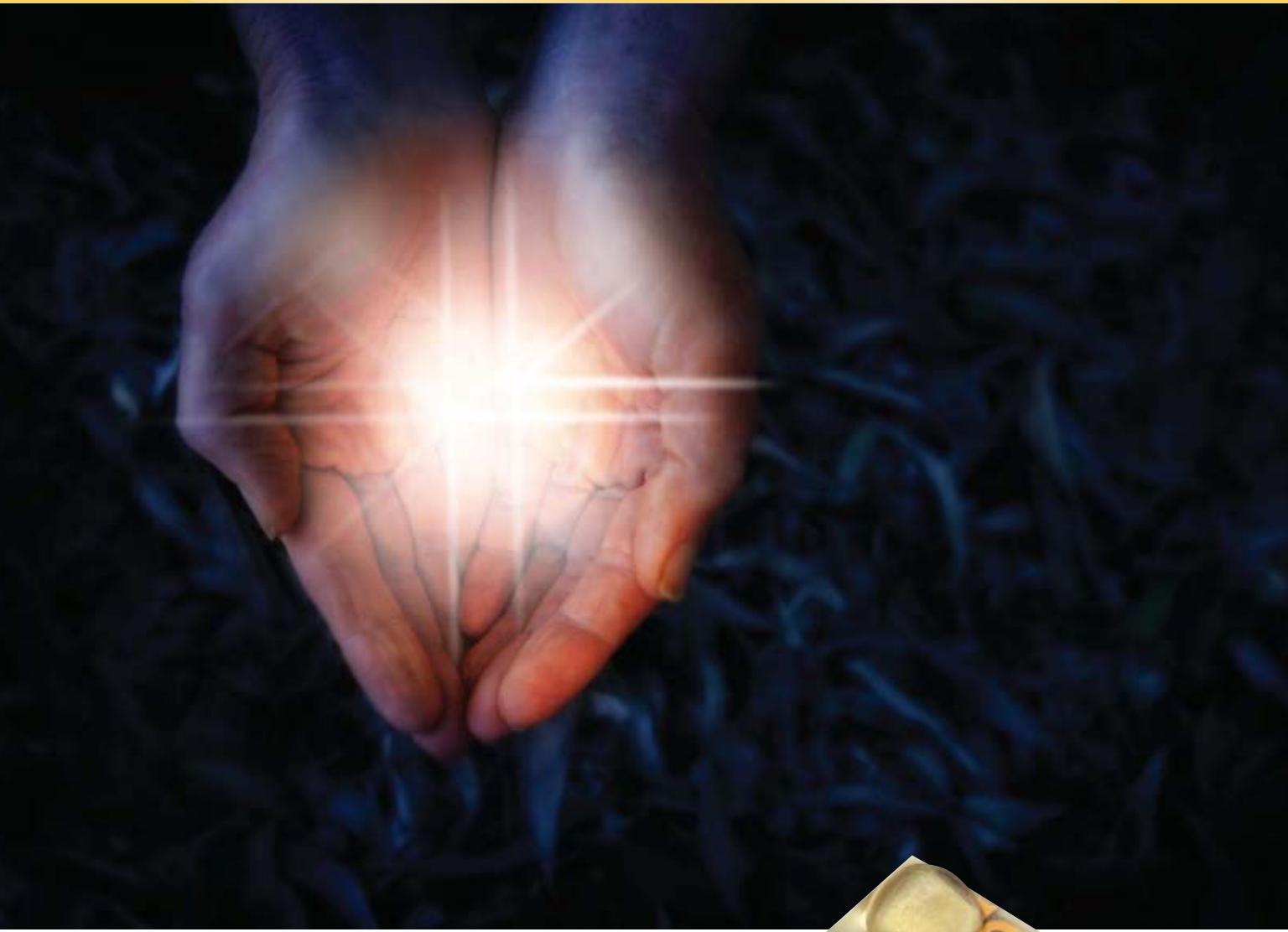

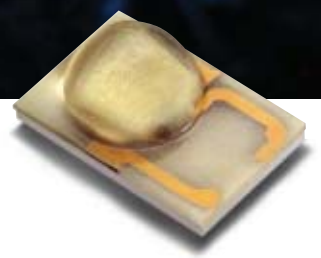

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ISSUE 35

may/june 2010

Cover Story

The Primopiano projector from iGuzzini, designed by Renzo Piano, exemplifies the sophisticated approach to LED lighting seen at the Light+Building tradeshow – see our article on p.32.

features

columns/departments

commentary

Vegas' brightest lights shined at Lightfair

Lightfair International (LFI) and Las Vegas are quite the combination. Take a city that loves bright lights and insert the brightest of new lighting technology in the form of LEDs. Excuse the pun, but I felt blinded by the light. It was hard to find a booth where LEDs – bright LEDs – weren't the focus. Exhibits covered LED sources all of the way through to the latest indoor and outdoor luminaires.

The adjacent booths from sister organizations Traxon and Osram Sylvania were a perfect example of the gamut of demos. Osram demonstrations ranged from LEDs and OLEDs to a prototype downlight luminaire that integrated speakers and supported wireless streaming of iPod music. The star of the Traxon booth was a transparent door-sized panel that had LEDs integrated within layers that comprised what could have passed for glass. Two of the sandwiched layers were obviously conductive, driving LEDs that could be seen clearly from either side of the panel.

Perhaps the biggest trend at LFI was the increased emphasis on LED retrofit lamps. Existing vendors of such products such as Lemnis introduced new models, and Japanese giants Sharp and Toshiba entered the market. Those Japanese companies have been major players in the Japanese lighting market and are now targeting a global market (see article on page 14 for more information on retrofit lamps).

Supporters of the EMerge Alliance were easy to spot around the show floor including at the aforementioned Osram booth. EMerge is pushing a low-voltage-DC, power-distribution scheme for use in commercial-building lighting (see www.ledsmagazine.com/products/22355). The Alliance claims that a single AC/DC power supply that powers multiple luminaires can boost efficiency 10 - 15% relative to LED luminaires that directly integrate an AC/DC power supply. Lunera Lighting (diffused panel fixtures) and Tyco (connectors) both had extensive EMerge demonstrations.

The outdoor lighting application stood out at LFI with a range of approaches to street, parking-garage, parking-lot, and area lighting. BetaLED and Cooper, for example, offer luminaires in which you can see the individual LEDs arrayed across the bottom surface of the luminaire. Outdoor LED newcomer Everbrite Lighting, conversely, showed a parking-garage light that hides the LEDs in the fixture and uses a unique reflector to deliver the desired light pattern.

The buzz around the street-light application is certainly attributable to the success cities are having in LED trials and the formation of the Municipal Solid-State Street Lighting Consortium in the US (see www.ledsmagazine.com/news/7/5/6). In his LFI keynote address, DOE Lighting Program Manager Jim Brodrick said, "We've got 70 to 80 cities already signed up." The Consortium will grow the segment enabling smaller municipalities to adopt LED technology.

I expected modules to make a bigger impact at LFI. Certainly Bridgelux and Molex got accolades for the Helieon module, winning an LFI Innovation Award (see www.ledsmagazine.com/news/7/5/8 or page 9). Toshiba did show a modular prototype, and I still expect a push in the modular area by many other companies, but clearly they didn't make it to LFI this year.

We will have a more extensive article on the LFI sessions and exhibits in our next issue. Meanwhile I need to rest my eyes, and remember next time not to look at the LEDs in the exhibits – or to don sunglasses before hitting the show floor.

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Webcasts

The Future of LED Control

ORIGINALLY BROADCAST: May 27, 2010

PRESENTERS: Amanda Beebe, Lutron
Russ MacAdam, Lutron

LED Lighting Testing: HAZLOC & EMC Certification

ORIGINALLY BROADCAST: March 30, 2010

PRESENTERS: David Schramm, Intertek
Lisa-Marie Martin, Intertek

Visit www.ledsmagazine.com/webcasts to access upcoming and archived presentations.

Web Exclusive Articles

The Daily Lightfair, sponsored by CRS Electronics

www.ledsmagazine.com/features/7/5

In May, Contributing Editor Brian Owen presented The Daily Lightfair, with news, views and opinions each day from the Lightfair International tradeshow in Las Vegas.

Featured Companies

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

CS Bright Corporation · Khatod Optoelectronic · Ligitek Electronics Co., Ltd. · Topco Enegry Saving Systems

ADVERTISERS index

FEATURED event

Strategies in Light Europe 2010

September 27-29, 2010
Frankfurt, Germany
A number of speakers have been announced for SIL Europe, with more to be added in due course: see www.ledsmagazine.com/features/7/5/6 for more details.

Keynote speakers (to date):

Martin Goetzeler, President & CEO, *OSRAM GmbH*

Jan Denneman, President, *European Lamp Companies Federation (ELC)*

Conference speakers (to date):

Roy Burton, Dialight

Dominik Wee, McKinsey & Company

Vrinda Bhandarkar, Strategies Unlimited

Wu Ling, Chinese SSL Alliance

Gordon Routledge, eldoLED

Andy Davies, GE Lighting

Peter Besting, CELMA & ELC

Stefan Gianordoli, Ledon Lighting

Martijn Dekker, Lemnis Lighting

Bob Kottritsch, Lynk Labs

Rudi Hechfellner, Philips Lumileds

Andreas Timinger, OEC AG

Markus Klein, OSRAM Opto

Mike Simpson, Philips

Uwe Hock, Sharp

Carl Rijsbrack, Barco

Tom van den Bussche, Bridgelux

Moritz Engl, OSRAM Opto

G.Q. (Kouchi) Zhang, Philips

Steffen Holtz, CELMA & ELC

The conference will also include two Workshops, one on Standards and one on Building the Perfect Luminaire.

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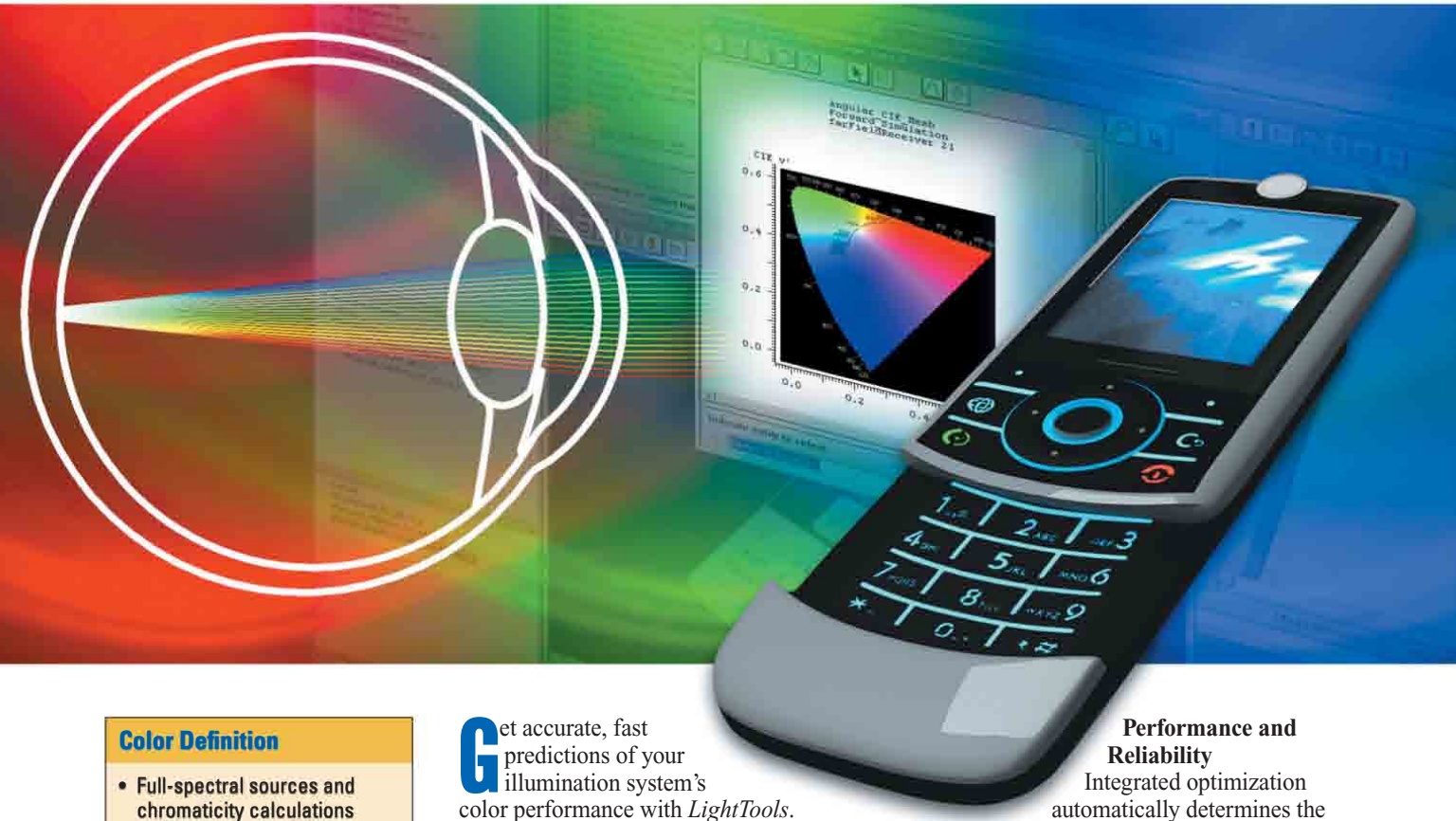

Color Definition

- Full-spectral sources and chromaticity calculations based on real colors using CIE coordinates
- Spectral-dependent materials, reflectors, and diffusers
- Color ray data, wavelength or tri-stimulus based
- Fully dispersive ray tracing
- Backward ray tracing for illuminance, intensity, and spatial and angular luminance calculations
- Wavelength-dependent bulk absorption, reflectance, and transmittance

Color Analysis

- Color meshes and points
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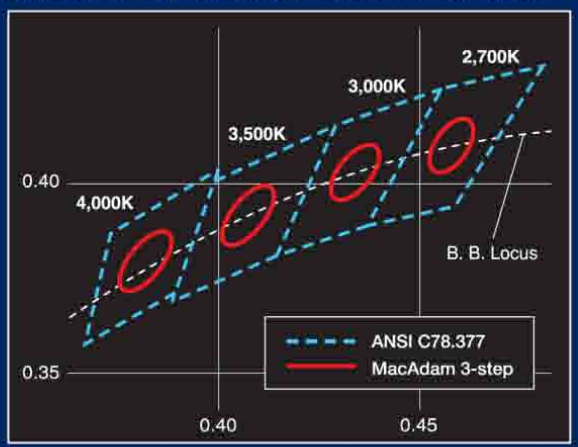

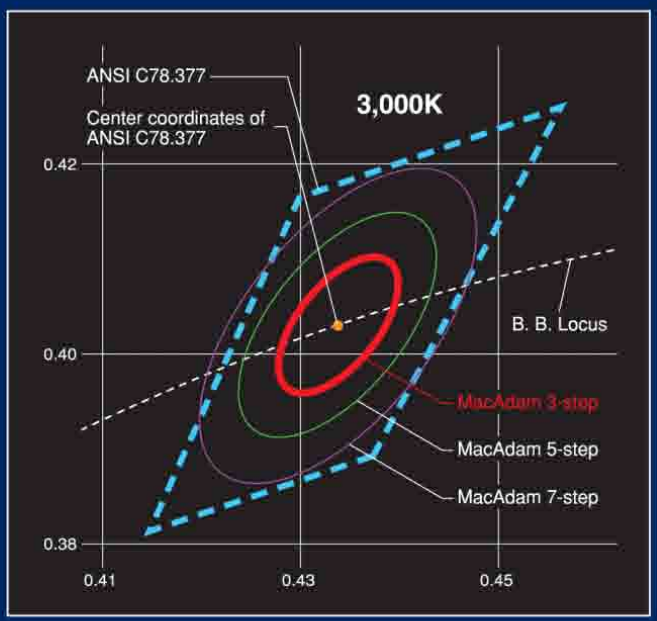

●Applicable packages

CL-L103 Series

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CL-L251 Series

4W/ 6W class

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CL-L233 Series

13W class

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Citizen Electronics efforts:

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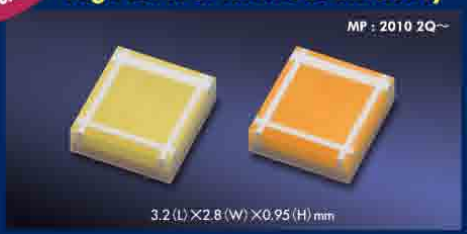

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news views

AWARDS

LFI presents Innovation Awards

The opening of the Lightfair International (LFI) tradeshow in Las Vegas on May 12 was marked by the LFI Innovation Awards to recognize innovative product design and technology. The awards program encompassed nearly 200 lighting-related products and designs introduced over the last 12 months or launched at LFI 2010. Each individual product was judged by an independent panel of renowned lighting professionals. LED-related winners of the most prestigious awards were:

The Most Innovative Product of the Year, the program's highest award, went to the Helieon Sustainable Light Module System by Bridgelux and Molex. These flexible, upgradable and replaceable LED modules offer 500-1500 lumen in 24, 32 and 50° beam angles (pictured).

The Design Excellence Award, recognizing outstanding achievement in design and application, went to Light-Drive Elite by Traxon USA. This is a glass-faced » page 10

FINANCING

Nualight gets EUR 9.1 million

Nualight, a Cork, Ireland-based supplier of LED-based lighting for retail display cases, has received a EUR 9.1 million cash infusion. Climate Change Capital Private Equity (CPE) led the investment round taking EUR 3.75 million worth of regular and preferred shares and joining ESB Novusmodus, the renewable energy investment fund of the ESB Irish State electric utility, in an additional EUR 5 million investment.

Nualight supplies LED luminaires to international food and high-end retail chains. CPE Partner Simon Drury said, "Our due diligence showed that Nualight is a clear leader in developing the most effective lighting solutions for retailers, both in terms of energy efficiency and merchandising effects. With the company's strong market position amongst display-case manufacturers and retailers, and its high-quality management team, we are confident that the company will continue their growth as this market accelerates." ◄

MORE: www.ledsmagazine.com/news/7/4/29

SUPPLY CHAIN

Philips and Future extend LED partnership

Future Lighting Solutions has announced an expanded relationship with Philips under which the companies will offer a broad range of LED lighting components and services to assist OEM customers and integrators in developing solid-state lighting products. The deal

Future Lighting Solutions helped to design LED fixtures for two road tunnels in central China - see www.ledsmagazine.com/casestudies/21993.

extends Future's 10-year exclusive LED distribution relationship with Philips Lumileds. Future will now carry an even broader line of Philips products including LED drivers, LED modules and other key components, and will become a direct supplier of its simpleLED light-engine components under the Philips LED licensing program. Customers will be able to use certain simpleLED light engines from Future to help qualify their licensed luminaires for a 0% royalty payment under the Philips licensing scheme. These light engines will utilize Lumileds LEDs and will carry a special Philips marking.

"This agreement will enable our customers to further speed their time to market, reduce their total systems costs, and simplify their supply chain by sourcing devices from one partner," said Gerry Duggan, Executive VP of Future Electronics. Rudy Provoost, CEO of Philips Lighting, added that this "exciting expansion of our relationship will allow Philips and Future to enhance our offer to the OEM market, serving existing and new customers with a broader portfolio of LED lighting solutions and services." ◄

MORE: www.ledsmagazine.com/news/7/4/11

news+views

DMX controller with onboard RGB LED feedback and touch wheel interface for controlling RGB LED luminaires.

The Technical Innovation Award, recognizing the most forward-thinking advancement in lighting technology, went to the SSL2101 by NXP Semiconductors. This is a switched-mode power supply controller IC that operates in combination with a phase-cut dimmer.

Among the eleven Best of Category winners, in areas ranging from drivers to downlights to theatrical lights, were the Professional LED Bulb CTA by Ledzworld Technology Sdn Bhd; the Element 3 LED Downlight by Generation Brands Tech Lighting; the SAFR Series LED Luminaires by AZZ/RAL Rig A Lite; and the Series 6000 HP LED Cove Light by Tempo Industries. ◄

MORE: www.ledsmagazine.com/news/7/5/8

CHIP PRODUCTION

Sharp expands chip capacity

LED maker Sharp Corporation will start mass production of blue LED chips at its Fukuyama Plant in Fukuyama City, Hiroshima Prefecture, Japan by the end of 2010. The company started blue LED chip production at its nearby Mihara Plant in January 2010, after

Sharp multi-chip Zenigata module on a Fischer Elektronik heatsink

signing patent cross-licensing deals with Nichia and Toyoda Gosei.

The new production capabilities will boost Sharp's production capacity of blue LED chips to approximately five billion units a year in fiscal 2011, the company says. The expansion is driven by the growth in demand for LED backlights for LCD TVs and LED lighting fixtures, which has led to a rapid increase in the demand for blue LED chips. Sharp has invested around Yen15 billion (around ($164 million) in the expansion. ◄

MORE: www.ledsmagazine.com/news/7/5/10

LIGHTING

Cree luminaire breaks 100 lm/W

At Lightfair, Cree unveiled a new LED-based troffer, the LR24HE, which delivers more than 100 lm/W fixture efficacy. With an output of 3200 lumens at 3500 K and a CRI of 90, the troffer is designed to last at least 50,000 hours. It is, says Cree, 30% more efficient than the best 2x2-foot fluorescent troffers and 15% more efficient than the best 2x4-foot fluorescent troffers. Cree also said that it will be reducing the price of its award-winning LR24 LED troffer by 15 percent to reduce upfront cost and accelerate market uptake.

With commercial availability planned for late summer, the LR24HE will offer Cree's new five-year warranty, also available on its entire family of fixture products. "We have almost 20,000 hours of real-world data on products from our early installations nearly three years ago, and the performance is rock solid," said Ty Mitchell, Cree VP and general manager, LED Lighting. "Lengthening the warranty lets our customers know that Cree stands behind the long-term performance and reliability of our fixtures." ◄

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

LED DESIGN

Illumitex optics emit uniform beam

Illumitex, a venture-funded company based in Austin, Texas, has unveiled its Aduro series of 4- and 16-die packaged LED arrays that closely tie an optical element to each chip. The company says that the new products will "transform LED lighting design" by emitting uniform, narrow-beam white light without the need for expensive, inefficient secondary optics. Illumitex has received around $22 million in venture funding from investors such as New Enterprise Associates.

Typically, LED manufacturers use a basic dome optic in an attempt to control the light output from the package, but this typically forces fixture manufacturers to utilize secondary optical lenses and reflectors. Illumitex says that its approach results in a highly efficient and uniform distribution pattern.

The Aduro LEDs are offered in cool, warm and neutral white light with radiation patterns of 10°, 20° and 30° beam half-angles. The 16-die package measures 16 x 24 mm and has a typical output of 500 lm at 5700K when driven at 500 mA. The typical forward voltage is 13V, so the input power is 6.5W and the efficacy is around 77 lm/W. ◄

MORE: www.ledsmagazine.com/news/7/4/3

LED PRICING

Intematix beats price target

LED maker Intematix has breached the one-cent-per-lumen barrier for warm-white LEDs with its new C1109D packaged LED arrays that deliver light output of 345 lm (warm white) and 450 lm (cool white). The company has priced the arrays aggressively at 110 lumens per dollar for warm white and 143 lumens per dollar for cool white, claiming that the pricing will reduce the payback period for SSL investments.

The new LEDs achieve greater efficacy through innovations in LED chips, phosphor, and packaging. Ilkan Cokgor, Director of Business Development for Intematix, points out that typical 5-10W LEDs have an efficacy in the 60-lm/W range for warm-white light and a bit higher for cool-white light. "We have improved this to 90-100 lm/W," says Cokgor. "We redesigned our C1109D package. We are now using a dome lens on each cavity which has improved the light extraction efficiency by about 10%. We also reduced the thermal resistance of the package, to improve performance when the LED runs at steady state." ◄

MORE: www.ledsmagazine.com/news/7/5/3

MANUFACTURING

Orders for MOCVD suppliers

MOCVD growth system suppliers continue to announce new orders for their equipment. Veeco has received multi-tool orders from Korea-based Seoul Optodevice and Sanan Optoelectronics of China, and has had a K465i system qualified by Taiwan's Epistar. Meanwhile, Aixtron is supplying systems to Jiang Su Can Yang, a manufacturing joint venture in China involving Taiwan's Forepi as one of the partners. ◄

focus on Outdoor Lighting

Germany funds 10 outdoor lighting projects

The German Federal Ministry of Education and Research (BMBF) has announced the 10 winning teams of the national competition "Kommunen in neuem Licht" ("Towns in a New Light"). The competition provides funding to introduce LED outdoor lighting in 10 towns around Germany. The organizers were taken by surprise when the number and quality of proposals exceeded all expectations. Among 141 participating towns from all over Germany, the ten best proposals will be granted up to EUR 2 million in sponsorship by the BMBF. The winning towns and districts are: Erfurt, Görlitz, Königsfeld, Wuppertal, Trier, Norden, München, Paderborn, Freiburg (Breisgau), and Rietberg.

MORE: www.ledsmagazine.com/news/7/4/31

Photo: Osram Sylvania

retrofit kit "greatly reduced system wattage, increased the system light levels and was easy to install."

MORE: www.ledsmagazine.com/news/7/4/15

Kolkata unveils LightSavers project

Under the mentorship of The Climate Group's Global LightSavers initiative, the Kolkata Municipal Corporation (KMC) in Kolkata (formerly Calcutta), India, has unveiled an extensive LED pilot project. This will involve an initial installation of 273 LED luminaires from Lumec, a Canadian company that is now part of Philips. The project involves 123 Philips Lumec 130W RoadStar LED luminaires to replace 250W HPS luminaires, and 150 RoadStar 180W luminaires to replace 400W HPS luminaires. Pilot projects internationally have so far shown a reduction of 40-50% in electricity use when LEDs replace HPS lamps, and savings of up to 70% when LEDs are used with smart controls. A further LightSavers pilot will be launched shortly in Hong Kong.

Photo: The Climate Group

MORE: www.ledsmagazine.com/news/7/4/28

University of Toronto adds LED street lights

The University of Toronto in partnership with Osram Sylvania recently sought to deploy a complete street lighting solution that allowed the campus to save energy, reduce maintenance costs and decrease the school's environmental footprint. HID lamps in 100 Lumec fixtures lining the streets and promenades of the main Toronto campus were retrofitted with 40-watt Post Top Fixture LED Retrofit Kits from Osram Sylvania.

Lighting typically accounts for over 20 percent of a campus' total electrical consumption so schools benefit greatly from an energy-efficient makeover. A spokesperson for the University said that, compared with existing HID lamps, the

LRC releases street-light study

The Lighting Research Center (LRC) at Rensselaer Polytechnic Institute (RPI) has released the results of a field study of LED street lighting in an upstate New York suburban business park. The field study confirmed the energy efficiency of the LED lights and that visitors judge the lights to be equal or superior to high intensity discharge (HID) street lights. The study evaluated 16 BetaLED Edge LED luminaires that were deployed along a curved, three-lane street built to serve a new office building. The LED lights, at 79W per luminaire, use 38% less power than a nearby HPS system used as a reference. LRC also recruited 26 volunteers who visited the site after dark and completed a survey that indicated a preference for LEDs in terms of light quality and feelings of safety.

MORE: www.ledsmagazine.com/news/7/4/26

DOE unveils municipal consortium

The US Department of Energy (DOE) has launched the Municipal Solid-State Street Lighting Consortium and tapped Seattle City Light, a utility, to direct the effort. The Consortium will enable broad sharing of information among municipalities across the USA, and more than 70 cities have already signed up. Edward Smalley of Seattle City Light, the consortium director, said "We want to reduce the needless duplication of efforts among members. We want to look at reducing the risk of making large-scale mistakes. We want to be able to bring the end users up to speed as quickly as possible and their ability to identify good products and proper applications. We want to reach out to members with limited budgets." Early priorities will include setting up demonstration projects, and establishing performance standards.

MORE: www.ledsmagazine.com/news/7/5/6

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LAMPS

LED retrofit lamp selection grows at LFI

The LED retrofit lamp market was perhaps the hottest segment at May's Lightfair International (LFI) tradeshow. Existing players including Osram Sylvania, Philips, Lighting Science and Lemnis Lighting expanded their offerings, while Japanese giants Sharp and Toshiba entered the retrofit market.

At LFI, Osram Sylvania, Lighting Science Group, and Philips all unveiled new LED lamps targeted at replacing the 60W incandescent bulb.

The Sylvania Ultra LED A-lamp is a 12W, 810-lm dimmable product with a 2700K color temperature and a color-rendering index (CRI) of 90. Sylvania did not announce a price but said the lamp would be available for purchase beginning in late August, and had a 25,000-hour lifetime (www.ledsmagazine.com/press/22405). The lumen-output figure is significant because it exceeds the value of 806 lm designated by the European Union as the minimum necessary to be able to claim 60W-equivalence.

Philips is the only company to enter a 60W-replacement bulb in the L-Prize (see p.19), and applied this experience to its new 12W EnduraLED light bulb (www.ledsmagazine.com/products/22417). The lamp outputs 806 lm, works with standard dimmers, and is rated for 25,000 hours of use. The new EnduraLED bulb (see photo) uses a similar mechanical design to the L-Prize candidate. Both use a remote phosphor. Both segment the bulb and use aluminum air channels between the bulb segments for cooling. The L-Prize candidate uses four illumination quadrants while the new design has three illumination segments. Note that the L-Prize target is more than 900 lm and less than 10 W power consumption. Philips believes the EnduraLED will

be more cost effective and serve a broader market than the L-Prize candidate. It declined to provide a price at launch, but plans to make it widely available in the fourth quarter of this year.

Lighting Science Group, meanwhile, did announce a price for its new 9W Definity A-lamp, which has an output of 770 lm (www.ledsmagazine.com/press/22419). The product will sell in the low $30 range, beginning in the third quarter of 2010, and has a product life of 50,000 hours. The company claims that 60W incandescent bulb sales have traditionally constituted 50% of the market and that's surely why so many companies, as well as DOE with the L-Prize, are targeting that segment. Lighting Science also announced that its 9W Ecosmart A19 LED lamp is being sold in The Home Depot with a retail price of $19.97 (www.ledsmagazine.com/press/22332). The 40W-equivalent lamp has an output of 429 lm (according to the packaging) and a color temperature of 3000K.

GE demonstrated its 450-lm, 9W LED bulb that was announced recently as a 40W replacement (see www.ledsmagazine.com/news/7/4/9). The company still doesn't have a definitive ship date, but at an LFI press conference indicated the lamp will be on sale in 2010 with a price in the $40 to $50 range. The lamp is rated for 25,000 hours. The unusual design of the lamp (p.32) is intended to improve the omnidirectional light distribution.

Sharp and Toshiba both made news at LFI announcing that they would enter the US and other world markets with LED lighting products. Both companies have been leaders in lighting in Japan, but have not supplied products beyond that country in the past.

Sharp is squarely focused on the commercial customer sector early on and has developed an extensive network of manufacturers' representatives. The company announced PAR38 replacement lamps as its first products and plans to follow with PAR30 lamps in the summer. The PAR38 (see photo) is available in 900- and 720-lm

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versions, targeted at replacing 90W and 75W halogen bulbs with 20W and 16W LED alternatives, respectively. In Japan, the company has primarily sold LED A-lamps and will ultimately bring those to the world market as well. Although the company only entered the LED space in August 2009, product manager Vini Petroni reported that the company shipped 1.5 million LED A-lamps in Japan in 2009.

Toshiba introduced various LED-based lamps at LFI. The company's A-lamps (see photo) come in 5.6W and 7.8W versions that range in light output from 230 lm to 350 lm, depending both on wattage and color temperature. Toshiba's featured announcement, however, was an A-lamp that is not yet ready for either the Japan or global markets. The company demonstrated an A-lamp that outputs 1690 lm and offers a 260° light distribution. Masao Omori, Director of LED Lighting at Toshiba said the company hopes to ship the high-output product within six months.

Moving back to an established player, Lemnis Lighting is among the leaders in LED replacement bulbs. Warner Philips, co-founder and CEO of Lemnis Lighting USA, reports that the company has sold 2.5 million LED bulbs. At LFI, the company announced an 800-lm PAR-style bulb called the Pharox 800, the Pharox MR16 that outputs 300 lm at 5W, and the Pharox Candle that produces 170 lm at 4W. In the A-lamp area, Lemnis introduced the new 500-lm Pharox 500 as a companion to its existing 200- and 300-lm lamps. Lemnis' Philips believes 500 lm and down is the sweet spot for A-lamps. He stated, "Lamps that output 800 lm at $60 will not compete." He believes that consumers won't pay that price premium. Philips claims that Lemnis will lower the price point for the low end of its A-lamp family to less than $20 in the coming months.

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EPA releases draft Energy Star requirements for Luminaires

The US Environmental Protection Agency (EPA) has released Draft 1 Version 1.0 of the Energy Star program requirements for Luminaires. This specification, in the long term, is intended to replace the existing Residential Light Fixtures (RLF) version 4.2 and Solid State Lighting Luminaires (SSL) version 1.1 specifications.

Stakeholders are invited and encouraged to submit comments on this draft to EPA no later than Monday, June 21, 2010. Comments should be submitted to luminaires@energystar.gov with "Energy Star Luminaires First Draft Comments" in the subject line. The specification, a cover letter and notes from a recent LRC-NEMA-ALA Roundtable Meeting can be found at www.energystar.gov/luminaires.

Back in December 2009, EPA and the Department of Energy (DOE) released the Lighting Integration Proposal, a plan to integrate the existing four lighting specifications (see www.ledsmagazine.com/news/6/12/3). As well as RLF v4.2 and SSL v1.1, this list includes Integral LED Lamps and CFL v4.0. It is now clear that EPA intends to introduce two "technology neutral" specifications: Energy Star Luminaires, and Energy Star Lamps.

The draft Luminaires specification will eventually supersede both SSL v1.1, which was implemented by the DOE, and RLF v4.2, which was amended in June 2008 to include SSL fixtures. However, for now, these specifications remain in place. The Luminaires spec is expected to be finalized by September 2010, and will become effective nine months later (June 2011).

Photometry

Photometry of SSL luminaires has been a source of intense discussion, with SSL v1.1 and RLF v4.2 taking opposite approaches. The proposal is that directional fixtures should be subject to luminaire photometry, and non-directional fixtures should be evaluated at the light-source level. Alex Baker, EPA Lighting Program Manager for Energy Star, said that the EPA believes this offers "the greatest near-term opportunity for efficiency gains and technological advances in the market."

Baker's reasoning is that when consumers buy certain types of fixtures, the aesthetics are at least as important as overall energy efficiency of the luminaire. Here, if Energy Star forces manufacturers to focus on luminaire efficacy, it will result in designs that don't compete well aesthetically, leading to reduced market impact and lower overall savings. So, the goal would be to have an energy-efficient source (lamp) inside an aesthetically-pleasing luminaire.

However, many applications are directional in nature (e.g. under cabinet, recessed downlights, track lights), and are designed and chosen with less emphasis on aesthetics. EPA believes these can and should be evaluated on the basis of luminaire photometry, measuring light delivered from the luminaire as a whole. SSL luminaires based on integrated components that cannot be replaced should also be subject to luminaire photometry.

Other key aspects

"Technology neutral" is another key aspect of the new draft spec. Baker said that "the Luminaires specification, to the greatest extent possible, is intended to » page 20

DOE updates L Prize progress

The DOE recently provided an update on the L Prize, which will reward companies that successfully develop very-high-performance LED replacement lamps. So far only one entry has been received, from Philips, in the 60W A-lamp replacement category (www.ledsmagazine.com/news/6/9/24).

Following initial photometric testing of the first entry, conducted at two Caliper-qualified labs (Independent Testing Laboratories Inc. in Boulder, CO and OnSpeX/CSA International in Atlanta, GA), the samples were shipped to Pacific Northwest National Laboratory for long-term testing, using a new test bed designed specifically for the L Prize competition. This phase will involve testing the samples for at least 6,000 hours (250 days), at temperatures that will be elevated to 45ºC.

Also, DOE is getting ready to ship out more than 1,400 samples of the Philips lamp to 14 L-Prize partners across the country. These partners are preparing to install the sample products in more than 40 planned locations – from kitchens in Cape Cod to coffee shops in Washington state – and will collect data on energy usage, light levels, and user perceptions.

Four more organizations have signed up as L Prize Partners, bringing the total to 31. With a combined buying power that includes more than 100 million electricity customers, these utilities and energy-efficiency organizations have pledged to develop markets for the winning products. Federal purchasing agreements and partner incentives are likely to prove much more valuable than the cash prize itself. Up to three prizes can be awarded in each category, but the exact value of the prizes is still to be finalized.

So are other entries likely to join the Philips one? DOE recently evaluated 24 LED "60W replacement" products on the market, and found them falling well short of the L Prize tar- » page 22

funding + programs

EPA from page 19

be technology-neutral in terms of key criteria such as luminous efficacy and color performance. This approach allows manufacturers across various technologies to compete on a level playing field… Because consumers shop for light fixtures, rather than lighting technologies, it is important for the Energy Star label to mean the same thing in terms of energy savings, regardless of technology."

Efficacy requirements for non-directional luminaires have been increased to 70 lm/W, up 40% compared with the RLF v4.2 spec. This applies to source photometry measurements of either an LED light engine or a lamp/ballast combination in the case of either fluorescent or HID lamps. Also for non-directional luminaires, each LED light engine or lamp/ballast combination must provide a minimum of 850 lumens. It's important to emphasize these values are the source values, not the luminaire values. In many cases, the requirements for different types of directional luminaires have been carried over from the values in SSL v1.1.

EPA proposes to require a minimum Ra value ("CRI") of 80 for indoor luminaires, applying to all luminaire types, and all technologies. The requirements will also include evaluation of special index R9 performance. ◄

MORE: www.energystar.gov/luminaires.

New DOE funding, CALiPER results

The DOE has announced two new SSL funding opportunities, and Round 10 CALiPER (Commercially Available LED Product Evaluation and Reporting) test results. The funding is directed toward two existing DOE program areas for Core Technology Research (up to $15 million) and Product Development (up to $10 million). The DOE is seeking funding applications for projects to advance research, development, and market adoption of SSL technology. This will be the seventh round of such funding that has been awarded in recent years. Funding is subject to congressional appropriations.

Round 10 of CALiPER testing included parking structure luminaires, outdoor wallpack luminaires, cove lighting luminaires (including two products marketed as "AC LED" products), and replacement lamps. The tests benchmarked SSL products against similar products that use conventional light sources. A summary report is now available from the DOE SSL website, and detailed test reports will be available soon through the searchable online system.

In upcoming events, the EPA is hosting a webinar on June 8, 2010 from 1:00–2:30 pm Eastern to provide an overview of draft 1 of the Energy Star Luminaires v1.0 specification. And the DOE will hold a SSL market workshop July 20–22, 2010 in Philadelphia, PA.

MORE: www.ledsmagazine.com/news/7/5/14

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get, with actual light output only equivalent to 25W to 40W incandescent lamps. Efficacy varied widely, ranging from 25 to 74 lm/W. The L Prize target is more than 900 lm at more than 90 lm/W. While most CCTs were in the 2700-3700K range, five had CCTs exceeding 3700K.

A similar evaluation of commercially available PAR-38 replacements found that they have significant ground left to cover in terms of light output, color quality, and center-beam intensity. No PAR-38 lamps have been entered yet. The DOE's Jim Brodrick said, "We deliberately set the L Prize bar extremely high...we're not looking for merely a 'better' bulb, but rather for a 'super' bulb that takes efficiency and performance to a whole new level."

But what happens after a company receives an L Prize? The goal should be for the winning prototype to become a high-volume product with "L Prize performance" at a price that will ensure widespread adoption. Brodrick told LEDs Magazine that the L Prize requires evidence of the manufacturer's capability to produce at least 250,000 units in the first year after award, and increasing in subsequent years. "DOE is currently developing policies and procedures to address design changes to the product to ensure required performance levels will be maintained," said Brodrick. "The competition document provides price guidance, and DOE is working closely with utility and energy efficiency partners to incorporate the L Prize winning products into their existing programs that provide product incentives, marketing support, retailer outreach, and other promotional activities.

MORE: www.lightingprize.org

• Announcement

Strategies in Light China will take place for the first time on May 10-12, 2011 in Kowloon, Hong Kong. See www.ledsmagazine.com/news/7/5/15 for more details.

• Correction

Our article on the Next Generation Luminaires competition (April 2010, p.34) showed the wrong photo for the USAI entry. The entry was the adjustable model of BeveLED. The downlight in the photo has different performance characteristics.

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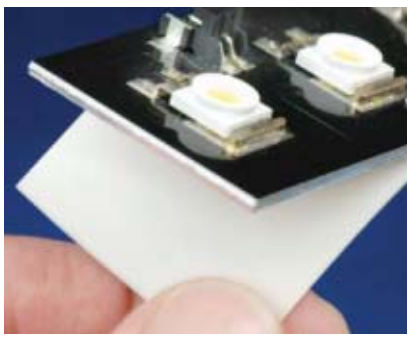

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Navigating uncharted waters: new challenges in specifying LED luminaire lifetime

Understanding and quantifying the behavior of a single LED, and calculating how this will affect a system with multiple LEDs, are crucial if lighting companies are to set their system warranty level correctly and assess the cost of failures potentially occurring within the warranty period, writes **FRANCOIS MIRAND**.

Power LED manufacturers claim many advantages for their products over traditional light sources; one is their presumed ultra-long life. In applications that cannot tolerate failure, or where maintenance and repair are difficult or costly, long operating lifetime and extended maintenance cycles are attractive, even when balanced against relatively high purchase costs.

Luminaire manufacturers, and lighting designers and specifiers, have generally been reassured by the claims from LED manufacturers that their devices will typically operate for 50,000 hours. But in fact, the claims of long operating life for LEDs, as for any component, only apply under certain conditions. What is more, LEDs can and do fail in rare cases.

So is LEDs' promise of long life and maintenance-free operation just a myth? This article intends to help the reader understand the most important factors that affect the operating lifetime of a solid-state lighting (SSL) system. This system includes not only the LED, but also the control circuitry, power supply, and optical and mechanical components. It will show that luminaire manufacturers can rate their products for long life with confidence – but only if the luminaire designer takes a system-wide view of the reliability issue.

Evolving concepts for LED reliability

In the early days of power LEDs, the most frequently quoted lifetime was 100,000 hours. However, no-one could really explain what was behind this magic number; it was probably more to do with marketing than science. Philips Lumileds, with its Luxeon LEDs, was the first LED manufacturer to specify a lumen maintenance rating. The early Luxeon I device was rated at an L70 lifetime of 50,000 hours at a given drive current and junction temperature (350mA, 90°C). This means that, under such conditions, the average LED's output declines to 70% of initial output after 50,000 hours of operation.

Then in 2003, Lumileds published the first document (Reliability Datasheet RD25) to explore the subject in depth, highlighting the key factors affecting long-term LED performance, such as junction temperature and drive current, and quoting real-life numbers for its own devices.

FIG.1. This LED downlight prototype has redundant optical design – the only impact of the failure of one single LED is a reduction in total light output.

Other LED manufacturers rapidly moved to claim the 50,000 hours number as well, although many omitted to specify the related operating conditions. Later, in 2007, Lumileds proposed a new graphical data set, known as Bxx, Lyy graphs, to help lighting designers predict power-LED lumen maintenance in different operating environments. In the Bxx Lyy concept, xx represents the percentage of an LED population that would fail, where failure is defined as either lumen degradation below a percentage represented by yy, or complete (catastrophic) failure. As an example, a value of "50,000 hours B50 L70" means that statistically 50% of an LED population would reach a <70% lumen maintenance point after 50,000 hours of operation. The concept was explained in the Technology White Paper WP12 entitled "Understanding power LED lifetime analysis."

At this time, Future Lighting Solutions introduced its online "LED Reliability Tool" (www.futurelightingsolutions.com/lrt), which produces the Bxx, L70 graph for all types of Lumileds power LEDs and all operating conditions; it also offers a probability distribution selected by the user.

To date, only Osram Opto Semiconductors

FRANCOIS MIRAND *is Technical Manager of Future Lighting Solutions (EMEA).*
Web: www.futurelightingsolutions.com.

has published B/L data for its Dragon family in a comparable format, although solely offering typical (B50) distribution numbers. As yet, there is no equivalent to Future Lighting Solutions' LED Reliability Tool.

Standards

Lumen maintenance is now recognized as an important property of power LEDs, and in 2008 the Illuminating Engineering Society (IES) established the LM-80-08 standard entitled "Approved Method: Measuring Lumen Maintenance of LED Light Sources." LM-80-08 is an attempt to establish uniform methods of lumen maintenance testing for LED light sources and to allow a comparison of performance between manufacturers. The US government's Energy Star program uses LM-80-08 as a reference in its certification of luminaires.

LM-80-08 does not provide guidance for the extrapolation of lumen maintenance beyond the actual duration of measurements. An extrapolation method, TM21, is under development by an industry committee. Separately, Energy Star's manufacturer's guide sets minimum lumen maintenance thresholds at a 6,000-hour measured data point.

Philips Lumileds was the first and, as of April 2010, only manufacturer to make an LM-80-08 test report publicly available (for its Luxeon Rebel Illumination range of LEDs – see Design Resource DR03). Other LED manufacturers have lodged LM-80-08 test reports with the US Department of Energy, and these are available to luminaire manufacturers on request.

Beyond lumen maintenance

The concept of lumen maintenance, then, has become entrenched to the point at which, today, LED reliability is generally thought to be defined by lumen maintenance.

This is, at best, misguided and at worst extremely damaging to LED luminaire manufacturers. First, LEDs have other failure modes than lumen maintenance: catastrophic failure and color deviation over time can both be observed in populations of LEDs. Second, the LED is only one among many components in an SSL fixture, and each of these components has the ability to cause malfunctions or failure of the luminaire.

Because LEDs operate so differently from traditional incandescent light sources, it is a common myth in the lighting industry that LEDs do not suffer "catastrophic" failure – that is, suddenly go completely dark – in the way incandescent lamps do. In fact, LEDs are like any other semiconductor component in this respect: albeit at very low rates, LEDs do fail catastrophically.

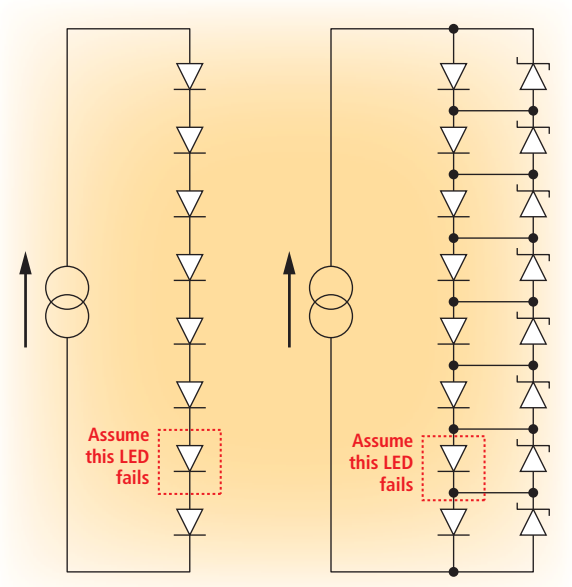

FIG. 2. In a series-connected LED array (left), when a single LED fails short, the remaining LEDs stay on and the drive current remains stable. However, if an LED fails open, all the LEDs turn off, unless the string is protected by additional components. Such protection, for example adding a zener diode in parallel with each LED (right), adds cost and complexity.

Understanding and quantifying the behavior of a single LED, and calculating how this will affect a system with multiple LEDs, are crucial if lighting companies are to set their system warranty level correctly and assess the cost of failures potentially occurring within the warranty period.

An SSL system designer should be able to calculate the catastrophic failure rate of the LED he is using under given operating conditions and use Failure Mode and Effects Analysis (FMEA) techniques to assess the impact of such a failure on its system performance. If the luminaire uses a single LED as the light source then the analysis is simple: a catastrophic failure of the LED means a total failure of the whole system. On the other hand, in an array of many LEDs, the catastrophic failure of one LED may do no more than reduce the output by a predictable fraction.

Luminaire designers must adopt techniques that mask or compensate for catastrophic failures at the probable rate specified by the LED manufacturer. This can be best illustrated by way of an example: a product specification for a downlight using 40 LEDs.

First, the luminaire designer should design a redundant optical system, so that if one LED fails the radiation pattern is not significantly affected, and the only impact is the loss of 2.5% of the light output (see Figure 1).

Second, a single LED failure must not be allowed to cause a complete system failure. It is crucial to know the LED failure mode (open or short circuit) in order to select the most appropriate wiring topology. Additional open circuit by-pass components might be needed (see Figure 2).

Finally, combining LED lumen maintenance and catastrophic failure rates will allow the designer to reliably predict the impact of LED reliability on their luminaire's economic life.

As shown above, then, LED lumen maintenance data are necessary but not sufficient for SSL system lifetime assessment. For decades, traditional semiconductor companies have published their reliability testing results and extrapolated failure rates; in general, the LED industry has yet to reach that level of maturity.

Philips Lumileds, however, has the ability to provide meaningful, accurate data about the long-term performance of its products. Contrary to what is commonly assumed, Philips Lumileds' B/L reliability graphs do account for all LED failures; they do not, however, allow the user to discriminate the catastrophic failure rate from the lumen maintenance failure rate.

Recently, Philips Lumileds unveiled a new model for specifying the long-term behavior of Luxeon LEDs (see www.ledsmaga-

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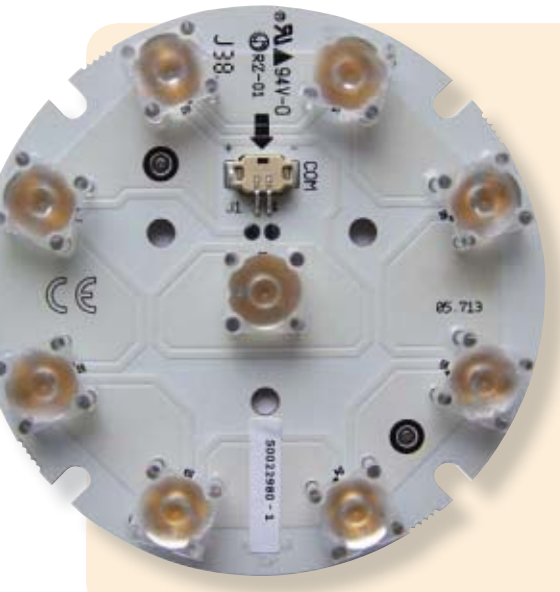

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FIG.3. A simpleLED light engine from Future Lighting Solutions, with some of the key design aspects that result in enhanced reliability.

zine.com/news/7/5/4). This includes separate expressions for lumen maintenance and catastrophic failures, and will support comprehensive lifetime analysis by luminaire designers.

Another potential failure mode of power LEDs is color or chromaticity maintenance over time, although this will only be a critical factor in certain applications. For white LEDs, the absolute deviation ($\Delta u'v'$) over time from the reference illuminant should ideally be characterized under various operating currents and temperatures. LM80-08 test reports, however, show relative chromaticity deviation – that is, how much an individual LED's color shifts over time from its original color.

Designing for LED reliability

Operating temperature and drive current are the acceleration factors in the lumen degradation of an LED; part of the luminaire designer's challenge is to select drive current values and thermal mechanisms so as to optimize the system for cost, size and performance.

But external factors can also cause early failure, including thermal, electrical or mechanical overstress, as well as chemical contamination. The luminaire designer can take steps to eliminate, reduce or mitigate these effects.

Thermal overstress occurs when the LED package or junction temperature exceeds the maximum ratings specified in the manufacturer's datasheet. It will generally find its root cause in weak thermal design, poor product assembly or uncontrolled operating conditions.

Electrical overstress is when the current and/or voltage applied to the LED are beyond the maximum ratings. Insufficient transient protection, inappropriate driver circuit topology or incorrect wiring procedures are the most common mistakes.

Mechanical overstress is becoming more of a concern as leadless ceramic bases are being more commonly found in LED packages. This applies to all leadless large packages and is well known in the electronics industry. The difference in thermal expansion between the PCB and the component package can result in solder joint cracks under repetitive temperature cycles with a wide spread between temperature peaks and troughs – this is common in exterior lighting. In addition, PCB warping or flexing during the assembly process could also crack the joints or component package itself.

Using suitable material, such as a low-E-modulus-dielectric metal-core or FR4 PCB, and following good PCB layout practice, will lower the risk. Mishandling throughout the manufacturing process is a frequent cause of mechanical damage. Both the board assembly and the luminaire assembly processes need to be carefully designed and managed.

Chemical compatibility remains a vast domain to explore. Most LED packages use silicone encapsulants, which are gas-permeable. Volatile organic compounds (VOCs) contained in adhesives, solder fluxes, conformal coating or potting materials and inks can embed themselves in the silicone structures and oxidize, limiting the transparency of the optical system. The reaction can be catalyzed by heat or light. The alteration is usually reversible if the exposure to VOCs is eliminated. Careful material and process qualification is the only way to prevent this, for example allowing sufficient air flow to carry away the VOCs.

Designing for system reliability

Creating a reliable SSL luminaire involves more than careful LED selection and a suitable light-engine design: it requires equal attention to other components in the system. An illustration of issues to be taken into account when designing for system reliability is shown in Figure 3.

The long-term behavior of the secondary optic can significantly affect a luminaire's lifetime performance. Plastic lenses are the most commonly used secondary optics in LED luminaires today. They are usually made of polymethyl methacrylate (PMMA) or polycarbonate (PC) thermoplastics. The merits of both materials have been extensively discussed in terms of transparency, resistance to heat and scratching, and cost. But light-transmission performance over time has not been characterized in detail. At best, lens manufacturers will say that PC tends to yellow under intense UV exposure, but that in 10 years of experience, they have never seen any example of catastrophic degradation even in the harshest application conditions, such as exterior wall washers directly facing the sun. It is also true that

60~150W
CLG Series
- PFC function
- IP65~67
- Potted with thermal-conducted glue for a better heat reduction
- Metal case
- Suitable for outdoor and street lighting

60~96W
CEN Series
- IP66
- UL8750
- Metal case
- Suitable for outdoor and street lighting

20~96W
PLN Series
- PFC function
- IP64
- UL1310 Class 2, UL879
- Plastic case
- Suitable for all kinds of LED lighting

30~60W
ELN Series
- IP64
- UL1310 Class 2
- Plastic case
- Dimming function
- Suitable for LED indoor lighting

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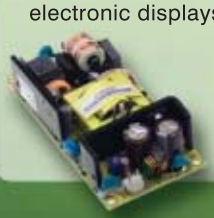
- UL8750
- Metal case
- Suitable for LED lighting and street lighting applications

18~60W
LP Series
- IP67
- UL1310 Class 2
- Plastic case
- Suitable for LED-based decorative, architectural lighting, and LED electronic displays

30~96W
PLC Series
- PFC function
- UL1310 Class 2
- Plastic case
- Terminal block type
- Suitable for indoor LED lighting and moving sign applications

20~60W
PLP Series
- PFC function
- PCB type
- Suitable for LED-based decorative, architectural lighting, and LED electronic displays



150W
ULP Series
- PFC function
- U bracket type
- Suitable for LED street lighting (built-in lighting fixture)

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outdoor luminaires will be sealed by a glass or plastic window that will act as a UV barrier in front of the lenses.

Still, the secondary optic should not be neglected in SSL system-lifetime assessment, in particular because of its potential to affect the chromaticity of luminaire light output. Manufacturers have no alternative but to run lifetime tests and explore alternative materials.

Part of the SSL luminaire is the LED driver. In a majority of applications, the driver is an AC mains to DC constant-current switch-mode power supply. This is similar to the power unit found in domestic appliances such as television sets, central-heating boilers, microwave ovens, low-voltage halogen luminaires and even HID lamp ballasts. It is a well-known technology the weakest components of which, such as electrolytic capacitors or optocouplers, can be properly specified to ensure long lifetime.

The best drivers from the most reputable suppliers can deliver hundreds of thousands of hours of reliable, continuous operation. Equally, the market offers a range of LED drivers at a wide range of prices. The difference between the best and the worst drivers is very marked indeed, and this will be reflected in the average lifetime each product offers.

Unfortunately, even the most reputable manufacturers neglect to provide reliability data such as Mean Time Between Failures (MTBF) ratings in their LED driver datasheets; this presents a considerable difficulty to the luminaire designer. In addition, the output voltage range of many driver modules is insufficient to support failure-proof LED array topologies.

Concluding remarks

The lifetime of LED-based luminaires is governed by numerous factors such as LED lumen maintenance and catastrophic failure rates; secondary optic performance stability over time and operating conditions; and LED driver reliability. An SSL system's reliability is only as good as the reliability of its weakest component, therefore the luminaire designer must take a system-wide view of the problem, rigorously selecting components and applying strict design rules.

Component suppliers should be expected to provide relevant reliability data and, for LEDs, additional standards are needed to enable an accurate and confident prediction of a light engine's economic life. The rapid progress made by this relatively young industry suggests that the key players have understood this point, and will quickly move to meet the industry's needs.

Solid-state lighting can certainly achieve long-term reliable operation; for the good of the whole industry, luminaire manufacturers and their supply chain must deliver on this promise.

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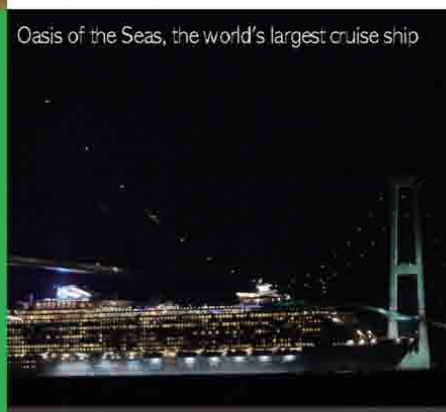
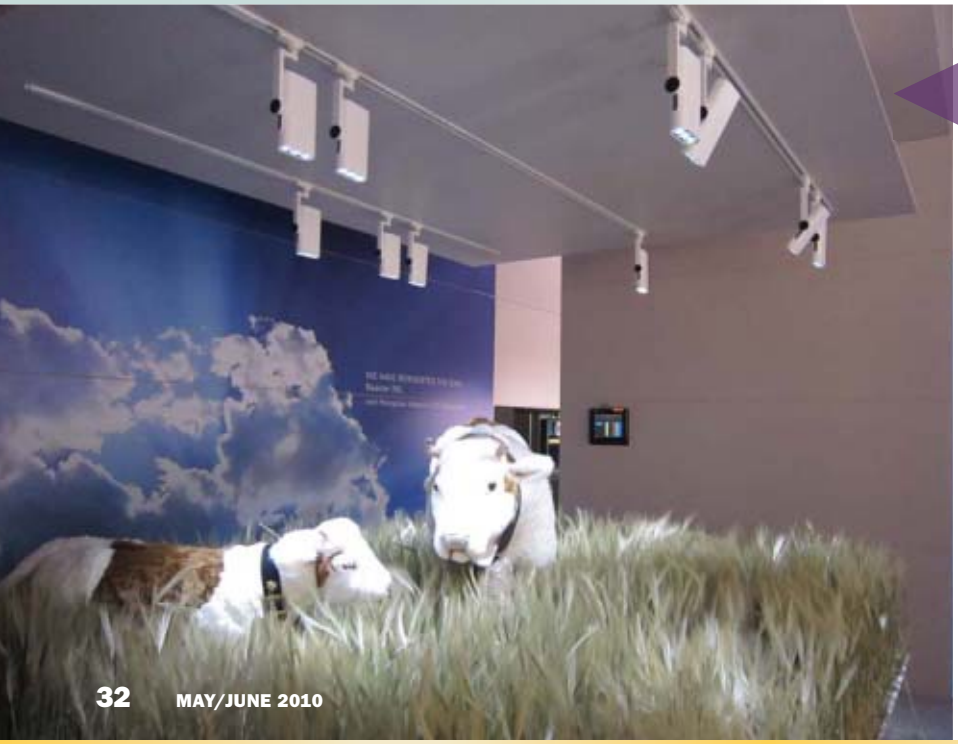


Light+Building showcases

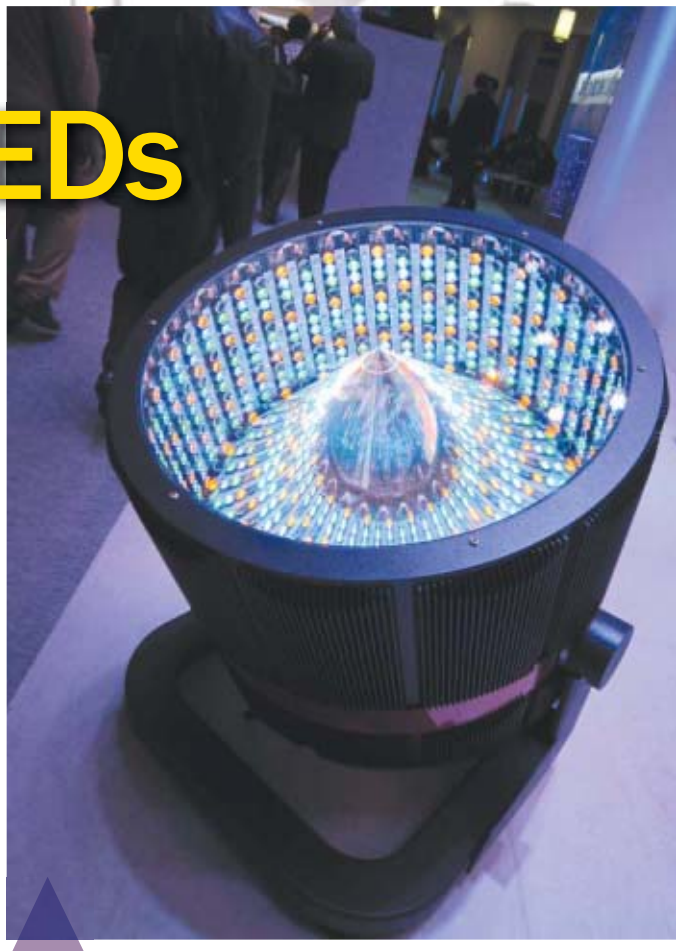
With more than 180,000 visitors, no-one can deny the status of Light+Building, held this year in mid-April in Frankfurt, Germany, as one of the world's pre-eminent tradeshows for the lighting industry. LEDs were everywhere, at least in the halls focused on lighting technology and applications. As we discussed in the Commentary piece in our last issue (www.ledsmagazine.com/features/7/4/11), exhibition booths lit with LED-based fixtures are no longer a novelty. Many lighting companies have now moved well beyond the discussion phase and are clearly committed to incorporating LED technology into their current and future generations of fixtures. In the following several pages we present some of the products that caught the eye.



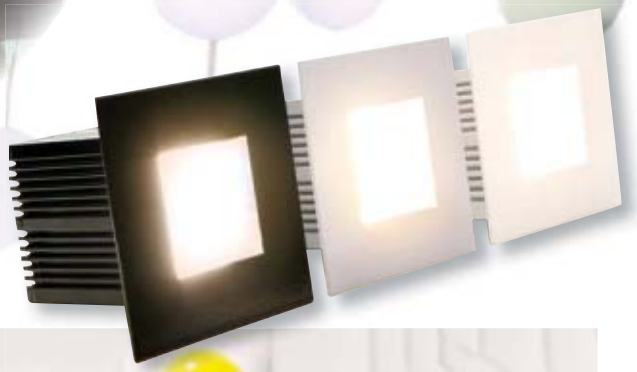
Switzerland-based Regent introduced, in several different fixture formats, its Perception Adaptive LED (PAL) light source technology, which is designed for demanding applications such as museums and lighting of fresh-food counters. PAL technology enables a CRI of up to 94 and allows continuous adjustment of the color temperature from 2700K to 6500K. The CRI and CCT remain constant in the dimming range of 20-100%. The Poco System PAL+ luminaire has a "food" setting with pre-programmed color tones for illuminating different foods such as meat or fish or cheese, as well as a "color" setting for creating accents on objects in shop windows and at points of sale.

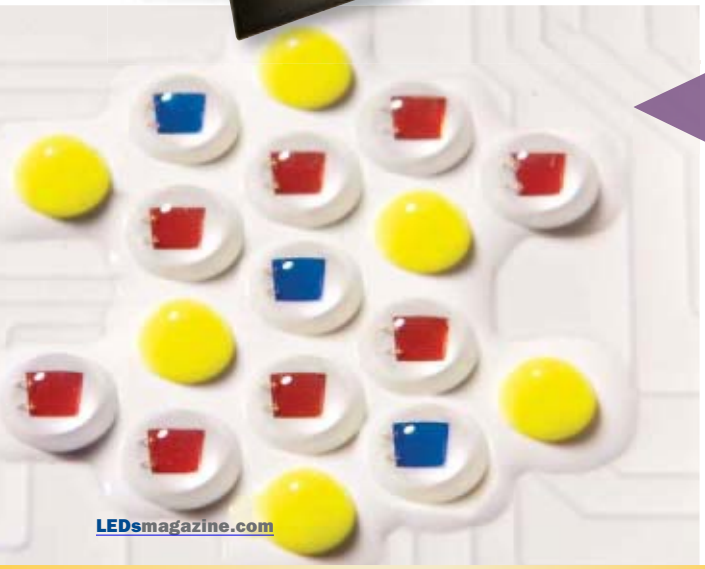
sophisticated LEDs

The booth shared by Traxon and e:Cue provided some striking visuals, using examples of LED lighting and control systems. Traxon announced a strategic alliance to launch Imagic Weave, which contains LEDs in a stainless-steel wire mesh to create a scalable solution for various sizes of media façade installations. Meanwhile, e:cue discussed control systems such as the one recently installed on the Yas Hotel in Abu Dhabi (www.ledsmagazine.com/press/20496).



The 600 LEDs in the Odin fixture from Spacecannon are positioned around the interior of the 70-cm-diameter spotlight housing. Placing all of these 1.2-watt LEDs on a horizontal surface would have required active cooling fans, rather than the passive cooling that is actually used. The light is reflected from a conical reflector, producing a single, powerful beam. Options include RGB mixed with either white or amber. The Odin is intended for major events and shows, and for large-scale architectural lighting, for example of very tall buildings.





Austrian company Lumitech unveiled its LED downlight E8 portfolio, tunable from 2700K to 6500K. With a color-rendering index (CRI) of 90, the E8 offers a comparable performance at 12W to 75W halogen lamps or 26W CFLs, and a long lifetime of up to 35,000 hours. Lumitech said that tunable white light "enhances well-being in accordance with human biorhythms, and is therefore perfectly suited for application in restaurant, hotel, wellness and residential lighting." The downlights contain Lumitech's PI-LED modules, in which greenish-white LEDs are combined with red and blue emitters to enable tunability with optimized efficacy.

One interesting, and perhaps surprising, aspect of Light+Building was the widespread appearance of OLED lighting modules, prototype luminaires and design concepts. Philips, Osram, Zumtobel, GE and others featured OLEDs as part of their exhibits, while for specialists including Novaled and NEDO, OLED was the main focus (see www.ledsmagazine.com/news/7/4/22). Osram Opto Semiconductors' booth featured an extensive OLED installation designed by LichtKunstLicht, and incorporating over 600 Orbeos OLED modules (see www.ledsmagazine.com/press/21427). Overall, Osram described its focus as sustainability under the banner "Sustainable products - choice for customers." The company showed the current stage of development for conventional lighting solutions such as halogen or CFLs, as well as the new generation of LED and OLED lighting. Osram reported that its PrevaLED light engine had achieved an efficacy of 122 lm/W, achieving a luminous flux of over 1,800lm while using only 15W of power. The warm white light (2700K) has a CRI of more than 90, and Osram says the light engine is suited to integration in downlights or spots.

In a booth named "OLED Japan", the New Energy and Industrial Technology Development Organization (NEDO) showcased energy-efficient OLED lighting technology, including products from Panasonic Electric Works and NEC Lighting. A video of the NEDO booth can be seen at www.ledsmagazine.com/news/7/4/22.

GE Lighting revealed the unique design of its 40W-equivalent Energy Smart LED lamp (www.ledsmagazine.com/news/7/4/9 and p.15) and provided a close-up view of its Infusion replaceable LED module and its LED streetlight, winner of a Best in Class award at the NGL competition (see LEDs Magazine April 2010). GE also launched the Tetra AL10 linear LED system with high color rendering (93 CRI) and stable color temperatures. Designed for retail and architectural applications, the slim and modular fixture offers multiple lengths, optical distributions and CCTs, and has a system efficacy of 47 lm/W, with optical precision in beam angles of 60, 90 and 120 degrees.

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- LED output current setting via LEDcode
- Highly efficient (90%) over a wide power range
- Integrated mains LED driver/controller simplifies setup and installation

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Megaman showcased a number of LED replacements for metal halide and MR16 lamps, all featuring the company's Thermal Conductive Highway technology. As shown in the photo, two LED arrays are mounted either side of an aluminum heat-bridge, which is connected to an exterior heat sink. Light is emitted into the reflector, which provides beam control. The LED lamp has a similar appearance to a halogen lamp, and Megaman says its 10W MR16 has the same light output as a 50W halogen, with CRI of 92 and a lifetime of 30,000 hours (www.ledsmagazine.com/press/21875).

LED maker Stanley has extensive experience in the automotive market, and for example showed an entire LED headlight system built for the Mitsubishi i-MiEV electric car. The company has a range of LED modules and LED devices, including the new J series package, which is available with color rendering of up to Ra = 95. The efficacy of the 5000K version with Ra = 70 is 134 lm/W with an output of 145 lm at 350 mA drive current. The 2700K version with Ra = 95 produces 85 lm with 78 lm/W efficacy.

In line with its decision to cease production of incandescent lamps and focus on LEDs, Toshiba unveiled a wide range of LED replacement lamps and downlights for the European market. François Séguineau, COO of Toshiba New Lighting - Europe, said the company intends "to make an active contribution to the coming revolution in the living habits and lighting consumption of European consumers." Masami Fukuda, president and CEO of Toshiba Lighting & Technology Corp., went further, saying "We want to see a world where all lights are replaced by LED." Toshiba also demonstrated a series of technology prototypes. Most impressive was an LED lamp with an output of 1690 lumen and a 260-degree angle of light distribution. This 85 lm/W lamp, equivalent in light output to a 100-watt incandescent, is 2.8 times brighter than Toshiba's 8.7W type LEL-AW8L LED bulb. For residential lighting, Toshiba showcased a 120 lm/W prototype as a replacement for linear fluorescent fixtures, and a bank light with an output of 22,000 lm. With a super-narrow beam of 3°, Toshiba's LED flood-light had a central luminous intensity of 1.72 million cd, surpassing the brightness of a 1.5kW metal-halide lamp with one-sixth of the power consumption.

EXACT CHROMATICITY COORDINATES

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

Sharp offers lighting designers and product developers a forward-looking LED portfolio for energy-saving general lighting applications – with more freedom in designing light fixtures because the shape and size of the luminaire is less restrictive. Whether single spotlight or wide-area ambient lighting, indoor or outdoor usage, Sharp LEDs are a shining example of extremely high colour rendering, utmost efficiency, maximum lifetime and minimal thermal dissipation – with colour temperatures from warm to cold white (2,200 – 11,500 K), various colour LEDs and compliance with the requirements of the international Energy Star Program. Sharp LEDs come in compact housings for big innovations in lighting. Have you seen the light yet?

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SHARP | Microelectronics

Alliance Optotek Corp (AOP) exhibited a series of street lights and flood lights built using its Optoblk module. Here, each of the three IP65-rated modules contains 24 high-power LEDs, with a typical output of 2600lm at 6500K or 1670lm at 3000K. The modules are 305 mm wide and weigh 1kg each, and different light distributions are available. An IP68 module contains 6 red, 6 blue and 6 green LEDs.

At Light+Building, Philips was "all LEDs, all the time," revealing for example its 60-watt-equivalent LED lamp that will hit the magic number of 806 lm. For OEMs and specifiers, Philips introduced the Fortimo twistable (see photo), a downlight engine designed to be easily replaceable as next-generation LED engines are developed. Philips also enhanced its relationship with Future Lighting Solutions (p.9), and showcased its Lumiblade OLED modules. On the outdoor lighting side, Philips showed luminaires based on its Ledgine platform, which allows easy upgrades to keep pace with improvements in LED modules and drivers. Through its LED Green Service program, Philips commits to ensure that all of a municipality's Ledgine luminaires have their LED modules upgraded at the right time.

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Popularization of LED Lamps

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Opening a new chapter of LED lamps
with very competitive price, standardized and light-weight design

NEW Benefits and Characteristics

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- Natural and soft light equal to conventional light bulbs
- High luminaire efficiency
- High light output with low power consumption: 480 lumens/5.8Watts models & 815 lumens/10Watts models (Pure White Model)
- **Very safe from electric shock as body of LumiDas-B&D is made of insulated plastic.**
- Unique cooling system using patented heat sink technology
- Dimmable/Non Dimmable
- High CRI of 83

LumiDas-B/D

Bulb Type / Downlight Type

5.8W
①ø63 × H109.5mm
②ø63 × H84.6mm

10W
①ø80 × H130mm
②ø80 × H107.8mm

LumiDas-CL

Candle Type

5W
ø52 × H135mm

Fixture-integrated Type

- Easy to install and uninstall
- More affordable prices!
- 3"(5.8W) / 4" (10W)

LumiDas-B 3.4W

Bulb Type (mini Krypton Type)

* Soon to be launched in 2010

- ø43 × H73mm
- E14 / E17 Base

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Among the products on the Edison Opto booth was the company's 100W EDIS-M100-X20 module for low/high-bay lighting applications. With a beam angle of 120° x 90°, the warm-white module has a light output of 4000lm at 3A drive current, rising to 5500lm for cool white. Edison's S Series high-power LED emitter, meanwhile, is capable of producing 120 lm at 350 mA and 200 lm at 700mA for the cool-white version, dropping to 95lm for neutral white and 85 lm for warm white (both at 350 mA).

Another company making its first appearance at Light+Building was Verbatim, a Mitsubishi Chemical company, which plans to introduce a wide range of replacement LED lamps, available via wholesale and retail outlets throughout Europe by the end of 2010. Initially these will use white LEDs based on blue LED chips in combination with phosphors. However, during 2011, Verbatim plans to introduce lamps that combine violet-emitting (405 nm wavelength) chips with red, green and blue phosphors. The resultant "Natural Vision LED" will enable lamps with a near-daylight color rendering index (CRI) of 98. Another advantage of the violet-chip approach, which is also used by GE in its Vio LEDs, is that the chromaticity of the white LED doesn't depend on the chip wavelength.

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Proven LED thermal management solution

Living Solutions by: Proven Thermal Solutions DSM Engineering Plastics

Stanyl® TC Thermal conductivity combined with design freedom for LED lighting

Developing a polymer solution for thermal management in LED applications was a challenging task. But finally the DSM Knowledge Team has found a solution they can warmly recommend. With Stanyl TC the heat dissipation is brilliantly combined with design flexibility and the high productivity of polymer technology.
Stanyl® TC is rapidly establishing a position as the material of choice for the LED Lighting industry. It's the first thermally conductive plastic which has an optimal balance of mechanical performance and heat dissipation properties.

It offers lighting producers and designers the ultimate design-freedom, whilst providing all the necessary metal replacement benefits, such as weight saving, higher productivity, easy processing and overall system cost savings.

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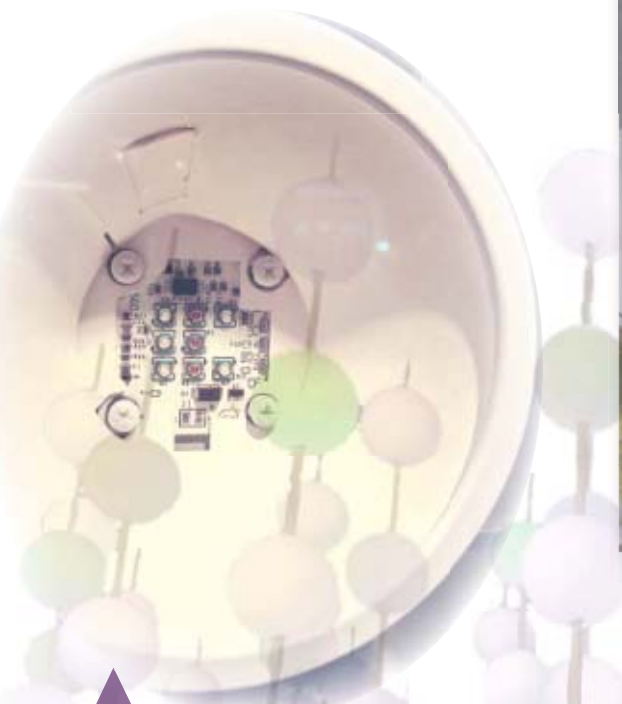
DSM Engineering Plastics

Unlimited. DSM

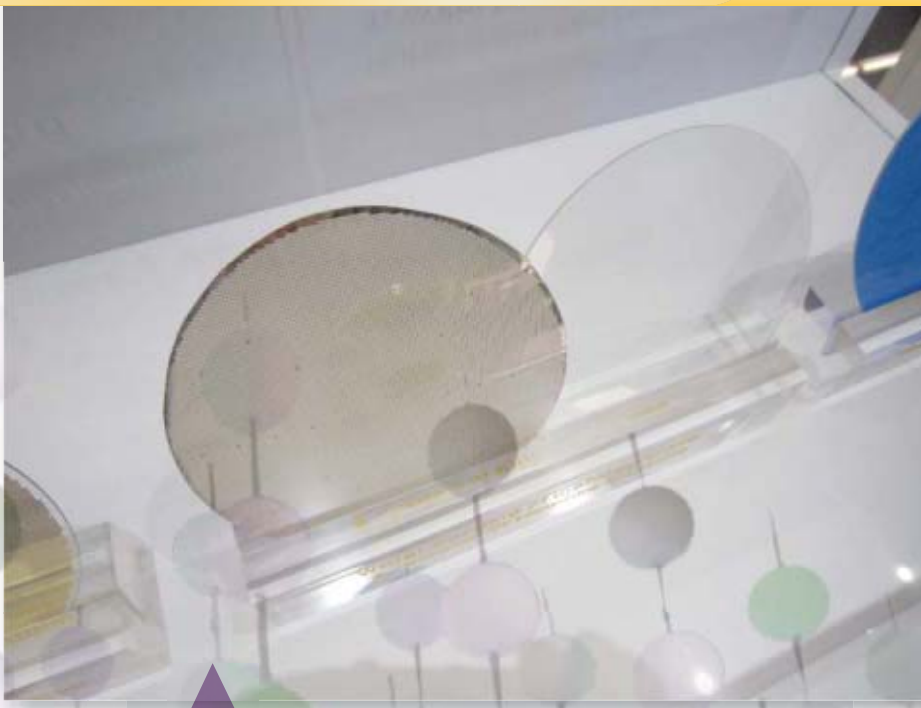
Nearly three quarters of the 40 exhibits on the Thorn stand incorporated LEDs, and the company has a Smart LEaDership program to incorporate LED technology into products "wherever it makes sense." Described as the "flagship" of Thorn's exterior offering, the StyLED road lantern comes in two outlines and four lumen packages, from 3000 lm (45W) to 10,000 lm (150W), catering for main roads as well as residential streets. The product will be marketed to municipalities when it becomes available this autumn. The optical design incorporates lenses to achieve the light desired distribution and baffles to reduce glare. An integrated timer enables automatic graduation of the luminous flux, and concepts in development include presence/motion detectors that will keep the lights dimmed until cars or pedestrians approach.

The Panos Infinity Stable White was one of several Zumtobel luminaires to use Cree's True White technology (www.ledsmagazine.com/press/21865), the result of an ongoing, multi-year collaboration between the two companies. The professional LED downlight family offers up to 2800 delivered lumens at 77 lm/W luminaire efficiency. The color temperature is either 3000K or 4000K and the Ra value is over 90. The luminaire is passively cooled due to novel aluminum extrusions that form the cooling ribs. The system is designed to be modular and future-proof. The LED mixing chamber and the cooling system are combined into one unit (at left), to guarantee a thermally-ideal connection even after replacement. This module is easily connected to the reflector optic (right). The Tuneable White version of the Panos Infinity uses Pi-LED technology licensed from Lumitech (www.ledsmagazine.com/news/7/3/1) to enable tuning across a continuous range of 2700-6500K, with Ra above 85.

Sharp highlighted the benefits of good color rendering with a catwalk show that demonstrated the use of LED technology to illuminate clothing and jewelry. The catwalk itself was made up of 6-meter long LED strips from LED Linear GmbH, each with a different color temperature. The strips contained DoubleDome LEDs from Sharp, which have a high CRI value of 85 due to the combination of blue LEDs with a special mixture of green and red phosphors.



Cree showcased a number of recent innovations, including its LMR4 module (www.ledsmagazine.com/news/7/4/4). As shown here, the module contains unsaturated yellow and saturated red LEDs, which are mixed according to the company's TrueWhite technology.



The shape of things to come: the photo shows 6-inch-diameter epitaxial (left) and sapphire (right) wafers from LG Innotek. The Korean LED maker is planning to commence mass production of LEDs on 6-inch wafers by the fourth quarter of 2010. The company makes vertical LED chips by wafer-bonding the LED layers to a metal support before removing the sapphire substrate. The company also disclosed details of its wafer-level silicon packaging, which can incorporate embedded zener diodes for protection, as well as its micro-lens array diffusers that remove hot spots and provide precise control of transmitted beams. LG Innotek also talked about Multi-Rank Mixing (MRM) to combine multiple LEDs from different bins to achieve the desired color point. "The LCD industry has learned the same problem 'the hard way' and has been successfully using MRM for its LED backlight units," said a poster. In addition to components, LG Innotek showcased an extensive range of LED modules for both indoor and outdoor luminaires.

As well as announcing a series of LED replacement lamps, Everlight unveiled a 3W version of its Shuen surface-mount LED which has an output of 170 lm at 700 mA, available in range of CRI options from 75 to 90 (www.ledsmagazine.com/press/21947). The company also announced the Zenaro Lighting Alliance (www.ledsmagazine.com/press/21946), of which Everlight and Texas-based Aphos Lighting are founder members. Zenaro will combine the core competencies of its members and provide products for street, interior, office and consumer lighting. Bernd Kammerer, General Manager of Sales and Marketing at Everlight Electronics, said "Combining global resources and product adaptations to multiple market segments with localized customer sales and support, Zenaro delivers product lines that meet and exceed exacting standards for performance and aesthetics for projects of any scale." On the issue of Zenaro bringing Everlight into competition with its own LED customers, Kammerer said that the experience of developing lighting products will help Everlight improve its components, for all its customers.

Efficient LED planar lighting begins at the light source

LED planar lighting is a new product category that uses LED technology to create large, flat surfaces of uniform light in a highly efficient way, writes **ITAI COHEN**.

Over the last decade we have witnessed mainstream market adoption of LED technology. This has been due to the phenomenal improvement in performance and reliability of high-power LEDs, and the reduction in cost that stems from high-volume manufacturing. These improvements mean LEDs have replaced traditional lighting in many applications. Early uses of LEDs included indication lights and traffic signals, while today we see a wide range of applications such as retail and display lighting, indoor and outdoor signage, wall-mounted fixtures, backlighting for LCDs, and even the replacement of incandescent bulbs. Developments in LED technology have also brought about the creation of new applications that did not exist before, specifically in the decorative and architectural lighting sectors.

One of the common denominators for many new applications of LED technology is planar lighting. LED planar lighting refers to the application of LEDs to create uniform surfaces of light. Since LEDs are a point source, creating large surfaces of uniform light has always been cost prohibitive, and has resulted in a significant loss of efficiency. However, a new technology has emerged that establishes LED planar lighting as a generic product category, without compromising on optical efficiency, product form factor or volume capabilities.

Market requirement for planar lighting

Planar lighting refers to large, thin, uniform surfaces of light. Planar lighting is ideal when there is a lack of physical depth or space for lighting fixtures, and where aesthetics and form factor are an advantage. Planar lighting also applies when space, cost and energy savings are imperative, when designers wish to reduce construction costs and are looking for a lighting solution with high lm/W and lm/$ ratios. Some planar lighting applications are built using light sources such as fluorescent lamps, usually resulting in a bulky fixture that is far from efficient.

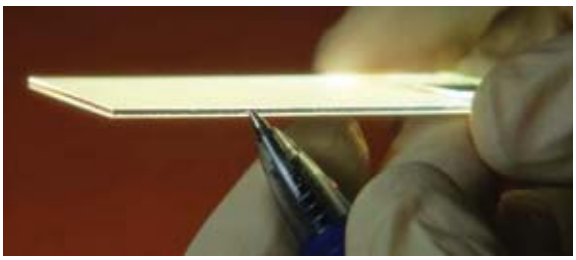


FIG. 1. Oree planar lighting modules.

On a short walk on any average street we are exposed to many planar lighting applications, such as advertisement light boxes, store signs, lighting in window displays and outdoor signage. An average office today incorporates planar lighting applications such as wall-mounted fixtures, under-cabinet lighting, task lighting, backlights for LCDs, and decorative and architectural lighting.

In all the applications mentioned above, and many more that were not mentioned, the inevitable transition to LEDs is made for exactly the same reasons as with any other lighting application: to reduce power consumption, eliminate hazardous materials, improve quality and lifetime, reduce thickness and allow controllability.

Planar lighting today

LED planar lighting refers to large, thin surfaces that are uniformly lit using LED technology. This type of LED-based lighting is intended to replace the current conventional solutions that are based mainly on bulky fluorescent lamps. Designers today want fixtures that are slim, energy efficient, simple to integrate, and have low construction costs. Although LEDs are superior in many ways to other light sources, they are still point sources and difficult to use when creating uniform surfaces. There is an inherent trade-off between thickness of the system, uniformity and efficiency. While it is relatively simple to create an efficient but very thick planar-lighting system with a projector, this is not a relevant solution for most applications. Reducing the thickness has a price, since applying secondary optics and diffusers to eliminate the point source and extracting the light requires a tremendous amount of energy.

ITAI COHEN *is vice president of business development at Oree (www.oree-inc.com), a planar-lighting company based in Tel Aviv, Israel.*

One of the main factors to consider in planar lighting is optics. The way light is converted from the source determines how energy efficient the system is. Designers consider both how to maximize the light coming from the LED inside the fixture, and how to extract it in the right direction.

To achieve a space-efficient and slim structure, designers traditionally place LED lights in a "planar" fixture that pulls off the flat effect, sacrificing light and efficiency in the conversion. However, by flattening the LED light source itself, the fixture would be planar oriented from the outset, and energy loss would be minimized.

Approaches to LED planar lighting

There are two basic approaches for LED planar lighting: back-lit and edge-lit. Both use general-purpose LEDs, and employ an external structure to force the light to create a uniform surface.

In both cases the "price" for uniformity and slim design is "heavy." In a backlit configuration the need for uniformity requires the use of many LEDs, resulting in an expensive system. On one hand, the optical loss when eliminating hotspots created by the LEDs is 50-60% and this would still leave a fixture thickness of over 30mm. On the other hand, the visual result is very good, highlighting the advantages of LEDs in terms of color, high color-rendering index (CRI), dynamic correlated-color temperature (CCT) and controllability.

By applying edge-lit technologies, one can create very thin structures at a relatively low cost, however the efficiency will not exceed 70% and the intrinsic advantages of LEDs will not be shown.

Oree has recently developed a new approach to planar lighting, which effectively repackages the LED point source so it sits in an ultra-thin structure. The technology utilizes proprietary LED optical packaging which allows LED chips to be embedded into a planar and thin lightguide. With advanced micro-optics, this enables color mixing within a small distance, as well as even distribution of light over the entire planar surface. By applying novel technology to control the light, the result is the first cost-effective, ultra-thin, highly energy-efficient lighting module that addresses sizable applications (Fig. 1).

There is a double benefit here. First, the lighting module contains the LED chips in a unique structure that is designed from inception to allow more of the extracted light to be utilized, and directs it through a series of micro-optic structures into a light guide with minimal loss of energy.

The second benefit is the high light-output ratio (LOR) of a system that is built by combining multiple lighting modules. Since the module is a uniform surface of light, the energy needed to achieve uniformity across a large surface is minimized. By connecting modules like roof tiles, designers achieve the most efficient LED planar lighting surface.

Future development roadmap

Recognizing that large-area lighting applications have specific requirements, and that there is a significant advantage to building a dedicated light source rather than using a general-purpose LED, Oree's planar lighting approach is translated into a product roadmap that is based upon the original product platform with specific features that correlate to different applications. As shown in Fig. 2, these are:

- A controllable RGB version that addresses decorative luminance applications, backlights for LCDs, and large outdoor signage markets.
- A tunable-white version for high-end indoor luminance and illumination applications that require controllability and a "fixed white".
- A white solution for the general lighting market where efficacy is critical.

Products currently focus on supplementing existing luminance applications in order to establish a volume curve and credibility in the market before addressing larger-volume functional lighting applications.

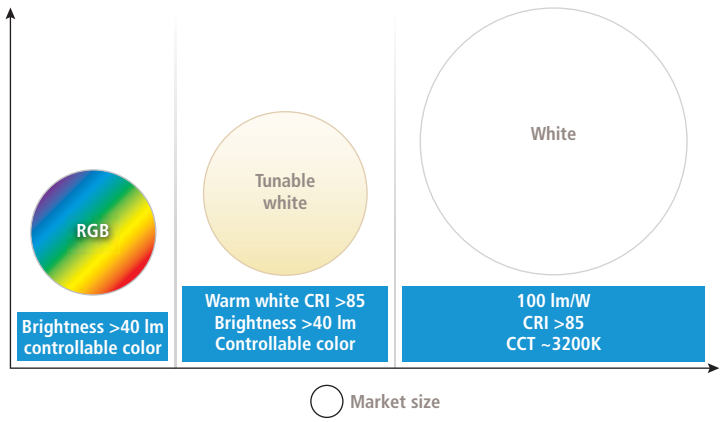


FIG. 2. Roadmap for planar lighting products in different markets.

Competing technologies

This overview wouldn't be complete without mentioning the OLED technology currently being developed by some of the leading lighting companies. OLED technology carries the ultimate promise of planar lighting and potentially offers performance levels comparable to the Oree planar technology. However, the efficacy of OLED is still inferior and it remains to be seen whether it will ever reach the volume, performance and price point of inorganic LEDs. Oree planar lighting products use standard LED chips and proven technology. Commercial launch of the RGB and tunable white products is expected by the end of 2010, with the fixed-white product to follow shortly after.

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LED-based T8 replacement tubes struggle as fluorescent retrofits

Early LED replacements for 4-ft, linear fluorescent T8 tubes don't deliver sufficient light output to make them cost-effective SSL retrofits, but the products will get better along with LED improvements says **MAURY WRIGHT**.

The pitch is enticing. Replace your commonly-used 4-ft, linear fluorescent T8 tubes with LED-based solid-state-lighting (SSL) technology and save money based on energy usage and maintenance. The long life and energy-saving attributes of LEDs have proven compelling in a number of applications. Unfortunately, early LED T8 retrofit products don't deliver fluorescent-equivalent light output. Moreover the need in most cases to modify the fluorescent fixture – primarily the removal of the ballast – leaves both technical and regulatory obstacles to widespread LED tube deployment. Indeed LED T8s need a lot of work, but the products will improve as LEDs get brighter and manufacturers optimize both the optics and the drive circuits.

Negative news of LED T8 tubes has arrived regularly and recently directly from the US Department of Energy (DOE). In yet another round of CALiPER (Commercially Available LED Product Evaluation and Reporting) tests, LED-based T8s performed far worse than fluorescent tubes. In his keynote presentation at Lightfair 2010 on May 11, DOE Lighting Program Manager Jim Brodrick stated, "We have yet to test one that works very well. [Relative to fluorescents you get] half the light output and half the efficacy."

Brodrick publishes a weekly *Postings* email (www.ssl.energy.gov/postings.html), and the March 16 and April 16 editions both discussed T8 LED replacements. Moreover the DOE held a webcast on March 18 on the topic and that archive is available online (www.ssl.energy.gov/interior-office_webinar.html).

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

T8s represent a huge opportunity

The webcast and the emails hammer home several key points. Brodrick pointed out that the T8 issue is of interest to many people because "there are tens of millions of these fixtures in use in this country alone." The huge installed base means that a more efficient SSL replacement could save significant energy. The installed base also offers a tremendous potential business opportunity to companies that develop a cost-effective SSL replacement.

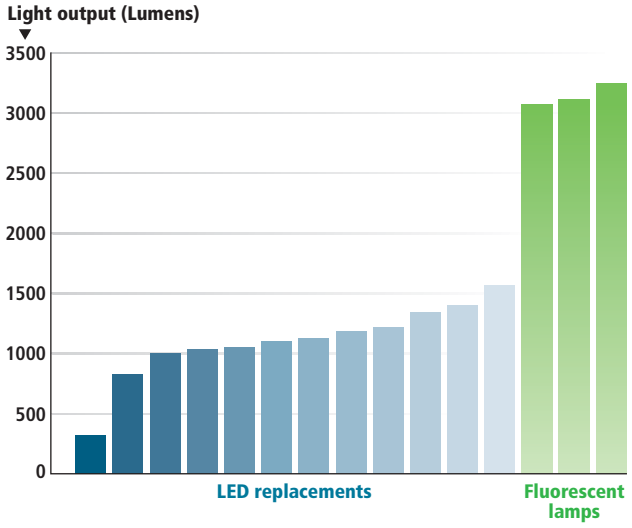


FIG.1. LED-based T8 tubes trail fluorescents significantly in light output. (Courtesy of the US DOE.)

Apparently the market potential has led some manufacturers of T8 replacements to publish product specifications that exceed the actual capabilities of their products. In the March *Postings*, Brodrick wrote, "Most of the manufacturers of SSL linear replacement lamps tested in Round 9 [of CALiPER] provided incorrect data, with some promising as much as 50% more lumens than their product delivered." Unfortunately the actions could result in distrust that might hamper LED T8 use even when better products emerge.

Anyone can register and view all of the CALiPER test reports. But the DOE recently published a fact sheet on the T8 issue summarizing the recent tests (www.ssl.energy.gov/factsheets.html) and has followed with a more detailed paper.

Consider Fig. 1. The graph slows the measured light output for the 12 LED T8 tubes that the DOE has tested relative to some typical fluorescent tubes. The graph clearly backs up Brodrick's Lightfair statement.

The DOE fact sheet compares the light output and efficacy of bare T8 LED and fluorescent tubes, as well as the light output and efficacy of the tubes in fixtures. DOE Program Manager Kelly Gordon described the method that the Pacific Northwest National Laboratory used to measure the bare lamp output saying, "It's put into both an integrating sphere and a goniophotometer. The gonio travels around the lamp and measures the intensity at different angles." The tests are those prescribed by the LM-79 standard.

Measured with two tubes in a fixture, the LED products averaged 1563 lm while the fluorescents averaged 4064 lm. The only win for the LEDs came in fixture efficiency. More of the light generated by the LEDs made it out of the fixture. That fixture efficiency was calculated based on measurements of the bare-tube light output and the fixture light output. The LEDs averaged 83% while the fluorescents averaged 66%. Clearly the directionality of LEDs provided the advantage. But as Brodrick wrote, "This wasn't enough to compensate for their much lower light output.

The brighter fluorescents present a stout challenge, especially given the cost differential. The LED-based T8s that the DOE tested range in price from $50 to $150 whereas fluorescent T8s cost around $3. The LED T8s do use less energy, generally under 20W per tube, whereas typical fluorescent tubes use more than double that amount of power. But there is no significant energy saving when you compare efficacy. Some of the LED T8 makers claim life as long as 50,000 hours whereas fluorescent T8s are typically rated for 24,000 to 36,000 hours.

Modifying the fixture

There are additional issues with the SSL T8 technology. The replacement lamps aren't generally true drop-in replacements the way an LED or CFL bulb can directly replace an incandescent bulb. Of the T8s tested by the DOE, all but one requires that the fluorescent ballast be electrically removed and the AC line connected directly to the electrical contacts in the tube connector base.

The retrofit process is potentially problematic in two ways. First, it is costly in that the rewiring will generally require the services of an electrician. Second, the rewiring apparently invalidates the UL approval that applies to the fixture.

At Lightfair, there was an ongoing debate about the position of UL on retrofits. Some of the LED T8 makers suggest that organizations place a sticker in modified fluorescent fixtures advising that the fixture has been modified and that it is no longer compatible with fluorescent tubes.

Contacted after Lightfair, John Drengenberg, Consumer Safety Director at UL, provided a detailed assessment. Discussing a T8 fixture, Drengenberg stated, "When you modify a product, it does invalidate your UL listing." But Drengenberg also notes, ""We do authorize and we do have coverage for products that can be retrofitted into existing fixtures."

A number of LED T8 makers have received UL certification for the tube itself, and that's the process that UL will use to cover retrofits. However, the tube maker must do more than supply a safe LED T8 tube to get certification. The manufacturer must also supply detailed instructions for the retrofit procedure to receive certification for the tube. Drengenberg said, "We make sure the instructions say what to do, what not to do, and how to do it."

Drengenberg has no problem with manufacturers providing some type of sticker noting that a retrofit had taken place, but UL does not require such a sticker. Drengenberg said, "You have to make some assumption that somebody replacing an LED tube, would certainly be able to notice that when they open up the fixture that it's not a standard fluorescent bulb."

In reality, the connection of the line voltage to the tube contacts shouldn't pose any worse hazard than a ballast connection to those contacts. Modern electronic ballasts output a high-frequency AC voltage in the 600V range.

There will be similar retrofit concerns in other countries around the globe. Indeed there have been rumors that LED T8 retrofits might be banned throughout Europe. Andy Davies, Senior Product Manager for GE Lighting based in the UK, said, "There has been quite a lot of discussion about [LED T8s] in various industry committees and it's true that there is concern in many quarters regarding the safety of such products. However it is not clear at present whether or not this will lead to an outright ban. I think that more likely there will be a set of criteria established that determine minimum performance and safety requirements for such products that would effectively outlaw unsafe and inefficient products whilst leaving the door open for potential good quality high efficiency units."

Davies also pointed out that the concern in Europe about T8s isn't just focused on safety. He said, "It's clearly ironic that halophosphate linear fluorescent lamps are being phased out on the grounds of poor CRI and low efficacy (compared to tri-phosphor types) whereas low quality LED replacements that may have similar or worse efficacy or CRI are still allowed."

Energy Star excludes LED T8 tubes

For now there is no Energy Star specification for LED-based T8 tubes. The DOE's specification for "Integral LED lamps" explicitly excludes linear replacement lamps.

The US Environmental Protection Agency (EPA) has since taken the reins of the Energy Star program. When asked about the omission of T8 lamps, Alex Baker, EPA Energy Star Lighting Program Manager, said, "My understanding is that the DOE analyzed the various lamp types that would be included in the scope of that specification and based on their analysis they concluded that SSL linear fluorescent replacement simply would not be cost effective."

Baker points out that the Energy Star program focuses on cases where the buyer of an energy-efficient product can recoup the extra investment in five years or less. Baker also noted that Energy Star regularly revises specifications and T8s certainly could be addressed down the road. Based on recent DOE LED T8 tests, however, there is no near-term plan to cover the tubes in an Energy Star specification. ◄

A ballast-powered LED T8

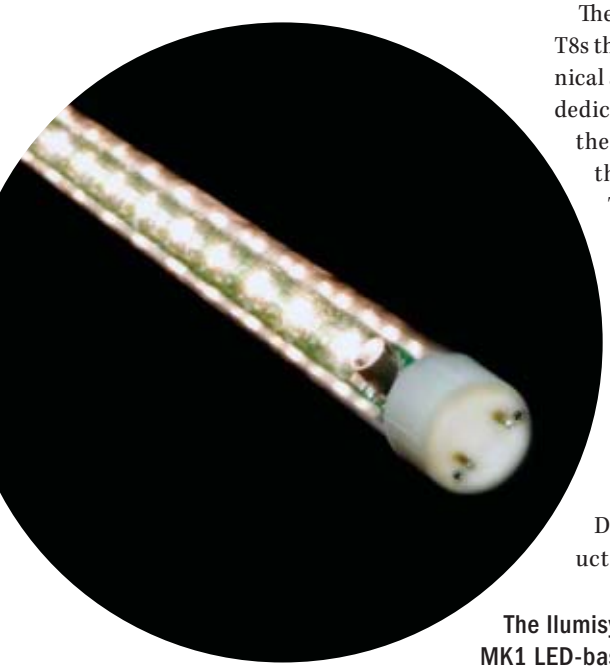
Although it appears tube makers have a path to approved retrofits, LED T8 tubes that work with the existing ballast clearly wouldn't have any regulatory or safety issue. But Jordon Papanier, Marketing Manager at LED T8 manufacturer LEDtronics, stated, "Designing an LED T8 that works off the ballast would drastically reduce the energy efficiency since the ballast puts out a very high voltage."

Ilumisys is the lone manufacturer of a DOE-tested LED T8 that can operate from a ballast. The company offers the MK1 that runs from a ballast and the MK2 that requires the ballast to be removed. Vice President of Technology Jack Ivey agreed that generally a tube connected to a ballast will be slightly less efficient than one connected to line voltage. Ivey claims that with some ballasts the difference is negligible while in a worst-case condition the ballast-connected tube efficiency would drop less than 20%.

Ilumisys President Dave Simon still sees the ballast-capable product as important stating, "We see people using the MK1 to evaluate LEDs." Simon's point is that an organization considering a retrofit could easily trial LED lighting with the MK1 model although they may ultimately remove the ballasts in a broader retrofit.

Simon also remains bullish on LED T8 replacements. He says that Ilumisys has supplied products to a number of pilot

installations. He claims that in some cases, such as California installations where energy costs are high and utility rebates are available, organizations can see payback on T8 retrofits in three to four years. And Simon believes in improving LED technology stating, "We're betting the LEDs, being very early in the game, are going to be better." He noted that when LEDs hit 140 lm/W, LED T8s would surpass fluorescent performance.



The Ilumisys MK1 LED-based T8 tube can operate from a fluorescent ballast and serve as a true drop-in replacement for fluorescent T8 tubes

There is one additional approach to LED T8s that might yet prove to be the best technical alternative. Some companies supply a dedicated AC/DC power supply to replace the ballast rather than trying to cram the power converter inside the tube. The logic is that if you have to rewire the fixture anyway, you can just as easily add the converter.

Two impressive LED T8 demos at Lightfair used the dedicated converter approach. MaxLite showed the F32 23W LED T8 with a claimed 50,000-hour life and 71-lm/W luminous efficacy. That efficacy falls at the high end of the DOE-tested T8s assuming the product performance matches its own spec.

The MaxLite product uses a diffuser to spread the light 360 degrees and looks more like a fluorescent tube than do other LED T8s. That might be considered a disadvantage given that directionality is generally a benefit of LEDs. But in the second recent paper the DOE published on T8 replacements, the testers reported that LED T8 lights don't spread light in a room the way fluorescent tubes do. The spreading is in part due to the parabolic reflector design in troffer fixtures. Most LED T8s don't leverage those reflectors but the MaxLite product will.

The second LED T8 with an external driver is the LEDRetro8 from Global Marketing Lighting. The published specs for the product fall at the high end of the DOE LED T8 tests.

Christopher Boyhan, president and CEO of Global Marketing Lighting, commissioned a study on a LEDRetro8 deployment in an Asbury Park, NJ apartment building. The deployment replaced hallway T8s on one floor of the building with LEDRetro8 tubes and drivers. An electrical-distribution company called SDM Metro surveyed the deployment reporting higher foot-candle readings on the LED floor as well as 79% energy savings.

The LEDRetro8 design relies on an aluminum substrate that hosts the LEDs as well as an aluminum half cylinder that forms the rear half of the tube – both designed to aid cooling. The tubes were powered on continuously at Lightfair yet remained cool to the touch. Boyhan believes that the external driver approach is the right one stating, "An internal ballast will never last for 50,000 hours."

A three-stage power supply efficiently drives multiple LED strings

A PFC stage, an inverted constant-current buck regulator, and a downstream DC/DC transformer circuit can drive LEDs with better than 90% efficiency says **JAMES ALIBERTI**.

Higher-power LED lighting applications such as street lights, high-bay stadium lighting and others favor multiple-string architectures for a multitude of reasons, including ease of design, flexibility and safety. The main engineering challenges are efficiency, long life and uniform light output, to name a few. Long life and higher efficiency play a critical role in the overall value proposition in LED lighting systems as they are needed to reduce costly maintenance occurrences.

Multiple buck regulator approach

The multiple buck regulator approach has a few advantages, which are mainly simplicity and fast time-to-market. This approach can be significantly more expensive, however, especially as the number of LED strings increases; this requires more buck regulators. A simple buck-regulator circuit typically consists of a pulse-width modulation (PWM) controller, inductor, MOSFET, diode, and a handful of resistors and capacitors. If higher efficiency is required, you can replace the free-wheeling diode with a MOSFET and use a PWM controller that enables synchronous buck operation.

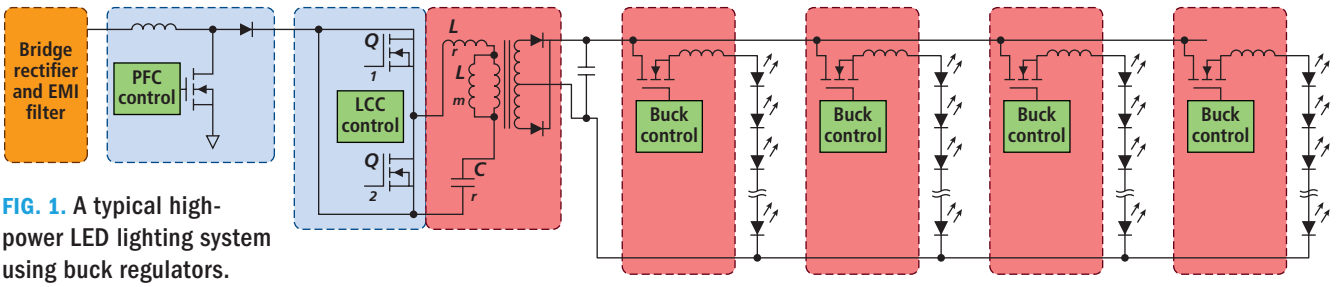


FIG. 1. A typical high-power LED lighting system using buck regulators.

The most popular approach to multiple string architectures is to purchase an off-the-shelf power supply with a power factor corrected (PFC) front-end with an isolated constant-DC output voltage where the output voltage feeds a regulator for each LED string. To maximize efficiency, the preference is to use buck regulators and a power supply with the highest possible DC output that is still within Class II or SELV maximum voltage levels of 60VDC. For this approach, I recommend using a 36V or 48VDC output as they are ordinary off-the-shelf power supplies commonly used in telecommunications applications.

An alternative approach is to use multi-transformers as shown in Fig. 2, based on TI's SimpLEDrive technology. This method uses a three-stage approach, comprising a PFC section, an inverted constant-current buck regulator, and a downstream DC/DC transformer circuit. This approach offers better than 90 percent efficiency and advanced string-current regulation that produces the highest quality, most uniform light output. It also can be made redundant for improved reliability by adding individual string crowbar circuits made up of passive-acting silicon-controlled rectifiers (SCRs). In the event of a single LED open, the crowbar efficiently shorts out the faulty string, while still maintaining good current regulation to the remaining strings. These attributes, along with a lower total system cost and modularity, make multi-transformers a model LED lighting power supply solution.

When using the multi-transformer approach, notice that this is an electrically isolated design where secondary side output voltages can be designed to stay within UL Class II or SELV levels, or 60VDC or 42VAC. With output voltage within these levels, it can greatly simplify the lighting fixture design, hence, eliminating repetitive safety agency approvals. This feature adds inherent flexibility allowing the same power supply to address different fixture designs for other lighting applications.

When it comes to operation, the multi-transformer approach has better string current matching of greater than one percent.

JAMES (JIM) ALIBERTI *is a product marketing engineer for Power Supply Controls at Texas Instruments where he is responsible for technical marketing of LED solutions. Jim can be reached at ti_jimaliberti@list.ti.com.*

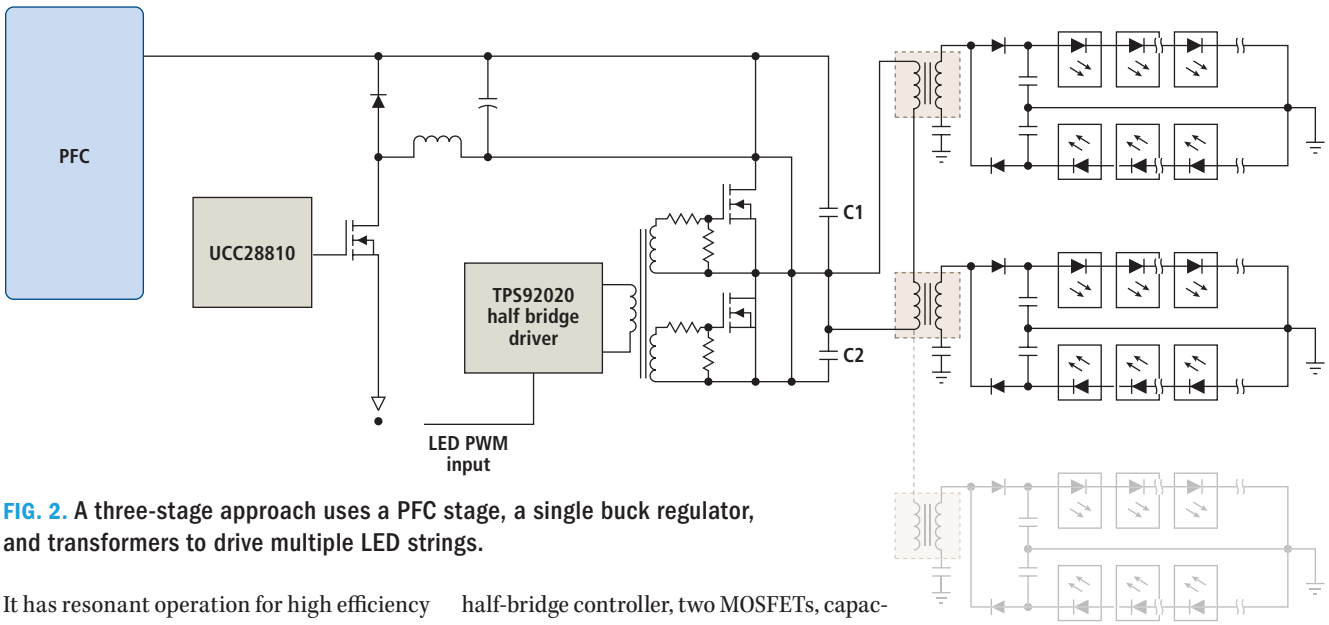


FIG. 2. A three-stage approach uses a PFC stage, a single buck regulator, and transformers to drive multiple LED strings.

It has resonant operation for high efficiency while the solution becomes more cost-effective as the number of strings increases.

Inside the three-stage approach

The output of the PFC circuit is a boosted DC voltage set at about 10–20 percent above the peak of the input line voltage. The PFC output is fed to the next stage, which is an inverted buck regulator configured to produce constant current output. The inverted buck is where the primary-side constant-current control loop is closed. The buck's current output is fed downstream to the DC/DC transformer circuit, which consists of a half-bridge controller, two MOSFETs, capacitors C1 and C2, and transformers.

This current from the buck then commutates through the half-bridge's MOSFET switches to the primary sides of the series transformers. Capacitors C1 and C2 serve a number of functions including as a voltage divider for the half-bridge, elements of the resonant circuit, and DC-blocking capacitors, which prevents transformer saturation.

The resonant operation allows the MOSFETs to operate with zero-voltage switching (ZVS). This significantly reduces switching losses and provides the option to operate at even higher frequencies to shrink the passive component sizes and maximize power supply efficiency.

The DC/DC stage converts the DC to AC current and commutates alternating current through the primary side of all the series transformers. This approach offers more flexibility as it allows more transformers to be put in series supporting more LED strings.

To calculate the turns ratios, we need the total number of strings and a good approximation of the LED string forward voltage. Assumptions are based on each string with the same number of LEDs.

Designing for maximum efficiency

In power-supply design, the best practice for maximizing efficiency is to process the least amount of power as possible. To do this, we need to minimize the ratio of output-to-input voltage where the output should be as close to the input voltage as possible. Since most high-power lighting applications require PFC, for simplification purposes, we consider it as a functional block and assign a typical value to its output and understand that it can and will vary depending on a number of factors.

Most active PFC circuits operate as a boost, so the PFC output voltage must be set higher than the peak of the highest AC line voltage. For a universal input range power supply, this is 85 – 265VAC, producing a peak voltage of about 375V. Headroom is added for tolerances and ripple, so 400V is a typical set point.

The 400V from the PFC section is fed to the input of the downstream inverted buck converter. Considering that the inverted buck needs to maintain regulation, if the output of the PFC varies from say AC line ripple which is typical in active PFC power supply designs, we need to determine the minimum output voltage of the PFC circuit. If we assume a typical ripple content of about 40V, all dictated by the LED load and bulk storage capacitance, then subtracting the 40V from the 400V leaves us with 360V as the minimum input for the inverted buck.

The inverted buck also needs to be designed with some operating compliance voltage output which also requires some compliance. So, in this case we will allow 80V, which makes the output 280V.

A 10-LED string example

Now that we have our operation boundaries fixed, let's look at a design example that explains how to calculate the constant-current set point of the inverted buck and how to determine the transformer turns ratio.

In this example we use two transformers to drive four LED strings with 1A current. Each string has ten high-power LEDs. We will assume an LED forward voltage (V_f) of 3.5V making the total string voltage 35V.

The 280V output from the inverted buck regulator is now the input to the DC/DC transformer circuit. The applied voltage to the series primaries is half the 280V from the capacitor voltage divider made up of C1 and C2. This results in 140V across the total series primary-side transformer arrangement. The primary voltage (V_P) of each transformer is the bridge voltage (140V) divided by the number of transformers (2), so that V_P = 70V.

Calculating the turns ratio now becomes simplified, as Equation 1 indicates:

$$\frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{70V}{35V} = 2 = \text{a turns ratio of 2:1}$$

Equation 1

N_P = Number of turns on the primary
N_S = Number of turns on the secondary
V_S = Secondary side or LED string voltage
V_P = Voltage across each primary winding

Calculating set points

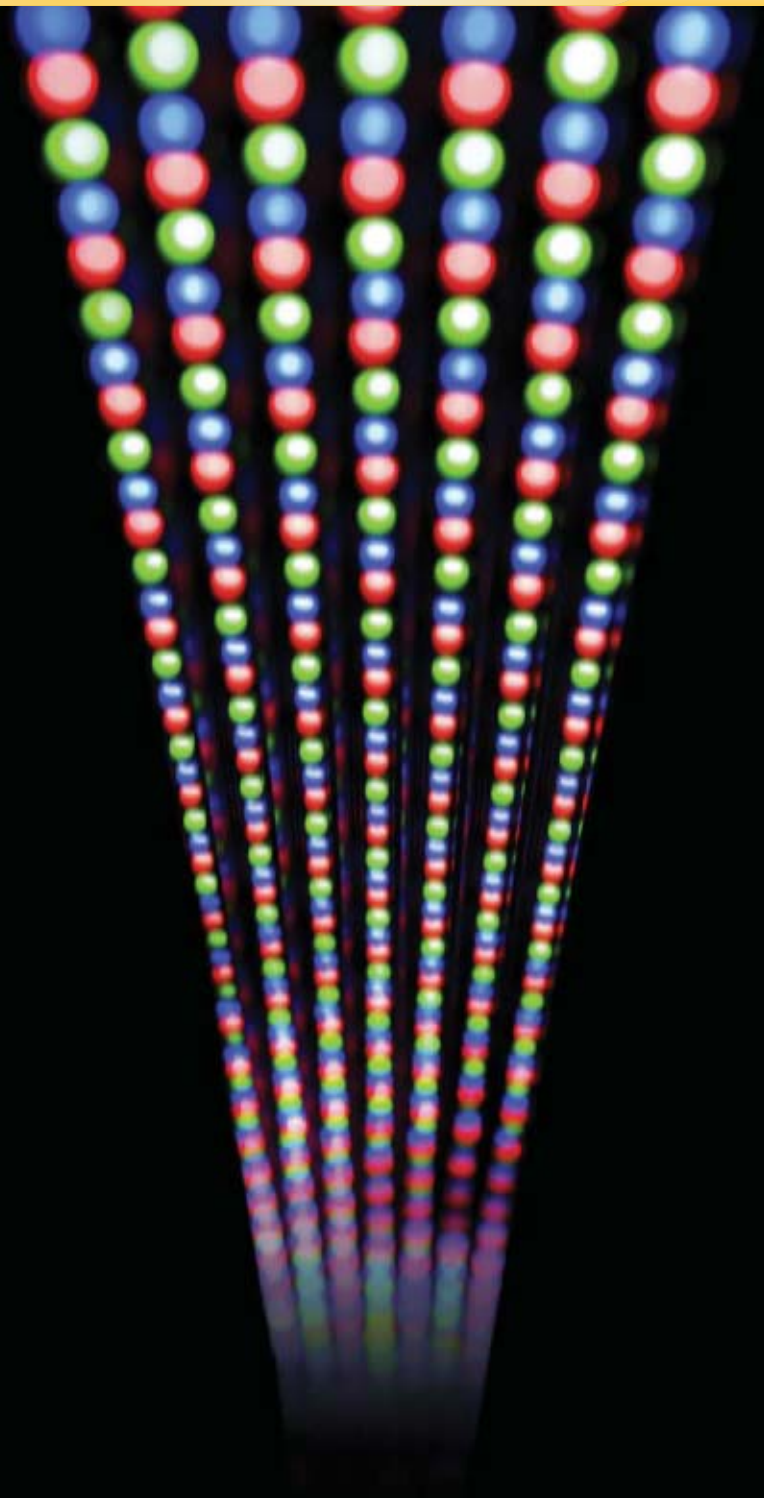
To calculate the inverted buck's current output set point, simply look at the total output power of the combined LED strings and work back to the inverted buck stage where the current control loop is closed. With four strings of 10 LEDs driven at 1A current, this equates to a total output power of 140W. With the inverted buck-regulator output voltage set at 280V, the current output should be approximately 500mA. Some losses will occur further down-stream from the buck regulator, so minor adjustments to the inverted buck regulator may be required.

Equation 2 calculates the buck regulator's current set point (I_{Set}).

$$I_{Set} = P_{LEDS}/V_{Buck} = \frac{140W}{280V} = 0.5A$$

Equation 2

This exercise illustrates how designing with multi-transformers is fairly straightforward. By making simple adjustments you can meet the requirements to address various LED currents or different numbers of LED strings. This modular solution addresses many lighting applications with little redesign.



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manufacturing | **COST REDUCTION**

Bringing down the cost of high-volume LED production

Collaborative efforts and government-funded research projects are targeting significant improvements in LED manufacturing costs, writes **PAULA DOE**.

If manufacturing technology development efforts now underway produce even a fraction of their projected improvements in production efficiency, solid-state lighting cost per lumen should come down drastically in the next few years. Driven by the growing market opportunity, and by $23 million in funding by the US Department of Energy (DOE), semiconductor equipment makers and their device-maker partners are at work on a series of projects. Each of these aim at major 30-50% improvements in basic manufacturing cycle time, yield, and cost, in part by applying approaches learned from high-volume semiconductor production (see www.ledsmagazine.com/news/7/1/12).

The greater semiconductor supply chain is starting to turn serious attention to the particular needs of the HB-LED market, as almost $1billion will be invested in building and equipping device-production facilities this year, according to SEMI's Opto/LED Fab Watch (see Fig. 1).

Targeting improvements

And now that it has their attention, semiconductor equipment makers think there's some low-hanging fruit to be harvested. Companies discussing their recently-funded development projects at the April DOE manufacturing workshop in San Jose, California, were targeting eyebrow-raising step-change improvements across almost all of the basic measures of manufacturing efficiency and quality consistency in the next few years. Many of these companies, and others working independently on disruptive manufacturing technologies, will also report further on their progress at the HB-LED manufacturing technology session at SEMICON West in San Francisco (see below and Links box).

Applied Materials' Nag Patibandla, director of external programs, said his company is working on a multi-chamber epitaxy tool using its IC-industry workhorse Centura platform, with one HVPE chamber and two MOCVD chambers, and in situ cleaning to speed up the cycle time. It uses lamp heating for better temperature control, reportedly allowing a very rapid temperature ramp of 5°C per second for sharp interfaces. Applied is targeting a 2X improvement in uniformity, 50% reduction in cycle time, and 50% improvement in quantum efficiency.

Veeco Instruments targets the very ambitious goal of 90% yield within the desired 2nm wavelength bin by 2013, enabled in large part by better temperature control. This starts with figuring out how to actually measure the temperature on the transparent sapphire wafer directly, instead of having to go by the temperature of the holder as currently done. Each 2°C temperature change results in a 2nm drift in emitted wavelength, and now perhaps only some 65% of die may be within 5nm. Sandia Labs has developed near UV and mid IR pyrom-

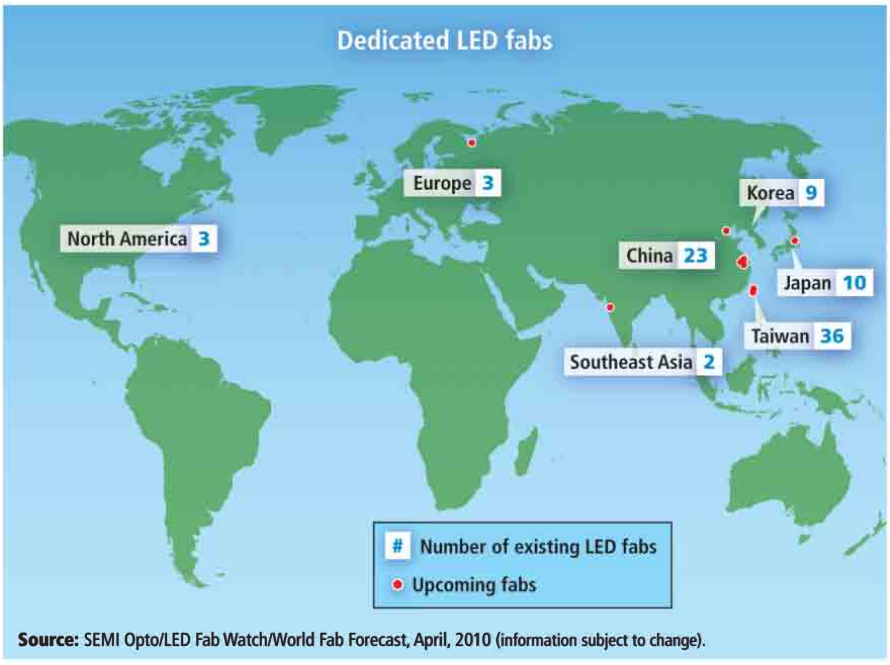

FIG. 1. Map showing number of existing, dedicated LED chip fabrication facilities in different countries and regions, as well as locations of upcoming fabs.

PAULA DOE *covers Emerging Markets for SEMI (www.semi.org), the global industry association serving the manufacturing supply chains for the microelectronic, display and PV industries.*

eters that can measure the temperature on the wafer directly, and Lumileds will test them in production. "We'd like to change the temperature profile across the wafer in real time," said Veeco chief technologist Bill Quinn, "and add model-based temperature control as used in the IC industry."

KLA-Tencor sees potential 50% cost savings from adding automated inline inspection to the LED manufacturing process. It is working on more sensitive tools to monitor the epi process for micro cracks, pits and epi uniformity, and software to more quickly correlate process excursions with end device performance. "This is used in the IC space," noted Srini Vedula, director of marketing for the Candela product. "The goal now is to understand the LED requirements." He argued that while most device makers worry about the major excursions that have a big impact on yield, these are actually rather rare, and are usually detected by the operators right after epi anyway. Actually more costly are the more common small excursions that hit yield by 4-6%, but happen once or twice per reactor per month, and cannot now be detected. "Half of front-end defects are not accounted for," said Vedula. "Automated excursion notification for root-cause determination is a 2x cost reduction opportunity."

Ultratech is targeting a 50-60% reduction in lithography tool cost-of-ownership by reconfiguring a projection aligner specifically for the needs of the LED industry. Unlike the usual proximity aligners, projection tools can be designed to maintain alignment and CD uniformity across warped wafers. The company is adding higher brightness illumination, and a lower cost lens for what CTO Andy Hawryluk said aims at a 40% lower cost tool with 30% higher throughput.

GE Lighting Solutions is bringing down the cost of phosphor-coating its LEDs by developing a high-speed, automated, continuous process line to make molded phosphor domes, instead of coating phosphor slurry onto chips in batches, for an estimated 20-50% reduction in cost. The approach involved developing a new line of process equipment with an outside vendor, and new in-line continuous metrology tools, instead of the usual one-off testing in optical spheres.

Philips Lumileds is aiming to make commercially-competitive warm-white LEDs on silicon substrates, using strain-control layers of AlN. It will start with 3-inch substrates, then transfer to 150mm wafers. Silicon is of course cheap and familiar, but section manager Michael Craven also pointed out that, "The better thermal conductivity of silicon results in decreased thermal gradients across the wafer, and the opaque substrate means temperature can be measured with existing optical pyrometry tools for better run-to-run consistency."

Applied, KLA, and Ultratech will be reporting further on the progress of these technologies at the HB-LED manufacturing program at SEMICON West on July 14 (see

Links). Other technical talks on significant developments in manufacturing technology include UCSB startup Inlustra on progress in nonpolar bulk GaN substrates for fewer defects; the Chinese startup Lattice Power on producing blue LEDs on silicon; Philips Lumileds on research progress in device efficiency; EVGroup on applying wafer-level packaging technologies from the MEMS sector to LEDs; Op-Test on appropriate bare-die testing measures that feed back real-world results to process controls; QD Vision on controlling light color with quantum dots, and Articulated Technologies on a minimalist approach to packaging by laminating die between ITO and copper strips. Strategies Unlimited will also give a market overview.

Other collaborative efforts

Also pushing the technology along are some early steps towards some of the pre-competitive collaborative efforts that have previously helped the IC, LCD and PV sectors drive down manufacturing costs.

The DOE's funding for LED manufacturing research is a big step. But almost as important is the way the DOE's annual workshops have helped push the US solid-state lighting manufacturers and suppliers into talking with each other about common issues, such as where best to focus investment to solve the sector's key technology issues going forward. SEMI is helping to push these issues forward as well, with its programs on device manufacturing technology at its shows worldwide, and its LED steering committee of industry executives exploring things like roadmaps, cost models, and common materials specifications and testing protocols. DOE and the supply chain are now starting work on building a common LED cost model, which aims to provide the industry with a more accurate picture of both the costs and the dependencies among processes, to determine where best to put resources to improve yields and reduce total costs.

The working sessions at the April 2010 DOE workshop identified the next key manufacturing technology needs, including epi materials, wafer-level packaging technology, better test metrics that feed back to manufacturing from all levels, and better metrics and failure analysis to improve driver reliability. Those in the phosphor sector wanted better tools tailored to LED production needs, with SECS/GEM compliance for eventual automation, to move to larger batch sizes, and towards turning the phosphor coating into a separate component. Chip users urged standardizing package footprints. DOE's funding of projects is guided by the roadmap that comes out of these workshops. The updated roadmap is due out in June.

LINKS

A one-day program entitled "More Lumens per Dollar: The Road to More Efficient HB LED Manufacturing– Progress and Next Challenges in Front-end Manufacturing" takes place on Wednesday July 14 at SEMICON West in San Francisco. www.semiconwest.org/SessionsEvents/ExtremeElectronics/index.htm.

DOE funds 17 solid-state-lighting projects to the tune of $37.8 million www.ledsmagazine.com/news/7/1/12

Supply chain maps a path to bringing down the cost of LED lighting www.ledsmagazine.com/features/6/11/2

Semiconductor supply chain sees big potential for cost reductions in LED manufacturing www.ledsmagazine.com/features/6/6/9

last word

Recessed LED accent lighting offers powerful potential for interior spaces

Advances in the design of LED-based accent lighting fixtures could open up a largely untapped market, explains **AL NEAR**, senior VP of sales and marketing with **USAI**.

For most of us, our daily lives are centered between two worlds: work and home. In fact, the average American spends 90 percent of his/her time inside. We can debate work/life balance and the health effects of fresh air, but the bottom line is this: there is an increasing need to make our interior spaces as comfortable, productive and efficient as possible. And lighting is one of the most powerful solutions for doing just that.

Advances in lighting are as plentiful as they are promising, and LED innovation is arguably the most rapidly evolving segment. In its relatively young history in the general lighting marketplace, LED technology has mainly been positioned as an energy-saving, mercury-free alternative to compact or linear fluorescent for interior lighting applications. As such, most recessed products introduced into the marketplace have focused on general illumination, task lighting and, more recently, wall-wash applications. It is recessed LED accent lighting, however, that presents the greatest untapped potential.

Providing an emotional layer of lighting, recessed accents create drama within a space, transforming the look and feel of any interior. In recessed LED applications to date, accent lighting has been sometimes marginalized or even eliminated altogether, due to limited ability of LED products to provide appropriate levels of contrast with the general lighting in the space.

Only recently has the directional source capability of LEDs been harnessed to produce an optimal effect for accent lighting. LEDs can produce a uniform, crisp beam that provides a significant amount of punch and very closely mimics the qualities of traditional incandescent point sources, such as MR16s.

Accent on performance and style

Until now, the replication of point sources with LED has been accomplished primarily with LED replacement-lamp technology, and there are without question a number of reputable products on the market. However, reality is that integral LED fixtures significantly outperform replacement lamps. This is particularly true because they are designed to address specific thermal and environmental conditions within the intended application, thus maximizing quality and performance. Integral LED fixture solutions offer up to 3 times the lumen output of average LED replacement lamps today and guarantee a full 50,000-hour rated life among other performance benefits.

As a general rule, accent lighting should be a minimum of 4 to 5 times the general lighting level to provide appropriate contrast. There are new recessed adjustable accent LED products on the market today, such as USAI's BeveLED, which deliver from 700 to 900 lumens into the space with center beam candlepower (CBCP) ranging from 5,000 to 14,000 candelas, depending on the beam distribution desired.

The optical elements incorporated into these designs allow for the blending of multiple LED beams into a single beam to create a single shadow – similar to that of incandescent and low-voltage halogen sources – while also ensuring optimal color consistency, not only within the beam itself, but also from fixture to fixture. Additionally, these optical systems eliminate all striations for even light distribution on the desired surface, and also mask the light source to further enhance the aesthetics of a space, particularly when the fixture is off. Often overlooked, the aesthetic appearance of an LED recessed product in its off state takes on particular significance when the product is combined with occupancy sensors, lighting controls, or a building automation system.

Advances in accent lighting fixture design present a bright future for the LED market and for the plethora of interior spaces that will benefit from the technology. With new LED accent lights, designers have the opportunity to harness a complete portfolio of LED options for holistic recessed-lighting applications: from museum and art gallery displays and office lobbies to elevator cabs, hospitality interiors, retail stores, residences, and healthcare facilities. Combined with an architectural family of companion recessed downlights and wall washers, LED recessed adjustable accents can now be seamlessly integrated into a designed interior space without sacrificing quality or performance while also saving the costly resources of time, money and energy.

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  - Signals
  - Electronic Equipment
  - Illumination
- LED lighting manufacturers
- LED product designers
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- Energy-efficiency organizations
- Corporate R&D staff
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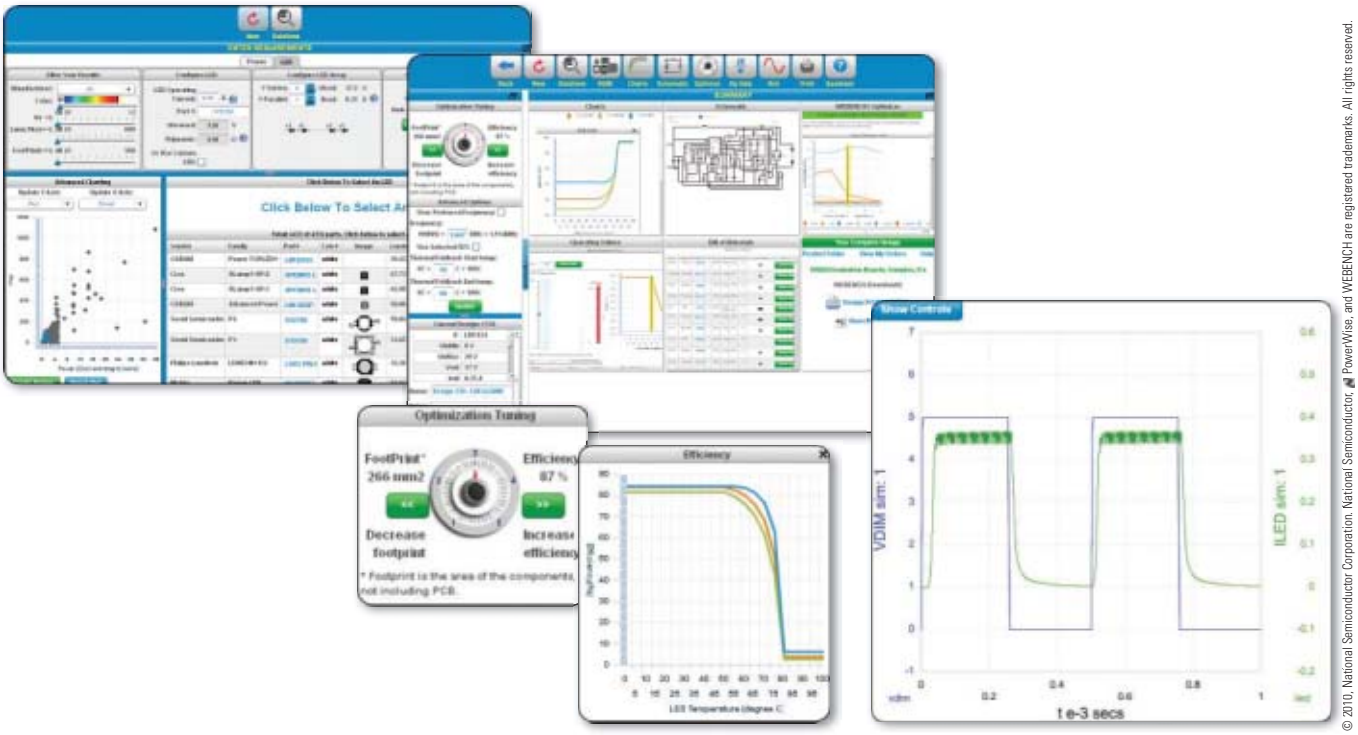

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