MARCH 2011

LEDs MAGAZINE

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TECHNOLOGY AND APPLICATIONS OF LIGHT EMITTING DIODES

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3D-TV creates new challenges P.47

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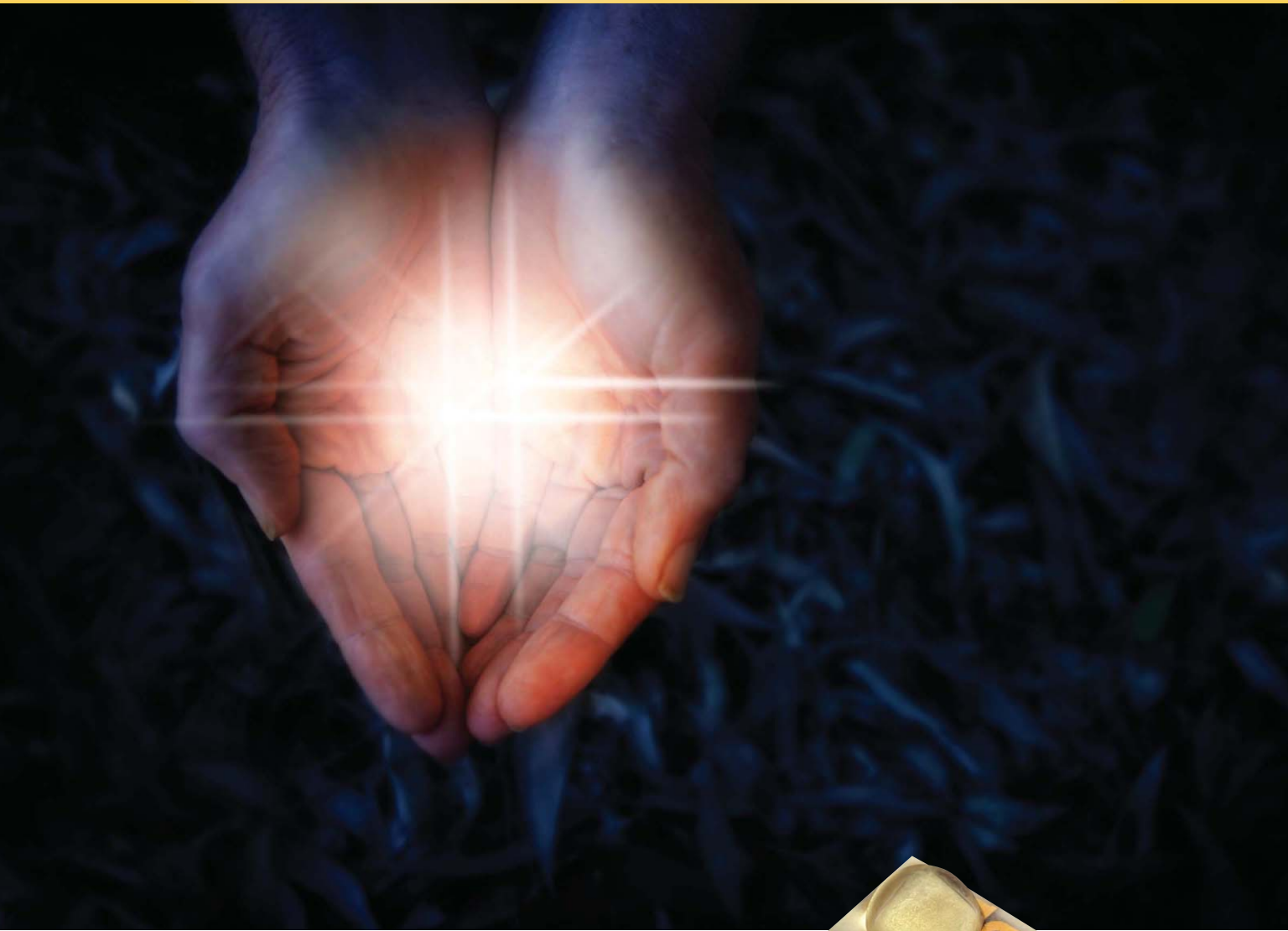

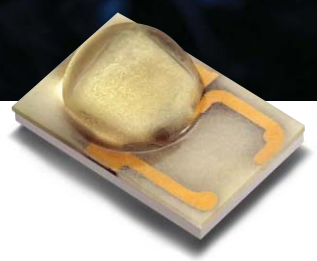

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ISSUE 41

march 2011

Cover Story

The US Department of Energy (DOE) took the podium on February 23 at the Strategies in Light conference, and announced the winners in the 2010 Next Generation Luminaires (NGL) competition. For winners, see page 26.

features

columns/departments

commentary

Market growth drives strategies in lighting

The LEDs Magazine team recently returned from Strategies in Light 2011 in California, where we enjoyed the company of some 4,200 registrants and nearly 140 exhibitors and sponsors. This was by far the largest event in the 12-year history of Strategies in Light, and the first part of our conference report begins on page 19. The second part will feature in our April/May issue. For the second year, the exhibit area included an LED Light & Design Pavilion, which featured a series of free presentations geared to the interests of lighting designers, architects and specifiers. Also running again was the Solid-State Lighting Investors Forum, in which early-stage companies gave short presentations geared towards the venture-capital community.

However, one notable change this year was the HB-LED market presentation, the traditional conference opener, which was given by Ella Shum, Director of LED Research, rather than Bob Steele, who has now retired but is a consultant for the various Strategies in Light events.

Shum's presentation summed up a stellar year for the HB-LED industry, with the market for packaged LEDs growing by 93% to reach $10.8 billion, driven by backlighting applications. As LED penetration in TVs, notebooks and other devices saturates over the next few years, lighting will then emerge as the main driver for market growth. The HB-LED market forecast for 2015 is $18.9 billion, as our article on page 15 explains.

Keynote speakers in the HB-LED Market track included Aldo Kamper, CEO of Osram Opto Semiconductors, and Michael Holt, CEO of Philips Lumileds. Both these LED makers have announced that they are converting to 6-inch wafers (see page 9), in anticipation of the growth still to come in the HB-LED market. Both are also already cashing in on the current levels of growth, and were both among the top five HB-LED manufacturers in 2010 (by revenue, at the packaged LED level – see page 15). Nichia was top, followed by Samsung LED.

Elsewhere in the LED supply chain, MOCVD equipment suppliers such as Veeco and Aixtron are also riding the LED wave. Veeco recently unveiled its TurboDisc MaxBright multi-reactor MOCVD system, which has a capacity of up to 216 × 2-inch wafers, or 56 × 4-inch, 24 × 6-inch or even 12 × 8-inch wafers (www.ledsmagazine.com/news/8/2/10). Meanwhile, rival Aixtron more than doubled its revenue during fiscal 2010 (www.ledsmagazine.com/press/30502).

Huge numbers of MOCVD machines are being ordered, especially in China. For example, GCL-Poly plans to install 100 MOCVD systems by the end of 2011 in a new LED production plant in Jiangsu, along with 170 sapphire crystal growth furnaces. Parent company GCL Power plans to invest a total of $2.5 billion and purchase a total of 400-500 MOCVD systems. Which should keep Aixtron busy for a while.

Next year, Strategies in Light 2012 will be held on February 7-9 in Santa Clara, CA. See you there.

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Near Infrared – Challenges in Lighting and Sensing

OSRAM Opto Semiconductors

DATE: Wednesday April 6, 2011
PRESENTER: Rolf Weber, OSRAM Opto Semiconductors

Standards for LED Retrofits – How to Certify Products for the US and Canada

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Metal-organic precursors and other LED materials

www.ledsmagazine.com/features/8/2/2

Compatibility Part 4: Economic benefits of compatibility testing of LED lighting

www.ledsmagazine.com/features/8/3/3

White Paper:

Universal Off-Line LED String Driver with PFC Design Solution

ON Semiconductor

www.ledsmagazine.com/whitepapers/2

FEATURED *event*

Strategies in Light China

Strategies in Light China 2011

May 10-12, 2011
Kowloon Shangri-La Hotel
Kowloon, Hong Kong

The first Strategies in Light event to be held in the Greater China region is entitled "East Meets West: Expanding the Global Market for LEDs and SSL." Unlike most of the other LED/SSL conferences held in China, the goal for SIL China is to be very international in scope, with roughly 50% participation (speakers and attendees) from Greater China and 50% from other world regions. The Hong Kong venue will provide easy access for foreign attendees as well as for mainland Chinese participants. All conference presentations will have simultaneous translation between Chinese and English. SIL China will explore the latest developments in LED markets, technology, and emerging applications. Speakers will address issues such as critical challenges and barriers to LED lighting adoption; regulatory issues and standards; government support and funding; technology updates and roadmaps; financing; investment and trade issues, and the international competitive landscape.

MORE: www.sil-ledchina.com

ADVERTISERS *index*

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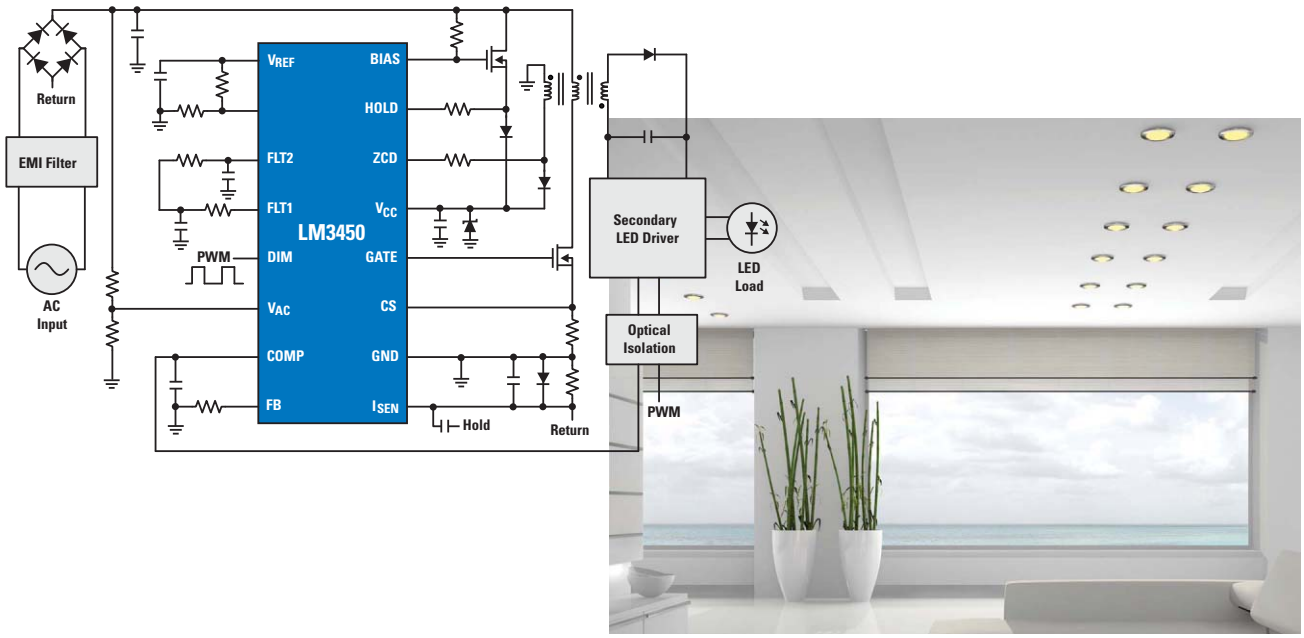
LM3450 LED driver integrates power factor correction and phase dimming decoding for flicker-free, uniform dimming.

National's LM3450 phase dimmable LED driver integrates active power factor correction and a phase dimming decoder, making it ideal for 10W-100W phase dimmable LED fixtures. It accepts universal input voltages, features unique dynamic hold circuitry for excellent dimming performance, and an analog adjust pin for differentiated features such as thermal foldback, interface to sensors, or dimmer range adjust.



High Performance

The LM3450 LED driver integrates a phase dimming decoder and unique dynamic hold circuitry to enable higher performance dimming without flicker and higher efficiency during dimming. It enables smooth, consistent LED dimming over a wide dim range without flicker even at low dim levels.

Flexible Designs

The analog adjust feature allows for the implementation of features such as thermal foldback, interface to sensors, or dimmer range adjust. The LM3450 is compatible with both forward phase (TRIAC) and reverse phase dimmers and can be used in either a single or two stage configuration.

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Dynamic hold circuitry allows for robustness to line disturbances to maintain current regulation, accuracy, and dimming performance over different line voltages and applications.

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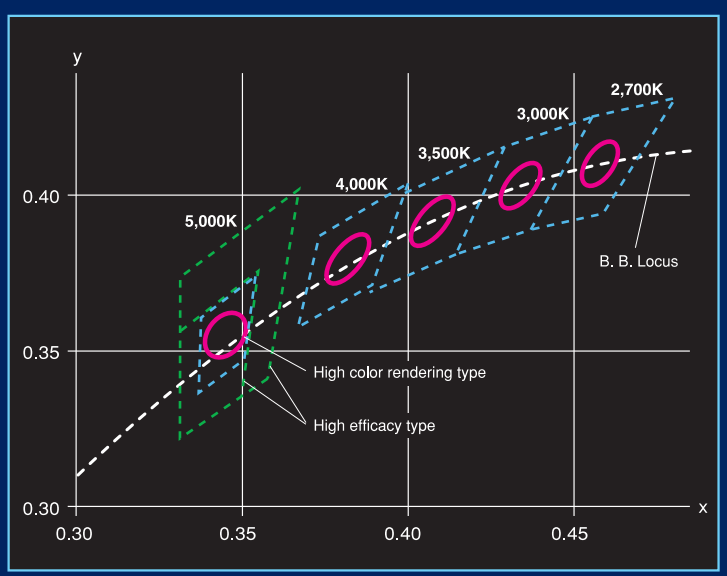
Feature

Citizen has decreased chromaticity variations providing LEDs that lie within the MacAdam 3-step ellipses.

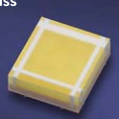


ANSI C78.377 — 3-Step MacAdam ellipse — Original range

- The high efficacy N (5,000K) does not lie within the MacAdam 3-step ellipses.
- In the CL-L270 Series, four colors (2,700K~4,000K) will lie within the MacAdam 3-step ellipses.

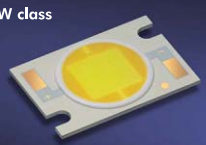
Euro luce 2011 in Milan
12-17 April 2011／Citizen booth : Pavilion 15, Stand No. F36

LFI 2011 in Philadelphia
17-19 May 2011／Citizen booth : Booth No. 2219

CL-L270 Series NEW
0.2W class

3.2 (L) ×2.8 (W) ×0.95 (H) mm

CL-L103 Series
3W/ 6W class

50.0 (L) ×7.0 (W) ×1.35 (H) mm

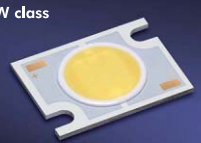
CL-L330 Series NEW
26W class

28.0 (L) ×19.0 (W) ×1.4 (H) mm

CL-L251 Series
4W/ 6W class

13.5 (L) ×13.0 (W) ×1.4 (H) mm

CL-L340 Series NEW
41W class

28.5 (L) ×28.5 (W) ×1.4 (H) mm

CL-L233 Series
13W class

23.0 (L) ×17.5 (W) ×1.4 (H) mm

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news views

MARKETS

LED luminaires show healthy growth

The total global market for LED luminaires is expected to grow from $3.8 billion in 2010 to $8.3 billion in 2014, according to a new report entitled "LED Luminaires, Market Analysis & Forecast" from market-research firm Strategies Unlimited. Replacement LED lamps are analyzed separately, and the market for these products will exceed $10 billion in 2014.

For many SSL applications, the quality of LEDs has improved to a point that performance is no longer an issue. Instead, the main issue is now the price of designing LEDs into luminaires. White-light LED applications have been boosted by improvements in HB-LED performance and price; heightened awareness about energy efficiency; phasing out of incandescent bulbs; and fiscal stimulus undertaken by various countries around the world. Quality issues that affected the market penetration of previous energy-efficient lighting technologies continue to affect the SSL market. However, the resolve to reduce energy consumption is likely to propel LED technology to be widely commercialized.

Strategies Unlimited says that China is the largest market for, as well as the largest supplier of, LED luminaires. Consumer-portable applications were the largest segment of the LED luminaire market in 2010. Colored and color-changing applications in architectural and entertainment segments together amounted to over $1 billion in 2010. Meanwhile, the commercial/industrial segment is expected to exceed $1 billion in 2011. Although starting from a small base, residential lighting is expected to be the fastest-growing segment, with a CAGR of 44% through 2014, while outdoor-area lighting is expected to grow at 38%. ◄

MORE: www.ledsmagazine.com/news/8/2/11

CHIP MANUFACTURING

Osram Opto expands LED capacity via 6-inch conversion

Osram Opto Semiconductors will be stepping up its LED production output "significantly" by converting its two LED chip-manufacturing facilities to 6-inch wafers, while expanding both plants. A new production building is currently under construction in Penang, Malaysia, while space at the company's fab in Regensburg, Germany, is being reallocated. The two facilities will each be converted to use 6-inch (150-mm) diameter wafers for InGaN-based LED manufacturing, replacing the current 4-inch wafer lines. These measures are expected to almost double the company's chip-production capacity for white LEDs by the end of 2012.

The company joins several other manufacturers, including LG Innotek, Philips Lumileds, Lextar and Cree, who have already signaled their intention to build LEDs on 6-inch wafers. At SIL (see page 19), Lumileds' CEO Mike Holt said that his company's conversion to 6-inch wafers would be complete by June.

Osram Opto says that the changes will put it on track to "cash in on the growth potential of international LED markets." The total manufacturing area of the Penang chip-manufacturing plant, which opened nearly two years ago, will increase to around 25,000 m^2 in 2012, creating some 400 additional jobs. At the Regensburg plant, InGaN production will be converted step by step beginning in summer 2011. ◄

MORE: www.ledsmagazine.com/news/8/3/6

AC-LEDS

Lynk Labs and partners show AC-LED packages

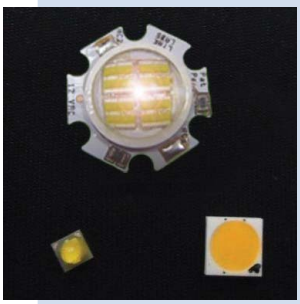
Lynk Labs, the Elgin, IL-based AC-LED developer, introduced 9 new AC-LED and high-voltage (HV) packaged LEDs at Strategies in Light 2011, as a result of separate cooperative efforts with packagers Citizen Electronics, Unity Opto and Everlight.

Demonstrations included a 12V, 12W package and a 100V HV-LED package made for Lynk by Citizen. A new relationship with Taiwan-based Unity Opto resulted in a newly-patented multi-voltage package designed to operate on either 12 Vac or 24 Vac. With Everlight, Lynk developed a 7W star package for MR16 lamps that will fully dim and eliminates all of the drive electronics required by DC-LED MR16 solutions, according to Bob Kottritsch, Vice President of Lynk Labs. "There is also a 2W package that will do the same for MR11 lamps," he said. Lynk also demonstrated a patent-pending multi-voltage design packaged by Everlight that » page 10

news+views

Lynk Labs from page 9

will operate on 100 Vac or 200 Vac for MR16 GU10 base and other applications. Also at SIL, Lynk demonstrated a new 0.5W package comprising a 12 Vac, 0.5W single LED chip developed by Epistar and Lynk.



"These AC-LED packages demonstrate many advantages in operation and reliability by reducing or eliminating the interface electronics needed to get LEDs to work in the general lighting AC-voltage domain," said Kottritsch. ◄

MORE: www.ledsmagazine.com/news/8/3/4

COMPETITIONS

LSG submits 60W L-Prize lamp

A 60W replacement LED lamp developed by Lighting Science Group Corp. and Light Prescriptions Innovators, LLC (LPI) is to be submitted to the L Prize competition. The light-bulb design is based on patented and patent-pending technologies developed by both companies. The L Prize was established by the US Department of Energy (DOE) to promote the development of highly-efficient, high-quality LED replacements for traditional 60W light bulbs. An additional section of the L Prize, covering PAR38 LED lamps, was temporarily suspended earlier this year.

Philips was the first to submit an L Prize entry in September 2009, and no other companies have stepped forward until now. Targets for the 60W replacement include 900 lm at less than 10W (i.e. more than 90 lm/W), as a well as a 25,000-hr lifetime, CRI above 90, a color temperature of 2700–3000K, an omni-directional light distribution and a consumer retail price starting at $22. ◄

MORE: www.ledsmagazine.com/news/8/3/7

TEST & MEASUREMENT

UL acquires Lighting Sciences, Inc.

UL, the Northbrook, IL-based product-safety testing organization, has boosted its photometric testing capacity via the acquisition of Lighting Sciences, Inc. (LSI), a provider of photometric testing services, test equipment, and advisory services in support of the growing SSL market.

One year ago, UL acquired Luminaire Testing Laboratory (LTL), a testing lab based in Allentown, PA, that provides performance testing of lamps and luminaires. More recently, UL earned approval as a third-party certification body for the Energy Star program.

Keith Williams, president and CEO of UL, said that the acquisition of LSI allows UL to "further extend its global safety mission and better serve companies in the rapidly expanding SSL markets" and will "allow the lighting industry to come to a single organization for testing and certification of their products to the applicable safety and energy-efficiency standards." ◄

MORE: www.ledsmagazine.com/news/8/3/5

MARKETS

PIDA predicts rapid growth for LED market in Taiwan

The economic rebound in 2010 drove Taiwan's total LED production value to reach USD 5.43 billion, according to the country's Photonics Industry & Technology Development Association (PIDA). As the LED application market expands, an annual growth rate of 40% is predicted in each of the next 2 years, resulting in a USD 11.3-billion market in 2012. Taiwan's LED manufacturers have, says PIDA, "become members of the international supply chain thanks to technical know-how, lower prices and outstanding quality, and have entered the high-growth application markets in backlighting and lighting."

In 2010 PIDA says that Taiwan was the number-one-ranked country in the world in terms of the production output of LED wafers and chips, with sales just below USD 2 billion, of which InGaN LEDs comprised 52%. The market for packaged LEDs was slightly less than USD 3 billion. The LED lighting segment of the industry made only a small contribution to the total in 2010, but is expected to grow rapidly in the next two years. ◄

MORE: www.ledsmagazine.com/news/8/2/3

LIGHTING

Osram buys Siteco

Osram is to acquire Siteco Lighting GmbH, a lighting company based in Traunreut, Germany, from Barclays Private Equity. The purchase price was not disclosed. Siteco has a worldwide workforce of 1250 and had revenue of around EUR 220 million in fiscal year 2010. The company supplies luminaires and lighting systems for urban infrastructure such as public and commercial buildings, streets, tunnels, airports and sports stadiums. It produces luminaires in Germany and China and has over 15 sales companies in Europe, as well as a global sales network. Osram says that the acquisition will provide it with broad access to the market for lighting solutions, and a modern range of products in the field of interior and exterior lighting. According to Osram, the Siteco portfolio ideally supplements the product range of the joint venture formed by Osram and Traxon Technologies in 2008. ◄

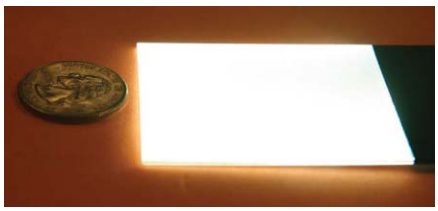
MORE: www.ledsmagazine.com/news/8/2/31

PLANAR LIGHTING

Future and Oree sign distribution deal

Oree, the Israel-based developer of planar LED-based lighting, has signed a worldwide distribution agreement with Future Lighting Solutions covering Oree's LightCell. This is a thin, flat and uniform SSL source with an

news+views



illuminated surface measuring 50 x 50 mm. Oree says the product is ideally suited for decorative and architectural lighting applications, in environments where there is a lack of physical depth or space for lighting fixtures, and where uniformity and thin form-factor are an advantage. ◄

MORE: www.ledsmagazine.com/news/8/2/22

REPLACEMENT LAMPS

CRS makes Energizer LED lamps

Canadian LED lighting manufacturer CRS Electronics Inc. has signed an exclusive agreement to manufacture a suite of LED lighting products under the brand name Energizer. The initial group of products includes MR16, PAR20, PAR30 and PAR38 LED lamps. Shipping of the Energizer-branded LED lights is expected to commence in the third quarter of 2011. Future products developed by CRS may also be considered by Energizer. In related news, CRS has begun trading on the OTCQX international market under the symbol LEDCF. ◄

MORE: www.ledsmagazine.com/news/8/2/14

FUNDING

Europe offers funds for large-scale SSL pilots

The European Commission (EC) is to provide funding of up to EUR 10 million in total, matched by equivalent contributions from participants, to support 2 or 3 solid-state lighting (SSL) pilot projects. Funding will be provided for large-scale "flagship actions" that demonstrate the best use of innovative SSL systems to achieve better light quality

Philips has supplied 293 LED luminaires for a 7-km stretch of highway near Amsterdam in The Netherlands (www.ledsmagazine.com/news/8/2/21).

and control with a substantial reduction in energy consumption. The objective is to demonstrate the value of using intelligent SSL systems under a variety of real-life conditions, to assess user perception, to determine total costs and energy savings, and to raise EU-wide awareness of SSL capabilities.

The primary focus is on the commercial and/or non-residential sector, including large public, semipublic or private infrastructures. Projects should include players across the full value chain from the lighting and luminaire industry, including end-users from the public sector as appropriate. The projects will be required to cooperate with each other and develop common measurement methods and reporting formats. Actions will also be expected to jointly contribute to the establishment of quality labeling initiatives and to relevant certification and standardization efforts in the field. The closing date is June 1, 2011. ◄

MORE: www.ledsmagazine.com/news/8/2/5

Russian President Dmitry Medvedev (second left) recently visited LED maker Optogan (www.ledsmagazine.com/press/30595).

MANUFACTURING

LED fab opens in Bulgaria

Octa Light recently opened the first high-power LED assembly line in Bulgaria, in an event attended by the Bulgarian Prime Minister and other luminaries. Octa Light has sold lighting fixtures for several years, and has now launched its first packaged LED, the Bullstar series. ◄

MORE: www.ledsmagazine.com/news/8/3/2

CONTROLS

Daintree promotes inter-operability for wireless lighting controls

Daintree Networks, Inc., a provider of wireless control solutions for energy-smart buildings, has launched the ControlScope Connected Partner Program. Lighting companies Finelite and Albeo Technologies and three other vendors are the first program members. All the partners have built products for the lighting industry — such as sensors, wall switches and LED drivers — using the ZigBee wireless standard for communications. Daintree says it is creating an "ecosystem" of open-standards products that can co-exist on a single, intelligent lighting network. ◄

MORE: www.ledsmagazine.com/news/8/2/6

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Backlighting applications drove massive 93% jump in HB-LED market during 2010

Display applications in TVs, monitors and mobile devices will continue to drive the LED market in the next two years, after which solid-state lighting will take over. **TIM WHITAKER** reports from the Strategies in Light conference.

The worldwide high-brightness (HB) LED market shot up from $5.6 billion in 2009 to $10.8 billion in 2010, a growth rate of 93%, according to market research firm Strategies Unlimited (www.strategies-u.com). Backlights for LCD TVs and monitors led the growth spurt, followed by mobile display applications. The total market is expected to reach $18.9 billion in 2015, representing a compound annual growth rate (CAGR) of 11.8%.

Strategies Unlimited's HB-LED market analysis includes only packaged devices, and does not include chips, back-light units, modules or fixtures. The information was presented by Ella Shum, Director of the company's LED Practice, at the Strategies in Light (SIL) conference on February 23 in Santa Clara, CA. See our report on page 21 for more news from this event.

2010 ranking	HB-LED maker
1	Nichia
2	Samsung LED
3	Osram Opto Semiconductors
4=	Philips Lumileds Lighting
4=	Seoul Semiconductor
6=	Cree
6=	LG Innotek
8	Sharp
9=	Everlight
9=	Toyoda Gosei

Source: Strategies Unlimited

FIG. 1. Ranking by revenue of the top 10 suppliers in the HB-LED market in 2010. Revenue includes packaged LED sales only. Companies have the same ranking when the difference in revenue is within the margin of error.

Ten companies accounted for more than 75% of the HB-LED market in 2010. Strategies Unlimited arrived at these figures after analyzing market demand as well as the supply-side activity of more than 40 HB-LED component suppliers. The ranking by revenue of the top ten suppliers in the HB-LED market in 2010 is shown in Fig. 1.

The leading suppliers have achieved success in different areas. Korean manufacturers Samsung LED, Seoul Semiconductor and LG Innotek rode the boom in the LCD TV and monitor backlight market in 2010, while Osram Opto Semiconductors benefited from the rise of the Chinese HB-LED market, especially in the automotive sector. Lumileds' success in high-power backlight products, cell-phone flash and architectural lighting contributed to its success, while Cree's dedicated focus on solid-state lighting ensured its continued strong position.

Year 1 of the Chinese LED Era

As shown in Fig. 2, Japanese and Korean companies accounted for 33% and 28%, respectively, of the 2010 HB-LED market. Meanwhile, Chinese LED suppliers captured two percent of the market. While Chinese HB-LED technologies are currently three to five years behind the rest of the world, Strategies Unlimited expects that huge investment in solid-state lighting (SSL) will help close the gap by 2015.

Ella Shum's presentation at SIL was entitled "Year 1" and she explained this was because 2010 represented Year 1 of the "SSL Empire" and also Year 1 of the Chinese LED era. "If this event [the SIL conference] was in China, the vice minister of Science and Technology would be here," she said, reflecting the importance to China of the SSL industry.

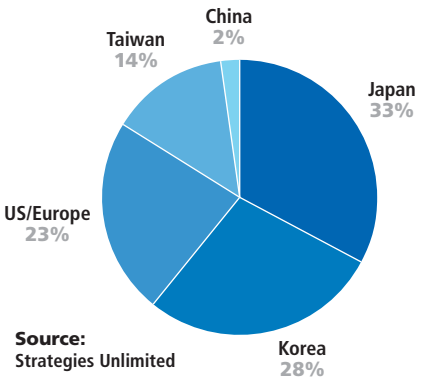


FIG. 2. HB-LED market in 2010 by country or region.

Investments of $17.4 billion have already been announced for 2010-2015, said Shum. Also, government subsidies and policies are helping companies to buy MOCVD systems, as well as driving initial SSL adoption, for example in street lighting. An estimated 2000 MOCVD system orders have already been announced, with buyers ranging from established local firms to new entrants to overseas firms from Taiwan and Korea. These overseas companies are building facilities in China to expand their capacity, to get closer to end markets (which are very significant for some applications), and to benefit from subsidies.

A key factor is the shift in the IP landscape. Chinese companies are acquiring know-how from overseas, for example through various joint ventures, and are importing talent by offering very high wages in the region of $150-250k for experienced MOCVD engineers. They are also developing home-grown IP (a good example being Lattice Power's GaN-on-silicon technology)

and "breaking down the IP wall" via partnerships that provide global access.

Mobile applications and backlighting

The largest HB-LED market segment in 2010 was Mobile, with a 39% share. This segment – which includes mobile phones, mobile computing (notebooks, tablets), MP3 players, portable DVDs, eBooks and other related applications – doubled in size during 2010 to reach $4.2 billion.

However, by far the largest growth was observed in the TV & monitor Backlighting segment, which Strategies Unlimited has broken out separately for the first time. This segment grew by almost a factor of ten compared with 2009, to reach 33% of the overall HB-LED market in 2010, or $3.56 billion.

Shum described display backlighting as the "engine for hyper growth" in the LED industry during 2010. The total HB-LED market for display backlighting (including both the TV & monitor Backlighting segment and also the backlighting part of the Mobile segment) was $6.7 billion.

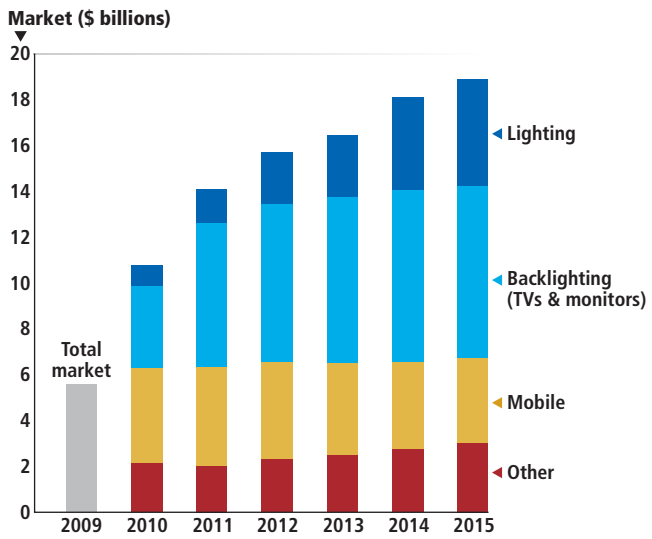
Penetration of LED backlights in TVs has increased dramatically, and manufacturers are engaged in a "beauty contest," introducing larger and thinner screens. They are also focusing on dimming technology for improved contrast, as well as energy savings and of course 3D. Shum pointed out two opposite trends in terms of LED consumption; one is to increase the die area and use multi-chip packages, which allows a reduction in the number of light bars in newer TVs. However, newer models of high-end TVs are using more LEDs to ensure good picture quality, especially for 3D.

In the notebook backlighting segment, unit sales of notebooks increased by 50%, while penetration of LED backlights also increased by 40%. LED adoption is already very high in this segment, so prospects for further growth are limited, unlike the tablet market which is still in an early growth stage, despite the iPad's success. Meanwhile, LED-backlit monitors are growing in number, driven by the interest generated by the TV space and also by the trend to adopt larger monitor screens.

An additional trend in backlighting is the rise of OLED screens. Shum said that "OLED will be making a dent very soon in the display market," especially for smartphones, where OLEDs will capture almost half the market by 2015. While 22% unit CAGR is expected in the smartphone market through 2015, HB-LED revenue in this segment will decrease by 3%.

Lighting and other applications

Among the smaller market segments in 2010, Lighting and Automotive both accounted for 8% of the total, with Signs at 6%. The signage market is expected to see high growth in China and India, said Shum. Meanwhile, vehicle sales rebounded in 2010, and strong sales of LEDs are expected in exterior lighting. For example, penetration of LEDs in rear-lighting applications is low in China, but growing rapidly. Front lighting, a relatively immature segment on a worldwide basis, is expected to see a CAGR of 29% through 2015. In vehicle interiors, instrument-panel backlighting has reached very high penetration, and revenue will fall significantly, but this will be counteracted by growth in ambient lighting applications.



Source: Strategies Unlimited

FIG. 3. HB-LED market growth from 2009 to 2015.

The Lighting market for HB-LEDs was worth around $890 million in 2010.

The lighting market for HB-LEDs was worth around $890 million in 2010, according to Strategies Unlimited. The largest segments were architectural (27%), replacement lamps (23%) and commercial/industrial (12%), with both outdoor area and consumer portable at 7%. "The wide availability of 100 lm/W LEDs has made SSL a commercial reality," said Shum. "LED performance is no longer the gating factor in the SSL market." Instead, LED luminaire design, rather than LED performance, has become the primary concern. A new report from Strategies Unlimited on the market for LED luminaires is discussed on page 9.

The typical efficacy of a high-performance one-watt cool-white LED has increased from around 40 lm/W in 2005 to around 130 lm/W in 2010. In the same period, the cost has decreased from about $70/klm (dollars per kilolumen) to around $11/klm.

Looking ahead

Strategies Unlimited expects the TV/monitor Backlighting segment to continue to be a strong engine for growth in the next two years, and then flatten out in 2013. Even so, the overall CAGR for this segment is expected to be more than 16% from 2010–2015. The Mobile segment will have a CAGR of around -3% in the same period, while the signage and automotive segments will grow by 10% and 8%, respectively.

Meanwhile, lighting will become the key driver for HB-LED market growth in 2014, as a result of the worldwide focus on energy efficiency and the phase-out of incandescent bulbs. The CAGR for HB-LED components for Lighting from 2010–2015 is predicted to be 39%.

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SIL presentations chart LED advancements and application evolution

LED technology has advanced to enable broad applicability, although component makers are still seeking to boost brightness and quality, and potential technology challengers such as OLEDs are lurking, says **MAURY WRIGHT** in Part 1 of our report from SIL 2011.

The 2011 Strategies in Light (SIL) conference showed signs of a maturing solid-state lighting (SSL) technology sector. Indeed, in one keynote presentation, Osram Opto Semiconductors president and CEO Aldo Kamper said, "We can now address all [lighting] applications with LEDs." Without question, LED component manufacturers have made significant gains in areas such as brightness and color quality, although there remains significant opportunity for further advances. Moreover, while SSL is steadily penetrating general illumination applications, other opportunities in areas such as life sciences and horticulture lie largely untapped. Still, LEDs aren't the only evolving lighting technology with promise, as OLEDs or other energy-efficient alternatives could steal some significant market share by mid decade.

Whether in the sessions or on the show floor, SIL had an upbeat feel attributable to what's a rapidly expanding LED and SSL market (see page 15 for the Strategies Unlimited HB-LED market forecast that was the first presentation in the SIL conference). The industry has made strides at the component level and perhaps more so in the system design area. The results of the Next Generation Luminaires (NGL) competition announced at SIL are evident of advances in luminaire design (see page 26). Moreover, the exhibit floor was full of examples of improvements in SSL technology in areas such as phosphors, driver electronics, and modular luminaire components (see www.ledsmagazine.com/news/8/3/3).

The keynote addresses by Philips Lumileds CEO Michael Holt and Osram's Kamper both had an LED component focus.

While both exuded confidence about the progress that's been made in LEDs, they also shared the thought that plenty of work remains. Holt stated upfront in his talk, "What I'm not here to tell you is that the lumen-per-watt war is over."

Kamper showed a graph from a DOE report on theoretical limits for LED efficacy and noted that while the industry has achieved 60-70% of that potential, there is a lot of work required to meet the DOE-defined limit by the projected 2020 date.

But while both keynoters addressed the continued quest for brightness, they chose to focus their talks on other areas – indicative of LED maturity. Holt primarily discussed color consistency, and Kamper described areas other than brightness in which the component makers must improve.

LED improvements

Kamper named cost, quality, fit, and intelligence as targets for improvement. He said, "We still throw away about 50% of the die that we produce." Obviously this is a yield issue that has a direct impact on component cost. He expressed a need for "better epi-layer homogeneity."

It was no surprise that a move to larger wafers was broached as a potential cost reducer. Kamper said that Osram made the move to 4-inch wafers six years back and will move to 6-inch wafers this year (see page 9). He also questioned whether a transition to a different substrate such as silicon might ultimately be the best solution for lowering costs. Large silicon wafers can be produced more cheaply than sapphire ones, and might afford compatibility with other IC manufac-

turing processes. But it's tricky to mate the GaN and silicon materials.

On the quality angle, Kamper included everything from standardization of components and modules to testing to binning to color rendering. He stressed the need to fulfill customer expectations for quality light and long life.

Kamper discussed fit – i.e. application-specific LED components – with reference to automotive applications. He pointed out the LEDs have succeeded in uses such as headlamps and brake lights, but that there is a need for many different types of LEDs in an auto. For example, an emerging application is tunable interior lighting that requires quite different LED types than headlamps. The message is that one size does not fit all, and that's equally true in other application areas such as general illumination.

With regard to intelligence, Kamper prescribed "light where it is needed in the quality that is required." Adaptive-control technology is key, he said, to both maximizing energy savings and providing people with an optimum environment.

Cree showcased MR16 reference designs using a reflector from Ledil (left) and an optic from Carclo (right). The lamps incorporated Cree's new MT-G LED (www.ledsmagazine.com/news/8/2/24), specifically designed for MR16 retrofits, which was unveiled at SIL. With a 9 x 9-mm footprint, the 12-chip MT-G package delivers up to 560 lm at 1.1A at 85°C or up to 1525 lm at 4A at 85°C in warm white (3000K). Both Cree and Lumileds claimed to be the first in the industry to test and bin LEDs at 85°C, which is a more realistic operating temperature compared with the standard test temperature of 25°C.

Color quality and consistency

Lumileds' Holt focused primarily on the light-quality issue, as well as his company's Freedom From Binning program and Luxeon S, a 9-chip LED launched at SIL. While the address was more of a product pitch than you might expect in a keynote, it included some good points. By testing LEDs at what's a typical operating temperature of 85°C, Philips is able to match the emitters with a suitable Lumiramic phosphor plate that ensure all of the packaged LEDs fall within a 3-step MacAdam Ellipse in color temperature (see www.ledsmagazine.com/news/8/2/25). Customers such as luminaire manufacturers could realize savings from a logistics point of view in not having to specify and stock binned components.

Holt recalled that a customer once asked him "While we use these things at 85°C how come you only test them at 25°C?" He confessed that even while giving the customer a marketing spiel as to why the low temperature test was sufficient, he knew the customer was right. He said that component makers have "conned" the customers into buying in to the 25°C specs.

Of course the problems with testing at a realistic temperature are time and cost. Holt said that Lumileds will produce over 1 billion Rebels this year, and hot-temperature testing of so many devices would be very difficult. But he added, "It's something our customers really ought to insist on." The new Luxeon S LEDs will be tested at 85°C.

While the focus of the program is to eliminate binning, Holt also claimed it will solve a potential light-quality issue that persists even with binning. He asserted that binned LEDs don't necessarily produce the same color temperature in hot conditions. He said, "We want them to look very similar or identical at their use conditions."

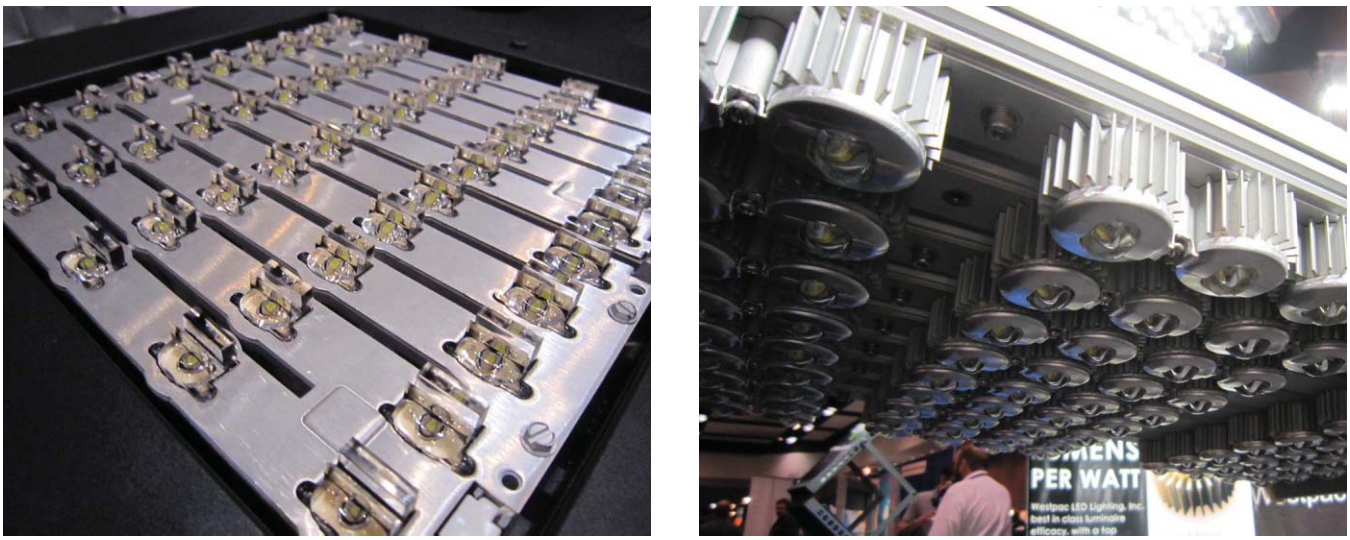
The third cycle

In the HB-LED market track of SIL, Jed Dorsheimer, managing director of equity research for lighting and solar at investment bank Canaccord Genuity, provided his outlook for the LED business for what he called "the third cycle." The third cycle refers to how the general lighting market will drive LED supply and demand as opposed to the second cycle that has been driven by display backlighting.

Dorsheimer started by discussing the huge potential for growth in lighting generally, especially in regions of the globe where there is limited electrical lighting now. LEDs enter the picture because of the energy-efficiency angle. Emerging geographic regions in Asia, Africa and other places that primarily rely on coal to generate electricity simply can't produce enough energy to satisfy the growing demand for lighting. Dorsheimer said, "The world needs to go on an electricity diet." With Canaccord estimating that 27% of the world's energy is used for lighting, SSL offers a path toward a reduction in energy usage and the ability within limits to satisfy the growing lighting demand.

Dorsheimer segmented the lighting market both by application and technology. While the residential market comprises the largest number of sockets and lamps, it is by far the smallest in terms of light produced when compared to the commercial, industrial, and outdoor segments. In those three larger segments, LEDs aren't competing with inefficient incandescent lighting but with much more efficient linear fluorescent and HID sources.

Given the tough competition for SSL, Canaccord developed a total-cost-of-ownership model based on what Dorsheimer characterized as "dozens of inputs and 200,000 formulas" designed to project the potential for SSL. Canaccord published results last August suggesting that LED lighting would reach 30-60% penetration by 2020. The broad



Alternative approaches to building outdoor-lighting fixtures from Acuity Brands Lighting (left) and Westpac LED Lighting Inc. (right).

range is bookended by bull and bear scenarios for SSL adoption, and Canaccord projected cumulative LED revenues between $105.9 and $313.8 billion.

It turns out, however, that some aspects of the backlighting market will accelerate SSL adoption, said Dorsheimer. Because LED-backlit TV sales have disappointed, some LEDs intended for that market have been redirected to the general illumination market and vendors have cut prices to reduce inventories. The updated Canaccord forecast released at SIL is for 54-75% penetration by 2020. But despite a greater penetration level projected in the update, Canaccord has lowered the cumulative revenue forecast to between $70 and $161 billion based on lower LED prices.

LED display backlights

Of course the second-cycle display market is still a significant factor in LED demand and may ultimately deliver a technology boost to the general illumination segment. David Barnes, chief research officer at the LCD TV Association, presented an update on the display segment.

Barnes opened with a broad defense of LCD display technology relative to OLED displays. He expressed doubt that the OLED makers will solve the manufacturing issues associated with economically making large displays. But even if they do so, it may not matter, said Barnes. He described the LCD business as "a bit like a snowball rolling downhill. It gathers momentum and it gathers more snow." Barnes characterized the sector as a $90-billion business that is growing in capacity at about 25% per year. "That will create, as it has in the past, quite a bit of an entry barrier to any alternative technology including OLED," he said.

While the OLED attack was likely based in Barnes' admitted bias toward LCD technology, the implications if correct will be positive for LED makers. Certainly the adoption of LED backlights will continue and reach 100% penetration at some point. But even Barnes stated that the backlight market will not create enough demand to fill LED fabs beyond 2012, especially with LED makers ramping capacity.

However, Barnes sees the lessons learned in backlighting as applicable to general lighting and specifically the planar-lighting segment that OLED proponents also hope to address. He asked, "Why would you expect OLEDs to be the next thing in lighting?" He pointed out the advancements in LEDs in terms of quality, referencing the Philips bin-free announcement and the ramp in manufacturing volumes and falling component prices. Meanwhile, he said, "The OLED guys are still trying to figure out how to make any light at all." Barnes suggested that LED sources used to edge-light a planar panel, similar to a TV backlight, is a far better idea.

LED-based table lamp designed by Mueller & Roehrig and built using wedges of Makrolon LED 2245 polycarbonate material from Bayer MaterialScience.

OLED fights back

Of course it was only fair that the OLED contingency had a chance

to respond via Barry Young, the managing director of the OLED Association and principal at Young Market Research. Young first discussed the penetration of OLED displays into the small and medium display market. He projected that, by 2015, 350 million OLED displays will be sold into smartphone and tablet applications annually. And he said, "I may be a bit short on that, because Samsung is saying it's going to be 600 million."

In the TV space, Young expects no significant penetration until 2013. Until then, "the fab process won't be available to build these things," he said. But starting in 2013 there will be manufacturing in place to produce 2.2x2.5-m panels for TVs. Young projects that in 2014 there will be 4.5 million OLED TVs sold, primarily displacing rear-LED-backlit LCD TVs that use 400 to 500 LEDs each.

Assuming that OLED makers deliver on Young's projection, it's fair to question how OLED and LCD TVs compare and how that might ultimately impact the general-lighting segment. Anyone that's seen one of the brilliant OLED displays on a smartphone would almost certainly judge it superior to an LCD model.

Young presented some technical specifications that further boost the OLED case. Energy consumption was at the top of the list, as some LCD proponents have claimed that OLEDs use more power

Philips Lightolier's Alcyon accent track light, a Recognized Indoor winner in the NGL competition (see page 26), is cooled by a SynJet ZFlow 65 from Nuventix (www.ledsmagazine.com/press/30574). A total of 8 Philips luminaires were honored in the competition (www.ledsmagazine.com/press/30596). At SIL, Nuventix also showed a very small SynJet for incorporation inside a PAR38 lamp as well as other design wins.

than LED-backlit LCDs. Young admitted that an OLED TV displaying a static image such as a web page that was 40% white would use 160% more energy than an LCD model. But he claimed an OLED TV displaying a photo would use 70% of the power of an LCD, and displaying a typical movie would use 15% of the power of an LCD.

Young then turned to a look at how the OLED characteristics from the display segment would transition to the lighting sector. He claimed that OLED life is already superior to what is required in lighting, but admitted that OLEDs can't meet the 10,000 lm/m^2 light output required for general illumination. Moreover, he pointed out that OLEDs are delivering 30 lm/W in efficacy for displays – far short of the 100 lm/W needed for lighting.

Still, Young projected a steady improvement saying, "We have a company like Samsung, this year alone investing $5 billion in OLEDs." He projected significant shipments of OLED lighting by 2015, perhaps reaching the penetration level of LEDs in planar linear-fluorescent replacement fixtures.

New LED applications

Whether OLEDs meet Young's projections or not, there is still a bright outlook for LEDs in lighting. Equally evident at SIL were new areas in which SSL might be deployed, further expanding the demand for LEDs. Cary Eskow, global director at Avnet LightSpeed, discussed industrial, life science, and other applications for UV LEDs which can be made on the same fab lines as the blue emitters used in white LEDs.

According to Eskow, UV LEDs have the potential to displace mercury-discharge lamps in a variety of UV applications. The mercury lamps have a broad spectrum whereas UV LEDs have a more efficient narrow spectrum.

UV light is widely used in coating and curing applications, eliminating the solvents used in other systems. Eskow identified the graphics arts industry as a potential market where UV is used for near-instantaneous ink curing. Eskow also described how UV light can produce healthier vegetables. Most greenhouses block the UV wavelengths that produce beneficial antioxidants called polyphenols.

UV LEDs could have a place in general lighting as well. According to Eskow, UV light causes the natural production of Vitamin D_3 in humans. So adding a UV LED in a luminaire could have direct health benefits.

Indeed, new applications for LEDs was a recurring topic at SIL. Osram's Kamper closed his keynote by focusing on new opportunities for HB-LEDs, and the potential is vast. He showed a photo of a Sony camera that incorporates an LED-based projector. And he expects future mobile phones to integrate such projectors.

Kamper said that, six or seven years ago, the Osram LED team thought that 50 lm was the maximum light that LEDs could project onto a screen. He said they can project 2000 or even 3000 lm today in standalone projector applications.

Still, it's clear that Kamper sees general illumination as the biggest LED demand driver. And he said "The underlying growth engine for the lighting industry is GDP," meaning that light consumption will increase continuously with growing global wealth. And as Canaccord's Dorsheimer pointed out, LEDs are for now the only lighting solution that might be compatible with a finite energy supply.

focus on Luminaires

The US Department of Energy (DOE) took the podium on February 23 at the Strategies in Light conference, and announced the winners in the 2010 Next Generation Luminaires (NGL) competition. The DOE, the Illumination Engineering Society of North America (IESNA), and the International Association of Lighting Designers (IALD) jointly manage the competition, which promotes excellence in energy-efficient LED commercial lighting. Judges evaluated 138 luminaires selecting four as "Best in Class," 33 as "Recognized" winners, and five as "Notable" for specific features.

MORE WINNERS: www.ngldc.org/10/winners.stm

A panel of 12 judges convened in early December to evaluate the NGL entries aided by Underwriters Laboratory staff who installed the products in typical application scenarios. The judges assessed lighting performance, appearance, construction, energy efficiency, and industrial design. Required documentation included LM-79 and LM-80 reports from an independent testing lab.

BEST IN CLASS

Fraqtir by The Lighting Quotient

A linear concealed LED cove light available in 1-9-ft lengths, the luminaire produces an asymmetric distribution through a combination of a refractor and total internal reflection lenses. Output: 1906 lm. Power: 42W. Efficacy: 45.3 lm/W. CCT: 3103K. CRI: 82.

www.thelightingquotient.com

RECOGNIZED

Taos LED by Edge Lighting

The wall-mount LED luminaire provides bidirectional lighting, features a satin aluminum finish, and can be used in indoor or outdoor applications. Output: 158.3 lm. Power: 6.5W. Efficacy: 24.4 lm/W. CCT: 3182K. CRI: 84.

www.edgelighting.com

Aculux by Juno Lighting Group

A recessed adjustable LED fixture with a 3¼-in aperture, the adjustable (370° rotation, 45° tilt) design is available in a choice of three color temperatures and comes with three field-interchangeable optics. Output: 595.5 lm. Power: 19.6W. Efficacy: 31.8 lm/W. CCT: 3022K. CRI: 83

www.junolightinggroup.com

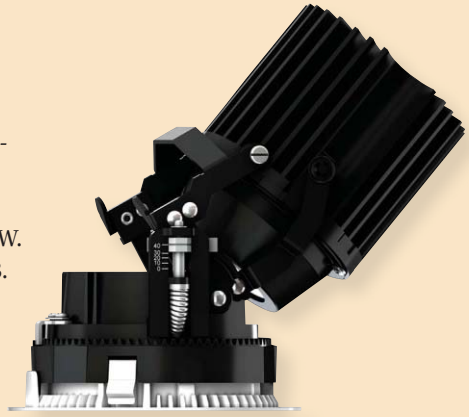
SCHX5 LED by Evolucia

An LED street and area light with a Fitted Target Efficacy score of 57, the luminaire uses Evolucia's AimedOptics technology to form the desired beam pattern and ensure uniformity. Output: 6596 lm. Power: 78.6W. Efficacy: 83.9 lm/W. CCT: 4440K. CRI: 76.

www.evolucialighting.com

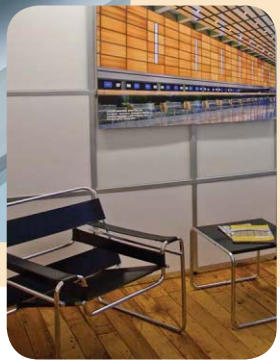
▲Equo LED Desk Lamp
by Koncept Technologies

Touch-sensitive controls allow a finger swipe to dim the LED desk light that features a counterweight design allowing a user to simply adjust the height of the lamp head. Output: 242.8 lm. Power: 5.5W. Efficacy: 44.3 lm/W. CCT: 3299K. CRI: 83.
www.konceptech.com



▲NanoLED by USAI Lighting

The recessed accent light features 40° tilt and 362° horizontal adjustments and is available with three beam-spread options (22° - 55°), four color temperatures, and two wattages. Output: 384.9 lm. Power: 10.4W. Efficacy: 36.9 lm/W. CCT: 3009K. CRI: 82.4.
www.usailighting.com



Close

▲eW B
by Philips Color Kinetics

Designed for exterior architectural lighting applications, the die-cast aluminum luminaire features four spread-lens options for beam control along with a louver and three cowls for glare control. Output: 1162 lm. Power: 29.3W. Efficacy: 39.7 lm/W. CCT: 2712K. CRI: 82.
www.philipscolorkinetics.com

▲LED Dock Light
by Philips Day-Brite

An energy-saving alternative to commonly used 150W PAR dock lights, the ruggedized luminaire utilizes a flexible arm allowing workers to direct the light as required. Output: 744 lm. Power: 15W. Efficacy: 49.6 lm/W. CCT: 6131K. CRI: 74.
www.daybrite.com

▲Portfolio by Cooper Lighting

An LED downlight available in 4- and 6-in aperture models, the luminaire integrates a curved transitional lens to evenly distribute light, and a light engine that's replaceable from below the ceiling with no tools. Output: 1286 lm. Power: 24.3W. Efficacy: 52.9 lm/W. CCT: 3349K. CRI: 82.
www.cooperlighting.com

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conferences | **DOE SSL WORKSHOP**

DOE workshop covers SSL case studies and technology development

LED industry participants gathered in San Diego to hear about the latest applications and enabling technologies, and to help map the DOE's SSL program, says **MAURY WRIGHT**.

The US Department of Energy (DOE) hosted its 2011 Solid-State Lighting (SSL) R&D Workshop in San Diego, California in early February, offering attendees a unique opportunity to hear about LED-based lighting developments and to participate in defining the areas where the DOE will fund LED and OLED research. The presentations covered the latest in SSL technology including details of indoor and outdoor case studies.

Jim Brodrick, the DOE Lighting Program Manager hosted the event, and kicked the presentations off with a quick update on the state of the LED and OLED lighting industries. He noted that LEDs are finding great success in outdoor applications like street and area lighting, refrigerated case lighting, and downlights for commercial spaces. But he noted ongoing concerns with LED lifetime, color consistency and droop. Brodrick asked, "If you go into a room and there are 24 fixtures up there, do they all look the same? What about three years later?"

Brodrick challenged the participants to drive improvements in drivers, dimmers, and control electronics. He demanded participation in the sessions intended to help define the DOE roadmap for future funding. And he emphasized alternative approaches, saying, "Let's think creative. Let's try to think out of the bulb." Brodrick also recognized some currently-funded R&D that are delivering good results (www.ledsmagazine.com/news/8/2/12); those companies also presented updates on their work.

Accelerating LED adoption

Cree Vice President of Corporate Marketing Greg Merritt presented the keynote address at the workshop. Merritt hit many of the same themes that Cree CEO Chuck Swoboda addressed last December (see www.ledsmagazine.com/features/7/12/10 and www.ledsmagazine.com/features/7/12/12) focusing on ways to accelerate the adoption of LEDs in general illumination. Merritt said Cree's primary focus is "How do we make it happen faster?"

Merritt did make some strong points about light quality and cost and how performance and price are intertwined. He emphasized the need for the industry to design and manufacture products that are as good or better than legacy lights, saying, "We need to spend an equal amount of time optimizing the other system elements in an LED luminaire, not only to drive the price performance, but also to make sure the solutions are better than traditional lighting."

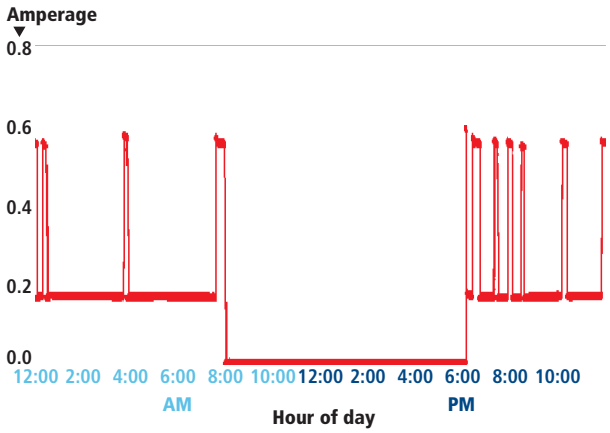

FIG. 1. A current-usage graph details the operational state of an SSL luminaire over a 24-hour period in the Nike parking lot Gateway demonstration.

While Merritt did acknowledge the need for continued improvements in the LED source, he suggested that the LEDs are a constantly decreasing part of the bill of materials in a luminaire. Optimizing performance and driving cost from other elements of a system such as drivers and optics may offer more potential to accelerate SSL adoption according to Merritt.

Merritt also provided one interesting way to look at LED component costs. He compared LED downlights that Cree designed in 2007 and 2010. The older one uses 42 LEDs and outputs 650 lm while the newer one uses 8 LEDs and outputs 560 lm. The older one sold originally for more than $100 to contractors while the new one sells for less than $50 at Home Depot. About SSL luminaire costs, Merritt said, "Sometimes reducing the number of LEDs is more important than reducing the cost of the LEDs."

The upbeat keynote was followed by Marc Ledbetter providing a more measured assessment of the state of SSL. Ledbetter is the Emerging Technologies Program Manager at DOE's PNNL (Pacific Northwest National Laboratory). Specifically, Ledbetter addressed the DOE Gateway demonstrations and Caliper programs that try to fairly measure and evaluate the effectiveness of SSL.

Caliper testing

Ledbetter addressed in detail the results of Caliper's latest testing of SLL T8 linear-fluorescent replacement lamps (see

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

www.ledsmagazine.com/features/7/6/6 for more on T8 replacements). According to Ledbetter, Round 11 Caliper testing revealed SSL replacement lamps that largely match linear fluorescent lamps in efficacy. But the LED lamps just don't effectively utilize the troffer fixture reflector design and trail fluorescents significantly in light output and distribution.

Linear replacements were also discussed later in the workshop program in a session moderated by Norman Bardsley of Bardsley Consulting. According to Bardsley, 60% of the lumen-hours of light produced in the US are from fluorescent fixtures. So the SSL industry will continue to try and win in what's a huge market niche.

But Finelite CEO Terry Clark addressed the lack of success for LEDs in fluorescent-replacement applications noting that "LEDs may not be the issue." Clark's point was that the latest fluorescent lamps are very good. According to Clark, what he calls the new Super T8 lamps offer 100 lm/W efficacy including the ballast and he noted that the high LED efficacy numbers that you see don't include the inefficiency in the driver.

Clark noted that new T8s are dimmable, albeit at an increased ballast cost but still far less expensive that LED replacement lamps. He stated that without dimming, the best T8s consume 0.45 W/ft^2 and that with dimming the consumption can hit 0.25W/ft^2. Because of the much greater cost of LEDs, Clark said, "If LEDs could be twice as good, [in terms of W/ft^2] ...so what?"

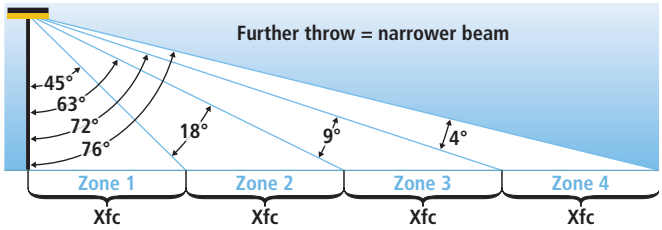

FIG. 2. Street lights must emit more light at increasingly narrow beam angles to uniformly illuminate areas that are further from the pole, at left. This creates glare problems.

While the T8 market may stay fluorescent, at least for now, PNNL's Ledbetter provided a much more upbeat assessment of how 2x2-ft recessed SSL fixtures compare to the fluorescent alternative. The 2x2-ft luminaires don't utilize replacement lamps but are integral SSL designs. And the latest products tested match fluorescents in efficacy, light distribution and lifetime klm-per-dollar assessments.

Gateway demonstrations

The workshop featured updates on a number of DOE Gateway demonstration projects for both indoor and outdoor SSL applications. Lighting designer Michael Souter of Luminae Souter Associates presented details not previously revealed about the indoor SSL project in San Francisco's Intercontinental hotel (www.ledsmagazine.com/news/7/12/10). Souter was the lead lighting consultant on the hotel when it was constructed in 2008 and a key part of the team that performed the SSL retrofit for the Gateway demonstration.

According to Souter, the hotel was reluctant at first to pursue the project after Pacific Gas & Electric had identified it as a candidate. The hotel chain previously had bad experiences with LED lighting, and according to Souter "aesthetics were more important that efficiency" when it came to lighting for the luxury brand. The hotel agreed to the project so long as the SSL installation maintained light quality, aesthetics, and safety; could be accomplished without disrupting guests; and offered a simple two-year payback.

The team was not able to find SSL replacements for all of the targeted lights. For example, the team couldn't find SSL replacements that matched the light output of the 120W PAR38 halogen lamps used in high ballroom ceilings. The team came close to finding a replacement for the AR111 halogen lights used in lobby and restaurant high ceilings, but for now have stuck with the legacy lights.

The team found three suitable replace-

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ments for MR16 lamps that had no flicker while offering good beam spread, intensity, and color. Only one 10W SSL lamp was deemed a viable replacement for 75W PAR30 halogen lamps. The SSL replacements were used in the reception area, elevator lobbies, and conference rooms, and will deliver a projected payback of 1.1 years – much better than the goal.

A Gateway trial at the Smithsonian Institute was also revealed at the workshop. Scott Rosenfeld is the resident lighting designer at the Smithsonian American Art Museum, and is experimenting with LED replacement lamps in some of the museum rooms.

Somewhat surprisingly, the test of SSL technology is not in any way due to the harmful effects of UV or IR light on art, and the fact that SSL doesn't include those wavelengths. According to Rosenfeld, the museum simply filters harmful wavelengths from legacy sources. The SSL project is purely focused on energy efficiency. Rosenfeld said, "I'm skeptical that we are going to be upgrading the quality of the lighting but what we will be doing is reducing carbon and saving energy."

The museum is testing SSL in rooms with relatively low ceiling lights ranging from 2.5m to 7m. The demonstration is replacing 50W and 66W PAR lamps with 7W and 18W LED lamps. According to Rosenfeld, the LED lamps don't offer equivalent brightness but are acceptable.

Rosenfeld is excited about the potential of SSL dimming technology. He said, "With LEDs I can reduce intensity without reducing color temperature." Today he uses filters for such dimming applications but acknowledges that filters waste energy. Still Rosenfeld is a bit of an SSL skeptic for now with more questions than answers. It will be interesting to monitor the results of this ongoing demonstration.

LINKS

2011 DOE SSL R&D Workshop presentations

www1.eere.energy.gov/buildings/ssl/sandiego2011_materials.html

Outdoor lighting

In the outdoor lighting area, Greg Sullivan, principal at Efficiency Solutions, presented the results from a completed Gateway trial that was staged on the Nike corporate campus in Beaverton, Oregon. Sullivan also briefly described outdoor Gateway trials in a Manchester, Hew Hampshire shopping plaza lot (www.ledsmagazine.com/news/7/6/13) and a Washington, DC parking garage (www.ledsmagazine.com/news/7/6/20).

The Nike demonstration included adaptive controls utilizing thermal-based sensors to detect the presence of pedestrians walking to their car. At night the lights were nominally set to 4200 lm. When a pedestrian was detected the output was increased to 9380 lm. The sensors could be set to stay at full power for an adjustable period ranging from 30 seconds to 30 minutes. The baseline setting in the demonstration was 10 minutes.

The parking lot trial yielded a lot of data because power monitors were installed at each pole base to take current readings every ten seconds. The short interval was used to capture any spurious activity attributable to the sensors.

Fig. 1 depicts a graph of a 24-hour operating period for one of

DOE SSL workshops

The DOE is holding several SSL-oriented workshops each year. The R&D workshop covered in this article is focused on technology developments in LEDs and materials such as phosphors along with SSL luminaire designs. Next up is the SSL Manufacturing R&D Workshop scheduled for April 12-13 in Boston, MA. That workshop will focus on manufacturing challenges for LEDs, luminaires, drivers, and electronics. ◄

Photo credit: Derry Berrigan, DBLD

FIG. 3. A Santa Fe Community College classroom features three layers of LED light including general illumination above student tables, two zones of wall washers, and task lighting over the main teaching board.

the seven poles where SSL luminaires were installed. As you might expect, no current was used during daylight hours. At night, the SSL luminaires used almost 0.6A at full power when pedestrians were detected, and less than 0.2A at other times. For reference, the existing metal halide fixtures consumed a constant current near 1A throughout the night.

The graph shows variable-length periods where the lights went to full bright setting. That's because a sensor that detected a second pedestrian would restart the 10 minute clock. The demonstration estimates a saving of 745 kW/h per year per luminaire with the controls yielding half of the saving on top of the LED efficiency. Alas some of the poles had sensors that triggered falsely, so there are issues with the technology that still must be perfected.

Challenges in street lighting

There was also an excellent presentation by Mark Hand of Acuity Brands Lighting on the challenge of cost-effective street lighting. Hand stated that pole cost and installation dominates the up-front cost of street lights. So lights that allow greater pole spacing have a huge economic advantage that can trump energy savings.

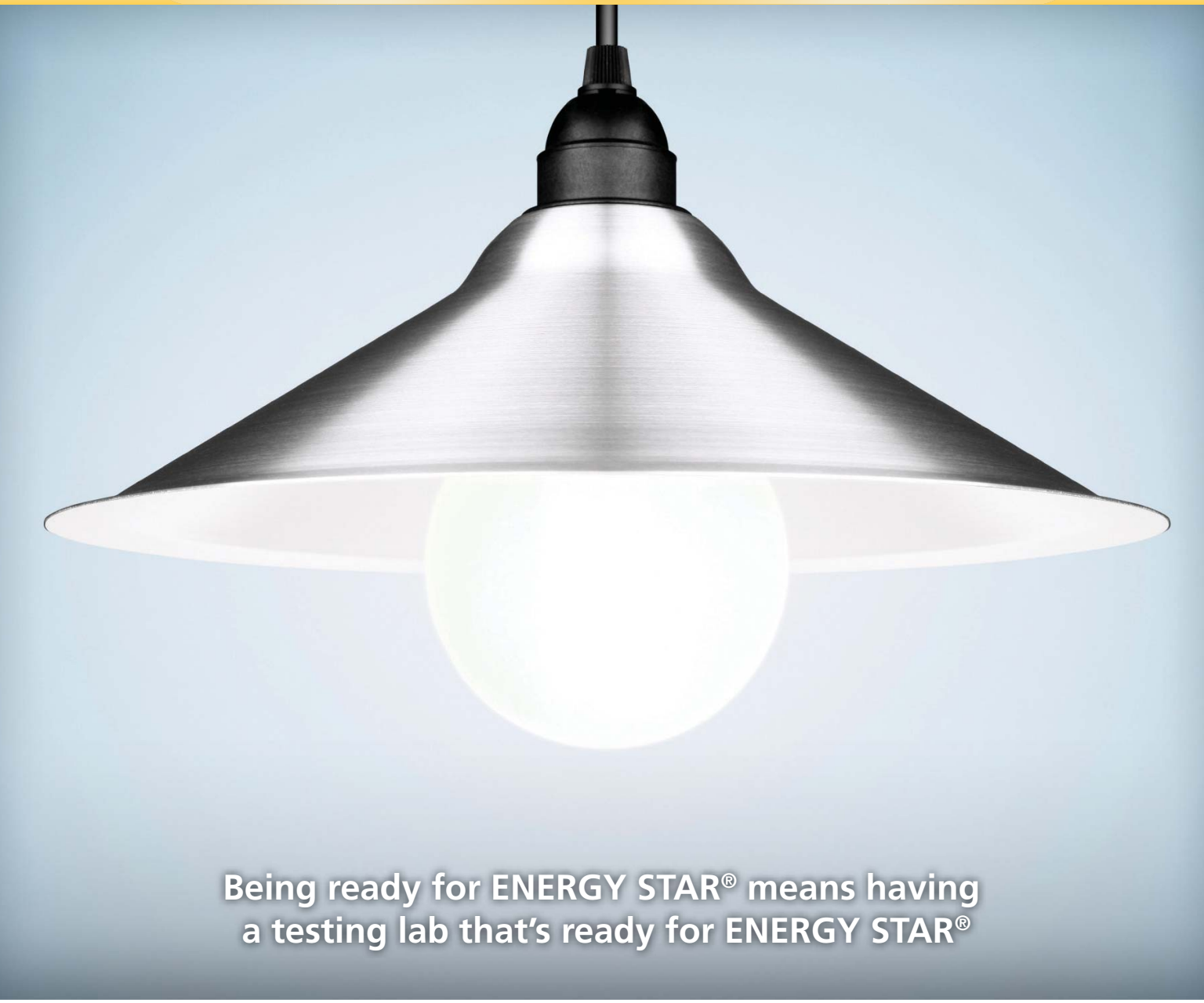
Hand described the problem depicted in Fig. 2. The goal is to put an equal number of foot candles (Xfc in Fig. 2) on the ground regardless of the distance from the pole. But longer throws have a narrower beam and the inverse square loss for light vs distance applies. The light must output 9 times the lumens to reach the far end of the last zone relative to the first, meaning that glare becomes a huge issue for greater pole spacing.

Hand didn't necessarily supply answers to the problem but noted that cheaper and brighter LEDs can't reduce pole spacing because of the glare problem. He asked, "Could big and dim be better than small and bright?"

On the final morning of the workshop, Derry Berrigan of Derry Berrigan Lighting Design took the stage and delivered a presentation on the challenges of both designing an SSL project and successfully seeing the project to completion. One of Berrigan's recent projects has been a new Trades & Advanced Technology Center building at the Santa Fe Community College in Santa Fe, New Mexico.

First let's cover the good news. Berrigan was able to use SSL luminaires in 96% of the facility (Fig. 3). The result is a facility that achieves an energy footprint of 0.64 W/ft^2 with lights at full power, and as little as 0.38 W/ft^2 with the installed adaptive controls dimming lights as appropriate. This is 51% below ASHRAE (American Society of Heating, Refrigeration, and Air-Conditioning Engineers) 2007 recommendations.

The bad news is that Berrigan fought obstacles throughout the project presented by engineers, distributors, contractors and others. Despite having a sustainable-lighting advocate as a client at the college, the lighting industry "ecosystem" attempted to replace specified SSL products with legacy lighting technologies and substitute inferior products even in the few places where SSL luminaire's weren't specified. In the end, the designer – and more importantly the college and students – won, but it required a designer and client that insisted on a sustainable project and resisted repeated attempts to derail that plan.



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Field trials collect performance data for LED outdoor-area lighting

While LED luminaires may be the popular choice for street and area lighting right now, **TOM GEIST** says "show me the data" that proves efficiency and other SSL claims.

It's not hard to pick up a trade paper and read about yet another demonstration of street lighting using LEDs. Of course, one reason for all of these demonstrations is the federal stimulus money. We, as both citizens and participants of the solid-state lighting (SSL) industry, should all ask, "What are we getting for our investment?" We should all demand, "Show me the data!" Show me the data verifying energy savings. Show me the data proving that LED lighting is equivalent to or better than traditional lighting. Show me the data that LED street lights are reliable.

At Electric Power Research Institute (EPRI), LEDs are a small part of a much bigger initiative targeted at reducing global carbon emissions. Advancing a portion of that initiative, EPRI is managing over twenty demonstrations of LED lighting technologies at sites located around the country. In this demonstration process, the focus is on accumulating "more and better data" and enhancing the collection of field data. Although data collection at EPRI's demonstration sites is ongoing, this article provides some early conclusions, conclusions that you may find surprising or that at least make you say, "Hmmm."

The potential of LEDs

LEDs matter. A DOE study in 2008 estimated potential savings of 4500 MWh per year if LEDs were to achieve 100% penetration. That's significant.

But we must make good lighting choices. In 1938, the first mercury vapor lights were installed. According to the same DOE study, 13% are still installed. Think about it – more than one out of every ten fixtures are still using a technology originally implemented when Roosevelt was president. If LEDs are adopted, they will be with us for a long time. That's why we need to get it right the first time.

When it comes to comparing LED lighting to other lighting technologies, you don't know how the alternatives really compare until you measure. Putting up lights and taking a pretty picture is not enough. We need to monitor energy consumption, verify light levels, and track reliability and performance over time.

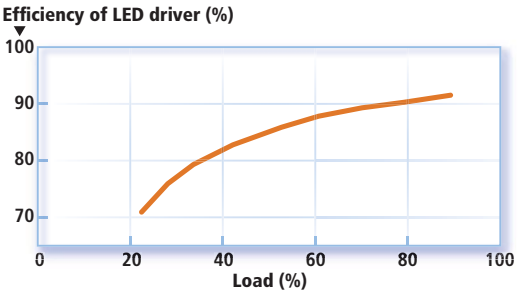

FIG. 1. As the load on this particular LED driver increases, the driver operates more efficiently.

EPRI's LED lighting demonstrations

For the LED portion of its energy efficiency initiative, EPRI developed a comprehensive analytic plan designed to answer questions for three main audiences.

First, many utilities want to know about load impact. For example, how will massive distribution of LED street lights affect a utility's load profile in terms of energy savings by season and coincident peak-demand savings? What about distortion and power factor?

Second, lighting owners such as municipalities need to know if LED lighting does the job. How is it different from traditional lighting? What about reliability?

Users – such as pedestrians on an illuminated walkway or automobile drivers in a lit parking lot – comprise the third audience. What do they think about the lighting? How well does it perform? Is it better than traditional street and area lighting? Do users feel safe?

To investigate the performance of LED street and area lighting, EPRI coined a new term called Defined-Area Efficacy (DAE), which is used to describe the field performance over time. EPRI and its participating utilities simply measure and calculate total luminance within a grid and divide the result by the measured electrical power. The resulting quotient is compared to subsequent measurements made over the course of a test interval, which in EPRI's case is about two years.

The DAE data will illustrate fixture degradation over time. The metric is similar to the fitted target efficacy (FTE) metric proposed by the DOE. However, DAE is not a computer simulation, but a measure of field performance that levels the playing field for all technologies and manufacturers.

We understand that illuminance and DAE data are only a part of the LED story. There are many more quantitative and qualitative points of comparison with other light sources. A complete comparison will include color rendering, and ease of installation and service. EPRI has also considered the qualitative opinions of users. But for our discussion here we'll focus on our illuminance and power measurements and the lessons we learned in the site and luminaire selection process.

Site and luminaire selection

A successful site must meet several criteria, such as a dedicated electrical circuit for all

TOM GEIST *is a Senior Project Manager at the Electric Power Research Institute (EPRI).*

fixtures under test, minimal light trespass, and separation from trees that throw shadows upon the test area.

LED luminaire vendor selection was equally complicated. EPRI pre-qualified several manufacturers using criteria that included a visual inspection for quality workmanship and survival of an accelerated life test using a hot box set to 50°C with the fixtures continuously energized for several months. For each site EPRI received at least five quotations from vendors that included specifications for just about everything – from the fixture warranty to detailed photometric plots. EPRI, the collaborating utility, and the participant (a city engineer for example) collaborated to select the vendor at each site.

We found in our assessments that LED fixtures are a specialty item. No two fixtures are the same. Optic designs are different. Some use optics; some don't. Is one better than another? More data is needed to address these issues.

Thermal designs vary from model to model. Heat sinks vary in shape and materials. And light patterns are very different from traditional light sources and even from one LED fixture manufacturer to another. What's the best and why? More data is needed.

Driver efficiency

What about driver efficiency? This is an area of key interest because at EPRI, we have a program to measure the efficiency of just about every computer power supply, which is very similar to an LED driver. From this data set, we know that the gold standard for efficiency is 92% when the power supply is loaded from 10-100% of the maximum power output.

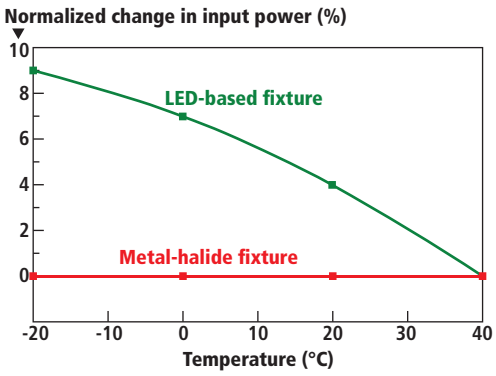

FIG. 2. Cold temperatures significantly increase the power consumption of LED fixtures.

Scotty – Mobile Light-Measurement System

The concept is simple. By tapping into the global positioning system (GPS), the EPRI-developed Mobile Light-Measurement System that we call Scotty knows its position on the earth accurate to within two centimeters. Scotty consists of a remote-control drive train above which is a platform with two light sensors (for both photopic and scotopic readings), temperature and humidity sensors, and a GPS receiver. A technician uses a remote control to wirelessly maneuver Scotty while operating a computer with custom software, which receives and logs data from the mobile sensors.

During setup, a simple calibration procedure allows the operator to define the measurement grid. Data is continuously streamed from Scotty to the computer at a rate of five measurements per second. As Scotty moves through the test area, the shading of each grid square on the computer display changes to provide a real-time indication of the illuminance level and progress. To date, the highest grid resolution EPRI has used in a test has been two feet. ◄

THE SCOTTY packs light-measurement and wireless-communication technologies on a small remote-controlled platform.

Fig. 1 is a plot of the efficiency for an LED driver from a well-known manufacturer as a function of loading from 20-100%. Notice the difference in driver efficiency as a function of loading (several tens of percent). If the goal is energy efficiency, the industry should use drivers with a higher, more constant efficiency, especially in light of recent industry suggestions to embrace LEDs' dimming capability to yield additional energy savings. Dimming will force driver operation at partial load. The technology exists to improve driver efficiency. Therefore, driver efficiency should be included in procurement specifications.

A little-known characteristic of LED fixtures is their requirement for more power at cold temperatures than at warm temperatures. Fig. 2 shows the results of thermal testing at EPRI. The metal-halide fixture did not have a temperature coefficient, but the LED fixtures did. The LED thermal characteristics impact efficiency claims – a 30% saving at 20°C decreases to 25% saving at -20°C – and may also impact utility pricing.

Regarding input power, what value should be used when calculating payback? The value on the fixture's data sheet may not equate with real-world performance. Consider some test data. EPRI tested fifteen supposedly identical LED fixtures from the same manufacturer. On average, the input power during normal operation was 4% above the rating of the input power on the manufacturer's data sheet – several tested 6% higher.

Traditional high-intensity discharge (HID) lighting can also exhibit variation in power usage relative to published manufacturer data. However, if the point of our investigation is energy savings, we should pay attention to this variation. What is the cause? How can it be reduced? How does it impact pricing? More data and discussion are needed.

Supply voltage can also impact power consumption and efficiency. For example, EPRI approved a site that is served by a circuit rated at 480V. What we found is that none of the fixtures tested by EPRI were optimized for use on a 480V circuit. In fact, in all cases the manufacturer simply added an autotransformer to facilitate connection to a 480V circuit. This caused a 7% increase in input power to the fixture.

The luminaire manufacturers were upfront in informing us of the power increase at 480V. The point is that we can do better. If a utility used transformers with a 7% power loss on its distribution circuits, that utility wouldn't be in the energy business for long. More work is needed to prop-

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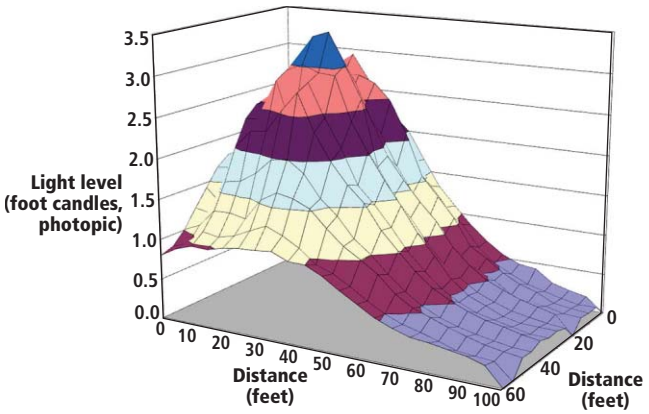


FIG. 3. The light output of an HPS fixture illuminates the ground unevenly—a cone shape.

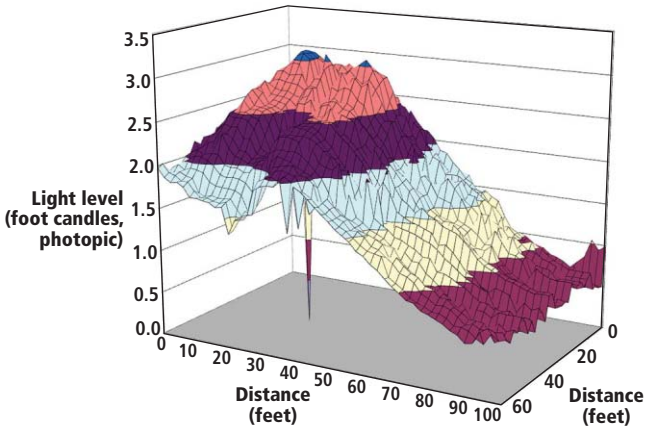


FIG. 4. The light output from this specific LED fixture is more evenly distributed on the ground.

erly design fixtures for use on 480V circuits.

Collecting field data

Ultimately our goal remains collecting real field data and EPRI found that existing test methods used in the field are time-consuming, make use of unwieldy handheld meters, and have limited resolution. The standard method of measurement requires laying out a grid, manually placing the light sensor at a grid intersection, moving out of the way, recording the reading, picking the sensor back up, and moving to the next grid intersection.

Engineers at EPRI decided there has to be a better way. That's why EPRI engineered Scotty, the Mobile Light-Measurement System enabled by GPS (see Sidebar, page 36) that automates the data collection process

providing more and better data.

Post-processing of the data from Scotty allows for a variety of outputs, such as the orthogonal plot of illuminance (Fig. 3) from a 200W high-pressure sodium (HPS) fixture. Here, the X and Y axes represent the two-dimensional surface below the fixture. The Z axis represents the magnitude of illuminance in foot-candles (photopic).

For this particular HPS site, we used a 5-ft by 5-ft grid for data collection over a total area of 100 by 60 ft. Within each grid square, the light output was averaged for readings. Notice that the light output peaks when measured directly under the fixture, and that the light output falls rapidly, following a cone shape.

Now, compare the HPS light output to that of an LED fixture (Fig. 4), with data taken using a 2-ft by 2-ft grid. The lighting levels beneath this particular LED fixture are more evenly distributed.

In addition to efficacy, EPRI is also interested in verifying energy savings. At each demonstration site, EPRI has installed an energy monitor with the ability to wirelessly transmit data to a server located within our Knoxville, Tennessee facility. The goal is to verify energy savings over time. Does each site perform as expected and realize energy savings? We will continue to collect data until the end of March 2012 and plan to publish the results thereafter.

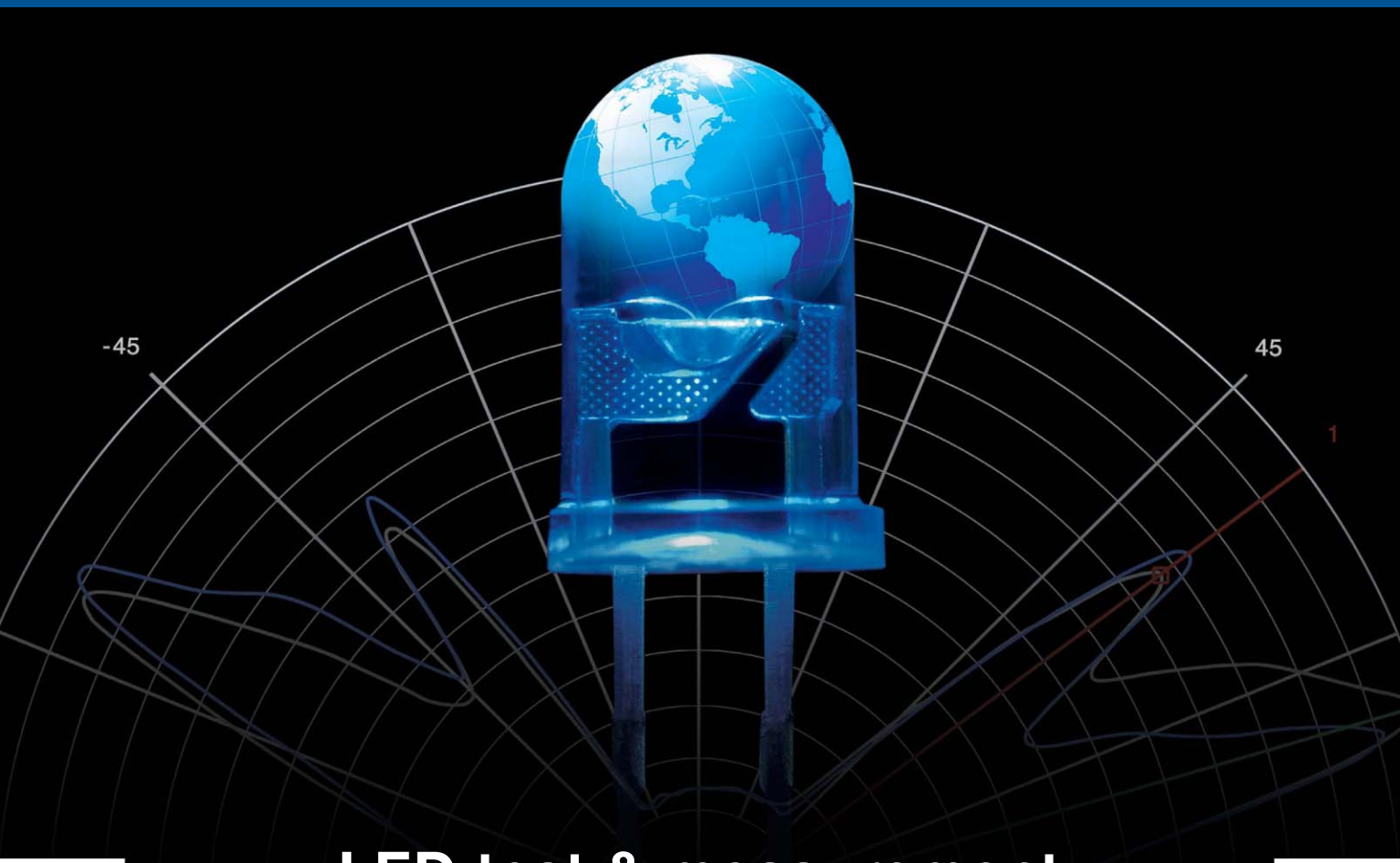
Lessons learned

Regardless of the hype, LED fixtures are just another tool used to fix a problem – in this case to economically illuminate an area. LED fixtures are unique, and the answers are not all in the specifications. LED fixtures, and all lighting technologies for that matter, are not directly comparable. What is comparable is the lighting design – the photometric qualities of both the fixture and the site details. Because manufacturers do not and perhaps cannot convey information about a lighting design, it's not possible to look at a data sheet and decide whether a particular fixture will succeed.

The good news is that early field results support the claim that a fixture using LED technology can in some applications provide acceptable illumination and energy savings. Saving money, however, is another issue. Many city engineers and politicians are surprised to learn that a 50% reduction in fixture energy use does not typically equal a 50% reduction in their electricity bill. It's more like 15%. The other 35% covers infrastructure costs such as pole and wire depreciation and maintenance. Care is needed when calculating simple payback.

LEDs are part of a solution to a big problem – carbon reduction. To reduce greenhouse gas emissions, there is no silver bullet, and we need every technology available. LED technology shows promise, and we must continue to research, develop, and field test.

We bring quality to light.



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thermal | CONDUCTIVE COMPOUNDS

LEDs chill out with heat sinks molded from conductive compounds

Thermoplastic compounds featuring conductive fillers can be used to fabricate LED heat sinks that offer high performance and design freedom, explains **HANS-OTTO SCHLOTHAUER**.

Heat sinks play a pragmatic role in LED lighting by dissipating heat that can impact performance and shorten useful life, but that does not mean they have to be utilitarian. Although traditional heat sinks are made with aluminum or copper, new conductive thermoplastic compounds in white and light colors offer expanded design freedom to create more-efficient heat-sink configurations. They also offer fresh aesthetics to complement stylish LED bulbs, enhancing the consumer appeal of LED lighting and driving adoption. Equally important, these compounds help to reduce system costs by replacing costly operations – such as the machining and finishing of metal parts – with efficient, high-volume injection molding.

The primary environmental and economic value of LEDs lies in their high-energy efficiency and exceptionally long life – up to 50,000 hours. Heat sinks are critical to both the performance and life span of LEDs. All types of electric lighting experience lumen depreciation with operation. For LEDs, the primary cause of this decrease in lumens is heat generated at the LED junction. The miniaturized and sensitive semiconductors used in LEDs are limited in their tolerance for heat.

Because LEDs do not emit infrared radiation, this heat must be removed by conduction or convection. If heat removal is insufficient, the LED can experience short-term color shift and reduced light output, as well as long-term lumen depreciation that impacts the overall value. Specifically, the forward voltage will begin to decrease, placing an increased load on the LED driver components and causing their temperature to rise. With higher temperatures, the optical wavelength can shift, causing orange lights to appear red or white lights to appear bluish.

In addition, a thermally-stressed LED will lose efficiency, and light output will diminish. If thermal management remains uncontrolled the LED junction may break down, typically leading to catastrophic failure. Other results of heat-stressed LEDs may include broken wire bonds, delaminating, internal solder joint detachment, damage to die-bond epoxy, and lens yellowing.

HANS-OTTO SCHLOTHAUER *is the Lighting Product Marketing Manager with SABIC Innovative Plastics GmbH.*

Thermal challenges

Technological advancements are making thermal management of LEDs even more challenging. One of the main issues stems from the steadily increasing power and current of LEDs. Today's LEDs often require 1W of power, up from milliwatt levels only a few years ago, and this upward trend is expected to continue, with wattages of 10W or even 20W on the horizon. To support higher brightness, current levels of 1A levels are now commonplace.

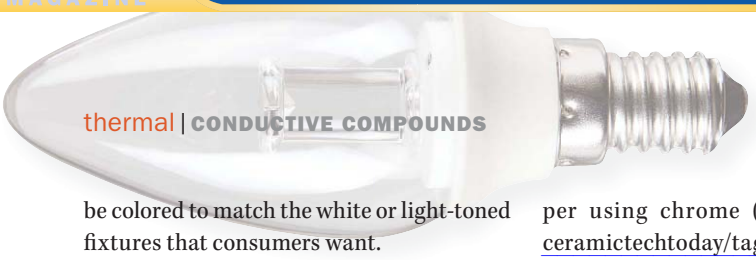
New heat-sink solutions required

To meet tomorrow's LED thermal challenges, designers must be free to create new configurations and geometries that optimize heat dissipation, and to utilize new materials that may offer higher performance. However, heat-sink materials and designs need to do more than just effectively dissipate ever-increasing heat. Besides the trend toward brighter and more powerful LEDs, other forces are at work in the general and retrofit lighting markets.

One of the most important is cost reduction. Currently, LED lamps are more expensive than incandescent and compact fluorescent lamps, a fact that has impeded widespread acceptance among consumers. Manufacturers are looking for ways to reduce costs to make LEDs more attractive to a mass audience. Rethinking the materials and processes used to produce heat sinks is one way to reduce total costs. In particular, the metal heat sinks commonly used in LEDs require time-consuming secondary operations and are not optimized for high-volume production, compared with thermally-conductive compounds.

Another impediment to market acceptance is aesthetics. Many traditional heat sinks are made from materials that cannot

FIG. 1. Leedarson Lighting Co. Ltd., has used white LNP Konduit conductive thermoplastic compound for heat sinks in two product lines: a 1.8W LED candle-shaped lamp and a 1.8W LED round lamp.



be colored to match the white or light-toned fixtures that consumers want.

New materials for heat sinks

Currently, many LED heat-sinks are formed or stamped from aluminum or copper using pin-fin or straight-fin designs. These fins, or extrusions, increase the surface area and produce more-effective heat convection. Aluminum has good thermal conductivity, while copper's performance is about twice as high. However, while aluminum is inexpensive, copper costs and weighs more, and tends to be used selectively in high-performance applications.

Now, heat-sink manufacturers are finding new and innovative solutions to the limitations of metals as follows:

Combining copper with diamond powder: Diamond conducts heat five times better than copper. Researchers at Germany's Fraunhofer Institute have found a way to bond the diamond powder to the copper using chrome (www.ceramics.org/ceramictechtoday/tag/heat-sink). In addition to this being an experimental technology, the cost of the diamond powder may be a deterrent to adoption.

Increasing the effectiveness of metal: Compared with solid materials, metal heat-pipes filled with a liquid are more efficient at conducting heat away from the device to the environment. This approach optimizes cooling, making a smaller heat sink more effective. The disadvantage is the complexity of the design and the need for heat pipes in addition to the heat sink.

Replacing metal with ceramics: Ceramic materials can be formed into almost any shape and provide heat conduction that is almost as effective as that of copper. Ceramic heat sinks are also cost-effective to produce, and can provide additional functionality in the form of component mounting, becoming both a socket and a heat sink for LEDs. The main disadvantages of such solutions are the need for secondary operations (deflashing), and the brittleness of ceramics compared with other materials.

Adding heat sheets: Heat sheets can be placed between a printed circuit board and the heat sink to improve thermal transference. Made from a pliable graphite compound, these sheets can be formed into various shapes, almost like a sheet of paper. They are relatively cheap to produce, and offer very attractive thermal characteristics. The compound conducts heat in the X and Y planes more effectively than standard materials such as copper and aluminum, while in the Z plane (thickness) it shows comparable effectiveness.

Conductive compounds

Thermoplastic compounds featuring conductive fillers can provide a comprehensive solution for LED heat sinks and help to manage the demands of increasing heat output. These materials combine high

thermal conductivity and electrical isolation properties, and adjustments to the amount and type of filler (ceramics such as boron nitride and graphite carbon) can be made to suit the application requirements of the LED. Compared to unfilled thermoplastics with a thermal conductivity of around 0.2 W/mK, most thermally conductive plastic compounds typically have 10-50 times higher conductivity (1-10 W/mK) and in some cases can deliver up to 100 W/mK.

Compared with aluminum and other metals, thermally-conductive compounds typically have lower coefficients of thermal expansion (CTE), and this helps reduce stresses from differential expansion. They also weigh significantly less than aluminum.

Further, many types of thermoplastics, including both crystalline and amorphous materials, can be used for the matrix; however, glass reinforcement is typically added to amorphous grades for dimensional stability. These material choices offer tremendous flexibility to designers, who also benefit from the freedom to create complex shapes and achieve part integration using injection molding instead of traditional stamping, casting and secondary finishing required by metals. Thermoplastics open the door to innovative configurations that can optimize heat transfer – all while providing the cost benefits of high-volume production.

Leedarson chooses white compound

Recently, SABIC Innovative Plastics introduced white grades of its LNP Konduit specialty thermoplastic compound to coordinate with white and colored bulbs and lighting fixtures favored by consumers. Leedarson Lighting Co. Ltd., a lighting manufacturer and exporter based in Xiamen, China, is the first customer to use white LNP Konduit compound for heat sinks in LED lamps (see Fig. 1).

Leedarson selected LNP Konduit compound as a replacement for aluminum to achieve more-stylish aesthetics for the heat sink without the need for secondary painting. Also, efficient, high-volume injection molding allows the company to easily scale-up production to meet strong demand for its LED lights, whereas significant investment would be required to expand the aluminum-processing capacity.

Leedarson chose LNP Konduit compound for its thermal-conductivity performance of up to 10 W/mK in combination with electrical isolation to pass the industry-standard 6 kV breakdown test. The material also provides non-halogenated flame retardance and stable color performance.

In conclusion, although there are a range of contenders to replace traditional metals, thermoplastic compounds offer the best combination of performance, design flexibility, aesthetics and production efficiency to meet new technology requirements and anticipated growth in user demand.

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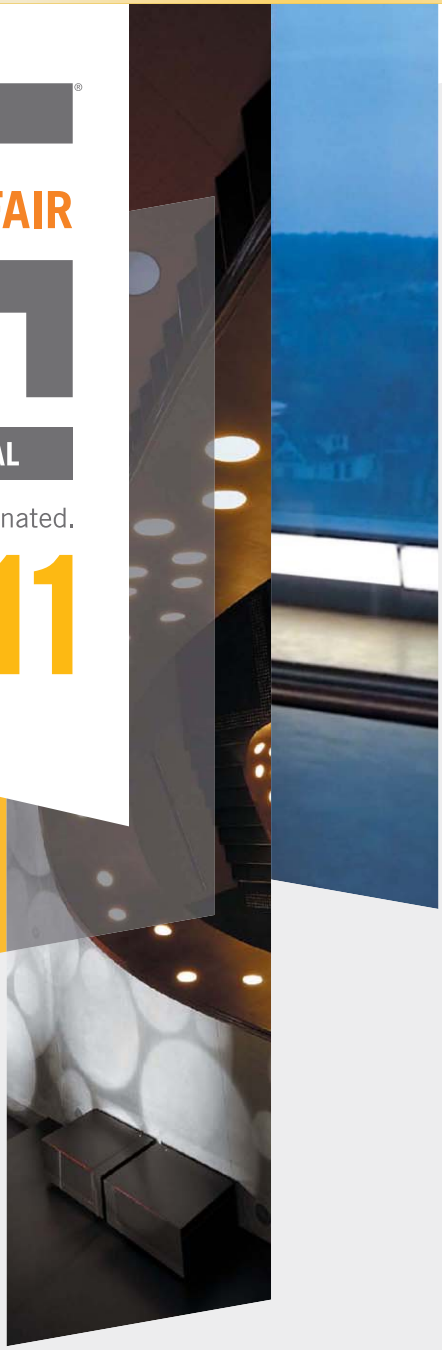

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LED drivers for 3D-TV backlights require extreme accuracy

Implementing a 3D mode in an LED TV increases the demand for current accuracy, peak current range, number of channels, timing speed and accuracy in the LED driver IC, as **WERNER SCHÖGLER, MARKUS LUIDOLT** and **MANFRED PAURITSCH** explain.

3D video is the hottest new technology in the TV industry. For the leading TV brands, it represents their most important strategy for maintaining margins and market leadership, because creating a fantastic 3D viewing experience calls for highly advanced technology and sophisticated image processing – fields in which they excel.

One challenging element of 3D-TV design is the power circuit driving the strings of backlighting LEDs. These devices need to be switched precisely for very short periods of time, but (for 3D viewing) to relatively high peak currents – and, to achieve consistent brightness across the screen, the amount of current supplied must be very accurately regulated.

Such a demanding combination of accuracy, current capability and timing has not been required previously in any application, and hence a new generation of LED drivers is emerging specifically designed for 3D TVs.

In order to properly evaluate the specification of a backlightLED driver IC, it will help to understand the main factors affecting the operation of a 3D TV.

Constraints facing 3D-TV designers

There is only going to be one winner in the battle between LCD and plasma for the 3D market. While plasma is faster than LCD, government-sponsored regulation in Europe and the US means that efficient LCD technology – plasma consumes up to twice as much energy as conventional LCD, and LED backlighting improves LCD efficiency still further – is the only viable option. Version 4.0 of the US Energy Star television specification came into effect on 1 May 2010, and set the industry a tight power budget. Version 5.0 planned for May 2012 cuts the maximum-allowed ON power even further (see Table 1).

LED backlighting is now being widely adopted because of the superior performance it provides. It is forecasted that by 2012, 70% of LCD TVs will use LED backlights rather than cold-cathode fluorescent lamps.

In particular, LED backlights offer improved colour gamut and saturation, a very short on/off switch-time (<100 ns) and a 100,000-hour lifetime, and they enable a compact, thin panel design.

There are two ways to implement LED backlighting (see Fig. 1):

In indirect backlighting, the LEDs are arranged at the edges, with a light guide to distribute the light uniformly across the LCD. This arrangement can be deployed with good optical uniformity in screen sizes up to 40 in, and enables backlight units with thicknesses of just 5-10 mm.

In direct backlight systems, the LEDs are located directly behind the LCD, enabling low power consumption, good thermal design and excellent scalability with practically no limit to the screen size. Panels can be made 10-25 mm thick. One key advantage is that direct backlighting enables local dimming, which reduces power consumption and increases dynamic contrast ratio.

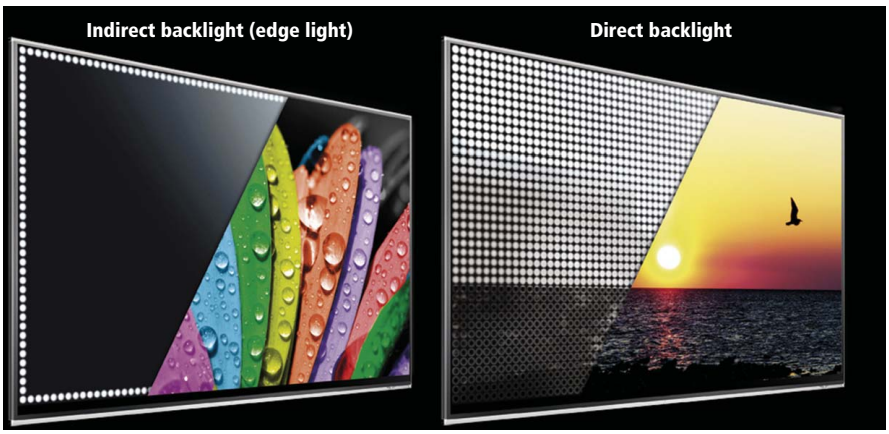

FIG. 1. LED backlighting techniques.

Producing the 3D effect

For 3D stereoscopic visualisation, glasses are used to effect time-multiplexing of the right- and left-perspective views of the right and left eye. It is already clear that shutter glasses will win over the competing technology of polarised glasses because of the superior 3D resolution and the excellent 2D

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picture quality. Usage of polarised glasses degrades the picture quality in 2D usage, and, for a long time to come, most viewing of 3D sets will be in 2D mode because of the scarcity of 3D programming.

The challenge with the operation of shutter glasses is to avoid cross-talk and flicker. Because of the time-multiplexing in 3D mode, an effective doubling of the display rate from 120 Hz to 240 Hz is necessary to avoid flicker problems. It is expected that for premium market TVs the picture rate will even increase to 480 Hz.

Crosstalk is the leak of the left image channel into the right eye's view, and vice versa. The perception of crosstalk is the so-called "ghosting", where a shadow image is visible (see Fig. 2).

Avoiding crosstalk requires extremely-precise synchronisation of the LCD, the LED backlight and the shutter glasses.

Liquid-crystal shutter (LCS) glasses have two issues that must be taken into account (see Table 2). First, they need significant time to switch between the transparent and non-transparent states: response time is 0.1 ms for open-to-close and 1.8 ms for close-to-open. Second, the transparency in open mode is limited, causing a significant reduction in brightness. To avoid crosstalk caused by the open-to-close switching duration, black frames are inserted during the transition (see Fig. 3).

In addition to the limitation of the shutter glasses, the LCD's response time has to be taken into account. The best-in-class value for new TV sets is 2 ms. Assuming a 240 Hz picture rate with a frame period of 4.1 ms, the ON time for the backlight is less than 2 ms.

This then defines the scope of the task facing the power-circuit designer: in 3D mode, high LED currents have to be applied for very short periods, and with very accurate control of the timing.

Because of the low duty-cycle and limited transparency of shutter glasses, high LED peak currents are necessary in order to produce sufficient brightness in 3D mode. The peak current in 3D mode is significantly higher than in 2D mode (see Table 3).

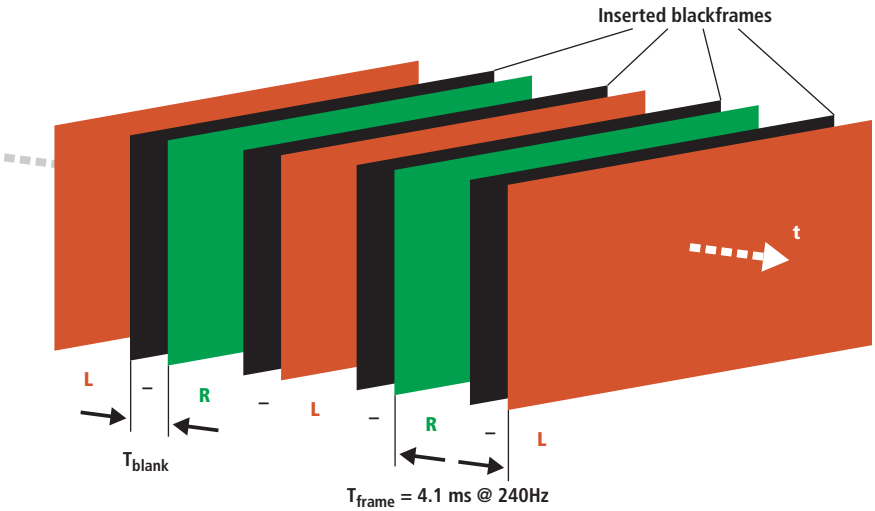

FIG. 3. Black-frame insertion (BFI) timing for 3D TV.

FIG. 2. Ghosting artefact caused by cross-talk.

High current accuracy

High-quality TVs must maintain uniform perceived brightness across the entire screen area. In LED backlighting systems, this means the accuracy of the LED driver must be ±1.5%. This accuracy budget must include all the deviations introduced by the LED driver device itself, and by external current-set resistors. What is more, this minimum accuracy must be achieved across the entire 2D and 3D current range – a range that is around five times wider than in 2D-only designs.

To enable this, devices from austriamicrosystems AG implement an architecture that uses one high-accuracy DAC to set the current in 2D mode and 3D mode with the same precision. This avoids the need for complex correction schemes such as mode-dependent correction look-up tables.

It should be said that a value of ±1.5% system accuracy is extremely difficult to reach. To give some insight into just how difficult, consider that the reference current is normally set with an external resistor: the resistor's accuracy is already ±1.0%. Therefore from a system point of view, there is only ±0.5% tolerance left for the on-chip current sink accuracy.

In order to reach an absolute current accuracy of ±0.5%, austriamicrosystems' panel-lighting LED driver products are based on trimmed, temperature- and offset-compensated high-precision current references. For

on-chip channel-to-channel matching, even better accuracy of ±0.2% is achieved.

The challenge here is not achieving the required accuracy at a single specified current – many ordinary driver ICs can achieve this already. The difficulty is achieving this accuracy value in the operating conditions of a 3D TV, where the driver IC must support the current ranges of both 2D and 3D mode, in the presence of fluctuating temperatures up to the levels experienced inside a TV set.

Table 1: Energy Star ON power requirements for various screen sizes.

Viewable diagonal screen size (inches)	Aspect ratio	Viewable screen size in inches	Screen area in inches² (cm²)	Energy Star® V4.0 maximum ON-mode power in watts	Energy Star® V5.0 maximum ON-mode power in watts
20	16:9	17.4 x 9.8	170.5 (1100)	37	27
32	16:9	27.9 x 15.7	438.0 (2826)	78	55
42	16:9	36.6 x 20.6	754.0 (4865)	115	81
50	16:9	43.6 x 24.5	1068.2 (6892)	153	108
60	16:9	52.3 x 29.4	1537.6 (9920)	210	108

Timing and communication

Demand for direct backlighting systems – in preference to edge-lit systems – is likely to be high because they support local dimming, which helps reduce energy consumption. This in turn requires a large number of LED channels to be set up within each frame. As many as 200 channels can be found in a TV, driven by multiple LED driver chips that must all be configured within a single frame period.

This calls for high-speed daisy-chained SPI interfaces connecting several LED drivers to the SPI master. austriamicrosystems has implemented a special SPI protocol for fast block transfer of pulse-width modulation (PWM) set-up data to several devices, either configuring all devices with the same data or writing blocks of multiple bytes for individual set-up of each device in the chain.

An SPI interface also enables the precise timing required to implement black-frame insertion (BFI) effectively. The timing must be synchronised to the frame rate by using VSYNC and HSYNC input signals. This then requires independent PWM generators that run synchronously with these signals, enabling flexible programming of the timing

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during a frame period. Under this scheme, interaction between a microcontroller and the timing controllers on the LED driver chipset can be minimised.

austriamicrosystems has implemented dedicated shadow registers that allow SPI data transfer during the whole VSYNC period; the update time for the PWM generator set-up data is precisely set by the VSYNC timing. This guarantees that SPI data transfer is completely decoupled from timing generation, and no dependency or error can be generated by SPI timings, which can be quite unpredictable if the master is implemented on a microcontroller.

With these shadow registers, the PWM set-up can also generate more than one pulse within each VSYNC period, enabling more complex schemes for BFI and doubling the frequency with respect to VSYNC.

Table 2. Example specification for shutter glasses.

Item	Product specifications
Method	Active shutter
Response speed	0.1 ms (open to close) and 1.8 ms (close to open)
Contrast ratio	5000:1 (perpendicular to the display)
	1000:1 (at a viewing angle of 30 degrees)
3D crosstalk ratio	0.1% or less (at a viewing angle of 30 degrees)
Transmittance	33%

Table 3: Peak LED drive current in 2D and 3D mode.

		LED current [mA]	PWM duty cycle [%]
Edge light	2D	50	80
Edge light	3D	200	40
Direct backlight	2D	20	80
Direct backlight	3D	120	40

Conclusion

Implementing a 3D mode in an LED TV increases the demand for current accuracy, peak current range, number of channels, timing speed and accuracy in the LED driver IC. At the same time, energy constraints will force manufacturers to use advanced power-saving schemes with intelligent dimming solutions for both edge- and direct-LED backlighting.

last word

LED lighting – embrace the change, seize the opportunity or become irrelevant

The opportunity to make and deliver an SSL product that improves people's lives is here today, says **TERRENCE WALSH** of **TEMPO INDUSTRIES**.

While LED lighting is a hot topic, there's a doubter for every proponent. Without question some designers and end users have suffered substandard experiences and high costs with poor ROI. Early inferior solid-state-lighting (SSL) technology, may be leading many to wait on the sidelines. That's a bad decision. LED technology has arrived for general illumination and industry players can either seize the opportunity or face irrelevance.

So, where are we? Despite all the nay-sayers, LED lighting is rapidly maturing and entering the market. One of the most cogent statements about LED adoption was created by Philips and illustrated, in a slide entitled "Rapid change is coming to lighting," with the direct statement: "By 2020, 80% of the world's lighting will be LED."

Let's consider some points that may help explain why the transition will happen and what opportunities lie ahead.

1) The worldwide power grid is not getting any bigger. It's essential that we reduce energy use and improve sustainability worldwide if we are to continue to develop and expand the quality of life for people. It doesn't matter which side of the global warming or climate change argument you're on. We should be able to agree that using less energy is mandated.

2) The new construction market for North America and the EU isn't coming back soon. However, estimates of potential lighting retrofits in the US are approximately $75-80 billion. This is a direct opportunity for good LED products.

3) LED technology is rapidly advancing. The train is on the tracks. You can get aboard and make it happen, you can choose to stay behind and become irrelevant, but you should not stand on the tracks with your hands up.

4) If the Philip's projection is accurate, then 80% of the world's lighting will be LED in nine years. What were you doing nine years ago? The most rapid growth will occur between now and 2016. Considering general macroeconomic factors – construction permits, new construction, housing starts – the advice to manufacturers of incumbent lighting technology is "tool up and invest in change" before your competitor does.

5) Sales/distribution channels are changing. The days of spec/bid/buy are at an end. The general economic environment favors solution providers, not product sellers to the customer. The package as we have known it is becoming extinct. Reps should change, trim their lines and get educated. Companies providing inferior products are being eliminated and we have a solid and positive forward outlook for SSL technology.

6) Consider the unintended consequences of LED adoption that provide other opportunities for renewable technologies. Incumbent lighting technology is a too-demanding market for less-efficient renewable power sources such as wind or solar. With more efficient LEDs, solar and wind sources become more viable. Consider off-grid opportunities in Africa, Asia and India where at least 2 million barrels of oil per day are consumed for kerosene-powered fuel lamps.

7) Update the ROI model. Replacing incumbent lighting with high power LED general illumination products will save energy, reduce maintenance, and improve sustainability. There are incentives from utilities as well as the little-known application of the Energy Policy Act of 2005. The present ROI model isn't relevant – if one applied this approach to buying a car they'd still be driving a '95 Corolla!

In summary, the technology is rapidly evolving. If you wait and see, or if you wait until LEDs really are a commodity, you may become irrelevant. The channels of distribution aren't evolving – they are becoming extinct. The opportunity to make and deliver a product, and a system that improves people's lives, and reduces energy consumption worldwide, and provides profit opportunity, is here now. Get aboard and enjoy the ride.

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