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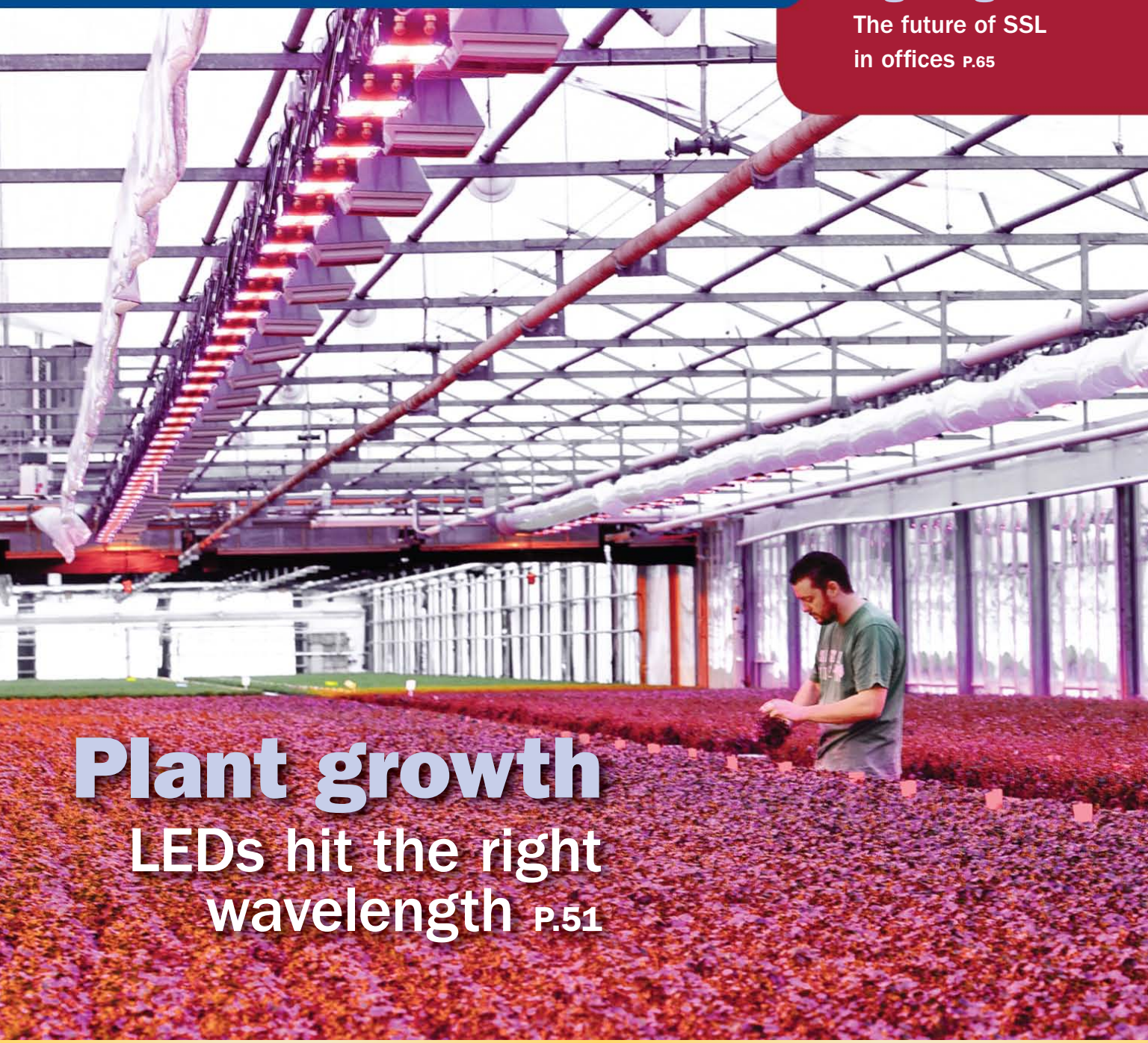
TECHNOLOGY AND APPLICATIONS OF LIGHT EMITTING DIODES

SIL 2011
LED Lighting Track in review P.33 & P.39

HV-LEDs
High voltage for retrofit lamps P.47

Lighting
The future of SSL in offices P.65



Plant growth
LEDs hit the right wavelength P.51

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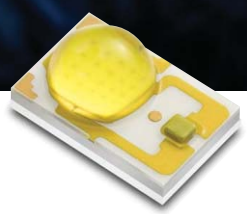

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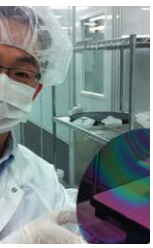
ISSUE 42
april/may 2011

Cover Story

LED light sources at specific wavelengths offer optimal performance in horticulture – see page 51. Photo: Osram Opto Semiconductors.

features



columns/departments

commentary

LEDs promote health in plants and humans

Since our last issue was published, world news has been dominated by the disastrous events in Japan. Our thoughts go out to all those that have been affected either directly or indirectly by this tragedy.

Many of our articles in LEDs Magazine are focused on solid-state lighting, looking at how LED-based systems can provide improved illumination with enhanced energy efficiency. Examples in this issue include retrofit projects in parking garages and cold-storage warehouses (page 73), all of which include the use of occupancy sensors to make sure that the lights are on only when someone is present. Meanwhile, in office environments, it is clear that further research is required into the human factors involved in LED lighting. As our article on page 65 explains, further adoption of LED lighting could be impeded without better knowledge of how people will respond to LED lighting, how they would use capabilities such as color changing, and how LEDs could affect office workers' performance and health.

On the other hand, it appears that LED lighting can be extremely beneficial to the health and development of plants. When the wavelengths of the LEDs are tuned to the absorption peaks of chlorophyll, the results can be spectacular, either in indoor plant factories where the LEDs are the only source of light, or in greenhouses where the LEDs supplement natural light. Plants can even be layered on shelves to pack as many as possible into the available space, as our article on page 51 describes.

In addition to affecting general feelings of well-being in humans, LED lighting can have various specific clinical effects. LED-based treatment of various skin conditions is relatively well known, and companies are already selling systems approved by the US Food & Drug Administration (page 20). Early-stage studies also suggest that red/near-infrared LEDs can have help patients recover from traumatic brain injury.

One important aspect of overall lighting performance is color rendering. While the ubiquitous color rendering index (CRI) has been widely used for decades, most experts agree that it has shortcomings, and several alternatives have been proposed. NIST, example, has proposed a color quality scale as an alternative (page 39), but has so far failed to have this accepted via CIE as a global replacement for CRI. Color science was one of the many key themes discussed at this year's Strategies in Light conference, along with dimming and controls, retrofit lamps, modules, and factors affecting market adoption, as our two articles on pages 33 and 39 explain.

The Strategies in Light (SIL) conference series moves to China for the first time this year, building on successful shows in the USA, Japan and Europe. SIL China will focus on an "East Meets West" theme, looking at ways in which China is developing rapidly as a supplier of LEDs and LED-based products and at the same time has become a very large consumer of solid-state lighting as the government seeks to promote energy efficiency. Our article on page 27 previews the conference, which takes place on May 10-12 in Kowloon, Hong Kong.

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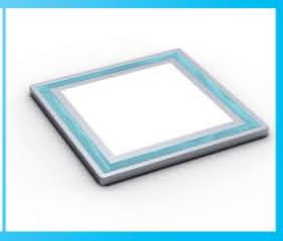
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ExCeL London Exhibition Centre chooses Dialight LED lighting to meet energy-efficiency targets

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FEATURED *content*

White Paper: Lighting Technologies, Principles and Measurement

The proper measurement of light is a precise and complex science. The first step in correctly measuring light is to understand the basics: color-rendering properties, color temperature, light distribution, total luminous flux and mura. This white paper explains these terms and more, and describes in detail the best and most accurate method for proper light measurement.

www.ledsmagazine.com/whitepapers/4/

White Paper: Controlling LEDs

Designers often do not know how to control LEDs or they have had negative experiences working with them. This white paper goes into detail about why you should consider dimming LEDs and what questions need to be answered in order to dim LEDs properly to meet your expectations. The overall goal is to make you more comfortable with using LEDs on your projects.

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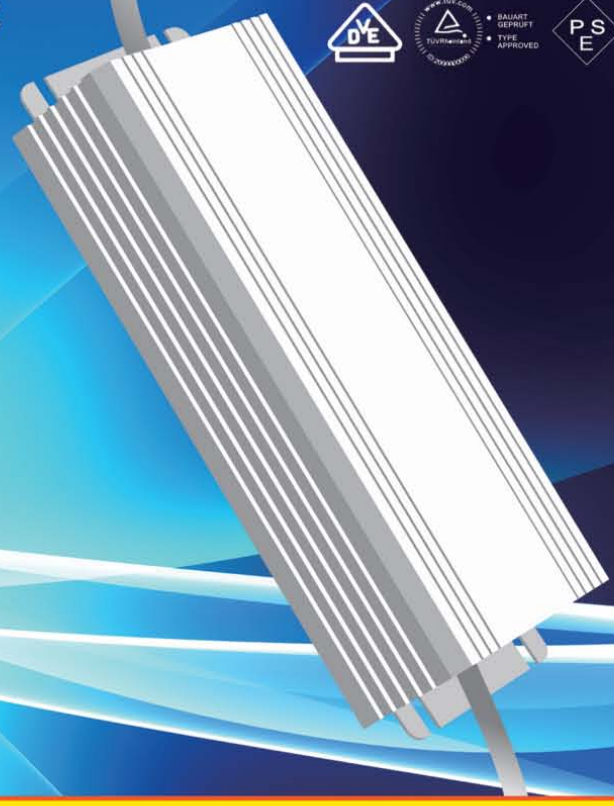

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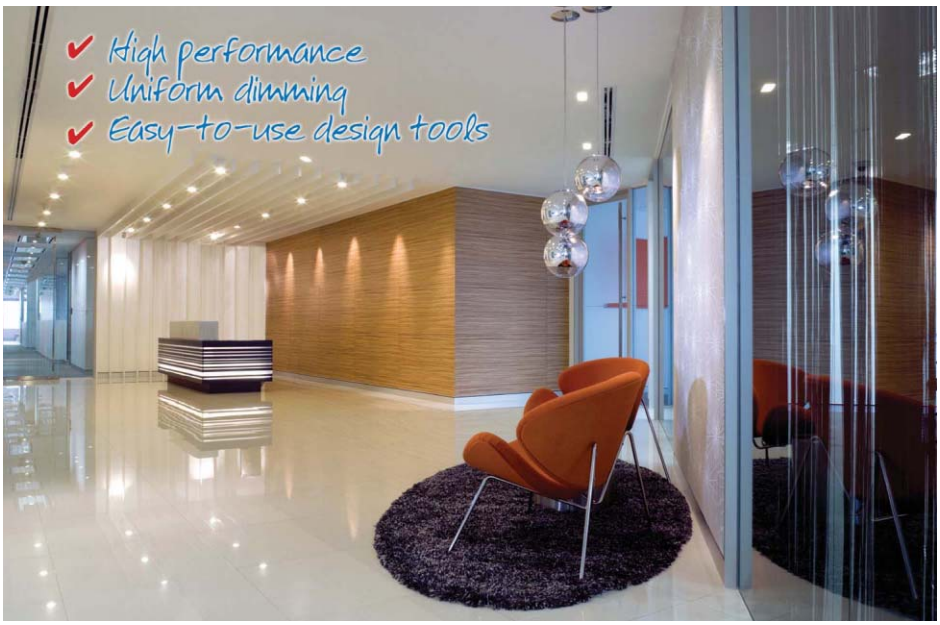

Phase dimmable LED driver

The LM3450 phase dimmable LED driver integrates active power factor correction and phase dimming decoding, and is ideal for dimmable LED fixture applications with output powers between 10W and 100W and accepts universal input voltages. It features unique dynamic hold circuitry which allows for excellent dimming performance.

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CHIP MANUFACTURING

Bridgelux reports R&D results for GaN-on-silicon

LED maker Bridgelux has reported impressive R&D results for GaN-based LEDs grown on silicon substrates, including the headline-grabbing figure of 135 lm/W for a white LED with a CCT of 4730K. Specifically this was a 1.5-mm power LED operated at 350 mA with an operating voltage of just 2.90V.

The company said that it "anticipates the delivery of its first commercially-available GaN-on-silicon products over the course of the next two to three years." This length of time indicates the effort that will be required to translate this R&D result into a commercially-viable process with good yield. The eventual goal appears to be the growth of GaN LEDs on 8-inch silicon wafers, judging by the photo shown here, and another showing three 8-inch wafers in an MOCVD reactor.

Bridgelux says that its R&D team has been investigating GaN-on-Si technology for the past five years. Other companies are also developing similar technology. A Wall

Street Journal blog article said that Bridgelux thought its announcement "is dramatic enough to force others to disclose their progress." The article also quoted Bill Watkins, Bridgelux CEO, as saying: "This will shake everybody out."

Although these have been erroneously described as "silicon-based LEDs," the light comes from the GaN-based layers grown on top of the Si wafer. These GaN layers are similar to those in today's GaN-based LEDs, which are » page 12

LIGHTING

Siemens plans Osram IPO, Osram appoints new CEO

Siemens AG, the German industrial conglomerate, plans to publicly list its subsidiary Osram GmbH in the fall of 2011. The parent company intends to retain a minority stake in Osram and will remain a "long-term anchor shareholder." In preparation for the initial public offering (IPO), Wolfgang Dehen (left) has taken over as president and CEO, succeeding Martin Goetzeler, who has become chief operating officer.

Osram, part of Siemens' Industry sector, is the world's second largest lighting manufacturer, and had a turnover of EUR4.7 billion in the 2010 financial year. The company has around 40,000 employees worldwide, supplying customers in 150 countries from its 46 production sites in 17 countries.

"Osram has an outstanding position worldwide as Siemens' lighting brand, and we intend to maintain our close ties to the » page 12

DRIVER ICs

Texas Instruments to acquire National Semiconductor

Texas Instruments (TI) has signed a definitive agreement to acquire National Semiconductor for $6.5 billion. While TI has a much broader product portfolio, the companies' product lines overlap significantly in the analog IC space. Moreover, both are players in power-supply ICs including LED-driver ICs for solid-state lighting (SSL).

The companies hope to finalize the acquisition in six to nine months. It will need regulatory approval from governments around the globe. TI has said as many as 10 regulatory bodies must approve the deal.

TI's motivation for the acquisition is an immediate and significant expansion of its product line. Moreover TI will gain the knowledge base of National's analog IC design team, and top analog engineers are in short supply. TI will also acquire valuable analog IC fabs located around the globe.

"This acquisition is about strength and » page 14

news+views

Bridgelux from page 11

grown on top of sapphire or silicon-carbide (SiC) substrates. But large-diameter (6 inch and above) sapphire and SiC substrates are costly, difficult to process, and not widely available, says Bridgelux.

However, growing GaN on larger, low-cost Si wafers that are compatible with modern semiconductor manufacturing can deliver a 75% improvement in cost over current approaches, claims Bridgelux. Optimization of the epitaxy process on 8-inch Si wafers will make LED manufacturing compatible with existing automated semiconductor lines.

Bridgelux maintains an "asset-light operating model" and says that it will leverage its R&D and intellectual property position in LED epitaxy to jointly manufacture GaN-on-silicon LEDs. The company says it is currently in discussions with a number of established semiconductor companies regarding the utilization of the many fully-depreciated 8-inch semiconductor fabrication operations available around the globe.

"The significantly reduced cost-structures enabled by silicon-based LED technology will continue to deliver dramatic reductions in the up-front capital investment required for SSL," said Watkins. "In as little as two to three years even the most price-sensitive markets, will seamlessly and rapidly convert to SSL." ◄

MORE: www.ledsmagazine.com/news/8/3/10

Siemens from page 11

future Osram AG as a long-term anchor shareholder," said Siemens president and CEO Peter Löscher. Osram GmbH has been a wholly-owned subsidiary of Siemens AG since 1978. "With the IPO," continued Löscher, "we want to give Osram complete entrepreneurial freedom to comprehensively further develop its leading competitive position in a lighting market being swept by technological changes." Of course, the IPO will also generate a large amount of cash for Siemens that it can direct towards its core strategic objectives.

Siemens described its Osram subsidiary as "a leader in all relevant stages of the lighting value chain, for conventional as well as new technologies," adding that Osram generates 20% of its total revenue from LED-based products. ◄

MORE: www.ledsmagazine.com/news/8/3/30

PATENTS

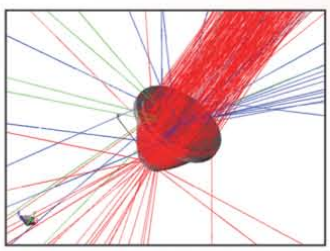
Osram and Cree sign LED patent-license agreement

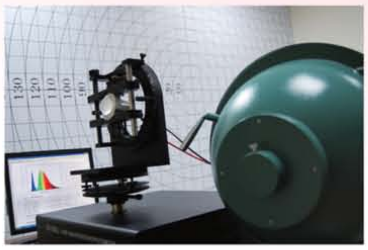
Two LED and lighting manufacturers – Munich, Germany-based Osram and Durham, NC-based Cree – have signed a worldwide LED patent cross-licensing agreement. The deal includes patents owned by

LedLink

Linking LEDs to The Real World

Secondary Optical Lens design





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Osram's LED manufacturing subsidiary, Osram Opto Semiconductors, as well as patents assigned to Cree LED Lighting, formerly LED Lighting Fixtures Inc.

The cross-licensing agreement covers patents from both parties in the fields of blue LED chip technology, white LEDs and phosphors, packaging, LED luminaires and lamps, and LED lighting control systems.

Osram describes the deal as a continuation of its policy of entering into similar agreements with other large LED manufacturers; in recent years this has included Nichia, Philips and Toyoda Gosei. Such agreements accelerate the spread of LED technology in all application fields, said Osram. "For all companies involved, the respectful management of intellectual property is essential for the smooth development of LED technology," said Martin Goetzeler, Osram's COO. "The agreement with Cree is an important step in this process."

The deal will help to protect customers of Osram and Cree from some of the potential patent disputes that may arise in relation to some of the companies' LED products. Cree recently announced a similar broad cross-license agreement with Philips and has existing patent agreements with Nichia and Toyoda Gosei regarding LED technology. ◄

MORE: www.ledsmagazine.com/news/8/4/1

TI/National from page 11 growth," said Rich Templeton, TI's chairman, president and CEO. "National has an excellent development team, and its products combined with our own can offer customers an analog portfolio of unmatched depth and breadth. In recent years, National's management team has done an outstanding job of improving margins and streamlining expenses." Templeton added that TI would accelerate National's growth with its much larger sales force. "The combined sales team will be 10 times larger than National's is today," he said.

Both companies have pointed out that their product lines are more complementary than competitive. But the companies clearly have many competing products in the analog segment. And both companies have aggressively targeted the LED-based SSL market with constant-current driver ICs.

According to IMS Research, TI and National held the first and second position in market share for LED driver ICs in 2010. Jamie Fox, senior LED lighting analyst at IMS, commented: "We estimate that TI held around 19% of this market in 2010, whilst National took 7%. The new combined company will be four times bigger than its nearest competitor in this high-growth market, which was worth nearly $1 billion in 2010." ◄

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news+views

REPLACEMENT LAMPS

Totalight offers free LED lamps

Totalight, a UK-based LED lamp supplier, says that it is giving away its new GU10 dimmable indoor LED lamps in return for a share of the energy savings that they create. The 5.3W LED lamps are intended to replace 50W GU10 halogen lamps. Based on the energy savings provided by switching to the LED lamps, Totalight will recoup regular payments as an alternative to a traditional outright purchase. Totalight calculates a regular payment schedule over a two-year period based on the customer's electricity price and estimated hours of usage. After two years, full ownership is transferred to the customer.

The lamps can also be purchased up front, so the buyer receives the full benefit of all the energy savings. Totalight acknowledges that it makes more money in the long run if it gives away the lamps for free, but says that

by shouldering the initial outlay it gives the customer a no-cost way to switch, which has zero impact on their cash flow. ◄

MORE: www.ledsmagazine.com/news/8/3/21

MEASUREMENT & SOFTWARE

Radiant Imaging merges with Zemax

Two optical software and test & measurement companies based in Washington state, USA, have merged in a deal facilitated by Evergreen Pacific Partners, the state's largest private-equity fund. The merger is between Redmond, WA-based Radiant Imaging, Inc. and Bellevue, WA-based Zemax Development Corporation. The companies said that, by combining their expertise and resources, they will offer a "powerful, end-to-end solution for developers designing, testing and producing the next generation of display devices and LED lighting."

Radiant Imaging is a test & measurement business and its systems are used in lab and production environments worldwide for products such as flat-panel displays, laptops, phones, stadium screens and LED devices. Zemax provides engineers and designers with a software platform for creating optical systems, including lenses, cameras, pro-

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jectors, scopes and instruments. Its software allows optical developers to quickly optimize designs to maximize performance while meeting cost requirements.

In the short term, the combined companies will be located in a single facility in Redmond, WA and will operate under their respective brands. Founders of both companies – Ron Rykowski, founder and CEO of Radiant, and Ken Moore, founder and CEO of Zemax – will remain in executive leadership and product development roles, with a goal of dramatic company expansion in the next three to five years through organic growth as well as strategic acquisitions.

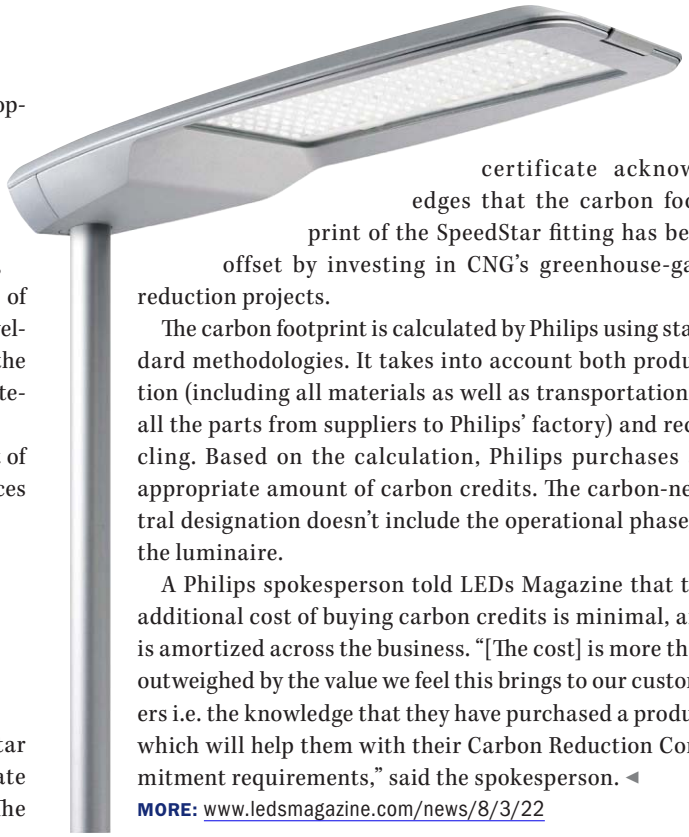
As part of the merger, Paul Caragher, most recently president of Tektronix Service Solutions, a leading test & measurement services provider, will become CEO of the combined companies. ◄

MORE: www.ledsmagazine.com/news/8/3/23

ENVIRONMENTAL

Philips SpeedStar road-lighting LED luminaire is carbon neutral

Lighting manufacturer Philips has announced that its SpeedStar LED road-lighting luminaire has been awarded a certificate of carbon neutrality by the Carbon Neutral Group (CNG). The



certificate acknowledges that the carbon footprint of the SpeedStar fitting has been offset by investing in CNG's greenhouse-gas-reduction projects.

The carbon footprint is calculated by Philips using standard methodologies. It takes into account both production (including all materials as well as transportation of all the parts from suppliers to Philips' factory) and recycling. Based on the calculation, Philips purchases an appropriate amount of carbon credits. The carbon-neutral designation doesn't include the operational phase of the luminaire.

A Philips spokesperson told LEDs Magazine that the additional cost of buying carbon credits is minimal, and is amortized across the business. "[The cost] is more than outweighed by the value we feel this brings to our customers i.e. the knowledge that they have purchased a product which will help them with their Carbon Reduction Commitment requirements," said the spokesperson. ◄

MORE: www.ledsmagazine.com/news/8/3/22

FINANCIAL

Cree shares drop after LED sales forecast revised

Shares in LED maker Cree, Inc. (Nasdaq: CREE) took a hit on March 23 after the company revised its financial targets for its fiscal third quarter ending March 27, 2011. Cree said in January it expected revenue of between $245 million and $265 million for the quarter. However, revenue targets have been reduced to a range of $215 million to $220 million, primarily due to lower sales of LED chips and LED components, said the company.

According to Cree, LED component demand has improved in the last few weeks, but revenue is lower than originally targeted. It has taken longer to work through customer inventories than previously anticipated, said Cree, and pricing was lower than the company had previously forecast. The company's LED chip business is also weaker than targeted, due to more aggressive pricing and weaker demand.

Cree expects its gross margin for the quarter to be approximately 43%, a decline which it attributed primarily to increased pricing pressure for its LED chip product line. Even so, Chuck Swoboda, Cree's CEO and chairman, tried to put a positive spin on the situation, saying: "The LED components business

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appears to be turning the corner. Despite the challenges we faced in Q3, distributor sell-through has improved and we target solid growth next quarter." Swoboda said that Cree is currently targeting revenue to increase by 10% to 12% in fiscal Q4, led by growth in LED components. ◄

MORE: www.ledsmagazine.com/news/8/3/20

LIFE SCIENCES

LEDs play an increasingly vital role in life-science applications

While LEDs are now widely used in a range of lighting applications, it turns out that LED lighting can also enable a broad range of life-science applications, including treatments for skin conditions and brain injuries. While the LEDs used in these applications may not be the same as those used in general illumination, LED makers can make the devices on the same fab lines, which can increase fab utilization and ultimately reduce component prices.

Skin conditions

The American Academy of Dermatology (AAD) has identified a number of uses for LED lighting in skin-related therapies. "LEDs are significant biologically because they can modify the function of mitochondria within cells," said dermatologist Murad Alam, chief of Cutaneous Surgery and Aesthetic Surgery at Northwestern University, Chicago. "This can have applications for dermatology, as LEDs may be able to improve wound healing by reducing inflammation, and improve sun-damaged skin by accelerating the growth of new collagen."

The narrow spectrum of LED lighting is important in some applications such as the treatment of acne. For example, the US Food and Drug Administration (FDA) has approved blue-light therapy in the 405-420-nm range for acne treatments.

"Although blue-light therapy is not as effective as oral antibiotics in clearing active acne, it appears to offer some degree of improvement for patients who are not good candidates for traditional acne therapies," said Alam. "However, in-office treatments must be administered up to three times per week to be effective." A number of over-the-counter blue-light devices are available for in-home treatments, although Alam notes these are less effective, at least for now.

Medical researchers are also exploring LED-based red- and green-light therapies, says the AAD. Red/infrared light in the 600-950 nm range can be used to treat acne, rosacea, and wrinkles. The red light works by stimulating the mitochondria in the skin that in turn cases older cells to behave like younger cells.

"When light of wavelengths in the 532-595 nm range – i.e. green to yellow – is used on the skin, it can reduce skin redness in some patients with age-related central facial redness and blood vessels, or rosacea," said Alam. "But future research is needed to explore light therapy in this area of dermatology."

Treating brain injury

It also appears that self-administered LED-based light therapy can help patients recover from traumatic brain injury (TBI). A new article published in the medical journal *Photomedicine and Laser*

news+views

Surgery has documented improvements in two TBI patients that coincided with the light therapy. While the article may be difficult to fully comprehend for anyone lacking a medical background, the website *Medpage Today* carries a vetted summary that describes the findings in simple terms.

Two patients with long-term cognitive impairments caused by TBI underwent four months of nightly treatment with LED lighting. Red/near-infrared LEDs were placed on the forehead and scalp. The patients showed improvements in cognitive ability after the treatment period. Moreover the patients regressed when the LED light therapy was discontinued – heightening the likelihood that the cognitive improvements were directly related to the LED lighting.

The primary author Margaret Naeser of Boston University and her associates concluded, "Results from the two chronic TBI cases described here, along with those from previous [light therapy] studies with acute stroke patients and chronic, major depression cases, suggest that further, controlled research with this methodology is warranted. Transcranial red/near-infrared LED may be an inexpensive, noninvasive treatment, suitable for home treatments, to improve cognitive function in TBI patients, as well as to reduce symptom severity in post-traumatic stress disorder."

POWER LEDS

Osram Opto demonstrates 142 lm/W warm-white LED

Osram Opto Semiconductors claims to have set a new laboratory record of 142 lm/W for a warm-white LED light source, with a CCT of 2755 K and CRI of 81. Measurements were taken at room temperature and under pulsed-mode operation at an operating current density of 350 mA/mm^2. The color coordinates were (x=0.46, y=0.41) on the Planckian curve and the company says this closely matches the perception of a classic incandescent lamp. "If we explore this technical approach further, and allow deviations from the Planckian curve, we should be able to achieve higher efficiency values of up to 160 lm/W for a CCT of 3000 K at (x=0.45, y=0.44)," said Norwin von Malm, Predevelopment Manager at Osram Opto Semiconductors. "If we apply this approach to a 2 mm^2 chip we can improve efficiency by a further 10 to 15 percent for the same operating current. We would then expect 180 lm/W for a pure warm-white LED with good color rendering."

The increase in efficiency was made possible by combining new procedures in thin-film and UX:3 chip technologies and in conversion (i.e. phosphor technology). Osram Opto says that its development engineers have benefited from combined know-how in all aspects of the production process, including epitaxial growth, thin-film chip architectures, conversion processes and package technologies.

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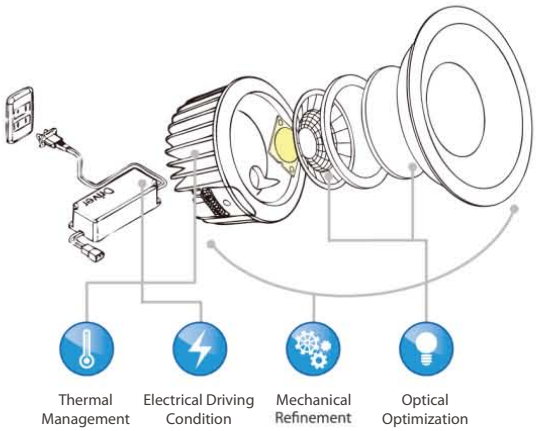
Power	Part Number	Color	I_F (mA)	Flux (lm)	V_F (V)	CRI
9W	EPSW-HFB4	○	250	970	38.7	68
	EPSX-HFB4	●	250	900	38.7	80
13W	EPSW-HFB6	○	350	1380	38.5	68
	EPSX-HFB6	●	350	1250	38.5	80

Lighting Solution as Example

Downlight (4"/ 6"/ 8")

Power: 15W/ 25W/ 50W
LED luminous flux: 710~2850lm
Operating voltage: AC 100~240V
Color temperature: 3,000K/4,000K/6,000K
Color rendering index: 80/75/68
Beam angle: 60°/100°
Dimensions: 4"- R130 H70/
6"- R170 H90/ 8"- R230 H120 (mm)



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DOE municipal consortium posts draft street-lighting specification

The US DOE Municipal Solid-State Street Lighting Consortium has posted drafts of street-lighting specification documents for review and is taking public comments through May 2. The documents are designed as a template for street-lighting buyers who are focused on solid-state lighting (SSL) projects. Buyers such as municipalities and utilities can use the documents as a basis for their procurement specifications.

The consortium has posted three documents (www.ssl.energy.gov/resources.html). The main document includes sections on items such as warranty, color temperature, environmental design elements, electrical requirements such as connectors, and mechanical mounting requirements. The main document also includes an Appendix B that is focused on evaluating LED lumen maintenance.

Posted in two separate versions, Appendix A covers the specification of luminaire electrical and optical parameters. The simple version of Appendix A, referred to as the material specification, covers a relatively small set of parameters such as beam pattern, power consumption, light output and color temperature. A more complex version of Appendix A – the system specification – includes a far more detailed set of requirements such as light uniformity, and a variety of illuminance parameters specified at ground level.

A buyer that wants to use the specification documents would combine their choice of Appendix A with the main document. The buyer would edit the Word files, inserting their own values for the specification parameters.

The posted documents include sample values for the parameters but those are strictly examples. For instance, the draft includes 105W and 210W luminaire examples for both versions of Appendix A. But the data in those example specifications should not be used by street-lighting buyers.

The intent of the specification documents is to allow buyers to "avoid starting from scratch and creating their own vocabulary," stated Jason Tuenge, senior lighting designer at the DOE's Pacific Northwest National Laboratory. Tuenge, who was instrumental in the creation of the documents, said buyers must identify their own parameter values to place into the specification documents and perhaps may still need consultants to help with that process.

Indeed, buyers that use the documents might even change the warranty requirements that are included in the templates. And Tuenge reminds that "If you are going to change the warranty period, you are also going to want to change the requirements for warranty enforcement."

It's possible that the DOE consortium will ultimately develop complete specifications for different types of roadways. But that would require significant time and effort given the breadth of the roadway lighting problem and the many different variables such as pole spacing that complicate the issue.

Still, the posted specification templates should help municipalities and utilities to jumpstart their SSL street-lighting programs and to utilize a specification methodology that will be universally understood by luminaire manufacturers, distributors, and lighting designers.◀

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

NEMA publishes two new SSL standards

The US National Electrical Manufacturers Association (NEMA) has published two new solid-state lighting (SSL) standards, both directed toward designers, manufacturers and users of SSL products.

NEMA SSL 1-2010 (www.nema.org/stds/ssl1.cfm) is entitled "Electronic Drivers for LED Devices, Arrays, or Systems." Topics covered include ratings, performance and markings. SSL 1 also provides specifications guidance for electromagnetic immunity, audible noise, and efficiency calculations.

SSL 1 Working Group Leader Tom Stimac of GE Lighting Solutions said: "SSL 1 is the first in a series of NEMA SSL standards aimed at setting the foundation for quality and performance of LED systems. LED drivers are used in every system today and the ability to verify key performance and quality aspects will be pivotal in achieving high efficiency and quality LED lighting systems."

NEMA SSL 6-2010 (www.nema.org/stds/ssl6.cfm) is entitled "Solid State Lighting for Incandescent Replacement—Dimming." It addresses the interaction between the dimmer and the lamp, and introduces requirements to help ensure good dimming performance and prevent damage to either component.

SSL 6 Working Group Leader Robert Nachtrieb of Lutron Electronics said: "SSL 6 is the first NEMA standard to tackle head-on the importance of dimming energy-efficient LED lamps that will replace incandescent bulbs. Building on the solid industry consensus we forged for SSL 6, NEMA will continue to develop standards for other applications of LED dimming."

Robert Hick of Leviton, chair of NEMA's Solid State Lighting section, said: "Standardization of evolving technology is essential...With future additions to this series, NEMA will continue to identify and eliminate gaps in guidance without discouraging innovation within the industry."

MORE: www.ledsmagazine.com/news/8/3/9

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- Applications:
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  Office lighting,
  LED electronic display

PLC series 30W - 96W

- 90% High Efficiency / PFC / Class 2
- Applications:
  LED indoor lighting,
  Office lighting,
  LED electronic display

ELN series 30W - 60W

- IP64 /Class II input / Dimming Function / Class 2
- Applications:
  Tunnel Lighting,
  LED decorative lighting,
  LED electronic display

LP series 18W - 100W

- IP67 / Class II input / Class 2
- Applications:
  LED decorative lighting,
  LED electronic display

PLP series 20W - 60W

- PFC / PCB type / 277VAC
- Applications:
  Built-in LED lighting system

ULP-150 150W

- PFC / U bracket / 277VAC
- Applications:
  LED streetlamp (built-in type),
  LED indoor lighting

PCD series 16W / 25W

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- Applications:
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SIL China focuses on LED and SSL market expansion

China is undergoing dramatic growth both in the manufacture of LEDs and LED-based products, and as a huge consumer of solid-state lighting. The first SIL China event will cover market expansion with an East Meets West theme, says **MAURY WRIGHT**.

China is pursuing the LED and solid-state lighting (SSL) markets from every angle, with every element of the vertical SSL supply chain represented in the country. The first Strategies in Light (SIL) China conference will focus on expansion of the global LED and SSL market as Chinese companies manufacture LEDs and SSL products for the global market, and global suppliers have significant opportunity to expand their sales via a huge emerging market for SSL products in China.

SIL China will bring together executives from the leading LED and SSL companies worldwide to explore the markets, applications, business outlook and most recent technology developments – all with a special focus on China.

The SIL conferences are now entrenched as the must-attend event for companies around the globe that are focused on LEDs and LED-based products. Successful events in the US, Europe and Japan make the debut of a China event a natural next step given the focus on LEDs and SSL in that country. The first Strategies in Light China conference (www.sil-ledchina.com) will be held in Hong Kong on May 10-12, 2011, and the conference theme is "East Meets West: Expanding the Global Market for LEDs and SSL."

Over the past few years, China has undergone dramatic growth as both a supplier of LEDs and LED-based products, as well as a market for these products. The government is highly supportive of the LED supply industry, and in addition is implementing a variety of policies that encourage a transition to SSL products on the demand side to promote energy efficiency.

The 610-meter-high Canton Tower, also known as the Guangzhou TV tower or "Slender Waist," is the world's highest stand-alone TV tower, and is illuminated from within by more than 6,000 Philips LED luminaires. Containing more than 330,000 LEDs from Philips Lumileds, the luminaires provide colorful, dynamic and vivid visual effects using just 500 kW of power.
MORE: www.ledsmagazine.com/press/30569.

Local governments in China are also subsidizing the purchase of MOCVD reactors, thus attracting a variety of new players to the domestic LED industry, as well as a host of foreign LED companies (mainly from Taiwan and Korea) who are establishing joint ventures and seeking to benefit from the subsidies. This activity may or may not lead to overcapacity in the LED industry, depending on whether or not reactor installations actually take place, and over what time period. Of course, that type of discussion will be front and center at SIL China.

China plays globally in LEDs

Regardless of how the supply-side stimulus of the LED industry in China plays out, it is clear that the Chinese LED and SSL industries are coming into prominence on the world stage. All the major non-Chinese LED component suppliers have significant sales activities in China, and some also have LED packaging operations.

Ella Shum, director of LED research at Strategies Unlimited, will kick off the conference with a global HB-LED market overview and forecast. Expect some specific insight into the supply and demand angles of the China market. Shum has deep experience in the LED market in general and worked as an early-stage advisor to China's SSL program.

Shum's presentation will provide a review and update of worldwide market developments in HB-LEDs in 2010 and 2011. She will discuss top-level market growth trends, as well as developments in each of the major

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

application areas, including lighting. In addition, Shum will provide a market forecast through 2015.

The conference will also include a significant focus on the use of LEDs in general-illumination applications. A large number of Chinese companies are using imported high-performance LEDs to manufacture lighting products for the export market, either under their own brands or on an OEM basis for foreign lighting companies. Also, domestic and foreign companies alike are producing LED lighting products for the growing domestic market. Therefore, it is clear that both Chinese-based and foreign companies have increasingly interdependent relationships in the rapidly evolving worldwide market for SSL.

HBTechnology Cast Group is supplying 120W and 180W LED street lights to three urban districts in Beijing to replace 250W and 400W sodium-vapor lamps. The luminaires use Oslon SSL LEDs from Osram Opto Semiconductors.
MORE: www.ledsmagazine.com/products/30621.

SSL keynote and key speakers

The conference Keynote Speaker will surely offer insight into the evolving lighting market. Biing-Jye Lee, chairman of Epistar Corporation, will present a talk entitled "Actualizing LED lighting." Lee is a highly respected LED industry veteran, having founded Epistar in 1996, and since built it to a position among the world's largest merchant suppliers of LED chips. Lee will discuss how the SSL industry's focus is changing from lumen per watt to lumen per dollar, thus enabling a much broader transition to SSL for general-illumination applications.

Several speakers at Strategies in Light

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- Blue (280 - 560)

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Color Temperatures (K)
- Cool White: Min. (4600) / Typical (5500)
- Warm White: Min. (2500) / Typical (3200)

Typical CRI: Cool White 72, Warm White 80

Luminous Intensity (mcd)
- Cool White (1800 - 4500)
- Warm White (1400 - 3550)

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China will address the LED industry and market developments in China. Jack Zhang, CEO of Gaogong LED Institute, will discuss the various government LED incentive programs in China and their impact on the worldwide markets and the competitive landscape. Zhang is among the most highly respected market researchers covering the LED scene in China, and he will describe how the Chinese government incentive program has created a huge worldwide investment in the upstream (epi and chips) segment of the LED industry in China.

Piet Derks, Philips Lighting senior director and general manager for lighting R&D in China, will discuss the challenges for the Chinese lighting industry to successfully introduce LED lighting in outdoor applications, especially for roadway lighting. Richard Sy, vice president and general manager, China at Cree Hong Kong Ltd., will address recent developments in the Chinese LED industry, including the domestic supply chain and the most recent investment trends.

Osram Opto Semiconductors Asia president and CEO Alfred Felder will present "The LED world – a revolution in the lighting industry." Felder's presentation will analyze the technical factors and challenges that will affect SSL development. Furthermore, it will provide insights on innovative SSL applications with state-of-the art LED technologies.

Other speakers focusing on the LED industry in China include Schiu Sche, policy advisor with the Taiwan Electrical and Electronic Manufacturers' Association; Waiming Poo-Cheong, Asia Pacific regional marketing manager for Philips Lumileds Lighting; and Enboa Wu, vice president and director of the materials and packaging technology group at the Hong Kong Applied Science & Technology Research Institute (ASTRI).

Sche will speak on strategic measures in Chinese public policy intended to accelerate SSL adoption. He will also address cross-strait investment trends. Poo-Cheong will address the differences in requirements in the Chinese domestic and export markets for LED products. And Wu will provide an overview of ASTRI's work on SSL. He will present research results on power GaN vertical LED chips, LED packaging, LEDs for indoor and outdoor lighting, and LEDs for flat-panel and projection displays.

Investing in SSL

While many of the presentations will include a financial element, there are a few sessions that will be especially useful to the investment community. Jed Dorsheimer, managing director of equity research for lighting and solar at investment bank Canaccord Genuity, will provide 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.

Sierra Ventures' partner Robert Walker will add a venture capitalist's view of SSL opportunities in China. Walker has direct LED industry experience having served as the CEO of Bridgelux from 2005 to 2007. He also has experience as a venture capitalist investing in Asia and will describe the burgeoning venture capital and entrepreneurial infrastructure in China.

SIL China attendees will also have the opportunity to meet and mingle with key players in the LED industry and leading LED and SSL manufacturers on the exhibit floor.

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SIL 2011: Progress continues but challenges still remain for LED lighting

In the second part of our review from Strategies in Light 2011, **TIM WHITAKER** discusses the views of lighting designers, LED market adoption factors, the LightSavers program, lightguide technology, and more.

Strategies in Light (SIL) 2011 took place in Santa Clara in February, and the first part of our conference review entitled "SIL presentations chart LED advancements and application evolution" was published in our March 2011 issue (www.ledsmagazine.com/features/8/3/7). Here, we look at another selection of presentations, while our third article on page 39 focuses on the LEDs in Lighting track.

LEDs in lighting

The total LED lighting market was worth $4.98 billion in 2010, according to Vrinda Bhandarkar of Strategies Unlimited in her opening presentation of the LEDs in Lighting track at SIL. Replacement lamps accounted for 20% of the total, or just below $1 billion, with luminaires accounting for the remainder. As shown in Fig. 1, the replacement lamp market will grow most rapidly over the next five years, particularly from 2013 to 2014 due to effects of regulations that ban inefficient lamps. The total LED lighting market will exceed $20 billion by 2015.

Consumer portable was the largest LED luminaires segment in 2010, with 20% of the $4.98 billion total, followed by architectural (18%), commercial/industrial (15%), outdoor area lighting (8%) and safety & security (7%).

Bhandarkar identified several challenges for SSL, one of which is that standards are not yet an industry norm. In terms of luminaires, manufacturers need to address the efficiency of product design, quality issues and product reliability. Other challenges include competing lighting technologies, as well as education of customers and end users.

Lighting designers' views

Two renowned lighting designers also spoke in the plenary session of the LEDs in Lighting track. Patricia Glasow, a Principal of Auerbach Glasow French, spoke about SSL in the real world. "Ten years ago, no-one had heard of LEDs," she said. "Now, they are always requested, event though the client may not know what LEDs are."

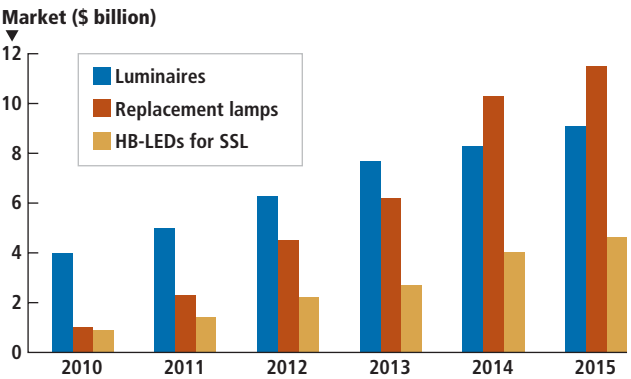


FIG. 1. The total market for LED lighting (LED luminaires and LED replacement lamps) will exceed $20 billion by 2015, and the market for HB-LEDs used in solid-state lighting will exceed $4.5 billion, according to Strategies Unlimited.

Nancy Clanton, president of Clanton & Associates, spoke to the SIL audience and LED community on behalf of other lighting designers. "Listen to us," she said. "We want to support SSL, we're your biggest fans. But don't use us as guinea pigs."

Glasow pointed to a number of areas in which LED lighting has improved, for example the availability of greater efficiency in warm white, the availability of high CRI, and the usefulness of the Caliper program. She pointed out that there are now multiple manufacturers of specification-grade downlights, and these are no longer a specialty product. Also, products are available that provide a variety of beam angles – from 14° spots to 50° floods – as well as beam control. "Drama is back," she said.

However, Glasow also said that much remains to be done. "We need candela distribution, not just lumens," she said. "Dimming performance is often disappointing. And we don't actually know how products perform over time."

Clanton discussed the use of LEDs in exterior lighting, and pointed out that the directionality of LEDs can eliminate wasted light and light trespass. However, it is not always necessary or desirable to have a sharply-defined light distribution pattern with perfect uniformity, she said. "In the situation where LEDs are working well [see Fig. 2], we illuminate what's required, but without the sharp edges."

Clanton also discussed spectral distribution, saying that white light increases peripheral detection and renders colors better, but that too much blue light could affect the environment. Glare is an issue, and lights should have an appropriate BUG (backlight, uplight, glare) rating; in fact this specification is being revised a little for LEDs, she said.

Clanton also advised that the industry needs better color consistency via tighter bins, and that she would love all luminaires to be dimmable.

LightSavers outdoor LED program

Phil Jessup, Head of International Lighting with The Climate Group, described progress on the LightSavers outdoor LED lighting program. The 10 LightSavers cities and their agencies operate 2.1 million street lights between them, 2% of the total worldwide. Currently, said Jessup, 27 products from 13 companies are being evaluated in 19 trials. He discussed the trial in Central Park in New York City, and said that an LED replacement program could have a payback of 3-4 years if the luminaire cost is below $600 each for 1400 lamps, assuming a 50,000-hour lifetime. This is based on purchasing the luminaires with a municipal 20-year bond with an average yield of 3.6%. Jessup noted that the city needs to make decisions on light levels; high light levels help to deter crime, but glare becomes a key aesthetic issue.

Jessup presented some lessons learned from the trials, for example that LED lamps can produce light comparable to baseline lamps with 63% savings. However, savings are less (10-25%) for high-power lamps on arterial roads. Also, the trials have revealed, perhaps not surprisingly, that there are considerable performance differences between different LED products, so it is important to test multiple products. LED luminaire suppliers need to work more closely with municipalities on trials, said Jessup, since this will improve acceptance of the technology. He also advised luminaire suppliers to model their product's performance in advance to ensure compliance with municipal needs. They should follow up with municipal staff to make sure their products are properly installed and operated, said Jessup, and ask for feedback and guidance on performance and product design.

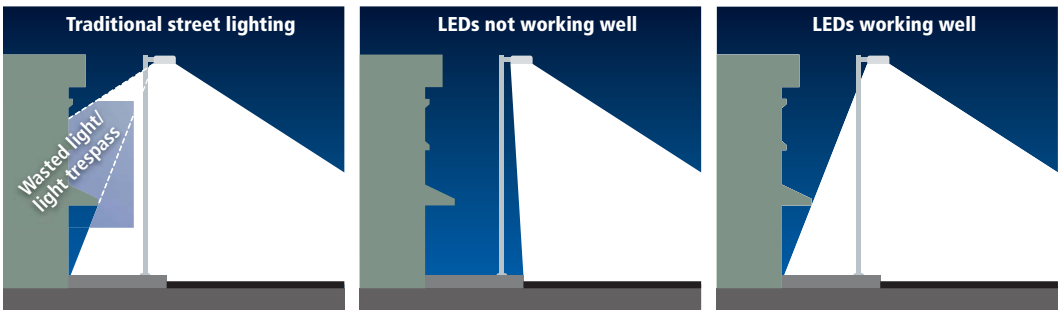
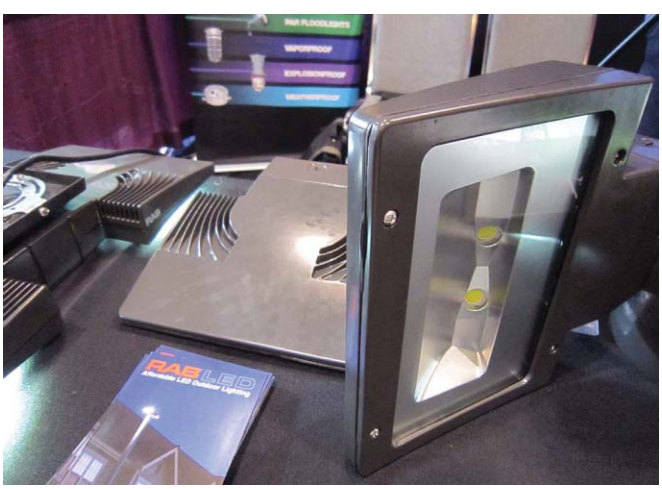


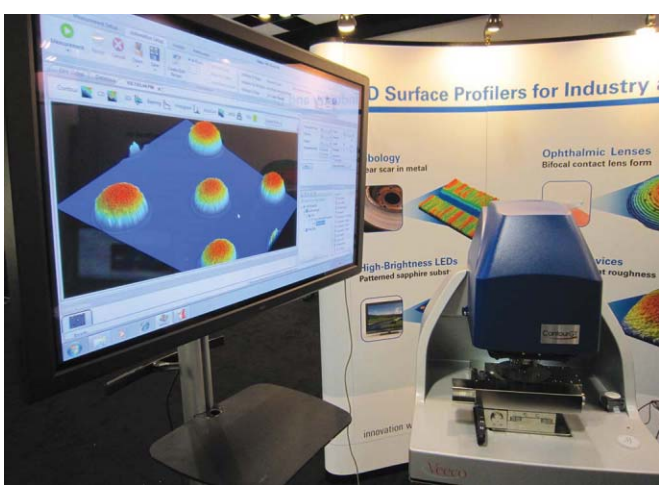
FIG. 2. Traditional street lights (left) can result in light trespass onto buildings, but some LED-based solutions are too directional with a sharp-edged light pattern, in this case (center) failing to illuminate the sidewalk. Source: Clanton & Associates.

Market adoption and s-curves

In the HB-LED Market track, Michael Watson, Sr. Director Marketing & Applications with Cree, focused on the s-curve for LED adoption. "S-curves don't just naturally happen," he said. "So how do we [the industry] make it happen?" There are many, many predictions of what the s-curve will look like, and each segment, such as flashlights, or outdoor, or retrofit lamps, has its own s-curve (Fig. 3). But, said Watson, the focus should be on driving adoption, and this is done by looking at the value to everyone in the lighting ecosystem. "Lack of value creates resistance, and this can't be ignored," he said. "Value creation will drive adoption." In order to accelerate adoption, the industry needs to evolve from the current situation, where supply is pushing demand, to a situation where the market is demanding SSL products.

Watson said that value is built by enhancing benefits and reducing costs, and this occurs along three axes; enhanced performance, application optimization and ease of use. In terms of performance, Watson commented that Cree will always push lm/W values, since it wants to be the industry leader. Application optimization essentially means that one size does not fit all applications. "Volume alone [for a single LED type] will not drive down cost," said Watson. Ease of use means making LEDs easy to build into





SIL attendees viewed outdoor lighting fixtures from RAB Lighting (left) and surface profilers from Bruker Corp (right).

luminaires, and also making LEDs easy to adopt, for example via consumer rebates. Education and promotion is an important part of this process. It's also important to develop SSL ecosystem partnerships, said Watson, adding: "Cooperation (not collusion) can help accelerate adoption."

Lightguides for lighting

Technology developed to improve light extraction from lightguides in display applications is now being adapted for lighting by Rambus Inc, as Marc McConnaughey, VP of Lighting and Display Technology, explained. The company's MicroLens technology was acquired from GLT in late 2009 (www.ledsmagazine.com/news/6/12/12) and has been developed further. MicroLens optical features enable precise control of the uniformity and exit angle of either diffuse or directed light, and perform better than printed dots or laser-ablated features, said McConnaughey. The MicroLens optical features can be varied by depth, shape, density and location to support any display size or light-source location. McConnaughey identified task lighting, area lighting and wall-wash lighting as suitable for light guides, and said the latter was the "most difficult problem to solve in lighting today."

However, the production process is the main bottleneck to enabling high volume and low cost. Rambus is developing a film-manufacturing technology in which the microstructures are replicated onto a 36-inch-diameter, 65-inch-long cylinder. This cylinder is used to emboss the features onto a wide, thin, plastic film. Rambus plans to license the process and the technology; luminaire makers could manufacture the films in-house, or more likely purchase them from a specialist supplier.

GaN-on-silicon LEDs

Lattice Power claims to have the first commercial, high-power LEDs based on GaN-on-silicon technology, according to Bo Lu, executive VP of the China-based company. LEDs are produced on 2-inch silicon wafers, but Latttice Power is looking to transfer production to 6-inch silicon in 2012, said Lu, in order to drive down costs and take advantage of standard tools for semiconductor IC manufacturing.

The company has developed various processes to overcome the challenges of growing GaN on silicon, for example the use of wet etching to remove the silicon substrate after growth. Selective growth is carried out on a pre-patterned substrate using a proprietary multilayer buffer. Lu said that optimizing the quantum-well structure is key for maximizing the internal quantum efficiency.

The current production average for a bare chip (0.95 x 0.95 mm) is 340 mW radiant power, said Lu, which translates into an output of 96 lm for a cool-white LED at 350 mA. The company is on track to improve these values to 380 mW per chip (105 lm for a white LED) by June 2011.

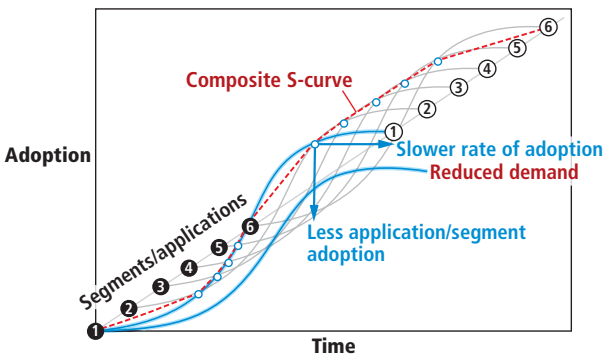


FIG. 3. The composite s-curve for LED adoption (red dotted line) is a combination of the s-curves for different segments and applications, numbered 1-6 here, which could include flashlights, outdoor and lamps. The blue lines show how negative effects such as a slower rate of adoption for application #1, or less adoption, can shift the s-curve to a position of reduced demand.

High voltage for retrofit lamps

The challenge for SSL is to increase both lm/W and lm/$ values, said M.J. Jou, president and CEO of LED chip-maker Epistar. The industry is involved in a race to 500 lm/$ for cool-white LEDs, said Jou, and the DOE roadmap expects this to be achieved by 2015. But Jou said that the industry needs to move more rapidly in order to accelerate the development of the SSL industry. "2015 is too late," he said. "We need to get there as fast as possible."

Jou believes the correct route is via high-voltage (HV) LEDs, which are described in more detail in the article on page 47. HV-LEDs are ideal for retrofit lamps since they don't require a driver and the extra space can be used for thermal management. Epistar's approach is to combine blue LED chips with red chips to create efficient warm-white LEDs: Jou claimed a record efficacy of 165 lm/W at 2691K and a CRI of 87 (at 15 mA and 70V).

Jou concluded with what he described as "the world's first 800-lm light bulb by HV-LED." The demo bulb was tested by ITRI and had an input power of 8.5W and an output of 820 lm (or 97 lm/W). The CCT was 2700K, the CRI was 87 and the power factor was 0.97, said Jou.

Chip-on-board packages

According to Shawn Du of Nichia America, LED efficacy improvements have made general lighting a reality, but a slow-down in such improvements can be anticipated in the foreseeable future. However, he said, "When LED efficacy is substantially above conventional sources, payback is dominated by LED cost."

Du discussed the example of an 850-lm A-19 LED lamp, which requires a 1000-lm LED source that fits onto a 1-inch diameter PCB, as well as a coin-sized driver with isolation and dimmability. Heat dissipation is limited to the bulb's lower-half surface only. Du compared different options, and said that accommodating 100 x 0.1W LEDs on the 1-inch-diameter PCB would be difficult. Using 10 x 1W LEDs requires costly assembly as well as complex management of color/optical mixing, multiple shadows and glaring.

Instead, Du presented a 10W chip-on-board LED, which he said is a brand new product from Nichia. As an integrated high-lumen source, this reduces design and manufacturing complexity, and lowers the LED bulb cost. Light mixing from the multichip array overcomes color variation, while the high forward voltage maximizes driver efficiency. "Innovative, highly-integrated, ultra-high-power packages are essential for lumen-dense applications," concluded Du.

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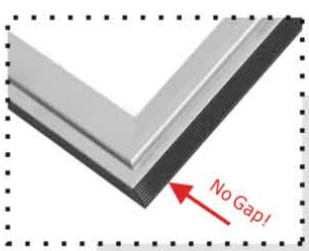

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SIL 2011: Lighting track spans color science, dimming, modules and retrofit lamps

The LEDs in Lighting track at the 2011 Strategies in Light conference afforded the opportunity to hear about color science, energy efficiency, dimming, digital control, retrofit lighting and other SSL topics, says **MAURY WRIGHT**.

For the third consecutive year, the Strategies in Light (SIL) conference featured an LEDs in Lighting track, with presentations covering light and color science, adaptive control and dimming technologies, and retrofit lamps and modular products. Presentations discussing the LED lighting market, and the views of lighting designers, are covered in our article on page 33.

Light science and color rendering was a major theme at SIL. Wendy Davis, a vision scientist at the US National Institute of Standards and Technology (NIST), discussed the trade-off between color-rendering performance and luminous efficacy. Davis said that combinations of LEDs should be used "if you want awesome color no matter what, and energy isn't a huge concern in your application." However, she acknowledged that some applications just need "good enough color to get by" because efficiency is more important.

Today, the color rendering index (CRI) is the only widely-used measure of color rendering. But Davis showed examples of how a poor light source sometimes gets a high CRI score and other examples where the opposite happens. CRI is a calculated value that describes how accurately a source renders eight pastel colors. Davis showed an example of an RGB LED with a CRI of 80 that performed reasonably well on the pastel colors but very poorly with more saturated colors – especially red.

Next Davis showed CRI results from an incandescent lamp that uses a neodymium remote phosphor. The light actually renders the saturated colors even more vividly than "perfect" color rendering (i.e. CRI of 100). But CRI penalizes a color shift in any direction, resulting in a value of 77 for the neodymium lamp.

FIG. 1. NIST has a spectrally-tunable lighting lab with 22 color channels that enables research into color rendering.

There are more problems with the CRI specification and perhaps the biggest is that products can be designed to get a high CRI score, even though the actual performance is poor.

Color Quality Scale

Davis is one of the creators and proponents of the Color Quality Scale (CQS) metric that is under consideration as a replacement for CRI (www.ledsmagazine.com/features/7/8/7). CQS utilizes a more robust set of colors, including saturated ones, to calculate a score. The methodology also ensures that sources are not penalized for an increase in chroma – essentially an improvement in rendering relative to the reference color.

Davis is currently serving as chairperson of the CIE (International Commission on Illumination) Technical Committee (TC) 1-69 that is searching for a replacement for CRI. Thus far neither CQS nor other proposals have garnered the support needed to supplant CRI. When asked what happens next within TC 1-69, Davis said, "Either CIE will come to an agreement by this summer. Or

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

the committee will be shut down, and we will pursue a US standard."

Dimming and control

Dimming and control of LEDs was also a hot topic at SIL. Robert Nachtrieb, a lead scientist at Lutron Electronics, asserted that dimming is a good idea for a number of reasons including the fact that an LED light dimmed to 50% brightness delivers about 50% in energy savings. Moreover, dimming an LED reduces the operating temperature, thereby extending the useful life of the LED components and the driver electronics. Dimming also enhances ambiance and is generally a feature desired by consumers.

Of course, dimming is a complex topic made difficult by the varied ways in which LED lighting is being deployed, ranging from retrofit lamps to new construction and LED-specific luminaire designs. Nachtrieb noted that in general LEDs have technical issues that make dimming difficult. He said, "LEDs have almost no inertia whatsoever." The point is that LEDs turn off instantly rather than gradually extinguishing like some legacy sources. Nachtrieb also noted that flicker can be a problem with the instant on-off characteristic of LEDs.

Nachtrieb advised the audience to completely understand the lighting scenario at hand in contemplating dimming. Obviously with retrofit lamps, you must ensure that the chosen product works with triac dimmers. Other products may utilize 0-10V dimming or the DALI standard. Unfortunately the industry isn't likely to ever enjoy a universal dimming approach.

The presentation had plenty of advice for designers contemplating requirements for a project. Nachtrieb suggested that products capable of dimming to 20% of full brightness would be suitable for lobby, atrium, and office applications. He said that more-difficult dimming to 1% is required in restaurants, media rooms and other applications.

Part of the issue with dimming levels is the difference between the light actually being produced and the light perceived by humans. According to Nachtrieb, lighting that is dimmed to 20% of full brightness, according to measurements, is perceived to be dimmed to a 45% level by a typical person. Also, this person would perceive a 10% level when the light is dimmed to 1%. Designers must consider these facts when choosing a dimming scheme.

LEDs vs. fluorescents

William Ballweg, product development manager at Lithonia Lighting (an Acuity Brand), also spent a significant part of his presentation on dimming with an emphasis on digital control and proving that LED lighting is superior to fluorescent lighting. He didn't advocate retrofit LED lamps, but said that SSL in general can be superior to fluorescent sources, and controls are a big part of the story.

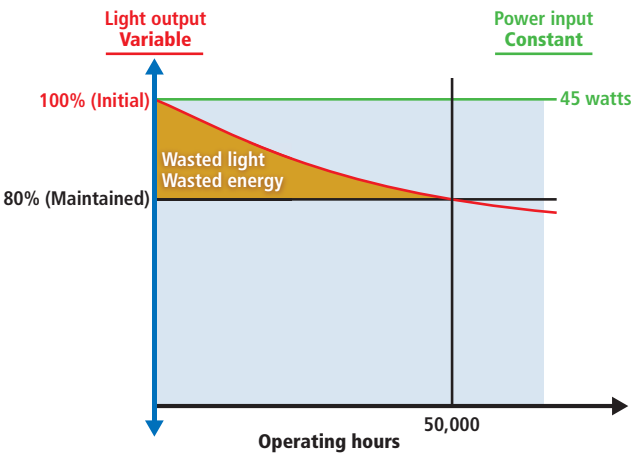
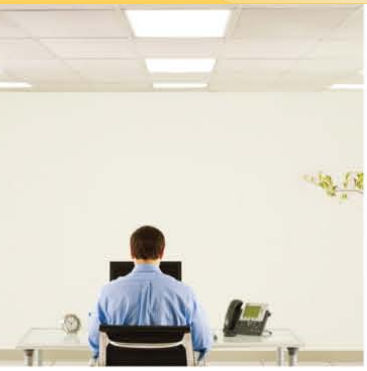


FIG. 2. An SSL product is driven at a constant power of 45W to ensure that the output is always at or above 80% of the initial value, even after 50,000 hours. However, this results in wasted light and wasted energy, compared with the case where lumen management is used to maintain the output at the 80% value throughout the lifetime.

Ballweg provided a comparison of typical T8 and T5 fluorescent lights with a typical SSL luminaire designed for the same type of application – say office lighting – but not based on linear tubes. He said that the 2-lamp T8 and T5 luminaires pro-



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duce more total lumens – 5016 and 5187 lm respectively – than the SSL luminaire at 4600 lm. But based on total internal reflection (TIR) optics, the LED fixture effectively delivers 100% of the lumens produced. The fluorescent fixtures deliver fewer lumens due to fixture inefficiency. Moreover, the LED fixture delivers 92 lm/W compared to 71 and 78 lm/W for the T8 and T5 fixtures, respectively.

While Ballweg came across as an LED proponent in general, he stressed that the bigger advantages with LEDs come through digital controls that can enhance the energy savings and extend the life of SSL products.

Ballweg suggested that today most SSL products waste energy that could easily be conserved with controls. Consider Fig. 2: a fixture that is designed to operate for 50,000 hours must create more light initially than is required for the application to account for lumen depreciation that occurs over time. That results in excess light produced and energy used.

Bulb power consumption	13.9W	13.0W	12.1W	11.2W
LED count	6	8	11	16
LED drive current (mA)	670	480	330	215
LED power consumption (W)	11.8	11.1	10.3	9.6
LED efficacy in application (lm/W)	68	73	78	84
LED temp (25°C/45°C)	106/125	96/115	87/106	79/98
Solder temp (25°C/45°C)	94/113	88/107	81/100	75/95
Heatsink temp (25°C/45°C)	90/109	85/104	79/99	74/93
Bulb efficacy (lm/W)	58	62	66	71

FIG. 3. Illustration of the tradeoffs in 60W retrofit lamp designs with varying numbers of LEDs. Source: Philips Lumileds

An intelligent fixture could be throttled back to 80% output when first installed, and the drive current could be slowly increased over time to maintain the required lumens. Such a scheme saves energy and also boosts lifetime due to lower operating temperatures.

Ballweg presented three scenarios for fixture life. A typical product installed to continuously operate at 100% output would last 50,000 hours until it reaches the 80% lumen maintenance level. A light designed for what Ballweg called lumen management that slowly ramps up the drive current would last 60,000 hours. However, a light designed for lumen management that integrates support for occupancy sensing and dimming could last 80,000 hours.

Ballweg described a system of networked office luminaires with RJ-11 jacks and standard computer-network cables as interconnects. And he summarized the potential financial savings relative to fluorescent lighting with and without controls using a 15-year period for the projection.

The upfront cost for a fluorescent system was half that of a fluorescent system with controls or an LED system with controls. Over the course of the 15-year period, payback can't be achieved on the added cost of a fluorescent system with controls compared to a standard fluorescent system. Based on today's SSL costs, the total cost of ownership for the LED system with controls is about 1% less than that of the standard fluorescent system. The savings are based on reductions in energy and maintenance costs. While the savings are small, the cost of SSL technology is dropping while efficiencies are going up, meaning the comparison will become more favorable for LEDs going forward.

A19 retrofit lamps

While digital control may deliver savings in new lighting installations, it's the retrofit lamp market that's ripe for companies to

FIG. 4. GE Lighting has introduced new versions of its Infusion module, which can be connected to a socket in the luminaire body with a simple twist-lock mechanism. Three color temperatures – 2700K, 3000K and 4000K – are available, each with 4 different light outputs. At 3000K, different modules offer 1100 lm (15W, using 7 LEDs), 1500 lm, 2000 lm or 3000 lm (46W, using 22 LEDs).
MORE: www.ledsmagazine.com/news/8/3/27.

experience immediate success. The products work with existing sockets, and governments around the globe are working to phase out inefficient incandescent lamps.

Philips Lumileds' global segment marketing manager Ray Chock described today's technology as being suitable for 40W replacement lamps, but said that the larger opportunity lies in replacing higher wattage lamps. He said, "You can think of the 60W as the sweet spot of the A19 market." He said the 60W segment comprises about two thirds of a 14-billion-socket market.

While Philips is already supplying a 60W replacement lamp, Chock said the price is too high today. He described the design process and tradeoffs necessary to yield reliable retrofit lamps. Every change that is made has an impact on other elements of the design. For example you can increase the drive current and use fewer LEDs, thereby lowering component costs. But that change will raise the temperature and may not be realistic given the thermal limit of the heat sink.

Chock described calculation models that allow a lamp design team to experiment with tradeoffs. Fig. 3 shows a variety of approaches to a 60W replacement lamp in terms of different numbers of LEDs and drive currents, and how those choices impact other factors. A change that seems like a good idea may require the use of specialty solder or larger heat sinks. And despite his emphasis on costs, Chock said it's often good "to spend a few more cents on the heat sink" to ensure reliability.

Modules and standards

Tony Marshall, director of product marketing at Bridgelux, turned the discussion to modular SSL approaches. A modular approach can move lighting designers and buyers to adopt SSL when they otherwise might wait for the next round of products, said Marshall. Someone faced with a 100 lm/W product as the most efficient luminaire on the market might choose to wait for the 120 lm/W version before moving to SSL. But a modular approach that allows the buyer to exchange the light engine when a better one becomes available can "stop the waiting game."

Marshall also pointed out the need for industry standards relating to modules. The Zhaga consortium has already started this process, and Mark Duffy, the manager of global industry standards ing (Fig. 4), provided an u sortium's work during a pre-conference workshop.

Duffy described the Zhaga process in which multiple companies present technical concepts for a standard. The consortium merges the concepts and ultimately delivers a standard that will allow multiple manufacturers to make compatible products.

Duffy said that four light-engine standards are at the specification-development phase. The list includes socketable and non-socketable light engines both with and without driver electronics. Zhaga has also approved its first standard for a socketable engine with driver electronics. There are photos of prototypes on the consortium website (www.zhagastandard.org/news/9/8th-zhaga-meeting). Duffy said that it's possible the first Zhaga-compatible products will be available by September.

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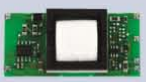

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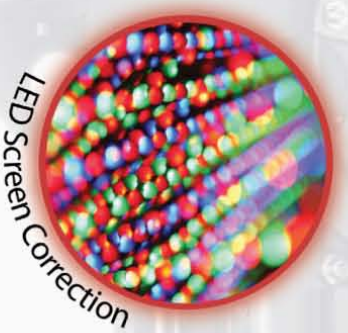

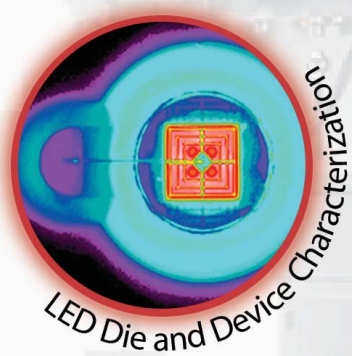

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High-voltage LEDs offer optimum solution for indoor retrofit lamps

High-voltage (HV) LEDs have a turn-on voltage that is closer to the mains supply than conventional high-current LEDs. This eliminates components, notably the driver, and offers other advantages, as Epistar's **ALEXANDER WANG** explains.

A high-voltage (HV) LED, as indicated by the name, is a DC-driven LED with a turn-on voltage greater than 20V, which is much higher than the 2-3V turn-on voltage of conventional LEDs. An HV-LED chip is usually constructed from many small LED cells, which are electrically connected in series. Fig. 1a shows a blue HV-LED chip containing fifteen cells connected in series. The operating current is 20 mA, and the total turn-on voltage across all fifteen cells in series is 48V. This blue HV-LED consumes around 1W in full operation. Fig. 1b shows a red HV-LED chip containing ten cells, again connected in series. The forward current is 20 mA and the overall turn-on voltage is 20V, so the power consumption is around 0.4W.

A major advantage of HV-LEDs over conventional LEDs is the forward current, which is typically an order of magnitude smaller in the HV-LED. Low current is favored in LED chip designs due to the better current-spreading effect.

FIG. 1. HV-LED chips. (a) Blue 15-cell HV-LED chip. (b) Red 10-cell HV-LED chip.

HV-LEDs, low-voltage LEDs and AC-LEDs

The turn-on voltage of a conventional LED is low, typically 2V for red and 3V for blue. When LEDs are used for indoor lighting, the input voltage is the mains AC voltage i.e. 120V or 230V. As shown in Fig. 2, in addition to an external rectifier (to convert AC to DC), a power converter is required to convert the voltage from mains to low voltage. The power converter is costly and bulky, and also lowers the total system efficiency due to the conversion loss.

AC-LEDs, on the other hand, are designed to be directly connected to the mains. As shown in Fig. 2, one design for an AC-LED is a monolithic LED chip that contains an integrated bridge rectifier. However, when an AC-LED is operated, not all the LED cells are turned on continuously, so the LED utilization is only 50-70%. This results in a higher chip cost.

An HV-LED is similar to the AC-LED approach, because the LED's turn-on voltage is closer to the mains value. However, the HV-LED utilizes a DC voltage and does not have a built-in rectifier, so an external four-diode bridge is required for rectification. However, the HV-LED has 100% chip

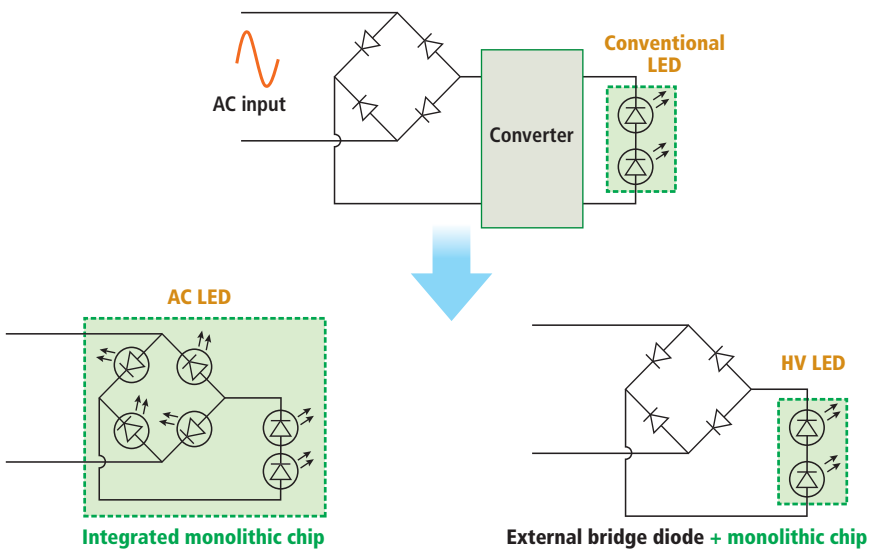


FIG. 2. Comparison between conventional LEDs, AC-LEDs and HV-LEDs. The AC-LED approach has built-in rectification of the AC supply, but the LED utilization is only 50-70%, since all the LED cells are not emitting light continuously when the LED is on. The HV-LED requires an external bridge rectifier, but all the LED cells are always on. Neither the AC-LED nor the HV-LED require an LED driver.

ALEXANDER WANG *is Special Assistant with Epistar Corporation (www.epistar.com.tw), a Taiwan-based LED chip manufacturer.*

HV-LEDs from Everlight and Lumileds

TIM WHITAKER

A number of companies have recently introduced HV-LED devices. For example, LED packager Everlight Electronics recently launched its HiVo series of 1W, 2W and 4W HV-LEDs, which are intended for use in LED-based retrofit lamps (www.ledsmagazine.com/press/30241). The 4W version contains four LED chips connected in series in a 6.0 x 6.0-mm ceramic package and operates from 95-111V DC in North America and Asia or 190-220V DC in Europe. The minimum output is 350 lm at 5700K and 250 lm at 3000K.

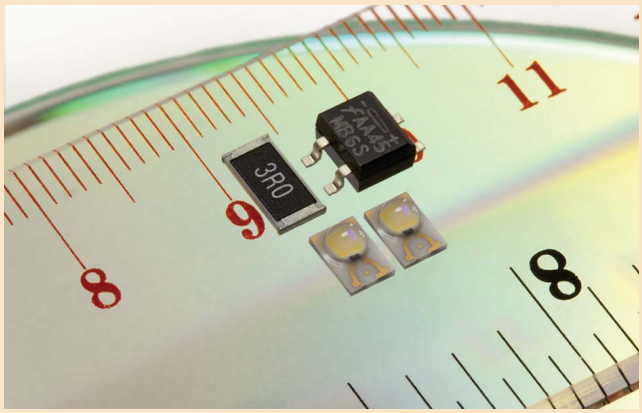
Everlight says that the HiVo LEDs operate with only a bridge rectifier, resistor and capacitor, resulting in higher overall efficiency and a decrease in bill-of-material costs for LED integral lamps. Eliminating the LED driver saves space, which allows more heat sinking to be added. Everlight says that the omission of often-fragile driver components, as well as improved thermal performance of the HiVo ceramic package, results in better LED lifetime.

Everlight is one of several companies, including Citizen, Unity Opto and Epistar, that have worked with Lynk Labs to produce HV-LED products that were demonstrated at Strategies in Light in February (www.ledsmagazine.com/news/8/3/4).

In late March, Philips Lumileds unveiled the Luxeon H, an HV emitter driven directly with rectified AC voltage rather than constant DC current. The 50V Luxeon H contains a multi-junction die, and the package has the same footprint as the Luxeon Rebel and Rebel ES. Two color temperatures are available, 2700K and 3000K, with typical flux of 84 lm and 90 lm respectively, and CRI of 83.

The emitter is designed to meet the demands of space-constrained retrofit bulbs, and supports both 110V and 240V supplies. The product eliminates the need for an electronic LED driver, and instead only requires a bridge rectifier and a resistor (see photo). This architecture maximizes space for additional thermal management, permitting an increase in the thermal limit for even the smallest bulbs, such as the candelabra and E10-E17 lamp types.

"The base of some light bulbs is so small that it's impossible to fit both an electronic driver and a heatsink in the space," said Frank Harder, VP of Product Marketing for Luxeon. "Luxeon H only requires a bridge rectifier and a resistor, both of which are very small, and the remaining space can be used for thermal management."



Luxeon H from Philips Lumileds

Harder also explained that Lumileds does not use direct red die like most other HV solutions. This means, said Harder, that Luxeon H "offers consistent, stable color from the instant the LED is powered, and maintains its color through its lifetime." Lumileds' approach of using a blue multi-junction chip and phosphor avoids issues associated with differential aging of the red and blue chips. ◄

utilization, the same as a conventional low-voltage LED.

From a market point of view, the three LED types – conventional LEDs, AC-LEDs and HV-LEDs – all have their suitable applications. Table 1 explains the advantages and disadvantages of the three devices from different design points of view.

An AC-LED is designed to be connected to the mains directly, so it is suitable for very small-sized lamps. For example, the G9 market is perfect for AC-LEDs. For the 2-10W candle and A-bulb markets, which have limitations in terms of space and cost, HV-LEDs are a good solution. For applications at 10W and above – e.g. down-light and street-light markets – conventional LEDs become the better choice.

LED lamp/ luminaire type	<2W Indoor	2-10W Indoor	>10W Outdoor
Space limitation	Very limited	Limited	Not limited
Driver cost	Cannot afford driver	Cost must be low	Can afford higher driver cost
Power factor (PF)	Not required	0.5-0.9	>0.9
Dimmable	Required	Required	Not required
Optimum solution	AC-LED	HV-LED	Conventional LED or HV-LED

TABLE 1. Comparison between conventional (low-voltage) LEDs, AC-LEDs, and HV-LEDs for different lamp and luminaire types.

Performance now and in the future

Epistar's goal for solid-state lighting is to reach 150 lm/W for warm-white (2700K) LEDs in mass production by 2013. The key concept that will make that goal attainable is the combination of blue and red HV-LEDs. Using a red LED instead of a red-emitting phosphor not only can enhance the lm/W number, but also can increase the color-rendering index (CRI) and the lumen-per-dollar (lm/$) number.

A recent trend in the market is to pursue a high CRI of 90 or above for warm-white

(2700-3000K) LEDs. With current LED technology, a hybrid approach combining red and blue LEDs is the optimum solution for the warm-white CRI 90 market, as shown in Table 2.

To further explain the concept and advantages of HV-LEDs, we can take a 60W, 800-lm LED lamp as an example. Constructing an 800-lm lamp requires a 1000-lm LED device (after various losses are taken into account).

There are two ways to achieve the 1000-lm device. One way is the conventional LED method, using a 2A drive current with a forward voltage of 3.3V. The other way is to use an HV-LED driven at 30 mA, with an HV-chip voltage of 220V. Both methods can provide 150 lm/W at 6.6W. However, low current is easier to handle in LED chip designs, and it can also make the power-converter design easier.

In addition to developing its lm/W performance roadmap, Epistar is also collaborating with its customers to try to push the lm/$ value of warm-white LEDs to 1000 lm/$ by 2015, based on an efficacy of 150 lm/W. Epistar believes that the lm/$ value is the key to increasing the penetration rate of solid-state lighting, and that 1000 lm/$ devices can help the market penetration rate to hit 25% of the total lighting market.

Epistar recently announced a 120-lm/W HV-LED chip solution for the 800-lm (60W replacement) and 1100-lm (75W replacement) LED lamp market. The concept is to combine two blue and two red chips in one package (designated 2B2R). The package can be driven at 2.3W (forward voltage of 135V and current ~20 mA) to yield 270 lm.

When four sets of the 2B2R solution are used, 1080 lm can be achieved, which is the required LED output to enable 800-lm lamp construction. Customers can also use six 2B2R packages to provide 1620 lm at the chip level, which is suitable for 1100-lm lamp construction.

	Cool white: conventional	Warm white: conventional	Warm white: hybrid
Technology	Blue chip + phosphor (yellow)	Blue chip + phosphor (red & yellow)	Blue chip + red chip + phosphor (yellow)
CCT	5700K	2700K	2700K
CRI	70	82	90
Relative efficacy	100%	65%	98%

TABLE 2. The conventional approach to making warm-white LEDs combines a blue chip with a suitable phosphor, but there is a significant reduction in efficacy. The hybrid approach of combining red and blue chips provides high CRI with high efficacy.

SSL applications | **HORTICULTURE**

Precise LED wavelengths spur plant growth

Light sources such as LEDs with emitted energy centered around specific wavelengths may offer optimal performance in horticulture, outperforming broad-spectrum sources such as HPS lamps that are widely used in greenhouses today, explains **MAURY WRIGHT**.

Research is rapidly advancing in the horticulture industry that indicates LED-based solid-state lighting (SSL) might boost productivity in greenhouse and plant-factory operations and reduce energy consumption. LED sources can produce light at the specific wavelengths that optimize plant growth, and a number of universities and commercial enterprises worldwide are pursuing further research on the topic. LED lighting can also afford other advantages in horticulture in terms of what's called multilayer cultivation and interlighting, where light sources extend vertically between plants.

There are two primary scenarios in which SSL will be used in horticulture according to Shih-Chen (Powell) Shi, assistant chief in the professional lighting department at Everlight Electronics. Everlight makes both LEDs and luminaires for horticulture applications. In Japan, Shi says that growers are developing commercial plant factories that are indoors and receive no sunlight. The plant factories utilize layering (Fig. 1) to pack as many vegetables as possible into the available space – especially important in a region with limited traditional farm land.

There are already hundreds of such plant factories in production in Japan, although the use of LEDs as a light source is relatively new. Most use some form of HID or fluorescent sources presently. The indoor factories offer the additional advantage that no pests can reach the crops and therefore chemicals aren't required in the growing process. Indeed the plants are safe for consumption without being washed. Moreover the growers can completely control the environment including humidity, temperature, and other factors.

In areas such as Europe, Shi says there is more interest in LED usage in greenhouses where the artificial light supplements sunlight. In both plant factories and greenhouses, LEDs offer an energy-saving alternative to other artificial light sources.

FIG. 1. Layers of vegetables are illuminated by GL-Flora LED-based luminaires from Everlight.

Chlorophyll absorption and energy usage

The key to the LED horticulture story is the chlorophyll absorption spectrum. Chlorophyll is a biomolecule present in the leaves of plants that absorbs light. Chlorophyll is critical in the photosynthesis process in which plants use the energy from light to covert carbon dioxide into organic compounds such as sugars that serve as plant food. Over many years, researchers have found that chlorophyll absorption peaks in the red and blue spectrum, and that chlorophyll absorbs little light in the green spectrum.

Most growing operations today that utilize artificial lighting rely on broad-spectrum sources such as high-pressure-sodium (HPS) lamps that are generally quite efficient light producers. Osram Opto Semiconductors' North American marketing and business development manager Drake Stalions identifies the problem with HPS sources, saying, "their light output is not centered in the chlorophyll absorption peak ranges and therefore a lot of that light is wasted." That equates to both wasted energy and less-than-optimum plant photosynthesis and growth.

Indeed the graph of radiated power relative to wavelength for an HPS source (Fig. 2), shows more energy concentrated in the green spectrum in the 550-600-nm range, than in the red or blue spectrum. Researchers, meanwhile have identified the 400-500-

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

nm and 600-700-nm regions as peak chlorophyll absorption areas.

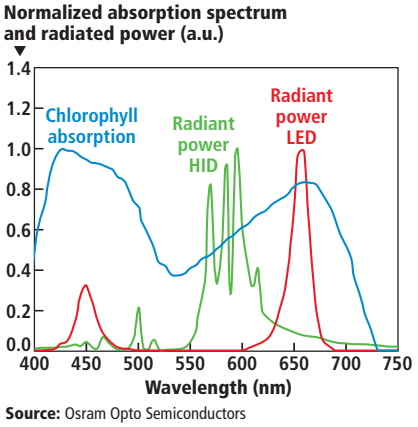
Deep blue and red

The chlorophyll research is leading luminaire makers to focus on red and blue light. Osram's Stalions said, "Two examples that we found to be particularly effective are centered at 455 nm and 660 nm." He said luminaire makers are mixing LEDs with these blue and red wavelength peaks in lights designed for horticulture.

In reality, SSL products optimized for horticulture are mostly in the developmental stages. The industry has had access to efficient blue LEDs for some time, but red LEDs are generally less efficient, especially at the ideal 660-nm wavelength. Last year, Osram announced 660-nm LEDs in both the Golden Dragon Plus and Oslon SSL product lines that offer 37% efficiency. That metric still trails the 42% efficiency that Osram offers in 455-nm deep blue sources.

Other component vendors have also announced 660-nm LEDs. Japan-based Showa Denko announced 660-nm LEDs back in 2009 that were targeted at horticulture (www.ledsmagazine.com/news/6/4/5). Later in 2009 a small-scale demonstration plant factory that utilized the Showa Denko LEDs was installed in a Japanese Minsitry of Economy, Trade and Industry facility.

Everlight also makes 660-nm LEDs and is using those components in its own GL-Flora line of luminaires targeted at horticulture (www.ledsmagazine.com/products/27170).



Source: Osram Opto Semiconductors

FIG. 2. LEDs can be chosen to match chlorophyll absorption peaks.

Lighting recipes

Researchers are still experimenting with the mix of wavelengths that's optimum

LINKS

Purdue gets $4.88 million grant to study LED lighting of plants
www.purdue.edu/newsroom/research/2010/101025MItchellGrant.html

Miniature spectrometers address challenges of LED research and production
www.ledsmagazine.com/features/7/11/7

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FIG. 3. Fionia Lighting is using Osram LEDs in a horticulture trial in Denmark.

for artificial, horticultural light sources. And the mix depends in part on any natural sunlight that reaches plants. But generally it appears that horticulture lights might need 4 to 10 red LEDs for every blue one.

The industry refers to the LED mix and the intensity of the light as a recipe. Everlight, for instance, notes the recipe on each of its GL-Flora data sheets. The luminaires typically use eight or nine red LEDs, and one blue one, and sometimes a white one as well.

Philips was one of the early proponents of LEDs in horticulture and has also been involved in research on recipes in conjunction with its partner BVB Substrates at a test lab located at a BVB facility (www.ledsmagazine.com/press/18829). The work began in 2009 and continues today, focused on testing recipes with specific types of plants and even adjusting the recipe at different stages of plant growth.

Philips has noted, for example, that more blue light leads to a more compact plant. Conversely, more red light leads to longer plants or what the researchers have termed as "stretching." The researchers have described LEDs as a "crop steering" tool.

Denmark pilot project

We are finally seeing some broad pilot projects for LEDs in horticulture and over the course of the next year there will be significant additional research. Fionia Lighting has been conducting a trial in Denmark (Fig. 3). Lights with a total of 50,000 Osram Golden Dragon Plus LEDs were deployed over "several thousand square meters" of Campanula

Bellflower plants. The trial has provided a precise demonstration of energy savings (www.ledsmagazine.com/press/26686). The LED lights reduced power consumption by 40% relative to HPS lights.

The horticultural performance is more difficult to quantify. The flowers developed equally quickly under LED or HPS lighting. The flowers grown under SSL were judged to have more buds which generally garnered higher selling prices for those plants. The grower was also able to reduce the use of chemicals in the LED-lit greenhouse.

FIG. 5. Netled Oy has developed an LED-based curtain-like system.

Interlighting tall plants

The Fionia trial utilized ceiling-mounted luminaires. LEDs may offer even more benefits in new growing scenarios such as the layered lighting used in plant factories and greenhouses. Another scenario is interlighting which seeks to maximize the amount of light that reaches plant leaves by placing linear luminaires vertically between plants. Interlighting is one angle that Purdue University (Fig. 4) will study using a recently-awarded $4.88 million grant awarded for the study of energy reduction and increased plant production.

Purdue has identified interlighting for what are called high-wire tomatoes as one area for test. The greenhouse-grown tomatoes can reach heights of 20 ft. Neither ceiling lights, nor sunlight, can effectively reach the lower portions of the plant. But horticulture professor Cary Mitchell believes LED interlighting will increase photosynthesis and flowering, and ultimately boost yield. Purdue will collaborate with Rutgers University, the University of Arizona, Michigan State University, and Orbital Technologies Corp on the four-year project.

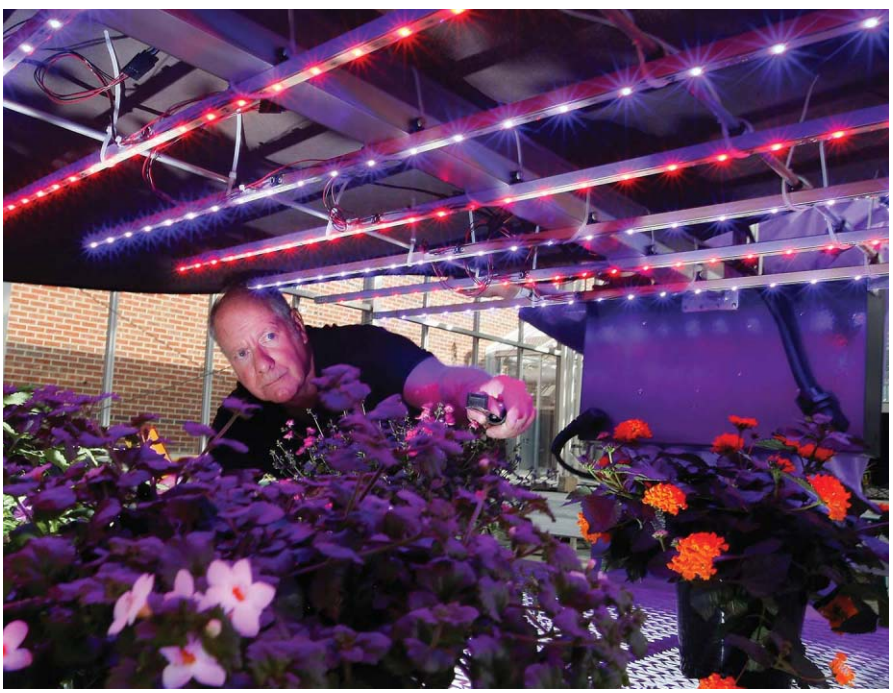

FIG. 4. Purdue professor Cary Mitchell studies LED lights for plant growth.

Finnish-based Netled Oy has developed another approach to deploying LED lighting between plants. The company develops products specifically for commercial greenhouses, and together with Osram recently announced a curtain-like system (Fig. 5) that has horizontal strips of LEDs (www.ledsmagazine.com/products/28239). Netled is testing the system in a greenhouse in Honkajoki, Finland.

Expect to hear a lot more about LEDs and horticulture as the year progresses. Osram will be working with Michigan State University's Department of Horticulture and Floriculture on a study.

You can also expect advancements in LEDs components and luminaires. Fionia Lighting, for instance, is moving toward commercialization of the luminaire it developed for the Denmark trials.

Osram has said that it will have even more efficient red LEDs for horticulture this year. Stalions said they will hit 45% efficiency by the end of this year. The company also has a very bright outlook for the size of the market, projecting that horticulture will consume $20 million in LEDs at the component level by 2013.

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regional | RUSSIA

Russia launches LED industry association to develop national capabilities

The LED lighting industry in Russia is becoming more mature as the country seeks to develop a vertically-integrated manufacturing infrastructure. *LEDs Magazine* spoke with **EUGENE DOLIN**, the CEO of a newly-formed LED industry association in Russia.

The Russian LED market is changing rapidly. State funding and investment from private companies is helping to build a domestic LED infrastructure and, all over Russia, companies dedicated to LED lighting technologies are emerging. A recently-formed manufacturers association, established by competitive suppliers Optogan and Svetlana Optoelectronics, is likely to play an important role in the evolution of the Russian LED lighting market. *LEDs Magazine* spoke with the organization's CEO, Eugene Dolin.

LEDs Magazine: Please tell us about the organization and its formation.

Eugene Dolin: The full trade name of the organization is the "Non-Profit Partnership for Manufacturers of LEDs and LED-based Systems," or LEDSM NP, and it is located in St. Petersburg. LEDSM NP was registered with the Ministry of Justice for the Russian Federation at the beginning of November 2010. The agreement between Svetlana Optoelectronics and Optogan, two of the largest Russian LED manufacturers (from epitaxy to lamps), was established at the beginning of November.

Interest in joining the partnership has been expressed by the majority of the largest Russian manufacturers of LED lighting and power supplies, as well as Russian research and science centers. At the present time new members are being accepted.

The partnership's supervisory board is formed with the participation of representatives from the Ministry of Industry & Commerce, the Ministry of Energy, the Ministry for Economical Development and the state corporations Rosnano and Rostechnology, as well as Russian Railways RZD, which is an OAO (open joint-stock company). The Nobel Laureate Jaures Alferov has agreed to become a member of the supervisory board.

Russian manufacturer Ledel (www.ledel-europe.com) has installed 500 Sveteco-48 LED luminaires in the Novo-Savinsky district of Kazan, a large city on the Volga. The 48W LED luminaires contain Osram Golden Dragon Plus LEDs and replace 150W sodium-halide lamps. **MORE:** www.ledsmagazine.com/press/30224.

What are the main aims of the organization?

The partnership's mission is the active development of an LED production infrastructure, providing for the development of the LED industry in Russia.

Who is eligible to join the organization?

According to the statute, members of the partnership may be Russian entities carrying out a range of functions – manufacturing, scientific, professional, design, development and regulation – in the sphere of the LED industry and neighboring fields.

The partnership unites Russian manufacturers of LEDs, materials and components; companies involved in LED light technology and its supply systems; as well as industrial media, project participants, educational and scientific organizations, and individuals.

Does the organization receive any state or regional funding?

The partnership's activities are carried out by means of funds from its members and are not financed by the state or regional structures.

What targets do you have to develop Russia's LED industry?

The basic objectives of the partnership are to protect and increase participants' effectiveness in national production, technology, science and education in LED and neighboring fields. Also, to develop markets for LED technology, both in terms of quality and quantity. Another objective is the formation of rules and regulations for the functioning of the Russian LED market. There are several methods to achieve these

objectives:

- Lobbying for the interests of Russian manufacturers of LEDs and LED systems at all levels of government and in various sectors of the national economy;
- Creation of discussion platforms, conducting industry conferences;
- Creation of systems for voluntary certification of LED production;
- Creation of industry-wide information resources;
- Accumulation of resources for implementation of targeted programs.

How is the industry infrastructure being developed within Russia?

The modernization course proposed by President Medvedev is a strong driver for the growth of industrial production and innovation. LED lamp-assembly plants are being created in all regions. Sales markets – including street lighting, the municipal sector and industrial lighting – are ready for the implementation of LEDs. Upgrades of standards in 2010-2011 will provide a modern system harmonized with the international standards.

On the agenda is a transition from mass imports of lamps to localized production of both lamps and LEDs. The state will support the national high-tech production.

Among the primary problems is the need to be able to confirm basic performance characteristics. Also, it will be necessary to create barriers for low-quality products capable of damaging the consumer's faith in LED technology.

Do you have plans to participate in international activities?

The partnership plans to participate in international working groups on standards and methods of measurements and tests, both independently and in cooperation with other national partnerships and associations.

Where are the opportunities for Russian LED makers to export their products?

Russian manufacturers of LED materials and chips already export their products. Many companies deliver LED lamps to countries in the CIS and the Baltic. The most promising areas for export are sapphire substrates, chips, lamps, traffic signals, and video and information LED screens.

Svetlana Optoelectronics

St. Petersburg-based Svetlana Optoelectronics (http://eng.svetlana-o.spb.ru) dates back to 1996 and produces a wide range of LED modules and lighting systems, including traffic signals, obstruction lights, illuminated indicator boards, and profiles for step-edge illumination.

Svetlana also produces high-power white LEDs, which were recently introduced to the international market by the company's subsidiary, Svetel LLC (www.svetled.org). Manufacturing is vertically integrated, from epitaxy to packaging. The Svetled LEDs, available in an array of color temperatures, were exhibited at the Strategies in Light event in February this year. Warm-white LEDs have a minimum flux of 105 lm (95 lm/W) in the highest bin.

Svetel plans to invest over $10 million in LED manufacturing equiment, in order to boost its capacity to 3 million LEDs per month, of which 50% are targeted for export markets. The new machinery will be housed in a completely refurbished production floor of over 1000 m². Further investment in capacity growth is planned in the second half of 2011. ◄

LINKS

LED market in Russia expands with investment and state support
www.ledsmagazine.com/news/7/10/28

Optogan opens largest LED production plant in Eastern Europe
www.ledsmagazine.com/news/7/11/29

Russian President Dmitry Medvedev visits LED manufacturer Optogan
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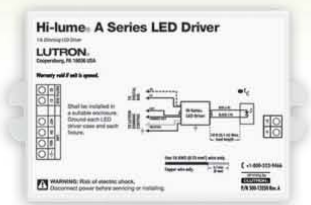

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Q&A | ENERGY STAR

Navigating the Energy Star maze for maximum market success

UL's **MATTHEW SALLEE** answers pressing questions on energy efficiency and Energy Star certification that lighting manufacturers must understand to bring products to market successfully.

As LED-based solid-state-lighting (SSL) technology advances and accelerates, regulatory bodies are working to develop and publish energy-efficiency requirements globally. Navigating this moving maze can be a real challenge for manufacturers. To facilitate transparency in these program changes, UL in conjunction with LEDs Magazine recently hosted a webcast on the 2011 Energy Star program requirements.

Energy Star and other energy-efficiency programs are vital to consumers adopting SSL. The programs provide consumers with assurance that they are buying quality products. Lighting manufacturers must both design products that meet pertinent regulatory and market requirements, and document and certify those designs to win in the market space, The recent webcast entitled "Energy Star and UL – Maximize your LED revenue potential" was focused specifically on Energy Star certification, and can be viewed at www.ledsmagazine.com/features/7/12/7. The questions and answers below cover the topics that were most asked about by viewers at the live event.

What has changed in Energy Star from past years?

The program has shifted from a self-declaration model to a third-party certification model. Previously, manufacturers could submit testing data to an EPA-recognized Certification Body (CB), and achieve approval assuming the documentation met requirements.

Now, to qualify for Energy Star certification, products must be tested at EPA-recognized laboratories, and labs must be accredited by EPA-recognized CBs. New Energy Star products must be qualified through a CB for approval. The testing process can either be handled directly by a CB, or performed by the manufacturer in-house (see below).

CBs can conduct testing assuming they have an EPA-recognized laboratory that has successfully completed the ISO 17025 audit process. The CB will then use that gathered test data and make a certification decision.

How is the in-house testing program set up for Energy Star?

While the Energy Star program has shifted from the self-declaration model to a third-party certification model to promote a more-level playing field among manufacturers, the manufacturers still have the ability to conduct in-house testing through the supervision of an EPA-recognized CB. There are two in-house programs for manufacturers to leverage for Energy Star testing. The Supervised Manufacturer Testing (known as SMTL) program allows manufacturers to generate test data and submit it to a CB for a certification decision on Energy Star compliance. In an SMTL program, the manufacturer's test laboratory is subjected to initial and annual audits by the CB to ensure continued compliance.

The Witness Manufacturer Testing (known as WMTL) program allows manufacturers to conduct testing at their facility. CB personnel witness and supervise the testing, and make the certification decision.

MATTHEW SALLEE *is the Global Business Manager, LED and Solid State Lighting at UL (www.ul.com). UL is both a qualified Certification Body and has multiple global Recognized Laboratories under the Energy Star Program. UL labs hold IAS accreditations and Caliper qualification. UL is not directly affiliated with the EPA, the DOE, the FTC, the CEC, or the DLC.*

FIG. 1. A Type-C goniophotometer at UL's Nansha, China facility.

What are the accreditation, lab and test equipment requirements?

There are 3 key elements to completing in-house photometric testing for the Energy Star program:

1) Laboratory: Recognized laboratories need to be ISO 17025 accredited, however labs under the SMTL and WMTL programs only need to be qualified through a CB, and go through the annual audit process.

The laboratory should have good control of the testing environment. Temperature, humidity vibration, airflow and power supply regulation are all key elements. Placing your laboratory on a second floor above

a one-ton punch-press or in the same room as a smelter would certainly have a negative impact on test reliability!

2) Equipment: Test equipment must be calibrated by an accredited calibration laboratory to a nationally or internationally recognized standard of measure. Additionally, equipment should conform to the standard requirements. For example, IESNA LM-79 requires a Type-C goniophotometer to ensure reliability and repeatability of test results.

3) Test procedures, documentation and qualified personnel: While having the right lab environment and equipment in place helps, it's also extremely important to have the appropriate test procedures, documentation and trained qualified personnel in place. A great place to start with in-house testing is the WMTL program, as this witness-testing program provides good insight into the competency resources needed to complete the testing puzzle.

What energy efficiency testing programs are available for LED linear tubes or outdoor street & area lighting?

There are no Energy Star programs presently available for LED linear tubes or outdoor street & area lighting. However, test programs such as the DOE's Lighting Facts label and the DesignLights Consortium (DLC) qualified-products list exist for these products. Moreover, tests for energy efficiency can still be performed centering around IESNA LM-79, a test procedure for the photometric and electrical performance of LED lamps and luminaires.

What is the difference in marketability of Energy Star certification compared to other energy-efficiency programs?

Simply because there isn't an Energy Star program available doesn't mean that products can't be tested and marketed as energy efficient. Energy Star is certainly one of the more robust certifications available today, and can qualify manufacturers' products for consumer incentive programs like rebates from retailers and utility companies.

Some products, however, simply aren't a good fit for the present requirements for Energy Star. The lack of potential for Energy Star certification doesn't have to be a barrier to marketing a product as "energy efficient."

FIG. 2. An integrating sphere at UL's Luminaire Testing Laboratory facility.

The voluntary DOE Lighting Facts label, for example, is built upon the same baseline evaluations as the Energy Star program (IESNA LM-79), but doesn't set performance levels or require the same rigor in evaluations for lumen maintenance, FCC, or acoustic noise. To date, over 175 retailers and distributors and over 200 lighting professionals (designers, specifiers, utilities) are looking at the Lighting Facts label as an effective stop-gap for products not presently included in Energy Star.

In July 2011, the FTC will make its own Lighting Facts label mandatory. This is intended to help consumers distinguish the various features of LED retrofit lamps at the point of sale. Testing is not required for the FTC label, and there are questions around the industry regarding the reliability of this type of approach.

Finally, the DLC, a collaboration of utilities and regional energy-efficiency organizations, has a goal to ensure that high-quality, energy-efficient lighting design becomes commonplace in all lighting applications.

Again, the DLC program offers a stop-gap for lighting products (primarily outdoor lighting) that are not covered under existing Energy Star programs. DLC evaluations are similar to that of Energy Star, in that both IESNA LM-79 and IESNA LM-80 testing are required. Additionally the test data must be produced by a NVLAP (National Voluntary Laboratory Accreditation Program)-accredited or DOE Caliper-approved laboratory.

What has changed recently with the Energy Star program?

On February 16, 2011, the Luminaries v1.0 specification was finalized, replacing the Residential Lighting Fixtures (RLF v4.2) and Solid State Lighting Luminaires (SSL, v1.3) specifications. Presently, applicable products can be tested and certified to the new requirements. After June 15, no new certifications to the old RLF v4.2 or SSL v1.3 will occur.

Any models presently qualified to the existing specifications will maintain their qualification status until October 1, 2011. After that date, any luminaire shipped with an Energy Star label must be certified to meet the new Luminaries v1.0 requirements.

Driving SSL innovation

As the drive for energy efficiency in LED lighting continues to grow, regulations and programs will certainly continue to change with them. While this change can sometimes feel counter-productive to progress, these small adaptations over time can pave the way for innovation breakthroughs in efficiency across the lighting industry.

The regulations and programs are already having a positive impact in segments ranging from residential to commercial lighting. Ultimately, the programs will allow lighting buyers across all segments to choose SSL products with confidence in both light quality and efficiency.

NRC-IRC imagines the future of solid-state lighting in offices

LED technologies require thorough investigation before they can be fully implemented in office environments, as **ERHAN DIKEL** and **JENNIFER VEITCH** explain.

The effects of office lighting on occupants' perception, performance and satisfaction, as well as on energy efficiency, have been examined for over 30 years by the lighting sub-program at the Institute for Research in Construction (IRC) of the National Research Council (NRC) Canada. The promise of LED technology brings together these two strands. Market acceptance of LED technology will require that it be trusted as healthful and safe. The initial cost premium will mean that the new systems need to offer features that users value, if LEDs are to displace the incumbent fluorescent technology.

NRC-IRC began in 2008 to investigate LED technologies with two overlapping activities: the development of new ideas for office lighting with LEDs, and laboratory experiments addressing how people would use and respond to the color-tuning capabilities of solid-state lighting (SSL) systems. This article gives a sample of the activities in this project, and additional information can be found at www.nrc-cnrc.gc.ca/eng/projects/irc/solid-state.html.

LED technology is radically different from existing light sources and opens new directions in lighting design. NRC-IRC brought together a group of people with diverse backgrounds and expertise from industry and academia for a design charette, or collaborative design session, in which we tried to imagine what a novel LED lighting system might be like. The ideas that came from the charette have directed both experimental design and demonstration projects.

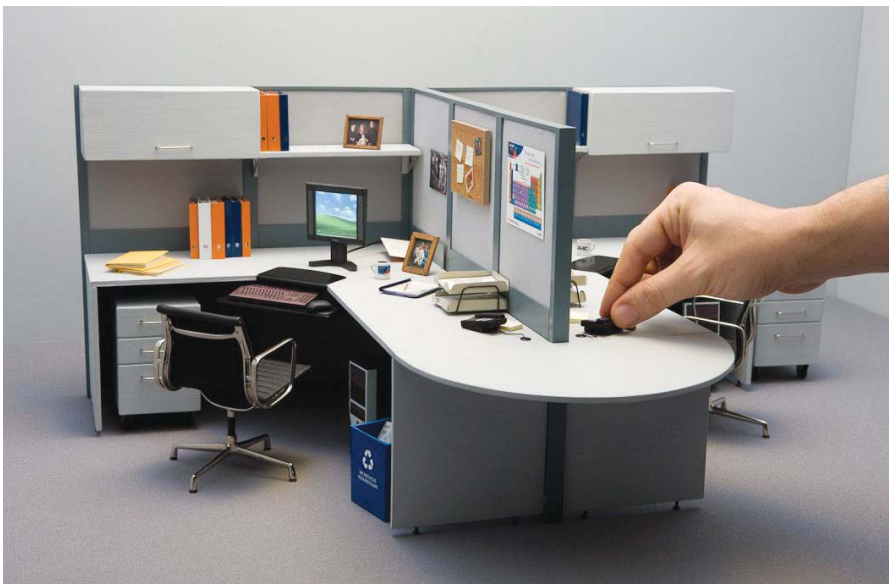

FIG. 1. The scale model of the office space used in the experiment.

Scale model experiment

The experimental work began with a scale-model experiment in which we examined the range of color-temperature and spectral-power distributions of participants' preferred lighting conditions. The scale model was a cost-effective option to create and test the desired scenarios. Participants viewed each lighting condition on a one-sixth scale model of a typical office in a light booth (Fig. 1). We introduced common office accessories to make the model as realistic as possible, with OLEDs for the computer monitors. The overall color scheme was monochromatic grey, to avoid having any one color bias the judgments. Some of the small accessories (e.g. folders and framed pictures) were painted with saturated colors to provide accents.

Participants first evaluated the appearance of the model in terms of its colorfulness, pleasantness, and brightness, under six lighting conditions: a 4100K fluorescent source and five LED spectra created using various combinations of the five channels: red, green, blue, cool white, and warm white.

Scenarios A (2855K) and D (6507K) were inspired from CIE Illuminants A and D65 with respect to their correlated color temperature (CCT). The other three LED scenarios – E (3728K), B (4751K) and C (5769K) – were distributed evenly by CCT on a scale between Scenarios A and D. Scenario E was specifically adjusted to 3728K to match the effective CCT of the fluorescent lamps (Fig. 2).

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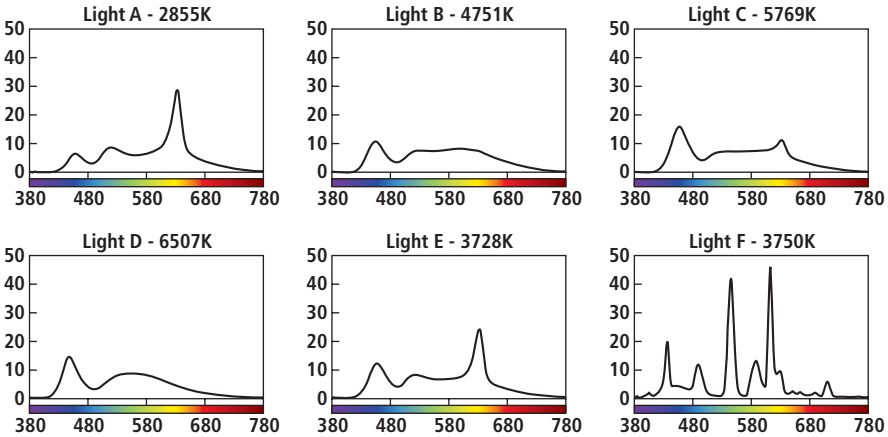


FIG. 2. The spectral distribution graphs for the six preset conditions.

In the second phase of the experiment, each participant was free to adjust the five channels of LEDs to create their preferred light: once with no constraints, and another time with a constraint of 500 lux maximum on the work surface.

Initial results showed a wide range of preferences for light-source spectrum, and thus no single preference for any one lighting condition, even when participants had the controls. These results (Fig. 3) confirm the importance of individual, personal control over their light. LEDs with multiple channels can offer individual control over light-source spectrum. This is almost impossible with other technologies (Fig. 3).

Full-scale experiment

Next, we shifted to a full-scale experiment. We redesigned one of the labs at NRC-IRC by equipping it with eight in-house-designed LED luminaires (Fig. 4). Each luminaire has eight RGBW LED light engines that can each be controlled with a DMX protocol; the total maximum light output from each luminaire is approximately 3500 lm. Users may create a preferred white color using custom software to control the LEDs; the interface uses the computer mouse as a pointer over a carefully designed color palette. The software reads the RGB values from the picture on the computer screen and converts these into digital signals.

In this experiment, participants work in the office for a full day, completing simulated office work and questionnaires about

their judgments of the space, their mood and their satisfaction. The day starts with a fixed spectrum (either 3000K or 6500K), and half of the participants have the opportunity to control the spectrum starting after lunchtime. Data collection for this experiment is ongoing, and preliminary results will be available in summer 2011.

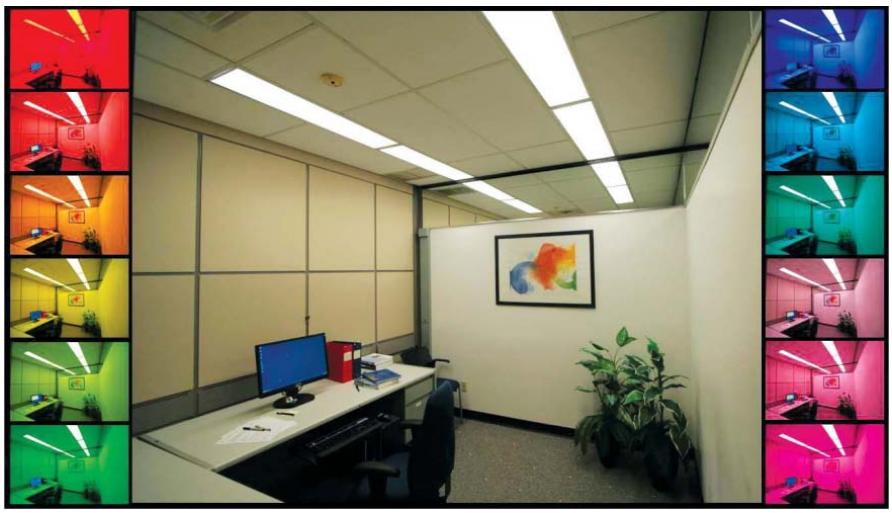


FIG. 4. The setting for the full-scale experiment.

LEDs for future offices

LEDs allow us to do things that we cannot do with conventional fluorescents, metal-halide lamps or halogen lamps. They can be controlled electronically and can be integrated into smart building control systems. Their efficiency is increasing each day. As with all other new technologies, the lighting industry will solve some of the issues with LED lighting like high initial costs, color quality, discontinuous spectral power distributions, and possible flicker.

The promise of LED technology is impressive; however, it may be too early to say that LEDs are the future of general room lighting. Offices will definitely need something better than the existing fluorescent fixtures, but without more attention to the usability issues of the new technology, it will not achieve the promises of reduced energy use for lighting. Only a small fraction of LED research focuses on the human factors of LED lighting. However, adoption may be impeded without better knowledge of how people perceive spaces lit with LEDs, how they would use LEDs, and how LEDs affect their performance and health. NRC-IRC research is intended to fill that gap, but the scope of the research issues is too great for any one laboratory to resolve alone.

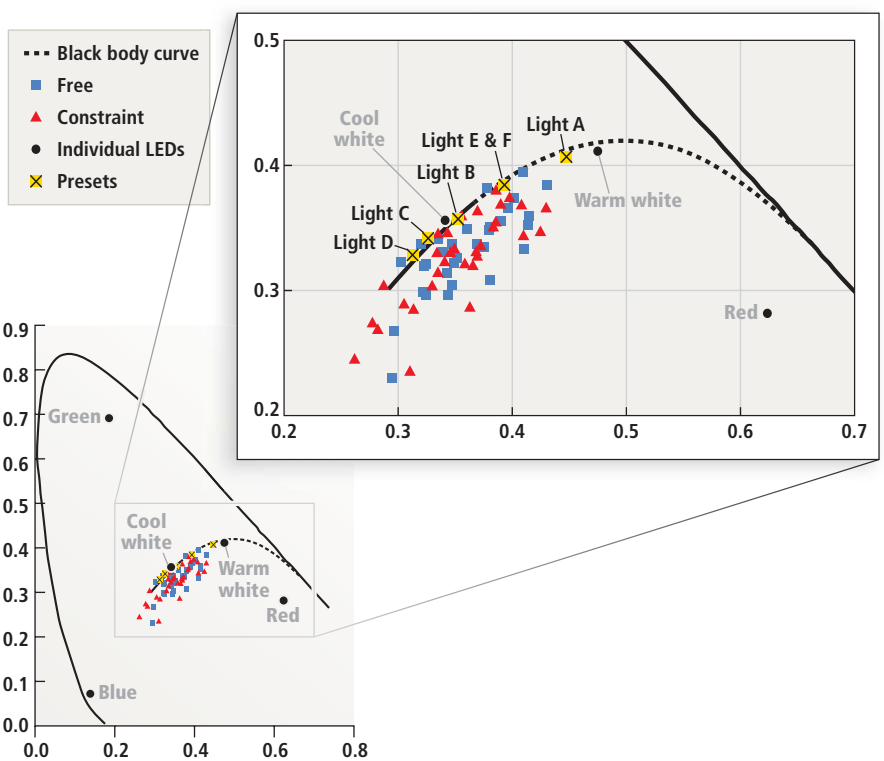


FIG. 3. The range of participants' unconstrained choices for light source spectrum, plotted on a 1931 CIE Chromaticity Diagram.

Acknowledgements

This project is sponsored by Natural Resources Canada (Panel on Energy Research & Development, Office of Energy Efficiency, Clean Energy Fund), British Columbia Hydro, Philips (Color Kinetics, Canlyte and Lightolier), Lutron, Go Lighting, Group IV Semiconductor, Public Works and Government Services Canada, the University of British Columbia - Structured Surface Physics Laboratory, and the NRC Institute for Research in Construction.

standards | UPDATE

LED safety standard UL 8750 requires further clarification

There is still some clarity needed in how UL 8750 addresses safety requirements for packaged LED components, which can even affect the choice of encapsulation materials, writes **JIANZHONG JIAO**.

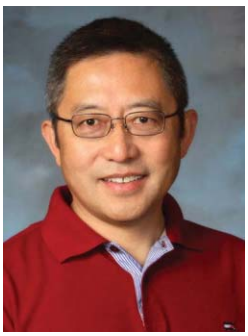
In November 2009, Underwriters Laboratories (UL) published a new LED light-source safety standard, UL 8750, entitled "Light Emitting Diode Equipment for Use in Lighting Products." This standard was based on research described in the "Outline of Investigation" report that UL had spent over two years developing. The report includes input from approximately 45 members of the UL 8750 Standard Technical Panel (STP).

Several LED manufacturers have already made claims of offering "UL 8750 recognized" LED products, but there is still some clarity needed in how UL 8750 addresses safety requirements for packaged LED components; it may not be as simple or direct as some may think.

In UL 8750, an LED light source is defined as any equipment including LED drivers, controllers, arrays, modules, and packages that forms an integral part of a luminaire. UL's initial intent was to establish a "horizontal" standard that would be interconnected with the other twelve UL standards for luminaires where LED light sources are concerned. In 2005, UL recognized that its existing lighting standards did not adequately address LED light-source construction features and performance attributes, and feared that the requirements for LED light sources were at risk of being independently developed and taken along diverging paths. UL believed that a uniform approach was needed for efficiency and consistency in certification decisions.

Safety hazards and risks

Over the years, UL conducted internal investigations on LED light-source safety hazards, which were fundamentally based on two safety measures: risk of electric shock and risk of fire. In simple terms, the risk of shock is related to the electric voltage (even for a smaller current), and the risk of fire is related to heat caused by the total power consumption.



In general, these two safety risks are gauged by the limits set by UL. Per UL 8750, risk of electric shock exists for a voltage exceeding 60 Vdc or 30 Vrms; and risk of fire exists when non-Class-2 circuits are employed. Therefore, under UL 8750, LED light sources are subject to these risks when LED luminaires are operated above the pre-defined risk limits.

For example, although each individual LED is operated with a relatively low voltage, typically around 3 Vdc, the string or array of LEDs can be connected in cascade up to the line voltage of 110V. This is a common approach for allowing high-voltage drivers to be used in outdoor luminaires because the manufactures claim that high-voltage drivers may be more efficient and less costly. In this type of application, the LEDs carry a risk of electric shock when the circuit is broken down. Furthermore, a single LED may be operated at a low wattage; however, when a large grouping of LEDs is assembled into a luminaire, the total wattage may exceed the Class-2 limit. Consequently, this type of LED light source could create an inherent risk of fire according to the UL definition.

Materials requirements

Despite providing clear measurements to indicate when LED sources (LED packages) and LED luminaires are at risk of causing electric shock and fire, the countermeasures specified in UL 8750 to ensure that LED sources and luminaires are safe from these risks are quite complex. These safety countermeasures focus on the polymeric enclosure material requirements and assembly requirements, which can be broken down into four aspects: impact-ability, flammability, electric high-voltage resistance, and ability to accept probe force.

UL 8750 allows the glass LED lens to be exempt from these requirements, but the confusion arises as to whether all LED (non-glass lens) packages are subject to these four requirements when they are used in high-voltage or non-Class-2 applications. The quick and simple answer is no. If a non-Class-2 LED luminaire has a polymeric enclosure (such as a cover lens or shade) that meets these requirements, then the LED packages do not need to comply with UL 8750. However, a practical issue exists that the polymeric enclosure materials used for the luminaires often do not meet these rather stringent requirements.

In addition, some LED luminaires are designed without a cover lens, and the pri-

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mary or secondary optics used for LED packages are directly exposed to the environment and users. In both cases, the LED packages, particularly the lenses (for primary or secondary optics), are treated as the enclosure materials for the luminaires, and therefore must comply with these safety requirements.

Encapsulation issues

Over years of LED research and development, the encapsulation or lens materials used for LEDs are often selected based on their optimized optical properties such as transmittance, stability for UV (or short wavelength) exposure, thermalcharacteristics, process-ability and, of course, cost. These materials are not chosen because of their impact-ability, flammability or other requirements mandated by UL 8750 safety measures, and that creates another practical issue with this standard. By adding these safety requirements into LED package material selections, it is uncertain how much this could potentially impact the cost of LEDs.

This subject has been discussed within the UL 8750 STP. During the June 2010 STP meeting, further questions were raised related to the Hazard Based Safety Engineering (HBSE) method for assessing the LED array electric shock and fire risks. The safeguards are fire-containing enclosures and prevention of ignition. This assessment poses some questions as to whether an LED lens should be considered as fuel material or as a fire-containing enclosure. In the first instance, because the individual LED lens is rather small and only a few millimeters in diameter, would it provide sufficient fuel to maintain fire even it were flammable? In the alternative scenario, if the LED lens was considered as a fire-containing enclosure, do the energy level and fuel characteristics within the LED package create enough potential risk? These questions still need to be resolved through UL.

With a clear need for improvement in LED and SSL standardization, working groups and members of the UL 8750 STP continue to work on this subject. Preventing LED lighting safety hazards is certainly a high priority, yet safety standards should not lead to adding unnecessary costs to LEDs.

LINKS

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

LED product safety standard requires ongoing updates
LEDs Magazine Nov/Dec 2010, p51: www.ledsmagazine.com/features/7/11/12

Manufacturing software is key as LED production volumes grow

As LED demand grows rapidly, automation software and process control can get more from current manufacturing lines, and this can be as important as getting new lines up and running quickly, as **PHIL WALKER** explains.

It's no secret that LED manufacturing is a booming business and is attracting the attention of hardware and material suppliers, industry analysts and even manufacturers from related sectors like the mainstream semiconductor industry. Across the industry, LED makers are intent on lowering cost and reducing variability in their production processes, and are searching for new mechanisms to help drive these reductions.

One new mechanism that is gaining popularity, for example, is a software solution that can trace a device from wafer to die, then to die-on-tape, and then to final product. Additional measurement steps have been added closer to the MOCVD tools that allow excellent correlation between tool settings, recipes and product performance. Some manufacturers also add in-situ metrology, which contributes even more data that can be correlated to product performance. This results in an opportunity to directly impact bin yield by merely adding software along with in-line measurement steps.

During this crazy period of growth in LED demand and production, getting more from current manufacturing lines is as important as getting new lines up and running quickly. Manufacturers understand the immediate value from software that can provide full product traceability and advanced process control to ensure that each production run outputs the highest quality product.

Automation software adds value by gathering data for analysis by the process engineers. It can come from process tools, such as the epitaxial and litho steps during LED manufacturing, the metrology tools which correlate process parameters and device performance, and process tracking, which provides the context backbone that makes the rest of the data pertinent. For example, being able to dig through data to analyze substrate lot ID compared to defect count could be critical to highlighting a suspect material lot.

Success in achieving maximum bin yields of the highest-value LEDs will rely upon four key components: (1) a real-time manufacturing system that traces lots, locations, times etc; (2) real-time process data coming off the key tools that is captured in a database; (3) real-time measurement data from all of the metrology tools (in-situ, probe, defect tracking etc); and (4) a solution that can pull the data together and easily drive real-time analysis of the data.

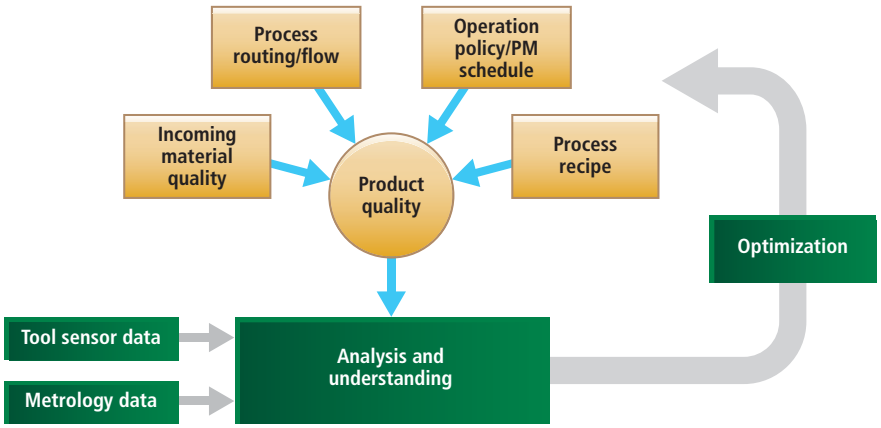

FIG. 1. Software-based analysis of data from multiple sources creates actionable information that can be used to drive process improvements.

The true added value in having all of this data comes from the ability to analyze it as a whole. It is a data-mining activity in which multiple data sources need to be analyzed together, as shown in Fig. 1. Only through analysis and understanding can we turn raw data quickly into information that is actionable.

Moving to larger wafers...

Another way to achieve higher LED output is to move from small wafers—two to four inches in diameter—to larger-diameter substrates, perhaps six- or even eight-inch wafers. However, there is a lot more at stake with larger-diameter substrates. A single scrapped wafer due to misprocessing or other problems could create an order of magnitude more wasted LEDs.

The manual loading and unloading of larger wafers can also present a problem. Therefore, companies that are moving to

PHIL WALKER *is Global Product Manager of Automation Products with Applied Materials (www.appliedmaterials.com), a global supplier of capital equipment, software and services.*

these substrates are likely to adopt more automation for material handling, process monitoring and fault detection. As was the case in the semiconductor industry, material handling, tracking and control will become increasingly important in these environments to drive quality and throughput and to further reduce costs. A more sophisticated preventive maintenance schedule that not only considers run time and chemical usage but also assesses tool performance and metrology data could deliver substantial cost savings.

...or sticking with smaller wafers

But what about LED makers who decide to stick with smaller substrates? Automation strategies can be leveraged here as well to cash in on performance and cost benefits. First, it's doubtful that the LED world will scramble to upgrade to larger wafers as fast as semiconductor manufacturers did. Though the processing expertise for sub-5 inch wafers is well established, there's an opportunity for continual refinement with advanced process control. Technologies like fault detection and run-to-run control can further boost the yields on the important and high-value parts, so LED makers can continue to produce batches with the high-value output that rivals even the largest substrate sizes.

Adding specific software technologies to small-wafer-size production lines will give manufacturers a good chance to remain highly competitive in the short term, and perhaps for many years to come. Certainly it would also provide them with more time to transition to larger substrate sizes if that is their plan and to help them leverage their experience with advanced process-control methodology as they are ramping.

Unquestionably, the growth in the LED business is exciting and the manufacturing technology will evolve quickly. Likewise, the inevitable sophistication of production processes that accompanies that growth is sure to include advanced automation strategies that offer substantial mechanisms for smart, profitable, volume manufacturing.

SEMI highlights LED fab investment

TIM WHITAKER

Last year saw "explosive growth" in spending on equipment for LED fabs, jumping from $606 million in 2009 to $1.78 billion in 2010, according to the newest update of the Opto/LED Fab Forecast from the industry association SEMI. Further growth of 40% year-on-year is expected in 2011, when the total will reach about $2.5 billion, says SEMI.

SEMI recorded 19 new LED fabs that started operation in 2010, with another 27 expected in 2011, and a further 15 coming online in 2012.

On the capacity side, SEMI says that worldwide LED fab capacity reached 4,350 thousand wafers per month (wpm, 2-inch wafer equivalents) in 2010. With strong demand from the LCD backlight market, a 50% capacity increase to 6,509 thousand wpm is expected in 2011. ◄

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applications | **WAREHOUSES & PARKING STRUCTURES**

Digital Lumens supplies LED lighting systems for 7 Americold warehouses

Groom Energy has installed LED-based lighting networks in three cold-storage warehouses, with four more planned, as **MAURY WRIGHT** describes.

Americold cold-storage warehouses in Massachusetts, Utah, and Wisconsin have been fitted with LED-based Intelligent Lighting Systems from Digital Lumens, which feature networked fixtures and adaptive controls. Digital Lumen's partner Groom Energy will install the solid-state lighting (SSL) system in four more Americold warehouses in separate states, seeking 90% energy savings relative to legacy lighting.

The Digital Lumens system is especially suited for warehouses because workers are only sporadically in aisles stocking or retrieving pallets. Occupancy sensors and network controls, combined with the instant on-off capability of LED lighting, mean that many of the lights can remain off during a significant portion of the operating hours. It's this combination of energy-efficient SSL and controls that can deliver 90% energy savings.

Groom says that the installations completed in the first three facilities, which comprise 850,000 sq. feet of warehouse space, will reduce energy consumption by 2.3 million kWh. Digital Lumens is currently shipping products to the other four sites.

Commissioning and training

Groom is handling installation in the nationwide project including commissioning the systems and training Americold employees. The typical operational scenario delivers high light levels in the areas where warehouse employees are working, and dims to what Groom calls "night-light levels" when no one is present.

"Groom Energy knew our operators' needs and designed and managed the implementations very effectively. Our teams are very pleased with the increased light levels, functionality and the significant energy savings," said Americold's VP of Engineering, Fred Walker.

When asked about the SSL choice, Walker said, "It's all driven by economics." He said that lighting is an expensive retrofit, but compares well against other energy-saving initiatives such as solar energy, better insulation and others. "The best payback we are getting is from lighting retrofits," he said. That payback comes from a combination of energy and maintenance savings, and incentive from utilities and government agencies. Walker indicated that Americold seeks to achieve a two-year payback.

Metal-halide lamps (top) and solid-state lighting (bottom) in Americold cold-storage warehouses.

The latest Americold project includes one new warehouse, while the remainder are existing facilities where SSL is replacing metal-halide (MH) lamps. The MH lamps are less efficient than LED lights, and also require a prolonged restrike time (off-on cycle) that isn't suitable in an adaptive-control scenario.

LEDs vs. dimmable fluorescents

Americold has utilized dimmable, high-efficiency linear-fluorescent systems in some facilities. Walker indicated that such lighting was an improvement over MH lamps, saying, "We got a lot of savings out of that too." But he believes that LEDs now offer even greater benefits. Walker lamented that you could only dim the fluorescent systems to 50% of full output because the system must keep the ballast

warm to support an immediate return to full brightness.

Bob Kirby, Executive VP of Groom Energy, pointed out other limitations of the fluorescent systems. The lifetime of the dimmable fluorescents can be shortened by frequent on-off cycles. Kirby said facility managers would typically set the fluorescent systems to stay lit for 30 minutes once triggered by an occupancy sensor.

The long on-time would eliminate cycles and prolong lamp life in the case where workers returned to the same area of the warehouse in a short period of time. But the longer on-period would also waste energy when workers don't return to the area. The LEDs can achieve far greater energy savings via much shorter on-periods and the fact that on-off cycles don't significantly shorten the lifetime of the light source.

Financial incentives and rebates

Groom also plays a major role in helping companies such as Americold work through the financial implications of a major lighting upgrade. Groom operates nationwide, and the rebate and grant programs vary greatly across the US. Groom's Kirby said, "One of our values is figuring out what the incentive will be and guaranteeing that incentive to the customer."

Kirby said that Groom must exhaustively evaluate each project and calculate the energy savings while also searching out all potential incentives. After the installation, Groom performs the required measurement and documentation to ensure that the customers receive the incentives or rebates.

Kirby said Groom has worked across a variety of scenarios where incentives cover anywhere from 0 to 70% of the cost of a project. Even with no incentives Americold's Walker said "LEDs can still pencil out if you have a lot of operating hours."

In the Americold project, LEDs were really a good fit for another reason. Walker said that, because all seven facilities are low-temperature warehouses, the fact that the LEDs produce no heat helps save on energy used for refrigeration.

SSL with adaptive controls deliver huge energy savings in Dallas parking garages

Lumetech Group and Lighting Science Group have retrofitted five downtown-Dallas parking garages with LED-based lighting, explains **MAURY WRIGHT.**

Solid-state lighting (SSL) luminaire manufacturer Lighting Science Group (LSG) and lighting vendor Lumetech Group have worked with the city of Dallas, Texas to upgrade five downtown parking garages to LED-based fixtures. The partners estimate that the retrofit will cut 1.7 million kWh in annual energy consumption. The savings are due both to the transition to more efficient LED light sources, and to occupancy-sensor-driven adaptive controls that dim the lights when no one is present.

The upgrades took place in parking garages at the Dallas City Hall, the Dallas Public Library, the Jack Evans Police Building, the freight terminal beneath Thanksgiving Square, and the Morton H. Meyerson Symphony center. LSG supplied its Flat Low-Bay LED luminaires to the project.

Generally, Lumetech replaced existing linear fluorescent fixtures with the LED luminaires. In the City Hall garage for example, 1998 fluorescent fixtures were replaced with 705 LED fixtures, according to Lumetech CEO Ron Lusk.

Lumetech utilized occupancy sensors and dimming to boost the energy savings. Lusk said, "The lights dim to 50% when there is no motion after four minutes." The lights are spaced at 30- to 33-ft intervals so a pedestrian would sequentially trigger lights as they walk through the garage.

Light quality and uniformity

While light quality should ultimately be judged on quantitative measurements, photos from the Dallas project seem to clearly indicate the superiority of the LED lights. Before and after photos from the Meyerson Symphony garage (page 75) indicate that the SSL retrofit provides brighter and more uniform lighting.

"The City of Dallas is committed to acting in the best interests of its taxpayers and to improving the efficiency with which it operates," said Ron Natinsky, Dallas Council Member. "Over the past few years, we have actively worked to become more environmentally efficient and have enacted a number of important green initiatives, including the recent efficiency upgrade of our parking garages."

Lumetech's Lusk said that, increasingly, facility owners and managers are taking proactive steps to increase the operating efficiencies of their properties and to reduce costs. "We are in the middle of what has proved to be an industry-wide, multi-year undertaking of commercial properties instituting 'green' energy solutions," he said.

Savings and payback

Like most SSL upgrades, the Dallas project targets both energy and maintenance savings. Lusk said, "The major driver behind this movement is the recognition of substantial savings in power consumption and labor costs, monetary rebates and

incentives offered by state and federal governments and utility companies and the accelerated rate of payback, often in less than 36 months. There is also an increased commitment from property owners and operators to act in the best interest of the communities in which they operate."

The Meyerson Symphony garage before (left) and after (right) the SSL retrofit.

In the case of the Dallas garages, said Lusk, the city will realize an even faster payback based on the magnitude of the energy savings. He said the payback could be as short as seven months, and the city also received some government grant money and utility incentives that would further reduce the payback.

The city hasn't projected maintenance savings attributable to the upgrade, but energy usage has been reduced by 60% compared with the previous lighting scheme. Councilman Natinsky said, "I hope that our actions [investment in SSL] compel the leadership of other cities and private sectors to follow suit."

Lusk also had some words for lighting professionals and lighting buyers that are avoiding LEDs. He said, "For those naysayers that think LED-based lighting isn't ready for broad deployment, they are just not as well informed as they could be."

MORE: *Our website includes case studies covering many different applications of LEDs and SSL.*
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focus on

Lighting Des

LEDs featured heavily in a number of the winning projects at this year's Lighting Design Awards, and both the interior and external luminaires categories were won by LED products. The awards are organized by the UK-based Lighting magazine.

MORE: www.lightingawards.com


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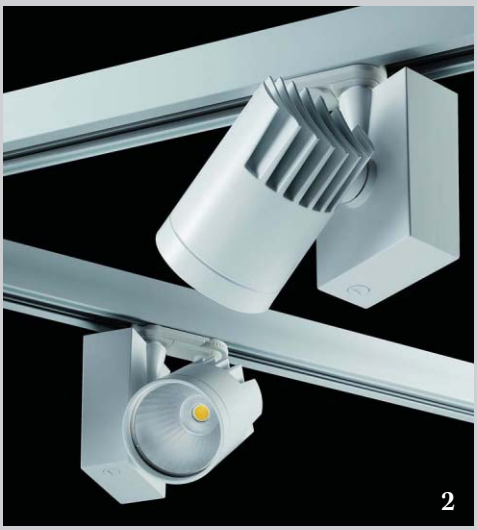

2

1. The Product Innovation: Light Sources & Controls category was won by the Alvara 400 plasma lamp from Ceravision, which delivers more than 90 lm per system watt. The power range spans 100W to 5kW and the CRI is up to 95. Ceravision has combined a number of technical breakthroughs, including the construction of the integrated resonator and plasma burner, plus an optically clear waveguide that harnesses all the light emitted by the plasma source. The judges described it as "a truly unique source – flexible, energy efficient and providing excellent photometric performance."

2. The Beacon LED spotlight from Concord Lighting, winner of the Product Innovation: Interior Luminaires category, is built around a single 13W LED module, and is designed to be an energy-efficient alternative to low-voltage tungsten-halogen lamps. The product is available in 15°-spot or 30°-flood versions, and produces 1055 lm at 4000K or 960 lm at 3000K, both with a CRI of 85. A Beacon Plus version has a CRI of 92, and 725-lm output at 3000K, and is suitable for museums, galleries and high-end applications.

3. With lighting design by BDP, the Projects: Lighting for Leisure category was won by The Point, the events venue at Lancashire County Cricket Club, England. Eighty percent of the lighting used LEDs, including RGB color-changing for events and corporate branding, as well as down-lighting, stair lighting and the white façade. "An excellent use of appropriate new technology to achieve an effective, flexible and complex scheme," said the judges. "Particularly impressive is the efficiency of such a visually appealing scheme."


3

Courtesy: David Barbour, BDP

ign Awards

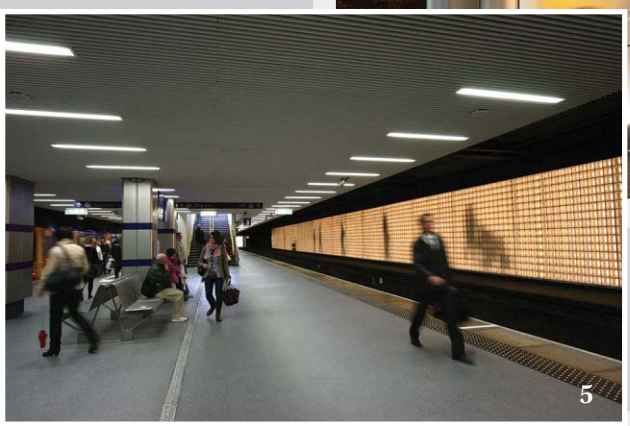
4. With lighting design by Licht Kunst Licht, the winner in the International Projects section was the Telekom Bridge in Bonn, Germany. The 74-meter footbridge connects two Deutsche Telekom offices across a roadway. The sides of the span feature a media display with magenta LEDs, while lighting on the deck comes from white LEDs in the handrail. The towers at each end have an interactive feature at night and respond to passersby with an amber light shadow. The judges described it as a "seamless example of light integrated with architecture."

5. Platform 5 at Sunderland Station, England, features a 144m-long, 3m-high, low-resolution video matrix designed by Jason Bruges Studio, and this was the Special Projects winner. Architainment supplied Philips Color Kinetics eW Flex SLX fittings with 15 node strings, each string containing 50 individually-controllable warm-white LED nodes. The glass wall features shadow figures walking back and forth along the platform in response to the motion and location of trains. One judge described it as "just the best dynamic light artwork I have seen."

6. Rubbie from Louis Poulsen Lighting, a rubber bollard that doubles as a seat, was the winner in the Product Innovation: External Luminaires category. The judges described it as "a superb and unique use of new materials" and "sexy, tactile and fun while being durable enough to survive all urban environments, and future-proofed with interchangeable LED components." The source is a 19W LED array at 3000K or 18W at 4000K, and the clear polycarbonate diffuser provides optimized glare-free vertical distribution.

4

Courtesy: Lukas Roth



Courtesy: James Medcraft

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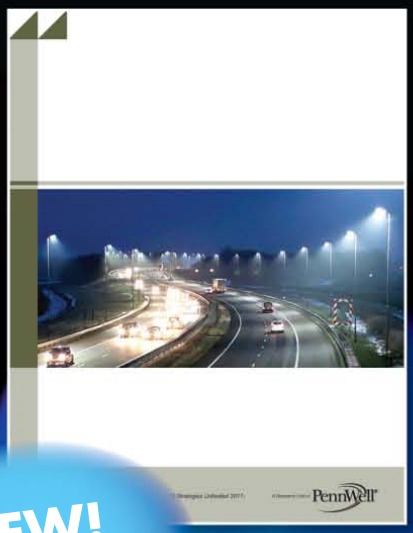
Where do we go from here?



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Compatibility Part 5: Who shares the responsibility for compatibility and reliability testing?

Part 5 of **PHILIP KEEBLER'S** series on compatibility explains that LED lighting manufacturers share responsibility for implementing robust products that can withstand disturbances and work in a compatible manner with the nuances of the power grid.

Responsibility for compatibility and reliability testing shares a three-legged stool. Utilities, end users, and manufacturers share the responsibility. Fig. 1 shows the relationship between the location of the disturbance, the number of disturbances and people affected and their respective area of responsibility.

Utilities were the first to realize that they are responsible for the disturbances that occur on their power systems – transmission and distribution. Many events affect the operation of the power system – vehicle accidents, contractors digging holes, and thunderstorms to name a few. Even though the utility did nothing to cause these events, their customers still end up experiencing some type of voltage problem that might only have caused their lights to blink or might have caused an over-voltage condition that burned up many electronic ballasts or other electronic loads.

Utilities are constantly making efforts to improve the quality of power they deliver to their customers. Industry can salute the utilities for also being the first to question the design and performance of end-use equipment. Utilities engaged EPRI researchers to further investigate why many types of equipment reacted to common everyday electrical disturbances that occurred on their systems. Utilities wanted to know what these disturbances looked like, how they were generated, and what they could do on their systems to reduce their severity and occurrence. EPRI, along with other industry players, was instrumental in developing equipment to monitor voltage, current, and power quality so disturbances could be studied, identified, and defined.

Fig. 1 also shows how end users (and facility engineers) fit into the mix of shared responsibility. This group is responsible for the electrical systems attached to and inside their buildings. This includes part of the service entrance (main panel system) and all of the wiring and grounding systems inside a building. Architects and engineers design buildings based on codes and regulations and good building design centered around well-established engineering principles for building design and construction. Engineers are just becoming familiar with power quality and how to improve the electrical designs inside buildings to minimize the impact that a disturbance will have on a piece of end-use equipment inside the building.

The third group that shares responsibility comprises the manufactures and designers of end-use equipment including appliances and other electronic devices such as LED lighting products. While disturbances actually affect buildings and the equipment inside them, the disturbances that occur are not limited to one or two types. Voltage sags and surges are only two of the most widely occurring disturbances that can affect the operation of essentially all electronic loads, however they are very threatening to LED lighting products. Other disturbances like voltage distortion and notching can cause sudden failure of LED drivers.

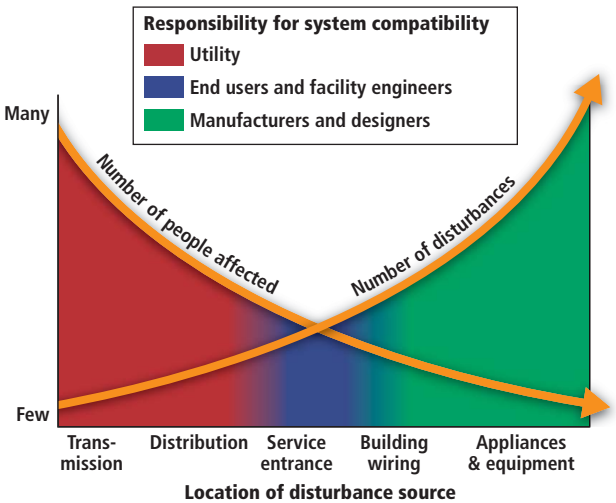

FIG. 1. Responsibility for system compatibility is shared among utilities, end users, and manufacturers.

Manufacturers are responsible for the design and performance of products. Not all manufacturers are in complete control of product design. Those that are not should certainly be involved in the process. While the cost of adding performance to a design depends upon what types of components are

PHILIP KEEBLER *is a Senior Researcher with EPRI Lighting Laboratory in Knoxville, Tennessee. EPRI (www.epri.com) is an independent, non-profit company that provides engineering research, development and testing for the electrical utility industry.*

added and their cost, many performance-enhancing measures are very economical to add. What manufacturers might not know is that the costs of adding capabilities to a design to overcome a compatibility, reliability, or power-quality problem are usually very inexpensive.

For example, in the case of immunity to voltage sags, the cost of improving the response of the product to the sag by adding a component to the control system is typically much less than five cents. In another case, a lighting product that has no protection against voltage surges will need that protection for the typical electrical environment. This protection can be harnessed at a higher cost around tens of cents.

In any event, the time and materials invested in ensuring some level of protection against failure from electrical disturbances will pay for themselves in fairly short order. The investment in this measure will be recouped the instant that the first destructive disturbance hits a building full of LED lighting products.

Impact of ignoring compatibility

Manufacturers do not always realize the impact of not considering compatibility and reliability for their LED products. Many manufacturers of LED products are new to the LED industry. Even the larger manufacturers of LED products have not come full circle with their products. Essentially all manufacturers lack the appropriate amount of field data to learn what they need to know about how their products perform in real electrical environments. It is worthwhile to shed some light on how LED products and the industry may be impacted if compatibility and reliability are not considered during the product design cycle.

Inability to document full performance: Performance of LED products under real-world electrical conditions is vital to document full performance. LED product performance cannot be fully addressed by only considering industry-standardized performance such as safety. Again, customers should not have to sacrifice expected performance for untested products at their field sites. Product failures should occur in development and testing labs. Full product performance should be based on controlled test environments in labs capable of reproducing actual field conditions. The EPRI Lighting Laboratory is an example of a lab fully equipped to apply real-world electrical conditions to LED products and accurately measure the response. In many cases, the application of certain disturbances will cause abnormalities in the light that manufacturers had never seen before nor could explain. Placing new products in the field should only verify enhanced performance identified in the lab. In other words, performance problems identified in the lab should be corrected in the lab and then monitored very closely in controlled field installations. Failures should be permissible in these installations.

Risk of high warranty claims: Manufacturers of early electronic fluorescent lighting products know what it means to have high warranty claims. Product failures traced back to immunity to electrical disturbances that was too low have been the cause of many high warranty claims. While small companies who design and manufacture LED products simply cannot endure the high costs of these claims, it can also be a struggle for large companies as well. It is much more difficult to aim at lowering risks after a new product has been launched than it is to manage the risk of failure during a product design cycle. One key area in managing the risk of high warranty claims is to determine compatibility and reliability performance of new LED products before they are released for market.

Lack of product data for warranty planning: Product warranties are not just pieces of paper with fancy gold borders. They are meant to be statements of promise from manufacturers defining how long a product should perform in an expected manner during its early life. Warranties are meant to guarantee product replacement should something minor occur during the manufacturing process or during shipping that could cause a product to fail early. Product warranties are not meant to be finance avenues for replacing products that have not been fully tested and performance-proven. Quite a few manufacturers have exhausted their warranty budgets before the end of the first product year by having to replace products that failed early because of some compatibility or reliability problem that was "overlooked." Manufacturers who plan their warranties carefully and use all sources of product performance data will be successful in not only developing satisfied customers of new products but also in keeping those customers for future higher-performance products.

Knowledge of performance at the component level: One of the interesting results of compatibility and performance testing involves performance even at the component level. This testing not only identifies the performance of a product at the system level, but can also expose component-level problems that might otherwise go undetected. EPRI research and testing has identified problems with power electronic devices and modules that only the application of certain electrical disturbances could identify. Total performance is vital to the success of a product at the system level as well as at the component level.

Missed opportunity to provide informative product datasheets: Potential customers and building designers pay close attention to what manufacturers place on product datasheets. Still today not enough performance data is included on datasheets. Several manufacturers of electronic lighting products now include compatibility-, reliability-, and power-quality-related data on their datasheets. It is not necessary to include an exhaustive set of performance data on these sheets but the right type of data that can help potential customers realize the benefit of using an electronic lighitng product over a traditional inefficient product.

In summary, manufacturers of LED lighting products should carefully consider the value of investing in compatibility, reliability, and power quality testing in efforts to identify all underlying product problems before products are launched into markets. Engaging in this process is by far a much smaller investment than the costs of having to develop a plan to address failures, redesign products, repeat testing, replace failed products, and go through a second product rollout trying to convince disappointed customers and new ones that the problems have now been addressed after the fact.

LINKS

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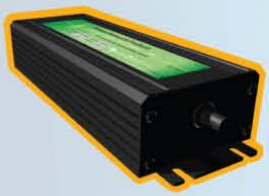

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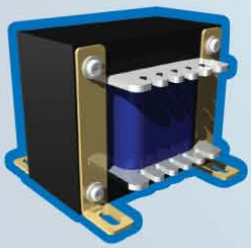

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Designing reliable LED power supplies requires careful attention to detail

The use of quality components, proper component derating and tightly-controlled manufacturing processes all contribute to the design of LED power supplies for long life and high reliability, explains **DAVID COOPER**.

HB-LEDs offer an extremely long lifetime compared to other forms of lighting, with typical ratings of 50,000 hours or longer. This makes HB-LEDs very attractive for applications where maintenance is difficult and expensive, such as street lighting, tunnel lighting, high-bay lighting and outdoor signs. One key difference between LED lighting and most previous technologies is the need to drive the HB-LEDs from a well-controlled, low-voltage DC current source. To fully realize the potential of the LEDs, this power supply must be designed to have very high reliability and long life, ideally greater than that of the LEDs themselves.

The LED power supply is an extremely complex assembly. It contains 200 to 300 components that utilize many different technologies and come from multiple suppliers. One power supply may typically drive 50 LEDs, which means that 80-85% of the electronic components in a luminaire are inside the power supply. Many luminaire failures are caused by a power-supply failure, and power-supply manufacturers have to work doubly hard to meet the reliability expectations.

Adding to the complexity, the power-supply assembly involves a number of very different manufacturing processes. Reflow soldering is used for the SMD components, and wave soldering (or even hand soldering) is used for through-hole components, followed by attachment of heatsinks, assembly into the housing and potting of the final product. Some of these steps involve manual procedures which are inherently more error-prone and have more variability than fully-automated processes. With this degree of complexity there is inevitably a risk of weaknesses in design, components or assembly, and extreme vigilance is necessary to achieve and maintain high reliability.

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In contrast, LED manufacturing is fully automated and very tightly controlled, and the assembly of LEDs into a light engine is also a single well-controlled process. All the LEDs in a luminaire typically come from one supplier, so that they behave very predictably, and they are driven with well-regulated DC current. Provided the LEDs are used within their specifications, there is every reason to expect they will meet their normal lifetime without unforeseen reliability issues.

MTBF is not the whole story

Almost every power-supply datasheet includes a reliability number, given as "mean time between failures (MTBF) = XXX hours." It is tempting to simply assume that the power-supply unit (PSU) with the higher number must be better, but this is far from the reality. Firstly, MTBF values can only be compared when calculated in the same manner, and at the same ambient temperature. Secondly, calculated MTBF does not take into account many of the factors which determine real-world reliability, such as PCB material and layout, weaknesses in design and test, or quality and consistency of the manufacturing process.

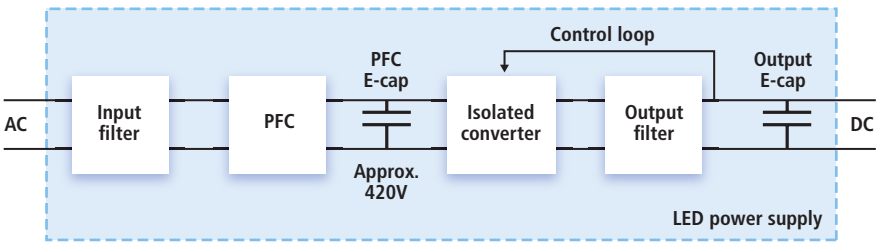

FIG. 1. Electrolytic capacitors (E-caps) are used in almost all AC-input power supplies, where they have two main purposes, namely in the PFC circuit and in the output filter.

At best, the MTBF prediction gives a rough indication of the expected failure rate, and the real reliability is largely determined by the integrity of the design and manufacture.

Designing for reliability

Designing a product to achieve high reliability involves all aspects of the design, from the initial specification and design calculations right through to the final assembly and test procedures.

A formal design-process document

defines all the steps that must be followed during the development of a new product and acts as a "corporate memory" of best practices. It provides a disciplined structure to guide the design team through the various stages and includes design reviews at key points in the development. In this way, all product designs benefit from being properly analyzed and reviewed before being released for production.

Component derating: To ensure reliable operation and long life, actual stress levels must be below the manufacturer's maximum ratings, a procedure known as derating. During the design the expected stresses on components are determined based on calculations and simulations. Stress levels must also be measured at the prototype stage to confirm the calculations under all conditions, including extremes of the specification, start-up transients and high/low temperatures.

Careful application of component derating is one of the most important aspects of design for high reliability. It is not sufficient to apply load derating of the overall power supply as is sometimes suggested. Derating the load to 75% or 50% of the power-supply rating will reduce the internal temperature increase, but it will have little or no effect on the voltage stresses applied to internal components.

Of course there is a cost associated with derating, both in increased design time and in the need to use components with higher ratings. For a critical application such as LED lighting, these added costs are well justified.

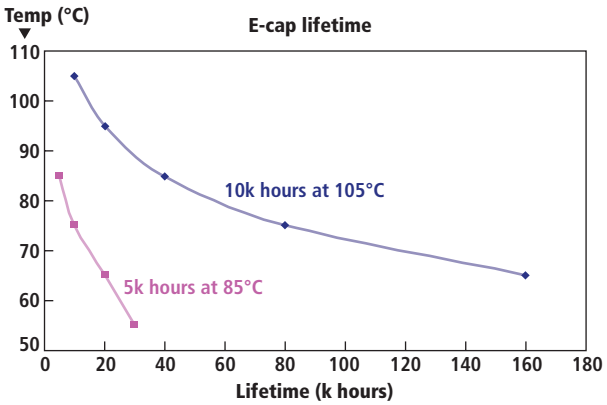

FIG. 2. Lifetime of electrolytic capacitor (E-caps) vs. operating temperature. The higher-quality E-cap rated for 10k hours at 105°C will have a lifetime of around 13 years at 70°C, while the other E-cap will have a life of less than 2 years at 70°C.

Component qualification: All components and materials must be fully qualified before being used in the design, preferably with two or more sources for each part. All vendors must be qualified to ensure they have their own standards, processes and controls that can deliver a consistent, high-quality product.

PCB material and layout: The PCB is one of the most important components in the power supply, and normally a high-quality multi-layer fiberglass material (FR4) is used. A single-sided PCB can lead to solder failures with through-hole components, especially under shock and vibration, because there is no copper plating inside the holes. This is particularly true for large, heavy components such as transformers and electrolytic capacitors. For high-reliability LED power supplies, a two-layer FR4 PCB should be considered the minimum acceptable option.

PCB layout and routing are also critical for reliability. A precise pad pattern and solder mask are essential to achieve reliable soldering of SMT components. If the spacing between traces or pads is not sufficient there is a possibility of voltage breakdown, especially if the PCB is under-etched or there is contamination or excessive solder during assembly. There is often a temptation to reduce the overall size of the power supply by packing components more tightly together, but compromises at this stage are likely to prove costly in terms of reduced manufacturing yield and increased failure rate.

Thermal analysis and measurement: The temperature of all components must be

below the manufacturer's rating under worst-case conditions, with sufficient margin. Thermal analysis software can be used during the early phases of the design to predict temperature rise before any prototypes are built.

Once the first prototypes are available, component temperatures must be checked under the full range of input voltage and load using thermocouples on key components. Many LED power supplies use potting, which significantly affects the thermal performance. On the one hand, most potting compounds have good thermal conductivity and reduce internal hot-spot temperatures. On the other hand, the temperature of passive components such as capacitors can be increased because the heat is spread more uniformly within the power supply. Potting must therefore be properly factored into the thermal design, simulation and test.

AC surge protection: The AC input of a power supply is exposed to the outside world, and any voltage spikes on the power lines are directly coupled into the input components. The EMI filter provides some protection, but additional protection is needed for higher-energy spikes and transients. In demanding applications a multi-stage design is necessary, where a primary protection device absorbs most of the energy and secondary protection devices clamp the residual energy to a safe level. For outdoor LED lighting, an effective approach can be to mount the primary protection device inside the luminaire across the AC input, with the secondary protection components inside the power supply.

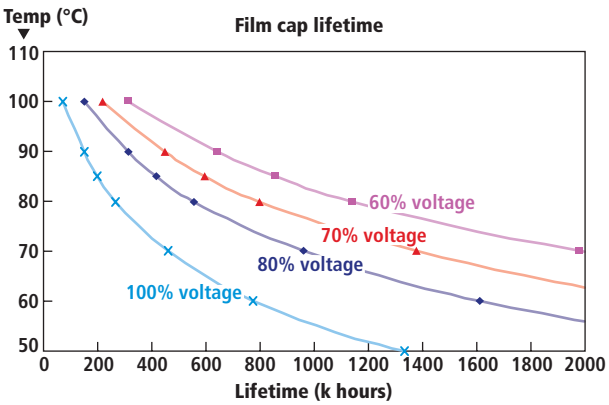

FIG. 3. Lifetime of polypropylene film cap vs. temperature.

High temperature, long life E-caps: Electrolytic capacitors (E-caps) are used in almost all AC-input power supplies, for two main purposes. One E-cap is used in the power-factor correction (PFC) circuit to store energy during the low portion of the AC input cycle. A second E-cap is used in the output filter of the PSU (see Fig. 1). Both of these caps are critical for PSU operation, and a failure of either of them will result in a failure of the PSU.

E-caps are available in a number of grades with different ratings for lifetime and temperature. It is possible to design for long life using high-grade E-caps and good thermal management. Lower-grade capacitors are cheaper but will not meet the lifetime needed for LED lighting. The operating temperature of the E-cap depends on many factors including the PSU power rating and efficiency, ripple current, internal layout and packaging. Assuming a temperature of about 70°C at the E-cap (35°C rise above ambient), we can expect a life of about 13 years (see Fig. 2) for a high-quality component rated for 10,000 hours at 105°C. However, a lower-quality E-cap rated for 5,000 hours at 85°C will have a life of less than 2 years.

The ultimate solution to the problem of E-cap wear-out is to avoid using them altogether. A power supply developed by AEG has the same functionality as shown in Fig.1, but the E-caps are replaced by polypropylene film capacitors, which do not have a recognized short-term wear-out mechanism. As shown in Fig. 3, the expected life of the film capacitors at 70% voltage stress is almost 160 years at 70°C, or about 12× that of the high quality E-caps. In practical terms, the life is effectively unlimited.

Ingress protection techniques: AEG uses three techniques for protection: conformal coating; watertight housing; and potting. Each of these offers advantages and disadvantages and it is important to choose the best solution for a given application. Conformal coating provides excellent protection against humidity and dust, and is a low-cost solution for outdoor applications where the luminaire offers good protection

FIG. 4. Power-supply unit in a water-tight housing.

against water. It also does not significantly increase the weight of the PSU. However, it is not adequate to protect against wet environments or direct water splashing.

Another form of protection is the use of a water-tight housing. For LED power supplies, this is typically an aluminum extrusion in the form of a rectangular tube, with flat end plates. The end plates are sealed using rubber gaskets, with sealing glands for the input and output cables as shown in Fig. 4. With good control of design and manufacturing, this type of housing can fully meet the IP67 rating.

A similar type of enclosure is often used together with potting to meet IP67 without the need for sealing glands. Potting is a complex process that can directly affect reliability. Some potting materials are hard and can cause mechanical damage to components, such as cracking of ceramic capacitors and ferrite transformer cores or weakening of solder joints. Thermal expansion and contraction can cause similar damage during long-term operation, particularly in outdoor applications where there can be a very large daily temperature cycle. There can also be chemical interaction with materials used for component packages leading to early component failure. Any residual contamination on the PCB is trapped by the potting material and can result in corrosion and premature failure, and voids within the potting material can cause problems with insulation breakdown. Because of these potential issues it is important to select the right potting material for the application, to do adequate qualification testing, and to have a tight control of the manufacturing processes.

Design verification testing

Design verification testing (DVT) is a key step in the design process and must be carried out by someone other than the designer to provide an independent, objective assessment. The more carefully and completely these tests are carried out the less likely that a design weakness will cause reliability problems.

The Highly Accelerated Life Test (HALT) uses a combination of stresses to expose any weaknesses in the design. Temperature cycling and vibration tend to show up mechanical issues such as poor assembly, low-quality solder joints or inadequate mounting of heavy components on the PCB. Input-voltage variation, rapid power on-off cycling and load cycling are more likely to show up electrical design weaknesses. This type of testing can rapidly reveal potential problems in a design and allow design improvements to be made at the prototype stage, avoiding potential reliability problems in the field.

Conclusion

Considering that the power supply may have 200 or more components to power 50 or fewer HB-LEDs, it should be no surprise that power-supply failures can easily become dominant. As a luminaire designer it is tempting to consider the power supply as a single component, but this is an over-simplification that can have disastrous results in field failures and customer dissatisfaction.

Designing power supplies for long life and high reliability requires careful attention to detail throughout the design process, use of quality components and proper component derating together with consistent, tightly-controlled manufacturing processes.

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last word

An epic year for the LED industry?

2011 could be a watershed year in the maturation of the LED industry, and intellectual property and new private companies will play a key role, says **DENNIS COSTELLO**, Managing Partner of **BRAEMAR ENERGY VENTURES**.

Spring looks like it is finally breaking through here in Boston after an epic season of snow. But is 2011 going to be an epic year for the LED industry as well? Will 2011 be a breakout year not only in sales but also in mergers, acquisitions and initial public offerings (IPOs)?

At least three major factors are lining up on the positive side of that answer. They are rapid LED sales expansion; the crucial role of patents and intellectual property (IP) in the LED industry; and the rapid growth of private companies in the sector. Let's examine each of these in a bit more detail.

LEDs are moving rapidly into many subsectors that comprise the nebulous term of "general lighting." Lower prices, higher brightness, improved efficiency and better designs are all combining to create an inflection point in sales growth. Penetration of LEDs in street lighting, refrigeration lighting, museum lighting, high-bay lighting and commercial/retail lighting (to name a few) will certainly show strong growth in 2011. And that growth will continue well beyond 2011. But 2011 could well be the year that public investors and public stock markets appreciate the full dimensions of the shift to LEDs.

That is indeed good news for the larger public companies that have already staked a claim in the LED space. Executives at companies like Philips, Siemens and GE, although always wary about forward-looking statements, seem quite optimistic.

There is also a great deal of cash on the balance sheets of these and similar large companies.

If one looks a bit more broadly and includes major global consumer-electronics and semiconductor companies who are just entering LED markets – or are likely to enter soon – one finds a lot more cash. This cash can be used for acquisitions of smaller or private companies for revenue, and for access to new customers, technology or IP.

Let's consider IP for a moment. The LED industry, more than any other lighting segment, is supported by a maze of patents, and there is a history of both cross licensing and litigation. IP has played a significant role in shaping the industry as we see it today. Chinese officials, for example, have been clear in stating that they want China to be a major player in the global LED industry. To accomplish that goal, they need (among other things) access to the patents that will allow them to sell around the world. One of China's explicit goals in its next 5-year plan is to acquire or create IP to allow that expansion. Major companies around the world may be less outspoken, but they share similar goals. IP is one of the keys needed to enter and expand in the LED market.

Private companies

Perhaps the most impressive indicator of an epic 2011 is all of those growing private companies that are entering the fray. Literally hundreds of small and developing companies fill the expo floors at each lighting tradeshow around the world.

Many of the private LED companies are growing at impressive rates, often with sales more than doubling year-over-year since 2009. Several of these companies will have 2011 revenues at or near $100 million. And there is a second wave of companies approaching the $50 million annual-revenue mark right on their heels. Some LED companies have completed successful IPOs on NASDAQ, which is inspiring others. There are at least a couple of other private companies giving serious consideration to IPOs later this year.

As more LED companies arrive on the public markets, investors take more notice of the sector. There are already several investment banks that have significant expertise in LED lighting (both analyst and investment-banking teams), with others trying to catch up.

Investment banks are another key part of the LED infrastructure needed to create an active public market in LED companies. Active public markets and robust merger and acquisition activity in LEDs will create value and wealth for all those who participate. More wealth leads to more investments in technology, manufacturing and sales efforts. The result is continued expansion of the LED industry, reduced cost, and better solutions for all the niches of general lighting. That is not only good for our industry but good for our environment and our planet.

DENNIS COSTELLO *is the author of "Venturing into LEDs: An overview of venture capital and its investment in lighting" - see www.ledsmagazine.com/features/7/9/3.*

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