APRIL 2010

LEDs MAGAZINE®

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TECHNOLOGY AND APPLICATIONS OF LIGHT EMITTING DIODES

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Entering a new era of growth P.23

SIL 2010
LED lighting under the microscope P.39

Thermal
Replacement lamps and modules P.53

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ISSUE 34

april 2010

Cover Image

Dialight has installed its DuroSite LED high-bay lighting at the Frontline manufacturing facility — see www.ledsmagazine.com/press/21512.

features

columns/departments

commentary

LEDs top of the bill at Light+Building

Volcanic ash affected the return journeys of many visitors to Light+Building in Frankfurt, but at the show itself the talk was all about the seismic changes happening in the lighting industry. OK, enough geology. No-one was really surprised to see LEDs everywhere at Light+Building, prompting several people to suggest the show should be renamed "LED+Building." Apart from this being an awful name, it's also inappropriate considering that, on many stands, other technologies still sit quite happily alongside LED versions of fixtures. GE was a good example of a company spreading its investment across the board, while Philips was keen to demonstrate its all-out dedication to the LED cause. Opinions vary on the merits of these two strategies. Somewhere in the middle was Osram, with its theme of "sustainable products – choice for customers" that allowed the company to showcase halogen and CFL technologies alongside its focus on LEDs and OLEDs.

In the past several iterations of Light+Building, which is held every two years, the status of LED technology has increased significantly. RGB color-changing LED fixtures were fairly common six years ago, with much variation in quality, while white-light LED illumination was hard to find. Exhibition stands lit with prototype LED fixtures were a novelty, while now they're fairly commonplace, and often use real products rather than something knocked together the week before. Often it's difficult to know that you are in an LED-lit booth; partly because the quality of the LED light is much improved, and partly because many designs don't simply use an LED array, so it's not obvious that LEDs are the light source.

Many lighting companies have moved past the discussion phase with LEDs, and are building very high quality fixtures for illumination that demonstrate a fundamental understanding of crucial factors such as optical and thermal design. Of course, there is still quite a bit of knocked-together rubbish around as well, but hopefully these companies will get their acts together soon.

Given the recent spate of announcements, it was no surprise to see lots of focus on LED modules and light engines as essential building blocks for luminaires moving forward. And of course many people showed LED replacements lamps in a huge range of styles. Some of the different approaches are discussed in our article beginning on page 53. More surprising was the number of companies demonstrating OLEDs, although this technology clearly has a long way to go as it attempts to stake a claim within the lighting industry.

And then of course there was the presence of consumer-electronics companies. Panasonic, Sharp, Toshiba, Verbatim and LG are all high-profile consumer brands that are trying to position themselves to benefit from the switch to LEDs and the projected growth in the replacement-lamp market (see page 9). Samsung was a notable absentee, but is likely to have an influential role going forward, given its vast consumption of LEDs for TV backlights. This doesn't guarantee success, but it can't hurt to have that kind of experience, backed by a major brand. It will be very interesting to see the size of everyone's tradeshow booths at the next Light+Building, in two years' time.

Tim Whitaker, EDITOR
twhitaker@pennwell.com

LEDs MAGAZINE®

SENIOR VICE PRESIDENT & PUBLISHING DIRECTOR Christine Shaw
cshaw@pennwell.com
EDITOR Tim Whitaker
twhitaker@pennwell.com
Tel. +44(0)117 946 7262
SENIOR TECHNICAL EDITOR Maury Wright
maurywright@gmail.com
CONTRIBUTING EDITOR Brian Owen
MARKETING MANAGER Luba Hrynyk
PRESENTATION MANAGER Kelli Mylchreest
PRODUCTION DIRECTOR Mari Rodriguez
SENIOR ILLUSTRATOR Christopher Hipp
AUDIENCE DEVELOPMENT Debbie Bouley

PennWell®

EDITORIAL OFFICES PennWell Corporation, LEDs Magazine
Corporate Offices
98 Spit Brook Road, LL-1
Nashua, NH 03062-5737
Tel: +1 603 891-0123
Fax: +1 603 891-0574
www.ledsmagazine.com

SALES OFFICES
SALES MANAGER (USA) Mary Donnelly
maryd@pennwell.com
Tel. +1 603 891 9398
SALES MANAGER (EUROPE) Joanna Hook
joannah@pennwell.com
Tel. +44(0)117 946 7262
SALES MANAGER (JAPAN) Manami Konishi
manami@ics-inc.co.jp
Tel: +81 3 3219 3641
SALES MANAGER (CHINA & HONG KONG) Mark Mak
markm@actintl.com.hk
Tel: +852 2838 6298
SALES MANAGER (TAIWAN) Monica Liu
monica@arco.com.tw
Tel: +886 2 2396 5128

CORPORATE OFFICERS
CHAIRMAN Frank T. Lauinger
PRESIDENT AND CEO Robert F. Biolchini
CHIEF FINANCIAL OFFICER Mark C. Wilmoth

TECHNOLOGY GROUP
SENIOR VICE PRESIDENT & PUBLISHING DIRECTOR Christine A. Shaw
SENOIR VP OF AUDIENCE DEVELOPMENT Gloria S. Adams

SUBSCRIPTIONS: For subscription inquiries:
Tel: +1 847 559-7330;
Fax: +1 847 291-4816;
e-mail: led@omeda.com;
ledsmagazine.com/subscribe

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Webcasts

The Future of LED Control

DATE: May 27, 2010

PRESENTERS: Amanda Beebe, Lutron
Russ MacAdam, Lutron

LED Lighting Testing: HAZLOC & EMC Certification

ORIGINALLY BROADCAST: March 30, 2010

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

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

Web Exclusive Articles

COMPANY PROFILE: Foxsemicon Integrated Technology Incorporated
www.ledsmagazine.com/features/7/1/1

COMPANY PROFILE: Neo-Neon LED Lighting International Ltd.
www.ledsmagazine.com/features/7/3/1

Featured Companies

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

Neo-Neon LED Lighting International Ltd • Shenzhen Refond Optoelectronics • Fobsun Electronics Ltd • ProLight Opto Technology Corp • Signcomplex Ltd • TEAM Instruments Co. Ltd • Optocore Ltd

ADVERTISERS *index*

FEATURED *event*

Strategies in Light Europe 2010

September 27-29, 2010
Frankfurt, Germany
This new European event will address current LED & lighting industry issues and provide a forum for debate, bringing together key industry players and decision makers.
MORE: www.SILeurope.com

Lightfair 2010
May 12-14, 2010
Las Vegas, NV, United States

ISSLED2010
May 16-21, 2010
Beijing, China

Lighting Africa conference
May 18-20, 2010
Nairobi, Kenya

LED Lighting 2010
May 21, 2010
Naples, Italy

Int'l Conference on MOVPE
May 23-28, 2010
Lake Tahoe, NV, United States

SID Display Week 2010
May 23-28, 2010
Seattle, WA, United States

LOPE-C
May 31-June 02, 2010
Frankfurt, Germany

Projection Summit 2010
June 07-08, 2010
Las Vegas, NV, United States

euroLED 2010
June 09-10, 2010
Ricoh Arena, Coventry, UK

LED Lighting Taiwan
June 09-11, 2010
Taipei, Taiwan

LED Expo and OLED Expo 2010
June 22-25, 2010
Kintex, South Korea

MORE: www.ledsmagazine.com/events

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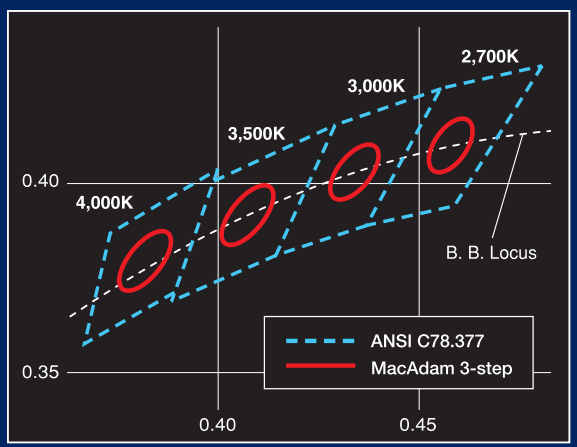
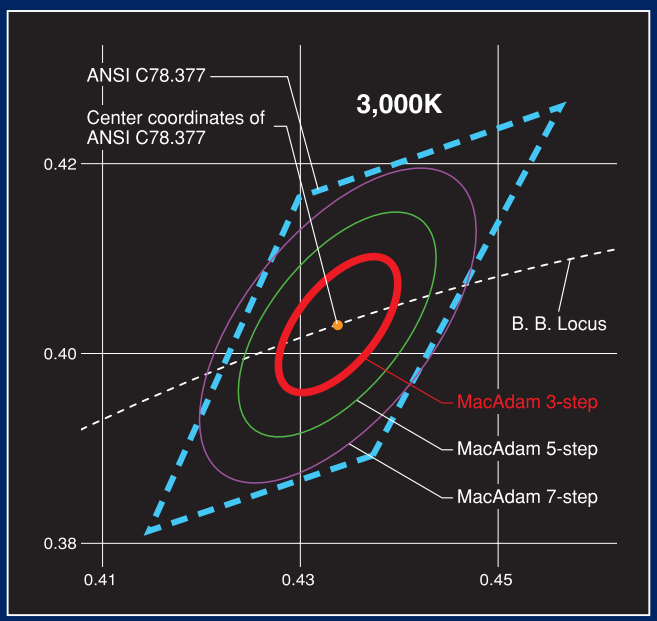
Compliance with ANSI C78.377 in 2009 ⇒ MacAdam 3-step in April, 2010

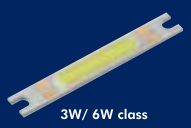
Narrower Chromaticity Range (2,700K~4,000K)





●Applicable packages

CL-L103 Series



3W/ 6W class

50.0 (L) ×7.0 (W) ×1.35 (H) mm

CL-L251 Series

4W/ 6W class

13.5 (L) ×13.0 (W) ×1.35 (H) mm

CL-L233 Series

13W class

23.0 (L) ×17.5 (W) ×1.4 (H) mm

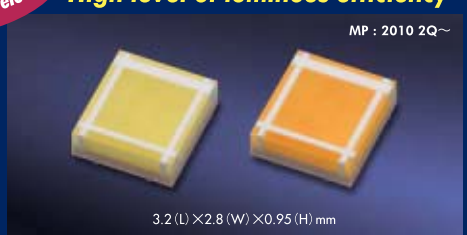
Citizen Electronics efforts:

Chromaticity control of CITILED has been shifted from Sorting after production to Elaboration in production. CITILED (2,700K~4,000K) provides MacAdam 3-step based on continuous technology improvement.

Visit us at
Light+Building 2010 in Frankfurt
April 11-16／Citizen booth : Hall 4.2, booth No. J81

Visit us at
LFI 2010 in Las Vegas
May 12-14／Citizen booth : 859

NEW release **High level of luminous efficiency**



CL-L270 Series (0.2W class)

IF:60mA 3,000K (Ra85) : 16.7 lm・ 83.1 lm/W
5,000K (Ra68) : 20.5 lm・102.0 lm/W

▶ Please contact us for samples!

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Distributors

Italy : Velco S.p.a. velco s.p.a.
Contact person : Paola Tonel Tel : +39-0444-922-922 E-mail : info@velco-electronic.com

Germany / Austria / Swizerland : Endrich Bauelemente Vertriebs GmbH endrich
Contact person : Albrecht Lohrer Tel : +49-7452-600756 E-mail : a.lohrer@endrich.com

England : Marl International Ltd. (Optosource) MARL
Contact person : Clare Millard Tel : +44-1229-582430 E-mail : clare.millard@optosource.com

France : Eurocomposant Eurocomposant
Contact person : Patrick Fichot Tel : +33-1-30-64-2602 E-mail : pfichot@eurocomposant.fr

Spain : Antonio Lopez Garrido, S.A.
Contact person : Jose Luis Garrote Tel : +34-96-192-06-34
E-mail : ventas@algsa.es (for sales) ／laboratorio@algsa.es (for technical assistance)

Scandinavia / Baltic states / Russia : Arrant-Light Oy www.light.fi
Contact person : Janne Makinen Tel : +358-2-2462-300 E-mail : janne.makinen@light.fi

Belgium / Netherlands / Luxembourg : Elincom Electronics B. V. elincom electronics
Contact person : Michiel Wubs Tel : +31-10-264-0270 E-mail : m.wubs@elincom.nl

Turkey : empa electronics empa::::electronics
Contact person : Volkan Akbiyik Tel : +90-212-465-71-99 E-mail : citiled@empa.com

Contact

Europe	Tel : +49-69-2992-4810
North America	Tel : +1-847-619-6700
Japan	Tel : +81-3-3493-2744
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EdiLine III Series New!

With the standard linear packaged selections of 1W and 3.5W EdiLine III series, Edison Opto recently announces a new module selection for EdiLine III arrays.

EdiLine III array is factory-mounted with Pb-free reflow soldering on MCPCB. With the MCPCB and provided M2 screw sockets, the EdiLine array is easy to be mounted and applied in a variety of fixture or design applications.

The new EdiLine arrays are available in single, double and triple types. Each type can be driven with common LED drivers having constant current output at 350mA, 700mA, 1,050mA.

Part No.	ELBx-1SC0	ELBx-2SC0	ELBx-3SC0	ELBx-3SB0
Picture				
Power	1W	2W	3W	3.5W
Dimension(mm)	42.0(L)x10.0(W)x2.10(T)	42.0(L)x15.0(W)x2.10(T)	42.0(L)x19.2(W)x2.10(T)	89.6(L)x12.0(W)x2.10(T)
Forward Current(I_F)	350mA	700mA	1,050mA	350mA
Forward Voltage(V_F)	3.4	3.4	3.4	10.2
Flux(lm@6,000K)	100	200	300	330
Flux(lm@4,000K)	80	160	240	260
Flux(lm@3,000K)	70	140	210	230

www.edison-opto.com.tw service@edison-opto.com.tw
T+ 886 2 82276996 F+ 886 2 82276993 4F, No.800, Chung-Cheng Rd., Chung-Ho City, Taipei 23586 Taiwan

news views

LIGHTING

Zumtobel guarantees luminaires, adds LED lamp business

Austria-based Zumtobel claims to be the first luminaire manufacturer worldwide to provide a five-year guarantee for its complete product range. The guarantee covers Zumtobel's entire luminaire portfolio including ballasts and control gear – and LEDs in the case of LED-based luminaires. Martin Brandt, COO of Zumtobel AG, explains: "Thanks to Zumtobel's superior design standards, we are the preferred partner for long-lasting lighting solutions that are not influenced by short-lived trends. By extending our product guarantee to five years, we emphasise on our long-term thinking to the benefit of our customers." Zumtobel says that the focus of LED development is increasingly shifting to quality and service life. Although LEDs potentially offer a service life of up to 50,000 hours, this can only be achieved "if the LEDs are integrated into a technically-advanced luminaire with an efficient cooling system and sophisticated components," says the company (see www.ledsmagazine.com/news/7/3/20).

In other news, Zumtobel has entered the LED lamp business with the formation of Ledon Lamp GmbH (www.ledsmagazine.com/news/7/1/19), and has signed a development partnership agreement with the Dutch company Lemnis Lighting BV, which markets various LED retrofit lamps under its Pharox brand name (see www.ledsmagazine.com/press/20935). Based in Dornbirn, Austria, Ledon Lamp will sell a broad portfolio of retrofit LED lamps, using LED technology supplied by Ledon Lighting Jennersdorf GmbH.

Ledon already supplies LED arrays that are the light source inside Lemnis' lamps. Lemnis and Ledon plan to jointly develop a full-line of LED-based lamps for residential and professional use. The lamps, designed to replace not only conventional light bulbs but also halogen spots, are to be marketed by both companies under the Ledon and Pharox brands. Under the terms of the agreement, Zumtobel Group companies are also defined as a preferred supplier for Lemnis Lighting. ◄

MARKETS

SSL market to reach $14 billion by 2013

The solid-state lighting market (measured at the LED luminaire and LED replacement lamp level) was worth $2.85 billion in 2009, according to Vrinda Bhandarkar, Senior Market Research Analyst with Strategies Unlimited. Opening the LED Lighting track at the 2010 Strategies in Light conference (our full-length report begins on page 39), Bhandarkar explained that this represents 32% growth over the $2.1 billion reported in 2008. Architectural lighting was the biggest application sector in 2009 with a 29.1% share, followed by commercial/industrial at 18.8% and consumer portable at 13.8%. Replacement lamps accounted for around $200 million, or 7% of the total market, in 2009.

By 2013, however, replacement lamps will be far and away the largest sector, with a value in excess of $6 billion, said Bhandarkar. Commercial/industrial will be the second largest sector. The overall market will reach $14 billion, or nearly 5 times the total for 2009 (see chart. p.10). That means that the compound annual growth rate from 2009 to 2013 will be a spectacular 49%.

Reviewing SSL market trends, Bhandarkar pointed out that one of the reasons to employ LEDs is the "high potential" of the technology, while other technologies have reached a »page 10

LIGHTING

Toshiba cuts incandescent lamps, focuses on LEDs

Toshiba recently stopped production of general-use incandescent lamps, products which Toshiba was first to make in Japan and that the company has produced for 120 years. In 2008, Toshiba decided to focus on environmentally-friendly lighting, introducing new products such as LED lighting. By concentrating on LED products, Toshiba's new lighting system business aims to reach sales of 350 billion yen (about $3.9 billion) by FY2015. The end of general-use incandescent lamp production comes a year ahead of the original plan, and marks the end for a total of 103 products for the company, which manufactured some 20 million units in 2008. ◄

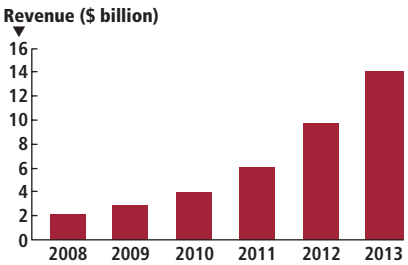
MORE: www.ledsmagazine.com/news/7/3/17

news+views

SSL Market from page 9

plateau. Also, laboratory results for LED packages are much higher than fixture efficiencies, indicating that further improvements will be seen, while the ability to integrate fixtures with controls will offer further energy-efficiency enhancements. However, economies of scale have yet to be realized, and mass-manufacturing efficiencies are to be expected at all levels from LED packages and other components to fixtures.

However, the SSL market faces many challenges, said Bhandarkar, among which are high initial price, reliability and quality issues, customer education, standards, recessionary pressures...the list goes on. The SSL market remains highly fragmented, encompassing many niche applications, of which architectural lighting is the largest. Hundreds of companies worldwide are participating in the market at the luminaire level; in fact Strategies Unlimited has identified 500 such companies, but there are many more. Volumes are small and costs are high, and products are highly variable in terms of quality.



Market outlook for solid-state lighting, showing revenue for LED-based luminaires and replacement lamps. Courtesy of Vrinda Bhandarkar, Strategies Unlimited.

However, many large lighting companies have identified LED as the next-generation lighting technology, and are investing in research and product development. Often, these companies outsource manufacturing to "low-cost geographies," said Bhandarkar. Others rely on outside consultants to design and develop prototypes. However, the industry also encompasses many small companies dedicated to SSL that have a high level of LED expertise. ◄

TEST & MEASUREMENT

Acquisitions mergers and reshuffles

Underwriters Laboratories Inc. (UL), an independent product safety certification organization based in Northbrook, Illinois, has acquired **Luminaire Testing Laboratory (LTL)**, based in Allentown, PA. LTL is an independent testing laboratory that provides performance testing of lamps and luminaires, and is one of five laboratories approved by the Department of Energy (DOE) for Energy Star qualification testing of LED lighting products. The acquisition gives UL the ability to offer bundled safety and performance testing capabilities to the lighting industry (see www.ledsmagazine.com/news/7/2/13).

Labsphere and **SphereOptics,** two companies that are well-known US-based suppliers of LED test and measurement equipment, will now operate as a single company based in North Sutton, NH. Labsphere president Kevin Chittim said that customers could look forward to "a broader and deeper range of products"

and that the company would be "a financially strong partner with a long-term strategy for growth" (see www.ledsmagazine.com/news/7/1/27).

Germany-based **Instrument Systems** extended its broad portfolio of LED and light measurement technologies by adding the **Optronik** product line from X-Rite in a recent acquisition. A new subsidiary, Optronik Berlin GmbH, will continue to serve testing and certification institutes, suppliers of automotive light products, and automobile manufacturers (see www.ledsmagazine.com/news/7/3/5).

Gooch and Housego has combined the former **Optronic Laboratories** and ChromoDynamics business units under the parent brand. The new organization will leverage Gooch and Housego's global engineering, operations, sales, distribution, and support channels. The US-based Optronic Laboratories business supplies LED measurement systems (see www.ledsmagazine.com/news/7/1/32). ◄

INTELLIGENT LIGHTING

Networked lighting builds energy savings

Three just-launched companies are targeting a networked approach to commercial lighting. Network control will add to the energy savings afforded by LEDs, via management of the lighting plant and dimming or shutting off lights automatically. Digital Lumens is targeting the industrial space, while Redwood Systems targets office space. Daintree Networks is focused purely on the enabling network and software technology.

Digital Lumens, a new entrant into the industrial-lighting segment, believes that the combination of LED fixtures, network control of each fixture, and lighting-management software can deliver major savings. Tom Pincince, president & CEO, states, "We can provide 100% of the light at 10% of the energy cost." The company will target applications such as high-bay lighting in warehouses. Pincince uses a cold-storage warehouse as an example, and says that only about 10% of such a facility is occupied at any given time, and lights in the remainder can be dimmed or even extinguished. Digital Lumens' initial product offering is an Intelligent Light Engine fixture (see photo) that integrates three removable LED-based light bars, a custom AC/DC power converter, a microprocessor, and a Zigbee wireless controller for network connections. The fixture is designed as a direct replacement for legacy AC-powered fixtures (see www.ledsmagazine.com/news/7/3/15).

Redwood Systems touts a network-centric approach to LED lighting in office environments. The company plans to deliver energy savings by consolidating the LED power source, distributing DC power and control signals to fixtures, and relying on efficient LED technology. VP of marketing Jeremy Stieg-

litz claims the technology-heavy approach can deliver a return on investment in two years for commercial spaces. The company claims its technology will deliver more than 90% of the input power to the LED. Referring to businesses, Stieglitz states, "Lighting is 20% to 40% of their energy load and they have no visibility into it." He claims that businesses want to cut energy cost and want better instrumentation in the lighting plant.

Given the founding team's heritage in the computer networking space, the system functions similarly to a computer network switch in a wiring closet. Installations will even link the central systems to lights via network cables in some cases. A single pair of wires will carry both the constant-current DC power needed to power a light and a proprietary power-line communication network. With a centralized power supply, a single PFC (power factor correction) front-end stage supplies a DC voltage to each light channel where dedicated DC/DC converters drive the lights. Stieglitz claims the centralized PFC stage offers an 8:1 advantage relative to having a PFC stage at each light (see www.ledsmagazine.com/news/7/3/7).

Daintree Networks is joining the quest to win business in the commercial lighting sector with a combination of wireless network technology and software, and has just won $8 million in venture funding from Lend Lease, a dedicated clean technology investor. Daintree believes its wireless technology will overcome the obstacles that are especially troublesome when it comes to retrofitting lighting in buildings. The company's approach will use the existing AC power infrastructure for power and wireless links for communications. It will rely on industry-standard Zigbee technology to implement wireless mesh networks between lighting fixtures. The products include connected light and occupancy sensors, and modular adapters that can be added to smart light fixtures. The company will augment the network technology with its Lighting Control Application software for commissioning and control (see www.ledsmagazine.com/news/7/3/25). ◄

LED MAKERS

Light engines and modules

A number of companies including Cree, Future Lighting and Osram have recently launched LED modules and light engines that are intended to enable luminaire manufacturers to significantly reduce the effort of developing new luminaires. The important thermal issues that need to be considered for both modules and replacement lamps are discussed in our article on pages 53-57.

Cree's LMR4 LED module integrates driver electronics, optics and primary thermal management, and delivers 700 lumens at a warm-white color temperature of 2700K with a CRI >90. It is designed to last 35,000 hours while consuming just 12 watts of power. Fixture manufacturers have the option to include a specially-designed heat sink to accommodate specific high-heat

news+views

ACQUISITIONS & FINANCING

TerraLUX

TerraLUX has announced a $5.6 million Series A financing round led by Emerald Technology Ventures with participation from existing investor Access Venture Partners. The new capital will be used to accelerate the company's growth in all segments of the business with a particular development focus on the rapidly expanding commercial general illumination products and LED modules.

MORE: www.ledsmagazine.com/press/21511

Lemnis Lighting

Pharox-brand LED lamp maker Lemnis Lighting has raised $35.7 million in series D financing. The equity funding, provided by a consortium of existing investors and new investors from Africa, will enable the company "to rapidly expand its portfolio of LED applications, accelerate international penetration of new markets and deploy innovative distribution models." Lemnis founder Warner Philips says the funding gives the company "a jump" on deploying products the markets are demanding. "We are now well positioned to meet the growing consumer demand for lighting that is energy-efficient and non-harmful to the environment," he said. "The jump from theoretical technology to products on your neighborhood hardware store shelves is upon us."

MORE: www.ledsmagazine.com/news/7/3/9

Barco

Barco has acquired the products, intellectual property rights and know-how of Element Labs, an LED video systems company based in Santa Clara, California. "This [deal] expands Barco's portfolio for the mid-range markets," said Eric Van Zele, Barco's president and CEO. "Element Labs' products in these markets…perfectly complement Barco's more high-end oriented market portfolio." Element Labs' products have been used in numerous concerts, events, corporate headquarters and flagship stores around the world. Barco said that the deal with help to accelerate the turnaround which is under way in its Video & Lighting activities, enabling the company to address a wider segment of the market, and leveraging its existing sales, marketing, and service capabilities.

MORE: www.ledsmagazine.com/news/7/3/18

Luminus Devices

LED maker Luminus Devices has closed a $19 million financing round led by existing investors including Argonaut Private Equity, Braemar Energy Ventures, Paladin Capital Group and Stata Venture Partners. The new funding will allow Luminus to expand product offerings and the breadth of target applications. Keith Ward, Luminus president and CEO, said "This financing has dramatically improved our balance sheet, simplified our equity structure, while better aligning investor objectives with management's market-focused strategy."

MORE: www.ledsmagazine.com/news/7/2/22

applications, like downlights for insulated ceilings (see www.ledsmagazine.com/news/7/4/4).

Osram has introduced PrevaLED Core, a range of LED light engines which are described as "an efficient and future-proof platform for LED illumination." The modules all have the same interfaces and dimensions (50mm diameter), and should help to reduce both development effort and time-to-market for luminaire developers. Options range from 800 lm to 3000 lm at a system efficiency of up to 75lm/W, with color temperatures of 3000K or 4000K. The light engines have CRI>90 and can be flexibly combined with various types of control gear, allowing the simple integration of additional functions such as dimming, if required (www.ledsmagazine.com/news/7/3/16).

Future Lighting Solutions has announced a line of light engines designed to accelerate the development, prototyping and delivery of SSL applications as well as reduce fixture development costs. The first light engines in the company's simpleLED program are available in 12 form factors and 600-plus customization options, all featuring ANSI-binned Luxeon Rebel LEDs integrated with key components. Twelve off-the-shelf configurations – available for immediate shipment – include linear, circular and square layouts with 1, 2, 3, 4, 6 or 9 white 3000K, 3500K or 4000K LEDs (see www.ledsmagazine.com/news/7/2/8). ◄

CHIP MANUFACTURING

Surge in LED demand prompts new fabs

The projected surge in LED demand is leading established players to expand their manufacturing capacity and newcomers to build their first LED chip fabs, as discussed in our last issue (LEDs Magazine, Jan/Feb 2010, p.23). As an established LED maker based in Boise, Idaho, SemiLEDs had previously disclosed plans (see www.ledsmagazine.com/news/6/11/17) to build a fab in Foshan, located in the Guangdong province of China. The new venture, Xurui Optoelectronics, will make LED epiwafers and chips, and has just laid the foundation for the plant. SemiLEDs is investing $350 million in the venture and owns a 49% stake with six other companies holding the remainder.

TSMC, the silicon semiconductor industry's leading contract IC fabricator, recently broke ground on its first LED fab in Hsinchu Science Park, Taiwan. The company believes it can transfer its manufacturing expertise to LEDs. "LED lighting is a promising industry, and we will make full use of TSMC's technology lead-

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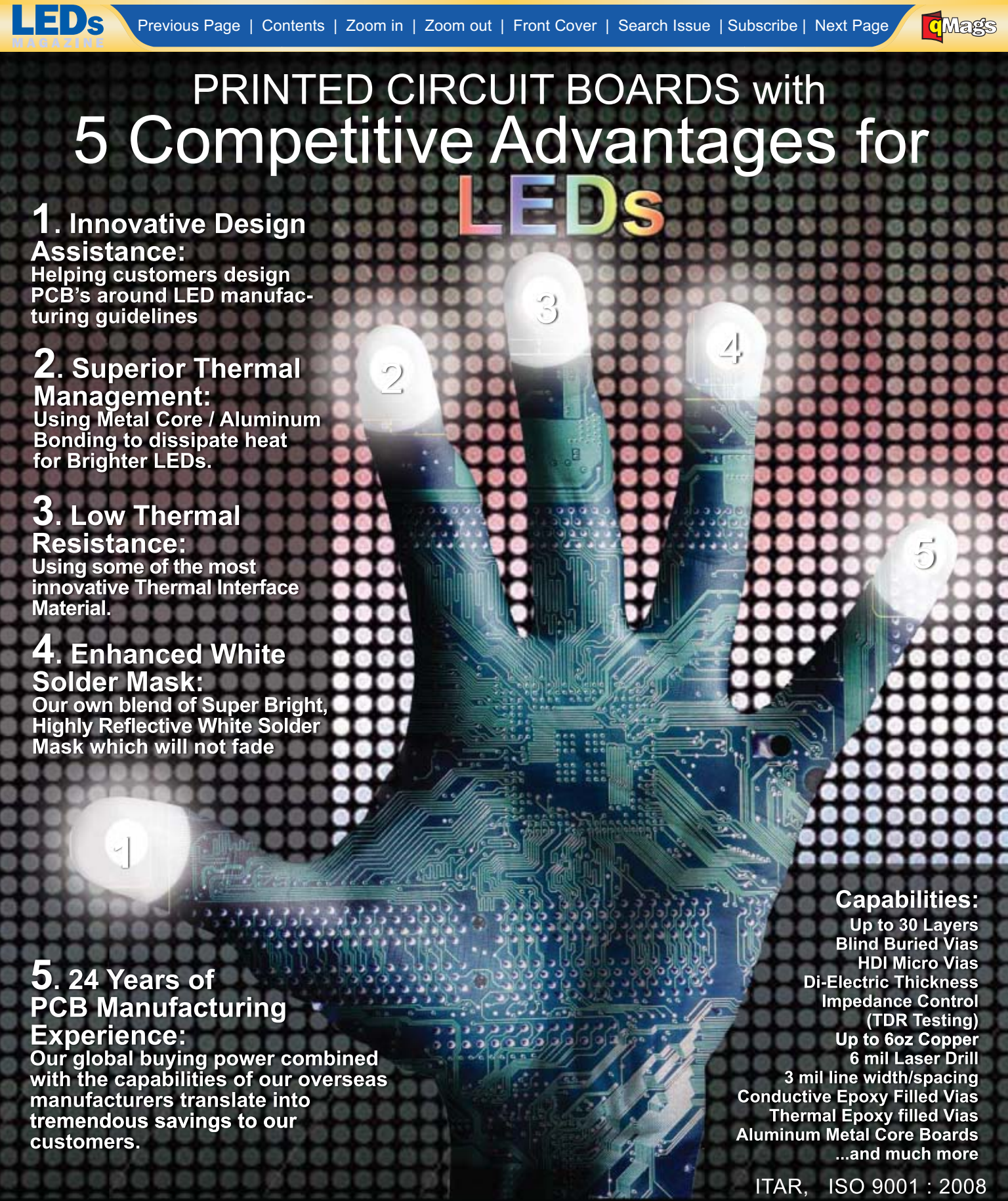

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ership and manufacturing excellence in semiconductors to develop and integrate LED technology, process, and packaging and testing," said Rick Tsai, TSMC President of New Businesses. Volume production is scheduled for the first quarter of 2011, with a first-phase investment of NT$5.5 billion ($170 million).

Meanwhile, another new entrant, De Core Nanosemiconductors, plans to spend approximately $200 million on a new LED fab at Gandhinagar in Gujarat, India. The company is a spinout of De Core Science and Technologies, and has focused on nitride-based materials. The LED chip venture will focus on nano-heterostructured white LEDs.

MORE: www.ledsmagazine.com/news/7/3/22 ◄

PEOPLE

Bob Steele retires, Seoul appoints Nakamura

Bob Steele retired at the end of March following 28 years with Strategies Unlimited, the market research firm which is a sister organization of LEDs Magazine. Steele has run the LED market research practice at Strategies Unlimited, and has been the figurehead for the Strategies in Light conference since its inception 11 years ago. However, Steele will have a consulting contract to work on program development for several new Strategies in Light conferences in other parts of the globe. The LED market research practice will be run by Vrinda Bhandarkar, who will continue to focus primarily on the LED lighting market, and Maria Marianashvili, who will focus primarily on the HB LED component market.

Shuji Nakamura, a professor at the University of California, Santa Barbara (UCSB), has been appointed as a scientific adviser to Seoul Semiconductor. Nakamura was involved in the development of commercially-viable blue, green and white LEDs and violet laser-diodes based on gallium nitride while working for Nichia Corporation in Japan in the mid-1990s. He joined UCSB in 2000, where he is also co-director of the Solid State Lighting and Energy Center (SSLEC).

Elsewhere, the highest-profile personnel moves were at Zumtobel and Philips. Zumtobel has appointed Harald Sommerer as its new CEO, effective May 1 (see www.ledsmagazine.com/news/7/3/24). Philips has parted company with Kevin Dowling, best known for his work on standards, his key role in the success of Color Kinetics and his almost inevitable appearance on the agenda of many LED-related conferences and workshops. Within Philips, Jim Anderson, Director of Strategic Marketing, will assume Kevin's responsibilities in managing government and private sector relations as well as continuing the creation and development of industry standards. Frank Penning, Global R&D Manager SSL, Professional Luminaires, will now lead R&D for Philips solid-state lighting advancements (see www.ledsmagazine.com/news/7/2/10). ◄

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DOE publishes updated R&D plan for solid-state lighting

The US Department of Energy (DOE) has published the latest edition of its Solid-State Lighting (SSL) R&D Multi-Year Program Plan (MYPP), which describes the activities the DOE plans to undertake over the next several years to implement its SSL mission. The plan, which can be downloaded at www.ssl.energy.gov/techroadmaps.html, reviews SSL technology status and trends for both LEDs and OLEDs, and gives an overview of the current DOE SSL R&D project portfolio.

The plan is updated every year in a process that is "highly collaborative" with input from "dozens of real-world experts" ranging from academics and researchers to device and luminaire manufacturers. Milestones have been updated to align DOE targets with progress made to date. Also, special attention has been paid to align the MYPP terminology with the recently published IES Recommended Practice RP-16, Addendum a. The DOE's Jim Brodrick, who runs the SSL program, described this as "a much-needed effort" to put the entire industry on the same page with regard to terminology, based on current standards and those in development.

The Plan also identifies areas requiring funding, and clarifies the scope and description of various tasks that will move these areas along. One interesting finding, says Brodrick, is that, although the efficacies of warm-white LEDs are presently well below those of cool-white products, there are ways to close that gap. Some of these are already being employed in products that have appeared on the market. Ultimately, both warm and cool LED package efficacies are expected to approach 200 lm/W. The DOE will continue to update the MYPP on an annual basis to incorporate new analysis, progress, and new research priorities as science evolves.

The table below shows DOE projections for LED packages. The DOE has also benchmarked the efficacy of cool-white LED luminaires (CCT of 4746-7040K) at 69 lm/W for 2009, and estimates that the figure will rise to 86 lm/W in 2010. Going forward, the DOE projects that the values will increase to 121 lm/W by 2012, and to 172 and 219 lm/W by 2015 and 2020, respectively. The figures assume a CRI of 70-80, a drive current density of 35 A/cm^2, and a reasonable package life and operating temperature. ◄

	2009	2010	2012	2015	2020
Cool white efficacy (lm/W)	113	134	173	215	243
Cool white price ($/klm)	25	13	6	2	1
Warm white efficacy (lm/W)	70	88	128	184	234
Warm white price ($/klm)	36	25	11	3.3	1.1

Summary of LED package price and performance projections. Cool white: 4746-7040K with CRI of 70-80. Warm white: 2580-3710K with CRI of 80-90. Measurements at 25°C with drive current density of 35 A/cm^2, package life approx. 50,000 hrs assuming 70% lumen maintenance.

Zhaga looks at light-engine interfaces

A consortium of international lighting companies is planning to develop standard specifications for the interfaces between LED light engines, which will in turn enable interchangeability between products made by different manufacturers. The Zhaga consortium has been formed by companies including Acuity Brands Lighting, Cooper Lighting, Osram, Panasonic, Philips, Schréder, Toshiba, Trilux and Zumtobel Group. At the beginning of April, there were 26 regular members and 7 associate members.

Zhaga says that it is being formed "for the benefit of consumers, in the expectation that standardization will prevent market fragmentation into incompatible light engines." The consortium says that standards will give consumers the confidence to specify and purchase LED products that will be easily replaceable and commercially available, while continuously enjoying the performance upgrades that LED technology enables. In addition, says Zhaga, this will foster innovation and competition .

Zhaga plans to define interfaces for a variety of application-specific light engines. The standards will cover the physical dimensions, as well as the photometric, electrical and thermal behavior of LED light engines.

Zhaga says that its membership will grow with the participation of other companies across the lighting industry. Membership will be drawn from LED light engine and LED luminaire vendors, as well as suppliers of components such as heat sinks and optics. The annual membership fee is EUR1000 for associate members and EUR10,000 for regular members.

Membership is dominated by luminaire makers, while there are a number of other companies that are already developing and producing modules (see our article on page 53). Among these, GE and Tyco have now joined Zhaga, while others such as Molex and Xicato have not. ◄

MORE: www.zhagastandard.org

funding + programs

DOE report analyzes savings potential of LED-based lighting

The US Department of Energy (DOE) has released a report that analyzes the potential energy savings of broadly deployed solid-state lighting (SSL) fixtures, predominantly LED- and OLED-based products. The DOE projects that, between 2010 and 2030, SSL could save 1,488 terawatt-hours of electricity consumption, representing a saving of $120 billion at today's energy prices.

The DOE has taken an active role in supporting and funding SSL lighting both to achieve energy savings and to position the US as a global leader in SSL technology. This latest report updates previous projections the DOE made in SSL lighting over the last decade.

The multi-faceted report begins with an examination of lighting inventory and lumen demand. It continues with a look at the installed base and the technology improvements in conventional light sources. The LED-centric content examines the improvements and cost savings expected in SSL over two decades. From a cost perspective, the DOE projects SSL to go from $169.49 per klm today to $5.03 per klm by 2030 for high CRI products. The report makes projections for other CRI ranges, and for OLED lighting as well.

The latter portion of the report focuses on projected market penetration and energy savings calculations. The analysis attempts to take a balanced view on the gradual replacement of technologies such as fluorescent with SSL alternatives. ◄

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

Flicker and LED lighting reviewed by IEEE group

An IEEE standards working group has produced a report looking at the health effects of flicker in LED lighting (see http://grouper.ieee.org/groups/1789). The report, which is open for public comment, looks at ergonomics, biological attributes, potential health effects, and methods in which some LED lighting may introduce flicker. Brad Lehman, who chairs the P1789 working group, says the document is a survey report and gives no recommended practices or standards. "Its intent is to educate stakeholders on flicker with applications in LED lighting, as per the request of several government agencies," he says.

The EPA recently revised the requirement for LED operating frequency in the Energy Star criteria for Integral LED Lamps, changing it from 150 Hz to 120 Hz after input from interested parties. ◄

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Strategically Speaking: LCD backlights and lighting drive largest growth yet seen in HB-LED market

A period of very rapid LED market growth will see unit volume demand increase to more than 200 billion units by 2014, says **BOB STEELE**.

Coming out of a year of relatively low growth for the HB-LED market (up 5% to $5.3 billion in 2009), largely due to the worldwide economic recession, the industry is now faced with an abundance of riches. It will come as no surprise to the readers of LEDs Magazine that unprecedented growth opportunities for HB LEDs will be provided over the next five years by lighting applications and backlights for LCD displays (including notebook computers, TVs and monitors).

In 2009, these applications helped to raise the overall HB-LED market from what would otherwise have been a dismal (i.e. negative growth) year, with a combined contribution to the market total of 29%. In 2010 and beyond, these two applications will be the dominant market growth drivers.

Lighting

The market momentum for LED lighting applications slowed somewhat in 2009 (as the overall lighting market declined by 15-20%), but it is resuming with a vengeance in 2010. Although LED lighting still accounts for less than 2 % of the overall lighting market, and still mainly addresses niche applications, growth continues to be robust, at an estimated 31% for 2010.

Many "mainstream" lighting projects are beginning to be addressed by LED lighting. Some of these include major retrofits at retail chains (e.g. Wal-Mart, Starbucks), hotels and casinos, parking garages, and municipal lighting. Energy efficiency is often the major driver, but other attributes of LED lighting such as long life (lower maintenance costs) and improved quality of light are often important factors.

Newly introduced LED replacement lamps and luminaires are showing much better performance than those of earlier generations. They appear to be using better and more efficient LEDs, although this generally means higher prices for lighting products. There is still an issue with low-price, low quality products in the market, but resellers seem to be getting more sophisticated about their offerings, often because of customer complaints and returns.

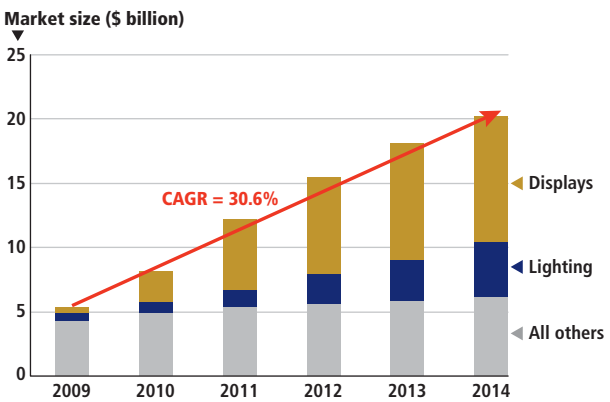

FIG. 1. HB-LED market forecast for lighting, displays (includes backlights for TVs and monitors, but not laptops or netbooks), and all other applications.

Backlighting

The use of LEDs for backlighting larger LCD displays (as opposed to small displays for mobile phones, digital cameras, etc.) began in earnest in 2006, when the first notebook PCs adopted them. Although the penetration was initially small (only about 3% in 2007), it then increased rapidly, exceeding 50% in 2009, and it is projected to exceed 80% in 2010.

Although the first LED-backlit LCD TVs were introduced by Sony in 2005, the market did not begin in earnest until 2008, when Samsung introduced its first mass-market LCD backlit models, then began to seriously ramp up in 2009. Significant volumes were shipped by Samsung, as well as LG and a few other LCD TV makers, amounting to a market penetration of 2.3%. We expect penetration of nearly 15% for 2010, with rapid increases in penetration in the following years.

Although some high-end LCD monitors have been shipped with RGB backlights since 2005, the move to the use of white LEDs for backlighting mainstream desktop monitors began only in late 2008. In early 2009, all major monitor manufacturers announced that all of their new models would use LED backlights, which will result in yet another high volume market for over the next five years.

» page 24

BOB STEELE *is Director of the Optoelectronics Program with Strategies Unlimited (Mountain View, CA). Tel. +1 650-941-3438. Web: www.strategies-u.com. "Strategically Speaking: Insights Into LEDs & Lighting" is a regular LEDs Magazine column from Strategies Unlimited (see www.ledsmagazine.com/strategies)*

Overall market growth

The developments discussed above have set the stage for a dramatic ramp-up in the market for HB-LEDs. We are forecasting a market growth of 52% in 2010 to $8.2 billion. Our longer term forecast projects a market growth averaging 30.6% per year, reaching $20.5 billion in 2014. In that year, we project that 56% of the market will be accounted for by backlights for medium-to-large LCD displays (10 inches and above), and 21% will be accounted for by lighting applications.

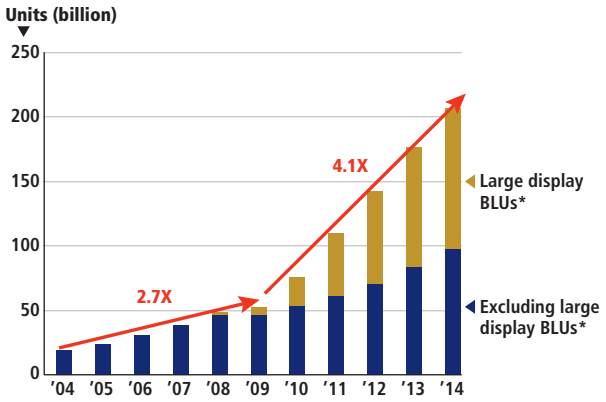

FIG. 2. LED unit shipment history and forecast. *Large display backlight units (BLUs) includes notebook PCs, LCD monitors, LCD TVs.

As might be expected, this rapid market growth will be felt in the unit demand as well as sales revenues. We are forecasting LED unit growth of 44% to 78 billion packaged devices in 2010. Our forecast for 2014 indicates that the unit volume demand will be four times higher than in 2009, exceeding 200 billion units. The demand for GaN-based LEDs will be especially robust, as these are the key components for backlights and lighting. Demand for GaN chips (before packaging) is forecast to grow at more than a factor of five from 2009 to 2014.

Manufacturing capacity

Clearly this will have profound implications for the need for production capacity. Although growth rates of this magnitude have been seen before in the LED industry, the absolute magnitudes were much smaller. For example, from 2000 through 2005, overall unit demand grew by a factor of 4.7. However, the demand in 2005 of 24 billion units was nearly an order of magnitude smaller than that projected for 2014. Thus, the scale of the industry required to serve the forecasted demand will be correspondingly higher.

The most critical manufacturing tool for LED production is the MOCVD reactor. The two main suppliers, Veeco and Aixtron, report unprecedented demand for their reactors, with both companies currently producing at full capacity, and with

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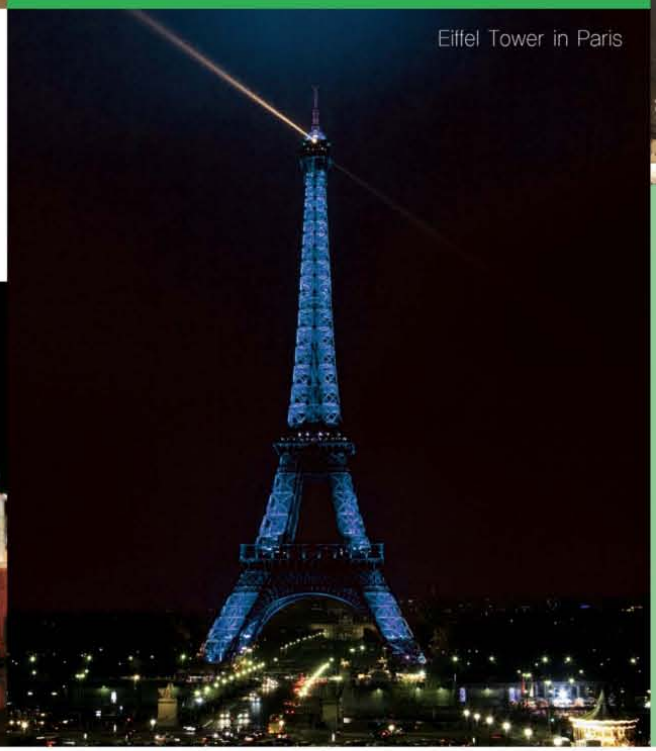

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plans to increase their capacity throughout the year. Fortunately for the LED industry, the production capacity of MOCVD reactors has increased along with the growth in unit demand. In the early 2000's, typical reactors could process 6 x 2-inch substrates. This later increased to 11 x 2-inch, and then to 21 or 24 x 2-inch. Today's high capacity MOCVD reactors can process 42 or 45 x 2-inch substrates simultaneously, or roughly seven times the capacity of the early 2000's generation. In light of this trend, the number of reactors that will need to be installed appears to be more tractable than one might initially imagine.

To meet the projected demand for GaN chips, Strategies Unlimited has calculated, based on our internal model, that 200 additional reactors will be needed this year and another 280 in 2011. This seems well within the capacity of the MOCVD manufacturers.

Shortages and over-capacity

There has been much discussion of possible capacity shortages in the near term and overcapacity in the longer term. Both are possible, but it must be remembered that in this rapidly growing market, timing is everything.

Currently reactor order lead times are about six months, and it takes another 3-5 months to get a reactor installed, running and qualified. Many LED suppliers have had reactors on order since late last year, and are just now getting them running and qualified, while others still have reactors on order. The rate at which these reactors can be installed and qualified, relative to the ramp-up in demand, will determine whether there are capacity shortages or overcapacity, and the situation is likely to be highly specific to individual regions, companies, and product types.

However, the main factor in these considerations is the tendency of LED suppliers to want to capture as large a market share as possible. A situation could develop similar to that in the 2002-2004 timeframe, during the rapid growth of the mobile-phone market. Excess capacity came on line in the latter part of that period, and prices were driven down, at least for the low-performance LEDs such as keypad backlights. If history repeats itself, then overcapacity within the next one to two years seems possible. However, as noted above, this may not be the case for all LED types in all regions, especially for the high-performance white LEDs used in lighting applications.

LINKS

For replacement lamps, LEDs are different (Dec 2009)
www.ledsmagazine.com/features/6/12/3

Recent conferences in Asia highlight LED industry progress (Oct 2009)
www.ledsmagazine.com/features/6/10/13

Demand-side economics speak in favor of LED lighting

An evaluation of an LED retrofit project and various financing options indicates that many users should move forward and embrace the benefits of LED lighting, writes **MATT MILLMAN**.

The economic benefits of taking on a LED lighting retrofit could not have come at a better time. All property owners have seen their assets decrease in value over the last 24 months as rents have dropped while utility rates, materials costs and labor rates continue to rise. For the first time in over a decade, facilities managers, asset managers and property owners are looking at cost cutting as the only way to increase their revenues. LED lighting retrofits offer a property owner significant opportunities to reduce their costs in multiple areas.

LED lighting retrofits can demonstrate quantifiable savings in power consumption, air-conditioning demand, material and labor cost for replacement, and recycling cost. Add to those savings the tax benefits of the deductibility of an operating lease or the ability to depreciate a capital lease structure (which will be explained in the example below), and one can see a payback as short as 1.78 years on fixtures that have a rated life of over 9 years. That's not to mention the benefits of "going green" including a significant carbon footprint reduction.

Retrofit case study

To highlight the favorable economics of such a retrofit, Table 1 illustrates a case study for a project currently undergoing pilot testing. The project is a structured garage in New York City with seven stories and rooftop parking, which is open 24 hours a day, 365 days a year. The facility currently has 1,054 metal halide (MH) fixtures which consume anywhere between 95 and 295 watts. It was recommended that each type of metal halide fixture be replaced with a comparable LED fixture.

The first column in Table 2 shows the calculated annual savings from the project, which include saving from lease deductibility. Calculations indicate a 1.78-year payback and an unleveraged internal rate of return (IRR) of 54% over a 10-year period (a time period consistent with the rated product life of the luminaires used). It is also important to note that the calculations performed do not include any state or federal rebates. Environmental benefits include a load reduction of 66%, a reduction of 131.95 kWh/year in electricity consumption, and a carbon-emission reduction in excess of 1.6 million pounds.

Current metal halide fixtures	LED replacements
28 x 95W in stairwells	44W
22 x 295W on roof poll tops	97W
4 x 295W on roof perimeter wall packs	53W
1000 x 190W on parking decks	54W
Input Assumptions:	
Annual operating time	8760 hours
Average electricity cost	$0.18 / kWh
Lamp/ballast replacement labor cost	$30.00 / hour
Average annual lamp failure rate	54%
Average annual ballast failure rate	14%
Utility annual inflation rate	5%
Rate applied for lease deductibility	40%
Project Costs:	
Cost of Fixtures	433,389
Cost of Installation	62,700
Sales Tax (8.0%)	34,671
Shipping ($4.0/unit)	5,016
Project Mgmt Fee	53,578
Cost	**$589,354**

TABLE. 1 Input data and initial assumptions for a parking garage retrofit in which metal-halide lamps are replaced with LED equivalents.

Financing

Despite the fantastic payback of the proposed transaction, spending over $585,000 may not be in the budget for the end user. However, the marketplace provides several options to finance these retrofits.

The first option is for the customer to use its own balance sheet or a line of credit for financing. Assuming you are a credit-worthy borrower, the resulting positive leverage would create a leveraged IRR of 177% (assuming 80% leverage at 10% interest rate and a 20% down-payment). This is clearly a profitable option, but the borrower's balance sheet is now encumbered with a new liability restricting its ability to obtain credit for other activities. Table 2 shows the calculated cash flow after the user has serviced the debt.

Leasing

The second option is to finance with a "green" leasing company that specializes in LED lighting. A leasing company should offer two lease options to the user. The » page 30

MATT MILLMAN *is a founding member of Relamp LLC (www.relampled.com), a provider of financing for LED lighting retrofits and other demand-side energy-efficiency projects.*

first one is an operating lease, which will allow the user to deduct the full lease payments like any traditional lease payment. If structured correctly this should allow a commercial landlord to pass through the lease expense as an operating expense to his/her tenants. The second lease option is a capital lease, which would allow the user to maintain the benefits of tax ownership. Both options provide the user with "unsecured" financing which will not tie down the end user with an additional liability.

When choosing a leasing company, two payment methods are available in the marketplace. The first traditional method is the straight interest payment; similar to leasing a car or a photocopier, an APR is determined and the user has a contract for a set period of time.

The second payment method is a more flexible "pay through savings method" where the lease term is adjusted based upon the customer's needs so that the project is cash flow positive on day one of the lease payment.

Table 2 provides an example of the "pay through savings method" for our case

Parking garage case study		Option 1: borrowing		Option 2: leasing	
Year	Annual project savings	Debt service payment	Cash flow to user	Lease payment	Cash flow to user
1	288,443	93,926	194,517	259,599	28,844
2	289,597	93,926	195,671	259,599	29,998
3	294,212	93,926	200,286	275,268	18,944
4	323,057	93,926	229,131	0	323,057
5	333,882	93,926	239,956	0	333,882
6	334,013	93,926	240,087	0	334,013
7	344,482	93,926	250,556	0	344,482
8	354,951	0	354,951	0	354,951
9	365,419	0	365,419	0	365,419
10	375,888	0	375,888	0	375,888
Total		657,482		794,466	

TABLE 2. Annual savings for the parking garage case study outlined in Table 1. Also shown are payments and net cash-flow for two different financing options, namely borrowing or leasing.

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study. The cost of capital for the lease option is higher than drawing down a line of credit. However, as mentioned above, this lease program is an "off-balance sheet" financing on a product which has no residual value such as an automobile or photocopy machine, and is a 100% project cost financing solution with no down-payment. This option produces a net present value to the end user after seven years of $3,456,165 (assuming an 8.0% discount rate and 8.0% capitalization rate).

ESCO option

The third option is that the LED retrofit becomes part of an ESCO (Energy Services Company) program where it is bundled with other cost saving measures. With an ESCO, a percentage of savings is given to the end user and a percentage of the savings is retained by the ESCO managing the end user's utility bill. Since the lighting portion of the retrofit is bundled with other cost saving programs, we are not able to present an accurate example of the economics of the lighting portion of the retrofit to the overall savings being offered the end user by the ESCO (see also p.49).

Where retrofits work best

LED retrofits make the best financial cases where the fixtures are left on for more than 12 hours a day, in geographies with a kilowatt-hour rate above $0.10 (about half the states in the USA as of November 2009) and there is a cost associated with maintaining the current fixtures. The best fixture candidates for LED retrofits are MR16s, PAR lamps, incandescent lamps, high-pressure sodium lamps, metal halide lamps, and T12 fluorescent tubes.

Among the best applications for LED retrofits are the common areas in commercial offices, multi-family buildings, regional malls, hotels, student housing, and assisted living buildings, as well as parking garages, hospitals and streetlights.

Summary

For the first time, commercial lighting has moved from a conversation piece to an investment decision that everyone from engineers to chief financial officers are paying attention to. As time goes on, more and more users will be switching to solid-state lighting as they start to address the demand side of their energy consumption. Furthermore, as evidenced by this case study, there's no longer a reason to put off a retrofit. The savings from going to solid-state are high enough that the cost of inactivity is more expensive than waiting for the technology to drop in price. In addition, as evidenced above, the market has come up with several methods of financing a retrofit so that the benefits of LED lighting are not limited to those with cash on hand so the end user does not have to rely on government subsidy to take on the retrofit of his or her facility.

focus on Luminaires

At Strategies in Light in mid February, the US Department of Energy (DOE) announced the winners of the 2009 Next Generation Luminaires (NGL) Solid State Lighting Competition. The competition is jointly sponsored by the DOE, the Illumination Engineering Society of North America (IESNA), and the International Association of Lighting Designers (IALD). In this the second year of the competition, 60 lighting companies submitted 126 luminaires for consideration in indoor- and outdoor-lighting categories. The judges anointed four submissions as "Best in Class" and 43 other submissions as "Recognized" winners.

MORE WINNERS: www.ngldc.org/09/winners.stm

A panel of 12 judges worked for two days in December reviewing the NGL entries. The judges reviewed submitted photometric files, LED data sheets, and driver specifications. Entrants were required to supply LM-79-08 photometric files from an independent testing lab. The judges also examined each luminaire installed in an environment that closely matched the intended product application.

RECOGNIZED INDOOR LIGHTIN

Curve by Finelite

The portable task light includes a field-replaceable LED module, touch-activated dimming, a 17-inch stem, and head and stem swivel. Output: 381 lm. Power: 7.8W. Efficacy: 48.8 lm/W. CCT: 3622K. CRI: 82.

www.finelite.com

BeveLED by USAI

Available with round or square apertures, the recessed accent light offers a choice of 15° or 30° beam with 362° horizontal rotation and lockable 40° vertical tilt. Output: 734 lm. Power: 21.9W. Efficacy: 33.5 lm/W. CCT: 2939K. CRI: 83.

www.usaillumination.com

Halo Stasis LED by Cooper Lighting

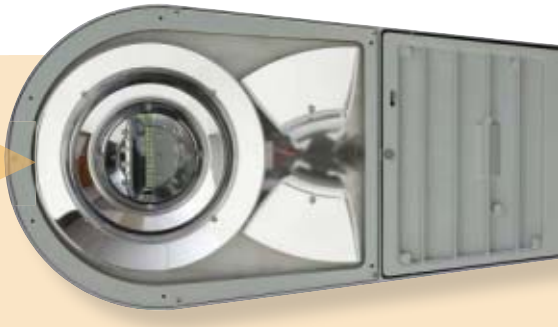
A track-mounted accent light, the extruded-aluminum luminaire is available in three beam-spread options, and includes a tilt guide and lockable aiming. Output: 942 lm. Power: 18.6W. Efficacy: 50.6 lm/W. CCT: 3000K. CRI: 85.

www.haloltg.com

BEST IN CLASS

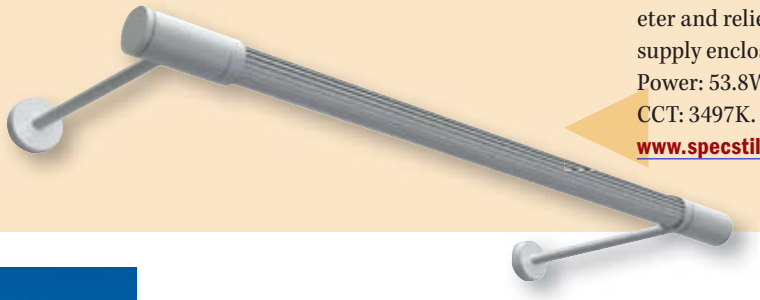
VizorLED by Philips Wide-Lite

Targeting parking garage and under-canopy lighting, the luminaire provides 5% uplight and includes options such as a dimmable driver and occupancy sensor. Output: 4112 lm. Power: 68.4W. Efficacy: 60.1 lm/W. CCT: 4009K. CRI: 64.
www.widelite.com



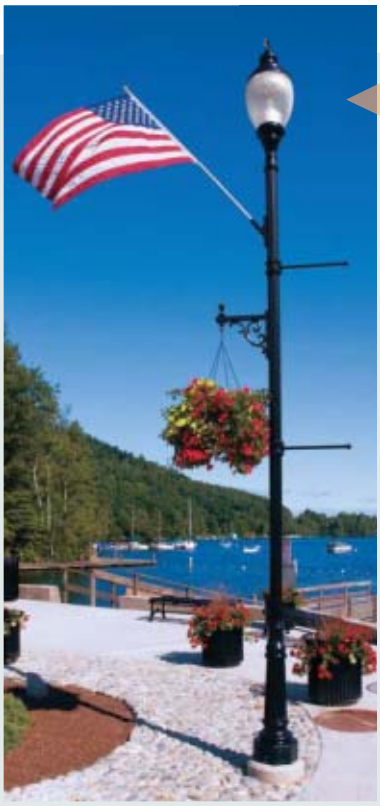
Evolve LED R150
by GE Lighting Solutions

The cobrahead streetlight utilizes nested concentric directional reflectors that provide good pavement uniformity, effective glare control, and reduced light trespass. Output: 4900 lm. Power: 91W. Efficacy: 53.8 lm/W. CCT: 4100K. CRI: 65.
www.gelightingsystems.com



Stile Styk
by Stile/Spilighting

Available in white and color light, the wall-mounted IP66-rated Stile Styk measures 1.5 inches in diameter and relies on a remote power supply enclosure. Output: 2645 lm. Power: 53.8W. Efficacy: 41.5 lm/W. CCT: 3497K. CRI: 83.
www.specstile.com



A850SR LED by Sternberg Lighting

The Old Town Series acorn-style luminaire is available in a choice of four wattages, is 40 inches high, and offers replaceable driver and LED modules. Output: 5763 lm. Power: 96W. Efficacy: 60 lm/W. CCT: 4343K. CRI: 78.
www.sternberglighting.com

Dalton Brass LED-32
by Winona Lighting

Molded from composite material, the upgrade light features a lens cut from tempered borosilicate glass, and lens, driver, and LED modules are replaceable. Output: 416 lm. Power: 7.2W. Efficacy: 57.8 lm/W. CCT: 4713K. CRI: 80.
www.winonalighting.com

RECOGNIZED OUTDOOR LIGHTING

RECOGNIZED INDOOR LIGHTING

Slotlight LED
by Zumtobel Lighting

Available in any length (2 inch increments), the luminaire provides direct illumination, includes a replaceable dimmable driver, and replaceable LED modules. Output: 664 lm. Power: 17W. Efficacy: 39.1 lm/W. CCT: 3479K. CRI: 81.
www.zumtobel-led.com

LR6-DR1000 by Cree Lighting

The 6-inch round downlight leverages a recessed lens for visual comfort and features a GU24 base so that the entire unit is easily replaced. Output: 1020 lm. Power: 11.9W. Efficacy: 85.7 lm/W. CCT: 2701K. CRI: 92.
www.creeledlighting.com

Stratus by Pure Lighting

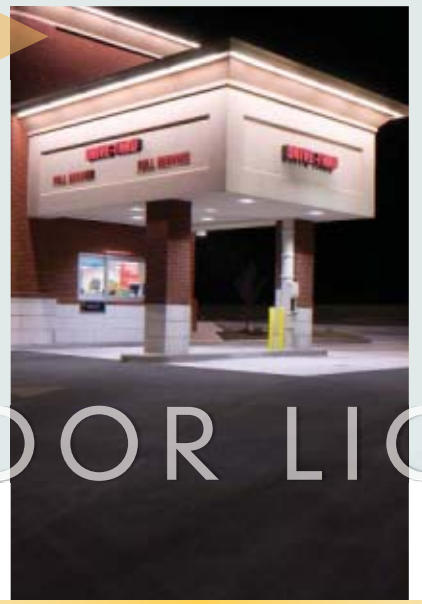
A wall grazer that can highlight textured walls as high as 30 ft, the linear luminaire relies on multi-reflector optics for beam control and comes in warm or cool white. Output: 1576 lm. Power: 79W. Efficacy: 19.9 lm/W. CCT: 2969K. CRI: 95.
www.purelighting.com

LEDway Streetlight by BetaLED

Based on a 22×11×5-inch aluminum housing with modular light bars, the streetlight allows ten optical configurations and field-configurable drive current. Output: 3031 lm. Power: 53.6W. Efficacy: 56.5 lm/W. CCT: 3928K. CRI: 79.
www.betaled.com

Crossover XSL LED
by LSI Industries Inc

Designed for recessed downlight applications such as drive-through retail, the formed-aluminum luminaire allows for LED and driver replacement through the aperture. Output: 4957 lm. Power: 62W. Efficacy: 80 lm/W. CCT: 5359K. CRI: 69.
www.lsi-crossover.com



Satellite S96M
by LED Roadway Lighting Ltd

Based on "cross lighting" luminaire arrays that can achieve a Type II or III light distribution, the streetlight can be specified with 24 to 96 LEDs and six drive current options. Output: 6720 lm. Power: 86.5W. Efficacy: 77.7 lm/W. CCT: 5000K. CRI: 70.
www.ledroadwaylighting.com

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- In 2009,we caught two hundred million as the sales volume.
- In 2010, six hundred million will be ploughed into the new LED industry park.
- 6 years experiences in manufacturing LED products mainly including: High power LED lamp, SMD, LED displays, LED spot light, PAR light series, Tube and various others.

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Strategies in Light 2010 illuminates the start of a new era for LED market growth

In its eleventh year, the Strategies in Light 2010 conference and expo was full of optimism for strong market growth in the years ahead. **TIM WHITAKER** and **MAURY WRIGHT** report.

After a turbulent year of sharp decline and recovery, resulting in a net revenue increase of 5% in 2009, the high-brightness LED market is now entering a new era of growth. Driven by demand from LCD backlighting and LED lighting applications, the LED market can expect to see more than 50% growth in 2010. This positive news was presented to attendees of the Strategies in Light 2010 conference and exhibition during the customary opening presentation by Bob Steele of Strategies Unlimited. However, after eleven years of presenting the Keynote Address and market forecast at SIL, and many more years tracking and reporting on the LED market, Steele has now announced his retirement. The article on page 23 of this issue describes Steele's view of the LED market and industry supply issues.

This year's SIL, the eleventh in an annual series, was held in Santa Clara, California, and featured two parallel conference tracks; the HB-LED Market track and, for the second year, the LEDs in Lighting track. The Lighting track was opened with a review of solid-state lighting market trends by Vrinda Bhandarkar of Strategies Unlimited (see page 9). New this year was an SSL Investors Forum, during which twelve companies presented themselves and their technologies to a room full of venture capitalists and other potential investors. Four half-day workshops and two half-day tutorials completed the packed agenda, while 90 exhibitors and nearly 3000 registrants ensured a packed show floor. Another important part of the event was the announcement of the results of the Next Generation Luminaires competition, described on page 34.

Brivo light engines from Foxsemicon Integrated Technology Inc. (FITI) were featured in a booth designed to simulate "driving down the street" – see www.ledsmagazine.com/press/21365.

The joy of lighting design

In the Keynote Address, Derry Berrigan, principal of DBLD Sustainable Lighting Design, gave a passionate argument against the view of lighting as a commodity, where price is the differentiator and profit margins are small. "Lighting is such a persuasive technology. It moves people. As a designer, I engineer an experience," she said. Berrigan has wide experience with SSL technology and says her projects are "97% LED." Why not all? "Because we need to meet the relevant lighting quality standards," she explained. She indicated that SSL will play a key role going forward, but the industry must take a holistic approach addressing lighting, controls, design, and daylight. She believes the SSL industry has delivered interesting prototypes to date, but went on to ask "For 2010, how do you build on the prototypes, and get mass transformation and implementation?"

She gave an example of a McDonalds restaurant in North Carolina where LED lighting creates "an invitation" and a better working and eating environment. Elsewhere, in a Wal-Mart store, replacing HID lights with LEDs allowed peaches to be on sale for longer, due to the reduced heating of the display items from the light source.

LED market cycles

Jed Dorsheimer, Senior Equity Analyst at Canaccord Adams, discussed the LED

market in terms of cycles. The first cycle began with mobile handsets in the early 2000s, when LEDs were used to illuminate keypads and later to backlight color screens. A surge in LED manufacturing resulted in over-capacity in the 2004/2005 timeframe. However, the first cycle also drove LED performance improvements and declining prices which in turn enabled the second market cycle, which is now providing LEDs for backlights in laptops and TV.

Based on the ramping TV market, Dorsheimer said that that the industry will experience significant under-capacity beginning this year, and a 70- to 100-billion LED deficit by 2012. Several hundred more MOCVD reactors need to be brought online, and a sapphire-wafer shortage could also impede adequate supply. However, Dorsheimer believes current trends will lead to a 30% overbuild in LED capacity and a "one- to two-year digestion period" in the 2014 to 2016 timeframe with little capacity growth. And again, the price declines and performance gains made in LEDs will help enable the third boom cycle, which will be driven by lighting.

The Acuity Brands stand showcased a Holophane streetlight with a ROAM (Remote Operations Asset Management) monitoring and networking solution featuring wireless transmission.

Reliability and efficiency

Presentations from Philips Lumileds and Inventronics focused on reliability and efficiency issues, targeted at the luminaire design process. Rudi Hechfellner of Philips Lumileds presented a methodical design-for-reliability approach that luminaire designers can follow. Hechfellner separately addressed the issues of lumen maintenance and catastrophic failure. While either a drop in lumen output below an acceptable level or a complete failure count toward reliability, the specific failure mechanisms for each can be quite different.

Nuventix unveiled a new Synjet product designed to operate with a Xicato light engine (www.ledsmagazine.com/features/7/2/8).

Speaking specifically about Lumileds' Luxeon Rebel LEDs, Hechfellner noted that driver current has a very strong effect on lumen maintenance while temperature has a very weak effect. For catastrophic failure, the opposite is true. He followed with models of lumen maintenance and catastrophic failures at different operating temperatures that scaled the probability of a single LED failing to a system failure – when the system is based on an LED array. Hechfellner pointed out that luminaire designers should perform a similar analysis on all components in an LED system including drivers and optics.

Marshall Miles, VP of Business Development at Inventronics, also addressed reliability issues. Specifically, Miles focused on the power electronics that drive LEDs, noting that what can be positive financial returns from SSL projects "turn negative very quickly if insufficient attention is given to the power electronics."

Miles pointed out that SSL return-on-investment (ROI) depends on a combination of product cost, energy savings and maintenance costs. The more-efficient driver electronics can impact ROI in three ways, namely; lower energy costs; lower component temperatures and therefore longer life; and lower component temperatures and therefore higher reliability.

Miles was quick to point out that reliability and life are different characteristics. Reliability refers specifically to the Mean Time Between Failure (MTBF). Miles explained that, in a deployment of any product regardless of reliability specs, there will be failures. Life, conversely, is the expected service time of a product before a predicted wear-out mechanism renders the product useless.

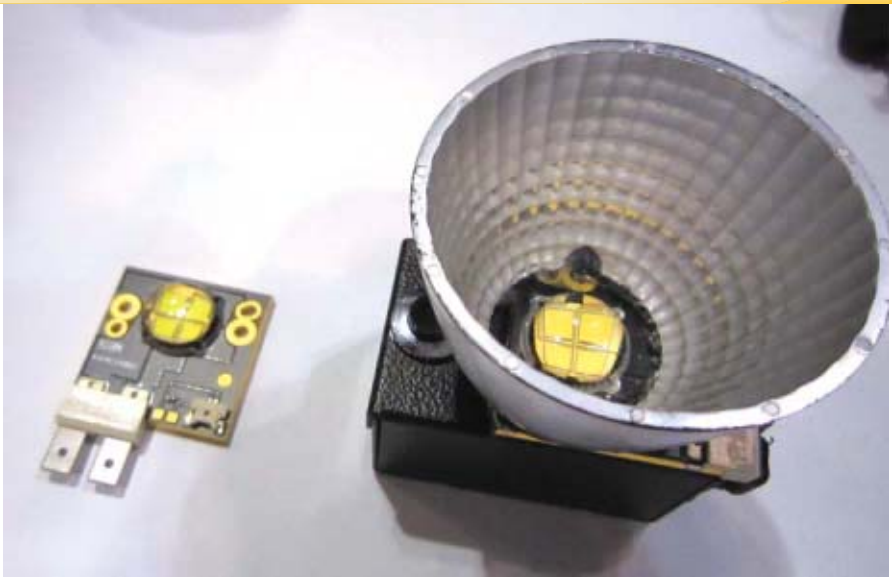
The presentation included two specific models of efficiency relative to lifetime power consumption and power loss. Miles pointed out that, over a 50,000-hour life, a 95%-efficient driver would save $83.60 over an 85%-efficient driver (based on energy costs of $0.09 per kWh). In terms of energy loss, the 85%-efficient driver has 3.3x greater loss, all of which is dissipated as heat. Miles claimed that the 85%-efficient driver has half the reliability of the 95%-efficient driver, primarily due to heat dissipation.

Optics and thermal management

Bayer MaterialScience and Carclo partnered to present "Material advancements for LED optics, diffusers, and reflectors," just as the duo has partnered to produce a polycarbonate (PC) optic for LED lighting applications (www.ledsmagazine.com/press/21222). Most optics are presently made from PMMA (poly methyl methacrylate), which is commonly referred to as acrylic. PMMA optics

have generally outperformed PC optics in terms of light transmission. But PMMA optics have temperature issues. The optics can deform at temperatures as low as 75°C, whereas PC is stable to 120°C. So PMMA optics require extra care in manufacturing because of the heat in the soldering process. Plus, LED and luminaire operating temperatures can be an issue. Bayer and Carclo claim to have developed new PC technology with transmission properties that are suitable for LED lighting. Moreover the companies can mold a reflector and a lens in a single optic.

In the thermal area, GrafTech research engineer James Petroski presented "SSL without heat sinks: Dream or reality?" Petroski pointed out that heat sinks add cost and are often incompatible with the mechanical form-factors of luminaires. He also pointed out an inherent thermal issue in lighting fixtures; the fixtures typically are made with cheap, thin metals that have poor thermal resistance and are of little help in cooling an LED source. Luminaire designers could certainly use more-expensive metals and more-complicated manufacturing techniques to produce more-thermally-efficient designs. GrafTech, however, proposed sticking with the cheap sheet metal and using a thin layer of its own graphite-based eGRAF material to spread the heat. Petroski showed some photos of an area-light case study even noting that the application of the eGRAF material is assembly-tolerant, meaning that the eGRAF material does not have to be perfectly applied to the inside of a sheet metal enclosure to solve the thermal issues.



At SIL, Luminus Devices launched warm-white PhlatLight large-area LEDs (www.ledsmagazine.com/press/21213).

Future LED applications

Two presentations took a somewhat blue-sky approach to speculate on new and innovative ways that the world will find to use LEDs. For example, Cary Eskow, director of technology at Avnet, discussed medical and psychophysiological applications. He pointed out a potential application for LEDs in medical diagnostic endoscopy. According to Eskow, a light source such as dichromatic or trichromatic LEDs would provide variable color temperature that could enhance tissue differentiation. Eskow also suggested that LEDs can be used to enhance human circadian rhythms, which regulate many functions including sleep and wakefulness. A controlled application of blue light via LEDs could enhance wakefulness and productivity without drugs or caffeine.

Steve Paolini, CEO and Founder of Telelumen, was more abstract, stating "the partitioning of the visible light spectrum will have a greater financial impact in this century than did the partitioning of the RF spectrum in the last century." That's quite a statement considering the financial impact of things such as cellular spectrum – especially when you count everything from spectrum licensing fees to consumer cellular services charges. Paolini was quick to say that

he couldn't predict exactly how partitioning of the light spectrum would have that great financial impact – quipping that such innovations would come from people smarter than he. He did suggest that communications would be one potential application.

Paolini stated that the LED will replace the light bulb and enable many new applications for light. One such application is the Light Replicator product that Telelumen has introduced. Paolini relates the early-stage product to an MP3 player. In the case of the lighting product, light scenes – a day of sunlight in San Jose, CA for instance – are captured and then reproduced by an LED array. Paolini showed graphs of sunlight intensity versus wavelength that were captured at four different times of a specific day in San Jose. The capture process is somewhat akin to the encoding process with MP3 music. The Light Replicator can then playback that sequence of light intensity and wavelengths using an LED array.

New lighting for an old culture

Ted Konnerth, CEO of Egret Consulting Group, discussed selling "new lighting" into an "old culture" in a talk entitled "200 lm/W...can I sell it now?" He compared LED guys with lighting guys in areas such as speed (product cycles measured in months, rather than decades), intellectual property (patents are "king" rather than just being "nice to have") and manufacturing. In terms of lighting performance, Konnerth said that LED guys view brightness as king, and stress lm/W. In contrast, foot candles are king for the lighting guys, with the emphasis on light on task and less glare. He likened the LED guys' approach to long-distance golf balls; "If you hit them 350 yards that's great, if you hit them 200 yards into the trees then it can be expensive." In contrast, the lighting guys are represented by controlled-accuracy golf balls.

Konnerth had advice for both camps. The LED guys were instructed to "slow down and learn the channel," to pick a strategy and then to find people who understand the strategy and have the relationships to implement it. He also said that lighting guys need to recognize the new competition; "Give up, it's here! Embrace it. Find LED partners to help and hire electrical engineers." He also advised lighting guys to "fix your channel – it's anachronistic and inefficient – and change your business model."

Truth in labelling

The Lighting Track's second session was entitled "Truth in Labeling" and featured four presentations followed by a panel discussion chaired by LEDs Magazine's own Brian Owen (see preview piece at www.ledsmagazine.com/features/7/1/2). The session explored the impact on the lighting community of inaccurate and inconsistent claims, as well as reviewing the various positive steps that are being taken by government

At SIL, Tyco Electronics launched low-voltage direct-current (LVDC) grid interconnects for the EMerge Alliance-compliant system, which can be used to control devices such as LED lighting (www.ledsmagazine.com/press/21179).

and industry to address these issues.

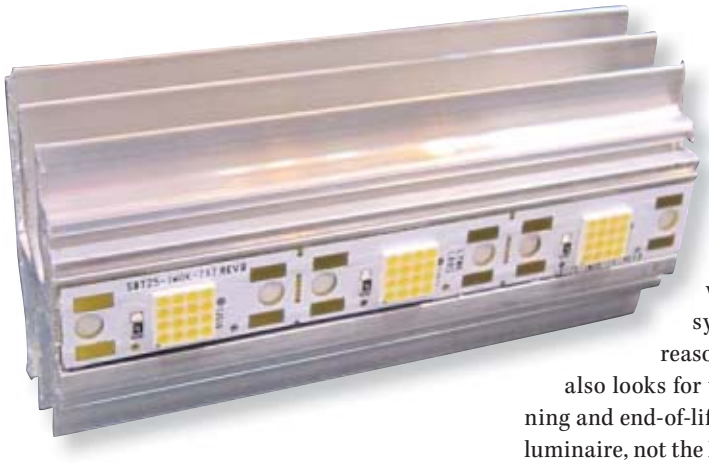
Marci Sanders of D&R International spoke about the DOE's Lighting Facts label (www.lightingfacts.com), which is intended to provide "truth in advertising" and "raise the tide" for continuous improvement of SSL product quality. In March, the Lighting Facts program had 446 approved products, of which 45% were replacement lamps, 20% were downlights and 15% were outdoor luminaires. In the last issue of LEDs Magazine (Jan/Feb 2010, p.19) we described recent upgrades to the Lighting Facts label that are designed to prevent counterfeiting. The same issue (p.21) also described the Federal Trade Commission (FTC) proposal to introduce new labels for all lamp types, which was explained at SIL by the FTC's Hampton Newsome. The FTC has the goal of protecting consumers by making sure that advertisers tell the truth and can substantiate their claims, both express and implied.

Outdoor lighting fixtures from Hilux, which also manufactures LED light engines, driver and control boards and other components.

What the labels mean

Avi Mor, a partner with lighting design company Lightswitch Architectural, presented some opinions on interpreting luminaire labels, awards and programs such as Energy Star. As well as highlighting positive aspects, he also noted that the programs have generated market confusion and fake labels, among other issues. Considering the Energy Star program, Mor lamented that "the program doesn't address quality." He also asked, "Who knows what it will be after this year?" referring to ongoing program revisions being undertaken by the EPA. Mor also pointed out that some manufacturers misuse labels, for example using the Energy Star Partners label and trying to imply Energy Star compliance. As Mor explained, "The Energy Star Partners label just means that you paid your money to join the organization." However, awards such as the Next Generation Luminaires program (see page 34) essentially provide free marketing and are considered a "good thing" by lighting designers.

Mor's company has some pretty stringent requirements for companies supplying SSL luminaires. "We want to see at least two samples with the same CCT," he said. LM-79 photometry and an independent lab



A unit comprising several Tesla 1.2W, 12 V AC LEDs from Lynk Labs. The Tesla combines "hybrid AC LED" technology at the circuit and die level with a patented ceramic array packaging and phosphor technology from Intematix, providing a totally integrated AC LED solution in a single SMT LED.

test report are required, along with LM-80 data and heat-testing data for the luminaire

"If I ask for this, and you don't have it, I've already moved on [to the next product]," said Mor. Another requirement is a written 5-year warranty, including all system components and reasonable labor. Mor said he also looks for written policies for binning and end-of-life that must apply to the luminaire, not the LEDs.

Street lighting under control in San Jose

While many cities in the US are trialing LED street lights, the City of San Jose, California, is blazing a trail by focusing on the use of "smart" technology and controls to improve energy efficiency and protect the night sky, explained Amy Olay, Senior Engineer with the city's Department of Transportation. Intelligent street lighting that leads to reduced energy consumption, improved light quality and unwanted light intrusion is part of San Jose's 15-year Green Vision. Ultimately, San Jose wants to replace all of its 62,000 streetlights with zero-emission fixtures by 2022.

LED installations are taking place in groups as sources of grant funding become available, said Olay. Several hundred LED street lights are already in place, while federal grants will lead to a further 1600 lights installed within a year.

A project in East San Jose, involving 118 fixtures in residential areas, has tested the use of power-line communication to control the lights individually or in groups. The City anticipates a 60% saving in baseline energy costs, an additional 10% saving due to dimming, and a 65% reduction in maintenance costs. Feedback from residents has been positive, said Olay, in terms of the color change from yellow (from the old low-pressure sodium lights) to white (from the LEDs), and the perception of more light. » page 49

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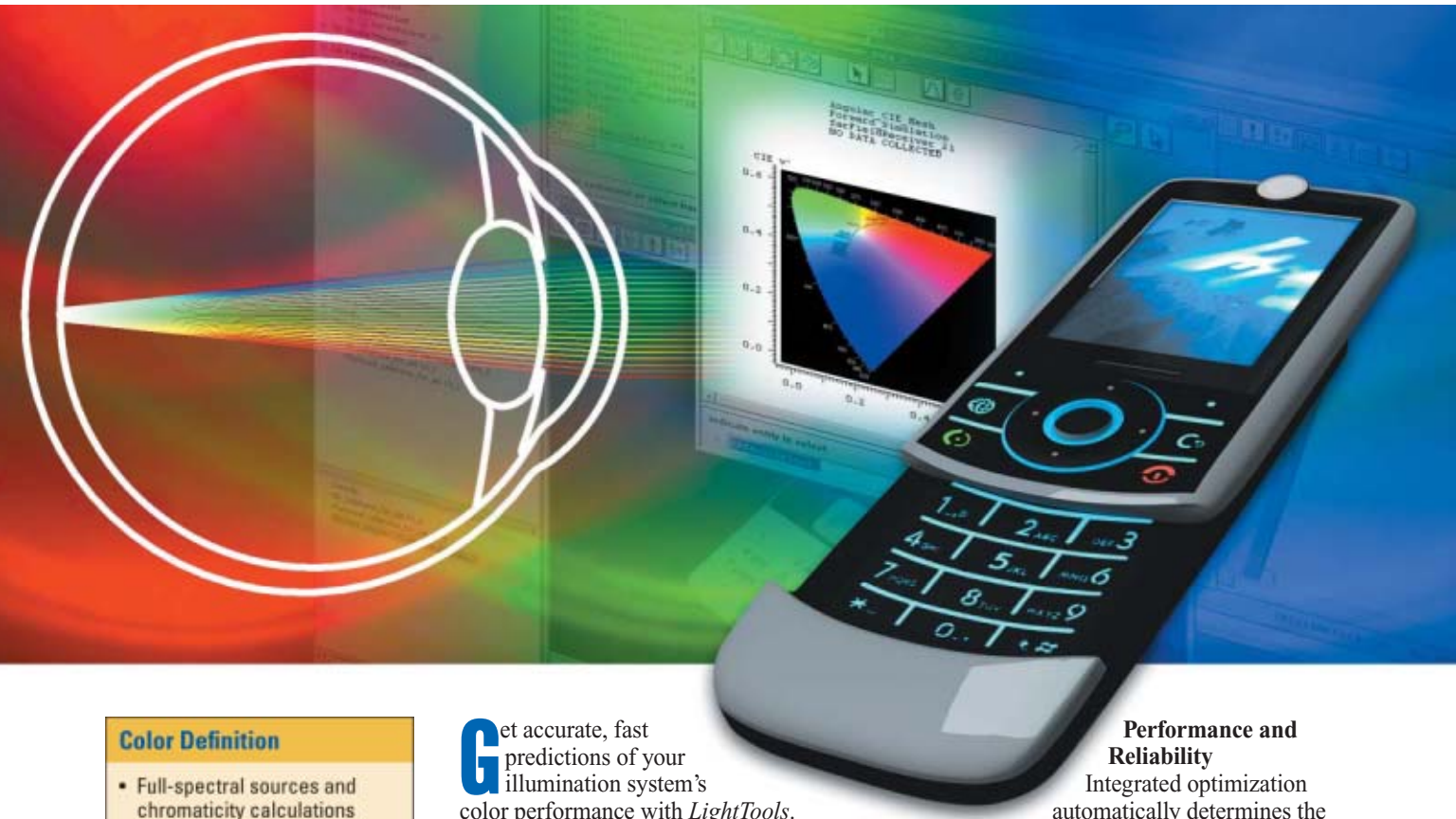

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Corporate Headquarters: 3280 East Foothill Boulevard, Pasadena, CA 91107-3103 (626) 795-9101
Fax (626) 795-0184 E-mail: info@opticalres.com Web: www.opticalres.com
Offices: Tucson, AZ | Westborough, MA | Pittsford, NY

LED street lighting in San Jose: before and after picture from the Cassell Neighborhood Project. Photo credit: PG&E Emerging Technology.

from page 46

"They are asking when we can convert the rest of the neighborhood," she said.

Another project, completed in North San Jose earlier this year, is testing wireless communication and control systems on 6-lane roadways in a non-residential area. One section of roadway runs right outside the Philips Lumileds LED factory.

Olay says that the City is working with industry to develop smart streetlights with metering capability. At present, the City pays a fixed amount for each lamp based on a flat rate schedule, irrespective of how much energy the lamp actually consumes. To fully benefit from the savings available from the use of adaptive lighting, the energy usage needs to be accurately monitored, so that this information can be used by the utilities. Many utilities will need to introduce new unmetered rate schedules specifically for LED lighting, like PG&E already has in San Jose. The full savings from the benefits of adaptive lighting will need a metered rate to be developed using the smart street lights' metering capability.

Performance contracts and ESCOs

The advantages of LED lighting can be leveraged in performance contracts (PCs) implemented by energy services companies (ESCOs). Michael Loth of Johnson Controls, one such ESCO, described how to successfully finance a PC, which is essentially a procurement tool that pays for building improvements using the savings that arise from these improvements. Under the PC, the ESCO guarantees the savings that will be realized each year after the improvements are made. This allows the customer to find financing (from a third party) for the upfront cost of the improvements. The customer pays the financing cost for several years while enjoying the benefits of the improvements; these should include lower utility bills as well as improved light and air quality, for example, leading to higher productivity.

However, explained Loth, the ESCO is responsible financially for any shortfall if the actual savings fail to meet the guaranteed level. Therefore the ESCO will look for proven technology that mitigates the risk. Lighting represents 16% of typical PC project, but has one of the shortest payback periods of 3 to 10 years. Loth highlighted a number of LED features that can impact contracting success, including lifetime, light distribution, redundancy and warranty. It would be critical to know, for example, whether to include in the PC the cost of replacing the lighting fixtures mid-contract.

Among several case studies, Loth discussed the replacement of more than 500 fixtures with LEDs in a parking structure at the Milwaukee Area Technical College in Wisconsin (see www.ledsmagazine.com/press/19602).

Lighting designers' viewpoint

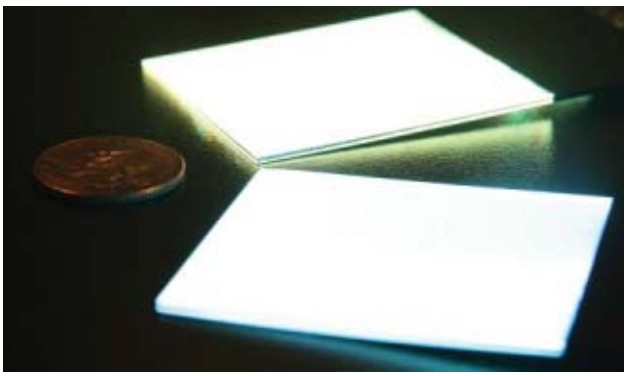
Designers face increasing challenges in defending their specifications of quality LED products when the allied professionals that they work with have little awareness of the issues, said Andrew Mackinnon, a principal of Gabriel Mackinnon Lighting Design. "LED makers and lighting designers have to protect each other's reputations," he said. "We have to deal with the consequences long after the project is installed."

There are many performance-related issues such as a lack of data allowing valid comparisons to be made. For example, there are limitations in the use of IES files to define outputs from multi-point-source LED fixtures. The selection process (of fixtures for a project) can be very time-consuming, and rapid product developments also create difficulties. Mackinnon suggested that manufacturers should slow down their product cycles, and make their intentions clear; for example, whether their next-generation fixtures would have higher light output, or maintain the same output while consuming less power, for example. Lifetime is also an issue, he said; "We all know that we don't know how long LED fixtures are going to last."

Somewhat optimistically, Mackinnon suggested that the LED source manufacturers might want to develop a rating system for fixtures that employ their LEDs. "Their reputations are at stake if their LEDs are used in poor fixtures," he said. He also suggested an industry-standard warranty for fixtures, which would be application-based, long-term (meaning 5 years) and covering output and color consistency. Another suggestion was lab testing of failed luminaires.

Michael Souter, design principal with Luminae Souter Associates LLC, said that lighting designers have responsibility for ensuring that the lighting specified is good quality and meets all of the design criteria, including efficiency, sustainability, codes, performance,

budget and aesthetics. "In order for SSL fixtures to be widely accepted by the lighting design community, all of these criteria must be met," he said. Souter gave a long list of issues that need to be resolved, and then ended with some recommendations, which included asking a lot of questions, and understanding driver requirements, location and size. "Request samples and make your own judgment," he said. "Always be cautious of claims that seem too good, in terms of lamp life, CRI etc. If you don't understand it, don't spec it. Be responsible and do not experiment on your clients."



OreeLED planar lighting modules are designed to be tiled to create very large, uniform light-emitting surfaces.

Planar lighting

According to Eran Fine of Oree Inc., there is a need in the market for planar lighting i.e. large surfaces of light that are ultra-thin, lightweight, easy to integrate into a system, and offer uniform and controllable color and light intensity across the entire surface. Oree has developed technology that enables the conversion of LED point sources into a highly uniform surface within an ultra-thin structure. "Planar lighting allows designers and architects to build new luminaires and use lighting in a unique way, opening the door to new applications," said Fine.

The OreeLED planar lighting module is the size and shape of a credit card, with a light-emitting area of ~50x50 mm. Oree has developed a modular approach to create a large surface of light that incorporates the different advantages of both edge-lit and back-lit approaches. Each module is lit by a single multi-chip LED light source and has an optical efficiency > 60%, with an efficacy of 40 lm/w on the surface of the fixture. The module thickness is 3.5 mm, and the weight is 8g. The OreeLED modules are designed to be combined, using a similar concept to roofing tiles, to build very large surfaces. A sensing and feedback mechanism inside each OreeLED module ensures uniformity over large surfaces and between many tiles.

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thermal | MODULES & LAMPS

Systematic thermal approaches enhance modular and retrofit LED lighting

Thermal issues are particularly thorny in space-constrained retrofit lamps, and also in systems with replaceable modules, says **MAURY WRIGHT**.

It's well known that thermal mitigation is required in LED-based solid-state-lighting (SSL) applications to remove heat from the LED junction. Operation at elevated temperatures reduces LED light output and life time, and may even cause catastrophic failure. Developing a robust thermal design is particularly difficult in the small mechanical space inherent in replacement bulbs, and in modular systems where heat and electrical conductivity relies on a connector of some type. A systematic approach to thermal design, including cooling both the LEDs and the driver electronics, can deliver reliable products.

Luminaire designers working on luminaires that directly integrate LEDs have substantial flexibility when it comes to thermal design. Such a design can accomodate large heat sinks or even use active cooling technology such as the Nuventix SynJet (see www.ledsmagazine.com/features/6/4/8 for an earlier LEDs Magazine article on such thermal approaches).

The replacement lamp market, however, has more growth potential in the near term compared to luminaires with integrated LEDs. At the Strategies in Light conference, Robert Steele of Strategies Unlimited stated, "Replacement lamps will be a major growth area, serving the retrofit market until the luminaire market is more firmly established."

Even luminaire makers not focused on the retrofit market have recognized that lighting designers prefer products that allow for replaceable LED and driver modules – both to replace failed lights and to allow for upgrades to the latest technology. Indeed in the 2009 Next Generation Luminaire design contest (highlighted on page 34 of this issue), many of the winning products have replaceable LEDs and drivers.

FIG. 1. The GE LED Module integrates both an LED array and the driver electronics in an easily replaceable module that makes electrical and thermal connections when inserted into the luminaire base.

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

Modular luminaires

Today, there are dozens of modular approaches to luminaire design and all have to address thermal issues to some degree. There's also at least one industry consortium – The Zhaga Consortium – that plans on standardizing a modular approach and lists thermal as a major issue that the standard will address.

Let's examine some modular designs. General Electric is moving closer to market with its GE LED Module, which is based on the modular technology that the company acquired from Journee Lighting last year. The formal product launch will come in Q2 2010 according to program manager Joe Hobbs.

The GE LED Module integrates the driver electronics and the LEDs in the removable module. That approach will certainly appeal to many SSL lighting buyers because both the driver and LEDs can potentially fail. The first products will include a transformer in the luminaire base that steps the line voltage down from 277, 240, or 120 VAC to 24 VAC. Ultimately, companies making luminaires based on the GE technology will need to include a luminaire base for a specific line voltage.

Hobbs said, "We think we may be able to come up with a universal step down transformer." Hobbs also noted that GE may design a module that can operate directly from line voltage in the future.

The GE system operates by inserting the module into the base with a clockwise turn that locks the module in place. That twist also must make the electrical connection and the thermal connection. The electrical connection is relatively simple since the driver electronics are mounted on a doughnut-shaped circuit board with concentric-circular, circuit-board traces on the back side. Those conductive traces press-fit against spring-loaded contacts in the base.

The thermal interconnect is based on what Hobbs calls a "top hat" aluminum module that extends through the center of the circuit board. Four LEDs in a single package mount to the top of the top hat, while the larger base of the hat is covered with a Bergquist thermal pad that makes

contact with a heat sink that luminaire makers must integrate in the base.

GE has published an application note that luminaire designers can use in product development. The note prescribes that, during development, engineers attach a thermocouple to the top hat and then monitor the effectiveness of the thermal interconnect and their base heat sink.

Hobbs believes the modular approach is a solid one from a reliability perspective. He admits, "Any time that you add a layer it affects your thermal model." But the company has exhaustively tested the operation in the 500-lm modules due at launch. And Hobbs claims that driving the 500-lm modules creates no heat issues in the driver electronics. Down the road, GE plans to offer 1000- and 2000-lm modules.

FIG.2. LED-based retrofit lamps come in a variety of styles, and most have some visible thermal features such as the heat sinks fins surrounding these lamps from Aeon Lighting, which won an iF Product Design Award (www.ledsmagazine.com/press/20658).

Helieon partnership

Other modular approaches will not integrate the driver electronics with the LEDs in the removable module. For example, Bridgelux and Molex just partnered to introduce the Helieon modular product (see www.ledsmagazine.com/news/7/3/21). Helieon includes a plastic base with pin-and-socket conductive terminals that make an electric connection to the LED Light Module.

FIG. 3. The Philips DOE L-Prize candidate utilizes aluminum air channels for cooling and includes four separate LED modules that radiate light in most directions.

But the Helieon thermal approach is somewhat akin to that of GE. Bridgelux attaches their die to an aluminum substrate or heat spreader and adds a layer of thermal interface material to the spreader. When the Helieon LED Module is locked into place, the thermal material is pressed against a thermal surface or heat sink that luminaire designers must integrate into their product.

Tyco is another company with a modular approach. The Star Board LED Pixel Holder includes a cast aluminum heat sink, contact carrier for electrical connections, and a locking ring. The company designed the product for use in GU10/MR16 fixtures.

The real question in the modular space, is whether the market stays fragmented with proprietary approaches, or whether there is an avenue to a manageable range of industry-standard approaches.

The Zhaga Consortium is certainly trying to guide the industry toward consolidation while not trying to limit creativity and flexibility in SSL products. Zhaga intends to define interfaces that can yield compatible LED light engines from multiple vendors.

Zhaga secretary general Menno Treffers said, "We want to promote continual innovation." Treffers also pledges quick work noting the organization plans meetings around the globe every six weeks. The consortium will define mechanical, thermal, electrical, and photometric (surface area and light output) interfaces to light engines.

Treffers envisions a family of standards that cover mechanical aspects such as connectors and control schemes for dimming. But the attempt to maximize flexibility and innovation may be tough to balance with the need for electrical and thermal standards. For example, Zhaga has indicated that it will support light engines with integrated or separate driver electronics. That decision alone goes against the typical industry-standards process that attempts to exactly define a feature so that multiple manufacturers can build compatible products. But perhaps the choice of driver location is simply an option in an electrical standard.

As for thermal, Treffers indicates that the consortium will specify thermal behavior such as "capacity of a heat sink" along with testing methods. Treffers said, "Ideally if you define an interface you don't tell people how to build it." Still a standard must include sufficient direction that ensures interoperable products from different manufacturers.

Retrofit lamps

Back to a more short-term outlook, the retrofit lamp makers have immediate opportunity and a plethora of products have come to market. Manufacturers include Osram, Philips, GE, Ledon, Lemnis Lighting, and many others.

The manufacturers of retrofit lamps may face an even stiffer thermal design challenge than those working on modular lighting. Norbert Engelberts, director of Advanced Thermal Solutions (ATS) Europe BV, stated, "Standard light bulbs were never optimized for cooling." In fact, incandescent bulbs were designed to radiate heat and certainly not to house driver electronics.

Let's examine some replacement lamps

and how the designers mitigated thermal problems and ultimately maximized lamp performance. Last October, Lemnis Lighting announced their Pharox60 lamp that is approximately equivalent to a 60W incandescent bulb and, according to Lemnis, was the first dimmable replacement lamp. The company has since renamed the product Pharox300, moving from an equivalent-wattage designation to a lumen-output designation.

According to Lemnis CTO Martijn Dekker the company took a system-level approach to the design. The team focused on optimizing driver efficiency, and the cooling scheme for both the driver and the LED module. The driver is 82% to 84% efficient, depending on the line voltage. That efficiency minimizes heat from the driver electronics. Dekker even points out that the company devised a dimmer circuit that dissipates only 30 mW to 40 mW at low light levels. The bleeder circuit used in many LED lamps that's required to ensure operation with triac dimmers can easily dissipate 1W to 2W.

Meanwhile, ATS approached Lemnis with a pledge to further improve the thermal design, and the two recently announced a partnership. Engelberts led the ATS contribution. He states, "You need to find the most critical component and concentrate the thermal design around it." ATS focused on cooling the LEDs while also advising Lemnis on potential improvements in the driver electronics.

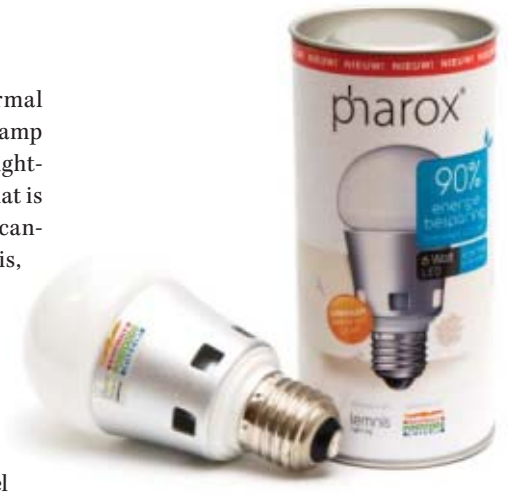


FIG. 4. An aluminum base serves as the heat sink in the Lemnis Lighting Pharox series of LED lamps.

According to Engelberts, the thermal project focused on material selection, shape, and finish. The process included making thermal models and then verifying the models with prototypes. The resulting design will use multiple layers of aluminum with air channels that comprise the lower base of the LED bulb.

Thermal and photometrics

Dekker is expecting a 22% improvement over the existing Pharox60 product that is selling now, and claims that a pilot production run on the new design verifies that expectation. Dekker points out that the thermal headroom affords options. You can run the LEDs 22 % cooler for longer life. Or you can keep the same temperature profile and boost drive current and lumen output 22%.

Dekker also notes that a system-level approach must acknowledge the photometric elements of a design. Lemnis uses a mix of blue LEDs with phosphor along with some red LEDs to produce a more-pleasing color temperature. But Dekker notes that the red LEDs degrade at a lower temperature than do the blue LEDs. So the photometric design directly impacts the thermal requirements.

Pushing further into the intersection of thermal, photometric, and mechanical/industrial design, Philips has completely revamped the form of a light bulb with its retrofit lamp that has been nominated for the DOE L Prize. The DOE has dangled a total of $10 million in prize money as a lure for companies that can develop capable LED-based replacement lamps (see www.ledsmagazine.com/news/5/6/7).

Philips was first to submit a candidate LED lamp to replaces a 60W incandescent bulb (see www.ledsmagazine.com/news/6/9/24) and the Philips product may still prove a winner. The Philips design, however, strays from the mechanical design of

incandescent bulbs and most of the LED replacement options.

Most replacement lamps, including the Lemnis example discussed previously, look something like an incandescent bulb. The optical lens still looks like a traditional light bulb even if the area just above the screw-in base is an aluminum heat sink (fig. 4).

The Philips design features four aluminum-lined air channels cut deeply into the bulb. In fact the lens is four separate pieces of material. At the top of the bulb, in the area where the maximum light exits other products, the Philips design includes an aluminum piece that joins the aluminum air channels (fig. 3).

At first glance, the Philips design seems fundamentally flawed. But remember that LEDs are very directional and quite different from an incandescent filament. Jim Anderson, director of strategic marketing at Philips, points out that if you put some of the LED replacement bulbs that are currently for sale in a table lamp, that all of the light goes up and is wasted.

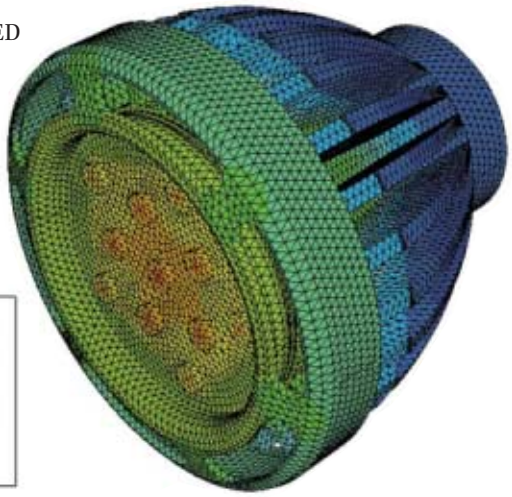


FIG.5. DSM Engineering Plastics performed a finite element analysis to verify the thermal performance of an MR16 lamp that employs the Stanyl TC thermally-conductive platic.

To win the L Prize, a replacement lamp will need to radiate light in virtually a 360° range. Philips isn't detailing the internals of its L-Prize candidate, but the design appears to include LEDs in each of the four 90° quadrants. That might be a more complex design compared to lamps in which all LEDs are mounted on one planar module directed away from the base.

The Philips design would appear to have thermal advantages compared to the more typical products on the market that only have a heat sink at the lamp base. Anderson points out that the slots were designed to encourage airflow between the quadrants. The LED assembly most likely connects thermally to the aluminum slots, and

the assembly probably has more thermal volume than do most replacement lamp designs.

FIG. 6. Bridgelux and Molex have partnered in the development of the Helieon LED Light Module that relies on driver electronics mounted in the luminaire.

Driver electronics

Without question, the LEDs are the major contributor to heat in SSL applications, but the electronic driver design can impact the overall thermal approach in multiple ways. Infineon, for instance, has announced the ICL8001G driver that specifically targets retrofit lamps and that pushes efficiency of the driver beyond 90%.

Wolfgang Meier, business development manager at Infineon, points out that the power converter topology is also important. The Infineon IC relies purely on primary-side regulation technology meaning that the control electronics reside entirely on the primary (or line-side) side of the transformer. There is no feedback from the secondary side to the primary side.

The topology yields galvanic isolation – there is no electrical path from the line voltage to the secondary side of the transformer. The isolation both helps isolate driver and LED thermal sources, and simplifies the LED cooling design.

Engelberts concurs with Meier's point. Engelberts said, "You don't have to deal at the LED base with electrical isolation." He was referring of course to safety requirements for electrical isolation that are inherent with galvanic isolation and he concluded, "It makes the thermal design easier."

Thermal materials

One other thermal angle that deserves attention is the area of thermal materials that offer great flexibility and/or low cost in terms of manufacturing. Both Molex and DSM Engineering Plastics have deployed thermal technology using new types of materials in LED-based retrofit lamps.

Molex relies on the plating technology that it first developed in its connector business and later refined in making miniature RF antennas by plating conductive material on a plastic base. Mike Picini, vice president of SSL at Molex, said "We knew that heat dissipation was an absolutely critical element, especially in fully enclosed LED fixtures. We take some thermal skin technology and use some of the base solutions that are already in the market."

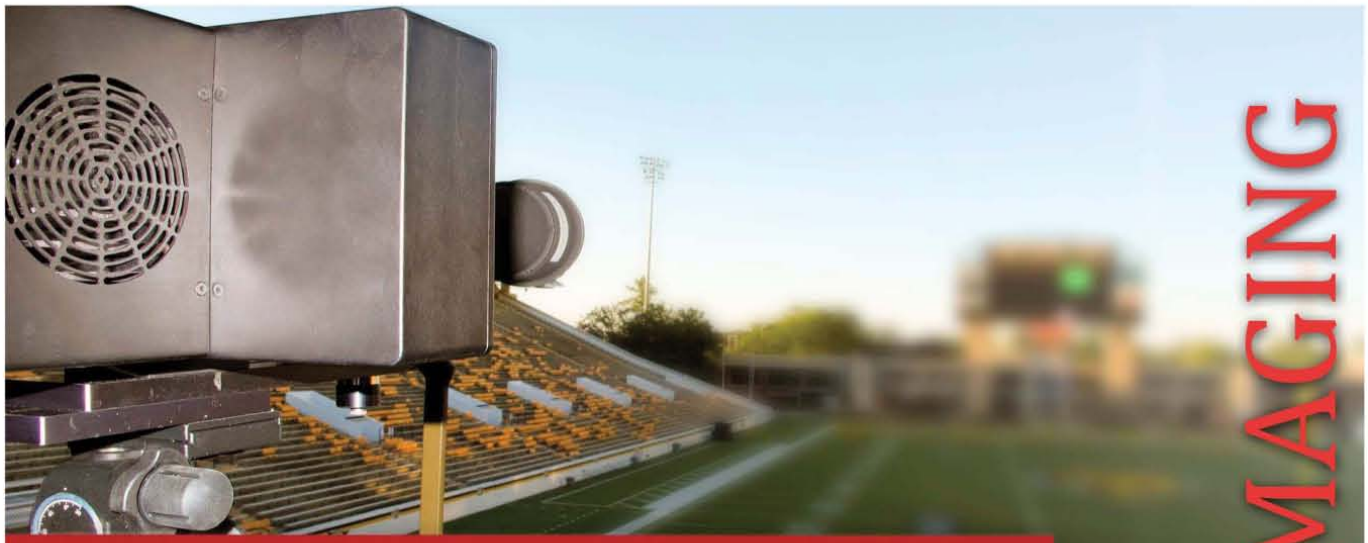
The company developed the Transcend series of retrofit lamps that are sold in the US by Leviton. The Transcend family includes several models designed for use with a GU24 base. The lamps use Seoul Semiconductor Acriche LEDs that operate directly from AC line voltage with no power converter required.

The LEDs still require a robust cooling scheme. Molex was able to use a plastic reflector that it plated with multiple layers of metal to both help cool the LEDs and reflect the light. A copper layer provides thermal conduction. A nickel layers protects the copper from oxidation. A silver layer provides reflection. The cooling scheme is enhanced with an aluminum heat sink on the outside of the module.

DSM Engineering Plastics, meanwhile, has partnered with Philips to develop a thermal scheme for LED replacements for MR16 halogen lights. Philips was able to replace the aluminum cover first used on Philips MR16 LED lights with a thermally-conductive plastic developed by DSM that's called Stanyl TC.

DSM points out a number of advantages for the plastic approach. The material is lighter in weight than aluminum and amenable to any shape and size. Lamp makers can use injection molding to form the thermal material allowing the geometric form of a product to be optimized for thermal performance and for aesthetics.

The myriad thermal approaches should rapidly move the SSL industry beyond the embarrassment of early LED lighting products that didn't deliver as promised. Proper cooling schemes will push SSL lifetime to lengths that make it justifiable in a growing range of general lighting applications.



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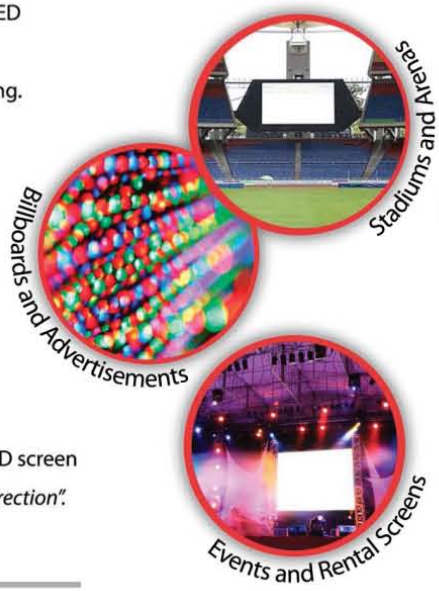

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Standards | **PROGRESS UPDATE**

LED lighting community benefits from ongoing standardization efforts

Industry input is providing valuable feedback on the LED lighting standards that have already been put in place in the USA, while further standardization efforts are continuing, writes **JIANZHONG JIAO.**

With the beginning of a new year and many signs of economic recovery, the LED lighting industry is gaining ground, expanding revenues and working to broaden LED product knowledge and acceptance. The continued market penetration of LED lighting is also providing the industry's standardization community with valuable, first-hand feedback from users of the technology. This is enabling various organizations to revise existing standards and to continue to develop new standards and to prescribe best practices for developing and using LED lighting products. This article updates progress on standards in the USA since our two-part series published last year (see Links p. 60).

LED lighting product life expectancy

In October 2008, IESNA (the Illuminating Engineering Society of North America) published LM-80, the LED lumen-maintenance testing standard. The purpose of LM-80 is to establish uniform test methods for lumen maintenance of LED light sources including LED packages, arrays and modules. In turn, this allows a comparison of test results from various laboratories. LM-80 lists what data needs to be reported, but it does not specify how the data should be presented, nor does it address the uncertainty of testing equipment and repeatability of testing operations.

With over a year of experience using the LM-80 standard, more evidence and data are available to analyze its impact. Increasingly, LED users realize and understand that LED lumen-degradation behavior in the first few thousand hours of testing, as specified in LM-80, cannot reliably be used to predict the much longer L_{70} life. L_{70} is the time taken for light output to fall to 70% of its initial value.

In this same timeframe, many LED luminaire products have been qualified for Energy Star certification. The Energy Star criteria for luminaires (SSL v1.1) sets specific lumen-maintenance threshold values that must be achieved after 6000 hours (in contrast with LM-80, which prescribes a test procedure.)

Over the past year, the standards committees have worked very hard trying to establish some type of generic mathematical model that can be used to extrapolate the data collected via the LM-80 test procedure to forecast a lumen maintenance lifetime (in hours). Because of the nature of LEDs, though several models or approaches have been proposed, no consensus has been reached. However, the product life expectancy of LED lighting is a very » page 60

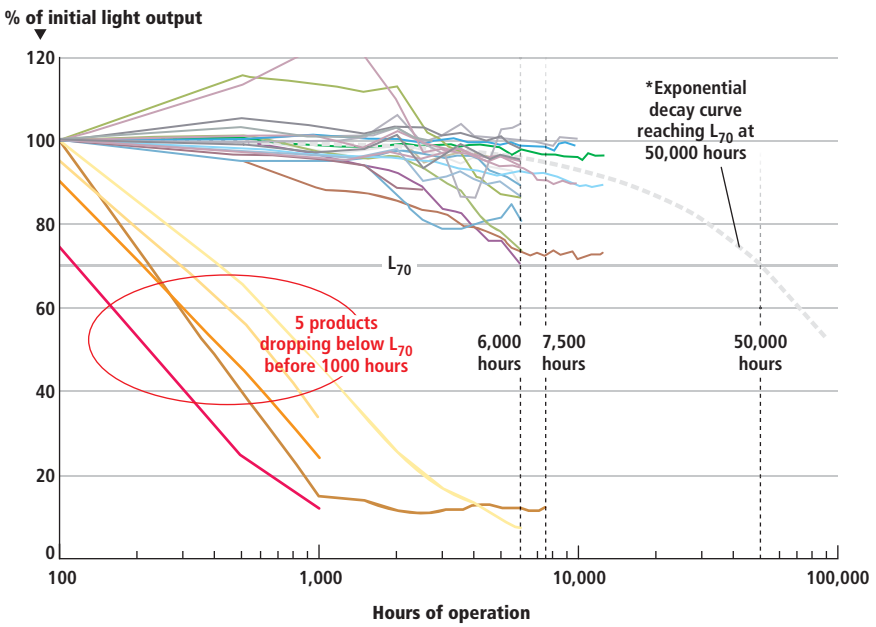

FIG. 1. Long-term lumen depreciation for 26 CALiPER fixtures and replacement lamps, based on spot illuminance measurements from CALiPER round 9 summary report.

JIANZHONG JIAO *(jianzhong.jiao@osram-os.com) is Manager of Regulations and Emerging Technologies at Osram Opto Semiconductors, Inc, and is actively involved in LED and SSL standard development activities. As well as serving as the Chairman of SAE Lighting Committee and being past Chairman of NGLIA, he serves as Chairman of NEMA SSL Technical Committee, and is an active member of several other organizations including the IESNA Testing Procedure Committee and Roadway Lighting Committee, ANSI SSL Working Groups and Standard Technical Panel of UL8750.*

important measure for consumers, and also for Energy Star qualification.

CALiPER testing

The DOE CALiPER program continues to collect luminaire lumen-degradation data, and the Round 9 report released in October 2009 provided a good overview of test results for current SSL luminaire life expectancy (www.ssl.energy.gov/caliper.html). The most convincing information is summarized in Fig.1.

The CALiPER results indicate that the output at 6,000 hours for LED lumen value may not be predictive of a much longer lumen-maintenance (L70) life. Many products that do not meet the single precise threshold at 6,000 hours set by Energy Star may continue to perform well and exceed the required L70 life. These observations are consistent with LED manufacturers' arguments or claims. Also, CALiPER identified that the lumen output of several SSL products declined to below 70% within 1,000 hours or less. This is also consistent with results of qualification tests conducted by major LED manufacturers. In these qualification tests, known as "accelerated life tests," severe stresses are applied to the LED, including extremes of temperature and humidity, and various power levels. These tests can usually identify design and manufacturing defects, and are often conducted before product launch. If the LEDs are designed and manufactured per a specified lumen maintenance life expectancy, and if they pass the tests, the lumen maintenance should be assured.

In standards committees, recommendations to adopt accelerated life tests have been discussed. The group of SSL products that failed L70 within 1,000 hours as identified by CALiPER tests, mostly likely would not pass the qualification or accelerated life tests.

Similarly, it might be possible in the future to verify via accelerated testing all components in an LED luminaire, so that the performance and lifetime of the integrated system may be more reliably predicted.

Rated life

Another discussion subject in the standard committees is how lumen maintenance (Lxx) relates to rated life (Bxx), and how to define Lxx/Bxx. A forthcoming International Electrotechnical Commission (IEC) standard and other US standards may provide a more precise definition.

> "The purpose of LM-80 is to establish uniform test methods for lumen maintenance of LED light sources including LED packages, arrays and modules."

Conventionally, B describes the product life in the statistical sense, taking into account catastrophic failures. For example, if an incandescent bulb has B50 life of 1,000 hours, this means 50% of the bulbs will be burned out within 1,000 hours. There is some basic consensus in the standards committees that, for example, an LED rated life of L70/B50 of 30,000 hours means that 50% of the LEDs after 30,000 hours of operation will have a lumen output at 70% of their original value. The catastrophic failures (LEDs burned out) are included, but not separated for the sample calculation.

Functional and decorative lighting

Standards committees around the world have been working on developing standards for LED lighting products based on their energy savings and performance. The energy-efficiency measure of luminous efficacy in lumen per watt is often used as the first criteria to qualify a lighting product for Energy Star. Because of the decorative features of many lighting products, especially for residential lighting fixtures, qualifying their energy saving may require a more practical approach.

Within the IEC, committees are considering the classification of lighting into two core categories, professional lighting and consumer lighting. In the US, NEMA (National Electrical Manufacturers Association) and ALA (American Lighting Association) jointly published a white paper in August 2009 entitled LSD-51 (www.ledsmagazine.com/news/6/9/7) which provides suggested guidelines for qualification of functional lighting, and of lighting products with decorative features.

The principle of the guideline is to have a two-tier qualification system for energy savings and associated performance. In general, if a lighting fixture is classified as functional and its primary purpose is to provide illumination, then the qualification, it is proposed, should be at the luminaire level, and the luminaire can be qualified for Energy Star. A task light is a good example of a functional luminaire.

However, if a lighting fixture has decorative features which give some desired lit appearance for users, then it is recommended that the qualification should be at the light-source level i.e. either the LED lamp or the LED light engine. If an Energy Star label is issued to these types of products, it should be labeled on the lamp and not on the fixture.

The SSL Energy Star program has recently been extended to LED lamps, effective by the end of August 2010 (www.ledsmagazine.com/news/6/12/4). In addition to luminaires listed in Category A of the SSL version 1.1 program requirements, LED lamps can also be qualified for Energy Star regardless of what type of luminaire the lamps are installed into. This two-tier Energy Star qualification process broadens the recognition of the energy-saving potential of LED lighting products.

Color quality of LED lighting

Fluorescent lighting products are labeled with CCT (correlated color temperature)

LINKS

"Why 2008 was the Year of LED Standards"LEDs Magazine April 2009, p29
www.ledsmagazine.com/features/6/4/1

"LED lighting standards and guidelines are now building on a firm foundation"LEDs Magazine May/June 2009, p29
www.ledsmagazine.com/features/6/6/7

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SPEAKERS: *Martin Schon, Thermal Management Product Manager, Sapa Extrusions*
Mick Wilcox, Director of Marketing, Nuventix

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SPEAKERS: *Greg McKee, Director Systems Business Unit, Labsphere*
Todd Straka, Director - Lighting Services, Intertek

As the solid-state lighting industry continues to grow, customers need to be reassured that the products they are purchasing will exhibit stated performance levels while also meeting any applicable standards. This Webcast discusses techniques for test and measurement, as well as the process of safety certification.

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values to give users information in regard to how "white" the light is. The tolerance or variation for target CCT values was set as a 4-step MacAdam ellipse in the ANSI (American National Standards Institute) standard for CFL, and as a 7-step MacAdam ellipse in the CFL Energy Star program.

In early 2008, ANSI C78.377 was established to specify the range of chromaticities recommended for LED products in general lighting applications, to ensure that the white light chromaticities of these products could be unambiguously communicated to consumers. Referencing fluorescent lighting, the original 7-step MacAdam ellipse was used to define the color-variation tolerance. In the past two years of using C78.377 as the SSL chromaticity standard, there have been some misconceptions and misunderstandings.

ANSI C78.377 and CCT requirements

C78.377 recommends two options for specifying white light chromaticity for SSL products. Option one is to choose from the eight selected nominal CCTs (2700K, 3000K, 3500K, 4000K, 4500K, 5000K, 5700K and 6500K). Option two is to choose any CCT with a 100K incremental step e.g. 3200K or 3700K. Furthermore, all the CCT recommendations are only for indoor lighting.

On the other hand, the Energy Star program specifies certain specific CCT values. These are 2700K, 3000K and 3500K for residential recessed, surface and pendant-mounted downlights, and 2700K, 3000K, 3500K and 4000K for LED lamps of any type. So a 3200K luminaire that complies with ANSI standard could not be qualified for Energy Star.

ANSI C78.377 and color consistency

Because CCT tolerance in C78.377 is based on a 7-step MacAdam ellipse, it should be understood that a group of SSL products that all have the same nominal CCT, and therefore sit within the same CCT quadrangle as defined by C78.377, may look noticeably different in color. This is also true for the Energy Star program.

LED lighting manufacturers can control their products' color variation and limit this to a 3-step MacAdam ellipse or even tighter color tolerance. As a result, a group of the same product types from a given LED manufacturer may all look alike in color. However, when comparing these same products to those of another LED manufacturer, who uses the same tolerance and target CCT, they may look noticeably different in color. Therefore, it is possible that SSL products meeting the same ANSI chromaticity standard or meeting the Energy Star requirement may not have consistent color in all cases. Also products labeled with the same CCT number from different manufacturers can look different in regard to color.

LED color-shifting behavior varies from manufacturer to manufacturer based on the LED chip and package technologies used.

ANSI C78.377 and color acceptance

ANSI C78.377 provides recommended chromaticity boundaries in the color space for indoor LED lighting products. This range was chosen based on the preexisting CFL lighting products and on LED manufacturability. Because perceived color can be subjective, it does not mean that the colors outside of the ANSI color range would be unacceptable, as some people prefer warmer-white light and some prefer cooler-white light. As LED lighting is "tunable", lighting experts can now continue to study human perception and adaptability to help identify an acceptable and more meaningful color range for good color quality for specific lighting applications.

ANSI C78.377 and color binning

Using ANSI C78.377 recommended color ranges and target CCTs, LED manufacturers further divide or sort the LEDs into smaller color-variation groups, and mark the groups with specific identification codes, in a process known as binning. LEDs are sorted into color bins after being measured at room temperature. However, LED color-shifting behavior varies from manufacturer to manufacturer based on the LED chip and package technologies used. Selecting LEDs from the same color bin from different manufactures may, therefore, not produce the same color appearance in the final luminaire or lamp, when the LEDs are operating at elevated temperatures.

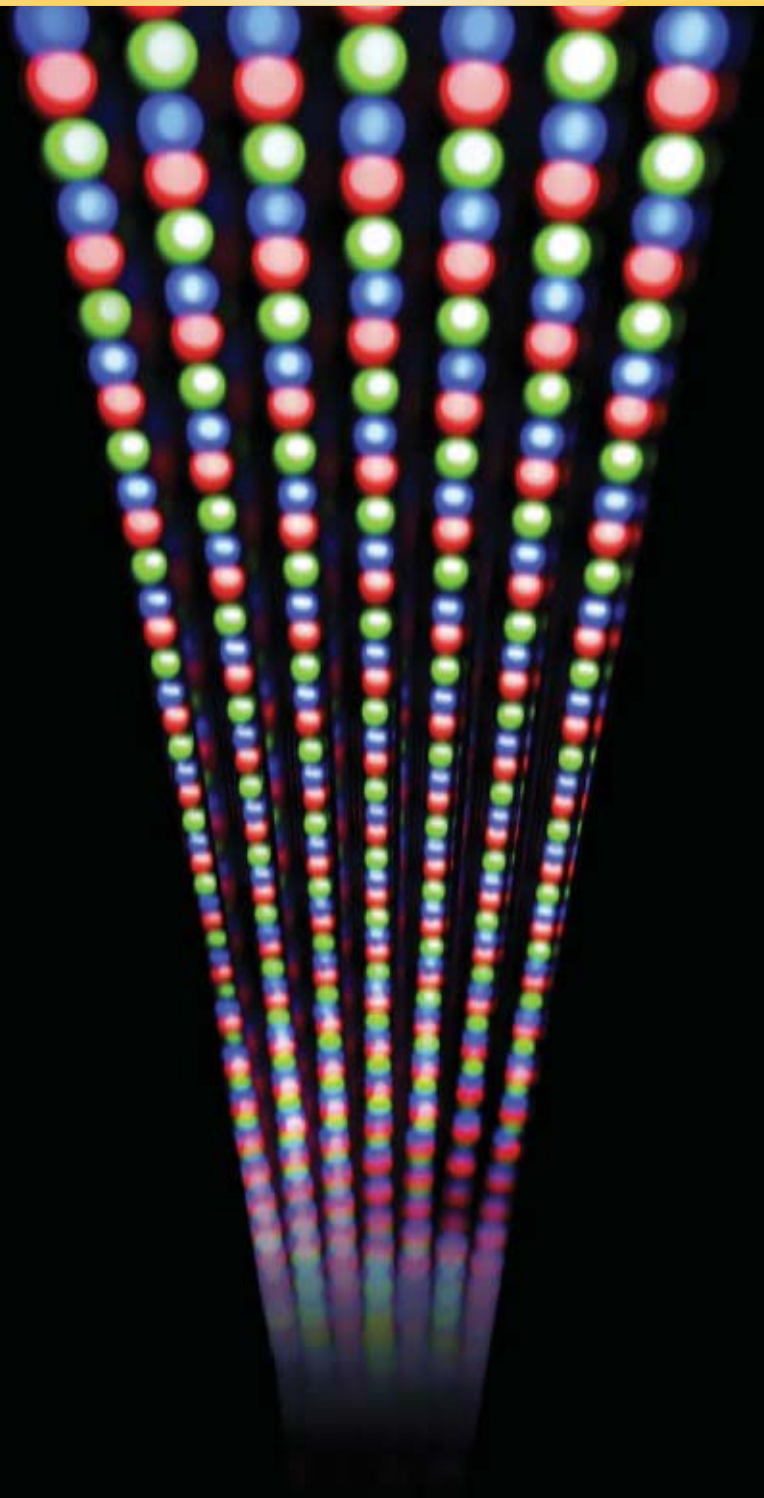
International harmonization

The global SSL standards harmonization effort continues. In the last few months, IEC has been actively working on several LED lighting related standards. Also on behalf of ANSI, the USA Technical Advisory Group (TAG) has been regularly participating in the IEC standard development work. Different from the US approach, where SSL standards are developed by IESNA (for testing), ANSI and NEMA (for performance) and UL (for safety), IEC is developing LED lighting related standards for all applications in a system that is similar to that used for other lighting devices.

IEC mainly divides the standards into two categories — safety and performance. Then it divides the LED lighting based on the level of integration or configuration: LED module, LED lamp and LED luminaire. From there, IEC specifies the safety and performance for each integration level. IEC also considers each standard's consistency across all applications, for example when LEDs are used for general lighting, automotive lighting, backlighting and other applications. This consideration is part of the initiation of LED binning standards currently under development in IEC.

Conclusion

LED lighting standards development has been moving forward, and many new standards are under way. Public education for standards users must be part of the next steps. The new standards affect LED component, subsystem and luminaire manufacturers, and they also affect lighting designers, specifiers, municipalities and utility companies. This means education is key in promoting awareness and understanding of the new standards, in order to continue to move forward the adoption of SSL.



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Intelligent LED drivers combine a constant-current source with sensing and control capabilities

Roll your own intelligent LED driver for maximum functionality and to establish your own intellectual property base for future products writes **STUART WOODROW**.

Countless number of lighting companies and engineering houses are jumping into the general illumination business with the advances and opportunities created by LED-based solid-state lighting (SSL) technologies. SSL brings many new challenges for those looking to redesign lighting fixtures or design retrofit lamps for existing Edison sockets. One major challenge is the LED driver. Companies can purchase off-the-shelf LED driver modules, although recent advances in driver ICs will allow many companies to design their own intelligent drivers with optimized feature sets such as dimming, color control, and sensors.

Many early adopters of LED technologies for lighting started out thinking the move would be a simple evolutionary step but quickly found out that the move was revolutionary. They discovered that they needed serious engineering disciplines to implement new electronics, optics and thermal technologies. Many who took the initial steps in electronics produced sub-par products and had to redesign their products to get more efficient and optimal results. Others outsourced their designs to competent power and analog engineers who spent a lifetime learning how to drive the power circuits and constant current required by LEDs. The electronics required have been called lighting ballasts or power supplies but are commonly and collectively referred to as LED drivers.

Off-the-shelf modules

Today, engineers can purchase standard off-the-shelf LED drivers from well known companies such as Philips Advance, LED Dynamics, Meanwell, or Magtech. LEDs require constant currents derived from various AC or DC input voltages. Universal AC inputs of 120VAC for North America or 230VAC for Europe are common for general illumination products while 12VDC and 24VDC are typical for specialty lighting subsystems.

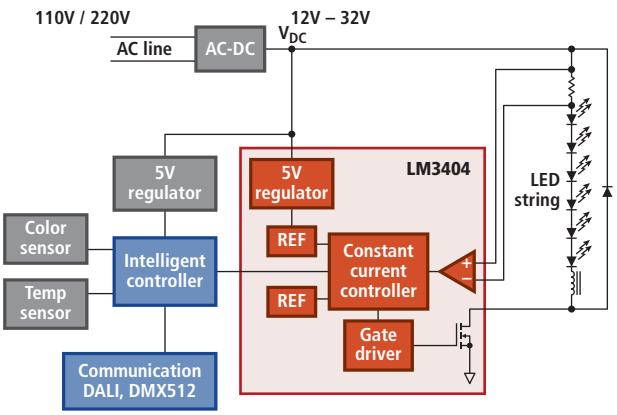

FIG. 1 Intelligent single-channel LED driver using a microcontroller and a constant current driver

Buying an LED driver module can provide fast time to market and an easy design cycle but will also add additional costs to the final product. Further, if your requirements do not match the LED driver specifications exactly you could lose efficiency in your product and not provide your end customer the truly green power savings offered by LED solutions.

Alternatively, there are many electronic products on the market which will let designers build intelligent LED drivers. Many of these products include microcontrollers which allow engineers to design programmable and flexible platforms that can be modified and used across multiple projects. This methodology allows designers to reuse the intellectual property that they develop and easily add new features and upgrade specifications while reducing R&D expenses.

For instance, it is becoming increasingly popular to add a communication link to LED lighting systems for control of power, dimming, color mixing, and strobing of the output. Power-line modems, wireless radios and wired links are becoming very popular. DALI is a widely used wired standard in Europe and DMX512 is used worldwide for entertainment and architectural lighting systems. An intelligent LED driver will enable a designer to easily add these communication links to a luminaire and control the luminaire via the microcontroller in the driver.

Energy spurs transition

LED lighting systems are growing in demand because of their inherent energy saving qualities. An 8W LED lamp can

STUART WOODROW *is Principal Business Development Engineer for Intelligent Lighting Solutions at Cypress Semiconductor.*

produce the equivalent lumen output of a 60W incandescent bulb. To further increase the energy savings of the LED fixtures, sensors are being added to these intelligent LED drivers to control when the bulb is required to be producing light. Ambient light, motion and occupancy sensors are easily added to intelligent LED drivers as most microcontrollers can read the analog voltage outputs of these sensors with their internal analog-to-digital converters (ADCs).

The benefits realized by using sensors and intelligent drivers are obvious in the fact that the fixtures are only producing light when required and the energy savings are easily calculated. This will certainly bring down the payback period of purchasing and installing intelligent lighting fixtures in both residential and commercial applications. Feedback from color sensors in RGB systems will also become popular and will require intelligence to ensure architectural designers get the precise color they have specified over the lifetime of the LEDs.

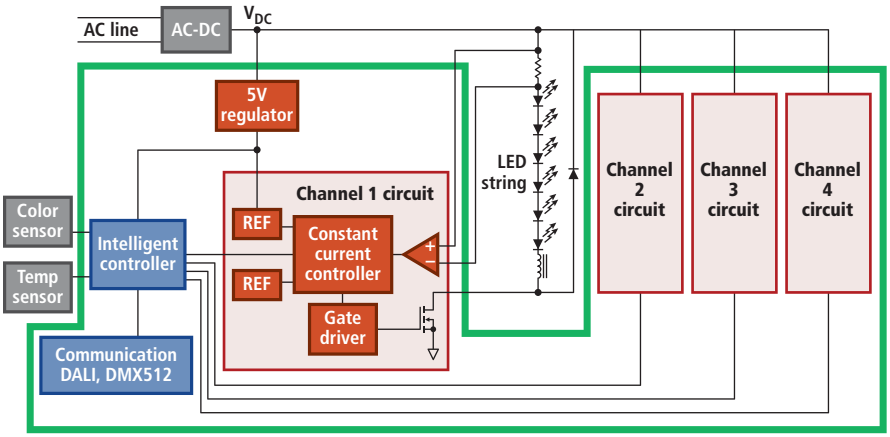

FIG. 2 The Cypress PowerPSoC is able to integrate up to a 4-channel LED driver (the circuitry bounded by the green line) with minimal external components.

Flash (non-volatile memory) based microcontrollers also provide the advantage of being able to write and store intelligent information about the lighting product. Critical run time information can be calculated, stored and read back at a future time. Fixture on-time, serial numbers, shock and temperature profiles are some of the pertinent information of interest to lighting manufactures today as they are able to use this

data to determine warranty terms and conditions. Lighting manufacturers are touting 50,000 hours on their LED lighting products and using flash memory to capture lifetime data on their products can provide critical feedback they require.

Design options

There are lots of components on the market today to help you design your own intelligent LED driver electronics. You can purchase and program your own microcontroller and interface it to a number of standard driver circuits like National Semiconductor's LM3404 which has integrated the 5V regulator, constant current controller, gate driver and a FET on a single IC. A typical 1-channel LED driver solution is depicted in Fig. 1. The circuit shows a microcontroller fed by a standard communications link for intelligent control. The microcontroller feeds the constant current controller/gate driver/FET to produce the required current for the single channel of 6 LEDs.

This methodology can scale to add additional channels of LED drive to create color schemes by adding additional LM3404s and using RGB-A LED arrays. While this is a common way to drive today's LED for high lumen output LED fixtures, it can be costly and cumbersome to include all of these components on a single PCB.

More integrated solutions are arriving on the technology front every day as driver manufacturers work to reduce component count and cost to their customers. Optimally, products like PowerPSoC by Cypress Semiconductor provide design engineers with all the building blocks required to build intelligent LED drivers in a single monolithic thermally-enhanced package. PowerPSoC integrates the widely-used programmable system on a chip (PSoC) architecture with current sense amplifiers, hysteretic controllers, a 5V (32V input) DC-DC regulator and power FETs onto a single integrated circuit. This system-on-a-chip approach enables luminaire designers to create platforms of drivers which will span across all marketing requirements.

Power and processor

PowerPSoC is the first device to combine the functionality of an embedded microcontroller with integrated high-power peripherals. The power circuits includes four internal 32V, 1A-rated low-side n-channel MOSFETs, four 32V, 6-MHz-rated current sense amplifiers, four 2-MHz hysteretic controllers that can be configured in either buck, boost, or buck-boost topologies.

Fig.2 depicts an implementation of a 4-channel intelligent LED driver in a concert lighting application which drives an RGB-A cluster of LEDs. All of the external components required in the previous application example are integrated into the Power PSoC including the microcontroller, communication link, constant current controller/driver, 5V regulator and FETs. The DMX512 protocol is an included module within the PowerPSoC development tool.

The 5V regulator on-board is able to take in the DC voltage and provide 5V for the Power PSoC as well as to provide current to other devices on the board including the RS-485 DMX512 transceiver. Additionally, the constant current controller/gate driver and FETs are able to drive strings of LEDs directly at up to 1A and 32V. In this example, the Power PSoC is driving 4 channels of (6) LEDs with a forward voltage of 21V at 700mA. It uses an efficient floating-load buck topology to provide the required 21V from the 24VDC derived from the AC-DC converter. Alternatively, the Power PSoC could implement a buck-boost, boost or SEPIC solution depending on the input voltages available and number of LEDs in the system.

last word

LED lighting can enable smart homes and enhance lifestyles

LED lighting could spawn integrated intelligence that can be spread throughout the home delivering myriad potential benefits, says **DON PEIFER** of **LUNERA LIGHTING**.

The first wave of "baby boomers" is reaching retirement age, and with it, a generation of self-reliant individuals faces the specter of assisted living. One possible outcome is the development of smart environments, where monitoring and home automation helps extend the time that "boomers" stay in their home while maintaining their normal life style. A large component of the smart home environment is lighting, and LEDs far exceed other technologies' potential to meet the needs of the aging population.

Circadian lighting is an obvious place where LEDs—by being able to give a unique spectral prescription of light—can help normalize the sleep patterns of older adults, increase their sense of well being and be able to reduce the symptoms of Alzheimer's disease. Research coming out of the Lighting Research Center suggests that not just the elderly but all segments of society—especially in the era of deep-core offices—can benefit from appropriately-timed doses of light. Light and health will play an important role in shaping the future home.

Another exciting possibility for LEDs in the future home is the integration of networked controls and lighting. LEDs are digital devices. They can be manipulated readily without adverse effect. The question to ask is: given this malleable, controllable device, what are the possibilities? One possibility, believe it or not, is the next generation of computing.

The discipline of ubiquitous computing was predicated on the fact that computers demand too much of people's attention, and, if they were to truly evolve, they should disappear into the environment where they could "calmly and quietly" assist people. In order to do this, the computer must shrink and then be distributed throughout the space. They would also need to sense their location and communicate with one another. In this way they could monitor, interact and assist the occupants.

Most of the components in the workaday environment already contain a chip: light switches, outlets, appliances are all *de facto* computers. Thus the first criterion, shrinking the computer and distributing it throughout the environment, has already been met. Where ubiquitous computing stumbled, however, was in thinking that all these little computers were cumbersome and needed to be stripped bare. Computing power and storage should all be done on the back-end. Feature sets, however, are sacrosanct to the appliance manufacturers, back end servers proved impractical and, as a result, the movement floundered.

Instead of stripping down the components, what advocates needed to find was a super-component, and they need look no further than LED lighting. It is digital. It is laid out in a fairly regular grid. It becomes the perfect Trojan horse for bundling not only processing and data storage but sensing and communications into one package and distributing it throughout the environment. With the cost of chips and sensors plummeting, a non-prohibitive add-on to each LED node in the house allows the potential of all the other components in the built environment to communicate, sense, locate and assist the occupant.

The future of lighting doesn't have to be limited to occupancy or daylight harvesting functions. The addition of RFID technology would allow for personalized lighting for each occupant. We could have under-cabinet fixtures, for example, which would be a glare source to a person in a wheelchair, dimming when that person enters the room. Way-finding, security, time schedules, heating/cooling, smart appliances would all be facilitated by LED lighting. It becomes the source of wireless internet and the information mesh for the entire building.

As seen with iPhones, once established, the application potential is limitless. Setting up the infrastructure is the important part. Build it, and they will come. The built environment should not be treated as a democracy however. Commercial buildings have endlessly struggled for years trying to establish a diplomatic protocol where the different elements (HVAC, lighting, security) communicate. It is time for one component to step up and lead the way, and LEDs because of their myriad utility is that component. The future of both homes and information technology lie hidden inside an LED fixture. All we have to do is harness that potential and unleash the possibilities. The result is an environment in which an aging society both benefits and evolves.

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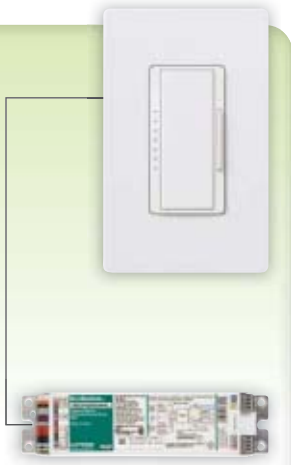
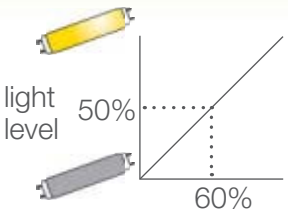
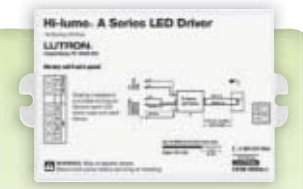




LED Dimming



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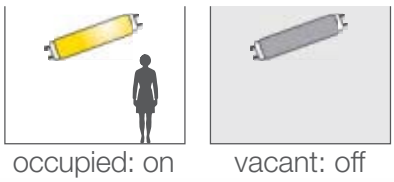

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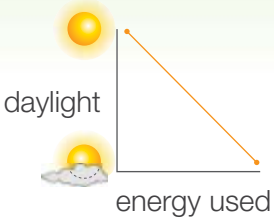

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