www.ledsmagazine.com Technology and applications of light emitting diodes

LEDs MAGAZINE

LEDs Magazine Review

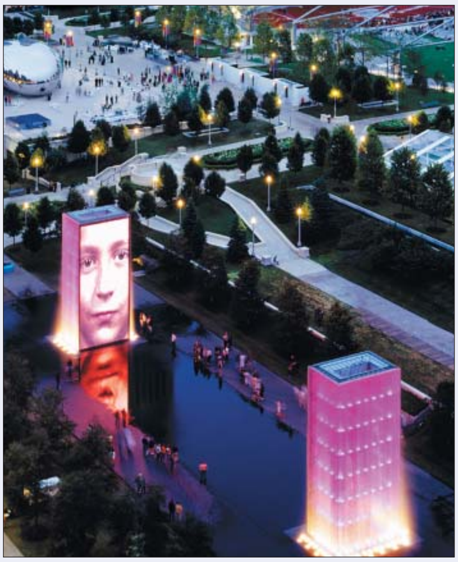
IoP

Issue 2 July 2005

Editor: *Tim Whitaker* editor@leds.iop.org Tel. +44 (0)117 930 1233 **Advertising sales:** joanna.hook@iop.org Tel. +44 (0)117 930 1028

Could the Audi Allroad concept become the first production car to feature all-LED headlamps? **p13**

This LED/incandescent light fixture can save on energy and costs, and reduce light pollution. **p33**



Projects featuring LEDs were among the winners of the 2005 International Lighting Design Awards. **p35**

LEDs Magazine is published by IOP Publishing Ltd and Cabot Media Ltd. Contact address: Institute of Physics Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK.

Primary sponsor: PHILIPS

Organised by: lighting equipment news

Photo courtesy of LEDs Magazine (c) www.lightmoves.com.au

Thursday 15th September 2005 - RIBA, 66 Portland Place, London W1

Integrating advanced technology in functional lighting design

The next **LED** generation

There is a wide discrepancy between the theory of manufacturers and the reality of the lighting market when it comes to LEDs. This unique conference will deal with the latest best practice methods on how to successfully use LEDs, covering everything from procurement, installation and management issues to new developments in standards and patents. Do not miss out on this chance to share expert knowledge on how to integrate advanced LEDs into your next lighting project and access lucrative business opportunities.

Industry leaders will provide:

- An analysis of the latest LED technology trends and their market potential
- Expert knowledge of maximising lumen output with controls, optical lenses and thermal management
- Professional advice on procurement issues with regard to colour binning and rapid new product development
- An understanding of standards for measurement of optical output and safe handling
- Insight on international patent law and the impact on your business
- Ideas for new market applications and creative lighting design

Expert speakers include:

Luc van der Poel, Innovations Manager
PHILIPS

Jim Anderson, Vice President of Marketing
LAMINA CERAMICS

Gordon Routledge, Managing Director
LUMIDRIVES

Dr Kevin Dowling, Vice President of Strategy and Technology
COLOR KINETICS

Brett Kingstone, President and CEO
SUPER VISION INTERNATIONAL

For more information and to register - Tel: 020 7505 6044
Email: conferences@emap.com **www.ledsconference.co.uk/2005**

NATIONAL PROGRAMS

Next Generation Lighting Initiative moves closer in US

The Next Generation Lighting Initiative (NGLI), a public–private partnership in the US that could provide up to $50 million annually to develop the national solid-state lighting (SSL) industry, may finally be passed into law this year. So far, the House of Representatives and the Senate have both passed versions of the Energy Bill, a major piece of legislation that contains a section authorizing the formation of the NGLI.

However, the two versions differ on some controversial issues that have derailed past versions of energy legislation; for example, drilling for oil in Alaska. At the time of writing, a conference committee was being formed to attempt to reconcile the two versions of the bill. The NGLI is not viewed as controversial and the wording in the two versions is essentially the same.

The NGLI authorizes the US Department of Energy (DOE) to receive a significant level of funding for SSL, and also instructs the DOE to work closely with industry to ensure that the fruits of its development program are ultimately turned into products that save energy. At present, the DOE operates a successful Solid State Lighting program, and funds many projects relating to LEDs and OLEDs.

In its current form, section 912 of the bill requests funding in the amount of $50 million for the NGLI in each of the fiscal years 2006 through 2008. The exact amount of funding that would go to the DOE is set by appropriation committees. At the moment the presidential budget request includes funding for the DOE to support SSL in the amount of $11 million for the financial year 2006. Clearly an increase to $50 million per year would have a significant effect.

The wording of the energy bill calls for the NGLI to support research, development, demonstration, and commercial application activities related to advanced SSL technologies based on white LEDs (which includes both organic and inorganic devices).

- More details: www.ledsmagazine.com/articles/news/2/7/8/1
- Energy Bill progress: www.energy.senate.gov/public

PATENTS

Color Kinetics and Super Vision await decision on jury trial

No decision has yet been reached on whether the patent dispute between Color Kinetics and Super Vision will go forward to a jury trial. The case, the outcome of which could have a strong influence on many LED equipment manufacturers, centers on the validity of Color Kinetics' numerous patents in the area of intelligent control of LED-based fixtures (see "Patent protagonists head to court").

Hearings on a number of summary judgment motions concluded in early June in Boston. (A summary judgment is a ruling that a case is not sufficiently strong to go forward to a jury trial.) The judge decided not to rule until he could review all the evidence.

This evidence included many affidavits from inventors and manufacturers in the industry that support Super Vision's claims that the Color Kinetics patents rely heavily on prior art. These affidavits can be viewed on the LED Alliance website.

Super Vision's aim is to move the dispute forward to a jury trial. Brett Kingstone, Super Vision's CEO, said, "We hope that we can bring this case before a jury of our peers who will be able to listen to the actual prior-art inventors and practitioners in person."

New affidavits have recently been filed by Brent Brown, inventor and manufacturer of the first LED display commercially sold in the US, and Paul Miller, founder of Sunrise Systems, who built his first LED sign in 1979. That sign had a fade in/out command that used ramped pulse-width modulation (PWM) to progressively dim the LEDs. The use of PWM within Color Kinetics' patents is central to the ongoing dispute.

Color Kinetics' first patent was filed in August 1997, and the company has claimed that, at that time, neither the circuitry nor control methods existed to replace incandescent systems with LED lighting fixtures. Super Vision presented evidence in court refuting these claims.

- See articles on the Color Kinetics–Super Vision case at: www.ledsmagazine.com/articles/features/1/12/10/1

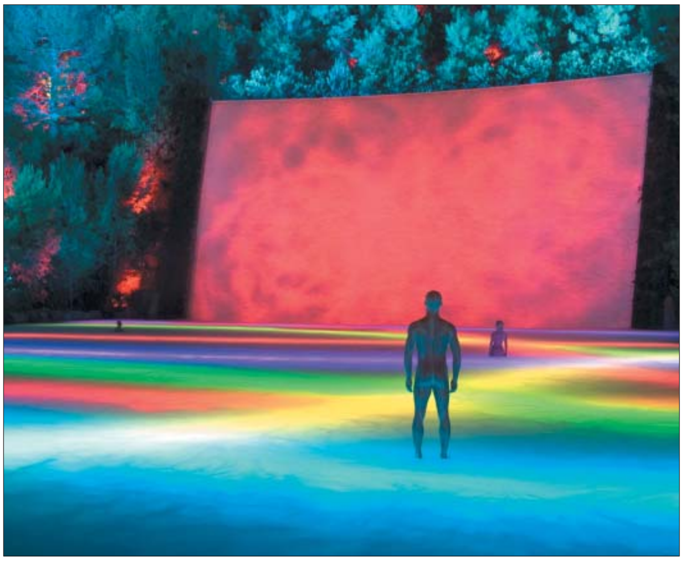
ENTERTAINMENT

Color Kinetics lights Lake of Dreams at Las Vegas casino

More than 4000 individually controlled underwater LED fixtures are providing spectacular lighting effects as the centerpiece of the $2.7 billion Wynn Las Vegas resort and casino. The Lake of Dreams spans 20,000 sq. ft and boasts a sophisticated underwater lighting system unlike any other. The Color Kinetics® C-Splash 2 units are installed on 700 removable panels at the bottom of the 4 ft-deep lake. Intricate patterns and psychedelic colors on the lake's surface complement video images projected onto a waterwall behind the lake.

In order to properly illuminate the lake, millions of tiny reflective bubbles are generated by air compressors, creating a reflective surface for the lights. The entire lake can be filled with bubbles in 15 seconds. The system integrator was Production Resource Group.

- More details: www.ledsmagazine.com/articles/news/2/7/9/1



More than 4000 individually controlled Color Kinetics C-Splash 2 LED fixtures are submerged beneath the Wynn Las Vegas lake.

OLEDS

European consortium tackles issues for OLEDs in lighting

Demand for OLED displays continues to grow at a healthy rate. According to iSuppli, a market research firm, the market will reach $615 million in 2005, based on shipments of 60 million units. Through 2011 the OLED market will see a compound annual growth rate of 34%, reaching $2.9 billion.

While many applications use OLEDs as an alternative to LCDs for displays in mobile phones, much larger displays are also on the horizon. At the Society for Information Display (SID) Symposium in May, Samsung Electronics unveiled the first single-sheet, 40 inch active matrix OLED panel. This development could pave the way for large-size OLED TVs with a total thickness of only 3 cm or less.

Others, however, are more interested in the applications of OLEDs in solid-state lighting (SSL). This is already a subject that receives funding in the US under the DOE SSL program (see p3). In Europe, 24 organizations from eight countries have joined together to form the Organic LEDs for Lighting Applications (OLLA) project.

Founded in October 2004, OLLA will receive a total of €12 million in funding over the course of its 54-month lifetime. OLLA project manager Peter Visser, who works for Philips Lighting in Aachen, Germany, says that the purpose of OLLA is "to gather and focus the European expertise in OLEDs to jointly accomplish everything necessary for the light sources of the 21st century."

Further details emerged at a workshop entitled Building European OLED Infrastructure, which was held in early June in Cambridge, UK, and was organized by the European Photonics Industry Consortium, in collaboration with SPIE. Visser described the principal goal of OLLA, which is to develop a white OLED prototype for general illumination by 2008. This will be a 30 × 30 cm light source with a brightness of 1000 cd/m^2, efficacy of 50 lm/W, a lifetime of 10,000 hours, and a color rendering index exceeding 70.

The group is already looking beyond OLLA towards higher-efficacy light sources, innovative packaging and driving concepts, color tunability, and flexible substrates. Tied to this are market expansion activities such as standards development (lifetime, testing, connectors, size, colors, driving) and mass-production process concepts.

To build a strong European OLED lighting industry, several factors are required, including closer co-operation between industry, academia and institutes, with faster innovation cycles and parallel tracks of fundamental research and production development; removal of technical roadblocks, using a multidisciplinary approach; defining early-entry applications, at the same time building end-user awareness; and building a skills base of experienced personnel.

Visser said that Europe is in a good position to develop OLED lighting, with a complete industry supply chain already located within the EU. Furthermore, OLLA provides the necessary multidisciplinary co-operation between industry, academia and research institutes. However, further research and investment is needed on both EU and national levels to cover education, research and market development.

Clearly, concluded Visser, to maintain the EU's position within the lighting industry, SSL should be included in the 7th Framework Programme (FP7), the next major European funding program for which the first calls will be issued in November 2006.

LIGHT ENGINES

Lamina receives extra funding for expansion in latest round

Lamina Ceramics, which develops super-bright LED light sources, has received a total of $9 million in its latest private financing round, which it will use to expand its operations. The company, spun off from Sarnoff Corporation in April 2001, has received total funding of $37.5 million to date. Lamina recently unveiled a new system of plug-and-play optics for its BL-4000 line of super-bright, high-power LED light engines, developed in collaboration with Fraen Corporation.

- www.ledsmagazine.com/articles/news/2/6/16/1

NeoPac demos 500 lm LED lamp

One of the highlights of the recent LED Lighting Taiwan exhibition was the presentation by NeoPac Lighting of its ultra-high-power LED light bulb. The E6400 NeoBulb Light Engine contains 16 high-power (1 × 1 mm^2) chips and has an output of 500 lm for an input power of 20 W.

- www.ledsmagazine.com/articles/features/2/6/3/1

DISPLAYS

U2's European tour showcases Barco SMD LED display tiles

U2 kicked off the European leg of the Vertigo tour in Brussels, Belgium, in early June with a spectacular stage set featuring a 500 sq. m backdrop of Barco's new OLite 510 indoor/outdoor SMD LED display tiles. The 10 mm pixel pitch technology provides a brightness of 5000 nit.

Earlier this year, Barco supplied its unique MiSPHERE spherical LED modules to form a curtain-like backdrop for the stage during the North American leg of the tour. Saco also supplied LED-based lighting fixtures to light the front of the stage.

- Barco MiSpheres: www.ledsmagazine.com/articles/news/2/4/13
- Saco fixtures: www.ledsmagazine.com/articles/news/2/4/26

Barco's OLite 510 tiles feature in U2's European tour. Earlier, Barco's MiSPHERE modules (inset) formed a backdrop in North America.

LEDs for general illumination: energy codes, lumens per watt, and other lighting criteria

The lighting community needs to be able to evaluate LED lighting products in the same way as any other competing technologies. **Jeffrey Schwartz** of ICF Consulting Inc describes some of the relevant criteria.

As researchers continue to improve the efficacy of white LEDs, lamp and fixture manufacturers will ask the design community to specify LED sources for general illumination on interior-lighting projects. Efficacy, based on lumens per watt (lm/W), is a valuable tool for determining what lighting source a designer will specify in a particular application, but it is only part of the story.

Jim Brodrick, Manager of the US Department of Energy's (DOE) Lighting Research and Development program, is responding to the Solid State Lighting (SSL) industry's request for assistance in helping speed the commercialization of new SSL products for general illumination. He says "We have planned a number of commercialization-assistance activities to make certain that the DOE's substantial investment in new SSL technology results in widespread use of these technologies and in large benefits to the US economy." Those activities include ENERGY STAR specifications (see box), technology demonstrations, assistance for development of voluntary codes and standards, development and distribution of technical information and tools, technology procurements, design competitions, and support of training programs.

If LEDs are to become part of mainstream lighting design, then lighting practitioners must be able to evaluate LED light sources and luminaries (fixtures) for energy-code compliance and performance in the same way they evaluate other lighting products. Below are some of the considerations that go into selecting light sources and luminaires, and the information needed by lighting practitioners before the decision to use LEDs can be made.

Energy codes

The US Energy Policy Act of 1992 (EPAct) is an important piece of legislation that set certain performance standards for lighting equipment. The EPAct was later amended, requiring state building energy codes to meet or exceed ASHRAE/IESNA 90.1-1999 [1] by July 2004.

In addition to certain lighting-control requirements, 90.1 set the lighting power allowance (LPA) for different building types and space types. The LPA is based on watts per square foot (W/ft^2). A typical example of LPA using the building method is 1.3 W/ft^2 for an office building. This means that in a 20,000 ft^2 office building the total lighting power allowance is 26 kW (20,000 × 1.3).

→

ENERGY STAR for residential lighting

by Tim Whitaker

The ENERGY STAR program is a qualification route for products that meet strict energy-efficiency criteria set by the US Environmental Protection Agency (EPA) and the Department of Energy. All traffic signals that have been awarded the ENERGY STAR use LEDs, while many LED exit signs meet the eligibility criteria in the category of operating on less than 5 W per sign.

For residential light fixtures, the ENERGY STAR program aims to move consumers from traditional incandescent fixtures to those using high-quality fluorescent or other energy-efficient technologies. Version 4.0 of the eligibility criteria, which will become effective in October 2005, says that the minimum system efficacy is 50 lm/W for lamps with a total listed power of 30 W, and there are higher efficacy limits for higher-power lamps. The lamp must have an average rated lumen maintenance of at least 80% of initial lamp lumens at 40% (at least 4000 h) of the rated lamp life. The color-rendering index must be at least 80 for compact fluorescent lamps, and must have a CCT with one of the following values: 2700, 300, 3500, 4100, 5000 and 6500 K.

The ENERGY STAR specifications do not currently include any provisions for LED fixtures. However, version 4.0 does include a temporary allowance for decorative LEDs. The document states that "LEDs used as decorative lighting elements in residential-lighting fixtures and ceiling-fan light kits are allowed, as long as the total wattage of the LEDs does not exceed 5 W, the average LED system (LED driver) efficacy is at least 20 lm/W, and the LED is used to supplement a primary light source that meets all of the applicable performance characteristics outlined in the eligibility criteria."

The EPA also says that it "plans to develop more comprehensive specifications for LED performance as the technology advances and becomes more widely used for residential applications."

- **Energy Star program**
  www.energystar.gov
- **Energy Star eligibility criteria for residential light fixtures**
  www.energystar.gov/ia/partners/prod_development/revisions/downloads/fixtures/RLF_V4FINALSpec.pdf

It is important for the LED community to understand that the installed interior-lighting power includes all power required by the luminaires to operate, including the demand from lamps, ballasts, current regulators and control devices. In the case of LED luminaires, this includes all the power used by the LEDs plus the drivers and any other electronic elements. Therefore, as we move from speaking about lm/W for individual devices to discussing general illumination luminaires, the total input wattage, including the driver wattage, must be readily available for evaluation by the lighting practitioner.

State and local codes can also establish other lighting requirements. For example, in California's Title 24 residential energy code, the definition of "high efficacy" luminaires is based on lm/W.

The current code only requires a minimum of 40 lm/W. However, from October 2005 new standards will take effect, and light sources will be considered high efficacy only if they comply with the figures in the table.

In the requirement for fixtures using pin-based fluorescent systems, only the watts of the lamp (not the ballast) need be considered.

LED luminaires can only be considered high efficacy if the "LED can be tested (according to UL) to be at least 40 lm/W on the line voltage input side of any power supply or other device." Otherwise the fixture is not considered high efficacy.

Title 24 Residential Lighting Standards

Lamp power rating	Definition of high-efficacy lighting (lm/W)
15 W or less	minimum 40
15–40 W	minimum 50
over 40 W	minimum 60

Source: California Energy Commission

Light levels

Building energy codes were not created in a vacuum. They are based on the amount of light needed for various applications and tasks, and represent an appropriate energy consumption to meet that light level. For example, based on ASHRAE 90.1, a manufacturing situation is allowed 2.2 W/ft^2, while a warehouse is only allowed 1.2 W/ft^2. The difference is based on the fact that a manufacturing application will typically need a higher light level (typically 50 foot candles) than a warehouse (typically 10 foot candles) for workers to perform the normal tasks. Therefore, the manufacturing building may require more wattage to provide that higher light level.

Light levels are not determined only by the lamp lumens emitted inside the luminaire. Lighting practitioners must calculate how much of the light exits the luminaire and where that light is being delivered. The real question is, "How much light is being delivered to the work plane where the task is being performed?"

To perform these calculations lighting practitioners rely on luminaire photometric reports that are available in standard IES format for software applications and in hardcopy format to easily show the various lighting metrics. While these numbers may not make sense to the untrained eye, when input into a software program a complete photometric report can be developed that tells the lighting practitioner how much of the light is leaving the luminaire, and where it is going.

These numbers can be entered into lighting-design tools to create simulated lighting layouts that show the resulting light levels. The IES reports also calculate the luminaire spacing criteria that tell the practitioner the maximum distance luminaires can be spaced from each other at a certain height, and still provide uniform lighting.

LEDs have well-defined optics, and the LED community should work carefully with luminaire manufacturers to optimize every lumen, so that LEDs can compete more successfully with other sources. IES photometric files are necessary to allow lighting practitioners to validate the results.

Other lighting criteria

In addition to evaluating energy efficiency, the *IESNA Handbook* and section 6.8 of the *Facility Standards for Public Buildings*, published by the US General Services Administration, recommend that quality issues be considered on all lighting projects. Most clients expect good quality along with energy efficiency and low maintenance. Typical quality specifications include a measure of lumen maintenance, a specific CCT, good CRI and glare control.

- **Lumen maintenance** describes the rate of decline in light output over time of a light source. Manufacturers publish curves that can be used to predict lumen maintenance; usually this is expressed as a percent of initial light output at a given number of hours. The behavior of most conventional light sources is well understood, but the LED industry has yet to agree on a standard for measuring and publishing lumen maintenance. Another important factor is a light source's fluctuation

LED luminaires exceed requirements

In May, Permlight Products introduced a series of products for the new-home market, which it claimed exceed the lm/W requirements of Title 24 and ENERGY STAR version 4.0. The luminaires are available in standard efficacy (25–35 lm/W) and high efficacy (40–55 lm/W) versions, which contain different LED modules. The Enbryten products feature completely replaceable and serviceable LED technology, with the LED boards and the power supplies easily changed using just a screwdriver.

- **LED luminaires "will be installed in new homes by fall 2005"**
www.ledsmagazine.com/articles/news/2/5/15

At the end of June, Cyberlux Corporation announced that its Aeon Pro E task and accent home-lighting products had been measured at 55 lm/W by Independent Testing Laboratories Inc in Boulder, CO. The lab confirmed that Aeon products exceed the new Title 24 requirement for kitchen and bathroom lighting of 40 lm/W, which will come into force in October 2005.

"The capability of solid-state lighting technology has advanced significantly," said Mark Schmidt, chief operating officer and president of Cyberlux. "Our Aeon Pro products harness this capability and give home builders, residential designers and home buyers a new, energy-efficient alternative to traditional lighting technologies."

- **Test lab rates Cyberlux LED lighting products at 55 lm/W**
www.ledsmagazine.com/articles/news/2/6/33

in light output as temperature varies. For example, fluorescent lamps dim as they get colder whereas LEDs get brighter, but at different rates for different technologies. Designers need to have quantitative information about any expected variation in light output. [3]

- **Correlated Color Temperature (CCT)** indicates the color appearance of the light emitted by a source, relating its color to that of light from a reference source when heated to a particular temperature, measured in degrees Kelvin (K). Numbers below 3200 K represent a warm source similar to incandescent lamps, while those with a CCT above 4000 K are usually considered "cool", or more like daylight, in appearance. Common CCTs used in general illumination are 2700, 3000, 3500, 4100, and 5000 K. The consistency of the color temperature over the life of the source is also important for uniformity of appearance. Practitioners need to know the color temperature and consistency of LED sources in order to blend them with other sources used in the same space.
- **Color rendering** is the ability of a light source to render the color of an object "correctly." The CRI measures the source's ability compared with a standard source of the same color temperature on a scale of 0–100. The higher the CRI the "truer" colors will appear. High CRI is important in applications where merchandise and people need to appear natural. High color rendering can also help to increase visual clarity and create a more pleasing and productive work environment. Lighting practitioners need to know the CRI of the LED sources being used in the luminaires. If, as some suggest, the color-rendering index (CRI) is not a good measure of LED lighting's appeal to viewers, then the industry should develop an alternative metric.
- **Glare control** is another important issue in many applications. As LEDs improve in efficacy and in total lumen output per package, designers will be challenged to direct the light out, without causing annoying or discomforting loss in visual performance and visibility. Standard photometric reports provide lighting practitioners with some information to evaluate the level of glare.

Conclusions

As the LED research and manufacturing community continues to improve the efficacy of LEDs, manufacturers should go beyond talk of lm/W, and instead quantitatively describe system performance. Total system efficiency is important for meeting building energy codes but there is more to the story, which lighting designers want to hear.

The lighting community needs to be able to evaluate LED lighting products in terms of how much light comes out of the fixture and where it goes. They expect to be able to do that in the same way they evaluate other lighting products. They also need to be able to evaluate other characteristics such as color temperature, CRI and glare by the same standards used for other products.

When LED luminaires for general illumination are available, and this important information is properly provided, then lighting practitioners can consider selecting LED products for specific applications. The final test will be the ability to justify those products based on their energy savings, lumen maintenance, life-cycle costs, and other design and quality benefits.

Links

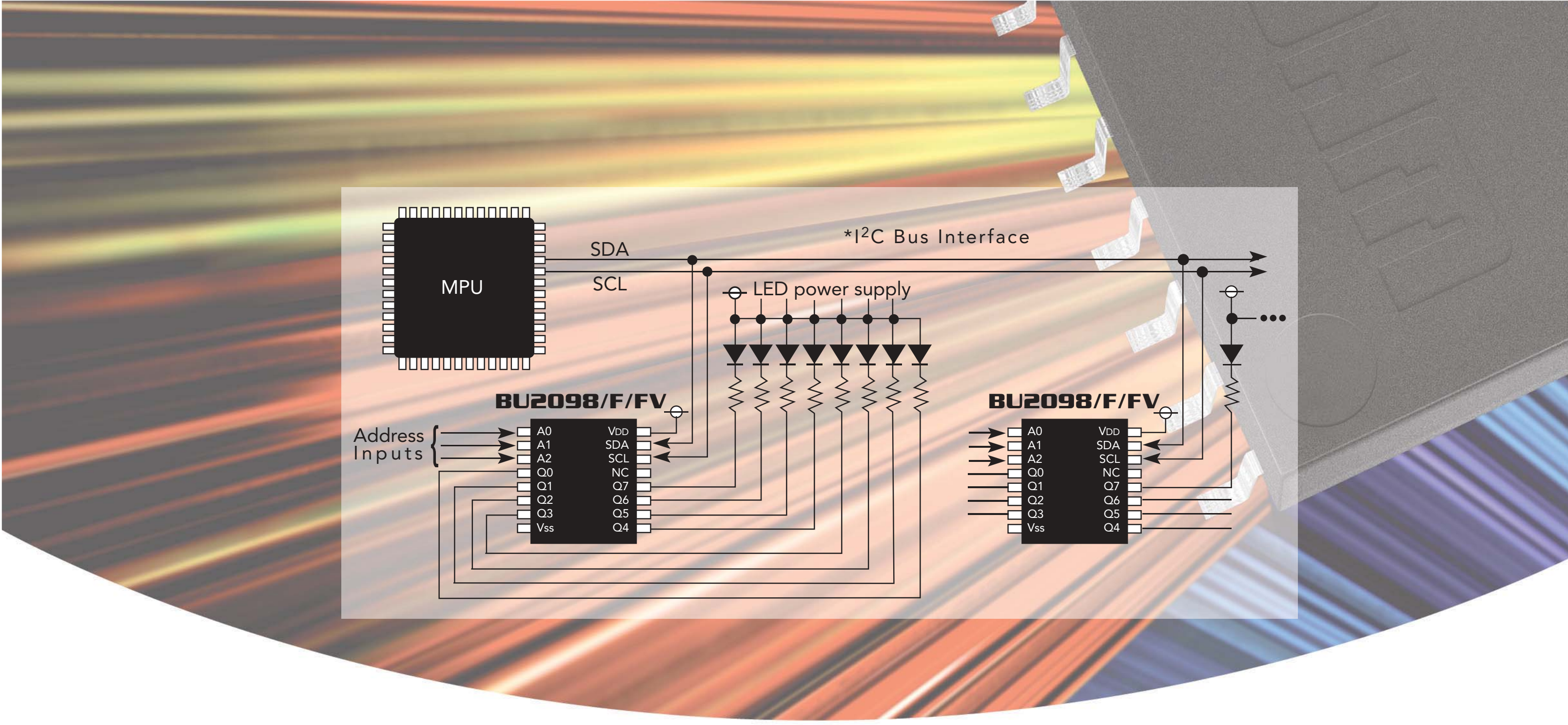
DOE Building Energy Codes program: www.energycodes.gov
The Illuminating Engineering Society: www.IESNA.org
US GSA Facility Standards for Public Buildings: www.gsa.gov
California Energy Commission, Title 24 program: www.energy.ca.gov/title24

About the author

Jeffrey Schwartz, LC, IESNA, is a lighting technical specialist at ICF Consulting Inc. He is lighting certified and is items chairperson for the National Council on Qualifications for the Lighting Professions (NCQLP) Test Committee. He is technical specialist for the New York State Energy Research and Development Authority's (NYSEDA) New York Energy $mart^sm Small Commercial Lighting Program, and serves as a lighting consultant to several utilities and government agencies. Special thanks to Kathryn Conway of LED Consulting for her help in preparing this article.

Footnotes

[1] ASHRAE/IESNA 90.1. The American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc (ASHRAE) and the Illuminating Engineering Society of North America (IESNA) cosponsored the ASHRAE/IES 90.1 standard for energy-efficient design of new buildings, except low-rise residential buildings.
[2] Light-level recommendations are based on the *IESNA Handbook*.
[3] Source: Kathryn Conway, LED Consulting.



LED Driver ICs

Expanding Your Micro Outputs

Part No.	Supply Voltage (V)	Number of Output Bits	Output System	Output Voltage (V)	Output Current (mA)	Strobe Control	Package
BU2090F/FS	3–5	12	open drain	25	20		SOP16/SSOP-A16
BU2092F/FV	3–5	12	open drain	25	20		SOP18/SSOP-B20
BU2050F	4.5–5.5	8	CMOS	5.5	25	✓	SOP14
BA823F	4.5–5.5	8	open collector	25	200	✓	SOP16
BA829	4.5–5.5	8	open collector	15	300	✓	DIP18
BU2099FV	3–5	12	open drain	25	20		SSOP-B20
BU2098F	2.7–5.5	8	open drain	15	10		SOP16
BU2152FS	2.7–5.5	24	CMOS	5.5	10	✓	SSOP-A32
BD7851FP	4.5–5.5	16	open collector	5.5	50		HSOP25

Features

- BD7851FP: 16 constant current output drivers that require only a single resistor for setting up LED current.
- BU2090F/FS, BU2092F/FV, BU2099FV: High output voltage drivers with output set to H impedance during the power up cycle.
- BU2098F, BU2090F/FS: I²C Bus interface.*
- BU2050F, BU2152FS: CMOS output drivers.
- The lineup's output drive current ranges from 10mA to 300mA.
- The lineup includes multi-channel output in a cascade configuration.

ROHM

1-888-775-ROHM
www.rohmelectronics.com

I²C Bus is a trademark of Philips Corporation

Designer-friendly LED luminaires increase conceptual options

Advances in solid-state lighting are opening up a whole series of possibilities in design and architecture that are limited only by our imagination, writes **Ian Mills** of Philips Lighting.

The rules of lighting design are being rewritten. Soon lighting effects will be created that were previously unthinkable: interactive benches that radiate changing colors, walkways with glowing footprints, and walls that reach out with dancing light.

This is all down to today's rapid advances in LED technology, which can be incorporated into almost any object, surface or appliance to provide dynamic lighting that can change color and intensity.

LEDs are ideal for color scene-setting in indoor and outdoor applications. The lighting effect can be diffuse or well defined, and the designer has full freedom in the use of colors. Using single-color LEDs or a combination of three-colored LEDs – red, green and blue – adds an extra dimension, opening up the possibility of mixing colors from different luminaires or within one luminaire. To achieve the optimum lighting effect, lighting controls enable the user to direct the interplay of dynamic colors and changing intensity, or to choose a predefined scene.

Retail experience

Croydon Centrale is one place where LEDs have been combined with architectural lighting controls, with exciting results. Situated in the heart of this bustling commercial centre in the UK, passers-by are intrigued by the flow of colored lighting that leads into the town's latest shopping mall.

On entering the atrium, customers are guided upwards through sweeping walkways by waves of colored light that is integrated within a series of glass floor tiles. Echoing the floor décor is a suspended 14 m-long tile feature that traverses all three levels of the Centrale mall (figure 1). Constructed using 18 tiles and 10 striplights, color-changing effects create a fascinating visual display.

A total of 19 effects have been programmed into the tile feature, corresponding to the seasons. In summer, for example, a touch of a button instructs all the tiles to be illuminated in blue, and there is a red and green option for the festive Christmas period.

Fig. 1. A 14 m suspended LED tile fixture in the Centrale shopping mall in Croydon, UK, provides an exciting decorative effect.

Advanced LEDs

Recent advances in the field of LED technology have opened the door to even more lighting concepts driven by, for instance, the trend towards miniaturization, increased lifetime and efficiency, and sustainability. Diode performance has been improved significantly, and light output is being directed more effectively by a succession of increasingly refined collimator optics. Combined with creative design, this has laid the foundation for a new generation of cutting-edge products.

This latest breed of LED luminaires will enable designers to fill, underline, pinpoint, mark or blend architectural elements with powerful illumination. LED luminaires offered by Philips, for example, are characterized by the integration of state-of-the-art high-power Luxeon technology from Lumileds Lighting (a joint venture between Philips Lighting and Agilent). As well as being among the brightest LEDs available, Luxeon sources offer industry-leading lumen maintenance in a mercury-free package without any heat or UV in the light beam. Moreover, Luxeon LEDs contain no epoxy, which can be prone to optical decay over time.

Mood enhancement

Origami is one example of this new crop of LED products. Compatible with both DALI and DMX, Origami has a pre-programmed color-changing mode for stand-alone use. Origami is a uniform, rimless lighting tile with maximum color impact that is available in square, circular and rectangular shapes. Its evenly lit surface displays a

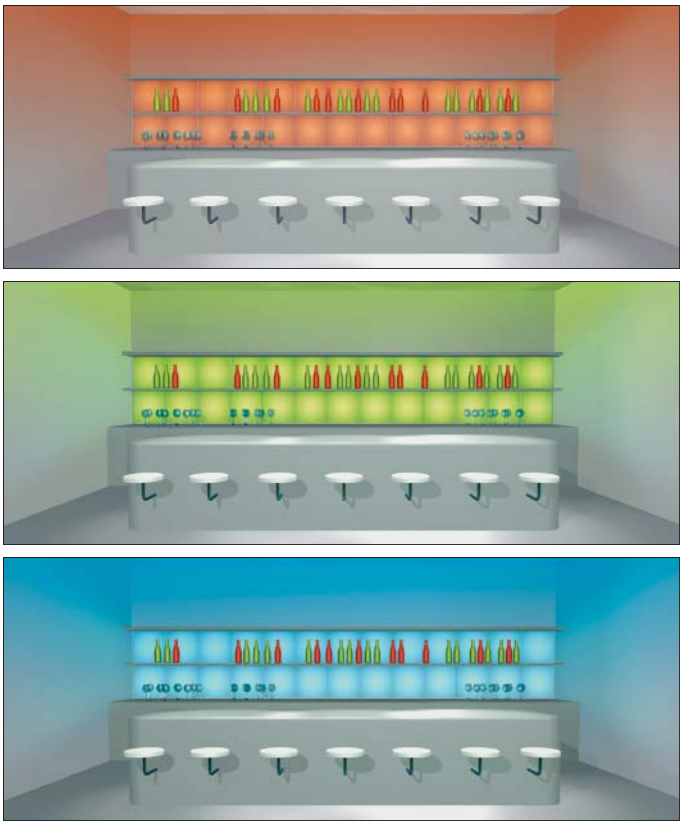


Fig. 2. The summer/winter bar, designed by James Irvine, uses LEDs to achieve optimum lighting conditions for winter (warm orange), spring (green) and summer (cool blue) temperatures.

virtually unlimited range of dynamically changing colors. This versatility, along with the fact that the pace of color changes can be easily adjusted, made it the ideal tool for the designer James Irvine to realize his innovative concept for a summer/winter bar (figure 2).

Research has shown that people in southern countries prefer cool color temperatures in lighting while people in northern countries prefer warm color temperatures. Playing with the fact that we often desire the opposite of what we have, the summer/winter bar changes its atmosphere depending on the temperature outside. On a hot, sunny day the bar offers a cool, fresh atmosphere; however, when it is cold outside, the bar welcomes its guests with a cosy and warm lighting mood.

Combining light and architecture

Looking at original concepts for exterior LED projects, architects Atelier Oï, based in Switzerland, have used LEDflood to develop their concept of intermingling the natural and artificial through light.

The LEDflood floodlight (figure 3) enabled Atelier Oï to depict the dynamic of natural night-time lighting. By gauging and responding to the time of night, the light on the decorative honeycomb panelling is in constant motion. Floodlights are placed behind a membrane façade and produce an inverted lighting effect (figure 4).

Increasingly, architecture and exterior design will be expressed through lighting rather than structure. Philips' LEDflood has been designed with this in mind, illuminating and enhancing structures with colored light, and expanding the creative palette. LEDflood's high visual quality, combined with its innovative and long-life light source, and high-efficiency collimating optics, provides new and advanced lighting possibilities for outdoor floodlighting applications.

Another range of LED-based floodlights is LEDline[2], which is ideally suited to enhance both contemporary and historical architecture. The range comprises three versions – surface, recessed and flood – for the widest possible coverage of grazing-light application, and features the latest technical innovations to facilitate installation, including an integrated power supply and a sealed-for-life optical unit.

Urban lighting

Decoration and guidance apart, the era of LED luminaires that is primarily used for luminance is now changing.

In the area of architectural street lighting, Equinox (figure 5) heralds a new chapter for designers, providing greater quality of light in the urban setting. Incorporating high-power LEDs, Equinox combines energy efficiency with reduced environmental impact, maintenance costs and relamping expense.

Miniaturization and elegance are the main characteristics of this state-of-the-art solution. Uniform illuminance on the ground is provided by the new high-efficiency collimating 'meniscus' optics combined with 18 white and amber Luxeon I and Luxeon III LEDs, which ensures a perfect warm-white color temperature at 2700 K, 3200 K or 4000 K.

Today's urban context, with its mixed architecture of old and new buildings, and functionalities such as streets, cycle paths and pedestrian zones, calls for a high level of flexibility in lighting. Historical façades, for example, made of materials such as brick or sandstone, require different light colors than modern structures made of glass or steel. For warm colors, a color temperature of 2700 K ensures

Fig. 3. Philips' innovative, long-lifetime LEDflood contains nine Luxeon III LEDs.

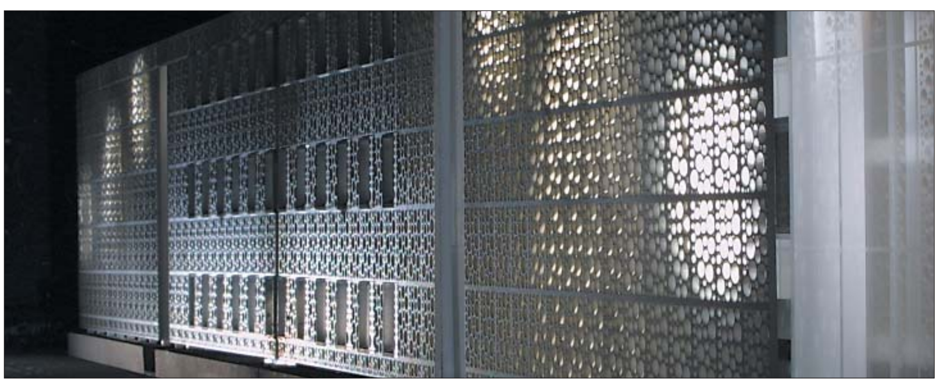


Fig. 4. Atelier Oï uses LEDfloods to translate the dynamic of natural night-time light into artificial lighting. The light on the decorative honeycomb panelling is in constant motion.

effective color rendering, while cool, fresh colors show up best under lighting of 4000 K. In this way, a welcoming ambience is created, promoting social interaction in the urban environment.

As advances in technology increase, without doubt the only limitation is that of our imagination. ●

Fig. 5. The Equinox luminaire, designed to illuminate pathways, squares and shopping areas, contains 18 white and amber Luxeon I and III LEDs in each optical unit, combined with 'meniscus' optics.

About the author

Ian Mills is market manager, outdoor architectural, of Philips Lighting, Guildford, UK.

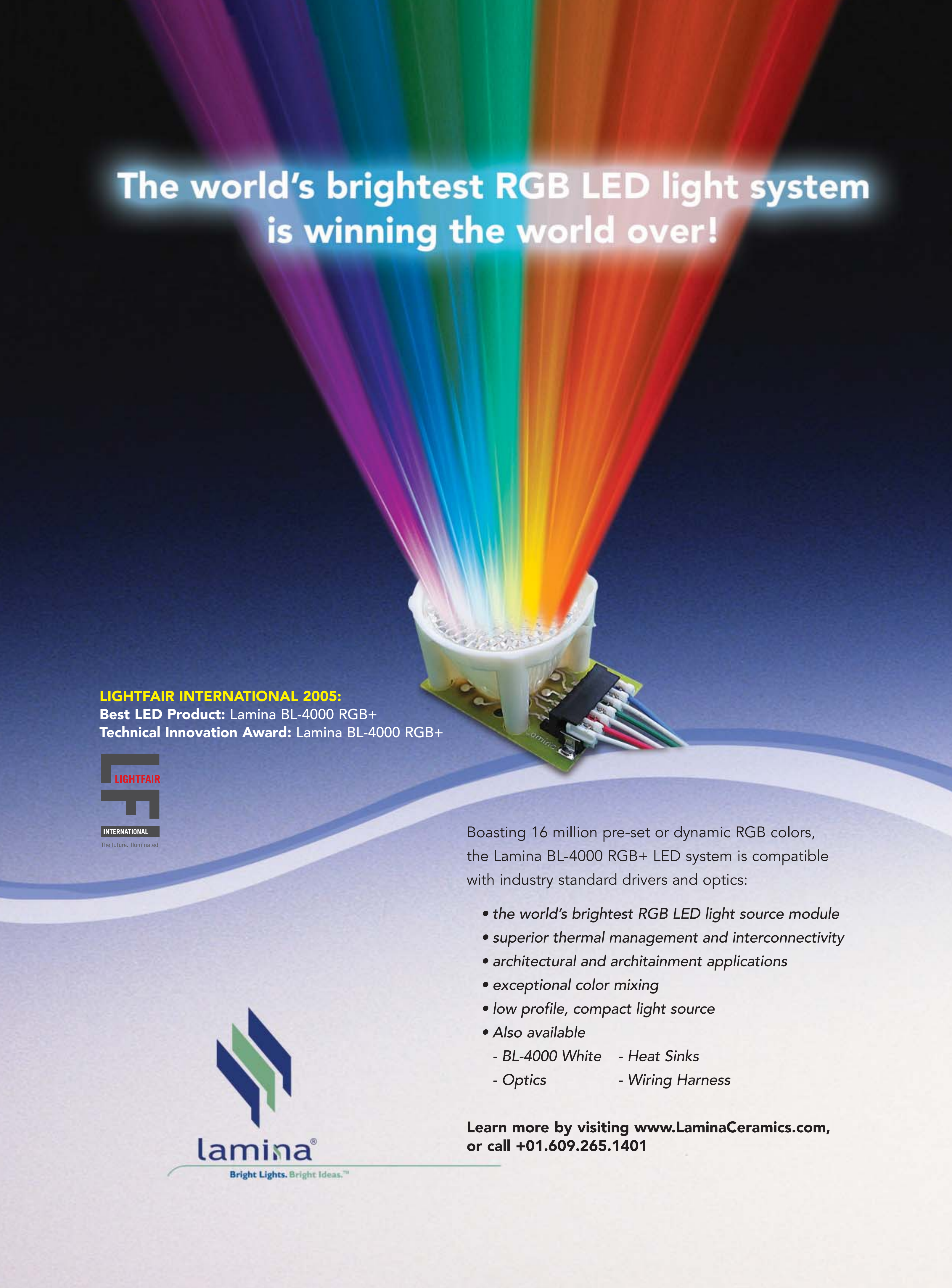
Links

Philips Lighting: www.philips.com/LED

In this issue:
Ambient Experience: LEDs soothe hospital patients
see p30

On our website:
Philips brings light to seating with Glowing Places
www.ledsmagazine.com/articles/features/2/1/14/1

Philips installs first LED streetlights in Dutch town of Ede
www.ledsmagazine.com/articles/news/2/7/16/1


The world's brightest RGB LED light system
is winning the world over!
LIGHTFAIR INTERNATIONAL 2005:
Best LED Product: Lamina BL-4000 RGB+
Technical Innovation Award: Lamina BL-4000 RGB+
LIGHTFAIR
INTERNATIONAL
The future. Illuminated.
Boasting 16 million pre-set or dynamic RGB colors, the Lamina BL-4000 RGB+ LED system is compatible with industry standard drivers and optics:
• the world's brightest RGB LED light source module
• superior thermal management and interconnectivity
• architectural and architainment applications
• exceptional color mixing
• low profile, compact light source
• Also available
- BL-4000 White - Heat Sinks
- Optics - Wiring Harness
Learn more by visiting www.LaminaCeramics.com, or call +01.609.265.1401
lamina®
Bright Lights. Bright Ideas.™

LEDs MAGAZINE

Automotive industry embraces LED use for forward lighting

The introduction of higher-flux LED systems and standardized modules is likely to help automotive forward lighting follow the development path of rear lamps, writes **Deval Desai**.

There have been tremendous developments in vehicular lighting during the last 100 years of the evolution of the automobile. From candles in 1900 to LED daytime running lamps (DRLs) today, lighting has evolved with the drive to increase road safety while providing vehicle differentiation through signature styling.

Rear lighting is a system that has changed relatively little over the past century. The first rear lighting (normally one kerosene lamp) was introduced just before the 1900s to illuminate license plates. Two taillamps became common in the 1930s in the US. In the next phase of development some basic rear-lamp functions (for example, taillamps, license lamps and brake lamps) became compulsory and their characteristics were specified. The first LED center high-mounted stop lamp was introduced on the 1984 Corvette, while the 2000 Cadillac DeVille featured North America's first all-LED rear-lamp cluster.

The first DRL to use white LEDs was introduced on the 2004 Audi A8. LEDs are also now used for front and rear side-markers, for turn signals and puddle lamps on wing mirrors, and for various interior applications such as instrument-panel backlighting and reading/vanity/courtesy lamps.

In 2004 the high-brightness LED market grew almost 30%, and is expected to reach $6.8 bn in 2008. The automotive segment is projected to surpass $1 bn as HB-LEDs continue to improve in light performance, and LED main-beam applications will soon become a reality.

First LEDs in headlamps

In terms of forward lighting, LEDs today are mainly used for secondary functions such as DRLs, turn signals and side-markers. The next-generation Audi Allroad Quattro (figure 1), featured at the auto show in Detroit this year, showcases an all-LED headlamp with discrete sections for low-beam, high-beam and DRL functions. It is believed that this vehicle could become the first production car to feature LED headlamps.

Audi says the headlights are fully roadworthy – with dynamic beam-range adjustment and integrated daytime running lights and turn-signal lights – and are already being put through countless tests and road trials in a prototype setup.

The headlamp also incorporates infrared LEDs to scan the road in front of the vehicle. Sensors behind the windscreen monitor the light beams reflected by the road, which are modulated in each case by characteristic features. This enables the system not only to distinguish between wet, dry and ice-bound roads, but also to recognize road surfaces that have specific grip, such as concrete, various types of asphalt, or gravel.

Styling advantages

One of the biggest advantages of using LEDs in forward lighting is styling flexibility, which enables manufacturers to introduce dis-

Fig.1. Could the Audi Allroad concept become the first production car to feature all-LED headlamps? The lights are fully roadworthy and have been put through countless tests and road trials. The different functions are as follows: turn-signal (a), low-beam headlights (b), high-beam headlights (c), parking lights (d), daytime running lights (e), and lights off (f).

Fig. 2. The Lexus LF-C concept car features an all-LED headlamp (right) that has a highlighted Lexus logo on the inner lens.

tinctive new designs with radical front and side sweeps. Several LED headlamps have styling cues that are not possible with existing headlamp technologies, such as halogen or HID.

Figure 2 shows the Lexus LF-C concept car, which features an all-LED headlamp carved into the vehicle front end. The LF-C headlamp contains an LED light-engine cluster, and has a highlighted Lexus logo on the inner lens.

LED-headlamp designs will take up less space in the front end, freeing up critical real estate in the engine compartment – necessary for other features, such as electric motors for hybrid vehicles. The compact aspect of LED headlamps is also conducive to the development of front-end modules, which offer system-cost savings in terms of components, manufacturing and engineering via the integration of key functions. Modules also decrease development lead times, and reduce inventory and logistics on the part of the automaker.

Signal lighting

LEDs have made huge inroads in vehicle signal lighting. As shown in figure 3, LEDs appeared in the rear lamps of 36 US car models in 2004, accounting for roughly 1.2 million vehicles, or around 6% of the market. The penetration of LED rear lamps is expected to climb to 12% by 2007, corresponding to some 2 million car sets.

Some of the new vehicles featuring LED rear lamps are shown in figure 4 – these include the 2006 Infiniti M, featuring the signature Infiniti "dot" styling for its stop lamp, and the 2006 Mercury Milan, which has a 12-LED stop lamp. The 2006 Cadillac DTS features a rear-lamp system developed by Hella; the lamp units on each side comprise 31 red LEDs for the functions of tail, brake, turn-signal and side-marking lights, as well as two white LEDs for the reversing lights.

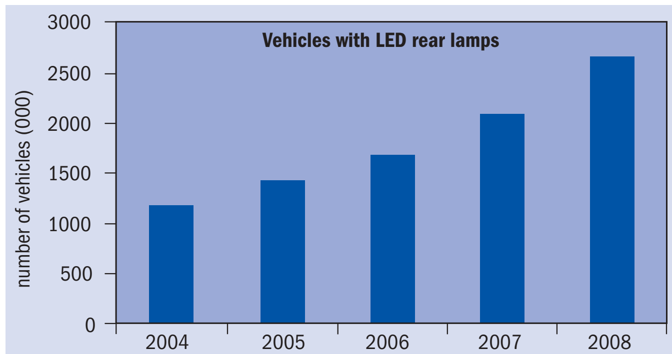


Fig. 3. The number of US vehicles with LED rear-lamp clusters will almost double between 2005 and 2008.

For signal lighting, LEDs provide increased safety because they turn on more quickly than incandescent filament light sources, which translates into a 19 ft decrease in stopping distance at 62 mph. LED rear lamps can also result in increased trunk space owing to thin lamp designs.

Power savings from LED use is another important advantage that becomes critical when considering the increased power demands from other electronic systems in the vehicle. For example, an LED stop lamp can save more than 30 W for the stop function compared with an incandescent stop lamp.

Auxiliary exterior lighting

Other LED applications include auxiliary exterior lighting functions (figure 5) such as turn-signal lamps and puddle lamps in mirrors. Mirror-mounted turn-signal lamps provide improved visibility and safety dur-

Fig. 4. Examples of 2006 models that have LED rear lamps: the Infiniti M (left), the Cadillac DTS (center) and the Mercury Milan (right).

Fig. 5. The wing mirror of the VW Phaeton features an LED turn-signal lamp and a white puddle lamp.

ing lane changes and convey a high-value image of the vehicle.

Mirror-mounted puddle lamps, which illuminate the ground below the wing mirror, provide passive safety by lighting up the area around the vehicle. Other novel applications of LEDs on the vehicle exterior include vehicle-entry lighting, which enhances a vehicle's luxury and provides passive safety, and accent lighting, which is used primarily for vehicle differentiation and brand-specific styling.

Future developments

The price disparity relative to conventional light sources continues to limit LEDs to luxury platforms. However, the introduction of higher-flux LED systems and standardized modules, such as the Joule system from Osram Sylvania (see p16), coupled with lower cost structures and higher LED volumes, will result in reduced prices per lumen.

As LED use in automotive and other applications increases, volume efficiencies will further lower the cost per lumen, making LEDs more compelling on high-volume non-luxury vehicle platforms.

Once they become design-feasible, forward-lighting LED applications will go through similar progressions to those seen in LED rear lamps, which went from a single 70 K annual platform to more than 36 vehicle models, accounting for more than a million vehicles today. ●

About the author

Deval Desai is director of business development at Magna Donnelly, where he is responsible for business intelligence, demand creation and market-development activities. He holds several US patents and has active roles in various SAE Lighting Committees, and other industry-affiliated programs.

Links

On our website:

Vehicles channel
www.ledsmagazine.com/articles/features/1/5/4/1

LEDs for heavy trucks and commercial vehicles
www.ledsmagazine.com/articles/features/2/2/4/1

NEMA and ASSIST focus on solid-state lighting adoption

Industry organizations like ASSIST and NEMA's solid-state lighting section fulfill an essential role as solid-state lighting technology moves towards the marketplace. *LEDs Magazine* spoke with **Chips Chipalkatti** from Osram Sylvania about the activities of these groups.

Although LEDs have successfully penetrated a number of markets, notably the mobile-phone and automotive industries, there is still a way to go before solid-state technology is widely adopted in the global-lighting industry. An essential aspect of this is the role of industry organizations, of which there are several in the US.

The National Electronic Manufacturers Association (NEMA) has a dedicated solid-state lighting (SSL) section in which participants are involved in developing SSL infrastructure. Operating at a different level is the Alliance for Solid-State Illumination Systems and Technologies (ASSIST), which is run by the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute.

LEDs Magazine spoke with Chips Chipalkatti, head of corporate innovation management at Osram Sylvania, who is chairman of NEMA's SSL section and is also closely involved in ASSIST.

NEMA seeks industry-wide consensus

The member companies of NEMA's SSL section are engaged in LED and OLED manufacturing, as well as developing systems and electronics (power supplies and controls). The group is working towards an industry-wide consensus on a set of issues in three areas: definitions, standards and deployment.

Definitions

A variety of terms are used to describe LEDs and the attributes of solid-state lighting sources. This can be confusing for people who make signs or lighting fixtures. Many terms, such as lifetime, efficiency and color-rendering index (CRI), are poorly defined, difficult to understand and frequently misused (see "Metrics for solid-state lighting").

"People talk of the lumen output of monochromatic light sources,

Osram deploys Joule LED lighting system

Osram Sylvania's Joule LED lighting system, which has a standardized, plug-and-play design, is to be used for the first time on the 2006 Mercury Mountaineer.

The Joule system is a bulb-type fixture that aims to make LED technology more accessible in the marketplace by providing OEM designers with a reliable, industry-standardized LED light source to simplify the design process. With its integrated mounting and thermal-management approach, Joule can be used on many vehicle platforms for rear combination lamp (RCL) assemblies.

"The Joule system will allow OEMs to offer their customers LED lighting without the complexity and cost of a custom LED assembly," said David Hulick, global auxiliary product manager.

In the Joule fixture, several LEDs are mounted beneath a circular cap (shown at top in the photo), and the light is directed towards a metalized optic. The large circular base features a wrap-around heatsink, with an integrated USCAR electrical connector.

The LED light source is hidden from direct view, and this makes the Joule system ideal for use with clear-lens RCL assemblies. The system has an input power of 4.8 W and a rated flux of 64 lm.

The number and type of LEDs used in the Joule system can be customized based on customer preference and performance requirements. The 2006 Mountaineer is equipped with a Joule system containing eight LEDs, while future system variations may use more or fewer LEDs. A combination of colors can be used within a single Joule fixture. The 2006 Mountaineer uses two fixtures, one on each side.

or about 'full-spectrum lighting' when a light source consists of a set of monochromatic bands," says Chipalkatti. "Our aim is to try to consolidate the various terms into a basic glossary that people can agree on and use."

Standards

Once the definitions are in place, then a series of standards has to be developed, for example an appropriate definition of CRI, or a standard method for measuring lumens. "We are conscious that standards should be global, and we know it takes a lot of time," says Chipalkatti. "Our approach is to adopt a series of working statements to get the ball rolling. These will evolve over time, until the standards bodies make the final decisions."

NEMA is likely to create a series of working documents that participants can subscribe to and work with as soon as possible, until full standards are reached in several years' time. NEMA's members also participate independently in the various standards bodies.

"We are keen not to reinvent the wheel; if there's an acceptable standard, NEMA could adopt and endorse it," says Chipalkatti. "NEMA wants to be the clearing house to rationalize this kind of information for the industry and the practitioners." Several issues, such as lifetime and CRI, are already being looked at.

Deployment

For SSL products to significantly penetrate the lighting industry, several infrastructural elements need to be in place, not least a quality-assurance program. "Already there are many SSL products from all over the world, and a lot of them don't do what they claim," says Chipalkatti. "This is not uncommon with an emerging technology but it can raise hopes only to shatter them."

Recovering from such bad experiences can be difficult for any industry. NEMA's eventual aim is to regulate its own standards and product quality. "We want to ensure that realistic, rational claims are made, and that these can then be met," says Chipalkatti.

The NEMA group is looking into different programs and the possibility of using a rating system, perhaps similar to the previously used NEMA Premium rating for motors. "This would not be an energy standard like ENERGY STAR," says Chipalkatti, "but would state that the product has been tested according to recognized standards, so that the customer can understand the datasheet and have confidence in what it says. For the installer, this would provide numbers that they can believe in, rely on, and design around."

Finding NEMA

NEMA's SSL section has a strategy task force that is considering all three elements – definitions, standards and deployment. The group meets every two weeks, usually by telephone. There are now 13 members, and other companies have expressed an interest in joining.

Participants, who must have manufacturing operations in the US, should become NEMA members then join the SSL section. The section has a tiered dues structure to assist small manufacturers. In return, says Chipalkatti, the company gains a voice that will have an effect at this important stage of the SSL industry's development. "For interested parties who want to have a say, this is the time to get involved."

NEMA's lighting director Kurt Riesenberg agrees with Chipalkatti. "The SSL industry is facing many challenges in terms of responsible, coordinated development and deployment," says Riesenberg, "and providing systems and component manufacturers with a forum in which they can legally meet to discuss the key issues facing them means that progress in this industry will come more quickly, and with more reliable results."

With NEMA also being the official strategic partner of the Department of Energy (DOE) as administrator of the Next Generation Lighting Industry Alliance, members also have an opportunity to coordinate closely with the DOE on issues such as commercialization and appropriations for future SSL research and development. →

Boeing 787 cabin has LED "sky"

Cabin lighting is used in a new way on the Boeing 787 commercial aircraft, which will fly for the first time in 2007. A unique ceiling treatment throughout the cabin employs state-of-the-art LED lighting to create a subtle but persuasive sense of having the sky overhead.

Both the brightness and the color of the sky-like cabin ceiling can be controlled in flight by the crew. Flight attendants can give passengers a sense of daylight when required, or they can help passengers rest by simulating a beautiful night-time sky.

The Lighting Research Center recently announced a new partnership with Boeing to evaluate current aircraft interior-lighting designs and to specify new lighting concepts and requirements for commercial aircraft. Many of the planned research projects will focus on lighting solutions for Boeing and its partners/suppliers for the new 787.

ASSIST

Chipalkatti is also involved in ASSIST, whose activities form a continuum with those of NEMA's SSL section. "The ASSIST group is focused on practitioners and the deployment of SSL technology, looking at the limitations and strengths in different applications," says Chipalkatti. One of the most useful activities, he says, is the LED Institute, organized quarterly by the LRC, which provides hands-on training.

Since late in 2003, ASSIST has fostered discussions between its members and others in the LED and lighting industries to recommend guidelines for LED operation, performance and measurement. The first *ASSIST Recommends* was published earlier this year, setting forth recommendations that define LED life and life-measurement methods for general lighting (see "Industry alliance proposes standard definition for LED life").

Clearly, this could feed into NEMA's work. "If there's a recommendation from a knowledge-generating group like ASSIST then this could be adopted by NEMA as its working document until a standard is introduced," says Chipalkatti.

The next focus of ASSIST will be to take a more strategic approach to look at what SSL will bring to the lighting applications industry. "We have to evaluate the infrastructural requirements," says Chipalkatti. "Do we make LED bulbs and screw them into Edison sockets, or do we take a fundamental, clean and fresh look to maximize the potential of SSL?"

ASSIST is sponsored by Boeing, GELcore, New York State Energy Research & Development Authority, Nichia, Osram Sylvania, Philips Lighting, and the US Environmental Protection Agency.

Links

NEMA solid-state lighting: www.nema.org/prod/lighting/solid
For information, contact Chips Chipalkatti at Makarand.Chipalkatti@sylvania.com, or contact Kurt Riesenberg, NEMA industry director, at kur_riesenberg@nema.org.
ASSIST: www.lrc.rpi.edu/programs/solidstate/assist/index.asp
For information about ASSIST and the activities of the LRC, contact Dr N Narendran, LRC director of research, at narenn2@rpi.edu.

In this issue:
Next-Generation Lighting Initiative moves one step closer: p3

On our website:
Industry alliance proposes standard definition for LED life (April 2005)
www.ledsmagazine.com/articles/features/2/4/5/1

NGLIA supports initiative to develop solid-state lighting industry in the US (September 2004)
www.ledsmagazine.com/articles/features/1/2/3/1

Moving LEDs into the mainstream: ASSIST develops research, education, and industry ties (September 2004)
www.ledsmagazine.com/articles/features/1/2/4/1

LEDs MAGAZINE

TIR's LEXEL platform provides cost-effective LED lighting

TIR Systems has developed a universal platform for solid-state lighting that incorporates important advances in thermal management, optics, color control and drive technology.

One of the highlights of the Lightfair International trade show in April was LEXEL™, a universal platform for LED-based lighting, which was unveiled by TIR Systems, a lighting company based in Vancouver, Canada.

The platform has been developed over the last two years, and is the result of a complete rethink of how to use LEDs. Rather than building luminaires around existing packages, TIR has incorporated chips into a system where the thermal, optical, mechanical and electrical aspects are all optimized to achieve the desired light characteristics. For example, the color temperature of the LEXEL fixtures can be precisely controlled by the user, and can also be maintained at a constant level when the fixture is dimmed.

LEDs Magazine spoke with Brent York, TIR Systems' chief technology officer, to discuss the developments that constitute the LEXEL technology platform.

At the Lightfair International trade show in April, TIR demonstrated several unique luminaires incorporating LEXEL technology.

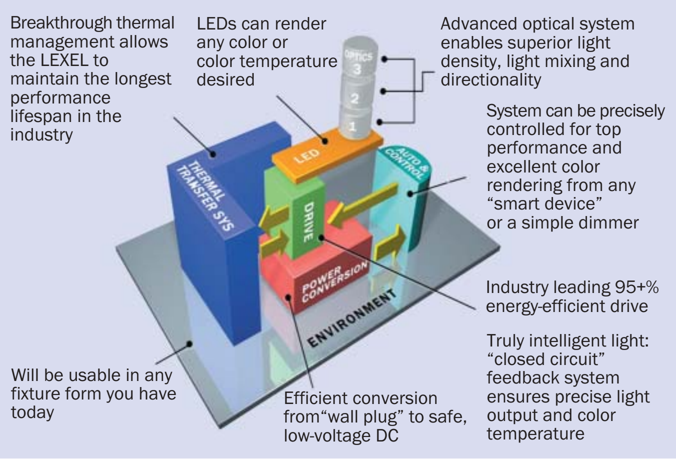
How do you summarize LEXEL?

LEXEL has solved all of the major roadblocks of performance, color temperature, consistency, longevity, quality, and competitive price that have held back solid-state lighting from displacing conventional lighting in specification grade and general lighting markets. Once commercialized, LEXEL will enable lighting manufacturers to compete in illumination markets with solid-state lighting products that outperform conventional luminaires.

How does the optical feedback system operate?

LEXEL uses a proprietary closed-loop feedback technology that cost-effectively monitors the LED color spectrum and light output, as well as thermal operation and electrical current. Using algorithms developed by TIR, the system adjusts the LED drive currents accurately at a frequency high enough to be imperceptible to an observer.

Correlated color temperature (CCT) can be selected and precisely maintained over the lifetime of the fixture, in a typical range from 2200 to 6500 K, and the CCT also remains constant when the fixture is dimmed to zero output. This is enabled by using a multispectrum (RGB, RGBA and beyond) set of LEDs combined with the closed-loop feedback technology described above.



A stylized system diagram of the LEXEL lighting platform.

Does the system also operate with fixtures containing white LEDs?

For simplified LEXEL fixtures that use only white LEDs with a range of color temperatures, the closed-loop feedback system remains active and the CCT will be maintained at a prescribed set point with provision for dimming.

It is important to note that the black body locus that defines the range of CCTs on the CIE chromaticity diagram is curved. This makes it important to have LEDs with a triangular range of colors (chromaticities) that will enable the feedback system to place the combined light output precisely on the black body locus.

For the simplest LEXEL applications that demand a single consistent and reliable CCT, it is possible to achieve cost savings by using most or all of the bins offered within a CCT range for white LEDs. →

Closed-loop optical feedback is used to place the CCT exactly on the black body locus. This removes the need for additional color binning by the luminaire manufacturer.

In contrast, a system that uses white LEDs with two different color temperatures and drives between these two points may only touch the locus once, and may be perceptibly off-white over much of its range. If a lighting application favors one end of this range of color temperatures, then half of the LEDs will be underutilized, and, without optical feedback, may gradually drift over time from the factory-set "white point."

How do you ensure that LEXEL provides useful life without degradation for at least 50,000 hours?

Several factors are responsible for degradation of light output in LEDs; some of these are internal to the LED and others are a function of the system. However, it is commonly thought that direct heat generation through optical conversion and extraction losses causes degradation of output and life in LEDs (up to a maximum current level that is much higher than manufacturers' ratings). The implication is that the primary factor for long life is more a function of thermal management.

The LEXEL platform is designed such that the LED die are operated at a lower temperature (for a given current) than when used in individual packages. Therefore, the die can be operated at rated (and potentially higher) currents without additional thermal stress.

As the LED performance degrades over time, the light output degradation is offset by gradually increasing the drive current. However, this is from a base level, which, as stated above, corresponds to an operating temperature well below the point at which performance generally begins to be compromised.

How have you dealt with thermal management?

One of the key breakthroughs incorporated in LEXEL is TIR's multiple-patent-pending system-level approach to thermal management: it incorporates an architecture for effective conductive and convective cooling without resorting to exotic materials, relying on large heat sinks, or utilizing active cooling techniques.

The thermal management technology is one of the most efficient methods of passive cooling. It moves the heat away from the die (chips) efficiently and ensures that this heat is then removed from the system, not conducted to the next layer of substrate, as other approaches require.

What's special about the LEXEL drive technology?

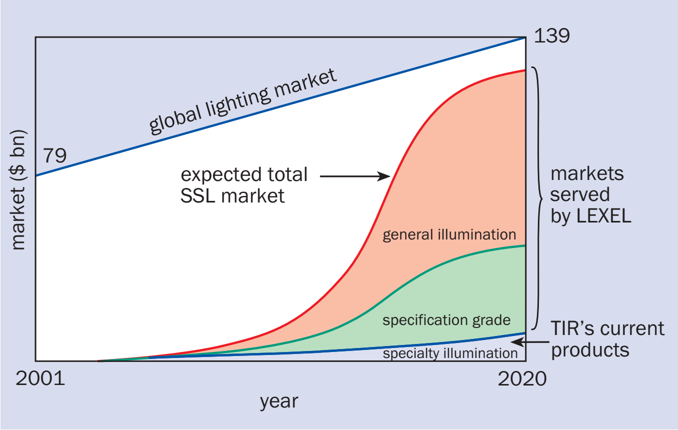
LEXEL has a drive efficiency of 95% – this indicates the amount of energy delivered to the LEDs themselves from the output of the power supply. The drive technology is another of TIR's patent-pending breakthroughs that is incorporated in LEXEL.

Does the optical feedback system introduce size constraints?

There will always be practical constraints on the physical size of the optics and the length of the optical path; these are determined by the LED source geometry. However, within LEXEL the optical mixing path and feedback system are designed as a system to enable them to be as compact as possible. The LEXEL system architecture and type of optical system does not impose as great a restriction on potential size as the incorporation of other system components that have to be optimized.

TIR believes that commercially available LEXEL fixtures, enabled by LED efficiencies that are forecast to be available within the next 12–18 months, will deliver 1000 lm of light in a system whose size is equivalent to conventional light sources such as R-, PAR- and MR-type lamps of equivalent lumen output.

The spot in the center background is from a 50 W quartz halogen PAR 30 fixture, while the side spots are from 35 W LEXEL luminaires. The left spot is from an RGB LEXEL light set to about 2800 K (LEXEL provides CCTs in the 2000–6000 K range), and the right spot is from a dimmable white LEXEL. In the foreground, an RGB LEXEL LED module illuminates a rose, which did not wilt over a four-day period.



LEXEL technology is being introduced to serve the markets in specification grade and general illumination.

How were you able to eliminate fringing effects?

The optical path was accurately modeled in software and designed to mix the light efficiently and provide a reference to the feedback system within a very short distance. These attributes produce a highly mixed light output at the exit aperture that virtually eliminates any spatial color differences – differences that otherwise can result in color fringing of shadows cast on an illuminated plane.

TIR has more than two decades' experience working with optical systems, and carefully chose an optimum balance between efficiency of optical throughput and elimination of fringing effects. The key is that the optical mixing is efficient and occurs near the area of light emission. This eliminates potential fringing effects for illuminated surfaces more than a few inches from the luminaire – which constitutes the vast majority of illumination applications.

How will LEXEL result in future cost reductions in fixtures?
It will benefit from the lower dollar/lumen cost of LED output as volumes increase, and from the improvements in efficacy (lm/W) that will allow fewer LEDs to be used to generate the required amount of light.

LEXEL is also designed to leverage existing manufacturing capabilities, and, as a result, the other components of the system are expected to exhibit cost-reduction curves similar to those of consumer electronics manufacturing, where substantial increases in volumes result in correspondingly large reductions in cost.

One of the key attributes of the LEXEL universal platform is that it was designed within a high-speed, automated production framework that will utilize commonly available materials, components, tooling and equipment.

We expect that LEXEL fixtures will achieve price points that can be competitive with conventional light sources.

What are the key aspects of LEXEL that could help to ensure it is adopted throughout the lighting industry?
As described above, LEXEL is a cost-effective platform that capitalizes on the many advantages of LEDs, and provides the best performance in a form that is optimized for the lighting industry.

Also, as a universal platform facilitating the use of many types of LEDs, LEXEL lowers the costs associated with changing from one type of LED to another. It also increases the ability of luminaire manufacturers to take advantage of advances in LED technologies without having to overhaul their product lines, as is now the case.

TIR has drawn on its experience of over 20 years in the manufacture of luminaires to ensure that, by offering a fully integrated system, LEXEL does not require luminaire makers to change their business model away from the lamp model now used throughout the industry.

LEXEL provides the benefits and advantages of solid-state lighting, but it does not require fixture manufacturers to obtain specialized knowledge of LEDs and the enabling technology. By offering predictable lumen packages, beam angles and distributions, and user-controlled CCT, LEXEL enables luminaire manufacturers to focus on their strengths: namely applications, design and customer support. ●

Links

TIR Systems: www.tirsys.com

On our website:
TIR Systems unveils LEXEL lighting platform
www.ledsmagazine.com/articles/news/2/4/19/1

LED dragon breathes fire into Japanese attraction

A 40 ft tower featuring two intertwining LED video displays is the highlight of a Japanese spa resort. **Louis M Brill** describes the design and fabrication challenges involved in the project.

The Dragon Tower on Enoshima Island, Japan, is a formidable LED sculpture where the convergence of fire, water, and pixel power have joined with the spirit of Japanese dragon mythology. A symbolic dragon body has been created with a set of matching spiral LED video screens that completely encircle a 40 ft tower. Designed as an audio-visual entertainment attraction, the Dragon Tower presents a 20 minute video show on its screens, synchronized with a water fountain show, and reaches a spectacular conclusion as the two dragon heads erupt in a fire-breathing finale.

"The video entertainment attraction was commissioned by Enoshima Spa and Resort, who wanted an attraction to draw tourists and local-area residents to visit the island and the resort," explained architect Kilhak Kunimoto of Kunimoto Architect Group, Atlanta, Georgia.

The tower design called for two matching LED video screens in the shape of a double helix. The task was undertaken by Optec Displays, an LED sign manufacturer based in City of Industry, California.

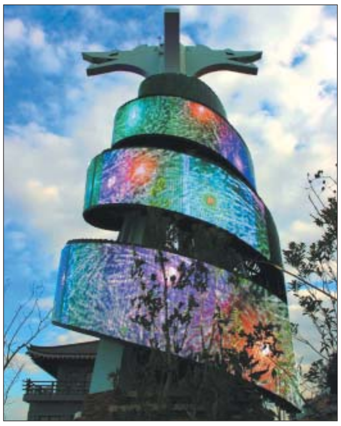
The Dragon Tower video display is the first of its kind. Bill McHugh, vice-president of sales for Optec Displays, said that the project posed a series of design and fabrication challenges. "For example, we were concerned with how we would wrap an LED video screen 720° (each LED screen wrapped two times) around a cylindrical tower. We needed to discover what geometric form the video cabinets would have as they curved upwards around the tower structure. We were also concerned with how the LED video modules would physically line up."

Video cabinets are tiled around the tower

The first problem to appear was caused by trying to use traditional rectangular LED video modules to encircle the cylindrical tower, said McHugh. "By tiling the video modules upwards along the curve, its top edges created an undesirable stair-step effect which caused a 17° pixel extension from video cabinet to video cabinet as they wound around the LED video band. At first Optec thought to use an architectural cladding that had a 'scaled' dragon body look that would hide the uneven edge of the video modules."

"The cladding idea was then replaced by switching to video cabinets shaped as parallelograms, eliminating the step effect. A cylindrical steel frame allows the LED video cabinets (184 per video band) to be tiled side by side around the tower."

Optec used its proprietary LED hybrid pixel cluster as the main building-block of its video modules. Each cluster is a 16 mm LED unit consisting of five diodes per cluster (two red, one green and two blue). In this design, each cluster is encased in its own housing unit and each unit is independently potted and sealed for complete weather resistance against the corrosive salt air around the Dragon Tower. Concerns about video cabinet heating were handled with a series of fans that keep each cabinet's electronics within an operational temperature range.

The video modules are based on Optec's LED hybrid pixel clusters.

Another challenge was getting flat 2D graphics, such as video images and text messages, to properly display on the curved parallelogram-shaped surfaces of the tower's video screens. Optec software engineer Pavel Bonev said, "We solved this issue by creating two specialized software programs for curved-screen displays. The first program was a 'transformation' file that translated the original finished video content from a 2D image in a classic television aspect ratio to a spiraling LED video strip that encircles the Dragon Tower."

The second software is a preview program that offers what-you-see-is-what-you-get (WYSIWYG) real-time simulation of the video content on a 3D virtual model of the tower. This allows the video content designer to see what the audience will see before the video show is launched for real on the Dragon Tower.

The Dragon Tower's LED video display presents a new era of outdoor signage that combines advertising, art and architecture as a public communications medium.

About the author
Louis M Brill is a journalist and consultant for high-tech entertainment and media communications. He can be reached at (415) 664-0694 or lmbrill@earthlink.net.

Link

Optec Displays: www.optecdisplays.com

Constant-current drivers provide power for automotive LED lighting

In automotive lighting and signaling applications, high-brightness LEDs require specialized power converters that deliver constant-current output. **Ahmed Masood** of Supertex explains that it is crucial to ensure that the LED driver is immune to conducted electrical disturbances.

LEDs have been the light source of choice for automotive interior lighting for years, particularly for signal applications. Owing to recent advances in solid-state lighting, LEDs are now being designed for exterior applications as well. Although primarily used in center high-mount stop lamps and rear combination lamps, LEDs continue to gain ground for most of the automotive interior and exterior lights.

Solid-state light sources are being widely adopted owing to their attributes such as small size, robustness, long lifetime, and high efficiency. Automotive manufacturers are attracted by the potential reduction in energy consumption and the space savings realized by smaller lighting fixtures. The styling potential of LEDs brings advantages for consumers, because it enables more attractive and distinctive designs.

Consumers can also benefit from the safety aspects of solid-state signal lighting. For example, faster turn-on of the stop lamps can reduce the risk of rear-end collisions. And perhaps the most compelling reason for using LEDs is the expected reliability and lifetime. This is a plus for both manufacturers and consumers, because it could significantly reduce the replacement and maintenance costs for automotive lighting.

High-brightness LEDs cannot be powered directly from the automotive battery voltage, owing to their electrical properties. They require specialized power converters that deliver constant-current output. The large variety of LED fixtures used in automobiles calls for various types of LED driver topology. These power converters must comply with numerous industry specifications.

This article will address applicable power converter topologies that are useful for driving LEDs. It will emphasize the immunity of the LED driver to the conducted electrical disturbances that exist in automobiles.

Voltage regulation conditions in automobiles

Under the normal operation of the vehicle, voltage at the supply lines ranges between 9 V and 16 V (in a 12 V system), or between 18 V and 32 V (in a 24 V system). However, a substantially wider range of voltages of both positive and negative polarity may appear along the supply lines as a result of conducted electrical transients.

Electrical disturbances generated by disconnecting inductive loads, sudden power cut-off in the main circuit, or switch bouncing are commonly referred to as "inductive switching". Disconnecting an inductive element causes a high inverted over-voltage on its terminals. Positive high-voltage transients occur at the supply lines after the ignition key cuts the battery supply circuit. In this case, the ignition circuit continues to release disturbances until the engine stops rotating.

Switching the power supplied by electric motors that act as generators (the air conditioning fan, for example) also generates over-voltage

Automotive applications of LEDs

The use of LEDs in exterior lighting is increasingly popular on trucks and buses because of their compact size and shock resistance. These advantages simplify compliance with various safety regulations. Exterior applications include taillights, stoplights, marker lights and identification (ID) lights. For example, the National Highway Transportation Safety Administration has issued a new compliance that trailers over 80 inches (2.03 m) wide must have ID lamps mounted over the rear door even if the space available is only 1 inch high. LED narrow rail lamps provide the only practical solution for such applications where space is at a minimum.

The HCD-8 concept car, with LED headlamps powered by Supertex. (Courtesy Hyundai.)

Although solid-state forward lighting seems rather distant, most major car manufacturers have experimented with LED headlights in their concept models. One such model is Hyundai Motor Corp's HCD-8. All of its signal and lighting devices, including headlights, use high-brightness LEDs from Osram Opto Semiconductors powered by LED driver solutions from Supertex Inc. However, production models with LED headlamps are not expected to arrive until 2007. Before then, LEDs in forward lighting applications will continue to be limited to daytime running lights, the signal lights that indicate that a vehicle is in use.

The trend of using LEDs in forward lighting is mainly driven by their styling potential. However, manufacturers are looking into the space savings in the hood opening that can be gained by using LED headlamps, as well as the reduction of the front overhang, which is mainly dictated by the headlamp construction.

Dashboard lighting is the most common interior application of high-brightness LEDs. Most European cars are equipped with LED backlights in the instrument panel. LED backlighting improves styling and makes the instrument panels more readable and comfortable for drivers. Other interior applications of LEDs include map and reading lights, doorsill lights, and ambience lighting. LED-based dome lamps are becoming increasingly attractive owing to their compact size, uniform light output and low heat.

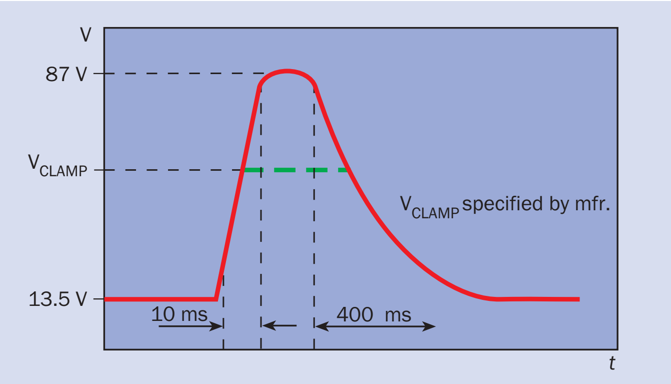


Fig. 1. A typical load dump test wave shape (12 V system).

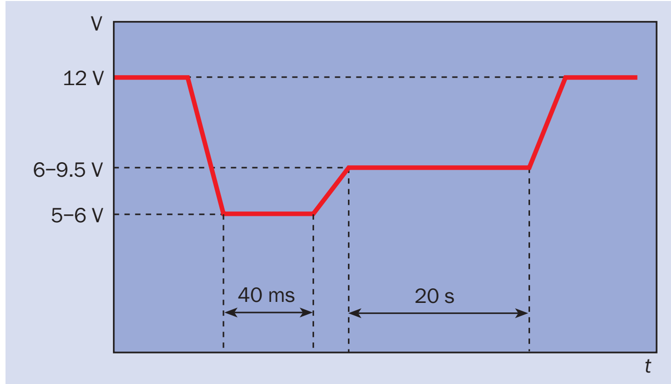


Fig. 2. A typical "cold cranking" test wave shape (12 V system).

spikes. Their amplitude is increased by the absence of filtering, which would normally be carried out by the battery.

Although inductive switching disturbances can generate high voltage up to 600 V of both positive and negative polarity, the highest energy available from these transients usually does not exceed 2.3 J per single pulse. Therefore, LED lighting devices can be protected from inductive switching transients merely by clamping the supply voltage at an acceptable level.

A more aggressive electrical disturbance occurs when the car battery is suddenly disconnected while being charged by the alternator. During such load dump conditions, the voltage on the alternator terminals increases rapidly. The length of this disturbance depends on the time constant of the generator excitation circuit and can be as long as several hundred milliseconds. Series resistance of the alternator circuit is only a fraction of one ohm. The energy available from the load dump transient, therefore, can reach 50 J. Positive over-voltage of up to 87 V (12 V system) or 174 V (24 V system) can appear along the supply lines. This type of transient can be lethal for LED lighting devices. Most modern alternators are equipped with a special centralized clamping circuit, which typically clamps the load dump transient voltage below 40 V.

Various automotive standards give different definitions of a load dump test. A typical one is shown in figure 1, as it is defined in (1). The dotted line designates the centrally clamped load dump pulse. However, some interior or exterior lighting fixtures may be intended for use in existing automobiles. These devices may require protection from unsuppressed load dump transients.

Fast input transients can present a serious problem for LED lighting devices owing to the low dynamic impedance property of the LEDs themselves. The driver circuitry must provide fast input supply rejection in order to protect the LED devices from high peak currents that could be potentially destructive. Both the power topology and the control scheme of the LED drivers must be carefully selected to ensure that the LED lighting devices operate reliably.

Certain safety-critical exterior signal devices may be expected to produce light down to a supply voltage of 6 V or 7 V, sometimes for as long as two minutes. These devices may include tail and marker lights that can potentially create a rear-collision hazard when not lit. This type of voltage drop occurs in the supply source when the starter circuit is activated. Cold temperature ambient conditions aggravate the drop in supply voltage.

A typical "cold cranking" test wave shape is depicted in figure 2. Some automotive standards (2) are less explicit about the cranking wave shape. However, it is a common understanding that a normal operating voltage condition always precedes the cranking transient.

"The driver circuitry must provide fast input supply rejection in order to protect the LED devices from high peak currents that could be potentially destructive."

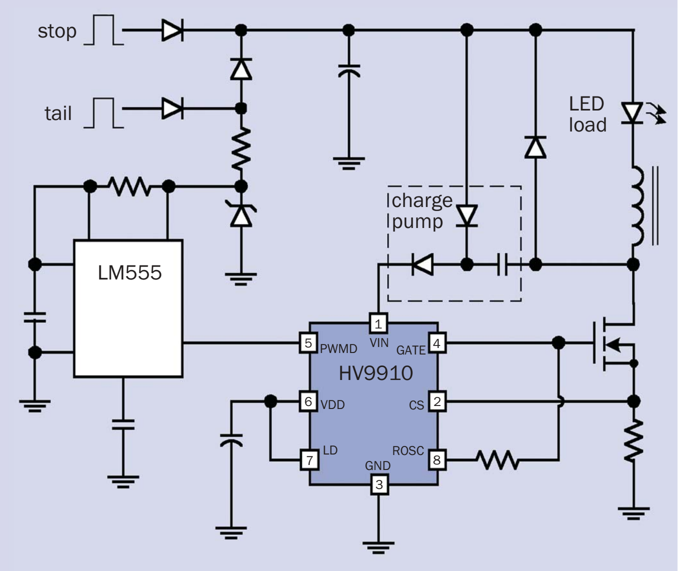


Fig. 3. Stop/taillight driver circuit that uses a buck regulator.

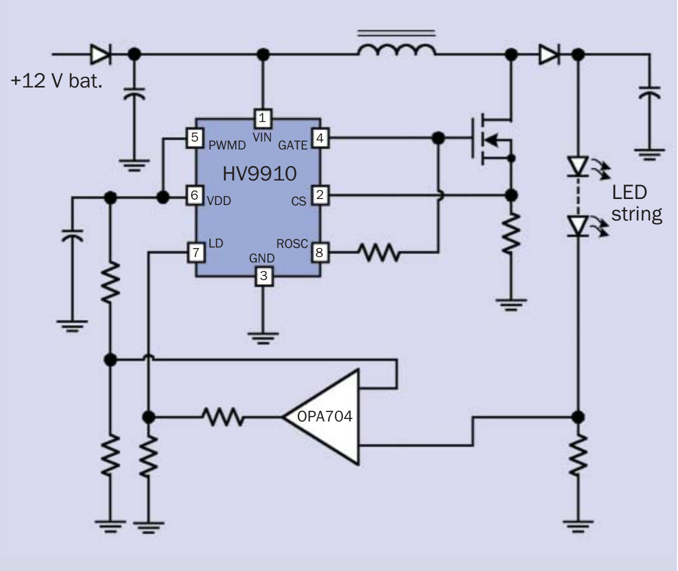


Fig. 4. A typical boost circuit for an instrument panel backlight.

Therefore, safety signal devices are not required to be able to start from the 7 V supply, as long as they do not extinguish at this low supply voltage. It will be shown in the following sections how this consideration can simplify the design of LED drivers.

LED lighting devices are also expected to survive continuous application of +24 V/–12 V (12 V systems) or +48 V/–24 V (24 V systems) during a jumper start. Garages and emergency road services have been known to use 24 V sources for emergency starts, and there are even reports of 36 V being used for this purpose. High voltages such as these are applied for up to five minutes and sometimes with reverse polarity.

Thus, in summary, automotive LED driver devices are required to:

- operate from a wide input supply voltage range;
- provide immunity to input voltage transients;
- include protection from input over and under voltage condition, and;
- include input reverse polarity protection.

LED driver topologies

Resistors and linear current regulators

One traditional low-cost way of driving LEDs in automotive applications uses a resistor in series with the LED device. Although this driving scheme is simple and inexpensive, it suffers from several disadvantages. The LED current can vary substantially over the battery voltage range even when the vehicle is operated normally, thus affecting the brightness and reducing the service life of the lighting device. Additional protection from automotive voltage transients and from reverse polarity is needed. These disadvantages are typically resolved by using constant-current linear regulators.

Besides driving the LEDs at a programmed current, these regulators can inherently protect from a reverse polarity application and block voltage transients up to tens of volts. Linear current regulators do not require input EMI filters and can yield inexpensive LED driver solutions. However, both resistor ballasts and linear regulators exhibit low efficiency. They may become impractical for driving high-brightness LED loads owing to excessive heat dissipation. Therefore, switching power converters are needed to drive many signal and lighting LED devices in automobiles.

Buck regulator

Buck DC/DC regulator topology is used in automotive lighting devices because of its simplicity, low cost and ease of controlling the output LED current. Figure 3 shows a stop/taillight controller that uses a buck regulator. The HV9910 is a peak-current-control pulse-width modulation (PWM) IC with an internal high-voltage regulator that powers the IC from 8 to 450 V supply voltage. The HV9910 control scheme provides high immunity to transients and surges on the input supply. The control IC enables the user to select between constant frequency and constant off-time modes of operation. The regulator in figure 3 is configured for the fixed tOFF mode, thereby permitting stable operation at duty cycles greater than 0.5 and reducing the effect of input voltage variation on the output LED current.

Automotive taillamps may be required to maintain certain light output even during cranking of the starter motor. The available supply voltage may become insufficient for enhancing standard-level MOSFETs that typically have $V_{TH(MAX)}$ of 4–5 V. On the other hand, the load dump conditions will dictate the MOSFET drain voltage requirements, ruling out most of the logic-level MOSFETs available in the industry. Adding a charge pump circuit in the V_{IN} path of the HV9910 maintains its operation down to input voltages of 5–6 V. As soon as the HV9910 starts on initial application of the nominal battery voltage, the charge pump doubles the supply voltage and applies it to the V_{IN} pin. This voltage will keep the HV9910 running even during the "cold cranking" transient.

The LM555 timer IC is configured in the astable multivibrator mode to decrease the duty cycle for the taillight function. Its low-frequency PWM signal modulates switching of the HV9910 via the PWMD input. Sufficient hold-up capacitance must be provided at the VDD pin to maintain continuous operation of the HV9910 in this operating mode.

Boost regulator versus boost-buck (Cuk) regulator

Boost regulators are typically used in automobiles for driving long strings of LEDs in instrument panel backlights and other lighting devices that require series connection multiple LEDs. A typical boost converter is shown in figure 4. It can drive strings of LEDs that have forward voltage in excess of 100 V. →

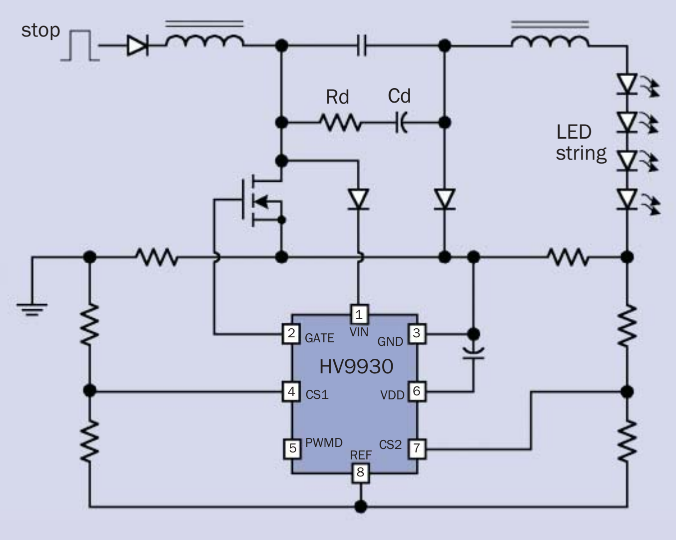


Fig. 5. A boost-buck circuit used in a stoplight application.

However, recent advances in high-brightness LED technology have substantially increased the power ratings of a single LED package. LED currents of 350 mA, 700 mA or even 1 A are typical. Therefore, fewer series-connected LEDs in the string are now used in automotive lighting devices.

Despite its simplicity, the boost converter in figure 4 suffers a serious drawback in automotive systems where the supply line voltage can easily exceed the forward voltage of the LED string. Disabling the switching MOSFET in this converter topology does not protect the LED load from being subjected to a potentially damaging overcurrent stress. The problem is aggravated as the LED string voltages become lower. Input supply regulators, voltage clamps or load disconnect switches will become unavoidable for this converter topology. A boost converter operating in continuous conduction mode (CCM) presents stability problems that limit the control loop bandwidth. The peak current-mode control scheme used in many PWM controllers does not reject the input supply transients for a boost converter as well either. Therefore, the LED loads will see substantial output current surges. In addition, the LED string voltage in some lighting devices may require both step-up and step-down conversion within the nominal supply voltage range. Such applications rule out both the buck and the boost converter topologies. A more suitable power supply topology is needed that is not limited to just step-up or step-down voltage conversion.

Boost-buck (commonly referred to as Cuk) converters can offer a solution for most higher-power automotive lighting applications, including both exterior and interior lighting. They can fit well even in forward lighting devices, when these become available. The CCM boost-buck converter integrates an input boost stage and an output buck stage, and is thus able to step the input voltage up or down as needed. Both the input and the output currents of the converter are continuous, yielding good EMI performance. Unlike the boost converter, this converter topology inherently protects the LED load from load dump transients. Its load is decoupled from the input source with a coupling capacitor, which would protect it even from the switching MOSFET failure.

Figure 5 shows a boost-buck converter driving a string of four high-brightness LEDs in a stoplight application. The HV9930 is a hysteretic input/output current regulator that is specifically designed to drive the boost-buck converter topology in an automotive lighting device. It offers ultimate input transient immunity and stable operation over a wide range of input and output voltages. The supply voltage for the HV9930 is derived from the drain of the switching MOSFET ($V_{DS} \approx V_{IN} + V_{OUT}$) for the "cold cranking" test compliance.

Although the output current loop is inherently stable, the overall stability of the converter still needs to be considered when the boost-buck topology with the HV9930 control IC is used. A damping circuit (Rd and Cd) across the coupling capacitor is needed to prevent oscillation. This damping circuit carries little current without causing noticeable reduction of the LED driver efficiency. The damping capacitor Cd must be selected to have five to 10 times the value of the coupling capacitor. An aluminum electrolytic or tantalum capacitor can be used to reduce the cost.

Summary

Recent advances in solid-state lighting open new horizons in automotive applications. The unsurpassed reliability, ruggedness, safety, high efficiency, compact size and great styling features of LEDs bring significant advantages. However, optimal solutions for driving LEDs in the automotive environment are needed. Immunity to conducted transient emissions is a key requirement that designers must address. The right choice of a power topology and a control scheme for the LED driver circuit becomes critical for meeting these requirements. ●

About the author

Ahmed Masood (ahmedm@supertex.com) is director of marketing with Supertex Inc.

References

1 Road vehicles – electrical disturbances from conduction and coupling – Part 2: electrical transient conduction along supply lines only (2004) *ISO 7637-2* 2nd edn (search for 7637-2 at www.iso.org).
2 Tests for signal and marking devices used on vehicles 2032 mm or more in overall width (2001) *SAE J2139* (search for J2139 at www.sae.org).
3 Electromagnetic compatibility – component test procedure. Part 42 – conducted transient emissions (2000) *SAE J1113-42* (search for J1113-42 at www.sae.org).
4 Rohit Tirumala (2004) Constant off-time, buck-based LED drivers using HV9910 *Application Note AN-H50* (Supertex Inc.) (www.supertex.com/documents/application_notes).

Links

Supertex: www.supertex.com

On our website:
Drivers Channel
www.ledsmagazine.com/articles/features/1/4/5

"Hyundai HCD8 sports coupe demonstrates design innovations enabled by LEDs"
www.ledsmagazine.com/articles/features/1/9/2/1

Micro-optics promote use of LEDs in consumer goods

Module size and power limitations impose major challenges for the design of optics for portable consumer products. According to **Markus Rossi** and **Michael Gale** of Heptagon, diffractive micro-optics can play an important role in meeting these requirements.

Improvements in the intensity and color output of LEDs has led to an explosion in their use for lighting applications in consumer products such as mobile phone cameras, LCD TVs and LED-based projectors. The requirement is for a compact, efficient light source that emits a well defined light distribution. This is achieved by using extra micro-optical elements for beam shaping and for enhancing the emission efficiency.

Since LEDs are basically broad-area wide-angle emitters, designing and realizing such micro-optics in a compact form is a challenge. The introduction of customized diffractive optical elements (DOEs), made possible by recent advances in design and fabrication technology, has resulted in a major advance in producing compact, functional and cost-effective LED lighting modules. The main issues for such lighting modules are:

- luminous efficiency – optimizing light collection, leading to brighter illumination and longer battery lifetime;
- optical function – optimally converting the LED output into the required light distribution (beam shaping), and minimizing unwanted color effects from white LEDs;
- packaging – reducing the size, in particular the thickness, of the lighting module;
- cost – reducing the component and assembly costs, and realizing surface-mountable micro-optics.

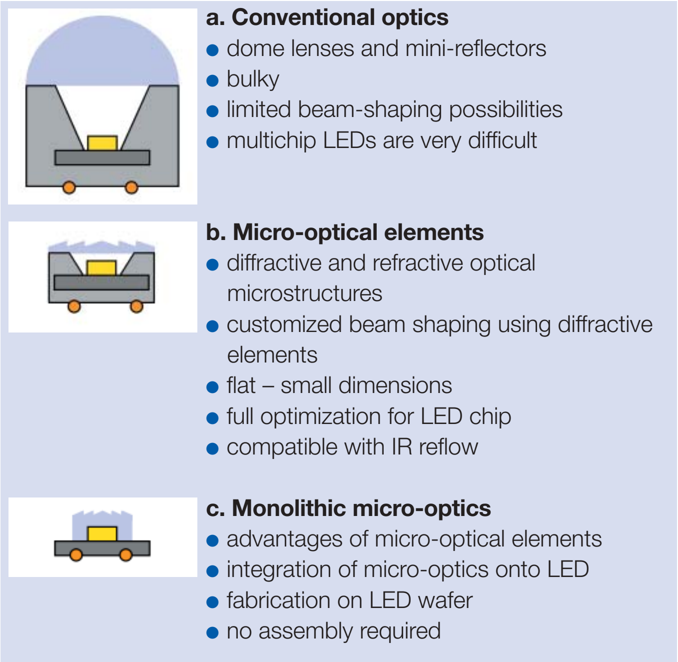


Fig. 1. The evolution of optics for LED lighting in portable consumer products. The final step, monolithic micro-optics, can significantly reduce volume production costs.

Optical approaches

The evolution in optics for LED lighting in portable consumer products is illustrated in figure 1. The classical approach has been to use conventional optics (figure 1a) such as dome lenslets and mini-reflectors to collect and form the light.

The use of micro-optical elements (figure 1b) enables the manufacture of thinner modules – this is an important advantage in applications such as the light source for cameras in mobile phones. Such elements can be produced by UV replication technology on thin glass substrates in polymer films, which withstand the infrared (IR) reflow process for the module assembly (1, 2). This lowers the cost of assembly and production.

Refractive Fresnel lenslets are a first step in this evolution. They replace conventional dome lenslets with a much thinner microstructure that is highly suited to fabrication by replication technology. The next step is to move to DOEs, which can offer much higher functionality for homogenizing and beam shaping the LED light output. The earlier limitations of diffractive elements, when used with broad spectral bands such as white light LEDs, have been overcome by using advanced design techniques and fabrication technology.

The ultimate step in the evolution is to fabricate the optical microstructure directly on the LED at wafer level. This monolithic solution (figure 1c) essentially eliminates, or at least greatly simplifies, the subsequent assembly and thus leads to a significant decrease in volume production costs. UV replication is highly suited to this approach (3).

Design methods for micro-optical elements

Designing beam-shaping DOEs for LED modules is a challenge that requires highly sophisticated design methods, in particular for white LEDs. A typical structure is shown schematically in figure 2. The LED die typically sits in a reflector, which may also contain a wavelength-converting resin. The optical element should be positioned as closely as possible to the LED, an extended white light source, and has to perform a highly efficient and flexible beam-shaping function. →

Parameters such as the die geometry (shape, size and position), the reflector form, properties of the light-converting resin, and the spectral distribution of the emitted light must all be considered in the design and optimization process.

New software has been developed to design DOEs that take these and other parameters into account and that find the best solution for optimizing efficiency and the output beam shape. The resulting designs represent a significant advance in customizing the micro-optical element for a given LED module. The DOEs typically contain finer and deeper microstructures than in earlier designs, and these can be fabricated and replicated by recently developed advanced technologies. Typical solutions are fabrication-tolerant designs that realize features such as:

- conversion of a Lambertian emission into a Gaussian flat top;
- customized far-field light distribution, including rectangular and round forms;
- opening angles typically between 20° and 60° at FWHM (full width at half maximum);
- optimization for LED die shape or arrangement for multichip LEDs;
- correction and compensation of color effects in white LEDs, in particular with wavelength-conversion luminous resins.

Mastering and prototyping

The mastering technology of choice for a given DOE depends primarily upon the microstructure properties, such as feature size and depth. Direct laser beam writing in photoresist (3) is a fast, high precision technology that is highly suited to such mastering. A first assessment of the optical properties of the DOE and the LED module can usually be made at this stage. A more thorough evaluation requires a replica fabricated from a mould.

Figure 3 shows an example of a beam-shaping element that converts the Lambertian illuminance characteristics of a white light LED (one chip with an active area measuring 1 × 1 mm) into a Gaussian distribution with a FWHM of about ±30°. The active area of this particular DOE is 4 × 4 mm and it is positioned at a distance of 0.2 mm from the LED surface. The on-axis brightness increases by a factor of approximately 2.7. Depending on the opening angle and the shape of the output distributions, this value can be between 1.5 and more than 4 for typical LED modules.

Volume production technologies

An overview of replication technology for DOEs can be found in (4). UV replication technology is highly suited to the production of DOE beam-shaping elements for LEDs. Following mastering and the fabrication of the mould, the elements are replicated into UV-curable liquid polymer in a batch wafer-scale process, which produces glass-like elements at highly competitive prices (1). Materials are available that can withstand an IR reflow process (temperatures up to 280 °C), long-term storage and humidity tests, and temperature shocks (in conformance with Telcordia/JEDEC regulations).

In addition to producing the optical microstructure, mechanical mounting features can also be integrated into the replicated element. Figure 4 shows an LED module with a replicated DOE positioned using replicated macroscopic mounting pins at the corners of the element.

Associated coating, packaging and dicing steps are compatible with other wafer-scale processes, thus guaranteeing the same advantages in terms of precision, efficiency and pricing. The process can also be adapted for implementing the monolithic solution with replication directly onto the LED wafer. The UV replication approach, which does not require additional heat and pressure, has particular advantages here.

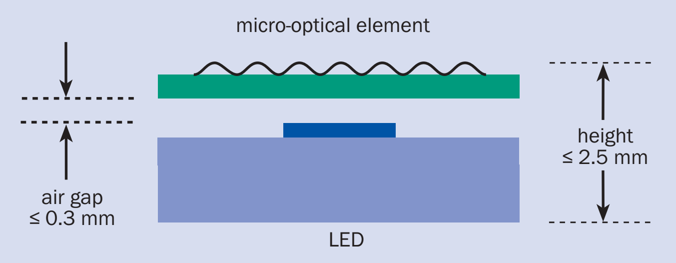


Fig. 2. Schematic drawing of an LED module that incorporates a micro-optical beam-shaping element.

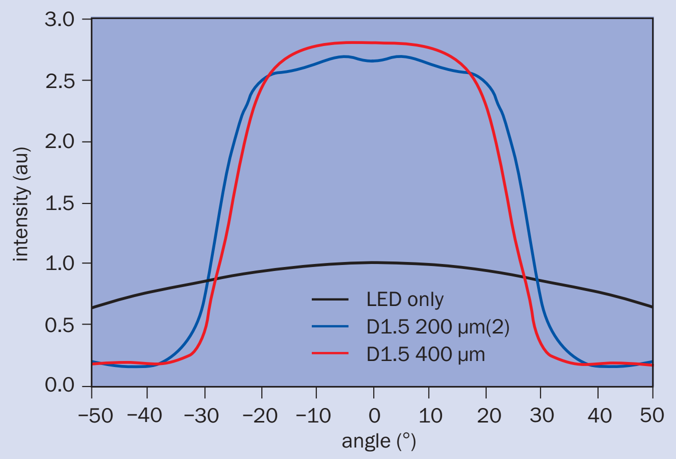


Fig. 3. The effect of a fabricated LED beam-shaping element. Black line: angular illuminance distribution of white LED without micro-optical element. Red and blue lines: output with a beam-shaping element positioned at different distances from the LED.

Applications and outlook

The use of customized micro-optics for LEDs results in major improvements in brightness, beam shape and battery lifetime. Portable consumer products in particular benefit from these features. The LED flashlight for cameras in mobile phones is just one example. The LED pocket lamp is another in which efficient beam shaping is a major requirement. LEDs are also used for display illumination in PDAs, mobile phones and a host of electronic consumer products. New, optimized micro-optics is resulting in a continuous improvement in the quality and power consumption of these displays.

Other areas of application are to be found in lighting for products such as machine vision systems, medical devices, and flat displays

"Diffractive micro-optics technology offers more degrees of freedom for the complex optimization of LED module optics, and can achieve better results than simple Fresnel microlenses."

Fig. 4. Beam-shaping elements with a replicated DOE, assembled using replicated mounting pins. Inset shows latest version.

in general. The emerging markets of LED lighting for automobiles and interior building lighting are not so critically dependent upon the size benefits, but power consumption and beam shaping are always a major factor, and micro-optics will play an increasingly important role in such products.

Diffractive micro-optics technology offers more degrees of freedom for the complex optimization of LED module optics, and can achieve better results than simple Fresnel microlenses. Improvements in design methods and fabrication technology are enabling the full potential of diffractive optics to be realized and implemented in advanced LED lighting modules. ●

About the authors

Dr Markus Rossi is chief technology officer at Heptagon, Zweigniederlassung Rüschlikon, Moosstrasse 2, CH-8803 Rüschlikon, Switzerland. Michael T Gale is a senior technology consultant for Heptagon.

Further reading

1 *Wafer scale micro-optics replication technology*: www.heptagon.fi/downloads/WaferScale%20Replication%20Technology%202003.pdf
2 *Micro-optical modules fabricated by high-precision replication processes*: www.heptagon.fi/downloads/MO%20Module%20Fabrication%202003.pdf
3 *One stop shop – prototyping*: www.heptagon.fi/oneStopShop/prototyping.html
4 M T Gale 1997 Replication technology for holograms and diffractive optical elements *J. Image Sci. and Techn.* **41** 211

Link

Heptagon: www.heptagon.fi

Ambient experience: LEDs soothe hospital patients

Philips Solid State Lighting has developed an LED lighting scheme that can create a more patient-friendly, supportive and efficient hospital environment, explains **Luc van der Poel**.

At the end of 2004 Philips realized its first "ambient experience" radiology suite at Advocate Lutheran General Children's Hospital in Park Ridge, Illinois. The customized lighting solution provided by Philips is based on LEDs.

The suite uses Philips' LEDs and consumer electronics to create a more patient-friendly environment for children undergoing medical scans. Patients can choose a mood theme, or "ambient environment", for the room by waving a radio-frequency card over a reader that triggers special lighting and animated images to be projected onto the walls and ceiling.

Changeable ambiances are already used in shops, bars and restaurants. In hotel restaurants, for example, a warmer, romantic atmosphere in the evening can replace the more dynamic light setting which is asked for at breakfast time.

A hospital might not be the most obvious location to benefit from a flexible ambiance, but considerable improvements can be made to these normally impersonal and gray spaces. Patient-friendly hospital design is considered key to greater productivity (that is, reducing the time needed to take medical images) and improved care – especially when the patients are kids.

"Providing a supportive and soothing environment to all our patients – and especially our pediatric patients – is very important to us," said Dr John Anastos, chairman of the Department of Radiology at the hospital. "We strive to offer a healthcare facility that meets and personalizes patient needs, and creating an ambient environment helps us achieve this."

Developments in the field of LED technology have opened the door to new lighting concepts driven, for instance, by ambient intelligence. In 1998 Philips Research introduced Ambient Intelligence as its idea of where developments in electronics would lead. In the future, electronic systems will become so sophisticated that they will not only recognize individuals but also adapt and respond to their personal needs.

The system developed by Philips aims to make the user experience richer and more absorbing, and also aims to tailor this experience to individuals who have distinct preferences or needs.

The ambient lighting system

In partnership with Philips, the hospital built the ambient experience suite as part of a new custom-made imaging center. The suite features a Philips Brilliance CT (computed tomography) scanner in a room with curved walls, creating a softer emotional environment. Children can choose their favorite animations, which are then projected onto the wall accompanied by calming surrounding lights and music.

The LEDs in the suite are positioned in a cove, and wash the curved walls. In total, about 1000 red, green, blue and amber 1 W Luxeon LEDs are used to light a wall with a total length of 35 m.

LED cove lighting around the curved walls of the radiology suite at this children's hospital provides a changeable ambience that can result in a more patient-friendly environment and improved care.

In the suite, a movie is projected onto the wall and the main color of the image is dynamically copied in real time by the LED installation. This is a similar concept to the Philips Ambilight flat TV, in which the area around the television is lighted up with the dominant on-screen color to enhance the sensations experienced when watching sport or a movie.

This extension of the picture to the hospital walls gives a colorful, theatrical effect in the space, which can distract the mind from the medical treatment taking place. Since LEDs are ideal for color scene-setting, this is one of the main areas where LEDs find their entrance in projects. Combining RGB and amber LEDs opens up the possibility to make a full range of colors from a single source.

The big advantage of LEDs above existing light sources is that digital controlled systems can be made without using mechanical devices like rotating color filters, which waste about 90% of the white light provided by conventional lamps. Customization combined with creativity leads to a cutting-edge solution. ●

About the author
Luc van der Poel is a senior application specialist/designer with Philips Solid State Lighting.

LEDs MAGAZINE

Urban lighting presents challenges for designers

LED fittings are now suitable for use as uplighters, and will soon become widely used for flood and wash lighting applications, although a number of issues need to be considered.

Carl Gardner, a lighting designer based in the UK whose main focus is on exterior and urban lighting, is involved in a city square regeneration project in the town of Sunderland in the north-east of England. The project, says Gardner, has focused his mind on the issues associated with using LEDs in this type of architectural lighting application.

What are the prospects for LED lighting?
LEDs are now being used in areas where two to three years ago they wouldn't have been considered. The power wasn't there for uplighting small fountains and trees, for example. Until now, the use of LEDs has been mostly confined to marker lights, recessed lights, and orientation lights in the ground. We're just about to see the advent of wash and flood lights, and genuine recessed burial fittings; I expect to see exponential growth in this area in the next 12–18 months as people come to grips with the issues surrounding LEDs.

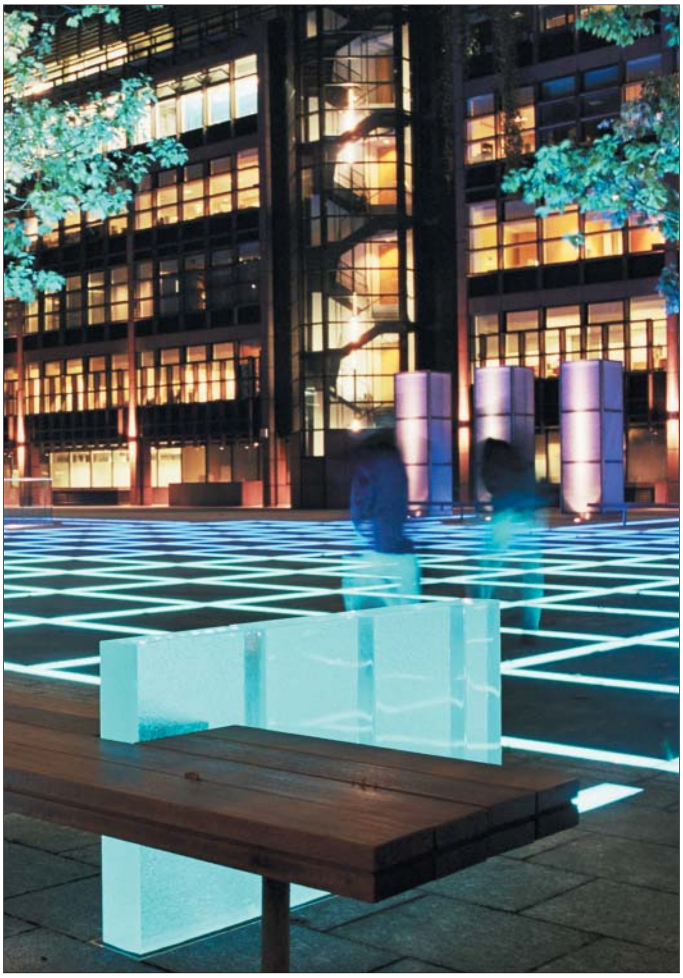
Why were LEDs chosen in your project?
In the Sunderland project, the landscape architects were reluctant to use conventional discharge sources for uplighting trees in the square, since even 35 W metal halides tend to produce a very bright splash on the trunk. We proposed the use of LEDs, which are now sufficiently bright for these applications, without wasting light. For walls, planters and other low-level features, it's not appropriate to use uplighters, but LEDs can be integrated into vertical surfaces.

Of course, LEDs offer a number of other advantages, not least their long lifetime and their solid-state nature, which makes them less vulnerable to vandalism. The issue of low maintenance is possibly the main advantage; if you can find fixtures that offer a fair amount of toughness and also a long life, that's ideal for local authorities [the government organizations that are normally involved with urban projects].

Some of the fixtures we have installed have color-changing capabilities and can also be dimmed, which allows for a change of ambience, for example according to the time of day or for special events; this can't be done with conventional discharge lamps.

What about cost and power consumption?
With public projects, initial capital costs are much less of an issue than ongoing costs and maintenance costs. Regeneration money is often available from various sources, but the big issue is who maintains the lighting fixtures, who runs them and who pays the energy costs for the next 10–15 years? LEDs are relatively expensive in investment terms, but this is offset by lower longer-term costs.

Since the lighting is for decorative purposes, we're not talking about huge amounts of power. Across the site there are hundreds of smaller fittings and about three dozen larger fittings, and the total consumption is not much more than 1.5 kW. LEDs are quite efficient at the moment, and more competitive than tungsten halogen, which also suffers from poor lifetime. Fiber-optic technology, another alternative, also has a short lifetime problem, and the fittings have to be custom made. →



This LED installation at Finsbury Avenue Square, Broadgate, in the City of London, is probably the largest and most expensive in Europe to date. Costing about £750 000 and designed by Maurice Brill Lighting Design, it involves 100 000 LEDs mounted in 650 sealed linear fittings that are set into the ground – and offers an infinite variety of programmed color and moving effects.

Are LEDs suitable to be used in burial fittings?
Yes, but I would want any burial fittings, using either conventional or LED technology, to be rated at IP68*. The heat produced by LED fixtures can suck in moisture when they are cooled, so this has to be accounted for. Also, many companies make the mistake of mounting them in stainless steel bodies, which are poor heat conductors, so they create heat dispersal problems – aluminium or brass are far superior conductors and should always be preferred.

Burial fittings are one of the most problematic pieces of equipment used by designers, and there is plenty of scope for problems. With conventional fittings, the main thing that can go wrong is with the installation. The units are not sealed and contractors have to take the lids off to put the lamps in, which can wreck their water-tightness.

An LED system is sealed at the manufacturers, and would not have to be removed until the end of life. At that stage you would have to replace the entire fitting, but if the cost has been amortized over 10 years then this is acceptable. For conventional fittings, 10 years would be considered good, and during that time you'd have to replace the lamps five times – each time, there is always the possibility that the front glass will not be replaced correctly.
[*In the IP68 rating, the 6 indicates total protection against dust, and the 8 indicates protection against long periods of immersion under pressure.]

How do you rate LED fixture manufacturers?
Everyone's on a rapid learning curve. There's a huge choice of LED fittings, so it's difficult to work out who is doing it right, and whether that manufacturer will be around in a couple of years if anything goes wrong. Conventional fixtures – and manufacturers – have been around for years.

If I specify LED fixtures on a project, and they fail or degrade substantially within a couple of years, then my company could be liable – but that's why we have professional indemnity protection. We're talking about unknown length of life. No one has actually run an LED in exterior conditions for five years. We've got various projections and simulations, but in effect we're gambling on the future.

What do you look for in fittings?
First, it's worth pointing out that lighting designers don't necessarily understand all the ins and outs of LEDs and how the science works. It's important to find manufacturers that you can trust.

When assessing fittings, it's essential to start with good light sources; I would only entertain products that use LED chips from about three or four manufacturers. Thermal management when the chips are put into fixtures is clearly a key issue. We need to know that the manufacturer is addressing heat sink issues and has invested in real engineering effort. We need to know that the chips and drivers are compatible and well made. In addition, there are all the issues of moisture ingress, as well as durability, and resistance to vandalism.

Color-change LED lighting by Crescent Lighting is concealed behind the bedhead of this residential scheme in the Barbican, London. The lighting scheme, designed by Carl Gardner and Karen van Creveld, was shortlisted in the Lighting Design Awards 2005.

Lumen degradation doesn't matter too much for decorative fittings; a drop of around 20–30% shouldn't ruin the scheme, although obviously at 50–60% degradation the scheme will start to look dim. This problem is much more obvious for spot or floodlighting. Again, you have to take on face value the information provided by the manufacturers; that if you drive and operate the fitting as the manufacturer has specified, then it will perform in the prescribed way.

Carl Gardner is an independent lighting designer and director of CSG Lighting Consultancy Ltd, specialists in interior, exterior and urban lighting design. He is involved, with two other consultancies, in implementing an urban lighting strategy for the city of York, as well as lighting an urban square in Sunderland. He also does product design, marketing and editorial consultancy for lighting manufacturers and distributors. Clients have included SLI Europe, Concord:marlin, Zumtobel Staff, Reggiani Lighting and DW Windsor. Contact: 0207 724 8543 or carlight@btopenworld.com.

Hybrid fixture lights up the night

The LED/incandescent light fixture developed by the California Lighting Technology Center and partners will save energy and costs, and reduce light pollution. The hybrid fixture, which includes a motion detector, is now being applied to pathway, entryway and security lighting.

Many exterior entry and walkway lights in residential and commercial locations use incandescent lamps because they are small and inexpensive. However, these lights tend to burn all night long, and their inefficiency leads to high energy use. The lights also burn out quickly, which compromises security until the lamps are replaced. Compact fluorescent lamps (CFLs) are more efficient and last longer, but cost more and can be difficult to fit into existing fixtures.

A hybrid LED/incandescent fixture with an integrated occupancy sensor (figure 1) addresses both energy and security concerns. A 5 W amber LED runs continuously during the night; the occupancy sensor turns on the incandescent lamp only when motion is detected, flooding the area with warm, bright light. After a few minutes the occupancy sensor turns off the incandescent lamp, while the LED array continues to run.

Developed by the California Lighting Technology Center at UC Davis, with funding from the California Energy Commission's Public Interest Energy Research (PIER) program, the fixture was initially produced by Shaper Lighting, one of the project partners. Also involved in the project were lighting controls manufacturer Watt Stopper, and the Sacramento Municipal Utility District (SMUD).

The use of high-efficiency amber LEDs will enable hybrid fixtures to meet the California Energy Commission's new 2005 Title 24 requirement of 40 lumens per watt.

The hybrid fixture provides efficient, low-maintenance, high-quality lighting, with a number of major advantages:

- **Energy use:** the LED/incandescent lamp combination uses less energy than standard incandescent or CFL fixtures (see table). The

Fig. 1. In this hybrid LED/incandescent outdoor fixture developed by California Lighting Technology Center and partners, a 5 W LED array burns continuously and a 75 W incandescent lamp turns on at a signal from an occupancy sensor.

Hybrid lighting cuts costs

	Standard incandescent fixture	Standard compact fluorescent fixture	Hybrid LED/incandescent fixture
Full power (W)	75	20	80
Reduced power (W)	0	0	5
Hours/year at full power	3650	3650	365
Hours/year at reduced power	0	0	3285
Energy use (kWh/yr)	274	73	46
Energy cost ($/yr)	27.4	7.3	4.56
Main bulb costs ($/yr)	0.91	5.11	0.09
Total cost ($/yr)	28.31	12.41	4.65
Savings ($/yr)	NA	15.9	23.66

The hybrid LED/incandescent fixture saves on both energy and maintenance costs. The calculation for the fixture assumes that although the LED array is on all night, both lights are only operating at the same time for one hour per night. Assumptions: energy cost = $0.10/kWh; operation time = 10 h per night; incandescent bulb life = 1000 h, bulb cost = $0.25; CFL bulb life = 10,000 h, bulb cost = $14; no LED replacement costs for 13 years.

Fig. 2. The amber LED used in this hybrid porch light fixture is a good match for the popular yellow "bug lights" used on many porches.

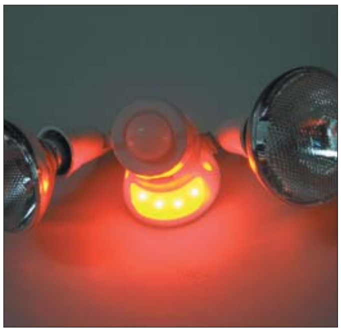


Fig. 3. This hybrid security light developed by Watt Stopper contains a 5 W amber LED array providing continuous illumination (left), while an occupancy sensor turns on the incandescent flood lamps when motion is detected (right).

LED array is rated at 5 W; the incandescent lamp is rated at 75 W. Energy savings will depend on patterns of use. For example, in a 10-hour nighttime period, if the incandescent lamp burned for one hour and the LED burned continuously, the total energy use would be 125 watt-hours.

- **Maintenance:** the LED source has an expected life of 50,000 hours – more than 13 years at 10 hours per night. The incandescent lamp has a much shorter life, on the order of 1000 hours, but reduced on-time means that it can last longer without burning out – almost three years at one hour per night.
- **Brightness:** the LEDs provide sufficient light to identify the surroundings, and the incandescent lamp provides the same light level as a typical outdoor fixture. The product offers several other benefits as well. By providing a pleasant, ambient LED background light, the fixture ensures that there is always light in the coverage area. That feature eliminates dark spots – the "all-or-nothing effect" commonly associated with motion-sensor systems. In addition, when the incandescent lamp burns out, the LEDs will still provide functional light until the incandescent bulb can be replaced. And, with the main light of the fixture directed downwards, there is little or no light pollution.
- **Applications:** this product is aimed at entryway and walkway lighting for office buildings, hospitals, apartment complexes, residential housing, universities, parks, and hotels and motels. It is also targeted at porch lights that use the popular yellow "bug lights" (figure 2). Those lights are very close in colour to amber LEDs, which are among the least expensive, brightest and most efficient of the LEDs on the market.

What's next

Field demonstrations of the Shaper hybrid fixture are now being conducted at an apartment complex, in co-operation with the SMUD. Researchers will monitor the use of the hybrid fixtures to quantify potential energy savings and receive customer feedback on the new designs.

Watt Stopper has applied the hybrid concept to a security light (figure 3). The prototype product features two flood lamps, an occupancy sensor, and an LED that operates all night long. The company is also in the early stage of developing a package integrating an LED driver with electronic controls, which will be available as a drop-in solution for fixture manufacturers.

Hunter Lighting, a division of Hunter Fan Companies, is developing a low-cost LED/incandescent lantern. Meanwhile, Shaper Lighting plans to make available version 2 of its LED hybrid for custom architectural applications in fall 2005.

This article is based on a technical brief produced on behalf of the PIER program by E Source, an energy information service and consulting company (www.esource.com).

PIER Lighting Research Program

The Public Interest Energy Research (PIER) Lighting Research Program (LRP) is a two-year R&D program focused on developing and introducing new energy-efficient lighting technologies into the marketplace. The program is funded by the California Energy Commission and managed by Architectural Energy Corporation. The goal of the LRP is to create new lighting technologies and products that can save energy, reduce peak demand, and reduce air pollution for the citizens of California.

The LRP integrates activities with lighting product manufacturers, and has leveraged co-funding from these manufacturers. The manufacturers provide a great asset for the introduction of these products into the market and further benefits will be realized because the program results are publicly available.

The program includes 15 research and three market-connection projects, and spans both the residential and commercial sectors, as well as outdoor lighting associated with buildings. All 18 projects have now completed their work and the individual final reports are available for review at www.archenergy.com/lrp/index.htm. The projects include three that are specifically related to LEDs:

- **LED Hybrid Exterior Luminaires**
Partners: CLTC, Berkeley Lab, Shaper Lighting, The Watt Stopper
See www.archenergy.com/lrp/products/ledhybrid.htm
- **LED Elevator Fixtures**
Partners: Lighting Research Center
See www.archenergy.com/lrp/products/elevator.htm
- **LED Tasklights**
Partners: Berkeley Lab, Luxo, Permlight, Advance, Cree
See www.archenergy.com/lrp/products/tasklight.htm.

Nancy Jenkins, manager of the Energy Efficiency Research Office at the California Energy Commission, told *LEDs Magazine* that future projects are likely under the PIER program. "We are beginning a scoping analysis to identify the best opportunities for future lighting research," she said. "We expect to develop a solicitation for that work later this year, possibly by the fourth quarter."

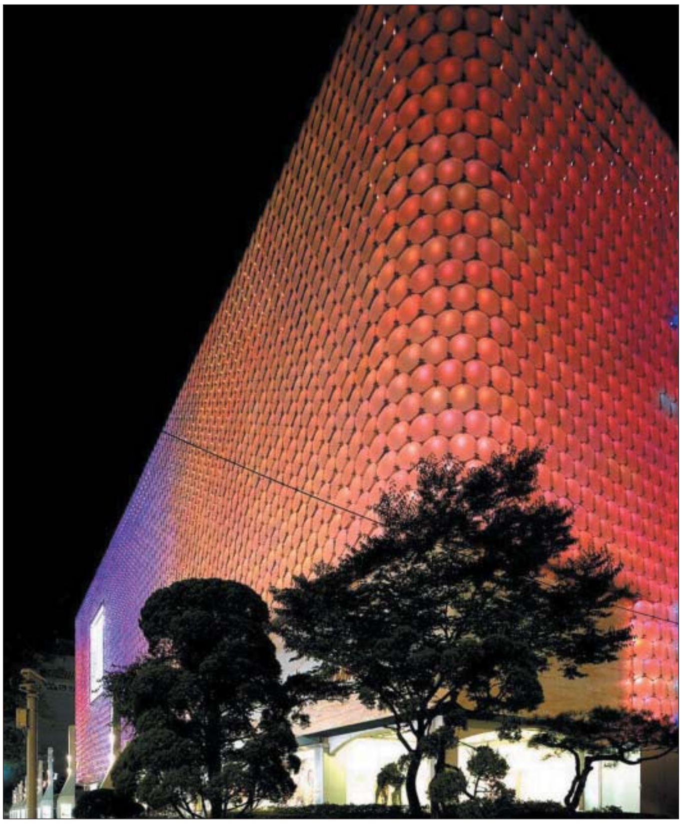
Links

Reports documenting this project and providing more details may be downloaded from:
www.archenergy.com/lrp/products/ledhybrid.htm
www.energy.ca.gov/pier/buildings/projects/500-01-041-0-2-2_1.html
Public Interest Energy Research (PIER) program:
www.energy.ca.gov/pier/buildings.com
California Lighting Technology Center: http://cltc.ucdavis.edu
Shaper Lighting: www.shaperlighting.com
Watt Stopper: www.wattstopper.com

LEDs MAGAZINE

IALD awards honor LED projects

Projects featuring LEDs were among the winners of the 2005 International Lighting Design Awards, presented by the International Association of Lighting Designers (IALD).

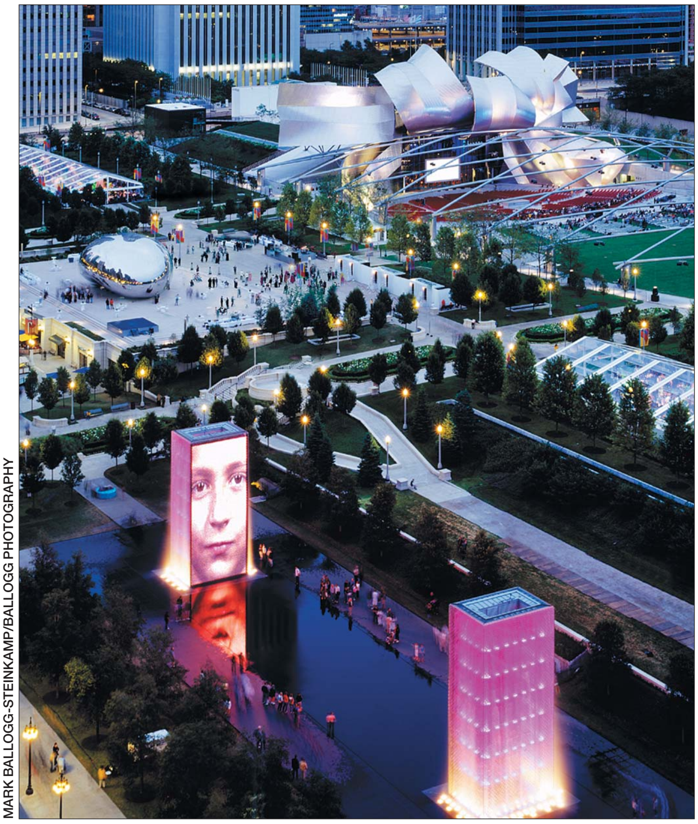


ARUP LIGHTING

The most prestigious presentation, the Radiance Award, went to Galleria West in Seoul, Korea. The outside of this shopping mall has been covered with 5,000 frosted glass disks backlit using LED fixtures supplied by Xilver of the Netherlands. Using individual controls, a series of dynamic, fluid patterns and images can be made to wrap around the entire building. The principal lighting designer was Rogier van der Heide of Arup Lighting.

- **LEDs transform department store in Seoul**

see www.ledsmagazine.com/articles/features/2/1/4



MARK BALLOGG-STEINKAMP/BALLOGG PHOTOGRAPHY

The Crown Fountain in Chicago, Illinois, won an Award of Excellence. Two 50 ft-tall glass towers, connected by a shallow reflecting pool, portray the faces of Chicago residents using giant LED screens supplied by Barco. On the other three sides of each tower, color-changing LED fixtures from Color Kinetics illuminate the interiors and provide vivid walls of color. The principal lighting designer was Jim Baney of Schuler Shook.

- **Chicago's stunning Crown Fountain uses LED lights and displays**

see www.ledsmagazine.com/articles/features/2/5/3

FOCUS LIGHTING

The Semiramis Hotel in Athens, Greece, which won an Award of Merit in the hospitality category, uses LEDs as a primary light source to conserve energy and reduce maintenance. Color-changing LED strips illuminate the lobby's pink glass wall and another white wall directly behind the front desk, providing a dramatically changing lobby environment. On the hotel's custom indicator board, each room "symbol" is individually illuminated by a cluster of LEDs, which alerts guests when they have a message. On the floor in the corridor outside each guestroom, LED message boards enable the hotel to program daily messages. The principal lighting designer on the project was Paul Gregory of New York's Focus Lighting.

Visit www.ledsmagazine.com/articles/features/1/3/3 for up-to-date events information and in-depth reports from recent shows and conferences.

5th International Conference on Solid State Lighting
31 July – 4 August
San Diego, CA, USA
Hosted by SPIE, speakers include George Craford of Lumileds, and Jim Brodrick of the US Department of Energy. A record number of submissions from all parts of industry and academia have been collected, promising the most comprehensive meeting on solid-state lighting to date.
http://spie.org/conferences/calls/05/am/conferences/index.cfm?fuseaction=IE431

PLASA
11–14 September
London, UK
A key event for professional lighting, sound, rigging and staging personnel, attracting visitors from all over the world. Europe's definitive exhibition for professionals and decision-makers within the entertainment, event, corporate, architectural or installation industries.
www.plasashow.com

The Next LED Generation
15 September
London, UK
A panel of experts will address practical issues and common pitfalls concerning LED applications. Starting with procurement, installation and maintenance, this conference will give useful state-of-the-art advice on how to control LEDs with drivers and optical lenses. It will also address the latest in standards and international patent law.
www.ledsconference.co.uk

Automotive Lighting Design and Technologies
20–21 September
Dearborn, Michigan
www.iqpc.com/transportiq

OSC-5: the Organic Semiconductor Conference
26–28 September
Cambridge, UK
OSC-05 will bring together individuals and organizations with an active interest in developing and commercializing organic semiconductor technologies.
www.cintelliq.com

Short course: An Introduction to Practical Light and Colour Measurement
13 October
Birmingham, UK
This course provides a foundation in the measurement, analysis and application of the fundamental lighting quantities used daily by those practising LED lighting design, and more widely, engineers and technicians engaged in photometry work within industry.
www.photonicscluster-uk.org

LEDs 2005
17–19 October
San Diego, CA, USA
This conference brings together key users, component suppliers, and manufacturers of high-brightness LEDs. Participants will receive a thorough assessment of LED markets, while having ample opportunity to discuss industry issues and network with experts, key LED executives and end-users in a three-day open-forum format.
www.intertechusa.com/leds.html

Power Signs 2005
17–19 October
Las Vegas, NV, USA
Power Signs 2005 will bring together executives from the digital signage and affiliated industries to explore the upsurge in on-premise and off-premise digital signage.
www.intertechusa.com/powersigns2005

Organic Optoelectronics Symposium
20–24 October
Tucson, AZ, USA
Part of the annual meeting of the Optical Society of America (OSA).
www.osa.org/meetings/annual/program/ooe

Workshop on Packaging & Assembly of Power LEDs
26–28 October
Palo Alto, CA, USA
This workshop, organized by the International Microelectronics and Packaging Society, promotes the manufacture and assembly of packaged power LEDs into arrays and final products. The core issues revolve around integration in assembly, packaging at the L2 and L3 levels, electrical drivers and color control, thermal management and materials for substrates and final products, device attachment processes, and testing of LED arrays.
www.imaps.org/leds

Bright Ideas
2 November
Boston, MA, USA
www.strategies-u.com

Entertainment Technology Show-LDI
11–13 November
Orlando, FL, USA
The interrelated events of The Entertainment Technology Week attract the top professionals and vendors of lighting, video-display/projection, pro-audio, staging, rigging, special effects and much more.
http://Entertainmenttech.info

OLEDs 2005
14–16 November
San Diego, CA, USA
This conference will focus on expanding markets, new and existing applications, lifetime requirements, and how recently commercialized products are faring in the marketplace.
www.intertechusa.com/oleds.html

COMING IN 2006

Photonics West
21–26 January
San Jose, CA, USA
www.spie.org

ARC 06
13–14 February
London, UK
www.arc06.com

Light + Building
23–27 April
Frankfurt am Main, Germany
www.light-building.messefrankfurt.com

Pushing the Boundaries of Solid State Lighting
16–17 May
Birmingham, UK
www.photonicscluster-uk.org

Lightfair International
30 May – 1 June
Las Vegas, NV, USA
www.lightfair.com