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LEDs MAGAZINE™

Technology and applications of light emitting diodes

Issue 21 May/June 2008

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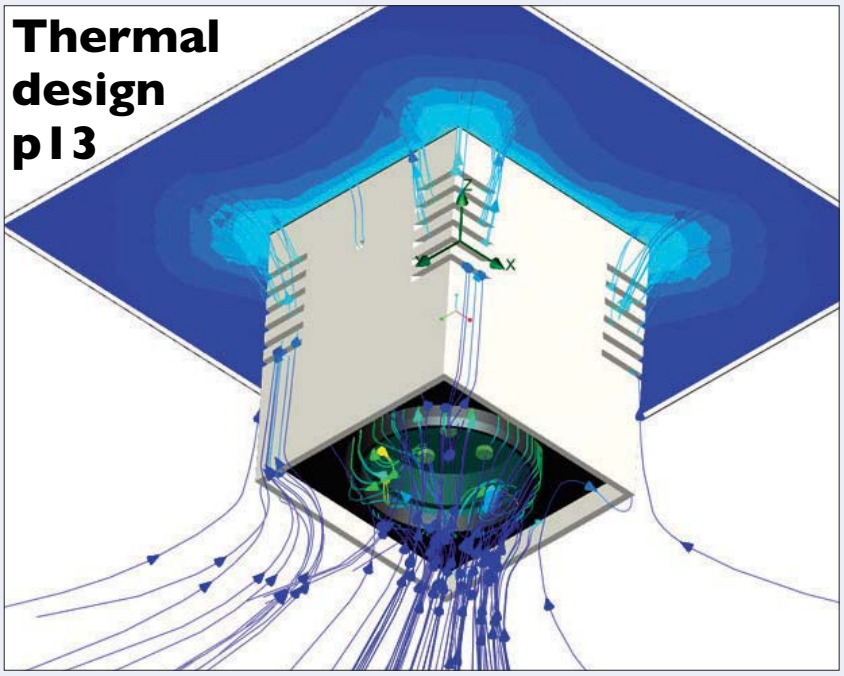

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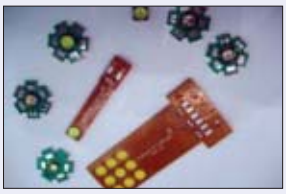

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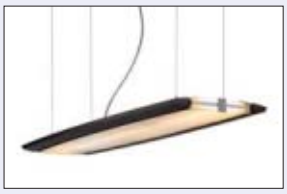

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LEDs MAGAZINE

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On the cover:
Images courtesy of Messe Frankfurt & Pietro Sutera (main), Voxdale (lower left), Eschenbach Optik (lower right)

LED lighting under control

With heightened awareness of environmental issues and strained public budgets, urban streetlighting is becoming the subject of close scrutiny. In LEDs Magazine we've reported a number of trial installations to evaluate the potential of LED fixtures, and the main advantages of using LED outdoor lighting in urban municipalities are discussed in the article beginning on page 46 of this issue.

However, some simple and cost–effective approaches are available to improve efficiency, without switching to LEDs. In Amsterdam the city council is evaluating LED lighting – see photo, below – and is also looking at very simple ways to save energy. Replacing old-style lamps with newer versions that do not require a warm-up time can result in an energy saving of 0.6%. Also, a refinement to the measuring system that calculates when to switch public lighting on at night and off in the morning leads to an energy saving of 1.5%.

Siteco, a German lighting company, says that intelligent control of outdoor lighting installations allows a reduction in energy consumption, light pollution and operating costs with a simultaneous improvement of road safety. The Siteco Control system allows large data packages to be bidirectionally transmitted between control units and luminaires, creating a communicative data network across an entire lighting system. Individual light points can be controlled, luminaire failures can be exactly located. The system also enables energy saving using flexible dimming. For example, on moonlit nights when the weather is good and traffic densities are low, it may not be necessary to have the highest light levels, but more light than normal may be required for places where accidents have occurred or under bad weather conditions.

Lighting control and dimming can also compensate for over-lighting that occurs when new lamps are installed. The efficacy of lamps within street luminaires reduces over time, so standard practice is for newly installed lamps to emit more light than is necessary when first installed. This ensures that lighting levels are still above the required minimal level by the time the next relamping cycle comes around. However, the use of light control enables the newly-installed lamps to be dimmed to the required level, preventing wastage.

The Siteco system is aimed at conventional lighting, but digital control can be applied potentially more effectively to LED lighting. At the luminaire level, a Canadian company, Dellux, has adopted a different approach from dimming to maintain a consistent light level over the lifetime of the LEDs. The individual LEDs are either on or off, and when on they operate at a constant level. To achieve a higher overall light output from the luminaire, more LEDs are switched on. Over the lifetime of the LEDs, as lumen degradation occurs, more LEDs are switched on to maintain the same total light output (see page 35 for more details).

Lighting control can tick a number of boxes by reducing energy consumption and light pollution, and the directionality of LED fixtures can also help in this regard. Alongside economic and "green" concerns, there are other reasons to avoid over-lighting. Some of our readers have highlighted health and environmental issues, including damage to fragile ecosystems and higher incidences of breast cancer, that can be linked to excessive night-time lighting levels. We hope and expect that installers and users will consider these issues as LED lighting moves to the fore as an environmentally-friendly technology.

Tim Whitaker, Editor & Publisher
twhitaker@pennwell.com

LIGHTS OF THE FUTURE

Things are looking up for LEDs

In July, the city of Amsterdam will evaluate LED street lighting from Philips, said Tjeerd Herreman (left), local councillor for transport, traffic and infrastructure and Rudy Provoost (right), CEO of Philips Lighting. The UrbanLine LED luminaires will be installed along the cycle path outside the town hall and opera house, and are expected to save around 50% in energy costs. Other trials are taking place in Rome and Xiangfan, China (see www.ledsmagazine.com/news/5/5/25).

Allegro's New Multi-Channel Constant-Current Drivers for LED Displays, Signs and Architectural Lighting

Features

- Output current up to 150 mA per channel (A6281)
- 10-bit PWM per channel (A6281)
- 7-bit current-control DACs for colour calibration (dot correction) (A6281 and A6285)

Benefits

- Precise current control for high quality images
- Accurate colour balance and white point
- Remote diagnostics

Applications

- Full-colour LED video displays
- Monochrome and colour message and graphic displays
- Channel letter signs
- Architectural and decorative lighting

Allegro's new family of LED driver ICs offers solutions for signs, large video displays, architectural and decorative lighting and control panels.

The ***A6281*** typically drives a cluster of red/green/blue (RGB) LEDs for one pixel in a large display or a lighting fixture. You can precisely control LED brightness via 10-bit pulse-width modulation (PWM) per channel, and adjust colour balance via 7-bit analog current control. The ***A6281*** requires only three external passive components to operate. The high level of integration and tiny 3 x 3 mm QFN package enable compact board designs. The ***A6281's*** unique clock-regeneration technique allows hundreds of devices to be cascaded on a single cable.

The ***A6282*** and ***A6285*** have 16 constant-current output channels. They can be cascaded to create megapixel text or video displays. They can also be used in smaller applications such as LCD backlighting or controlling LEDs in an instrument or control panel. Both the ***A6282*** and ***A6285*** operate with LED supply voltages up to 12 V, which allows stacking of three or more LEDs per channel. The ***A6282*** is available in 24-lead surface-mount packages: QFN, SOIC, and TSSOP. The ***A6285*** features open-LED detection and dot correction and comes in a 32-lead QFN.

All of these devices operate over the -40 to +85°C temperature range.

Model	Number of Channels	Current per Channel	LED Voltage	PWM	Dot Correction
A6281	3	150	17	10-bit	7-bit
A6285	16	80	12	External	7-bit
A6282	16	50	12	External	-

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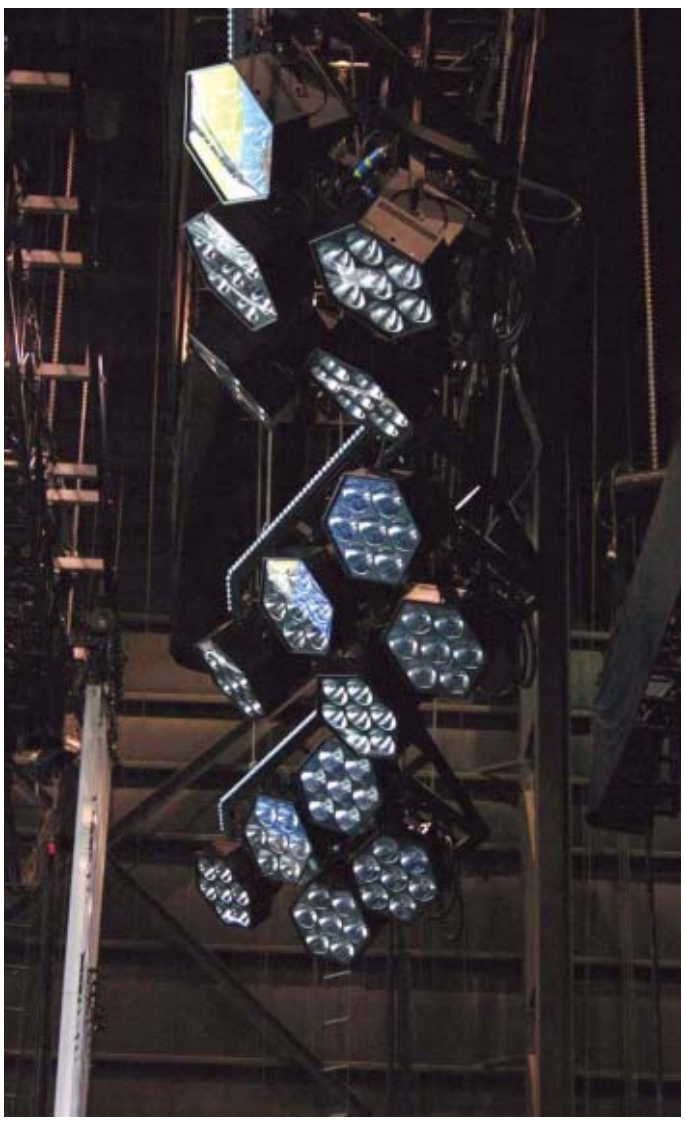
ENTERTAINMENT

Radiohead tour is bulb-free with i-Pix LED fixtures

Rock band Radiohead is using an all-LED lighting rig for its world tour, which kicked off in the US at the start of May. UK-based LED innovators i-Pix have created the BB7, a brand new fixture, for the tour, and this is being utilized by Radiohead's lighting & visuals designer Andi Watson. Watson's unique energy-saving design includes three different types of fixture from i-Pix, plus other LED products, all of which work seamlessly together.

Chris Ewington of i-Pix said he was surprised how soon it has become possible to use LED lighting throughout, for a major tour. "We all appreciated Andi taking a massive leap of faith in having the courage to dispense completely with conventional lighting in his show," said Ewington. "Not having a single discharge or incandescent lamp in the design sets a new benchmark at least a couple of years [earlier than] we had anticipated."

The new BB7 is a seven-cell high power homogenized 10 degree RGB source, which consumes 210 watts at 240 volts. Forty-eight of the BB7s are in various positions around the rig, including 25 in five custom 5-way frames produced by Specialz. Watson is also using 48 new production-model BB4s from i-Pix on his front truss. The BB4 is a four-cell, high-power homogenized 20 degree RGB lightsource, and consumes 120 W at full power. Additionally, 14 i-Pix Satellites with holographic film are mounted on the floor in and around the backline to light the band at close quarters. The BB4 and BB7 fixtures both contain custom LED light engines produced exclusively for i-Pix by Lamina Ceramics in New York.



Ewington says that the project started when he visited the US last October to see Lamina's new prototype narrow optic. He then showed Watson the BB4, which was already in production in January this year, along with a test rig of the embryonic idea he had for the BB7 - without optics. Once the new optic became available, Ewington sourced the first 12 and again met Watson in March, along with Radiohead production manager Richard Young and lighting crew chief Andy Beller, and showed the first prototype BB7 with the new narrow optic.

Watson liked it and thought the fixture was exactly what he wanted, after which i-Pix priced up the project for Richard Young. From this came an order to produce 206 fixtures (enough for 2 rigs) from scratch in just over 5 weeks! Having just undergone the "birthing process" with the BB4, the i-Pix team was well geared up for this challenge. "From our experience, most shows spend months in discussion and a maximum of 6 weeks in prep, so this timescale did not come as a surprise," said Ewington. "Our first fixture, the Satellite, was developed under similar circumstances to coincide with Radiohead's last tour." To meet the schedule, the design period was condensed from six months to 4 days, the components were produced in two weeks and the units built over two weeks. i-Pix completed the production task with 4 days to spare.

- More details: www.ledsmagazine.com/news/5/5/19

CONSUMERS

Study finds US consumers warming to LEDs for energy-efficient lighting

A new study of US consumers says 87% would be willing to try LED technology for some or all of their home lighting in order to be more energy efficient, and that many would pay slightly more for LEDs than traditional lamps. The study, commissioned by Arrow Electronics and conducted by Harris Interactive, also found that consumers have become increasingly more aware of energy-friendly lighting options, and that the next wave of mass-market residential and business lighting could be coming from LEDs.

"While the benefits of LEDs have long been recognized by electronics makers, the public's rising concerns over energy costs and the environment signify a positive shift for this important technology," said Michael Long, president and COO of Arrow Electronics. "It represents a rapidly developing market where electronic lighting modules are playing an increasing role."

The study found that consumers say they would be willing to pay an average of $4.70 per LED-based bulb, which compares with an average of $0.50 for incandescent bulbs and $3 for compact fluorescent lamps (CFLs). Eleven percent of consumers are open to paying between $6 and $10 for an LED bulb, and 4% say they would be ready to spend $11 or more.

Additional findings include:

- 82% of consumers cited the cost savings that LEDs can deliver as motivation to pay more for the bulbs, while 53% pointed to the environmental benefits.
- 47% of consumers use CFLs in their homes, 36% use regular fluorescent lamps and 20% use halogen bulbs.
- The most popular methods of light-related conservation in the home (of those listed) are hitting the "off" switch (87%) and replacing incandescent or regular glass light bulbs with CFLs (46%). Other energy-saving measures include keeping the thermostat lower in the winter (58%), using Energy Star appliances (50%) and using renewable energy sources such as solar and wind power for some or all of their energy needs (4%).
- Many consumers indicated that the use of LED lighting by a friend or family member or by their employer would encourage them to use LED lighting in their home.
- Factors that would influence a consumer to pay more for LED lighting than alternative bulbs are cost savings on their energy bill (82%), fewer replacements over time (77%), and more natural lighting (48%).
- Four in 10 consumers (40%) stated that they are more concerned about saving money in the short term than with saving energy.

News is posted daily on our website at: www.ledsmagazine.com/news

VEHICLES

Marl wins Amtrak contract to supply LED downlights

UK LED company Marl is to supply LED downlighters to US railroad operator Amtrak, for installation into Superliner diner lounges. The contract was awarded on the basis of energy efficiency, ease of installation, and suitability for high vibration applications such as train coaches, according to Graham Round, Marl Opto's VP of

NEWS & ANALYSIS

sales. "We have been able to meet all the applicable US railroad safety regulations, especially those covering emergency lighting. In the event of total power loss, Marl LEDs can continue to provide illumination for four hours from the back-up battery."

Amtrak is to install 24 of these lights into each refurbished Superliner dining car.

• More details: www.ledsmagazine.com/press/16242

CHIP MAKING

Bridgelux invests funding in LED chip capabilities

After receiving $23 million in venture capital financing in August 2007, LED chip maker Bridgelux completed a financing round in April 2008 that included $30 million of private equity investment (see www.ledsmagazine.com/news/5/4/13). LEDs Magazine asked Bridgelux CEO Mark Swoboda why VCs are particularly impressed with Bridgelux. "I believe that there are two key reasons why our investors have confidence in us. First we have world-class LED technology including proprietary MOCVD reactor designs, innovative epitaxial processes and chip design capabilities that continue to drive the performance of our high power LED chips."

The second reason, said Swoboda, is a management team that has "deep industry experience, a team that we are expanding. It is also a team where many of the members have worked together before at other companies in the LED industry." One example is Keith Scott, formerly of Philips Lumileds, who has "deep lighting industry experience, LED applications experience, and an impressive understanding of market requirements both current and emerging," said Swoboda. "Keith's role is to talk with our customers and partners and facilitate the new product definition and marketing processes."

At the time of its latest funding round, Bridgelux said the cash would enable it to rapidly expand beyond its LED chip product offerings and move aggressively into LED lighting products. Swoboda elaborates on these plans: "Our goal is to facilitate the market adoption of solid-state lighting. We continue to drive our chip technology and will be introducing new, higher performance products in 2008. The general lighting industry is a diverse, global industry and we continue to work with a number of partners whose requirements go beyond the chip. Since LED lighting is still an emerging technology there are a wide variety of potential applications. We plan to introduce new products over the next 12 months that will enable the adoption of LED technology in new applications. Obviously, I can't divulge much information about those at this time."

Although the company began life as a fabless chip supplier, it is now making some of its own chips. "We have epi and chip manufacturing capacity in Sunnyvale, California," says Swoboda. "We've been developing propriety MOCVD hardware and process technology for the last 4 years. We purchased a chip fab in late 2007 and have been processing chips since Q1 2008. We will also use outsourced manufacturing whenever required to support market requirements and the needs of our customers."

ENTERTAINMENT

Halo Lighting installs LED ceiling in London nightclub

Halo Lighting has transformed the London nightclub Area with a lighting ceiling built from customized, modular X-Panel LED video matrix tiles from around LED-Lites. The Halo Lighting design team led by Yann Guenancia built a precision custom-made metal grid, allowing the 200 x 200mm panels, with their 40mm pixel pitch, to follow the curvature of the arches. Halo had to package the fixtures into modular panels 2 x 1 m long, and assemble the whole structure on site to create the matrix. "It was the modularity of the X-Panel that enabled us to do this — but if you think that the slightest deviation on an 18 metre line of LED's would show up instantly, you get an idea of how complex this task was," states Guenancia. The Unistrut frame contains no fewer than 768 of the X-Panels, hooked up to two dedicated X-Image Pro 36 data drivers — each capable of controlling 36 DMX universes at high speed, and handling the pixel mapping.

BUSINESS

Lighting Science Group teams with Acuity Brands, buys Lighting Partner

Acuity Brands Lighting, one of the world's leading providers of lighting fixtures, has entered into a strategic alliance with Lighting Science Group Corporation (LSG) to develop and launch multiple LED-based lighting products. Acuity Brands Lighting (ABL), a wholly-owned subsidiary of Acuity Brands, Inc, had fiscal year 2007 net sales of approximately $2.0 billion. The LED products developed will form part of ABL's well-established portfolio, including Lithonia Lighting, Holophane, Hydrel, and Gotham – some of these brands already manufacture LED-based fixtures.

ABL and LSG say they will jointly develop selected new LED-based products for architectural, commercial, industrial, and public infrastructure use. The companies say that the alliance is designed to leverage the channel strength, product innovation, delivery capabilities, and brand recognition of ABL in combination with the LED technology know-how, speed of innovation, and rapid design capabilities of LSG.

"This alliance allows Acuity Brands Lighting to enhance its existing LED portfolio using advanced technology," said Vernon Nagel, CEO of Acuity Brands. "We continue to seek out strong alliances to accelerate our ability to integrate advanced technologies, such as LED, into leading-edge fixture design to serve specific customer needs. LSG's patented technology, experienced team, and expertise in thermal management, driver design, and color control will give us a broader offering for the growing LED market."

This is clearly an important deal for LSG, providing access to new global channels via Acuity's respected brand names. It's worth noting that several LSG executives were formerly with Acuity, including Ken Honeycutt, president and COO of LSG, who is a former CEO and president of Acuity Brands Lighting. There is no indication of exclusivity in this deal, and Acuity will doubtless continue to work with other LED companies as well.

• More details: www.ledsmagazine.com/news/5/5/10

NEWS & ANALYSIS

LSG ACQUIRES LIGHTING PARTNER

In late April, LSG completed the acquisition of Lighting Partner BV (LPBV), an innovative manufacturer providing a broad range of LED and high-intensity discharge (HID) lighting solutions for residential, commercial, and retail applications based in The Netherlands.

LPBV had revenues of $23 million with positive cash flow in 2007, and approximately 70% of its business is LED-based. For example, the company launched Eyeleds, an LED lighting system that is currently distributed in over 35 countries and is used in the commercial and residential market.

"The acquisition creates a significant and immediate global presence for both companies and provides the foundation for us to become a leading player in the LED lighting market," said Govi Rao, CEO of LSG. "Combining LSG's extensive LED integration capabilities with LPBV's fixture design expertise and access to high quality manufacturing, puts us in a position to significantly accelerate the proliferation of our high performance lighting solutions."

LSG has acquired 100% of the outstanding common stock of LPBV, and has paid $5 million to the former shareholders of LPBV as well as issuing a total of 4.632 million shares of LSG common stock (around 16% of total shares). A majority of LSG shares is held by LED Holdings, LLC, a portfolio company of Pegasus Capital Advisors, a private equity fund manager. LED Holdings acquired LED Effects in 2007.

• More details: www.ledsmagazine.com/news/5/4/27

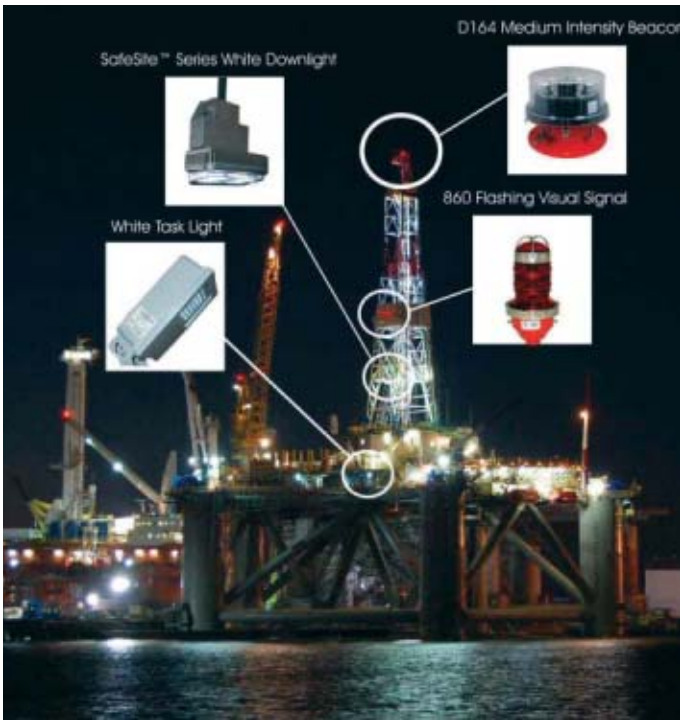
PROGRAMS

Term starts for Cree's LED University program

LED streetlights installed at the Tianjin Polytechnic University campus

Following its LED City and LED Workplace programs, Cree has launched LED University, which brings together an international collection of universities that will all work to accelerate the adoption of energy-efficient LEDs. North Carolina State University (NCSU) is joined by Marquette University (Milwaukee, WI), University of California at Santa Barbara (UCSB), the University of Arkansas and Tianjin Polytechnic University in China. The institutions have committed to evaluating and using LED lighting in areas such as offices, dormitories, parking garages, walkway lighting and streets across their campus infrastructures. Each is conducting LED lighting pilots to determine the cost and environmental benefits of switching to LED lighting in campus applications. Initial installations include:

• NCSU installed LED recessed can lighting from Cree in the chancellor's office and a dormitory, and is installing LED parking garage lighting from BetaLED.
• Marquette University installed LED T8 replacements from LED Dynamics in the vice president for administration's office and is installing LED recessed and task lighting.
• UCSB installed 23 LED streetlights from BetaLED on a campus street and reports that compared to its traditional streetlights, it is achieving a 44% reduction in energy use as well as better light distribution and color rendition.
• University of Arkansas has installed the first set of what it plans will be approximately 1,700 recessed LED lights from Cree in university buildings, starting with lighting the chancellor's residence.
• Tianjin Polytechnic University installed 1,500 LED streetlights designed by its graduate students on the campus' main roadway(see photo).



BUSINESS

Zumtobel acquires Italian LED company SpaceCannon

The Zumtobel Group, a major Austria-based lighting manufacturer, has acquired the Italian company SpaceCannon, a specialist in LED-based lighting for outdoor, façade and event lighting. Based near Alessandria in Piedmont, Italy, SpaceCannon posts annual sales of approximately EUR 7 million and has a current workforce of almost 50. Around 70 percent of SpaceCannon's applications are LED-based, supplemented by xenon technology for outdoor lighting effects that are visible from a long distance.

CEO Andreas Ludwig said that SpaceCannon provides Zumtobel with access to sales channels and expertise in new market segments, such as event and show lighting. "SpaceCannon makes the ideal complement for us as we continue to expand our technology base and applications know-how in LEDs – the market of the future," he said.

The integration of SpaceCannon into Zumtobel's LED division, Ledon, will enable new sales channels, while Zumtobel's Thorn brand will be able to draw on the expertise of SpaceCannon in its core activities in professional outdoor lighting, not least in the development of LED-based outdoor and façade luminaires.
• More details: www.ledsmagazine.com/news/5/4/28

HAZARDOUS LOCATIONS

Dialight provides zero maintenance lighting for rigs

In the first installation of its kind, LED-based illumination has been retro-fitted on a drilling rig of a major oil and natural gas producer. Dialight's SafeSite illumination fixture was selected for this particular test installation as it has been specially designed to operate in the harsh and hazardous environment of drilling rigs where vibration is the major cause of failure for traditional light sources such as metal halide and high pressure sodium. With a very robust housing designed to UL Class 1 Division 2 standards, it is virtually impervious to shock and vibration, making expensive re-lamping a thing of the past not only for rigs, but also for refineries, oil platforms, chemical plants and other hazardous locations.

The low voltage and low operating temperatures of these fixtures also make them much safer for use in combustible atmospheres as well as in extreme temperatures or in wet-wash locations where conventional lamps would shatter under sudden temperature changes. The 100-watt SafeSite fixture can replace traditional HID fixtures that require up to 250 watts for potential power savings of up to 60%. The fixture is designed to focus the light efficiently so that it illuminates only the required area. In addition, the LED fixtures do not require a warm-up period, so can function as "instant-on" safety lights that turn on when required, rather than wasting energy by being illuminated 24/7.

BUSINESS

Nexxus Lighting closes acquisition of Lumificient

Nexxus Lighting Inc. has closed the previously announced acquisition of fellow solid-state LED lighting manufacturer Lumificient Corp based in Maple Grove, Minnesota. Nexxus believes that the strength of Lumificient's intellectual property, combined with the potential to build on its own IP with expanded R&D capabilities, positions Nexxus Lighting to bring more new products to market faster. Lumificient had 2007 revenue of ~$2.2 million and 1Q08 revenue of ~$933,000.

"The team at Lumificient brings expanded R&D capabilities to Nexxus and a platform of new technology that we feel will provide significant opportunities for growth in the general illumination `white light' market," stated Mike Bauer, President and CEO of Nexxus Lighting. Zdenko Grajcar, founder of Lumificient, will serve as Nexxus Lighting's CTO. "We expect to introduce several exciting new products utilizing patent-pending technologies developed by Zdenko and his team at LightFair in late May," added Bauer.
• More details: www.ledsmagazine.com/news/5/5/5

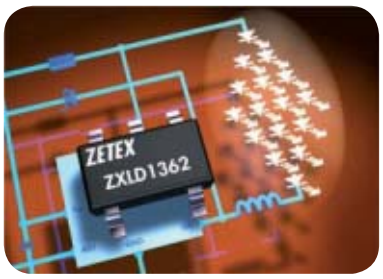
Visit us at euroLED, booth # LED20.

16 LEDs

Zetex SOT23 IC drives 16 LEDs

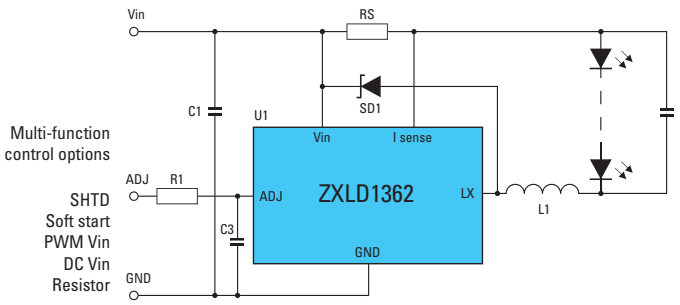
The ZXLD1362 is a highly integrated, SOT23 packaged LED driver. Housed in a single compact package, it can drive as many as 16 high-brightness 1000 mA LEDs, achieving up to 95% efficiency.

A new member of the ZXLD1350/1360 series, the ZXLD1362 is compatible with all other products in the range, enabling designers to change drivers easily to meet the specific needs of any application.



ZXLD1362

Buck 6 to 60 V 1000 mA SOT23 with multifunction ADJ pin



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  No large inrush current at turn-on
- **Dimming ratio – 1000:1**
  Suitable for precision brightness control

Applications:

- Street lights
- Tunnel lights
- Automotive lighting
- Desk lamps

Product	Output current	Operating voltage	Number of driven LEDs	Dimming method
ZXLD1362	0–1000 mA	6–60 V	1–16	PWM or voltage
ZXLD1360	0–1000 mA	7–30 V	1–8	PWM or voltage
ZXLD1350	0–350 mA	7–30 V	1–8	PWM or voltage

For more information, please visit: http://www.zetex.com/zxld1362

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Solving the system-level thermal management challenges of LEDs

Thermal management is critical to LED performance and life, so mechanical designers need to consider thermal issues from the earliest stages of the development process, writes John Parry of Flomerics.

In referring to LEDs, the US Department of Energy (DOE) states that no other lighting technology offers so much potential to save energy and enhance the quality of our building environments. Thermal management is critical to LED performance because the lifetime is a function of junction temperature. Rudi Hechfellner, applications manager for Philips Lumileds Lighting, says that thermal management is by far the most critical aspect of LED system design. LED system manufacturers are addressing this challenge by seeking out improved heat sink designs, high efficiency circuit boards, high thermal conductivity enclosures and other advanced thermal design techniques. Thermal simulation is playing an increasingly important role through its ability to evaluate various alternatives and optimize the system-level design from a thermal standpoint prior to the prototype phase.

Thermal challenges for LEDs

High powered LEDs provide greater thermal challenges than most other light sources, largely because LEDs don't generate infrared radiation. According to the DOE, 75-85% of energy used to drive LEDs is converted to heat "… and must be conducted from the LED die to the underlying circuit board and heat sinks, housings or luminaire frame elements." The DOE has produced a fact sheet on "Thermal Management of White LEDs" (www.netl.doe.gov/ssl/PDFs/ThermalLED_Feb07_2.pdf). In the short term, the excess heat can reduce an LED's light output and produces a color shift. However, another reason thermal management is so important are the long term effects, which include accelerated reduction in light output, resulting in a shortened useful life. The DOE says that manufacturers normally test LEDs at a fixed junction temperature of 25°C. On the other hand, under constant operation the junction temperature is typically 60°C or greater, and under these conditions the LED's light output may be 10% or more below the rating. For products with inadequate thermal design, this figure can be significantly higher.

For tungsten light bulbs the heat flow path is direct from the filament to the surroundings by thermal radiation, with some participation of the glass. The primary path of heat transfer in an LED device is usually conduction from the junction to the system enclosure. The LED device manufacturer provides the package-level thermal management, and the biggest concern is minimizing the thermal resistance from the junction to the outside of the package. Some LEDs, typically small devices mounted on panels, have leads that form the main thermal conduction path. For these devices the thermal resistance from the junction to the leads is most critical.

Package design varies by manufacturer and type of LED but the concepts between packages are similar. In the example shown in Figure 1, the LED chip is attached with a bond layer to a metal interconnect layer which is then attached to a ceramic substrate and an electrically-isolated thermal pad. The entire package is designed to maximize optical output and move heat away from the back of the LED chip.

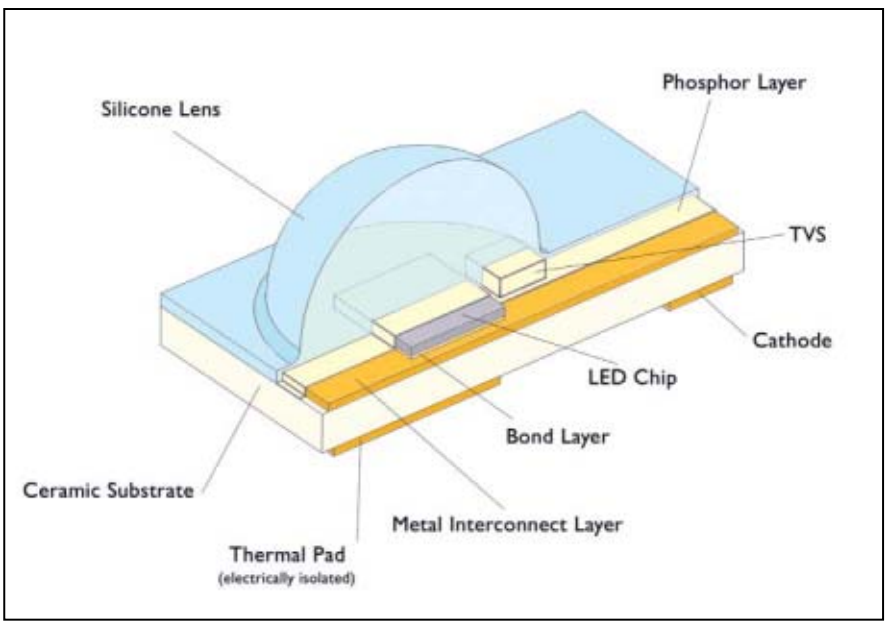

Fig. 1. Schematic of a high-power LED package (white Luxeon Rebel from Lumileds).

Hechfellner pointed out that even the most thermally-efficient LED device requires that a cooling system be developed around it. He said that because most traditional lighting methods radiate heat, they do not have the same thermal issues. Many systems manufacturers have much more experience in the electrical and mechanical than in the thermal aspects of design. "What the engineering community needs is a change of their mindset: They need to think thermal first and electrical later," Hechfellner said. "Thermal represents 90% of today's design challenges for LED systems manufacturers while electrical and mechanical together provide only 10%."

The biggest challenge facing systems companies, said Hechfellner, is to develop a thermally-efficient socket that will enable an LED device

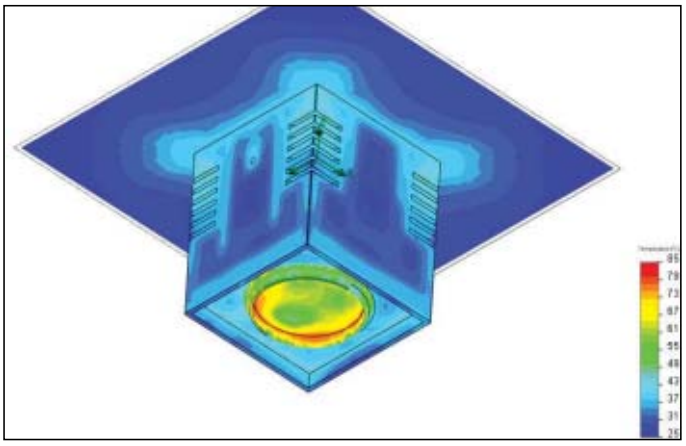

Fig. 2. Surface temperatures of the entire lamp.

to simply be plugged in while the heat is conducted away to the environment. "To the best of my knowledge, there are no such systems currently on the market," he said. "Improved thermal interface materials and design tools are needed to develop them. We are focused on creating an infrastructure that helps our customers create a better thermal design — such as simulation tools that enable accurate models of LED devices to be dropped directly into the systems design."

The nature of an LED package is such that even as LEDs increase in efficiency, the challenge of thermal management will not disappear. As light output reduces with temperature, a greater proportion of the electrical power is turned into heat, further increasing the temperature. The light output from an LED reduces as it ages, so its heat output may increase over time, accelerating the rate of degradation. A common cause of lumen depreciation in white LEDs is a yellowing of the phosphor which may be heat- or environmentally-induced but does not necessarily mean that the chip is working less efficiently or that there is more heat being generated. Thermal management solutions will need to be sufficient to remove the heat dissipated by the LED over its useful life.

System-level design considerations

Design considerations are different for every LED, and care must be taken to understand the metrics and performance of the LED being used in the application. The essence of LED system design is transferring the heat efficiently from the LED thermal spreader, slug or wire leads to the ambient. First of all, a secure and thermally-efficient bond must be provided between the slug and the circuit board pad. The thermal connection typically runs through a small thermal via in the PCB to a large copper area on another layer. Heat is typically conducted through this layer to the enclosure or an external heat sink.

An external heat sink may be required in situations where an exceptionally large amount of heat is dissipated within the enclosure. Copper and aluminum are commonly used materials for LED heat sinks. Optimizing the geometry of the heat sink is a critical concern in many applications as the heatsink-to-air thermal resistance

is often significant. Heat sink performance varies depending upon factors such as the material, number of fins, fin thickness and base thickness. External heatsinks extend the surface area available for heat to transfer to the ambient air. The optimum design depends on the local air-flow conditions that are affected by the introduction of the heat sink, increasing the design challenge.

Copper offers superior thermal conductivity, while aluminum is lighter and less expensive. In some cases PCBs made of materials that improve heat transfer through the board may be used. These boards may be made of ceramic, coated steel or aluminum, or one of several other materials.

The most difficult LED applications are those that require an air-tight enclosure to protect the LED from its environment. One way to address this challenge is to use an enclosure material having a high thermal conductivity. In other cases, more elaborate measures may be required. One example is an air-to-air heat exchanger design that uses internal fans to circulate hot air over internal fins that conduct heat into the walls of the enclosure. External fans are then used to move cool ambient air over fins fitted to the outside of the enclosure to remove the heat. Heat transfer is then via a series of convection and conduction steps.

Obviously, there are a large number of design variables that need to be considered when designing LED systems. Optimizing the thermal design is critical for a number of reasons. The DOE's fact sheet on thermal management notes that excess heat affects both short-term and long-term LED performance. The reversible short-term effects are color shift and reduced light output. Minimizing color shift is critical in, for example, back-lighting in emerging applications such as LCD TVs where increasing the LED density improves the color variation in the image but makes the cooling more challenging.

Increased junction temperature can severely affect lifetime and reliability performance of a power LED. For example, a 10° change in junction temperature — all other things being equal — has a dramatic effect on lifetime and reliability. Optimizing the thermal design may also have a major impact on product cost. For example, the effectiveness of the thermal design may determine whether or not it is necessary to use a heatsink, a decision which will substantially affect the overall cost.

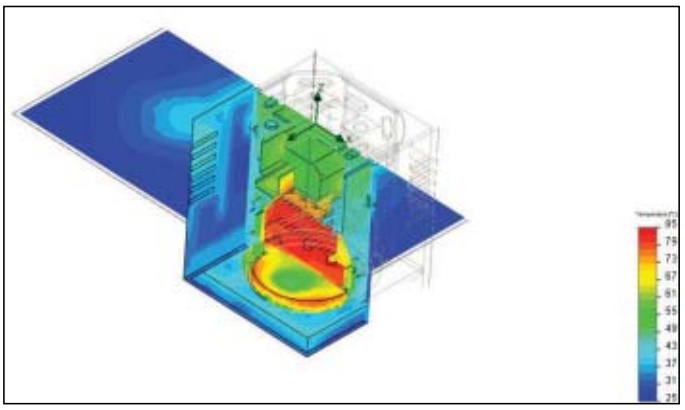

Fig. 3. Temperatures inside the lamp shown with a 50% slice.

Role of simulation

Most original equipment manufacturers (OEMs) and component suppliers have long accepted the need to identify and resolve thermal issues in the early stages of the design process. Many have adopted software that performs component- and system-level analysis to address thermal management prior to physical testing, with the goal of avoiding additional design iterations.

However, manufacturers of LED systems are frequently used to designing systems built around other lighting technologies that do not provide the same thermal management challenges. These companies may not have the necessary knowledge and expertise to use the powerful and sophisticated computational fluid dynamics (CFD) software used by semiconductor device manufacturers and large electronics OEMs.

All CFD codes of a decade ago, and many of today, require the user to have a deep understanding of the computational aspects of fluid dynamics in order to be certain of obtaining accurate results. For example, users need to know how to translate their computer-aided design (CAD) model into the CFD environment, then "reverse"

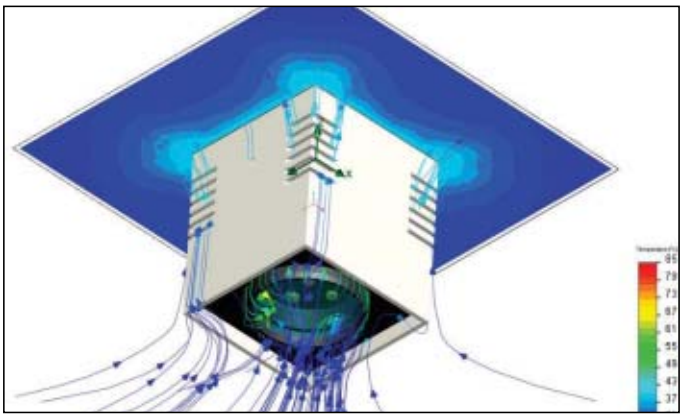

Fig. 4. Visualization of the flow trajectories caused by convection; this brings cold air inside the lamp while hot air escapes through the slots.

the model so that empty flow space rather than the solid product is modeled. They also need to create a mesh with the right properties, determine boundary conditions, select the right physical models, tweak solver settings to ensure convergence, as well as other tasks. Previous generations of CFD software also required a substantial amount of tuning and tweaking such as manually modifying cells to improve the mesh quality, and adjusting solver controls such as the relaxation factors, in an effort to get it to converge to a solution.

But in the last few years a new generation of CFD software has been introduced that addresses all the major reasons for the relative lack of use of CFD software. Its use of native 3D CAD data, automatic detection and gridding of the flow space, and managing the flow parameters as object-based features, eliminates the need for engineers to understand the computational part of CFD. This enables them to focus on the fluid dynamics of the product, which is already their responsibility to understand and master. The newest generation of CFD software contains sophisticated automatic control functions that ensure convergence in almost every application without the need for manual tuning.

This new generation of software is well suited to the thermal design of LED systems. The skills required to operate the CFD software are simply knowledge of the CAD system and the physics of the product, both of which the vast majority of design engineers already possess. The ability to utilize the native 3D CAD saves time and makes it possible to capture the full geometric complexity of LED systems. The new generation of software also covers all of the possible thermal transfer mechanisms so it can be relied upon for accurate analysis. By automating all of the steps required in creating a CFD model, the new generation of CFD software makes it possible for LED systems designers to evaluate a large number of design alternatives very quickly.

Figures 2, 3 and 4 show simulations of a lamp built using six high power LEDs. These LEDs and the built-in power supply dissipate heat. No fans were used so engineers could only count on conduction, natural convection and radiation. Using a CFD software package embedded in their CAD system, engineers from Voxdale, a consulting firm, defined all materials and their characteristics, heat dissipation for LEDs and power supply, gravity direction for convection, and other factors. After automatic meshing and solving, the results were visualized on the native CAD geometry as shown in the images (all courtesy of Voxdale).

Dialight plc, a leader in applied LED technology, uses CFD software embedded inside its CAD software for the design of LED lighting systems. "Although power LEDs are becoming more efficient, a significant amount of input power translates into heat," says Gordon Routledge, Dialight VP of illumination products. "Cooling of the electronics and LED devices is critical to long-term reliability and so thermal analysis — including airflow analysis — is vital to help us meet our demanding development schedules."

Physical testing

Physical testing is too costly and time consuming an approach to use to investigate speculative design changes, but is highly effective for both validating the final design and in investigating manufacturing issues. Physical testing can confirm the material property values used in the simulation, check bond line thickness, and identify problems such as voids in the die attach.

The leading approach takes advantage of the fact that the temperature is proportional to the forward voltage drop of a specific device. After determining the forward voltage drop at a specific measurement current, a large current is applied to the LED, and this heats the LED. Then this current is turned off while another much smaller test current is applied for the measurement. The small test current used to characterize the device after heating has to be identical to that used previously to measure the device's forward voltage. The forward voltage is measured very quickly before the junction has the chance to cool down. The ability to monitor the temperature change with respect to time can provide detailed information on how heat flows through each layer in the path from the junction outwards. This allows direct measurement of the key thermal resistances in the heat flow path, such as the die attach resistance.

Sophisticated measurement hardware that can measure the temperature change within a few microseconds of the device being powered off is required, due to the LED's fast thermal response. This type of thermal transient measurements can be used to generate highly accurate "structure functions," which provide detailed internal information for power-LED packages, revealing die-attach failures and other structural integrity problems.

Conclusions

LED technology offers enormous potential to save energy and enhance lighting quality and reliability. Thermal management is critical in LED design in order to meet performance, lifetime and cost requirements. Systems designers have a wide range of possible alternatives to consider in meeting thermal challenges. The latest generation of CAD-embedded thermal and fluid simulation software enables design engineers to diagnose thermal problems, evaluate alternative designs, and iterate rapidly to an optimal solution. The final design can be qualified with measurements at the prototyping stage to ensure manufactured tolerances, e.g. for interface thicknesses to meet the thermal design requirements and to identify any manufacturing problems. The knowledge gained can be used to improve future design simulations.

About the author

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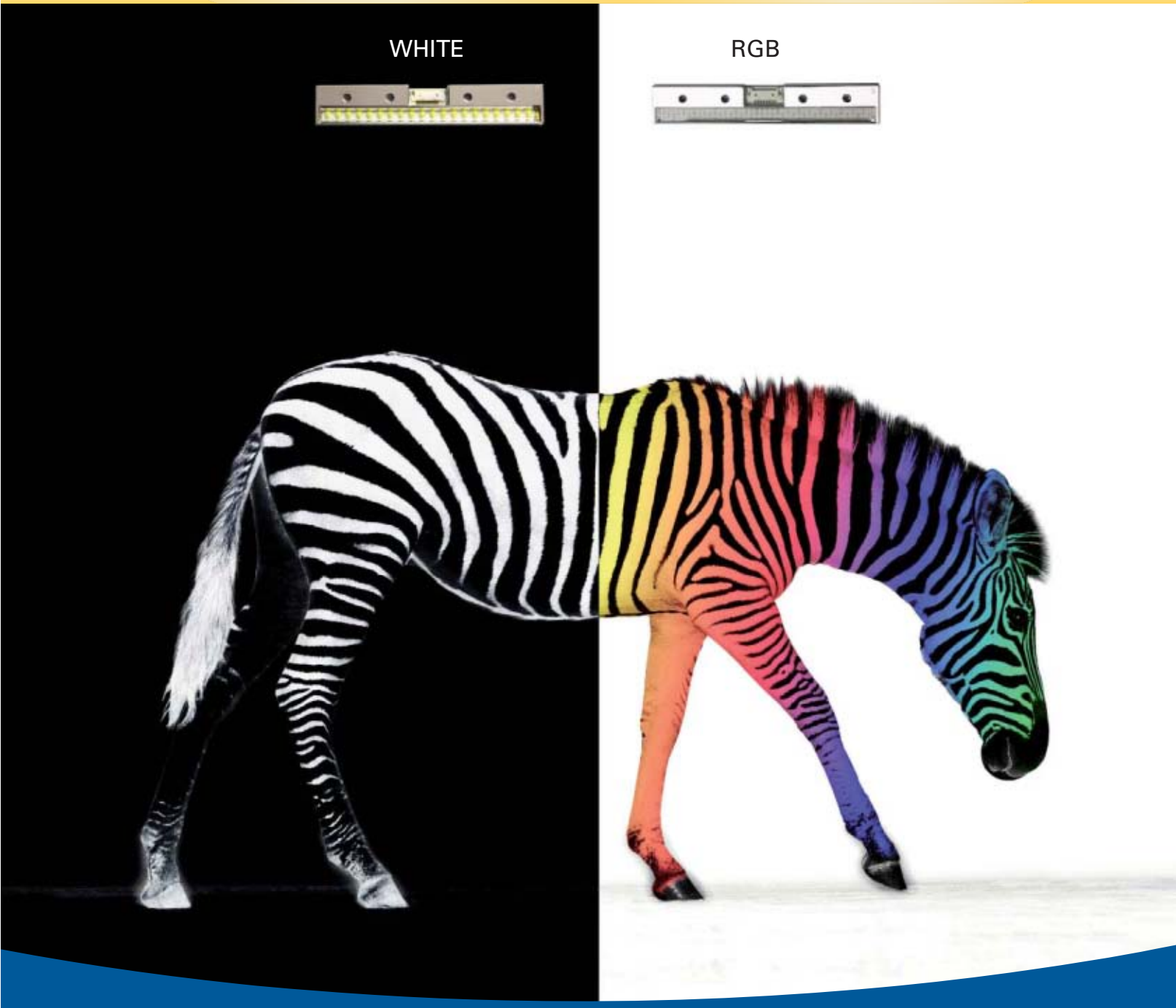

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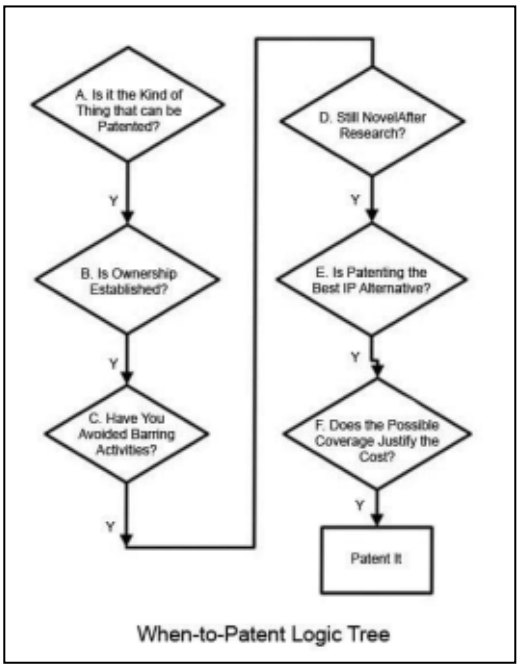
Patent logic tree identifies key decision steps for filing

The crucial decision whether to file a patent should follow a logical, six-step decision process, explains patent attorney Marshall Honeyman.

Say your company uses LED flood arrangements to illuminate billboard signs. Since most road signs are remotely located, the floods have conventionally been powered using a battery/solar panel arrangement. During the day, the panels charge the batteries, and during the night, the LED floodlights drain the power. This works great for a few hours of operation, but after that the batteries drain completely, and the sign remains invisible until the dawn. This dead time has long been accepted in view of the high cost of adding solar cells and battery arrays.

That is, until now. Your product development engineer Jones has envisioned a concept you see as viable. The Jones concept incorporates a sound-recognition system that is able to (1) identify the sound of a vehicle (e.g. a truck) and then (2) turn on the LED floods only when a vehicle is present. Thus, the floods illuminate only when needed (i.e. a vehicle is present). You think Jones' idea is one that will give your company an incredible edge over the competition. Besides immediately ramping up for production, you think you also need to file for a patent – now!



The When-to-Patent Logic Tree; a "no" answer at any stage of this decision process means that the patent should not be filed.

But maybe not. Many times useful patent protection is simply not available. Even if obtainable, the patent may be completely useless when received. Therefore, the company should first address several questions shown in the When-To-Patent Logic Tree (see figure). This decision tree shows the thought process undergone by the patent attorney in advising clients as to whether to patent something. It is a process of elimination in which a "no" answer in any of steps A-F means that a patent should not be filed. Six straight affirmative responses, and it likely makes sense to file.

Step A: Patentability

With respect to step A, although a few things are not patentable – for example natural phenomena, products of nature and mathematical formulae – the general rule is that virtually "anything under the sun that is made by man" can be patented. Thus, man-made devices, systems, processes, and certainly the Jones invention discussed above all qualify as the kinds of "things" that can be patented. Business methods and computer-related inventions are particular areas where inventors often incorrectly dismiss patentability. Thus, the answer to the step A question will tend to be "yes".

Step B: Patent ownership

With respect to step B, the company, before pursuing a patent, should know that it owns the invention made. The general rule is that an employee inventor owns the rights to inventions made in the course of that employment unless (1) there is some expressed obligation, for example, a contract that obliges the inventor to assign these rights to the employer, or (2) the inventor-employee was specifically hired to invent the sort of thing at issue. Whether an inventor was hired to invent depends on numerous factors, with cases often going against the company. Thus, it is critical that employees be required to agree, for example in employment agreements, that any inventions made within the scope of employment are owned by the company. Additionally, the employees should be required to sign assignments that are submitted along with any patent application filed.

Unless the company has established ownership as described above, or in some other way, Jones may own the rights to the invention, and even gain control of the application while in the Patent Office. Therefore, unless you can establish an ownership interest above that of the inventor Jones, it will normally not be advisable to file for a patent.

Step C: Public disclosure

Step C requires an inquiry into whether any activities have occurred which might preclude patenting. US law provides you will lose your patent rights if you sell, offer for sale, publish, or publicly use your invention more than one year before filing a patent application on that invention. And most countries won't even give you the one-year grace period. Thus, a company should immediately contact counsel after the invention is recognized, and especially before marketing or publicly disclosing it. Further, the company should internally investigate whether Jones or others have made any public disclosures or

committed any other acts which might compromise the patent. If any legal bar exists, you should not file, because—even if you are able to get a patent on the sound-activated lighting system—that patent will be invalid anyway.

Step D: Prior art

"Keeping the invention as a Trade Secret might be the best option if the company is able to maintain secrecy of the invention while still using it for economic advantage"

With respect to step D, before filing a patent, the business normally should perform some sort of patentability research. This may be done internally, but the most common practice is to have patent counsel retain a professional searcher. The searcher is normally a specialist who is not only comfortable with the technological subject matter, but is also proficient using prior art databases. The cost for the search should be relatively low, and the publications returned will likely introduce you to prior art you did not know about beforehand. This prior art will provide you with a good estimation of what patent coverage might be available. For example, the searcher may be able to find sound-activated systems relevant to the Jones invention. The company's patent attorney can then use the search results to advise the client as to how patentability might be limited. If the potential coverage available is too narrow, an application should not be filed.

Step E: Trade secrets

Step E addresses whether a patent, even if available, is the best IP alternative. Keeping the invention as a Trade Secret might be the best option if the inventor or company is able to maintain secrecy of the invention while still using it for economic advantage. This would be unlikely with the Jones invention. However, if the invention is a process that occurs in a concealed, private room in a factory, and if it cannot be learned by reverse engineering (e.g. looking at the sold product), secrecy alone will preclude copying because outsiders won't be able to replicate the process. Because patent terms are limited to 20 years from the date that they are filed, trade secret status, if maintainable, might be a better option than patenting because the invention is able to be exploited exclusively by the company indefinitely.

Going the trade-secrets route, however, can create problems. First, the company will have to take proactive measures. First of all, anyone exposed to the secret information should be made subject to an agreement requiring them to keep the secret so that the secrecy can be enforced, and breaches are actionable. If a third party other than those bound to the agreement discovers or learns of the invention by independent means, there may be no recourse for the theft of ideas. Further, the company will likely have to limit access to facilities and label any secret materials as "proprietary" to maintain trade-secret status.

PATENTS

Patents do not present these kinds of problems because they create a well-defined, enforceable property right. The scope of that right is defined by the claims section in the patent much in the same way a property description in a deed expresses the precise boundary lines. This enables the patent owner to accurately determine whether or not particular activities by competitors are in violation. And there is no obligation to keep secrets. The patenting process actually requires disclosure to the public before patent rights are granted.

Step F: Analyze all the costs

The step F question is all business. Just filing a patent can range in cost anywhere from $5,000 to $20,000, and there may be significant costs after that depending on what happens during examination in the Patent Office. Because of this, as a preliminary, the company should have at least one clearly-focused business objective in mind for every patent application it pursues. In the Jones case, we already know one objective exists: to prevent others from copying so that the company has a competitive advantage. Other objectives might include generating revenue from licensing, or cross-licensing with a competitor so that that your company can use some of the competitor's technology.

That said, the next part of the Step F analysis involves determining whether the scope of patent protection you might get justifies the cost. This is done with the help of the patent attorney, and involves the analysis of the search results obtained in Step D along with other information. The company must evaluate whether the potential scope of protection will enable you to enforce the patent against competitors. For example, if the company patents the Jones invention, will competitors be able to easily avoid the patent by designing an alternative that does the same thing? For example, if the scope of our patent is going to be limited to only covering sound-recognition as a trigger, will we still be able to enforce it against competitors using photosensors to detect vehicle headlights instead? If the photo-sensor arrangement works equally as well, the company may not want to file depending on its current balance sheet. But if the potential protection is extensive enough, and if the invention includes a superior system or process, the company may be able to dominate the market with respect to the particular product involved.

Concluding remarks

The When-To-Patent Logic Tree is intended only as a high-level view of the hoops to be jumped through in determining whether or not to file for a patent—and perhaps a bit of an oversimplification. Obviously, your patent counsel should be involved in the entire process. A fatal "no" answer in any one step can be temporally deflating, but it is much better than realizing years later that you have exhausted significant company resources pursuing a worthless patent. And that, unfortunately, happens often to those who are not diligent. ●

About the author

Marshall Honeyman (mhoneyman@lathropgage.com) is a patent attorney in Overland Park, where he is Of Counsel to the firm Lathrop and Gage, L.L.P. Previously he worked at the USPTO, most recently as an Associate Solicitor, and before that as a Patent Examiner specializing in the examination of inventions related to illumination technologies using LEDs as well as numerous other light sources.

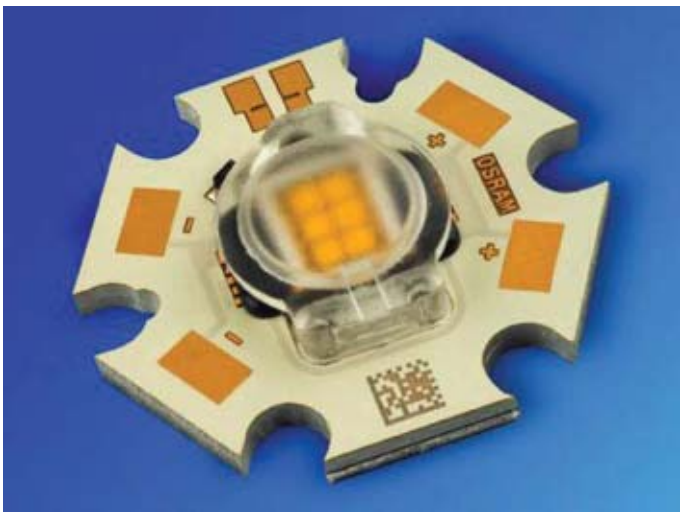
Silicone lenses for LEDs resist UV and high-temperature operation

Plastic lenses can be degraded when coupled with very high-power LEDs, says Thomas Luce, but silicone materials offer a compelling alternative.

Over the years, various materials have been used for optics attached closely to the LED chip, beginning with epoxy used directly for the housing of the well-known 5mm LEDs, for example.

Today, materials such as PMMA (polymethyl methacrylate, also known as perspex or acrylic), PMMI (polymethyl methacrylimide) and PC (polycarbonate) are quite commonly used for lenses and other optical elements to realize different emission characteristics of high-brightness LEDs. Their advantage is the low cost of the plastic resins, as well as the high transparency and easy manufacturing with standard precision injection methods.

On the other hand, with the increasing radiation density and power of LEDs, especially blue and white, these organic materials reach their limits. The high temperatures and UV content near the chip cause cracking of chemical bonds, resulting in yellowing of the material which reduces the transparency. Typically, once this degradation process has started, it accelerates itself due to the increased energy absorption, resulting in rapid failure of the optical system. The higher the performance of the LEDs and the closer the optic is attached to the die (which is desired to achieve better efficiency), the higher is the probability that this degradation occurs. There is only very limited possibility to improve the resistance of the plastic material, due to their organic nature.



6-chip Ostar lighting module from Osram Opto Semiconductors, with silicone lens from Eschenbach-Optik.

Superior silicone

Especially for multichip applications and where lifetime is key, there is an increasing need for a superior material that can withstand the harsh conditions in close proximity of the LED chips. Optical-grade silicone is a highly transparent material (transparency > 95%, even better than PMMA) which fulfils these requirements. It comes with various refractive indices (between 1.42 and 1.53) and has been used for several years as a globe top encapsulant and an index-matching gel, so it has already been proven in applications that it can work in this environment without degradation.

Silicone can be injection-molded, so that virtually all shapes that are possible with conventional organic materials can be realized by a silicone injection process. A further benefit of the silicone lenses is that they can withstand the high temperatures typically experienced during soldering, so that they can be attached to the LEDs before the reflow soldering process (this applies even for lead-free soldering).

Production in volume

In recent years, Eschenbach-Optik has developed a silicone injection technology which enables the mass production of silicone lenses even for the highest-performance multichip LEDs without lifetime compromises. Since silicones for lenses are thermoset materials, the two components have to be mixed properly before injecting into the mold. Special care has to be taken to tighten and seal the optical inserts properly; otherwise flashes will reduce the quality of the lenses. A thermal process is then used to cure the lenses. To allow for large quantities, multi-cavity injection tools with 48 or even 64 cavities have been developed.

To guarantee an accurate positioning of the lenses with very tight tolerances, a two-component injection process is applied, where the silicone lens is injected around a thermoplastic carrier with very accurate mechanical tolerances. This carrier serves as a precise lens holder, and the physical and chemical stability of the silicone lens guarantees a functionality of the optics over the whole LED lifetime, even at elevated temperatures in excess of 150°C.

The first silicone lens applications have already commenced series production, demonstrating the performance of the silicone lens technology. It seems obvious that, due to the increasing power density of LEDs, more and more applications will switch to optical elements made of silicone, to make sure that the product lifetime typical for LEDs is not affected by the degradation processes of the optics.

About the Author

Thomas Luce is Vice President Production/Technology at Eschenbach Optik (www.eschenbach-optik.com), a supplier of high-precision plastic lenses for industrial and ophthalmologic applications.

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About Carmanah's EverGEN solar engine

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About THE EDGE LED Luminaire from BetaLED

THE EDGE line of LED luminaires sets new standards for performance and efficiency. Balancing form and function, THE EDGE offers more lumens per watt and its modular design is built for durability. With extraordinary heat dissipation qualities and exclusive NanoOptic™ technology that virtually eliminates reflective or refractive losses, THE EDGE luminaire is a natural fit with Carmanah solar technology.

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Green light for LEDs at Light+

Energy efficiency, green technology and LED lighting were central themes of Light+Building, the biennial trade fair that took place in Frankfurt in April. Tim Whitaker reports.

With more than 2100 exhibitors and 165,000 visitors, the Light+Building trade fair was a big, exciting extravaganza of lighting technology in which LED fixtures and components featured prominently. Many companies chose energy efficiency as the theme of their exhibition stands, although companies such as Osram and Philips were showcasing the advances that continue to be made in other technologies as well. Over the next few pages we look at some of the highlights of the show and ask several participants for their opinions on the event and the progress shown by LED lighting.

Fig. 1. Philips showcased LED-based pendant luminaires in which the LED mo

Figs 1 and 3 courtesy of Messe Frankfurt Exhibition GmbH and Pietro Sutera

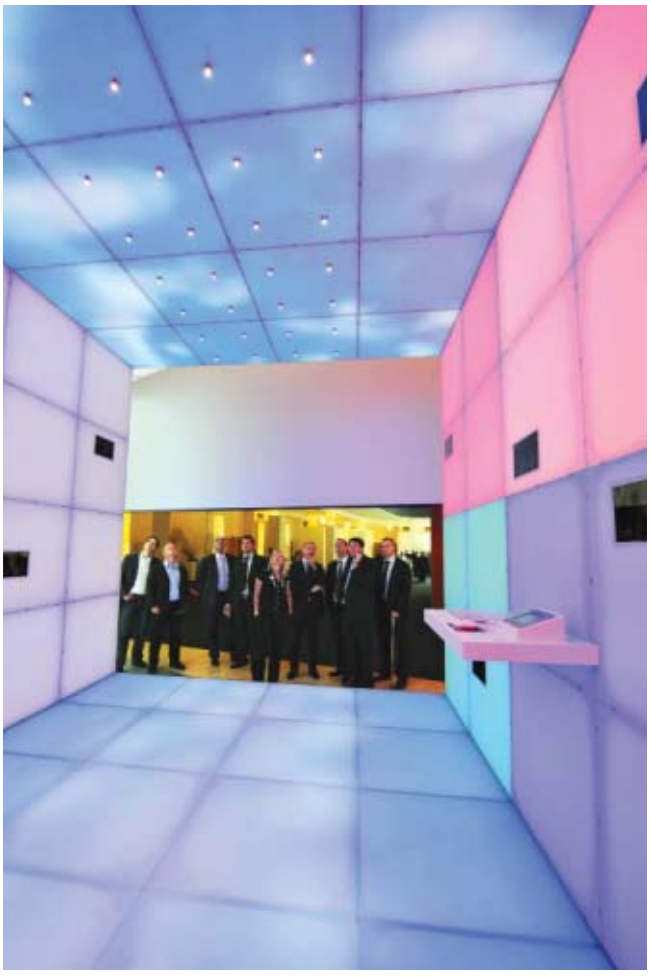

Fig. 3. Colorful LED panels enhanced the Zumtobel booth.

Fig. 4. LED downlights from Ledion, a subsidiary of Edison.

Building fair in Frankfurt

odule's phosphor was optimized to enhance displays of fresh food.

Fig. 2. A giant Barco LED display pulled the crowds for Osram.

Fig. 5. Zumtobel LED spotlights incorporating Cree LEDs.

Fig. 6. Philips Fortimo module cooled by SynJet technology.

L+B: Viewpoints

We asked several Light+Building attendees for their views on the show.

Ulrich Kastner-Jung, senior director global marketing & strategy LED systems, Osram GmbH and Michael Fiebig, director marketing and business development solid state lighting, Osram Opto Semiconductors.

The LED was the light source of the show, with all its benefits such as color changeability, small form-factor, the ease with which light can be directed & controlled as well as high brightness and energy efficiency, and lifetime advantages. LED solutions are no longer mid-term future; instead, many exhibitors showed that they are already getting established in everyday applications.

We saw the trend confirmed that LEDs in the SSL sector are already well-established in market segments such as decoration/beautification/architainment as well as channel letter backlighting. Breakthroughs in illumination are visible on the horizon. Several residential and commercial applications were addressed – especially street lighting – primarily based on ECO (economical & ecological) aspects but also the opportunity for new designs and intelligent lighting features (motion and situation adaptation) is recognized as an attractive value-proposition.

Lawrence Madanda, global marketing director and Heather Goldsmith, marcom manager, Future Lighting Solutions

Light+Building confirmed that LED lighting is going to play a dominant role in all lighting segments. We observed a major focus on white light versus colored light this year. Area and street lighting continues to be a major segment of interest, especially with the availability of 100-lumen devices. Surprisingly, the optics strategies are similar in that the approach of individual LED output overlaying the same light pattern has dominated, as opposed to each LED lighting a portion of the light pattern. This allows for easily modified luminance levels simply by adding more LEDs with the same optics. General lighting applications were dominated by downlight and spot fixtures. Task lighting and MR-16/11 footprints also continue to proliferate. Improved data for spec-to-spec comparisons was available in some booths, which was more appropriate to the requirements of lighting designers.

Mick Wilcox, director of marketing, Nuventix

I was quite surprised, even shocked almost, at the quantity and quality of LED fixtures at the show. It seems like the LEDs have finally taken the entire lighting community by storm. In the past I have seen significant talk in the LED world but it hasn't translated to the general lighting community. At L+B that seems to have finally changed. I am particularly interested in seeing if that is going to translate to Lightfair in Las Vegas or if it is more of a European pull. One additional comment came from an Asian supplier, who was very concerned about other Asian LED suppliers giving LED fixtures a bad name by producing low-quality products. Overall, this was a very good show for us and I think for LEDs in general.

Fig. 7. LEDworx: the Austrian LED lighting specialist had one of the most interesting presentations at L+B. The company's "black tower", a completely enclosed, two-storey dark space, allowed visitors to experience LED street lighting without the distraction of other lights, to stunning effect. The company has developed a range of modular LED street lighting luminaries, including the new Hawkeye 3. The company uses 10 W LedEngin devices. Later this year, LEDworx will be involved in a project in the Austrian town of Melk to install some 1300 LED luminaries.

Wolfgang Reis, business development manager, EBV Elektronik

Light+Building was the best example for the increasing interest, the relevance and the importance of LED technology. The LED fixtures on show demonstrated the huge range of this technology and the different application possibilities. In the lighting area, LED technology will continue to expand and gradually replace the conventional lighting technology. It will be the future for residential and architectural lighting - especially from the point of view of energy savings and the realisation of lighting concepts that have not been possible with the conventional lighting technology in the past. Both EBV and our customers think this year's Light+Building fair provided the trigger for the gradual replacement of conventional lighting technology with innovative LED technology.

We were impressed by the function table light from lighting designer Ingo Maurer based on the use of organic LEDs (OLEDs) from Osram. The light, known as "Early Future", is being produced as a limited edition. It works with tiles straight from the laboratory and demonstrates the enormous potential of OLEDs for future applications as eye-catching illumination and design elements.

Madanda and Goldsmith, Future

An adoption split was apparent where some major lighting OEMs have not fully adopted LED lighting. Yet, those OEM companies that have already adopted were displaying the same products as 2 years ago. Possibly a desire to show that they continue to have awareness of the LED technology; perhaps indicative of their reluctance to be more aggressive until the LED supply chain stabilizes (in terms of standards, performance, test conditions and pricing).

Philips Lighting was the most aggressive lighting company, showcasing LED and other "green" technologies in a variety of settings including retail, store front, street, office and home. However, of course, they were not limited to LEDs as they still had a strong push

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Fig. 8. Fulham and Exclara: Widespread adoption of LED lighting will require flexible, turnkey products that can be adopted with the minimum of fuss. This applies not only to light engines but also to drivers, so it was good to see the Advanced Multi-channel Driver from Fulham, a leading supplier of electronic ballasts for HID and fluorescent lamps. The driver is powered by technology developed by Exclara, a fabless semiconductor company founded to develop digital power management for solid-state lighting. The new Fulham driver has an output capacity of 90 W that is distributed among 4, 6 or 8 independent channels or LEDs strings. In the photo, the driver is controlling 8 LED downlights. The device provides precise control of current in each string, regardless of voltage and temperature fluctations. For intelligent lighting applications, multiple sensors can be added for dimming and thermal management.

on CFL and incandescent.

The decorative lighting hall had the least number of LED applications (floor lamps, chandeliers, hanging decorative fixtures etc). Although there could be a strong fit to transition to LEDs for several reasons, including major cost savings in maintenance and energy, it appears that the decorative fixture makers are more focused on design rather than technology and efficiency.

Kastner-Jung and Fiebig, Osram

RGB approaches were widespread and impressive solutions in the entertainment, architainment sector were exhibited. A major leapfrog is "intuitive and easy to use" light-interaction user interfaces. These include pre-defined but re-programmable scenarios to conserve light and energy saving, and touchscreens to easily chose color on demand. Even interaction via smartphones (like iPhone) was demonstrated. Easy and intuitive interaction will be an important success factor for the future of SSL.

A lot of progress was made in LEDs towards "white light success factors" especially in terms of "quality of light" addressing

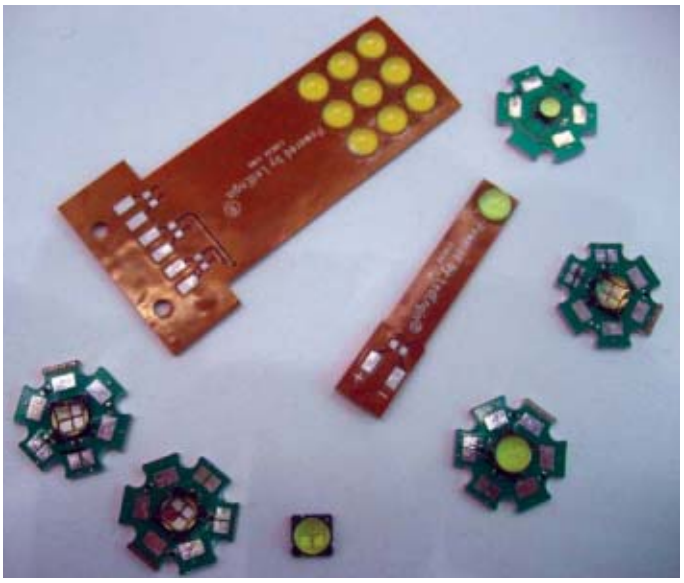

Fig. 9. LedEngin revealed details of the packaging technology used in its multi-chip power LEDs. The company uses a thermal insulated remote phosphor (i.e. the phosphor layer is not in contact with the chips) to enhance lumen maintenance and improve conversion efficiency. A proprietary multi-layer encapsulation process optimizes light extraction, and robust glass lenses are used that are attached with a high strength interlocking mechanism. Also the package has a ceramic substrate to minimize thermal resistance, and a unique die attach process to maximize power density and reliability.

properties such as color rendering, fine binning, color of white in dependence of viewing angles, etc. These impressive improvements will pave the way towards next generation retrofits – where the current portfolio of more decorative dominated designs will then be enhanced by significantly higher performance and more energy-efficient products.

It is amazing to see how many trends are coming up in the LED lighting space. New light designs were seen (luminaires, modules and systems) – design with a great look & feel but also clearly designed to increase the ratio of usable lumens (in the application) vs. generated lumens in the light source. In short, the goal is "no waste of photons." Also, light designers, planners and architects are now taking the opportunity to come up with creative light solutions e.g. "decentralizing the light" which means light consists out of a large number of small light sources distributed around the space instead of one large light source in a fixed position. Another trend was off-grid lighting solutions that are independent of a fixed ac power supply and can be used precisely where they are needed.

With increasing SSL awareness and interest of end users and light planners, the use and adaptation of standard and customized modules is rapidly increasing. SSL value-networks such as our "LED-Light-for-you" group are definitely hitting the spot, as the above mentioned target group is now able to create professional light solutions utilizing the support of qualified partners to manage thermal, optical and electromechanical challenges quite easily.

Light+Building 2008: A Quick Tour of the Global Marketplace

By Vrinda Bhandarkar, Strategies Unlimited

Light+Building 2008 had the feel of a global marketplace. Unlike the shows in the US, the booths were designed to conduct brisk business – accommodate customers who could talk to company representatives and close deals over food and drinks. The show is organized to cater to a wide range of professionals – lighting designers, electrical component suppliers, luminaire designers – for a wide range of technologies and applications, manufacturers, and buyers. The show was spread out in the different pavilions, and LED fixtures were sprinkled all over the show – most of the fixtures were being introduced for the first time and the manufacturers were gauging customer interest at the show.

The really big companies like Philips, Osram, Zumtobel, and Siteco were exhibiting in the "Festhalle" and the "Forum." In Hall 3, Artemide, BEGA Gantenbrink-Leuchten, ERCO Leuchten, FontanaArte, iGuzzini Illuminazione, Luceplan, Targetti Sankey, and Trilux had carefully choreographed (and very large) booths, each with its own color scheme. There was a sprinkling of LED fixtures – step lights, recessed spots, in-ground path lights, bollards, and accent lights. iGuzzini had a funky table lamp resembling a coiled snake that was exhibited in hallways and in iGuzzini and Cree booths (see pizzakobra.iguzzini.com).

Halls 1.1 and 1.2 presented decorative lighting where LEDs face tough competition from incandescent technology. LightWave LED Products, a Swiss company, offered floor, wall, and suspended lights that used LEDs, while Swarovski used LEDs to show off crystals. Pamalux, Molto Luce GmbH, and Evado Art offered more decorative, rather than illuminating, LED fixtures. The designers are familiar with incandescent lighting as it shines through the luminaire. LEDs as a new directional point sources are a new alphabet in the vocabulary of decorative lighting design.

In the pavilion for consumer luminaires, Tobias Grau, Neuhaus Design, Holtkötter, and Bopp Leuchen introduced task lamps, accent lamps, table lamps, sconces, and suspended lighting fixtures. Philips introduced a line of consumer luminaires mostly for residential applications, while Momentum Design (Lucesco) and Baltensweiler AG from Switzerland offered designer table lamps. There were plenty of colored and color-changing fixtures used for their lighting effects, rather than for their design. These were in standard categories: LED strings, linear fixtures, circular spots (in all sizes), and rectangular wall washes.

There were also plenty of outdoor area lights – Se'lux, QuadLED, Ruud, Siteco, enLED, C Luce, Thorn, WissenLux, and Sill all offered lines of architectural lighting fixtures for outdoors.

The China Pavilion (Hall 10) felt like a separate world unto itself – it had manufacturers from the Far East offering similar fixtures at low prices. After spending three days at Light+Building, I am not sure how much of the show I did not see.

Fig. 10. Advanced LEDs: Hall 5.0 featured a good selection of LED outdoor lighting luminaires, including the Barracuda from Advanced LEDs Ltd. The LEDs (in this example, 5 arrays of 16 Cree XLamps) are mounted on the nose section and directed upwards, so that the light hits the reflector and produces the required distribution pattern. Heat pipes carry heat to the fins at the rear, while the whole nose section containing LEDs and drivers can be removed for maintenance if necessary. Photo courtesy of Carl Gardner.

L+B: Products and Technology

Light+Building showcased a range of new technologies, from LEDs, optics and drivers to lighting fixtures. We selected a few highlights, but there were many others we didn't have space for.

Enfis warm white LED light engine

Many lighting applications require a high-quality warm-white light source, and many users require simple integration into their luminaire. Enfis has addressed these issues with its UNO Warm White High CRI product (available as an array or a light engine) which has a broad spectral output. The company describes it as an exceptionally high quality, powerful spot source of light that is ideal for high-end retail and museum displays, in a compact and cost-effective package. It has a CCT of 3200K under typical operating conditions, and can give a CRI of >90. However, the focus has been on obtaining a true broad spectral performance over and above hitting nominal CRI values – there is more to color quality than CRI. The array is capable of producing 1000lm from an emitting area of just 0.5cm^2. Enfis will supply the array, or a complete light engine with electronic and (if required) thermal management, ready to integrate into a luminaire. Enfis can also provide optics to simplify integration even further, enabling customers to minimize time to market and risk. This product is the latest in a range of Enfis arrays and light engines from 36W to 400W available in white, single colour, RGBA, RGBW and Hi CRI Vari-CCT options.

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Nuventix cools Fortimo

Tucked away in a distant but busy corner of the Philips stand was a very interesting combination of a Philips Fortimo Downlight LED Module (DLM) and a SynJet fan-less air cooling module from Nuventix (see page 25, fig. 6). The SynJet technology enables the Fortimo DLM to produce 1100 lm for the combination shown, or 2000 lm if a much larger SynJet module is used.

The SynJet module uses patented actuator technology to create turbulent, pulsated air-jets that can be directed precisely to locations where thermal management is needed. The vortex-dominated SynJet flow enhances small-scale mixing near the heated surfaces. This yields higher effective heat transfer at low-volume flow rates compared to conventional air movers. "SynJet air cooling technology is ideal for LED luminaires and is the only solution that offers ultra-high reliability active cooling for LED lighting," said Jim Balthazar, Nuventix president and CEO. Elsewhere at L+B, SynJet modules were used by LedEngin in its MR-16 modules.

Geert van der Meer, global product marketing director SSL for Philips Lighting, said that SynJet technology is a perfect fit for the Philips Fortimo DLM and Lexel DLM products. "It enables compact, customized cooling solutions that overcome the thermal challenges in luminaire design, especially when using high-lumen output LED modules for general lighting." Philips and Nuventix will supply their respective products separately, although the two are clearly fully compatible in terms of form-factor. Although a customer could design a luminaire using a Philips DLM without the SynJet, they would have to make absolutely sure that the thermal management was able to cope with a 1100-lumen module.

Philips is aiming its Fortimo LED DLMs, which have a color temperature of 4000K and Ra of 80, at the general lighting market. This version will be available in August, with a 3000K version to be introduced in January 2009. The module itself looks a little unusual; it is a small box measuring about 82 mm square and 44 mm in height, with a circular yellowish colored opening around 67 mm in diameter. The yellow color gives a clue to how the module operates; this is a phosphor plate that is remote from the blue LEDs contained inside. In a conventional white LED, the phosphor layer is located immediately on top of, and in contact with, the LED chip. The Fortimo module contains a total of 18 blue Luxeon Rebel LED chips, with the phosphor plate at the exit aperture. The Rebel LEDs can be driven at different current levels, allowing the same Fortimo DLM to produce either 1100 lm or 2000 lm, assuming adequate thermal management can be provided. A special Food version of the module, with an optimized phosphor composition, is designed to optimize the presentation of fresh food in retail displays (page 24, fig. 1). In addition, Philips introduced a new version of its Lexel color-changing module (originally developed by TIR Systems) with a similar form-factor to the Fortimo module.

New approach to amber

Blue and green LEDs are made using nitride-based materials, while red and orange typically use the AlGaInP material system. But you can also make amber by combining a blue chip with the appropriate phosphor, and this is what Lumileds has done. A blue Rebel chip with a Lumiramic phosphor plate results in an amber LED that has higher efficacy and reduced variance in light output with temperature, compared with conventional AlGaInP LEDs. Lumileds also showed the first stage in its effort to reduce the number of bins for white LEDs. The upper bins above the blackbody locus (BBL) between 3500 and 2760K have been dropped, and the same will be done for other color temperatures. This, says Lumileds, is enabled by the control provided by its Lumiramic phosphor technology. Ultimately, there will be a single row of bins sitting above the BBL.

Citizen multi-chip power

Citizen continues to improve the performance of its high output, multi-chip LEDs, which could also be seen in the LED incandescent replacement lamps on the Lighting Science Group stand. Citizen's CL-L230-C10-A series, for wide area lighting, provides 305 lm from a single package when driven at 350 mA (91 lm/W) and 700 lm when driven at 900 mA (66 lm/W), with a color temperature of 5000K.

The CL-L220-C16-A series generates 328 lm at 350 mA (102 lm/W) at 5000K. This part can be driven up to 1440 mA, where the output is 1150 lm. The size is 17.5 x 28. x 1.4 mm and the thermal resistance is 2.4°C/W.

Inspired by Nature

Invented by Nichia

Only nature produces a brighter, cleaner white than Nichia, creator of the white LED. And like nature, Nichia covers the entire range of white, from cool to warm and everything in between, for every architectural lighting application. Our LEDs are also nature-friendly, using less energy than traditional lighting while running cooler and lasting longer. So, for all your lighting needs, reach for the stars. Ask for the original white LED, only from Nichia.

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Fig. 11. LED-Linear unveiled its VarioLED Flex family of high luminous flux and efficiency, IP67-protected, separable linear LED strips on flexible printed circuit board with self-adhesive back. VarioLED Flex Dona is LED-Linear's high luminous flux, high efficiency solution working with a 12V supply voltage. It will be available in white, warm-white and a high color rendering index of Ra=92, delivering a luminous flux of up to 300 lumen per linear foot and 80 lm/W module efficiency.

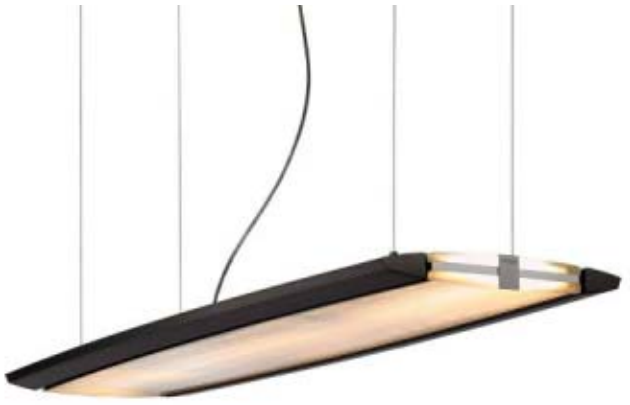

Fig. 12. The Orbiter 2 from Siteco is a suspended luminaire for office environments with a combination of high-performance LEDs and Eldacon micro-prismatic technology to reduce glare. The luminaire emits both warm-white direct light and cooler indirect light to simulate daylight, and both components can be dimmed separately, and combined to create various light atmospheres. Additional blue LEDs create a decorative 'night glow' effect within the offices during nocturnal hours. The transparent light core is enclosed on its sides by a special aluminium profile with built-in cooling ribs.

Nichia making plans for Rigel

Koito, a Japanese manufacturer, has produced an LED streetlight using Nichia LED modules, and several other modules were on show on Nichia's stand. However, these are not in mass production but are intended to "test the market", according to a spokesperson. Nichia had a number of new LEDs on show, for example the first "2W" Rigel device, a single-chip LED with a domed cover. Until now, Nichia has limited its lighting-class LEDs to operation at the 1W level. The new device (NCSx136 series) is capable of producing 180 lm typical at 550 mA and 3.5 V (equivalent to 94 lm/W) at a color temperature of 5500K. A warm white version produces 135 lm.

Nichia has also developed its multichip power LEDs (NS6xx83x series). The NS6W083B has a typical output of 100 lm at 300 mA and 3.3 V, equating to 100 lm/W, at 5500K. The warm white version produces 80 lm. There is now also a "2W" version producing 150 lm at 500 mA and 3.5 V, or 120 lm for warm-white. The 1W devices are also available in high CRI versions with Ra value of 92, but naturally the efficacy is lower than for the standard versions.

Although not applicable for lighting applications, Nichia's Raijin LED sets a new benchmark for efficacy. The package produces 8.7 lm from a drive current of only 20 mA, and forward voltage of 2.9 V. The efficacy is – hold your breath - 150 lm/W.

Cypress controls LedEngin LEDs

Cypress Semiconductor shared a booth with LedEngin (see fig. 9), and the companies jointly demonstrated various LED lighting systems, based on EZ-Color LED controllers. One demo board combined EZ-Color with Cypress' CapSense for touch sensitive controls, creating a dynamic color-selection interface. The board also featured Cypress's proprietary 2.4-GHz wireless technology for remote control of colored lighting. The RF technology overcomes limitations of infrared, eliminating line-of-sight requirements and providing over five times the range.

Tunnel vision with Dellux

Tunnels are generally suited to LED lighting, with energy and maintenance savings the primary benefits. In some cases, however, regulations require such a high lighting level that the payback period for LED lighting can be prohibitive. However, there have been a number of installations of LED lighting in tunnels. Canadian company Dellux has provided LED fixtures in four major road tunnels in Montreal, and has also installed an LED street lighting test installation in the same city. Also, Dellux LED fixtures are currently being evaluated in the Holland Tunnel in New York.

Later this year, Dellux will install almost 800 LED luminaires, each containing nearly 100 LEDs, in the Schmuecke tunnels on the A71 autobahn in the German state of Thuringia.

The key differentiator of Dellux luminaires is to ensure that the light output remains the same over the lifetime (as much as 15 years) of the LEDs. Rather than drive the LEDs to achieve the desired brightness level, and accept that lumen degradation will occur, Dellux uses more sophisticated control. The individual LEDs are either on or off, with a constant LED junction temperature, and if higher light levels are required then more LEDs are switched on. Over time, as the light output of each LED falls, more LEDs are turned on to maintain the total overall light level.

Connectors for optics

BJB introduced a new connection system that provides a rapid "plug-and play" method to combine power LEDs with 20 mm lenses from Carclo. The system has two components in addition to the lens and the LED, namely a lens holder that snaps into a connection piece that carries wiring terminations. The connection pieces are tailored to fit specific LEDs from Edison, Lumileds, Osram and Seoul.

DOE and lighting designers discuss pros and cons of LEDs

The US Department of Energy believes lighting designers have an important role to play in overcoming the challenges that will lead to successful commercialization of solid-state lighting in the years to come, reports Julie MacShane.

A group of 16 lighting designers met with the US Department of Energy (DOE) on March 19 to examine the solid-state lighting (SSL) market, debate technology issues, and encourage a discussion of the designers' recommendations regarding the SSL industry. The DOE recently released a report on the roundtable discussion, held in Chicago, Illinois, which was also hosted by The International Association of Lighting Designers (IALD) and the Illuminating Engineering Society of North America (IESNA).

When welcoming the designers to the roundtable discussion, the DOE's James Brodrick, SSL portfolio manager, emphasized that the lighting design community is a critical part of the complex process of getting SSL into the marketplace. He said that the DOE intends to share designer feedback from the meeting with researchers, manufacturers, and product designers to help improve the whole process of getting products to market.

"We received a number of useful suggestions from the lighting designers," Brodrick told LEDs Magazine. "We like to touch base with various groups in the lighting industry so we can adjust our programs properly – the programs are changing all the time. The roundtable re-focuses your attention; designers articulate their problems slightly differently than we would."

As one of their tasks, the designers were asked to list "what's going right" and "what's not going right" in the SSL industry from their own perspective (these comments are summarized in the Table on page 38). Although they listed twice as many "wrongs" as "rights," Brodrick was not surprised, given that the industry is in its early stages. "We're not trying to sell anybody [on SSL]. We're a fair broker. We're looking to improve products coming on the market." In other words, he expected to hear about the various problems that the DOE needs to solve, so that it can work towards assuring higher product quality, developing informational materials, and supporting educational programs.

When asked about the most important issues and concerns the designers brought up, Brodrick listed three main areas of concern and described the actions the DOE plans to take on each. "We're looking to be responsive," he said. "We work hard to be transparent and participatory."

Environmental issues: Although LEDs are touted as an environmentally-friendly technology, LED manufacturing has an impact on the environment. "LEDs save energy, but are they putting toxins into the environment? We have to do testing," said Brodrick. He added that in response to these concerns, DOE will start an analysis of the impacts of SSL relative to energy balance, materials use, hazardous materials, and other items. A DOE spokesperson will outline the planned study and engage in a discussion with the audience at the DOE's workshop that takes place on July 9-11 in Portland, OR. The

Recent DOE funding opportunities

In May, the DOE announced two funding opportunities for SSL projects, representing the fifth rounds of funding for both Core Technology Research and Product Development. The DOE will make $7.5 million available for core technology projects and anticipates making 5-10 awards for specific advances in LED and OLED lighting. Awards will not exceed $600,000 per year for up to 3 years, and the closing date for applications is June 19. This announcement marks the fifth SSL core technology funding opportunity in a series expected to span a decade. Core technology funding supports applied research in certain key technical areas by fostering a collaborative atmosphere favorable to overcoming the significant technical challenges that restrict the application of SSL. There are six specific areas of interest in this round. For LEDs, the three areas of interest are: internal quantum efficiency, phosphors and conversion materials, and encapsulants and packaging materials. Involving OLEDs, the interest areas are high efficiency OLED materials and structures, OLED encapsulation and substrates, and OLED fabrication.

In the product development funding opportunity, DOE is soliciting applications from industrial organizations for high-priority product development activities that will advance the state-of-the-art of SSL used for general lighting applications. Information on the estimated total funding and expected number of awards is not available yet. The applications are due by June 27.

This is the fifth funding round for product development projects, which are designed to develop or improve commercially viable materials, devices, or systems. Technical activities are to be focused on a targeted market application with fully defined price, efficacy, and other performance parameters necessary for success of the proposed product. The six areas of interest are LED-based integrated luminaires; high-efficiency LEDs or arrays; phosphors or encapsulants; electronics development; OLED lighting panels; and low-cost substrates and encapsulation for OLEDs.

"Voices for SSL Efficiency 2008" market introduction workshop is sponsored by the DOE, the Northwest Energy Efficiency Alliance, the Energy Trust of Oregon, and Puget Sound Energy.

Quality of products: "The designers say they are excited to try new SSL products out, but some work and some don't," Brodrick said, meaning that it is crucial to focus more attention on a DOE-sponsored product quality initiative. Brodrick said that such an initiative will also be announced at the upcoming July workshop.

Getting the right information: Purchasers need accurate information before making a buying decision. "Some of the products' metrics are not familiar to the designers or differ from manufacturer to manufacturer. Standardizing these metrics also concerns the DOE," Brodrick said. At the roundtable, the DOE report says that Jeffrey Miller, IALD board president, reported that clients are telling designers they want to use LEDs, but much is still not known about lifetime and other performance variables. He cautioned against a single platform, noting that multiple viable SSL platforms would broaden design and financial choices.

Brodrick said that the roundtable also offered a look at the DOE's SSL-related market introduction activities. He briefly reviewed the "pathways to market" supported by DOE, including testing, demonstrations, design competitions, Energy Star-related efforts, technical support for standards, and technical information channels.

CALIPER testing and lighting designers

The designers also commented on DOE's LED product evaluation and reporting (CALiPER) program, which for the past 1.5 years has been independently testing commercially available SSL products for the general illumination market and providing unbiased information on their performance. Test results also serve to discourage low-quality products, helping to reduce the risk of buyer dissatisfaction from products that do not perform as claimed.

"We often test products with big claims to make sure they're appropriate," Brodrick said. Product criteria for CALiPER testing consider characteristics such as the expected product performance, visibility, market impact, and specific design characteristics. He added the "designers seem to like the CALiPER program," noting they sometimes base buying decisions on the unbiased results listed on the DOE website.

The designers mentioned at the roundtable that they would like enhancements to CALiPER, and Brodrick said the DOE will be doing that, including the addition of a "Sort" function to the web site, as well as the addition of more products to the approximately one hundred up there now.

The IALD's Miller also encouraged development of industry standards that make sense. "CALiPER has been doing a great job in testing light fixtures to see if they meet manufacturers' claims," he stated. He urged IESNA and the American National Standards Institute (ANSI) to establish benchmarks that designers can use for comparisons. Finally, he recommended that DOE convene similar meetings more frequently, because designers want to be involved and to have more opportunities to share knowledge and understanding, whether with manufacturers, standards-setting groups, or demonstration projects.

Since the IALD association thought the roundtable meeting "had value," Brodrick said, "we'll probably reconvene in a year. Meanwhile, we're trying to pull designers in to help out with the Gateway program."

Lighting designer roundtable feedback on solid-state lighting

SSL: WHAT'S GOING RIGHT

- Small format allows luminaire design and architectural design flexibility
- Low expected connected load
- Efficiency above similar sources
- Color changing ability – LED systems can be tuned for lighting mood effects
- Low heat (front) – Little heat is radiated towards occupants and objects providing more comfort
- No UV – ideal source for fragile artifacts
- Long lamp life allowing reduced maintenance
- Vibration resistance due to no filament and compact format
- Cold temperature operation without the issues with fluorescent technology
- Direct low-voltage input good for some renewable systems and design flexibility
- Can easily daisy-chain fixtures with low voltage connectors

SSL: WHAT'S NOT GOING RIGHT

- Lack of definition of SSL as tool – is it a lamp or a system?
- Rapid pace of technology changes
- Immediate performance vs. down the road
- Information flow
- Government should provide seed money for industry collaborative effort for standards

Manufacturing/Products

- A design cycle is 2 years, including design, spec and install. The product might not be around in 2 years.
- Truth in advertising is not there. They do not "last forever."
- More standardized cut sheets (templates) among LEDs, and also among competing products
- Model specifications, like a "nutritional guide" or a standardized form
- Published data must follow some government standard
- Maintenance contract issues
- Potential availability of matching replacement parts
- "Box on a shelf" vs. separate parts
- Lack of modularity
- Want to be able to compare things in my tool box
- Easier if fitting into current model; a universal LED socket design could accommodate issues
- Lack of information on product details
- LED uplights shift to green and have to go back to factory

Cost issues

- Volume of sales not yet high enough to bring down costs
- Hard to track true price of SSL
- Perception of low cost may not reflect complete luminaire costs

Distribution system: potential for new way to sell and market

- Start with government contracts?
- Put new products out as direct sales?
- Recommend to owners to buy direct
- Government role to support direct sales

NATIONAL PROGRAMS

Gateway program will add designers

The intent of DOE's SSL technology demonstration Gateway program, Brodrick explained, is to provide a source of independent, third-party data for use in decision-making by lighting users and professionals. Each Gateway demonstration compares one SSL product against the incumbent technology when deployed for an in-the-field application. Through the roundtable and future interaction, Brodrick hopes to encourage more lighting designer involvement, especially in qualitative analyses.

"With the Gateway program, we ask: Does the product perform in its application, for example outdoor lighting. We have 3-5 designers contracted to participate in this because they might see different things," said Brodrick, noting that designers have expertise that DOE often lacks.

Competitions

National design competitions such as Lighting for Tomorrow encourage and promote energy-efficient lighting fixture design. Sponsored by DOE, the American Lighting Association, and the Consortium for Energy Efficiency, Lighting for Tomorrow recognizes well-designed, energy-efficient residential LED fixtures. In addition, Brodrick previewed the May 2008 launch of the "Next Generation Luminaires" competition, which seeks to recognize and promote commercial LED luminaires.

Another competition that will further heighten awareness of high-performance solid-state lighting products is the "Bright Tomorrow Lighting Prizes" competition. Section 655 of the Energy Independence and Security Act of 2007 includes provisions for significant prizes for new lighting technologies that can serve as replacements for inefficient lighting products that dominate the market today (see www.ledsmagazine.com/features/5/2/12). The legislation challenges industry to develop a 60W incandescent replacement lamp, a PAR-38 halogen replacement lamp, and a 21st century lamp. Further details of the prize will be revealed at LightFair at the end of May.

Labels and standards

The development of Energy Star criteria for SSL products will accelerate market penetration of better performing, higher efficiency products. Criteria were announced in September 2007, with labeled products expected to be available in October 2008. To disseminate information on Energy Star, DOE plans to host a webcast on June 26 entitled "Energy Star for SSL: Getting Ready for September 30."

DOE also supports the development of standards and test procedures, and keeps industry and consumers informed through the DOE SSL website, regular SSL updates, SSL technology fact sheets, the SSL Technical Information Network (TINSSL), planned market studies and technical evaluation reports, and annual R&D and Market Introduction workshops.

Although there are many manufacturers of LED fixtures, designers who specify products — and consumers themselves — must be cautious, IESNA SSL sub-committee chair Kevin Dowling advised. He said standards are needed, and are gradually coming into place, with the recent release of C78.377-2008 and LM-79, and the imminent release of LM-80, as the first tangible results of an accelerated, collaborative standards development process.

DOE/IES Design Guide for LEDs

Samantha LaFleur, a lighting designer with AtelierTen in Baltimore, MD, joined Eric Richman of Pacific Northwest National Laboratory to update roundtable participants on the status of the DOE/IES *Design Guide: Lighting Design with LEDs.* The guide features technical information on performance, special characteristics of LEDs, and application challenges, as well as design guidance on specific applications according to space and building types. Feedback from participants included requests to add space types such as theaters, arenas, and healthcare facilities; to talk about quality of light in the "task" section of the Guide; and to address such concerns as "the biggest issue" of liability. Suggestions from participants will be incorporated into the final draft version of the Guide, to be forwarded to IESNA by June 2008.

Session wrap-up

The DOE report said Brodrick concluded the gathering by expressing his appreciation to all the lighting designers who came and contributed throughout the day. He stated that, as a result of the insights and input designers had provided, he anticipated DOE program fine-tuning, most notably in the Gateway and CALiPER programs. "Better-quality communication between links in the chain is essential," he noted, "and we will look closely at that need to identify areas where DOE might be of assistance."

"I anticipate that DOE will be coming back to you with at least one proposal that will essentially capture what you've told us today," Brodrick told the designers. "And, we will be asking you to sign on—to offer us your continuing experiences and recommendations. Please feel free to contact us, as this is just the start. Taking action will be next."

Links

DOE SSL website
www.netl.doe.gov/ssl
Portland Market Introduction Workshop
www.netl.doe.gov/ssl/PortlandWorkshop.html
CALiPER test reports
www.netl.doe.gov/ssl/comm_testing.htm
Gateway demonstrations
www.netl.doe.gov/ssl/techdemos.htm
Lighting for Tomorrow
www.lightingfortomorrow.com
Information on SSL standards
www.netl.doe.gov/ssl/usingLeds/measurement-series-standards.htm
Energy Star
www.netl.doe.gov/ssl/energy_star.html
TINSSL
www.netl.doe.gov/ssl/technetwork.htm

Prize-winning LED lamps demand high-efficiency LED drivers

The race to build replacement LED lamps for the Bright Tomorrow Lighting Prize will require the development of advanced LED drivers, according to Doug Bailey.

Combining a serious challenge with a considerable cash prize has always been a great way of inspiring invention, innovation and change. From crossing the Atlantic to combating climate change, the formula of fame and fortune still holds sway. The most obvious example of the lure of fame and fortune driving change dates back to 1927, when Charles Lindbergh won $25,000 plus a ticker tape parade for being the first to achieve a non-stop flight from New York to Paris.

Nearly a century later, driven by the desire to take a very significant step towards reducing the amount of energy we waste lighting our homes, offices, factories and municipal buildings, the US Congress has offered a $10 million prize for the first company able to develop a 60-watt incandescent lamp replacement using an LED in a standard A19 form-factor.

Designing a power supply that can efficiently drive the LED at the required brightness level, yet is small enough to fit into the normal bulb fitting, while still meeting EMC regulations, presents a huge challenge. This article describes a 10W power supply that is able run at over 91% efficiency while providing a constant LED current and meeting EMI requirements in a simple low cost design.

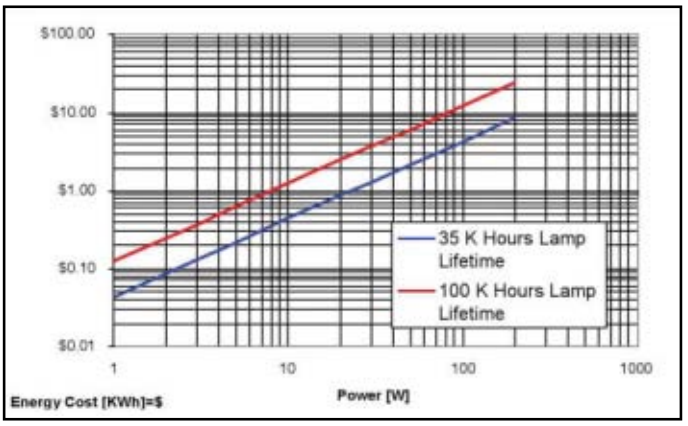

Fig. 1. Estimated cost saving over the lifetime of two LED lamps (with 35k and 100k hours lifetime). Each line shows the expected cost saving for a specific power input, when the power supply efficiency is increased by 1%.

Eyes on the prize

The standard light bulb as we know it is set to undergo a serious evolution in face of demands for more energy-efficient products. Driven by the need to conserve energy and combat global warming, several states and countries worldwide are in the process of banning inefficient incandescent lamps. New technologies are being applied to replace incandescent bulbs, with the compact fluorescent lamp (CFL) being the main candidate. Although this type of lamp only consumes approximately 20% of the power of an incandescent bulb, it contains mercury, a toxic material.

In contrast, LED-based lamps offer an even more efficient and environmentally friendly solution. LEDs were first used commercially in the early 1970s, but their light output was very low, which limited their use to applications such as indicator lights and calculator displays. Now, high power LEDs producing white light are improving in efficiency and reducing in price year on year to the extent that they are a serious contender for mainstream lighting. LED technology is forecast to achieve a flux efficiency of 150 lm/W and a cost below $5 per 1000 lumens by 2012 (source: OIDA) making LEDs viable as a source of room lighting.

Sensing that the goal of a standard light bulb replacement using LEDs is within reach, the US Congress has mandated a $10 million prize for the first organization or individual to create and validate a LED-based screw-in replacement for the standard Edison-type 60-watt incandescent lamp. The prize is one element of the Bright Tomorrow Lighting Prize, which is part of The Energy Independence and Security Act, which was recently accepted into US law (see LEDs Magazine Jan/Feb 2008, p12).

Once the prize is awarded, the US government purchasing office will be directed to use LED lamps in all government buildings. However there are stipulations attached to the prize. The lamp must produce 900 lumens while consuming less than 10 watts (>90 lm/watt) and have a correlated color temperature (CCT) between 2750 and 3000K. A predicted operating life of over 25,000 hours with 70% lumen maintenance is required, and the bulb must be sold in competitive commercial volumes.

Efficient power supplies

The ultimate winner of the $10 million prize will have earned the money because significant advances in LED technology, design and implementation will be required. The highest efficiency currently achieved by warm-white LEDs in production is about 75 lm/W, but LED manufacturers are making excellent progress towards the 100 lm/W mark, at which point the target of 90 lm/W for the lamp will be within reach. However, a very compact power supply capable of 90% efficiency will still be required.

San Jose-based analog power semiconductor company Power Integrations has shown that it is now possible to design a power supply fitting within the envelope of a light bulb that exceeds 90% efficiency and is economically viable for mass production.

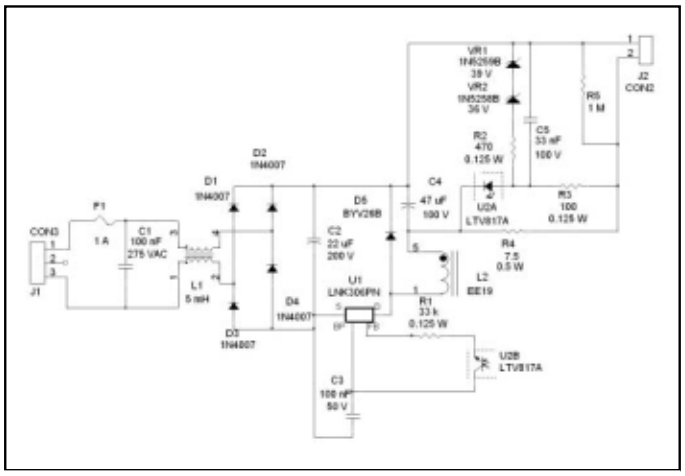

Fig. 2. Schematic of a 70V, 9W constant-current buck converter for driving LED arrays.

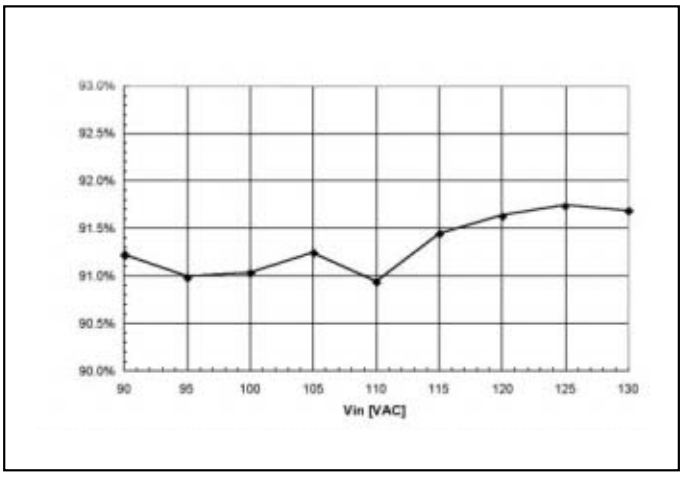

Fig. 3. Efficiency vs line input for the power supply design.

A highly efficient power supply is essential for the successful development of an incandescent lamp replacement. First there is a thermal problem. As an example, a 70% efficient power supply would simply transform 30% of the electricity consumed into heat. Unless this heat is removed, the progressive rise in temperature of the light bulb would significantly reduce the life of the LEDs and the power supply.

Even more importantly, an efficient power supply is a fundamental requirement in minimizing the so-called 'Total Cost of Light". This parameter incorporates both the initial cost of the bulb (and its replacements) together with the cost of the electricity consumed. If LED lamp manufacturers are to gain a significant share of the light bulb market they must demonstrate that the total cost is lower for LED lamps versus competitive solutions. As shown in figure 1, even a 1% improvement in LED power supply efficiency is significant.

Figure 1 shows that for a 10W LED lamp (60W incandescent lamp equivalent) a saving of $0.42 in the energy bill results from just a 1% improvement in power supply efficiency (for a 35k hour lifetime). Therefore, a 10% efficiency improvement will totally offset the initial cost of a 1000 lumen LED lamp within its operating lifetime, enabling LEDs lamps to provide a lower "total cost of light" than incandescent bulbs.

Power supply design

The power supply design described below utilizes the minimum of components yet exceeds 90% efficiency under all operating conditions. A simple method of optimizing electrical efficiency is to maximize voltage and minimize current. To achieve this goal, LEDs are connected in series and a buck power supply configuration with 70V/135mA is used (see Figure 2). Although some 20 LEDs would be required in this configuration, the use of a large number of low-current LEDs rather than a few high-current devices permits a much better spread of light in all directions and keeps the power dissipation within any single LED to a low manageable level. The consequent lower temperature rise within the lamp contributes to increasing the life of the lamp and improves the efficiency.

The power supply design uses a LinkSwitch-TN device in a low side buck configuration to deliver a constant current of 130mA at a voltage of 70VDC for an AC input voltage of 90–132V. (The supply is optimal for driving LEDs, which must be driven with a constant current rather than a constant voltage source.)

At the supply, input filtering reduces conducted EMI and a full wave rectifier generates a DC voltage across C2. The load J2, inductor L2 and switching controller U1 are all connected in series. The LinkSwitch-TN device (U1) integrates a 700V power MOSFET, oscillator, simple On/Off control scheme, a high voltage switched current source, frequency jittering, cycle-by-cycle current limit and thermal shutdown circuitry onto a monolithic IC.

Output regulation is maintained by the LinkSwitch-TN's On/Off control scheme whereby switching cycles are enabled and disabled (skipped) in response to changing line and load conditions. During normal operation an entire switching cycle will be skipped if current in excess of 49µA is delivered into the feedback (FB) pin of U1 by the transistor of optocoupler U2. The FB pin is sampled at the beginning of each cycle to determine if this cycle is to be skipped or not.

During U1's on time, current flows through capacitor C4, the load (70V LED string) and inductor, L2. This current flow results in energy stored in L2 in addition to energy being delivered to the load. During U1's off time, the polarity of L2 reverses in an attempt to maintain the current flow. This polarity reversal forward-biases the freewheeling diode D5, which allows current to flow and energy continues to be delivered to C4 and the load.

Resistor R4 acts as a current sensing element. The voltage across R4 also appears across R3 and optocoupler diode U2A, providing current control feedback to U1.

The power supply described meets EN55022B limits for conducted EMI with greater than 10dBµV margin and achieves above 90% efficiency levels throughout the operating range (see Figure 3). Similar results would be expected for a 220V input supply.

This power supply design, combined with anticipated advances in LED efficacy, enables the construction of an incandescent replacement LED lamp consuming only 10W of power, yet delivering 9W to the LEDs. Once LEDs with an output efficiency of 100 lumens/W become available in production quantities, the US Congress prize will be within reach.

About the author

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Cities realize advantages of LEDs

The LED street light demonstration in the city of Oakland highlighted many of the benefits that LED lighting can bring to municipalities, writes Kevin Orth.

As municipalities and businesses look for ways to control energy costs and reduce their carbon footprint, they are beginning to realize that lighting is not a fixed expense, and that innovation will be the agent for change. Recognizing these benefits, the city of Oakland, California, set out to study the real-world effects of LEDs on its own streets.

Project leaders from Oakland teamed up with the Emerging Technologies program at Pacific Gas and Electric (PG&E), a utility company, to find solutions to help curb the city's annual $4 million energy and maintenance bill for streetlights. The project leaders approached the US Department of Energy (DOE) to work with its Solid State Lighting (SSL) program, a national initiative to implement energy-efficient commercial lighting projects in local communities.

These entities collaborated and selected a three-block area to put LEDs to the test:

- One block used only new high-pressure sodium (HPS) area luminaires, the current light source.
- One block was converted to half LED and half HPS.
- One block was switched completely to LEDs.

The lights were installed in October 2007, and operated through December 2007. Initial anecdotal reactions were positive—both residents and city personnel perceived the areas lit by the LED fixtures to be safer and brighter than those using the conventional lighting.

LEDs entering the mainstream

The results of the DOE SSL Technology Demonstration are encouraging for proponents of LED technology. However, there are additional considerations that should be taken into account, including technological advances, reduced production costs and ecologic benefits.

According to the DOE, the technology is changing at a rapid pace. The overall performance of LED luminaires is advancing in efficiency at ~35%/year, allowing for fewer light modules and/or fixtures to be used per application, reducing energy and expenses even further.

This degree of change indicates that LED affordability is about to turn a corner. Early adopters are willing to pay larger up-front costs knowing that the payback benefits will take more time to realize (which is still reasonable, given the tremendous longevity of LEDs), the time is fast approaching when those who wish to see a more immediate return on investment will achieve this by implementing LEDs.

LEDs provide energy reductions and efficiency increases immediately upon installation. However, LEDs truly begin to show their value when it comes to perpetual-use applications such as traffic signals, parking garages and street lights that operate on a 24/7 basis. The payback for applications operating on a continual basis is significantly shorter versus nighttime-only applications. Typically, 24/7 applications will see a payback time of only a few years, where nighttime-only applications may take longer, depending on conditions and other variables. As noted before, however, the continual improvement in efficiency and decline in price will lead to dramatic reductions in payback time in the near future.

Fig. 1. During a short study, LED streetlights in Oakdale, CA, proved to lift residents morale and reduce city energy costs.

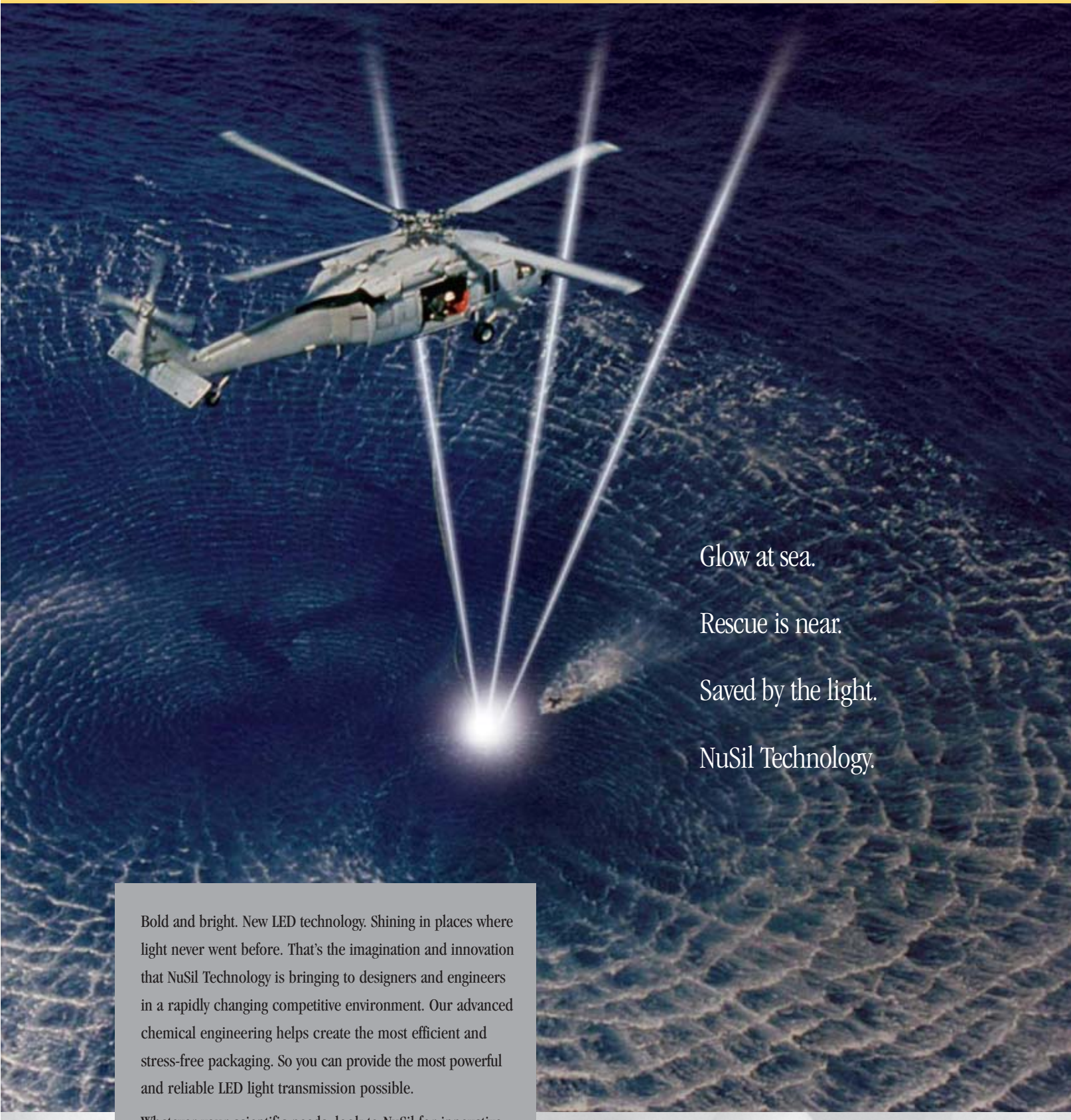
Municipalities pinching pocketbooks

Most Americans have begun to feel the impact of a slowing economy. Local municipalities are not immune to these economic challenges and must look at ways to trim budgets and hedge expenses as much as possible. Overtime for city workers is often one of the first areas cut by local governments, which often means a reduction of police, fire and other emergency personnel. Next come services such as trash and snow removal, to name only a few.

Tightening purse strings serve to emphasize the benefits LED luminaires can have for a community of any size. The city of Oakland, following their initial test of LED streetlamps, has calculated the annual savings for the city to be between $885,000 and $1.475 million. And this figure does not include the savings from eliminating the need to re-lamp. This costs an average of $50/year for each of the city's 36,000 street lights, which amounts to nearly $2 million.

With the trial of LED area luminaires in Oakland, the city has joined other North American cities that are committed to investigating the benefits of LED lighting. These cities include Toronto, Ontario; Ann Arbor, MI; Raleigh, NC; and Austin, TX, the last of which recently announced plans to change over thousands of its street lamps to LEDs after a successful test in a municipal parking garage.

"Back in 2003, for instance, we changed out all of our street signals [to LEDs], about 6000 red lights and the crosswalks, and with



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that reduced the energy consumption of our street signals by about 90%," Austin Mayor Will Wynn said. "There was only about a two-and-a-half year payback on that. We now are saving taxpayers $1.4 million every single year." Austin officials also expect to see a simple payback on the installed LED streetlamps of about 6.5 years.

LEDs improve environment

External environmental impacts must also be taken into account with the adoption of LED technology. LED luminaires significantly reduce carbon emissions, up to 2 million tons/year for some cities, and completely eliminate the use of mercury, unlike HPS sources. According to the city of Austin, the installation of LEDs will keep 4600 tons of carbon dioxide out of the air, as well as eliminating the presence of mercury in the luminaires.

These cities, and others, will continue to realize the dramatic effects of widespread implementation of LEDs. Not only will the luminaires save energy and maintenance costs, but also will improve safety by creating highly visible traffic signals and illuminated streets. Significant fringe benefits also include the reduction in time and effort for city workers undertaking the dangerous task of replacing incandescent and high-intensity discharge (HID) luminaires that have exceeded their usable life.

Energy is not a fixed expense

Although the Oakland study has a somewhat small sample size, the results were sufficient to note any overwhelming trends, but insufficient to perform any statistical extrapolation. The indications of those interviewed showed a strong and consistent preference for the new streetlights. Much of this appears to be attributed to improved visibility for drivers and pedestrians and the overall positive effects of the new streetlights on several aspects of the neighborhood's general appearance and nighttime safety.

With taxpayers pinching every penny, and $100-a-barrel oil a reality, retaining and attracting citizens and businesses to a community will become challenging. Engineers, architects, designers and specifiers will all be looking at new technologies to meet customer requests and the demands of locales across the country. As the nation becomes more aware of the impact they have on their environment, positioning a municipality as eco-friendly may be an effective way to stimulate business and preserve a strong community.

About the author

Kevin Orth is director of sales for Beta LED, a manufacturing company specializing in innovative, energy-saving, high performance LED lighting for outdoor commercial applications.

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Links

Beta LED: www.betaled.com

DOE releases Oakland LED streetlight demo report: www.ledsmagazine.com/news/5/1/30

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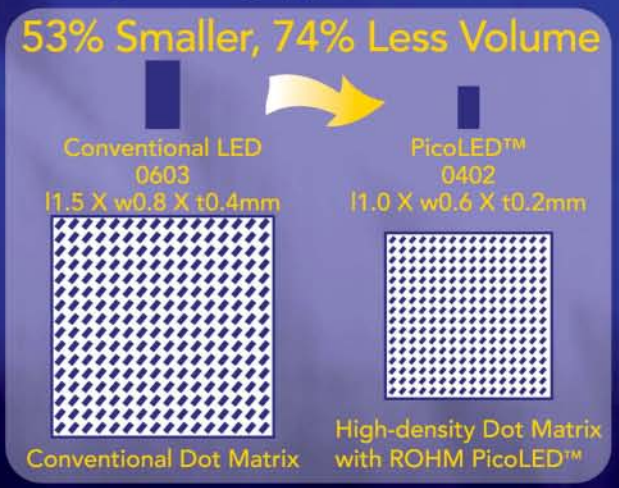
- All light-emitting elements are of the high-reliability four-element (InGaAlP) or high-luminosity (InGaN) type ensuring continuous, long-term, reliable operation.

Applications

Devices requiring thin compact components such as mobile phone keypads, small dot-matrix units, seven-segment displays and more.



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