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

LEDs MAGAZINE

LEDs Magazine Review

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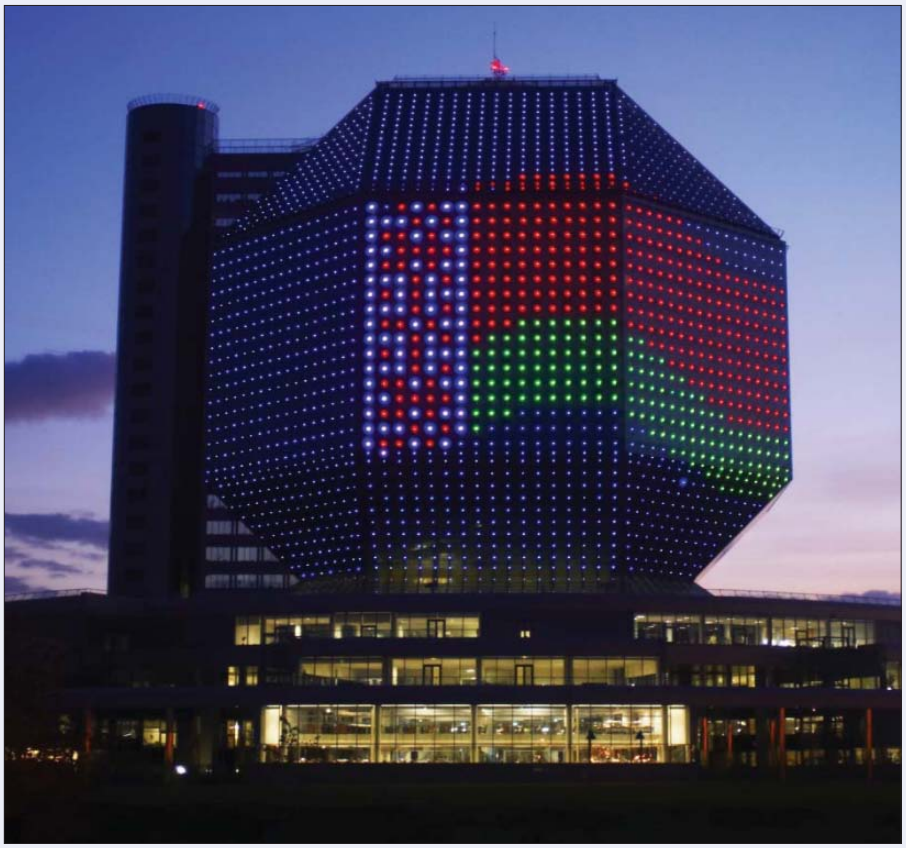
Editor: *Tim Whitaker* tim.whitaker@ledsmagazine.com **Advertising sales:** joanna@ledsmagazine.com **Cabot Media Ltd** Tel: +44 (0)117 941 5378



The National Library of Belarus in Minsk is decorated with 4646 RGB LED lighting fixtures. **p2**

Prescolite has unveiled a well-engineered, specification-grade white LED downlight.. **p17**

Crowds flocking to electronica saw a wide range of LED products and technologies. **p18**

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POWER LEDS

Seoul Semiconductor single-chip LED produces 240 lm at 1 A

LED manufacturer Seoul Semiconductor (SSC) has launched a new power LED product, the P4, which has unprecedented values of efficacy and luminous flux. Containing a single die, the P4 emits 240 lm at a drive current of 1 A. Further, it has the industry's highest luminous efficacy of 100 lm/W when operated at 350 mA. Both Nichia and Cree have reported efficacy values in excess of 130 lm/W, but these were for white LEDs based on small chips and driven at 20 mA.

SSC has ambitious plans to improve the luminous efficacy of the P4 up to 135 lm/W by 2007, and to 145 lm/W by the first quarter of 2008. "Conventional LEDs have been known to emit more than 100 lm with several dies," said Jung Hoon Lee, CEO of Seoul Semiconductor. "Seoul Semiconductor's P4 is the only LED product in the world with 240 lm via a single die."

By way of comparison, six- and four-chip lensed versions of Osram Ostar produce 420 and 280 lm, respectively, at 700 mA. Cree's new XLamp LED, announced in October, is a single-chip package delivering up to 160 lm when driven at 700 mA. Typical values for the LEDs in volume production are 80 and 70 lm/W at 350 mA. The Luxeon K2 from Philips Lumileds, also a single-chip package, delivers 140 lm at 1500 mA (24 lm/W) and 100 lm at 700 mA (40 lm/W).

SSC packages chips bought from suppliers that include Cree. It says that its own patented phosphor and packaging technologies give P4 the highest luminous flux and the superior reliability characteristics needed to meet customer thermal-management requirements. Two different types of P4 product are available: one with 80 lm at 350 mA (typical) and the other with 100 lm at 350 mA (typical).

PACKAGING

ThermaLynk packaging technology from Lynk Labs moves goalposts for LED packaging and assembly

Lynk Labs generated considerable interest at the LEDs 2006 conference (San Diego, CA, October 16–18, p7) with the introduction of two new LED-lighting-related innovations. The company, based in Elgin, IL, released its SnapBrite AC LED module product series and also unveiled ThermaLynk, an advanced LED packaging technology.

ThermaLynk has developed an integrated thermal solution for LED packaging, which was developed by Lynk Labs in collaboration with Cool Polymers Inc of Warwick RI. Lynk Labs initially looked at how CoolPoly thermal conductive material was being utilized as a replacement for metal core PCBs in LED assemblies. It realized that the CoolPoly materials could offer significant advantages if taken down to the LED die level. The result is two new patented methods of packaging LEDs, including LED packages made from thermal conductive plastics, and what Lynk Labs refers to as "Chip On Luminaire" (COL). In the COL concept, LED die are placed directly on a ThermaLynk luminaire molded into any form of end-product, such as an automotive tail-light, traffic signal or backlight for displays.

● Read the full article on our website at www.ledsmagazine.com/articles/features/3/12/2.

ARCHITECTURAL LIGHTING

Belarus library gets LED lighting treatment

The National Library of Belarus in Minsk has been decorated in stunning fashion by 4646 color-changing RGB LED fixtures supplied by Walter Industries, a subsidiary of Canadian lighting manufacturer GVA Lighting Inc.

The 23-storey, 62 m diameter library was designed in the form of a diamond and is covered by glass panels. During the day all 24 sides sparkle like a real diamond, and architects Victor Kramarenko and Michael Vinogradov wanted to preserve this vision at night.

Prof. Kramarenko described the challenge: "In the evening, the sparkling effect vanishes. External floodlight-type illumination of the building is not effective, because glass panels reflect light into space. We suggested hiding the light sources behind the glass to create an illusion of a giant color display. A total of 4646 color-changing LED fixtures were installed all round the building. As a result, spectators are able to observe a fantastic show with incredible dynamic plots from hundreds of meters away. It is an extraordinary creative venue for lighting designers."

The 4646 custom-made RGB light fixtures each contain three 1W Luxeon LEDs (red, green, blue) and are driven by a sophisticated control system controlled through custom-designed software operating on a standard PC.

● Full details of the control system and the project can be found on our website at www.ledsmagazine.com/articles/features/3/12/3.

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PATENTS

Color Kinetics responds to article on lighting control

Fritz Morgan, CTO of Color Kinetics, has written to *LEDs Magazine* about our article on patent 7,015,825, awarded to Carpenter Decorating. Our article described this as "a core technology that sits as a direct alternative to Color Kinetics' Chromasic technology, which has been widely licensed throughout the LED industry". However, Morgan disagreed with the statement that Carpenter had patented "a fundamentally new and different LED lighting control method" and reminded readers that "a host of Color Kinetics' patented technologies, which merge intelligence with LEDs…remain relevant to the LED lighting community."

- Read the original article "Carpenter patent reveals new LED control technology" at www.ledsmagazine.com/articles/news/3/10/18 followed by Color Kinetics' reply at www.ledsmagazine.com/articles/news/3/11/24.

WHITE LEDS

Nichia research yields 400 lm white LED at 2 A plus 138 lm/W for small-area devices

Nichia researchers have made further progress in staying at the forefront of developments in high-efficacy and high-power white LEDs. The results included white power LEDs producing 400 lm at 2 A and exhibiting efficacy of more than 90 lm/W at 350 mA. Furthermore, the company has pushed the record efficacy for a smaller device operating at 20 mA to 138 lm/W.

In a paper in the *Japanese Journal of Applied Physics* (www.ipap.jp/jjap), first author Yukio Narukawa and colleagues reported ultrahigh-performance white LEDs built from blue chips coated with YAG phosphors. The chips use patterned sapphire substrates and an indium tin oxide (ITO) contact as the p-type electrode.

Ultrahigh efficacy in small LEDs:: Nichia has developed small (240 × 420 μm) blue LED chips with a quantum efficiency of 63.3% at a forward-bias current of 20 mA. White LEDs produced with these chips had a luminous flux of 8.6 lm and a luminous efficacy of 138 lm/W. This exceeds the value of 131 lm/W reported by Cree recently for a standard-sized LED, and it is 1.5 times as great as that of a triphosphor fluorescent lamp (90 lm/W). The forward-bias voltage was 3.11 V and the wall-plug efficiency (WPE) was 41.7%. The white LED had a correlated color temperature of 5450 K.

High-power LEDs : Nichia has also fabricated high-power white LEDs using large (1 × 1 mm) blue LED chips that have an output power of 458 mW at 350 mA. White LEDs demonstrated a luminous flux of 106 lm at 350 mA together with a luminous efficacy of 91.7 lm/W. The forward voltage was 3.29 V and the WPE value of 27.7% is greater than that of a fluorescent lamp (25%) in the visible region. The correlated color temperature of the high-power white LED was 5450 K. Moreover, the luminous flux of the high-power white LED reached 402 lm at 2 A, which is equivalent to the total flux of a 30 W incandescent lamp.

- More details at www.ledsmagazine.com/articles/news/3/11/22.

DECORATIVE

LED lighting from Color Kinetics stars in holiday movie

LED lighting technology plays a key "role" in a new family holiday movie, *Deck the Halls*, in which dueling neighbors try to create the ultimate Christmas light show. The project was achieved using Color Kinetics iColor Flex SL, which resembles a traditional holiday string light but allows precise digital control of every RGB LED node on the strand. A total of 14 300 RGB nodes were used, drawing 7150 W – the equivalent of four average hairdriers. Wrapping the house in the same fashion with conventional exterior string lights (7 w C9 lamps) would have drawn around 100 kW. Filming was interrupted numerous times by small aircraft that were attracted to the set by the lights.

- More details at ledsmagazine.com/articles/news/3/11/19.

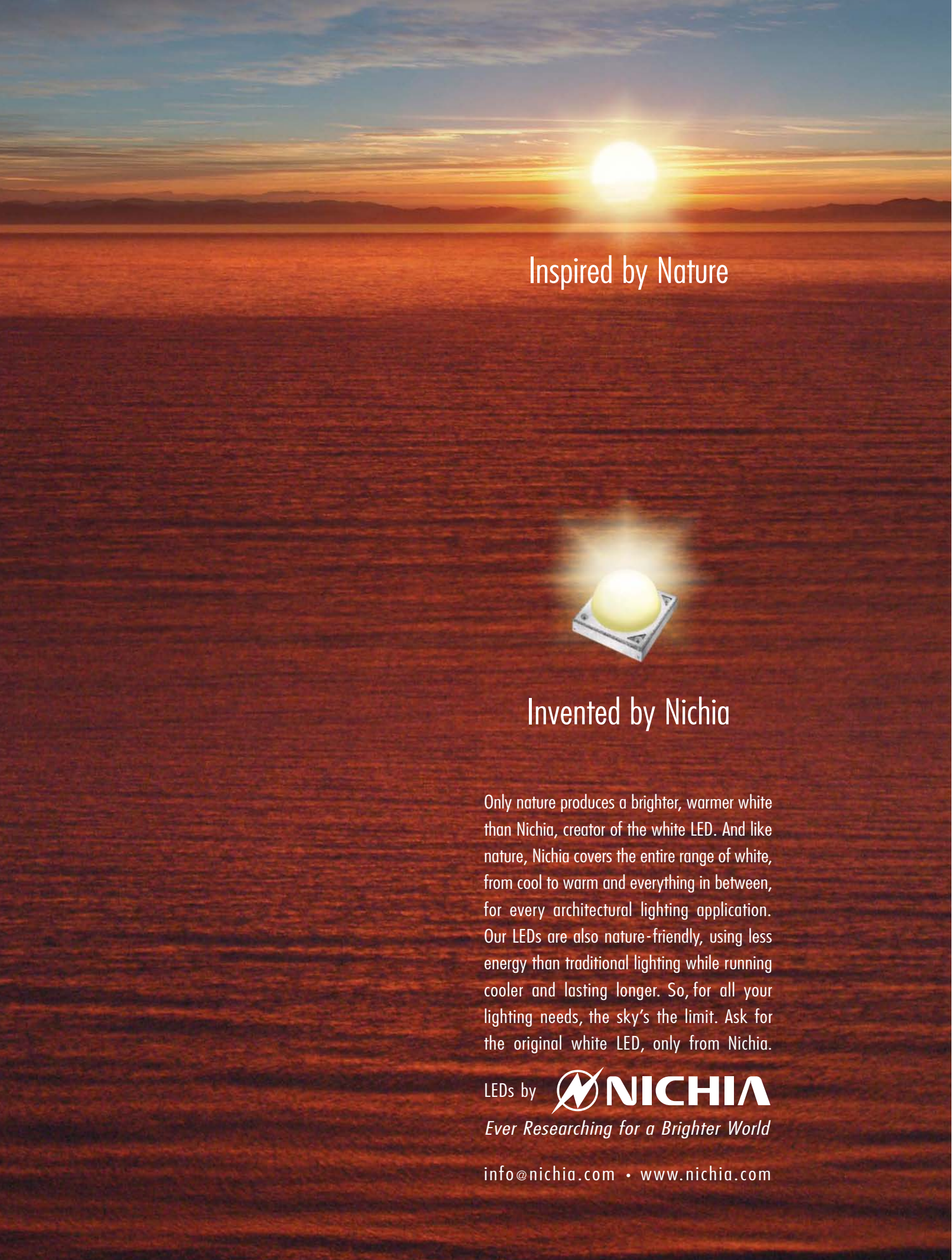
LUMINAIRES

Philips to acquire home luminaire manufacturer PLI

Philips Electronics is to acquire Partners in Lighting (PLI), a leading European manufacturer of home luminaries. PLI markets its products under brand names such as Massive, Cucina and Aqua, and it expects to have revenues of €400 million in 2006. Theo van Deursen, CEO of Philips Lighting, described this as a "strategic move" for Philips that will "confirm our leadership position in solid-state lighting, in particular for the home where energy-efficient LED solutions and creating atmospheres will be the name of the game".

PLI has 24 sales organizations and exports to 70 countries, which will extend Philips' reach into the home-lighting market, where it has a negligible share of luminaire sales. "PLI entrepreneurship, design innovation and 25% renewal rate of its products each year made them a true market-driven company, responding to market and consumer lifestyle trends,æ said van Deursen. Subject to receipt of regulatory approval, Philips will acquire PLI from CVC Capital Partners, a private equity investment company, for approximately €590 million in cash. The transaction is expected to close in the first quarter 2007.

PLI develops, manufactures and markets a wide portfolio of more than 10 000 distinct home-lighting luminaire products, currently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mainly for the European market. "Through Philips' broad expertise in lighting, its wide capabilities in LEDs and its extensive global reach and resources, we will be able to expand our home-lighting business further," said Jules Noten, CEO of PLI. "We look forward to becoming a global player and industry shaper in the transition towards LED applications."

AC LEDS

SSC's Acriche LEDs connect directly to the AC mains

At the electronica trade show, Seoul Semiconductor (SSC) unveiled its Acriche LEDs, a series of modules designed to run directly from an AC power source. Each LED package contains 2two LED chips measuring 2150 × 850 μm. There are three different Acriche modules, including a 4 W version with two LED packages that produces up to 150 lm, and a four-LED, 8 W version rated at 300 lm. These have connectors to allow direct attachment to an AC supply. The module boards contain resistors, and SSC says that these are used to lower the peak value of the AC power source. "This increases the chip stability, and when the AC electric power source's voltage fluctuates it can have a buffer effect on the chip structure," said a company spokesperson.

According to the company's description, Acriche LEDs have "dozens of cells organically connected to each other within a chip". These cells form two series-connected arrays, corresponding to the two directions of the alternating current. Each array is illuminated alternately for the different directions of current flow. This allows Acriche LEDs to be directly connected to an AC electric power source.

The SSC spokesperson says that, when the light source is considered, the performance of DC LEDs is still a little better than Acriche in terms of lifetime and luminous flux. "However, with respect to AC lighting fixures, Acriche performs better because DC LEDs need AC–DC converters, which have a much shorter lifetime and are less efficient than LEDs."

- More details at www.ledsmagazine.com/articles/news/3/11/14.

ON OUR WEBSITE

High-power in a 1 mm^2 chip: the origins of the 350 mA '1 W' LED

For years, high-power LEDs were defined by two specifications that seemed to be engraved in stone: that each chip was 1 mm^2 and could be driven at 350 mA. This "1 W" LED launched the use of solid-state illumination in general lighting applications and became the *de facto* standard in the industry. Ironically, however, these specifications were the product of serendipitous design decisions rather than deliberate engineering choices that were calculated to generate a specific level of performance. The design team simply put a stake in the ground and the rest of the industry followed.

- See www.ledsmagazine.com/articles/features/3/11/2.

RETAIL LIGHTING

Wal–Mart fits refrigerated displays GELcore LED lights

Wal-Mart is to deploy LED lighting from GELcore in its refrigerated display cases in omore than 500 US stores. The giant retailer expects that energy cost savings from the retrofit will exceed $2.6 million annually, compared with incumbent fluorescent technology. Wal-Mart will employ occupancy sensors and LED dimming capabilities to reduce the time that the LED refrigerated display cases are at 100% light levels.

Wal–Mart reports that subsequent phases of the initiative will be aimed at retrofitting existing refrigerated display cases at many of its worldwide network of 6689 stores. "We have committed to invest up to $500 million annually on energy-efficient technologies," said Charles Zimmerman, VP of prototype and new format development at Wal-Mart. "It's our hope that one day all of our reach-in refrigerated display case lighting will use LEDs."

GE says that 8 of the top 10 US grocers/supermarkets are testing or using the company's LED refrigerated display lighting. LED lighting offers a range of benefits. One of these is reduced energy consumption by lessening the load on the compressor. For every light watt reduced in a frozen-food case, the compressor works less hard, saving about 0.45 W. On a five-door case, the additional energy savings from a reduced load on the compressor can reach 70 W compared with T8 fluorescent lighting.

- More details at www.ledsmagazine.com/articles/news/3/11/16.

DISPLAYS

Barco supplies LED backdrop for George Michael tour

LED display specialist Barco has supplied 3000 of its MiSTRIP LED modules to form a highly unusual stage backdrop for George Michael's 25 Live Tour. The modules, playing video and graphics effects, form an unprecedented curved display of LEDs behind and underneath the performer that can be both stood and danced on.

LEDs MAGAZINE

Speakers at LEDs 2006 conference search for near-term LED markets

One of the underlying themes of the LEDs 2006 conference, held on October 16–18 in San Diego, California, was to identify the key near-term applications that will drive growth in the next few years, writes **Tim Whitaker**.

In the early part of this decade, consumers clamoring for color screens in handsets created a huge demand for white LEDs. Certain market sectors, such as general illumination and backlighting in LCD screens, have the potential to create similar growth rates in future years – but not quite yet. However, while explosive growth is not likely in the short term, the good news is that there are many applications, both existing and new, to push the LED market forward.

Although the developing world is not usually considered a prime market for LEDs, there are an estimated 1.6 billion who lack access to the electrical grid. LED-based lighting systems are considered an excellent option for such people compared with lamps that burn kerosene or other fuels. At LEDs 2006 the International Finance Corp (IFC) launched a project to facilitate the development and market introduction of such systems – on a commercial basis. Margins will not be high, but unit shipments could be. (For more details, see p15).

Jagdish Rebello of market research firm iSuppli spelled out that the new growth driver for the LED market is the ultra-high-brightness segment, which iSuppli defines as LEDs with power dissipation at or above 500 mW. He predicted a CAGR of 57% for this segment through 2011. The overall LED market will reach $10.6 billion by 2011.

Handset applications remain the dominant market sector and are continuing to grow, but at a slower rate than in previous years, as a result of price erosion and reduced handset shipment growth rates. However, the introduction of white SMD LEDs, with luminous intensities of 1500 mcd and above, is offsetting ASP erosion to some extent. In the conference exhibit, ROHM Electronics showed a roadmap for white side-view LEDs. Conventional devices are likely to reach 2000 mcd by 2008, while wide-color-range LEDs (using red-green phosphors to increase the color gamut by ~15%) will reach 1600 mcd.

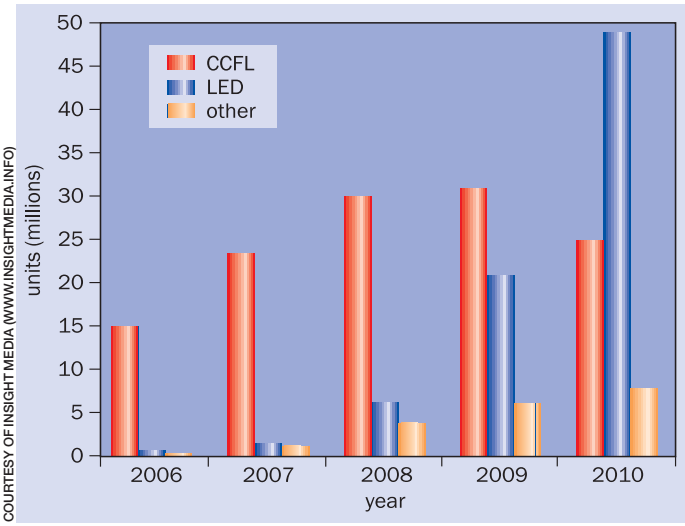

Fig. 1 Shipments of LCDs with different backlighting technologies.

Richard MacKellar of Brightside Technologies described the use of LEDs in high-dynamic-range displays, which are intended to match the luminance capabilities of the human eye. While a conventional display uses a uniform light field for the backlight, Brightside's uses individually modulated LEDs to create a non-even light field that varies according to the image content. The bright areas of the light field match the bright areas of the image, vastly enhancing the contrast (see www.ledsmagazine.com/articles/features/3/6/6). The demonstration display shown by MacKellar (right) was clearly better than the conventional display and used 1380 LEDs, each consuming 2.3 W, so that a fan was required. The unit uses white LEDs, so the color gamut is not expanded, but with a much greater black depth the "volume" of color is increased, he said.

Display backlighting

Like many others in the industry, Rebello speculated that the backlighting of large-screen LCD displays could be the next "killer" application for HB-LEDs. "The backlighting unit (BLU) is a significant cost item in the TV panel and has a dramatic impact on performance," he said. "LED backlights offer superior performance over CCFL backlights, offering better contrast and richer colors. Furthermore, the LCD TV and monitor market is experiencing explosive growth, and LED prices are dropping and performance improving dramatically."

iSuppli estimates that by 2010 the price of LED BLUs for 32 inch TVs will be only slightly more than for CCFL units, as a result of a decrease in the price of LEDs, improvements in light-guide technologies and, of course, much higher volumes.

Matthew Brennesholtz of Insight Media spoke in more detail about the use of LEDs in both LCD and projection displays. First-generation LED backlights for LCD-TV used direct illumination, with multiple LEDs across the backplane of the display. Brennesholtz said that

PHILIPS LIGHTING

Fig. 2 LED lighting played a major role in the 2006 Philips Simplicity Event, in which the company showed some of its simplicity-led design concepts that are aimed at improving the quality of life and contributing to a healthy lifestyle. Ideas included reconfigurable interactive floor tiles, lighting that simulates sunlight to help with sleeping disorders, and LivingColors (above). The color and light intensity of LivingColors can be changed using a simple remote control, to create atmosphere and ambience. Philips plans to launch the product in early 2007 in select markets.

edge-lit designs, which are currently used for smaller displays, require fewer, but higher-performance, LEDs. "Edge-lit LED BLU designs will become more cost-competitive in progressively larger sizes as LED performance improves," he said. This also depends on the development of appropriate light-guiding technologies to distribute the light from the edge-mounted LEDs in a uniform manner across the backplane. Insight Media's forecast for different backlight technologies is shown in figure 1.

Brennesholtz also discussed the projection market for LEDs. "We expect that LEDs will eventually replace lamps in most projection systems with an on-screen luminous intensity up to about 1000 lm," he said. For reasons such as improved color rendition and instant switch-on, consumers recognize and appreciate LED illumination in projection applications.

However, the cost of the whole LED system, including die, packaging, cooling systems and drive circuits, will remain significantly higher than for UHP lamps, which means that light from LEDs must be used more efficiently to compete with other light sources. For example, LED light sources will have an estimated cost of 10 cents/lm in 2007, while for a 120 W UHP lamp the cost will be closer to 1 cent/lm. Brennesholtz also pointed out that, for projection systems, the output of green LEDs is a limiting factor and that this situation is expected to continue through 2010.

Solid-state lighting

Niels Haverkorn of Philips Lighting began by explaining that solid-state lighting is very important to his company, which has made significant investments recently in acquiring LED maker Lumileds and luminaire manufacturer PLI (see www./ledsmagazine.com/articles/news/3/11/17 and report, p4).

Philips' current global theme is sense and simplicity, which means using technology to improve people's lives in a meaningful way but at the same time reducing complexity (figure 2). "LEDs enable creativity, and solid-state lighting has the potential to create ambience and mood rather than simply replacing the light bulb," said Haverkorn.

Having used LEDs in special applications, such as traffic lights and automotive applications, and projects such as outdoor and entertainment lighting, the technology is now moving towards customized general lighting. However, said Haverkorn, standardized LED products for the general lighting mass market are not likely to become widely available before about 2010.

Philips is strongly promoting a modular approach to LED lighting, which can address many technical issues, and deliver quality and system reliability. Haverkorn explained: "Customers such as furniture makers have no experience in lighting, so offering building blocks can help significantly."

For LEDs in the general illumination market, Philips sees that the biggest challenge in the US and Europe is to deliver tunable, high CRI white light, while for other markets, such as China, the total cost of ownership is paramount.

Lighting the streets

Outdoor lighting is the first major general illumination application that can be served by LEDs, said Mark McClear of Cree, who described the experiences of his company in designing prototype LED-based streetlights. Cree's new XLamp provides a typical output of 80 lm and 70 lm/W, and this, said McClear, "delivers an economic value proposition to outdoor lighting that was formerly not possible". (See www.ledsmagazine.com/articles/features/3/10/4 for more information about streetlighting).

Concluding the conference was a review of the competition to design new street lights for New York City, which was won by an LED-based design from the Office for Visual Interaction (OVI) (www.ledsmagazine.com/articles/features/1/12/2). In a city with 5700 miles of streets and more than 300 000 streetlights, this project could be a major consumer of power LEDs – assuming that everything goes ahead as planned. Enrique Peiniger and Jean Sundin from OVI said that the tender for the fixtures has yet to be finalized, although this is beneficial for the city – the design has a modular approach so that fewer LEDs will need to be used as devices become more efficient in the future.

Modules and luminaire design

Questions regarding the likely form-factor of successful solid-state lighting products continue to swirl around the industry. Kevin Dowling of Color Kinetics dismissed LED versions of incandescent bulbs as "a platypus of light", and said that solid-state lighting needs time to evolve its own form and vocabulary. "SSL is not just a replacement technology; this approach weakens its capability," he said. Important lessons can be learned from attempts to introduce compact fluorescent lamps into the US, where improved energy efficiency was not enough to overcome poor light quality, flicker and high prices.

Dowling outlined some concepts for a next-generation LED lighting system, with power supplied by a line voltage digital ballast, and control from a light switch, a dimmer, a control network or something more complex. A crucial development will be a solid-state "lamp" with an appropriately designed interconnect or "socket" that allows the lamp to be replaced. This concept acknowledges that even LEDs don't last forever but also allows, for example, a warm-white lamp module to be easily replaced with a cool-white version. The "lamp" could contain multiple LEDs, together with the appropriate primary

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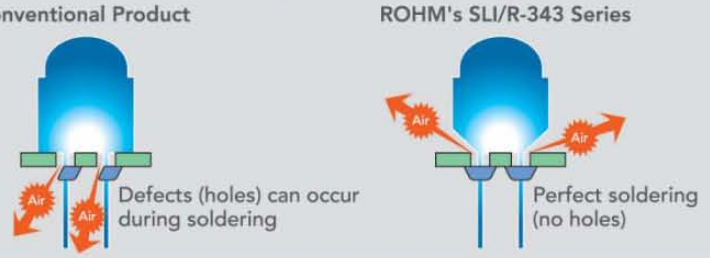

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Clint Terry of iLight Technologies described some of the supply chain issues in different markets (current and potential) for LEDs. For signage, he said, installation and maintenance are very important, and here LED-based products offer advantages over neon. For institutional lighting, the most important factors are payback, lifetime and energy efficiency, while for commercial lighting the key drivers are special effects and lamp/fixture characteristics. Conversely, the initial cost is by far the most important issue for residential lighting.

Terry said that LED retrofit lamps need to be properly designed, not built with a one-size-fits-all approach. For integrated fixture design using LEDs, acceptance will require a focus on light quality, appearance and suitability for the application. Questions such as how the fixture looks when it is not lit, and where the light goes, are crucial. "Fixtures that look ugly or don't control the light properly will not be specified by the architectural design community," he stated.

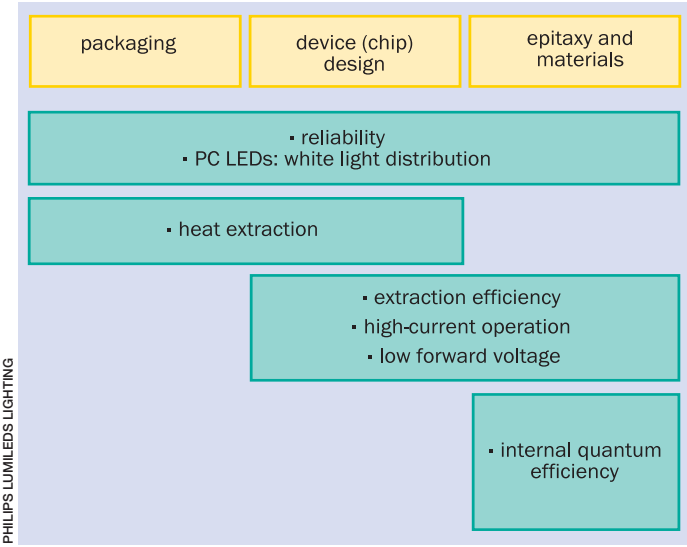


Fig. 3. High-power LED challenges, with areas for improvement.

Chips and packaging

Sudhir Subramanya of Lumileds Lighting described how improvements in LED die and packaging technology continue to result in significant enhancements in the performance of power LEDs. "The battlefield for lighting will continue to be in the 'power' segment, from 350 mA upwards," he said. As shown in figure 3, improvements in packaging, device (chip) design, epitaxy and material properties all contribute in different ways to power LED performance.

In creating its Luxeon K2 package, Lumileds made several fundamental changes, such as an improved heat-sink design, which resulted in reduced thermal resistance and a higher maximum operating temperature. In turn, this allows a higher operating current and higher luminous flux per package. Other changes included moving from a thermal epoxy to solder for submount attach and lamp attach (i.e. heatsink to board), and changing from a PbSn solder bump to an gold-gold stud bump process for chip attach. The gold-gold interconnect process has a number of advantages, including a short bond cycle of about 0.5s, a small number of process steps (four or fewer) and a low bonding temperature of less than 150 °C. The result is a metal-to-metal contact that has excellent thermal conductivity.

Subramanya also pointed out that thermal management – currently a major issue for any LED package or system – will become much more straightforward as LED efficiency improves.

Photonic crystals

Extracting more light from LEDs was described by one speaker as the holy grail of LED design. An entire session was devoted to discussing ways to enhance light extraction, centered on the use of photonic crystal structures (see www.ledsmagazine.com/articles/features/3/8/7). Patrik Lundstrom of Obducat AB described his company's nanoimprint lithography equipment for the mass-production of LEDs with photonic crystal structures, which are essentially two-dimensional diffraction gratings that enhance extraction from the LED surface.

Norbert Linder of Osram Opto Semiconductors compared photonic crystal LEDs with the roughened surface structure used by Osram in its ThinGaN chip family. With these textured surfaces, the estimated extraction efficiency into air exceeds 50%. "Photonic crystals enhance LED emission but…are they as good as roughening or surface texturing?" he asked, concluding that this remains an open question. Photonic crystal LEDs appear to be most suitable for generating higher optical flux in systems with small aperture angles, such as etendue-limited projection systems. However, such designs require larger chip areas, resulting in a higher cost, and they have higher power consumption and lower system efficiency. Photonic crystals don't provide any advantages for white phosphor-converted LEDs because the conversion process destroys any directionality from the photonic crystal.

Jeon Heonsu from Seoul National University described a novel structure in which angled sidewalls are introduced at the edges of the GaN layers in a GaN-on-sapphire LED. In general an air-GaN-sapphire structure creates a thin-film waveguide in which light is guided laterally through the GaN layer. In the "sidewall-deflector-integrated" LED structure, the angled GaN sidewall deflects light out of the GaN layer and through the sapphire layer to the outside of the device.

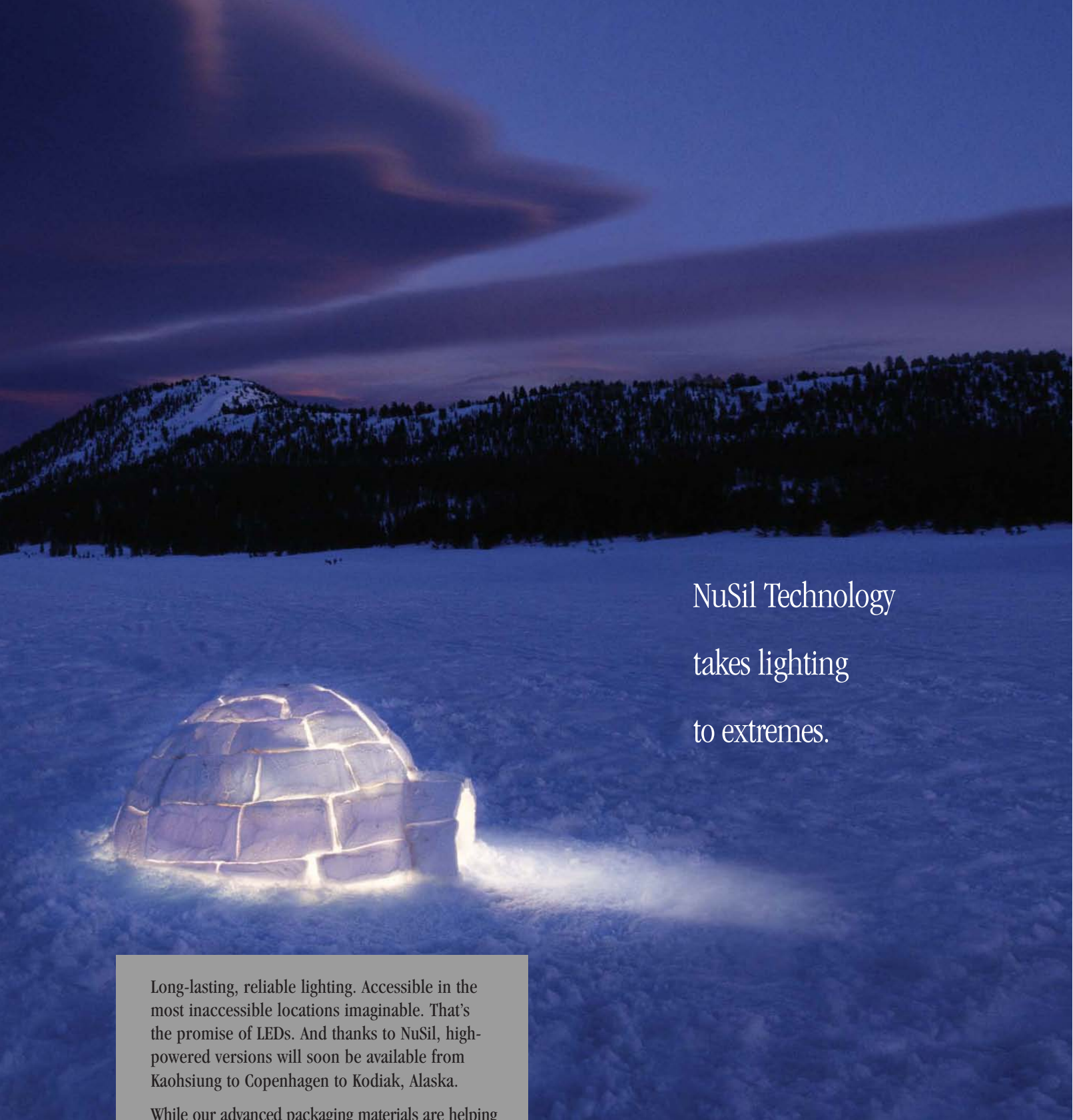
Phosphors

A critically important component of white LEDs, the best phosphor for any situation depends on factors such as the LED power, the application and its requirements (e.g. color rendering), and the package. Frank Jermann of Osram GmbH said that for daylight-white (5500–6500 K) the best choices are the yellow-emitting aluminum garnets, YAG:Ce and TAG:Ce. Yellow orthosilicate phosphors, he said, have serious limitations. TAG:Ce is also an efficient and easy-to-use solution for cool-white (~4000 K) LEDs.

For warm-white (2700–3400 K) LEDs, Jermann suggested the combination of yellow garnet and red nitride phosphors, where red nitride refers to $(Ba,Sr,Ca)_2Si_5N_8$:Eu. The red nitride phosphor and a green oxynitride version were also suitable for color-on-demand applications (where the phosphor composition is tweaked to allow the selection of specific emission colors) and high-temperature applications. Jermann said that, in the future, Osram expects to develop better phosphors that can produce white LEDs with higher luminous efficiency, and that are less dependent on excitation wavelength and operating temperature (figure 4).

LED display development

Bruno Verhenne of Barco gave an interesting and unusual presentation on how LED technologies and spectator expectations drive each other. When LED display products were first introduced (Verhenne



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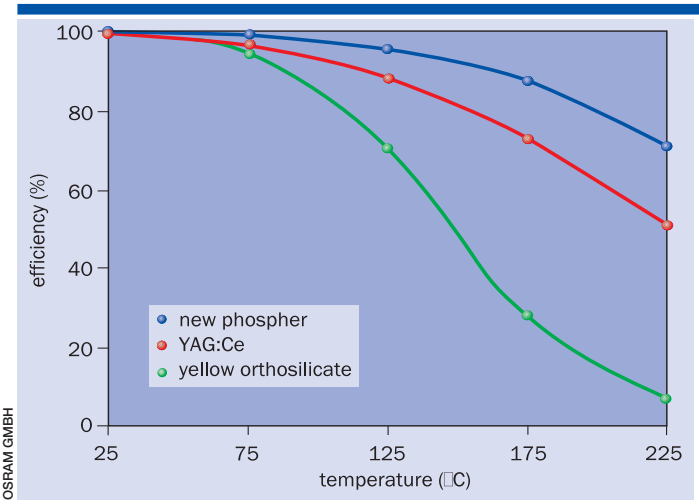
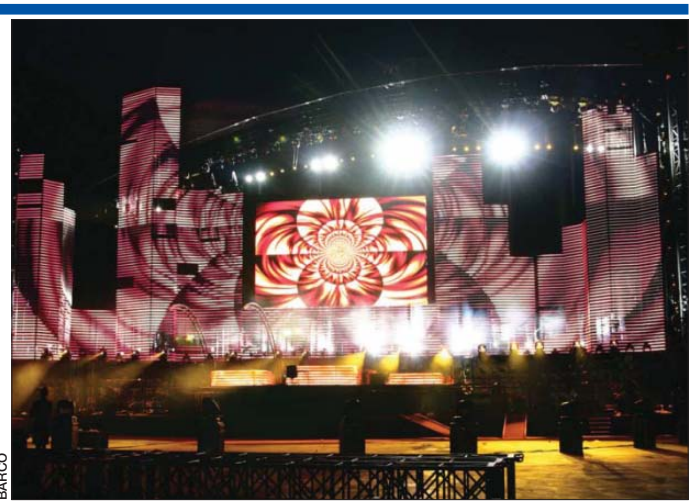


OSRAM GMBH

Fig. 4. New phosphors are expected to have much better high-temperature performance than exisiting ones, such as YAG:Ce.



BARCO

Fig. 5. At a recent Bon Jovi concert, 2.2 km of LED strips were used to create a free-form 3D backdrop, blurring boundaries between video and lighting (www.ledsmagazine.com/articles/news/3/6/10).

called this the "first wave"), the driving force was to get the maximum brightness at a decent cost, which in turn required LED makers to develop SMD devices, three-in-one RGB packages and higher-efficiency LEDs. The second wave was largely a cost-cutting exercise as end customers reduced their assembly costs and looked for markets that would provide a good return on investment, such as rental companies and sports environments. The LED makers were asked to reduce costs through enhanced yield and improved production processes.

In the third wave, customers started to look beyond straightforward video displays, becoming interested in creating atmosphere, and combining video and lighting in a creative manner. Barco has been involved in many examples of this approach, such as the recent Bon Jovi concert tour (figure 5) and the Uniqa Building in Vienna. The driving force for LED makers was to increase efficiency and output flux. The individual LEDs need to have sufficient brightness to operate in these types of large-scale, low-resolution displays.

The current fourth wave has been driven by the availability of improved video sources and high-definition content, requiring a parallel improvement in LED performance. As well as efficiency, a key parameter is color gamut, so that the video industry can display a more natural range of colors. For outdoor displays, said Verhenne, higher brightness is required. "The sun still hasn't been beaten," he said. Indoors, improvements in efficiency will allow manufacturers to move towards almost silent displays if cooling fans are eliminated. Different emphasis is needed for different colors, added Verhenne. "Blue efficiency is high enough, but green needs more improvement. The focus should be on the correct color balance."

Verhenne finished by advocating a model for co-operation in which LED suppliers and display makers work together to select the areas most in need of attention. "LED manufacturers are too far away from end users to understand which parameters to improve," he said.

Opportunities in aerospace

According to Scott Mangum of Honeywell Aerospace, the total lighting revenue from the aerospace market is approximately $0.5 billion, which "does not represent a huge opportunity" relative to that of the broader lighting market. Aerospace is, however, an early adopter and a "great proving ground" for LED technologies.

There are many aviation lighting applications, some of which are safety critical, and most other (non-LED) light source technologies are in use on aircraft today. Mangum noted that, "LEDs have the potential to impact almost all applications, displacing existing technologies with the exception of high-power landing lights, at least in the near term." For exterior illumination, Honeywell has developed position lights (see www.ledsmagazine.com/articles/features/1/10/4) as well as anti-collision lights (see www.ledsmagazine.com/articles/features/2/10/13), and it is pursuing floodlighting applications, such as logo lights, wing inspection and exterior cargo loading (figure 6).

Interior lighting also offers great opportunities for LEDs and, with less demanding requirements than exterior applications, this is a more competitive market. Interior illumination examples include reading/attendant lights, cabin illumination, signage and even cargo compartment lighting. "The absence of substantial forward heating, as we see with today's incandescent-based product, allows luggage to be stacked in closer proximity to the light," said Mangum.

Even with these great opportunities, LEDs face many challenges in the aviation market. Mangum noted that most applications are retrofits into existing aircraft, not new platform opportunities, so the LED luminaire and associated electronics must fit within the same volume and geometry as the technology being replaced. Binning is another issue – federal regulations specify usable aviation color points, some of which are not currently available from some manufacturers. Additionally there is a need to understand how LED color, particularly white, may shift with life. Initially a new product might meet the appropriate color specification and then drift outside of the requirements over time.

Cost is, of course, important. "We need to develop a total cost of ownership story, including the impact of flight delays caused by non-functional lights," said Mangum. He pointed out that lighting currently has a "razor and blades" model, where a low upfront cost for the unit is followed by significant ongoing expenditure on replacement lamps. "LEDs turn this model upside down," he said.

Similarly, weight is a key issue. "Overall weight has a direct impact on operational costs and range of aircraft," said Mangum. Thermal management and the increased electrical complexity associated with LEDs can result in greater weight. "The introduction of LEDs with higher efficacies and higher operational junction temperatures are


HONEYWELL AEROSPACE.

Fig. 6. This light, one of two sections of a pilot director light, is fixed to the underside of a refueling tanker aircraft to guide the incoming receiving pilot. The sections are 22 ft long and contain 3000 LEDs.

ILIGHT TECHNOLOGIES

Fig. 7. LED linear lighting can replace neon in signage applications. The Regal Ceinema in Knoxville, TN, uses more than a mile of LED exterior trim and accent lighting, supplied by iLight Technologies.

of great benefit to our market," he added. "This allows fewer LEDs, with reduced thermal sinking, to be used, thereby helping to reduce overall system weight."

Frank Robertazzi of CML Innovative Technologies agreed, saying that "many customers would sacrifice lifetime in order to reduce weight". Other challenges include the need to improve the quality of light and color rendering, and to introduce warmer whites. However, Robertazzi said that LED technology has a clear value proposition in terms of color mixing and maintenance, and that the aviation market should be able to leverage breakthroughs in other markets, such as automotive.

Mangum concluded by saying that solid-state lighting offers clear and measurable benefits to many aerospace applications, such as dispatch-critical lights. But challenges associated with system design as well as LED supply remain, and these must be addressed to ensure full appreciation of the opportunities and benefits of this technology.

Opportunities in automotive

Thomas Luce of Valeo Vision Systems described the use of LEDs for automotive lighting, a hot topic also discussed on p21. Luce said that LED front lighting was expected to reach the market in 2007, and that white multichip LEDs are available today that achieve HID performance. To achieve quick market penetration, a huge reduction in cost is required because the LEDs alone (without drivers) currently account for 50% of the headlamp cost. "In the medium term, LEDs will replace HID and part of the halogen market," said Luce, citing the increasing importance of energy saving as a key factor.

Among the many important LED-related factors is reliability. During the estimated lifetime (i.e. the time when the headlights are used) of 6000 h there would be ideally no need to exchange the LED modules, and no change in color. Both the LEDs and the fan that would be required for effective heat management are critical components in need of further reliability investigation. In conclusion, said Luce, LED makers need to aim for higher luminance, no color deviation between multichip sources, the ability to operate at higher junction temperatures and, of course, lower cost.

Links

On our website:
Exhibit highlights from Intertech LEDs 2006 conference
www.ledsmagazine.com/articles/features/3/11/1

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KEYNOTE:
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Neal Hunter
Chairman and Co-Founder, LED Lighting Fixtures, Inc.

FEATURED SPEAKERS INCLUDE:
A Major Luminaire Manufacturer's View of the Role of LEDs in Lighting
Ruedi Hug
Managing Director, LEDON Lighting GmbH

Photonic Lattice-Based LEDs: A New Class of Solid-State Light Sources
Bob Karlicek
Chief Scientist, Luminus Devices

Near-term Application Opportunities for LEDs: A Laboratory-to-Marketplace Perspective
Michael Siminovitch
Director, California Lighting Technology Center

Accelerating SSL Adoption in the Broad Market: The Emergence of Global HB LED-Focused Distribution
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Director, LightSpeed, Avnet Electronics

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LEDs MAGAZINE

IFC project stimulates LED market for off-grid lighting

A project organized by the International Finance Corporation aims to help LED companies to sell lighting systems to homes and businesses that rely on fuel-based lighting.

COURTESY OF EVAN MILLS, LBNL

LED lighting can have a huge impact on microbusinesses, such as this sandal seller's stall in Tanzania, which would normally use a single kerosene lamp (left). The quality of light and the appearance of products are significantly improved using a single 1 W white LED (right), and the merchant would expect to make substantial cost savings by switching from kerosene to LEDs.

The International Finance Corporation (IFC), the private sector investment arm of the World Bank Group, has launched a project with around $7 million in funding to bring LED-based lighting to areas of the globe that lack electrical power. The project is funded primarily by the Global Environment Facility, and developed and implemented by the IFC. Potential participants are encouraged to visit the project website at www.ifc.org/led to register their interest. As of November 30, says IFC's Fabio Nehme, 145 organizations from 27 countries have expressed interest in taking part.

LED lighting, powered by photovoltaic systems or other power sources, could have huge benefits for the developing world. At the same time this project could stimulate a very large market for the emerging LED lighting industry.

At a recent seminar to announce the project to the LED industry, IFC's Russell Sturm said that the motivation to become involved might be either humanitarian or profit-driven. "Both these factors are important for the project to be a success," he said.

Replacing fuel-based lighting

IFC's Lighting the Bottom of the Pyramid project aims to assist companies to sell LED-based lighting systems to the 1.6 billion people around the world who are not connected with the electrical grid, not to mention a large number with intermittent access to electricity Lacking access to electrical lighting, many of these people and businesses instead rely on fuel-based lighting.

Lanterns that burn kerosene represent the dominant type of fuel-based lighting, but these are very inefficient, produce a very poor quality of light and are very expensive to run. The annual cost of buying kerosene can easily account for a month's wages in some countries. Where lighting is limited by cost, this can have serious implications. For example, child literacy is affected by restricted study hours, and small businesses are affected if they cannot afford to stay open after dark. To make matters worse, burning kerosene indoors can have health implications and pose a fire hazard.

Evan Mills of the US Department of Energy's Lawrence Berkeley National Laboratory and consultant to the IFC project has estimated that fuel-based lighting consumes $38 billion each year in fuel expenditure, on a global basis (and this was before the recent run-up in world oil prices), and this figure is rising. IFC's goal is to help project participants to penetrate this huge and established market. In comparison, electric lighting consumes $185 billion in electricity costs, according to Mills – a number that is falling, thanks to ongoing improvements in electric lighting.

Pilots in Kenya and Ghana

The project will focus initially on Kenya and Ghana, since these countries have 15.9 million customers who spend $1.4 billion a year on fuel-based lighting. Sturm says that this is the pilot for what IFC expects to be a global initiative.

Phase 1 of the project will bring together private sector consortiums

of firms that might include off-grid power source suppliers (e.g. photovoltaic system suppliers), LED makers, LED product assemblers, local distribution companies in Africa and other strategic partners.

Phases 2 and 3 of the project, beginning in 2007, will conduct a detailed assessment of customers in two main segments: households and small businesses. For example, it is essential to understand how much customers pay for lighting, what properties they value and how much they would pay for "modern" lighting.

Sturm says that, as part of phase 2 market assessment work, IFC will procure multiple products for field-testing in Ghana and Kenya. "These will help to determine the characteristics of a modern lighting product that responds to the market needs and conditions," he said. "This information will then be shared with the industry to support development of new products for the market."

These phases will also build an understanding of distribution channels, and develop technical standards. IFC's role is that of a "neutral coordinator" supporting all participating companies.

Current status

Fabio Nehme says that between August and November the organization has been working to form a consortium of private companies that are part of the value chain (component manufacturers, integrators, entrepreneurs and potential distribution channels for LED products in Kenya and Ghana) or stakeholders at large that are related to the project (technical/engineering institutes, NGOs involved in this space, entrepreneurial funds, etc). This outreach effort has included a two-week trip to Kenya and Ghana to engage additional organizations.

"We are focusing on a couple of key items," said Nehme. "One is creating the system to allow participating companies to access each others information to support partnerships/alliances. The other is preparing to retain a firm to conduct a market assessment for the industry."

Links

Lighting the Bottom of the Pyramid – project website:
www.ifc.org/led
Lawrence Berkeley National Lab's research:
http://eetd.lbl.gov/emills/PUBS/Fuel_Based_Lighting.html
On our website:
White-light LED home lighting systems provide great benefits for India's remote tribal villages
www.ledsmagazine.com/articles/features/2/12/8
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www.ledsmagazine.com/articles/features/1/5/11

In our next issue: An interview with Dave Irving-Halliday, founder of Light Up The World Federation.

LEDs MAGAZINE

LED downlights from Prescolite make the grade

Hubbell Lighting's Prescolite division has unveiled a specification-grade LED downlight that has been designed with future LED improvements in mind.

Prescolite, a divison of Hubbell Lighting Inc, one of the largest lighting manufacturers in North America, recently added to its LED product range with an LED recessed lighting fixture. The company, based in Spartanburg, SC, described this as the first specification-grade LED downlight that performs like a CFL downlight.

Ron Newbold, senior product manager with Prescolite, told LEDs Magazine that his company has tracked the improvements in LED technology. "LEDs have reached lumen-per-watt levels that raised our eyebrows," he said, describing the product as the first very-high-quality LED downlight that has taken a balanced approach between optics, aesthetics and thermal management.

The Architektur downlights, with 4 or 6 inch apertures, are built around a light engine/reflector assembly containing ten 3 W white Luxeon LEDs from Philips Lumileds. These devices have an average output of 57 lm, a typical color temperature of 5500 K and a lifetime of 50,000 h at 70% lumen maintenance.

A key aspect of the downlight is the high quality of light that it produces. "Each LED has its own parabolic reflector," explained Newbold. "This enables light from the 10 emitters to be mixed smoothly and uniformly before it reaches the illuminated surface."

"Traditional lighting manufacturers don't necessarily have the skill sets to integrate LEDs, although we do have the manufacturing and lighting market knowledge, as well as established sales channels."

This approach to efficient white-light mixing also reduces problems caused by variations between LEDs within each light engine. Color rendering is determined largely by the LEDs, but the value of around 75 compares favourably with CFLs, which are around 82.

To develop the downlight, Prescolite worked with Philips Advance, which also supplied its Xitanium drivers. "Our engineers worked together to develop the light engine design," said Newbold. "Traditional lighting manufacturers don't necessarily have the skill sets to integrate LEDs, although we do have the manufacturing and lighting market knowledge, as well as established sales channels."

The downlight was developed by targeting a specific quantity of light onto the work surface at a predetermined angle, says Newbold. "We defined the application requirements back into the product and this pointed us towards the LED that could give us the required amount of light. The K2 was the only suitable choice at that time."

The Architektur D6LED downlight is built round a light engine comprising 10 white Luxeon K2 LEDs, each with a parabolic reflector, providing very uniform light output.

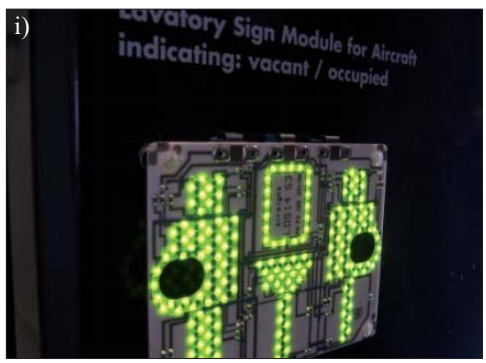
Another benefit of the K2, he says, is the capability to overdrive the LEDs to higher junction temperatures and increase the light output while still maintaining good lifetime. "We still keep the temperature well below the datasheet maximum value of 125 °C. We're being very conservative and have very good heat sinking, possibly overengineered for this product." However, the goal was to establish a platform for future downlights. "As LED technology continues to improve, we can rapidly introduce these advancements into the platform without having to design a new heat sink," said Newbold.

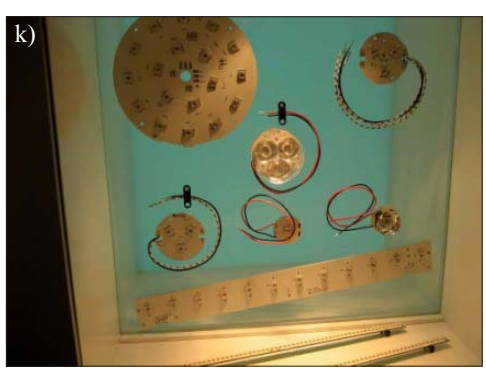
Befitting a high-quality specification-grade product, the downlight is tamper-proof to prevent vandalism. The light engine/reflector assembly installs easily into an internally threaded rod that is factory-installed into the housing.

Newbold and Prescolite are very positive about the future prospects for LED lighting. "As a company, we think LED technology will be extremely substantial, especially when you look at the predicted advancements in lumen-per-watt values for white LEDs," he said. "Energy requirements and environmental restrictions surrounding mercury-containing lamps are becoming more stringent. LEDs appear to be positioning themselves as the key lighting technology to address these issues, not just a trend or niche."

Links

Prescolite: www.prescolite.com
Unique Prescolite LED downlight launches new era for solid-state lighting (press release)
www.ledsmagazine.com/press/13673





(a) Samsung Electronics compared its 40 inch LCD with LED backlights (bottom) to a model with conventional CCFL backlighting. (b) Mobile-phone applications from Everlight. (c) PerkinElmer Elcos exhibited chip-on-board products, including this red anticollision light. (d) Samsung Electro-Mechanics showed its range of power LEDs for lighting. (e) Osram Opto Semiconductors' stand was illuminated with 120 LED spotlights, each containing six Ostar Lighting LEDs. (f) Roal Electronics' area lighting fixture incorporated optics from Fraen. (g) Large numbers of LEDs can be incorporated into gaming machines, as shown on distributor Rutronik's stand. (h) Stanley Electric showed how vehicle instrument displays are made much brighter with its new range of SMD LEDs. (i) VS Optoelectronic has supplied chip-on-board signs for Airbus aircraft. Each "pixel" contains a red and a green chip. (j) CML Innovative Technologies has built LED light-guide products for vehicles and consumer electronics. (k) VS Opto has also developed a series of high-power modules in various formats.

Crowds flock to electronica 2006 trade show to see LEDs in action

Lighting, displays, mobile phones and automotive were among the applications that were targeted by LED makers, driver IC suppliers and other exhibitors at electronica this year.

The electronica trade show, a prominent feature of the electronics industry calendar held every two years in Munich, Germany, took place this year on November 13–16. Seoul Semiconductor launched its new Acriche AC LED (p6). The modules contain two or four LEDs and can be connected directly to an AC LED supply.

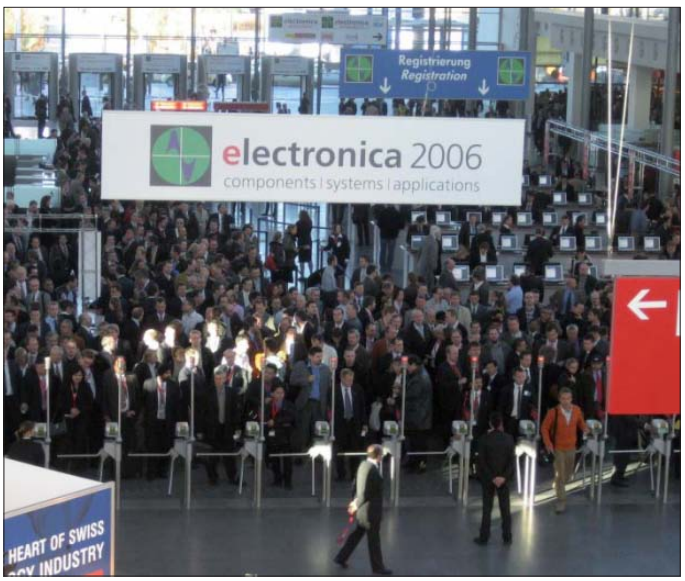
Osram Opto Semiconductors (photo e) divided its stand into different areas, such as business and living, and used daylight and warm-white LED spotlights to create appropriate types of lighting for each. The German company used the event to discuss progress in its LED Light For You network (p28) and also introduced the Ostar Headlamp, a new version of its multichip power LED, which is intended for automotive forward lighting applications (p23).

Lexedis unveiled the nanoXED, which produces 25 lm from a tiny 2.5 × 2.5 × 0.6 mm package at a current of 200 mA. The package is unique in that it is machined from silicon, and Lexedis has made another breakthrough by eliminating chromatic binning via very tight process control (www.ledsmagazine.com/articles/news/3/11/15).

Roal Electronics, a digital power management company based in Italy, showed a number of digital constant-current switch-mode power supplies. It assembles LED boards and drivers, and works with a major architectural and entertainment lighting manufacturer. Roal showed a proof-of-concept demonstration of an LED lighting fixture for area illumination (e.g. streetlighting) containing 35, 1 W LEDs and using electronics from Roal and optics from Fraen (photo f).

Optek Technology announced a series of new LED-related products including a new 1 W package with longer leads that sits flat on the surface of the circuit board, enabling easier assembly (www.ledsmagazine.com/press/14205). The company also says that it has developed an in-house visible LED lab designed to assist customers in developing solutions for applications involving solid-state lighting (www.ledsmagazine.com/press/14206).

Avago Technologies unveiled the automotive industry's smallest 0.5 W LED, available in an adapted PLCC-4 package with additional heat sinking (p23). It also discussed its high-power LED modules, containing 50 RGB chips (10 blue, 20 red, 20 green) mounted onto a metal-core PCB (www.ledsmagazine.com/articles/news/3/9/30). The case can be screwed onto a heat-sink assembly. At 10 cm long, the modules generate up to 480 lm while dissipating 24 W. A 9 W version is planned, and white modules will be released early next year. Avago's Patrick Trueson demonstrated a luminaire mock-up incorporating six modules together with a color-management device that would enable the light output of several such luminaries to be calibrated and controlled.



Ready, steady, go! Crowds wait for the doors to open at electronica.

Bergquist introduced a new thermal material that fills a performance gap for LED applications. It is 3.5 times as good as FR-4, while for still higher performance an insualted metal substrate would be used (www.ledsmagazine.com/articles/news/3/11/26).

VS Optoelectronic displayed a number of chip-on-board products and applications, including a lavatory sign used in Airbus aircraft showing vacant or occupied status. Red and green chips are housed beneath the same droplet of encapsulant (photo i). VS Opto also uses power LEDs to manufacture modules that are sold via Vossloh-Schwabe to luminaire manufacturers (photo k). As well as LEDLine High Power strips with 12 power LEDs, VS Opto introduced a new constant-current source providing up to 1.05 A (www.ledsmagazine.com/press/14250). Last but not least, as the European distributor for Cree, VS Opto showed the new XLamp, which when driven at 350 mA was brighter than the older version driven at 700 mA.

Stanley Electric focused on automotive and handset applications, with ultrathin LEDs for keypads and side-view LEDs for backlighting (0.35 and 0.45 mm high, respectively). As well as showing LED "auxiliary" lights for flash, it had an ultracompact xenon tube measuring about 1.5 × 0.8 × 0.6 cm and driven by a 330 V, 14 µF capacitor. On the automotive side, Stanley used an instrument panel mock-up (photo h) to

demonstrate improvements in high-output LEDs in PLCC-2 packages. The white VEW1147LS, illuminating the numbers in the speed dial, has a luminous intensity of 1500 mcd at 30 mA. The firm also exhibited a lensed chipLED with a wide distribution angle of 160°, designed to provide very uniform backlighting of switches and panels. The red UR1106W produces 100 mcd at 2.2 V and 20 mA.

Future Electronics had an LED experience room to demonstrate the capabilities of Luxeon LEDs from Philips Lumileds. It was also offering a dimming driver based on a new microcontroller from Freescale.

PerkinElmer Optoelectronics showcased a range of chip-on-board LED products for a variety of applications, including medical, machine vision, and illumination and specialty lighting. Among these was an anti-collision light (photo c) designed to replace xenon flash tubes and offering much lower power consumption, higher reliability and resistance to vibration failures.

Sharp demonstrated its capabilities as an LED supplier for the lighting market with prototype arrays of 37 small-area LED chips on a hexagonal PCB. Different phosphor coatings were used to achieve different white color temperatures. The company also showed a 19 inch LCD display with LED backlighting for industrial applications. A spokesperson said that lifetime, ruggedness and color quality were key advantages of using LEDs.

Harvatek's stand included a demonstration of a 32 inch LCD TV backlit using RGB LEDs, 84 of each color, consuming 220 W with a brightness of 400 nit. The company also displayed its HarvaLED package for solid-state lighting. Depending on the chips inside, the same package can handle 1–10 W, allowing customers to use the same design.

Everlight's stand included a range of LEDs for mobile-phone flash applications (photo b), as well as a range of ultrahigh power LEDs for lighting applications, most of which are still in development. One 10 W package contained seven chips and produced 350 lm with a current draw of 2450 mA. A nine-LED chip-on-board array driven at 540 mA produced 180 lm with 5.5 W power consumption.

Samsung Electro-Mechanics showed its Sunnix range of discrete 1 W packages (photo d) providing up to 60 lm (40 lm typical) at 350 mA, with a 115° viewing angle. The company has also built MLCMP 4 × 4 arrays, which when driven at 13.6 V and 1400 mA (19 W) produce 396 lm typical (21 lm/W).

Samsung showed a side-by-side comparison of 40 inch LCD TVs using either CCFL or LED backlights (photo a). The mercury-free LED-based version had a power consumption of 130 W compared with 180 W for the CCFL version. The LED backlight also enabled a much higher color gamut of 105% of NTSC, a much more rapid response time of 6 ms versus 16.7 ms, and a contrast ratio of 10,000:1 versus 1000:1. This latter feature is a result of local dimming of the backlight in areas of the screen where the image is less bright.

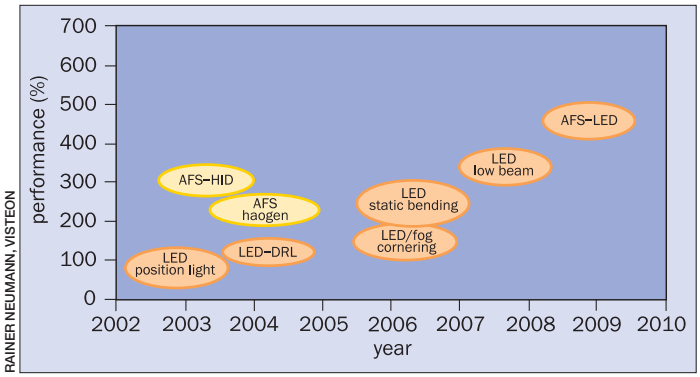
LEDs MAGAZINE

Car makers find new ways to create intelligent automotive LED lighting

European regulations, heat exchangers in LED headlight systems, ambient lighting with LED light-guides and adaptive rear lighting were among the subjects discussed at a recent automotive lighting conference, reports **Tim Whitaker**.

AUDI

Fig. 1. Audi is vying with Lexus to bring the first car with LED headlights (www.ledsmagazine.com/articles/news/3/10/23). The headlights for the Audi R8, featuring a distinctive curved line of LEDs for the DRL, were supplied by Germany's Automotive Lighting. The company says that this new LED headlamp incorporates more than 20 innovations in areas such as thermal management and control electronics, and that it has received special permission from the European Commission for the series application of LED headlamps in road traffic.



RAINER NEUMANN, VISTEON

Fig. 2. Roadmap for introducing new LED lighting functions.

For car owners, lighting is not a priority, so how can we bring this to the fore? This was a question raised at the Intelligent Automotive Lighting conference, held on September 27–28, 2006, in Frankfurt, Germany. One answer is to emphasize the beneficial safety aspects of high-quality lighting. Also, it is possible to add further control at relatively little cost by developing intelligent electronics.

European regulations

LEDs are not yet an approved light source for headlights in European directives governing the automotive industry. However, LED headlights could appear as early as 2007 if car manufacturers apply for an exemption to the regulations, said Wolfgang Schneider, DG Enterprise and Industry F/1, European Commission (EC). "Manufacturers can request an exemption if they have a technology that is good enough but not yet accepted in the regulations, and that provides at least an equivalent level of safety," he said. "At least one manufacturer has applied for approval, and this could be granted by early 2007."

Schneider did not name the car maker in question but it is likely to be Audi, which recently said that its new R8 would offer LED lighting as an option from late 2007 (figure 1). Lexus plans to introduce LED headlights on a new vehicle in the US next year, where LED headlight usage is not prevented by regulations. In Europe, explained Schneider, new types of lamp require specific approval in headlighting applications. According to the European Directives and the applicable UN/ECE regulations, the rules for headlamps and daytime running lights (DRLs) are different and vehicles using LEDs for DRLs are already on the road. The procedure in Europe is that the member states working in the Economic Commission of Europe (ECE) develop technical requirements for the UN/ECE regulations that are later transferred for use in EuU directives. However, this takes time, said Schneider: "In the lighting field, technology development is very fast and it is difficult to keep pace within the regulatory framework."

Excluding the exemptions mentioned above, the normal procedure should see a legal framework in force for LED headlights by spring 2008, although this still represents the most optimistic timeframe.

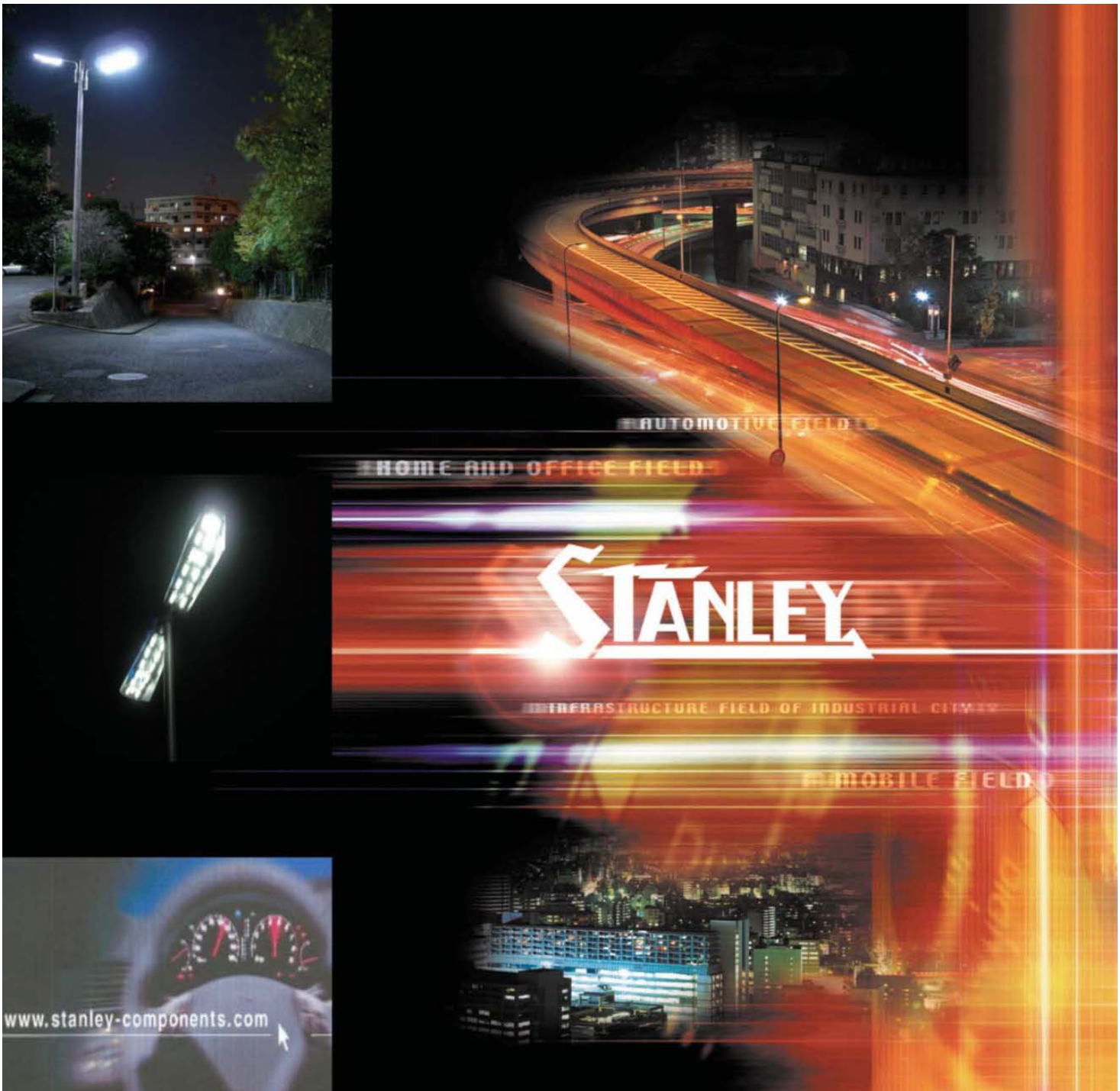
Among the issues being discussed by the group run by Schneider is how the LED light source can be replaced in case of failure. There may be a requirement to shut down the entire headlight if one LED fails, which would ensure that the car is not driven with a light that doesn't provide sufficient output. Other solutions are that the car maker would provide a warranty to replace the full LED light if it fails, or that there are LED modules that could be replaced individually.

Front lighting

Rainer Neumann of Visteon Corporation, a tier-one lighting supplier (also know as a set maker), said that car makers, set makers and LED makers are all convinced that LEDs are the way forward for front lighting. "But we are not there yet," he said.

A key advantage of LED technology is styling flexibility, which enables brand differentiation and the creation of signature lighting. Lifetime is also a big advantage if the thermal-management issues are handled correctly.

Figure 2 shows a roadmap for LED headlamp introduction, together



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Berkshire RG12 1BW, UK.
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Fax +44 (0) 1344 393 153

France

33, rue des Peupliers,
92000 Nanterre, France.
Tel +33 (0) 1 47 81 85 85
Fax +33 (0) 1 47 86 09 16

Germany

Am Berg 7,
64546 Morfelden-Walldorf,
Germany
Tel +49 (0) 6105-9305-3
Fax +49 (0) 6105-9305-55

Table 1. Comparison of light sources for forward lighting

Light source	type	luminous intensity (lm)	efficacy (lm/W)	luminance (Mcd/m²)	lens area* (cm²)
Gas discharge	35 W Osram D2S	3400	97	200	2.2
Halogen	55 W H7	1500	27	20	22.0
LED	1 W Osram Dragon	40	40	2	220.0

*The lens/optic area is necessary to generate 70 lux at a distance of 25 m

STEFFAN STRAUSS, L-LAB

with the performance of the best available lights available today, namely the bi-xenon low beam/high beam combination. "With reasonable costs it is not possible for LEDs to compete with these lights today," said Neumann, who argued that the companies rushing to be the first to introduce LED headlights will inevitably have to accept a lower light performance.

Neumann expects to see the first LED headlamps with both low and high beam functionality in 2007, as well as lights with other functionality, such as fog lamps, static bending lights and cornering lights. "However, it is likely to be 2010 before we see the first LED headlamp in Europe with equivalent costs to HID/xenon headlamp systems, and 2015 before LED headlamps achieve a reasonable market share – around 5% – in the market."

Steffen Strauss of L-Lab also spoke about front lighting, saying that,while LEDs can be used as the only light source (as exemplified by the Audi R8), this involves a lot of complicated optics, thermal management and mounting tolerances. "Using HID for lighting and LED for styling is a good compromise," he said.

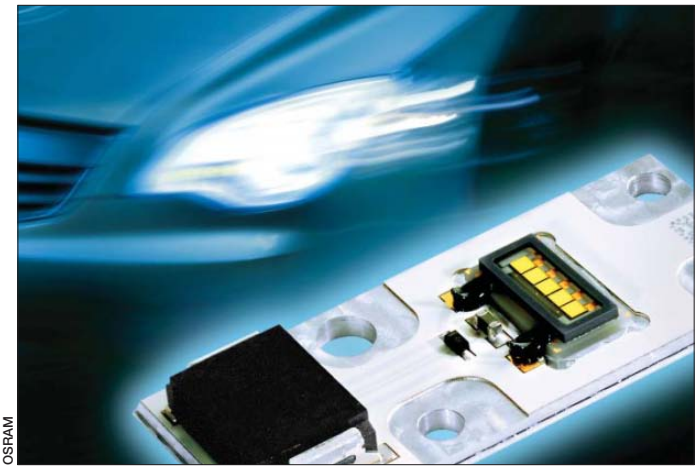
One interesting use of LEDs could be a sensor-based system that detects objects of interest to the driver that are outside the light distribution of the normal headlamps. The sensor would then activate one or more LEDs in a linear fixture to illuminate the object.

Strauss compared different lighting technologies (table 1), while stressing that the key parameter is illuminance on the street. High-beam illumination requires a wide beam pattern and a hot spot at infinity of about 60–90 lux. Many LEDs are currently required to achieve adequate lighting levels. For multiple LEDs with individual optics, it is difficult to adjust the light pattern to achieve the hot-spot requirements. Placing all of the LEDs onto one board reduces the tolerance but means that all of the heat is one place. An intermediate solution consisting of several emitters, each with several chips, is probably the best way round this.

Optics, thermal issues and styling

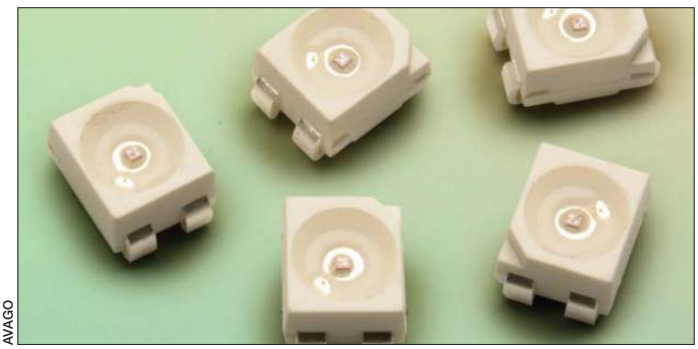
Robert Apfelback of Schefenacker Vision Systems said that LEDs are attractive for headlamp applications due to a high market demand for new lighting features in luxury, sports and crossover segments. Xenon, today's premium technology, is standard in upper segments, and differentiation is not possible without introducing new technology. "Also, the cost and performance of white LEDs is approaching an affordable level," he said. Although Schefenacker does not manufacture headlamps, Apfelback said that LED headlamps have much more in common with LED taillights than with today's headlamps.

Apfelback showed a number of optical solutions, using either single-chip packaged LEDs (Luxeon K2) or multichip packages (Osram Ostar), using Schefenacker's symbiotic optics approach (www.ledsmagazine.com/articles/features/3/7/5). Low-beam lighting can be achieved using 6 Ostar 2 × 2 LEDs, producing 2400 lm from a module measuring 6 × 14 cm. The efficiency is 60% and the hot spot is 67 lux. High beam is created by adding another 4 Ostar LEDs, with individual lenses. The efficiency is 70% and the hot-spot is 130 lux.



OSRAM

Fig. 3. At electronica, Osram Opto Semiconductors unveiled the Ostar Headlamp, a five-chip LED package providing 250 lm at 700 mA. The initial product without a lens is sampling now and is intended for reflector-based systems using customer-specific optics. The Ostar Headlamp Hot Spot, available early next year, has a lens and delivers as much as 350 lm, with uniform illumination of the target area (www.ledsmagazine.com/press/14203).



AVAGO

Fig. 4. Avago introduced the industry's smallest 0.5 W LEDs at electronica. The new Envisium LEDs produce 6.6 lm and 9.3 lm in red-orange and amber, respectively, with a current of 150 mA. The package, a direct replacement for industry standard PLCC-4 packages, has two dummy leads to assist with heat extraction and measures 3.2 × 2.8 × 1.9 mm. The junction-pin thermal resistance is 60 °C/W, compared with 100 °C/W for the PLCC-4 package.

Customer perception is, of course, important for headlamps, and LEDs can convey an image of advanced technology and performance. However, xenon and halogen have a certain recognized aesthetic

MARKUS DAUBNER, CML INNOVATIVE TECHNOLOGIES

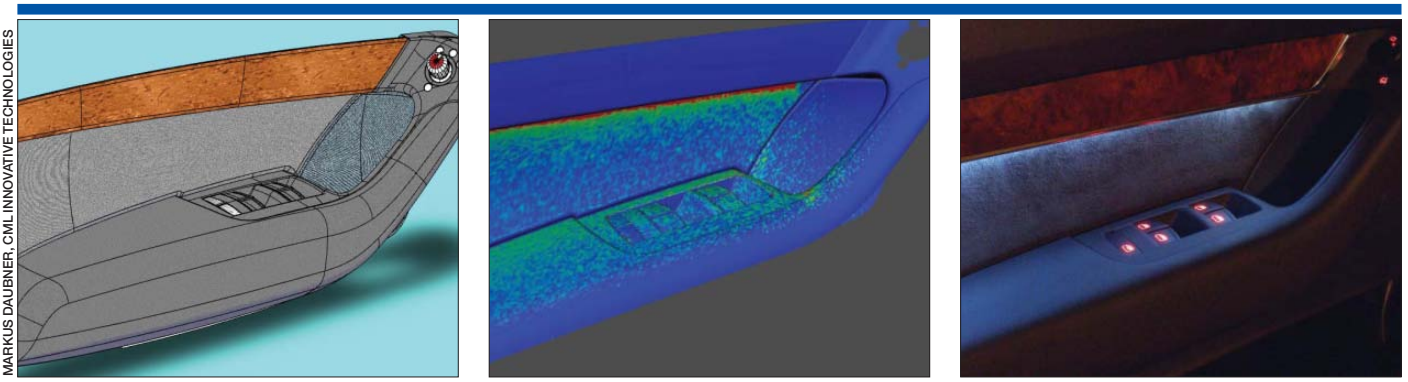


Fig. 5. A door panel for the Audi A6 was designed using CAD software (left), modelled using optical software (centre) and then built using an LED light-guide under the wood panel.

ROBERT APFELBACK, SCHEFENACKER

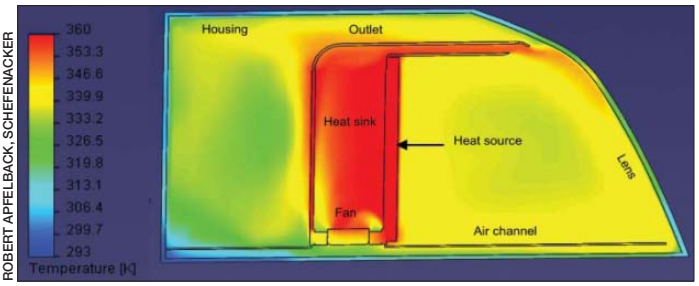


Fig. 6. Schefenacker's LED headlamp uses a fan to circulate air across the heat sink behind the LEDs (labeled heat source). The hot air is cooled when it passes across the inside of the lens, and then returns to the fan via the air channel.

appeal, and the unfamiliar geometries of LED solutions may introduce negative associations, such as insect eyes. Apfelback emphasized that styling and geometric concepts are driven by a combination of the OEM's marketing strategy (or the "brand face"), the consumer's habits and demands, and technology and legislation.

Thermal management is recognized as a key issue, and passive systems result in severe problems, so the Schefenacker solution uses a fan in a reverse heat exchanger (figure 6). This blows air across the heat source, in this case the rear of the LED board. The air is then circulated across the inside of the front lens, where it is cooled. This process also serves to reduce condensation on the interior of the lens and reduce exterior icing. In conventional headlamps, these functions are achieved by the heating effect of IR radiation emitted by the light source.

In summary, said Apfelback, LED performance is on the way to enabling a light distribution at the HID level with a practicable package. "The technology is ready to be implemented in customers' applications," he said.

Ambient lighting

According to Markus Daubner of CML Innovative Technologies, ambient lighting achieves several effects in vehicle interiors, such as creating moods and emotions, softening the contrast between task light areas and removing zones of complete darkness. The usual requirements for ambient lighting are that the light source is not visible; that it doesn't distract the driver; that it matches color cues from the dashboard and indicators; and that it supports the color and structure of the interior materials.

Daubner explained that CML's ambient lighting products use light guides to direct light to the appropriate site using the principle of total internal reflection. Notches, roughened areas or white coatings are added to the light-guide structure to extract light at the appropriate point. Simulation and modelling is a vital part of the procedure for developing light-guide systems, as demonstrated by figure 5.

Electronics are likely to play a key role in future lighting systems, with the use of a light sensor to adjust the level of ambient lighting according to, say, the driving environment in a city, in the countryside or on a motorway. Capacitive sensors can be used in a map pocket, for example, to sense an approaching hand and to switch on the light.

Comparing technologies, Daubner said that LEDs with molded light guides offer a range of colors, long lifetime, easy electronic control and good value for money, despite the need to invest in a molding tool. In contrast, electroluminescent material provides a low-profile, uniform lighting surface but is expensive, has a shorter lifetime, requires an inverter (which raises EMC concerns) and lacks a deep-red color. Finally, OLED technology also provides low-profile, even illumination but is a new and expensive technology with limited life.

Adaptive rear lighting

Filip Rosenstein of the Advanced Engineering Department of Schefenacker Vision Systems described the development of adaptive tail-lights optimized for different driving conditions. The major purpose of such lights would be the avoidance of rear collisions, which account for 25% of accidents.

There are many factors affecting observer perception of an exterior vehicle light source: dirt or water on the outer lens; weather conditions, such as dust, rain, spray, snow and fog; and environmental contrast, such as time of day, sunshine, and entering and leaving tunnels. Adaptive rear-lighting systems would allow the light output to be increased in poor weather or reduced in clear, dry conditions.

Rosenstein's approach was to use two combined data sensors: a lidar (laser direction and rangefinding) sensor and a dirt sensor to detect loss of transmission through the outer lens. This system uses LED light that is directed across the face of the lighting unit and then detected. The optimum approach for the LED light source for the tail-light was to use a chip-on-board array. This system makes better thermal management possible.

Legislation to allow adaptive tail-lights is still going through the system, but Rosenstein expects to see systems on the market by autumn 2007. The regulations are expected to permit significantly increased maximum light levels for adaptive systems, such as up to 730 cd for stop lamps versus 260 cd in conventional, non-adaptive systems.

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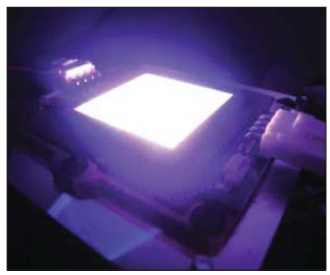
LEDs MAGAZINE

Solid-state lighting and LED news from the Photonics Cluster (UK)

Photonics Cluster (UK) members are becoming increasingly active in areas relating to LEDs, and the organization is gearing up for next year's euroLED conference.

News from PC(UK) members

PC(UK) members are encouraged to send news, case-studies and new product releases to the PC(UK) team at info@photonicscluster-uk.org.



Enfis has launched a range of high-performance LED light engines and arrays, available on two platforms. Shaun Oxenham, CEO of Enfis, said: "We realized this year that what we are great at is building integrated high-performance light engines that have very tightly controlled monitoring and performance feedback." The QUATTRO is a 16 cm^2 array containing up to 1600 RGBA high-power LED chips and IT is driven by Enfis' proprietary drive circuitry. The light engine is rated at 200 W and emits 3500 lm. The QUATTRO intelligently measures light output as well as the thermal load of the array, and it guarantees optimum performance and colour temperature. The UNO measures less than 1 cm^2 and is brighter than competitors' products that have four times the footprint. It is available at 18–36 W from UV-A to IR and white, and it comes in a plug-and-play light engine format with integrated drive electronics and thermal-management system in a compact and easy-to-integrate unit. "These products have been four years in the making," added Oxenham, "and we at Enfis are delighted to see them going to market now, as there's clearly demand for reliable, plug-and-play light engines that can deliver solid-state light."

- More details: www.ledsmagazine.com/press/14182.

MARL International, **Future Electronics**, **Enfis** and **Supertex** were among the many Cluster members exhibiting at the electronica trade- show (p18).

Dialight Lumdrives has launched its new LINKLED IP range, offering the ability to control a line of LEDs extending over a considerable distance, and bringing new benefits, including IP67 rating and multichip technology that enables color mixing at source. It is now ideally suited to cove lighting, and interior and exterior feature lighting.

- More details: www.ledsmagazine.com/press/14263.

Pacer is now offering warm-white and daylight-white LEDs from Optek's new range of high-luminance Lednium 1 W products. The new white cup devices meet RoHS and Pb-free reflow soldering requirements at 260 ºC.

- More details: http://ledsmagazine.com/press/14079.

Polymer Optics has developed a narrow-angle color-mixing optic and is working with fellow member **Universal Science**, which is developing MCPCBs and a range of heat sinks to suit the product. Polymer Optic's Mike Hanney says that the novelty of this product is that the color-mixed beam has a narrow 6° half angle and the light is well mixed, even over short distances. "This previously has been difficult to achieve," he said. "Colour mixing was typically achieved by spreading the light into a wide angle to improve the mixing." The narrow-angle LED color mixer assembly is precision molded in optical grade polycarbonate for thermal stability and system durability. POL's novel hexagonal design allows the optics to be clustered together to make larger narrow-angle color-mixing arrays.

- More details: www.polymer-optics.co.uk.

Lasermet has acheived accreditation for LED and laser testing at its test facility in Bournemouth from the UK Accreditation Service (UKAS). This is the culmination of a very rigorous process of examination and evaluation, which has lasted more than two years and covers testing to the following standards: EN/IEC 60825-1, EN/IEC 60825-12 and EN/IEC 60601-2-22. UKAS accreditation is not a legal requirement, but most test houses and large companies will much prefer to use a UKAS-accredited test facility, because the UKAS approval guarantees a high level of expertise, traceability and rigorous practice. Lasermet is the only testing laboratory other than NPL to achieve UKAS accreditation for LED and laser testing.

- More details: www.ledsmagazine.com/press/14129.

Forge Europa has developed a number of standard assemblies known as aLEDs using high-power LEDs. These comprise a high-power LED mounted onto a thermally optimized substrate complete with a connector or solder pads. This takes away the headache of thermal design from the luminaire manufacturer and gives them an easy-to--use subassembly. When multiple units are combined into one fitting, Forge Europa can measure the junction temperature of the LEDs to verify that the design is working within its recommended parameters. A range of standard optics are offered.

- More details: www.ledsmagazine.com/press/14262.

LED Light For You network gathers know-how for general illumination

An Internet-based partnering network set up by the lighting manufacturer OSRAM aims to build partnerships and support the penetration of LEDs into the lighting market.

LEDs are now powerful enough to be used in many general lighting applications, but many companies will require additional skills in order to target this market successfully. OSRAM has now set up an Internet-based platform at www.ledlightforyou.com where all kinds of specialists, from electricians to architects, and luminaire manufacturers to suppliers of tailor-made lighting systems, can find extensive know-how and skilled partners for producing LED solutions. By the time of electronica, held on November 14–17 in Munich, 25 certified partners had already signed up to the worldwide network.

Network aids lighting market

The versatility and small size of LEDs make them ideal for a range of lighting tasks in general illumination. They can be used for all kinds of lighting – for direct, indirect and backlighting, in traditional luminaires and in illuminated signage. Many users, however, still have little experience of using LEDs for these applications. This is why OSRAM presented the Internet platform LED Light For You (LLFY) as an international skills network at Light + Building 2006 in Frankfurt. In addition to complete solutions and LED systems, this offers potential users high-quality assistance in the areas that are essential to LED lighting solutions: optics, thermal management and electronics.

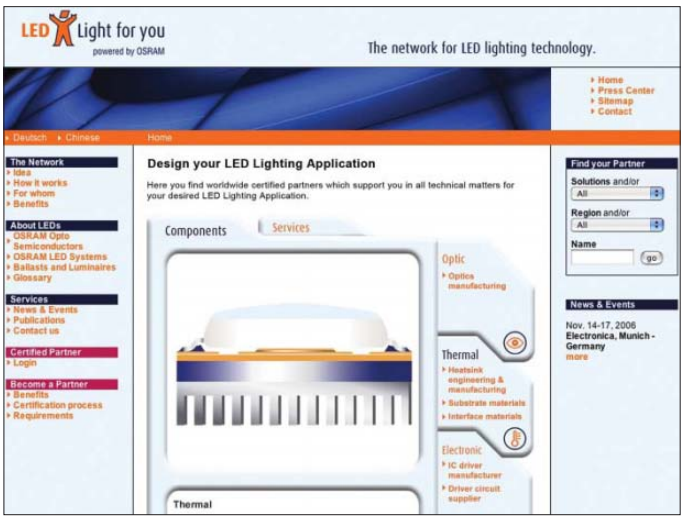
The LLFY network also provides an opportunity to find experienced partners who can support projects by providing first-class help and advice. With more than 25 certified and trained partners, LLFY already offers a balanced portfolio of companies, from highly specialized but comparatively small regional firms to international enterprises in the focus regions of Europe, Asia and the countries in the North American Free Trade Agreement (NAFTA).

Networked knowledge

As a worldwide network the platform has been presented at major lighting fairs in Europe, Asia and the US. In only a few months, 25 companies worldwide with different core competencies in optics, thermal management and electronics had been signed up as partners.

The most important criteria for selecting partners are specialist engineering knowledge, comprehensive service, advanced production facilities and solution-oriented consultation skills. Each company adds its own performance profile to the network. The aim in the medium term is to use LLFY to link about 100 partner companies in the principal regions of the world so that users are offered the best possible support in terms of product components and advice. This will lead to shorter innovation cycles, lower costs and higher product quality.

Before they can be accepted into the network, potential partners have to undergo a multistage certification process. The competence and reliability of the partners are essential requirements for co-operation based on trust and for the successful completion of projects. Only after the potential partner has been visited by OSRAM and has successfully completed the certification process is it accepted into the network and its specific skills presented on the Internet platform.



LED Light for you partners can be found through the network's website (www.ledlightfor you.com) and provide support in finding optical, thermal and electronic solutions for LED products.

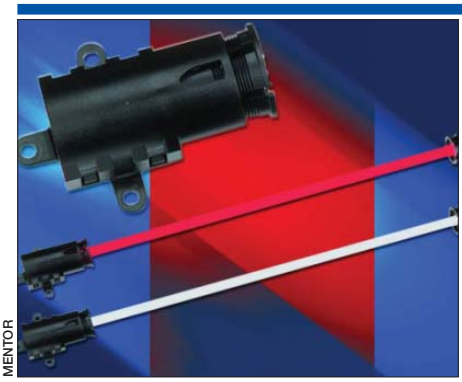
Working together for greater growth

Apart from having their skills advertised, partners benefit from the exchange of information on the network. At the same time they promote individual lighting projects by users who have had little experience of LEDs, thereby helping to establish these light sources in general lighting applications.

This market promises to be highly lucrative over the next few years. The Strategies Unlimited report on high-brightness LEDs, published in June 2006, assumes average growth of 30% in the coming years. This means that sales of LEDs for general lighting applications will increase from about $320 million to about $900 million by 2010. The LED lighting market will therefore be one of the two strongest growth segments in the entire LED industry.

To exploit the enormous potential of this market and create a broad know-how base, the activities of LLFY are not restricted to the Internet. As soon as partners enter the network, OSRAM works very closely with them. This co-operation is strengthened by meetings known as partner events. Each year these provide an excellent opportunity for employees of the participating companies in Europe, Asia and NAFTA to make long-lasting personal contacts. Workshops on optical, thermal and electronic solutions are arranged in each region. Joint advertising campaigns with the partners then round off the network package.

LEDs are characterized by long life, minimal maintenance costs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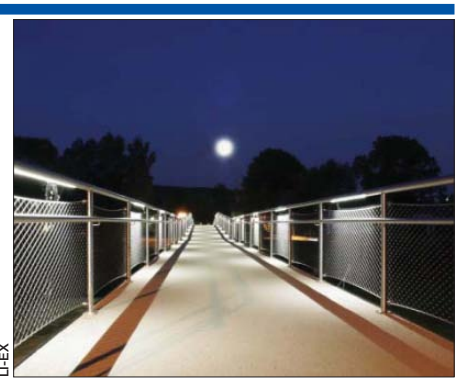
LI-EX

Left: the M-Tube from LLFY member Mentor consists of a light guide bar clamped to an LED housing. Two housings, each containing one SMD LED, are required for a light guide of up to 2 m in length, while a single light source is required for lengths of up to 1 m. The design of the LED housing allows adhesive bonding as well as screwed connection of the M-Tube, thus providing a high degree of freedom of mounting. Centre: Osram's electronica stand was lit with LEDs. Right: LEDs illuminate the handrail of the Kassel Bridge.

and low power consumption. Thin-film technology enables OSRAM Opto Semiconductors to produce LEDs with a luminous efficacy that makes them ideal for general illumination. This process involves the substrate being used exclusively for crystal growth and then removed, so the thin light-generating layer is so close to the surface that almost all of the light is emitted at the top.

The luminous efficacy of these LEDs is 32–40 lm/W, depending on the white tone. For an operating current of 500 mA, the Golden Dragon achieves a typical luminous flux of 64 lm in cold white, 58 lm in neutral white and 47 lm in warm white, in each case without a lens. The high-power Ostar Lighting LEDs, which consist of six chips, achieve a typical output of 300 lm from an operating current of 700 mA without a lens and as much as 420 lm with a lens.

Under laboratory conditions both LED types have achieved a luminous efficacy of up to 75 lm/W in cold white. Continuing R&D progress will allow for further increases during the next months.

Versatility

Thanks to their improved brightness, LEDs can now be used for general lighting applications. They can produce interesting effects. For example, they can be integrated into three-dimensional illuminated tiles. Their small size opens up a wide range of options for spotlighting items of furniture and objets d'art. Sensitive items are protected, thanks to low thermal output. Different white tones can be combined so that the lighting for bars, restaurants, exhibition rooms and museums can be adapted to suit different moods. In other words, the colour temperature of the lighting can be changed in line with the natural rhythm of daylight. Sophisticated control systems can present the exhibits in cool white light or they can change the entire exhibition into a riot of brilliant colours by switching in coloured LEDs.

For both indoor and outdoor lighting, LEDs, LED systems and LED luminaires are so compact that lighting designers have enormous freedom to put their ideas into practice. What's more, existing buildings can easily be upgraded with these innovative lighting concepts.

Links

LED Light For You
www.ledlightforyou.com
OSRAM Opto Semiconductors
www.osram-os.com
On our website:
OSRAM Opto Semiconductors company profile
www.ledsmagazine.com/articles/features/3/7/1
Osram launches *LED Light For You* website (April 2006)
www.ledsmagazine.com/articles/features/3/4/8
OSRAM Opto Semiconductors opens Light Shop on the Internet (Nov 2006)
www.ledsmagazine.com/press/14201

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PATENTS

Super Vision capitulates in Color Kinetics patent battle

The long-running patent litigation battle between Color Kinetics and Super Vision is finally over, and predictably Color Kinetics has come out on top. In order to be allowed to keep selling its LED-based products in the US, Super Vision has agreed to pay a royalty fee to license Color Kinetics' substantial LED patent portfolio. Color Kinetics was naturally very pleased with the settlement, saying that it "sends a strong message to the industry".

The dispute, which dates back several years, has been written about in great detail by *LEDs Magazine* (see www.ledsmagazine.com/articles/features/1/12/10). At the instigation of its then CEO, Brett Kingstone, Super Vision challenged Color Kinetics and its intellectual property portfolio on behalf of a group of other LED lighting manufacturers that became known as the LED Alliance. The dispute centered on the validity of Color Kinetics' core patents concerning methods to control intelligent LED-based lighting fixtures. As well as complaining about unfair business practices on the part of its rival, Super Vision claimed that certain of Color Kinetics' core patent claims are based on prior art.

While this is a view that is – rightly or wrongly – still widely held in the LED community, Super Vision was wholly unable to make any progress against Color Kinetics and has now accepted the inevitable. As well as taking a royalty-bearing license to Color Kinetics' worldwide patent portfolio, Super Vision will pay a set fee of $825 000 as settlement for all past claims that Color Kinetics has made against Super Vision.

Super Vision has also agreed to drop its pending claim of infringement against Color Kinetics with respect to US patent 4,962,687, and will instead grant Color Kinetics a royalty-free license. This patent was acquired by Super Vision in its attempts to demonstrate a body of relevant prior art that pre-dated Color Kinetics' earliest patent filings.

Super Vision has also waived its rights to appeal the final judgment granted to Color Kinetics by the US District Court of Massachusetts on November 8, 2006, which permanently prohibited Super Vision from manufacturing or selling in the US any of the Super Vision products that were held to infringe Color Kinetics' patents. Clearly, this was the final straw for the Super Vision management, who accepted the settlement and licensing agreement in order to be allowed to continue the sale of all prohibited products. Mike Bauer, president and CEO of Super Vision, said that it was "time to put the past behind us and get refocused on the business of lighting".

Bill Sims, president and CEO of Color Kinetics , said that his company "chooses not to exclude players from the field, but rather enable the market through an active licensing program". He continued: "The resolution of this case, combined with an ever-growing number of patents and broad list of prospective licensees, will allow us to aggressively pursue new agreements in diverse markets – ultimately helping to advance the adoption of LED illumination worldwide."