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LEDs MAGAZINE

Technology and applications of light emitting diodes

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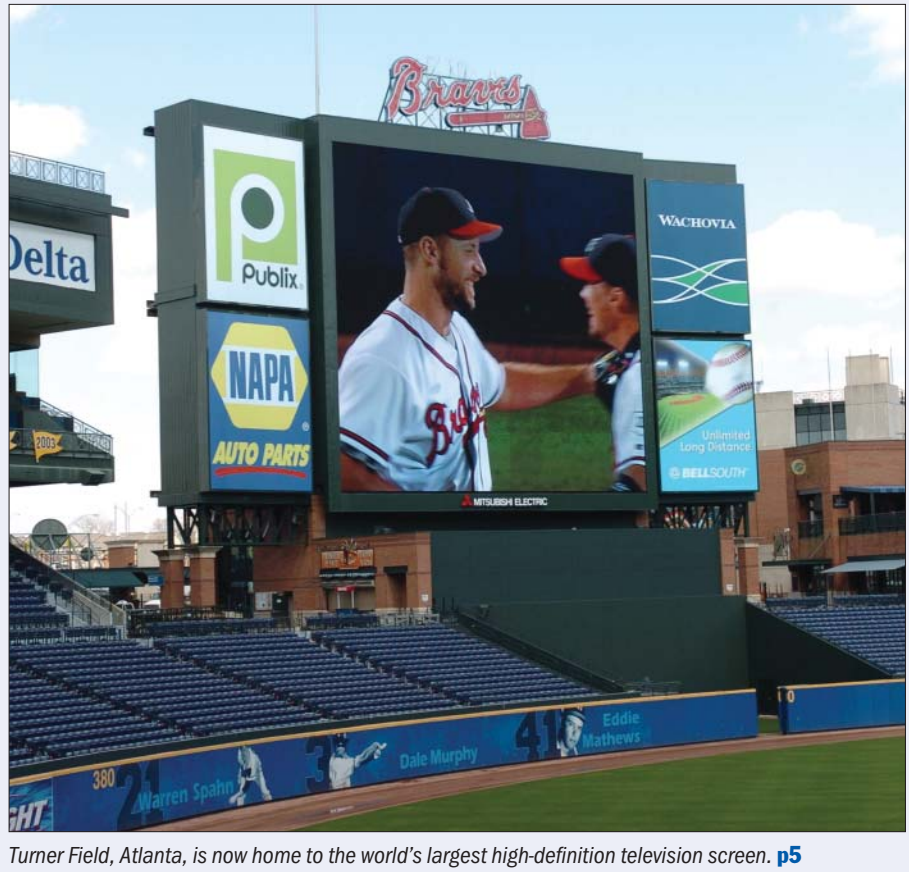

Turner Field, Atlanta, is now home to the world's largest high-definition television screen. **p5**

Many factors have to be taken into consideration when designing LED flash units for camera phones. **p19**

The Chinese government is funding developments in solid-state lighting. **p16**

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LEDs MAGAZINE

Patent protagonists head to court

By Tim Whitaker, Editor, *LEDs Magazine*

The Michael Jackson media circus might be the highest-profile trial this year in the US, but not as far as the LED lighting community is concerned. All eyes are on Boston, where the patent dispute between two rival LED manufacturers, Color Kinetics (CK) and Super Vision (SV), is due to be heard in May. The dispute casts a long shadow over many other companies involved in selling LED lighting equipment. Some fear the prospect of having to pay large royalty fees to CK, or quitting the LED business altogether (at least in the US). And then there's the credibility of the US Patent and Trademark Office (USPTO).

If you're not up to speed with what's happening you have a lot of background reading to do (see Timeline, right; and Links, p4). At the heart of the case is CK's patent portfolio: 38 patents granted to date and more than 130 applications pending. CK has licensed its patents to a number of companies, and has also used the patents as the basis for cease and desist orders to prevent its competitors from selling infringing products. While CK might be guilty of sharp business practices, the concept of deriving revenues from patent licensing is, of course, widespread and entirely legitimate.

Color Kinetics under fire

But what if your patents are not all they seem to be? The core issue is that many believe CK's patents to be largely without merit, saying they contain claims which are obvious or do not have an inventive step. The patents are based only on prior art, say critics; that is, they use technology that was available in the public domain at the time of filing. Not only that, but some of the claims in the patents are extremely broad; for example, apparently covering any LED system that is controlled using pulse-width modulation (PWM).

Recent affidavits from industry experts, filed by SV as part of the infringement case, go even further. They point the finger directly at CK founder George Mueller, the company's president and CEO, saying (to paraphrase) that Mueller, having been advised how to build LED-based color-changing systems by others, promptly used this technology as the basis for CK's first patents. These "others" in question had not filed patents because they believed that all of the technology involved was in the public domain.

One of the affidavits, signed by lighting engineer Tam Bailey, is specific on the issue of prior art: "Based on my skill in the art at the time, in 1996 and 1997, I know that the use of PWM to control color-changing in LEDs was common knowledge among those in the industry, that addressable and controllable fixtures were easily designed by one skilled in the art, and that networking of the LED lighting fixtures was a known method of using any number of LED light fixtures to accomplish a given result in concerts, stage productions, and any other suitable lighting application." The other affidavits contain similar statements and also include additional documentation that is said to constitute prior art.

Prior art is pretty straightforward: if any documented prior art (such as published patent applications, technical papers or public conversations) is discovered that matches and predates a patent claim, then the application is toast. Johan van der Linden, a patent examiner at the European Patent Office (EPO), explains the procedure: "For the inventive step analysis, we compare the patent application with the closest prior art. The difference between the two describes the technical problem to be overcome, and the patent should describe a solution to that problem. For a patent to be granted, the solution has to have a clear inventive step."

Judging an 'inventive step'

Van der Linden says that the EPO judges an inventive step from the point of view of a person "skilled in the art", that is someone with an encyclopedic knowledge of all relevant technology but no capability to make an invention. If it's obvious to this person that combining technologies without adding anything new will result in the same solution offered by a patent claim, then the claim is no good. The criterion for linking existing technologies via the technical problem of the application makes this assessment somewhat less subjective. In other words, something should prompt the skilled person to seek this particular combination. It's also highly relevant to point out that many inventions, or inventive combinations of technologies, can seem obvious in hindsight.

Many industry participants are extremely angry that CK has, in their

Timeline

1979	Jerry Laidman builds Saturn lighting systems using red, green and amber LEDs.
Sep 1988	Richard Belliveau *et al.* file "Variable color lighting system" patent, issued as 4 962 687 in Oct 1990.
Mar 1997	Tam Bailey files "Multicolored focusable LED stage light", issued as US 5 752 766 in May 1998.
Aug 1997	Color Kinetics (CK) files its first patent, "Multicolored LED lighting method and apparatus," issued as US 6 016 038 in Jan 2000.
Mar 2002	Super Vision (SV) files lawsuit seeking to have certain CK patents ruled invalid.
Jun 2002	CK files lawsuit claiming infringement by SV of certain CK patents.
Mar 2004	SV acquires "687" patent from High End Systems.
Mar 2004	SV files infringement lawsuit against CK over "687" patent.
Oct 2004	LED Alliance formed by SV and other industry members.
Nov 2004	LED Alliance gathers evidence of prior art relevant to the lawsuits.
Feb 2005	SV files motion for summary judgment, attaching numerous affidavits.
May 2005	expected date of trial in the CK v SV infringement case.

"If any documented prior art is discovered that matches and predates a patent claim, then the application is toast."

opinion, combined prior art with very broad claims to build a patent portfolio that it can use to gain dominance over others in the industry. This threatens individual companies and the growth of the industry in general. From an ethical standpoint, it's fundamentally wrong that any company should gain patent protection for something which isn't an invention, or which it did not invent. This is not how the system should work, but in some cases it does.

Despite all of the negative comments made against the company, CK's patents are valid until a jury decides otherwise. If CK's opponents are right, how did this situation arise? Did CK manage to pull the wool over the patent examiner's eyes? Or has CK, quite legitimately, made the system work in its favor? Relevant prior art is meant to be uncovered and understood by the examining patent office, so was/is the USPTO overworked, or too inexperienced? And what will happen within the USPTO if the jury says that CK's patents shouldn't have been allowed – will the floodgates open as everyone tries to get their rival's patents overturned?

Obtaining broad protection

At this point, it should be stated that there's nothing to prevent someone filing for broad protection. A patent attorney friend of mine explained that it's common practice to "chance your arm" with the independent claims, by making them as broad as possible. As Johan van der Linden says: "It's rare to see true innovation. Most patent applications involve incremental steps, so by definition their patentable claims are narrow." Of course, any claims that match the prior art should be thrown out at the examination stage. In Europe, third parties can use the centralized system to file observations when the patent is still at the application stage, and can also file an opposition to the patent up to nine months after it has been granted. After that, it becomes a matter for the courts in each individual country.

"It's rare to see true innovation. Most patent applications involve incremental steps, so by definition their patentable claims are narrow."

As we all know, it's not just CK that has (apparently) made the system work for it. An anonymous person wrote to *LEDs Magazine* to say: "Truck-Lite has patented such things as a License Lamp with LEDs (US patent 5 934 798), and is currently in a court battle with a company called Maxxima. They claim Maxxima infringes on their patent because their lamps have such things as a lens, housing, and an attachment member. I am amazed at what kinds of things currently make it through the US patent office."

In open letters to the USPTO, Wayne Howell of Artistic Licence, a prominent LED Alliance member, has rubbished the independent claims of certain CK patents. For example, of patent 6 869 204 Howell writes that "claim 1 simply describes a colour-changing light designed to be immersed in a liquid, effectively a simple underwater light. This is in no way novel, and was commercially available prior to the priority date."

The LED Alliance is going further in its attempts to put pressure on the USPTO, encouraging anyone who feels strongly about this issue to sign and send a petition, which can be found on the LED Alliance website. The petition concludes: "Due to the willful and repeated attempts to monopolize our industry and its prior art we hereby request the USPTO to review all patents issued to Color Kinetics as well as all pending applications."

It should not be denied that CK has furthered the development of the solid-state lighting industry, as CK executives have persuasively argued in several articles on the *LEDs Magazine* website (see Links, below) and elsewhere. However, no matter how much money a company invests, and how clever its lawyers are, it does not deserve to profit from technology which it should not own, or to monopolize a segment of the industry. For now, CK owns the patents and is in the driving seat. Whether it remains there is for the jury to decide. ●

● We welcome your comments on this article or any other items in *LEDs Magazine*. Please send an e-mail to editor@leds.iop.org.

Links

LED Alliance: www.svision.com/ledalliance
Color Kinetics patents: www.colorkinetics.com/corp/ipinfo/patents

On our website
A series of articles relating to CK, SV and the LED Alliance can be found at: www.ledsmagazine.com/articles/features/1/12/10/1.

PARTNERSHIPS

Tridonic and Toyoda Gosei join forces to promote white LEDs

Executives attend the signing of the joint venture agreement.

TridonicAtco GmbH & Co KG, the lighting components and control gear division of the Zumtobel Group, has signed a joint venture agreement with Japanese LED manufacturer Toyoda Gosei to advance the development of high-power white LEDs.

The 50:50 joint venture has been established with a fund of €2.6 m ($3.5 m), and further capital investments will be made in the future. The joint-venture company will be based at Jennersdorf in Austria and will commence business in May 2005, with production expected to start by the end of the year.

The venture will sell high-power LED packages and components for the general lighting market. The company is also aiming to develop LED applications specifically for the European market, not least for the automotive and communications industries.

"We are delighted to have found a competent partner in Toyoda Gosei whose technological expertise and market presence make the perfect complement for our existing LED activities," says Zumtobel Group CEO, Andreas Ludwig. "Our common goal now is to grow the joint venture in the medium term into the world's premier supplier of high-performance LEDs for integrated lighting solutions."

Austrian-based Zumtobel Group is a global lighting manufacturer that made sales of €1.14 bn in the year ending April 2004. The group's divisions include Thorn Lighting, Zumtobel Staff and TridonicAtco. In 2001 TridonicAtco assigned its LED activities to a separate subsidiary, Tridonic Optoelectronics GmbH, based in Jennersdorf. Toyoda Gosei, a company of the Toyota Group, is one of the largest manufacturers of blue LED chips, which are used to make white LEDs.

The relationship between the Zumtobel Group and Toyoda Gosei started in November 2001 when Toyoda Gosei incorporated the phosphors developed by three companies, including Tridonic Optoelectronics, into Toyoda Gosei's high-luminosity white LEDs. Subsequently, in July 2004, Toyoda Gosei obtained a share of patent number WO02054502 (PCT/AT01/00364), held by the three companies, which describes a new phosphor used in combination with a blue LED chip to create white light. Tridonic and Toyoda Gosei have since jointly applied for patents on the improved technology.

- TridonicAtco: www.tridonicatco.com
- Toyoda Gosei: www.toyoda-gosei.com

PARTNERSHIPS

Cree agrees distribution rights with European LED vendors

US LED manufacturer Cree has signed distribution agreements for its XLamp products with European LED specialists Vossloh-Schwabe (VS) Optoelectronic and Forge Europa. VS Optoelectronic will distribute XLamp LEDs in Germany, Switzerland, Austria, France and the Benelux countries, while Forge Europa's remit covers the UK, other European countries and Russia. Cree spokesperson Deb Lovig told *LEDs Magazine* that the company "believes that partnering with experienced LED companies like VS Optoelectronic and Forge Europa is the ideal way to access European lighting markets".

Both Cree and Toyoda Gosei (see left) are playing catch-up with their rivals that have a strong grounding in the European market: Osram Opto Semiconductors, based in Germany, is vertically integrated into the lighting market through its parent Osram, while Lumileds Lighting, a joint venture between Philips and Agilent, has a facility in the Netherlands.

DISPLAYS

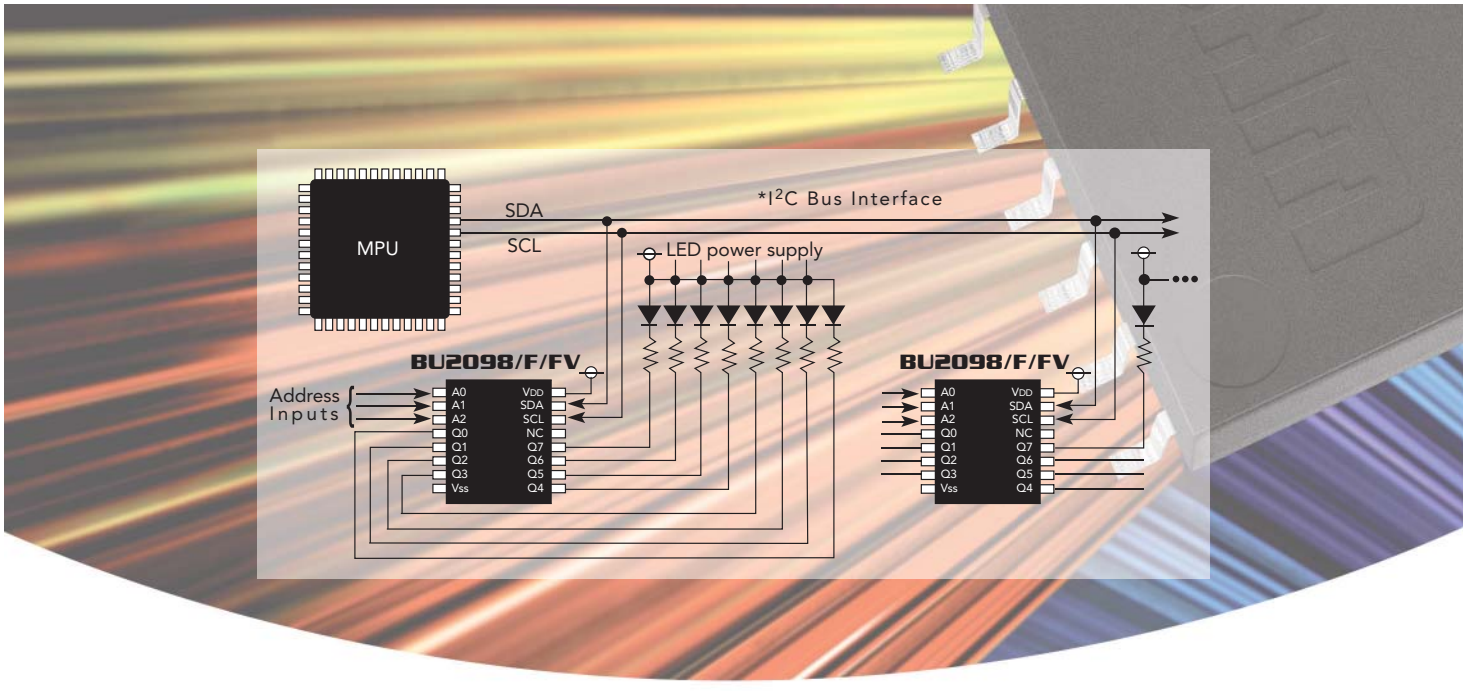
Atlanta baseball ground has record-breaking LED display

A huge high-definition display will entertain Atlanta Braves fans at the newly renovated Turner Field in Atlanta this season. The 5600 sq ft Diamond Vision screen built by Mitsubishi Electric was recognized by Guinness World Records as the world's largest high-definition television screen.

The screen measures 21.76 × 24 m (71.4 × 78.8 ft), weighs 50 tons, and contains nearly 5.2 million LEDs in 266 separate modules. There are 1080 × 1200 pixels, with each pixel containing four LEDs. The pixel pitch is 20 mm. The 400 000 W screen, which is cooled by 10 fans that move 60 000 cu. ft of air per minute, can be accessed for service via a nine-tiered catwalk behind the display.

- Diamond Vision Systems: www.diamond-vision.com

Turner Field is home to the world's largest high-definition display.



LED Driver ICs

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BU2092F/FV	3–5	12	open drain	25	20		SOP18/SSOP-B20
BU2050F	4.5–5.5	8	CMOS	5.5	25	✓	SOP14
BA823F	4.5–5.5	8	open collector	25	200	✓	SOP16
BA829	4.5–5.5	8	open collector	15	300	✓	DIP18
BU2099FV	3–5	12	open drain	25	20		SSOP-B20
BU2098F	2.7–5.5	8	open drain	15	10		SOP16
BU2152FS	2.7–5.5	24	CMOS	5.5	10	✓	SSOP-A32
BD7851FP	4.5–5.5	16	open collector	5.5	50		HSOP25

Features

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

ROHM

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

** I²C Bus is a trademark of Philips Corporation*

Serial-to-Parallel Drivers

SUPPLY CHAIN

Lumileds and distribution partner look to the future

High-power LED manufacturer Lumileds Lighting and its distribution partner Future Electronics have formed Lumileds Future Electronics, a joint effort to improve customers' access to Lumiled's Luxeon high-power LED products. The purpose of the venture is to enable lighting system manufacturers and designers to easily and quickly engineer, prototype and manufacture solid-state lighting systems incorporating Luxeon LEDs.

Lumileds Future Electronics describes itself as "a single, global resource offering services and resources not offered by any other lighting or electronics distributor". Customers will be able to gain access to certified providers in areas such as Luxeon assembly, board integration, illumination systems, standard and custom optics, heat management solutions, optimized power solutions, and technical, design and manufacturing support.

- Lumileds Future Electronics: www.lumiledsfuture.com

DISPLAYS

Toshiba launches LED video display that has 'curvability'

Toshiba has introduced its latest 6 mm-pitch TechnoRainbow LED video wall, which is said to be the first in the industry to offer "curvability". The video wall, which can be configured in both convex and concave curves, is made up of square modules with 64 × 64 pixels. The modules have sides measuring 384 mm (15.12 in) and a depth of 160 mm (6.3 in). The calibrated brightness is 2400 cd/m^2 and the maximum power consumption is 230 W. The modules themselves are flat, but can be connected in such a way as to provide a curvature of up to 20° concave or 10° convex. The minimum radius of curvature is 1.1 m (3.61 ft) concave and 2.2 m (7.22 ft) convex.

- Toshiba: www.technorainbow.com

DEVICES

Nichia targets LED sales of nearly $2 bn by end of 2008

Nichia, the world's largest LED manufacturer, has drawn up a four-year plan that targets LED sales of ¥210 bn (US$1.94 bn) in the year through December 2008, according to an article in the Japanese newspaper, *Nihon Keizai Shimbun*.

Nichia's sales figure last year of approximately ¥160 bn (US$1.48 bn) was hit by a slump in the price of white LEDs (used predominantly in the backlights of color screens for mobile phone handsets). The market for LEDs in 3.5 in or smaller displays is expected to shrink from ¥150 bn in 2004 to ¥100 bn this year.

To retain its competitiveness in terms of price and performance, Nichia intends to invest about ¥30 bn ($277 m) in plant and equipment, and spend around ¥17 bn ($157 m) on research and development in each of the next four years.

The company expects LEDs for phone screens and other small displays to account for 25% of its total sales in the 2008 business year, with LEDs for large displays representing 18%, and LEDs for automotive illumination applications contributing 15%. Nichia also said that it believes LEDs for cars will represent a major proportion of sales in or after 2010.

- Nichia: www.nichia.com

SIGNS

Familiar CITGO sign in Boston gets the LED treatment

A landmark sign that forms part of the Boston skyline has been updated and improved by replacing the neon lighting with 8000 linear ft of LED tubing. The 41-year-old CITGO sign measures 60 × 60 ft. It is now lit on both sides with linear LED tubing that matches the color of the fascia, having been restored by Young Electric Sign Company (YESCO). Rod Wardle and Steve Sluder of YESCO's Las Vegas office explained to *LEDs Magazine* that several different LED combinations were used to create the necessary colors for the sign.

"The LEDs are mounted on circuit boards inside linear extrusions, with 30 LEDs per linear foot," says Wardle. "For the white section, each pixel contains red, green and blue LEDs, while blue alone is used for the CITGO letters."

The red triangle is split into three segments, each of which has a different color. "For these segments we used three reds per pixel, or two reds and one amber, or one red and two ambers," says Wardle. All parts of the sign had to match CITGO's corporate colors, so the output of each strip is tuned using a microcontroller on the circuit board. This allows recalibration in the future if necessary, although cleaning the boards is often sufficient to restore the original output levels, says Wardle.

Maintenance was one of the major drivers for replacing the origi-

nal neon lighting with LEDs. "Replacing broken neon tubes was very expensive," says Wardle. "Ice formation was a particular problem; falling chunks of ice often destroyed large sections of neon."

Power consumption has been reduced to between one-half and one-third of its previous value. The safety aspects of using a low-voltage source were also a consideration in switching to LEDs, as well as the environmental problems associated with neon.

- YESCO: www.yesco.com

DEVICES

Agilent and Lumileds launch Envisium product range

Agilent and Lumileds have launched the first three products in the new Envisium mid-power family of PLCC-4 (plastic leaded chip carrier) surface-mount LEDs, intended for automotive exterior and interior lighting applications. Lumileds is a joint venture between Agilent and Philips. The LEDs are available in red (630 nm, typical total flux 2.6 lm), red-orange (617 nm, 4.3 lm) and amber (592 nm, 3.0 lm). They fill the gap between current Agilent PLCC-4 products, which operate at up to 200 mW, and Lumileds' Luxeon LEDs, which operate at power levels of 1 W and higher.

Agilent's Patrick Trueson explained to *LEDs Magazine* that the products combine Agilent's package with Lumileds' TS (transparent-substrate) AlInGaP LED chips. Agilent also contributes best-in-class supply chain performance, offering a short standard lead time of six weeks for the Envisium products. This is particularly important in the electronic signs and signals market, said Trueson, where installation times tend to be short once a project has been awarded.

The products have a substrate made of a molded plastic reflector on top of a bent lead frame. The die is attached within the reflector cavity, which is encapsulated by an Agilent proprietary epoxy blend. This package design allows the LEDs to perform with high reliability over the –40 °C to 100 °C temperature range, which is crucial in the harsh automotive operating environment. Other applications include home and commercial-building mood lighting and highlighting, and garden lighting, while other colors using InGaN chips will open up new markets.

- Agilent: www.agilent.com/view/led
- Lumileds: www.lumileds.com

SIGNS

Color Kinetics provides sign solution at Sunset + Vine

Color Kinetics has supplied more than 450 ft of iColor Accent to illuminate the landmark sign at the corner of Sunset + Vine in Hollywood, California. "After considering multiple solutions, including neon, we determined that LEDs were the most reliable light source for this large-scale application," said Charlie Stroud of Arrow Sign Company.

Landmark benefits from LEDs.

"Color Kinetics' iColor Accent units and flexible control options proved to be an elegant solution for generating the desired effects without the limitations of conventional lighting methods, such as high operating costs and frequent servicing," says Stroud.

- Color Kinetics: www.colorkinetics.com

DRIVERS

Catalyst and TAOS agree to promote LED system solutions

Catalyst Semiconductor Inc, an LED driver IC manufacturer, and Texas Advanced Optoelectronic Solutions Inc (TAOS), which makes a range of light sensor products, have signed a non-exclusive agreement to jointly promote each others' products to their global solid-state lighting customers. The companies manufacture complementary sets of products, which will be marketed jointly through their common distribution channel, Future Electronics. The companies will include each other's products in application notes, evaluation boards and reference designs.

- Catalyst: www.catalyst-semiconductor.com
- TAOS: www.taosinc.com

LEDs MAGAZINE

Industry alliance proposes standard definition for LED life

The Alliance for Solid-State Illumination Systems and Technologies has developed guidelines for defining LED life as a step towards establishing product standards, writes **Jennifer Taylor**.

Despite continual improvements in LED brightness, color and efficacy, one problem remains that could hamper the LED's success in the lighting community: the absence of a consistent definition of life. At the moment there is no standard for defining or measuring LED lifetime. Much of the confusion within the lighting community is related to the fact that LEDs do not fail in the same manner as other types of light sources. Rather than experiencing a complete operational failure, LED light output slowly decreases with time. Long-life claims without concrete data also have led to skepticism among lighting professionals and would-be purchasers of LED systems. Manufacturers do not present measured life data primarily because no standard testing procedure exists and life tests are generally too time consuming and costly.

The Alliance for Solid-State Illumination Systems and Technologies (ASSIST) – a collaborative group of LED and fixture manufacturers, systems end-users, and government agencies organized by the Lighting Research Center (LRC) at Rensselaer Polytechnic Institute – recently set forth recommendations that define LED life and life measurement methods for general lighting. These recommendations were developed from studies of LED life and light level acceptance conducted at the LRC and by other researchers, as well as from input provided by major LED and traditional lighting manufacturers.

Nadarajah Narendran, PhD, director of research at the LRC and head of its Solid-State Lighting Program, says a definition for life and a standard method for testing are necessary in order to advance LED technology for general illumination applications. "Ultimately the success of LEDs and their adoption by the lighting community will depend upon a consistent and accurate presentation of life data," he says.

Definition of LED life

The guidelines, published in *ASSIST recommends: LED Life for General Lighting*, revolve around the concept of "useful life" that was first proposed by Narendran *et al.* in 2001. The term describes the period in which a light source provides an acceptable light level for a given application, and in addition does not have a noticeable color shift.

In defining this period of useful life, *ASSIST recommends* uses lumen maintenance values, or how a lamp maintains its light output over its lifetime. The guidelines specify two levels of lumen maintenance for different types of LED lighting applications. The group has proposed a lumen maintenance of 70%, corresponding to a 30% reduction in initial light output, as the end of useful life for general lighting. For decorative lighting applications where light level is not critical, the group recommends a drop of 50% as the end of life.

The 70% cut-off was based on research showing that most people will accept up to a 30% reduction in light level (see *ASSIST recommends: LED Life for General Lighting* for references on light level acceptance). Narendran says: "by setting a lumen maintenance level based upon human factors studies, the guidelines will not become dated as the technology advances".

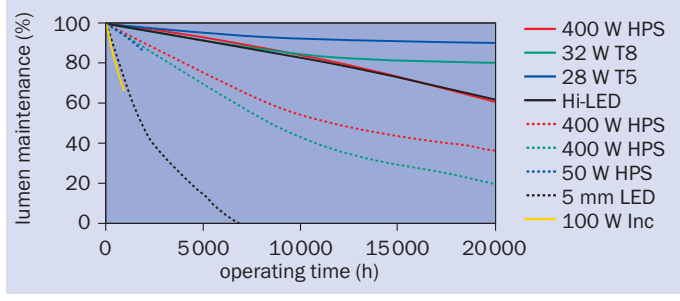


Fig. 1. Lumen maintenance curves for various light sources out to 20 000 hours (Rea 2000; Bullough 2003). High-power LEDs (Hi-LEDs) show much better lumen maintenance than 5 mm LEDs.

In certain applications where light sources are placed side by side, however, light output differences of more than 20% may reduce the visual aesthetics of the space (for example, wall washing in a corridor). In these situations, the lighting specifier may choose an 80% lumen maintenance value for relamping.

Most successful light sources sustain lumen maintenance values greater than 70% before failure (figure 1). Therefore, lamp life based on lumen maintenance criteria is relatively uncommon, says Narendran. However, relamping at the end of useful life rather than rated life is not uncommon. For example, certain types of metal halide lamp can exhibit a light output depreciation of as much as 50% at only 40% of rated lamp life (Figueiro 2003). As a result, some manufacturers recommend group relamping of metal halide lamps long before operational failure.

ASSIST also recommends that within the useful life period, LEDs should not exhibit color shifts greater than a four-step MacAdam ellipse. "Excessive color shift results in reduced visual aesthetics of the lighted space, and this would not be accepted by occupants," says Narendran.

Manufacturers who follow the ASSIST recommendations will publish the number of hours a product will operate before reaching 70% and 50% of initial light levels. Providing the operating time will assist specifiers and designers in selecting the right LED product for the job, says Narendran.

Measuring lumen maintenance

Along with the lumen maintenance recommendations come methods for measuring and extrapolating data to estimate life, in hours, for both LEDs and integrated systems using LEDs. ASSIST has outlined

different methods for components (the individual LEDs) and systems (the integrated packaging of LEDs).

For measuring both components and systems, ASSIST recommends a minimum operating period of 6000 hours (250 days) at rated current and voltage. The first 1000 hours is an initial seasoning period for the LEDs, and the next 5000 hours is for actual light output measurement. Light output data collected between 1000 and 6000 hours is used to measure or estimate the time needed to reach 70% and 50% lumen maintenance. ASSIST recommends an initial seasoning period because studies at the LRC have shown LED light output to increase during this time (Gu *et al.* 2004). The LRC's comparisons of extrapolated and measured life show that inclusion of the first 1000 hours of data can lead to false life estimates.

LED life is related to junction temperature (T_j) (Fukuda 1991), but T_j can be difficult to measure, especially once LED dies are packaged into their housing. A reasonable estimate of T_j can be made by measuring the temperature of the closest measurable location to the LED junction (T_s). This is usually where the LED is soldered to the circuit board (figure 2). Because T_s can be measured more conveniently and has a similar relationship to life as T_j, ASSIST recommends using T_s for component life measurements.

The ASSIST guidelines propose component life measurements to be taken at three different T_s temperatures. For high-power components (those operating above 100 mA), the recommended T_s temperatures are 45 °C, 65 °C and 85 °C. For low-power components (those operating below 100 mA), the recommended T_s temperatures are 35 °C, 45 °C and 55 °C.

Different T_s temperatures can be achieved either by changing the current or by changing the ambient temperature of the testing space. In this case, because the document guidelines say to run the component at rated current, the manufacturer would have to vary the ambient temperature to achieve the desired T_s testing value.

For LED systems, ASSIST recommends measuring life inside a temperature-controlled space at an ambient temperature of 25 °C.

Because the goal of *ASSIST recommends* is to encourage manufacturers, small and large, to provide life data, the document calls for inexpensive test equipment. Since relative light output is the only measurement needed, a broadband detector that can measure radiant energy is an acceptable alternative to expensive light measurement equipment with V(λ) correction, says Narendran.

If 70% and 50% lumen maintenance values are not reached within 6000 hours, ASSIST recommends applying a mathematical fit to the light output data collected between 1000 and 6000 hours and extrapolating to estimate when the light level will reach these values. Figure 3 shows a sample life graph that an LED component manufacturer may provide.

ASSIST cautions that as LEDs improve in the future, it may be necessary to increase both the initial seasoning period and the measurement period to longer than 6000 hours in order to develop reasonable predictions of light output.

Consistency in life estimation and data reporting methods

The new recommendations will help on two fronts, says Narendran. First of all, they will establish a realistic life expectancy for LED lighting products, which will help consumers to conduct lifecycle estimates and comparisons among lighting products. Second, the measurement and extrapolation guidelines will ensure that all LED lighting manufacturers test their products in a similar manner.

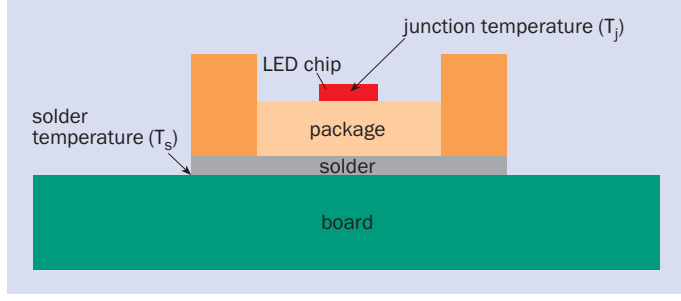


Fig. 2. LED package showing the position of the T_s measurement.

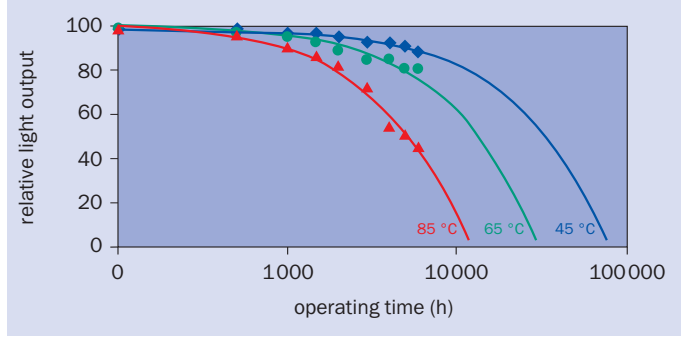


Fig. 3. Sample high-power LED component life graph for one product at each recommended T_s temperature (not actual data). Solid lines represent the mathematical fit for the extrapolation of life data to 70% and 50% lumen maintenance.

In addition to the recommendations, ASSIST has provided sample data-recording sheets for high- and low-power components and for LED systems. For component manufacturers, these sheets list other details that should be recorded beyond life data, including sample size, thermal resistance coefficients, and junction temperatures. As for system manufacturers, ASSIST is calling on them to provide life data beyond that which is provided by component manufacturers, primarily because LED system life can vary depending on the packaging.

Next step: industry standards

Narendran says these recommendations are the first step towards the creation of standards for LED lighting products, such as those in place for traditional light sources. Going forward, he says the group plans to contact LED component and system manufacturers and encourage them to review *ASSIST recommends* and to provide life data using the guidelines.

"This is really just a starting point for the industry to begin collecting sufficient data and evaluating these recommended methods. Hopefully, these can lead to the establishment of good standards down the road," says Narendran.

Feedback welcome

The Lighting Research Center welcomes all comments on these proposals from LED component and system manufacturers and other interested parties. Send your comments via *LEDs Magazine* to editor@leds.iop.org, or contact the LRC directly at lrc@rpi.edu.

Companies participating in the development of *ASSIST recommends* include Boeing, GELcore, New York State Energy Research and Development Authority, Nichia America Corporation, Philips Lighting, OSRAM SYLVANIA/OSRAM Opto Semiconductors, and the United States Environmental Protection Agency.

Further reading

J D Bullough 2003 *Lighting Answers: LED Lighting Systems* (Troy, New York: National Lighting Product Information Program, Lighting Research Center, Rensselaer Polytechnic Institute. See www.lrc.rpi.edu/programs/NLPIP/publications.asp).

M G Figueiro 2003 *Lighting Answers: Mid-wattage Metal Halide Lamps* (Troy, New York: National Lighting Product Information Program, Lighting Research Center, Rensselaer Polytechnic Institute. See www.lrc.rpi.edu/programs/NLPIP/publications.asp).

M Fukuda 1991 *Reliability and Degradation of Semiconductor Lasers and LEDs* (Artech House, Boston).

Y Gu, N Narendran and J P Freyssinier 2004 White LED Performance *Fourth International Conference on Solid State Lighting, Proceedings of SPIE* **5530**, eds I T Ferguson *et al*. 119–124.

N Narendran, J Bullough, N Maliyagoda and A Bierman 2001 What is useful life for white light LEDs? *Journal of the Illuminating Engineering Society* **30(1)** 57–67.

M S Rea ed. 2000 *IESNA Lighting Handbook: Reference and Application* 9th edn (Illuminating Engineering Society of North America, New York).

Links

ASSIST: www.lrc.rpi.edu/programs/solidstate/assist/index.asp
LRC Solid-State Lighting program: www.lrc.rpi.edu/programs/solidstate/index.asp
A free download of *ASSIST recommends: LED Life for General Lighting* can be found at: www.lrc.rpi.edu/programs/solidstate/assist/recommends.asp

On our website

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

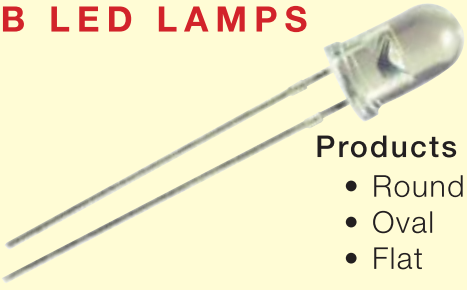
"Lighting Research Center applies research, demonstrations, and education to advance LED technology"
See www.ledsmagazine.com/articles/features/1/2/5/1.

About the author

Jennifer Taylor is a communications specialist with the Lighting Research Center at Rensselaer Polytechnic Institute.

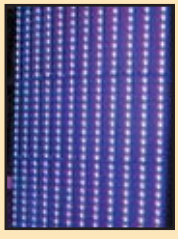
Expanding with Qualified Manufacturer Representatives and Distributors

HB LED LAMPS



Products
- Round
- Oval
- Flat

LED BACKLIGHTING SYSTEMS



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- Signage
- Backlight
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NUMERICAL, ALPHA-NUMERIC & DOT MATRIX DISPLAYS

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- Custom

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- Decorative
- Accent
- Retail / Display

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- Edge

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- Backlighting
- Halo
- Cone

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LEDs MAGAZINE

Escaping the bulb culture: the future of LEDs in architectural illumination

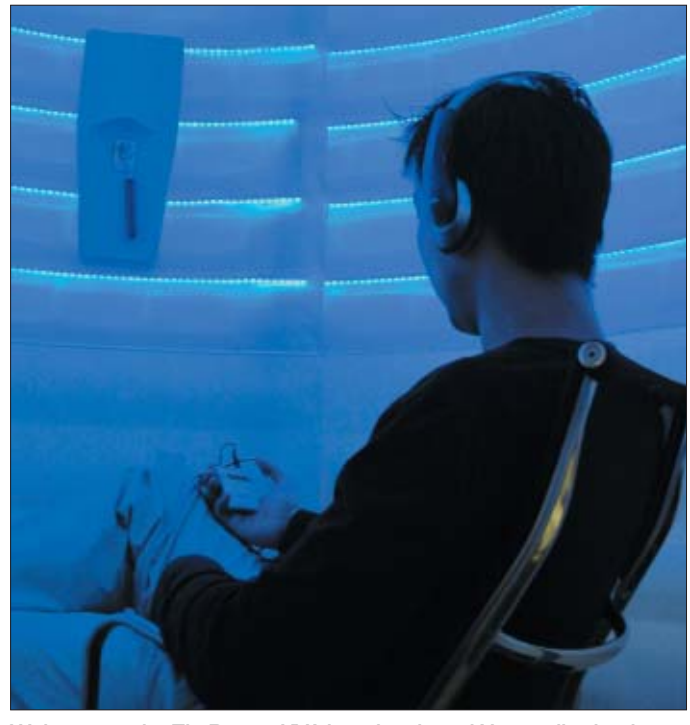
The real value proposition for LEDs lies in the change from bulb culture to digital light. *LEDs Magazine* spoke with **Sheila Kennedy**, a passionate advocate of LED technology.

One of the hurdles faced by LED technology as it starts to penetrate general lighting applications is the need to overcome misconceptions about the true value proposition of LEDs. While some are seeking to replace existing fixtures with LED light bulbs, others recognize the new paradigms that are evolving.

Sheila Kennedy, principal of Kennedy & Violich Architecture Ltd (KVA), speaks passionately on this subject. "Semiconductor technology is not part of bulb culture illumination, and very few people understand this," she says. "LEDs offer a new model for light – digital light – with a set of features that completely change the value proposition of light, the relationship between light and information, how consumers experience light, how they control it, how they can use it in their everyday lives."

Kennedy's Boston-based firm is an interdisciplinary design practice that explores new relationships between architecture, technology and emerging public needs. KVA's material research unit, MATx, designs new applications for the integration of digital light and information infrastructure in architecture. At a recent conference, Kennedy described her work for Herman Miller Inc to create a reconfigurable smart ceiling system incorporating LED lighting.

The system delivers data and power through a series of suspended tracks on the ceiling, and includes digitally controlled LED lighting that is integrated into a light-diffusing fabric. The fabric is lightweight and is easy to ship due to its concertina-like structure. The purpose of the infrastructure is to allow lighting and digital media equipment to



Welcome to the Zip Room: KVA has developed Nextwall, a luminous soft-wall product that is on display at the Extreme Textiles exhibit, which opened on April 8, 2005 at the Cooper-Hewitt National Design Museum in New York. The wall contains a DC power distribution system and plug-in ports for digital tools, such as cell phones, PDAs and solid-state lighting. The Zip Room "think-tank" has integrated acoustical inserts and color-changing LED illumination, enabling users to control their own private sound and light scape. Credit: Kennedy & Violich Architecture Ltd.

KVA's award-winning designs for the East River Ferry Landings in Manhattan, New York, incorporate bollards that contain LEDs and that are driven by solar power. Credit: Kennedy & Violich Architecture Ltd .

be selected and assigned to different locations, enabling users to rapidly reconfigure the available space according to their requirements. After a working demo containing more than 20 000 LEDs was assembled in a 7000 square foot space in Los Angeles, a prototype system has now been installed in Harvard University's Design School.

From bulb culture to digital light

Kennedy sees the value proposition for LEDs as the space defined by a triangle linking LEDs, digital electronics and DC power sources such as photovoltaics. This is vastly different from "bulb culture", a term which Kennedy has coined to describe the technical processes used to make light; the set of traditional artefacts in the lighting industry such as bulbs and fixtures; and the set of uses or experiences associated with bulb technology.

Even though LEDs are technically advanced compared with filament bulbs, the way they generate light is much more like bioluminescence – living light – which is produced, for example, by fireflies, bacteria and fish. "Nature produces light in a very efficient manner without producing disproportionate amounts of heat," says Kennedy. "The same can be said about LEDs, while the opposite is true of incandescent bulbs."

Bulb culture, the current lighting paradigm, has been built around the idea of lighting as objects, fixtures or appliances: usually brittle, hard and stationary objects. "For a hundred years, lighting has formed a category that is fundamentally different from furniture, or from infrastructure or architectural elements such as walls, facades or ceilings," says Kennedy. However, the extreme miniaturization that can be achieved with LEDs allows the devices to be integrated into materials, to produce light-emitting furniture, architectural surfaces, or clothing, for example. "This is very transgressive to the categories that design disciplines have constructed, and offers a new way to think about material performance. Not only can we integrate light into materials but we can also readily organize many points of light, in an interactive manner with computerized control," explains Kennedy. "This eventually leads us towards displays, and the crossover between illumination and information."

The true value proposition of LEDs

Compared with bulb culture technology, LEDs enable a whole new set of uses and experiences: the ability to experience light at the scale of the body and the building; to introduce dimming and color control; and to enable interactivity between the user and the light source. "With LEDs, we can bring the light where we need it close to our work surfaces, with lots of points of light coordinated together, rather than having the light shining down from a single fixture on the ceiling," says Kennedy. Digital electronics allows LED lighting to be precisely controlled using effectively instantaneous on/off switching and techniques such as pulse-width modulation. Also, LEDs use low-voltage DC power, which is much more user friendly. "The importance of being able to operate from DC power cannot be overemphasized," says Kennedy, citing the increasing efficiency of photovoltaic (PV) power sources. Although PV technology needs further improvements, the area ratio of LEDs and the PV cells required to power them is now at a manageable level.

"I'm very excited about using PV technology to create more transportable forms of light," says Kennedy. "It is an important first step that will help to take the pressure off brittle centralized electrical supply structures such as the one we have in the US. We will be able to make new products and building systems that will help to make electrical hard-wired infrastructure redundant."

Building knowledge bridges

Clearly, there remains a sizeable gap that must be bridged, in scale and in concept, between the semiconductor chips themselves and the use of LEDs as light sources within buildings. The issues to be addressed include package design, integrating multiple chips with driver control,

"LEDs offer a new lighting model with a set of features that completely change the value proposition of light."

Sheila Kennedy, Principal, Kennedy & Violich Architecture

building codes and legal issues, and many others. Simply building LED fixtures in a laboratory environment without dealing with such challenges is not the optimum approach, Kennedy contends.

Rather than using existing LED fixtures, the role of KVA's MATx group is to create ideas and prototype applications that exploit the advantageous properties of LEDs, which can be specified and customized by other architects and designers. "My company gets involved early in the innovation process, we don't simply specify fixtures and design them in," says Kennedy. "People come to us when they want a more integrated solution, when they want to understand and leverage the market value offered by LEDs."

So are building regulations a major issue? "Many people think that you can't integrate LEDs into buildings owing to regulations such as fire codes and NEC class 2 restrictions," says Kennedy. "This has not been our experience. We've applied our knowledge of building codes to design distributed LED integration strategies that meet the electrical load restrictions. We've worked very closely with LED industry leaders to realize large-area LED integrations in architectural projects that are fully code-compliant."

The key to stimulating the use of LEDs in architecture appears to lie in a creative, integrated approach that encourages industry leadership to recognize the value proposition offered by these devices, combined with public outreach. "We need a major thrust of education about semiconductors," concludes Kennedy. "My company is working to help the public understand the benefits of digital light, and accelerate the adoption of LEDs in architecture."

Links

Kennedy & Violich Architecture Ltd: www.kvarch.net
Cooper-Hewitt National Design Museum: http://ndm.si.edu

On our website
"LEDs for smart ceilings"
See www.ledsmagazine.com/articles/features/1/11/6/1.

China promotes benefits of solid-state lighting

The Chinese government is funding a national program that aims to make considerable energy savings, reduce pollution, and position the country as a leader in solid-state lighting.

As the solid-state lighting industry evolves, it is becoming clear that China will be both an enormous consumer for lighting products and an engine for growth and innovation in solid-state lighting.

Progress is already under way. The Chinese government has launched a National Solid-State Lighting (SSL) Program, targeting huge energy savings from a large-scale conversion to LED lighting, as well as reduced environmental pollution.

Ling Wu, the director of the National SSL Program Office, told the audience at the recent Strategies in Light conference that China could save 100 billion kW/h annually by 2015, if LEDs reach efficacies of 150 lm/W and achieve a 40% share of China's incandescent lighting market. Such savings would be more than the output of the massive Three Gorges hydroelectric project, she said.

Barco has provided LED displays for automotive shows in China, as well as the Formula 1 race track in Shanghai. The 2008 Beijing Olympic Games are expected to provide a huge boost for suppliers of LED displays and lighting equipment. Credit: Barco.

National program

China's National SSL Program kicked off in June 2004 when the Ministry of Science and Technology pulled together the activities of several different regional development groups. The program has already received RMB 140 m ($17 m) from central government, and 15 research institutions and more than 50 enterprises are involved. Major investment in SSL is expected when China's 11th five-year plan is unveiled in July 2005.

The National SSL Program Office has already initiated comprehensive strategy research, industry-standard preparation, and research programs into intellectual property (IP).

In October 2004 a group called the China R&D and Industry Alliance for SSL was formed, with the aim of improving the competitive ability of the country's SSL industry. The group will develop mechanisms to share resources such as technology and IP, while encouraging regional collaboration and international co-operation.

Rapid progress

According to Ling Wu, China is continuing to make progress with its LED development, with domestic companies supplying 12 million blue chips at the 6–8 mW level (20 mA) and power chips at 120 mW (350 mA). Packaging companies are able to supply white LEDs at 20–25 lm/W using domestic blue chips, and at 30–35 lm/W using higher brightness imported chips. This statistic gives an indication of the status of China's LED industry relative to the rest of the world.

Of course China is a newcomer: as recently as 2002 the country's LED packaging industry imported all of its blue chips, while the emerging domestic chip industry supplied 5% of demand in 2003. This figure grew to 20% in 2004, with Chinese companies also supplying GaN-based epiwafers, and a target of 40% of blue chips is set for 2005.

China's LED industry had sales of RMB 12 bn (around $1.45 bn) in 2004, up from RMB 10 bn ($1.2 bn) in 2003. Ling Wu estimated that more than 600 Chinese enterprises, with more than 40 000 employees in total, are directly related to the LED industry.

Industrial bases

The country already has four national SSL industrial bases, in the cities of Dalian, Shanghai, Nanchang and Xiamen. A fifth base is under

Links

China National Solid-State Lighting (SSL) Program: www.china-led.net
China SSL Forum: http://www.china-ssl.org

On our website
"China promotes energy efficiency using LED lighting"
See www.ledsmagazine.com/articles/news/1/12/14/1

TIR completes architectural project in China

Solid-state luminaries from TIR Systems contribute to the light show at the Full Moon Tower in Tianjin, China. Credit: TIR.

LEDs have been used to illuminate the 52 m (170 ft) high Full Moon Tower at Galaxy Park, a leisure park in Tianjin, which is a port city of more than 10 million people located approximately 200 km south-east of Beijing.

Destiny CW and Destiny DL solid-state luminaires from TIR Systems are part of a computer-programmed color-controlled animated lighting show that plays nightly in Galaxy Park. Artistic License of the UK supplied its Colour-Tramp lighting control system, specifically designed to handle the complexity of two- and three-dimensional lighting arrays.

City officials consider this project to be a key element in increasing Tianjin's profile within China in the ramp-up to the 2008 Olympic Games. Architecture in Asia leads the world in the use of color and dynamic color-changing light as a design element, and architects are incorporating new building technologies into their plans.

TIR Systems, which has already delivered several prestigious projects in Asia, including the landmark Kuo Hua Insurance Building in Taipei, Taiwan, considers Asia a key market that will enable the company to successfully implement its global strategy for solid-state lighting.

development in Shenzhen, the territory adjacent to Hong Kong. Representatives from Century Epitech were also present at Strategies in Light; the company is attempting to find tenants for the new Shenzhen park. Foreign companies are incentivized by tax breaks, as well as the expectation of low labor costs.

Ling Wu was keen to emphasize that SSL plays an important part in China's energy policy, and it is a major area of focus for the government. China's SLL road-map is set to be unveiled at the International Forum on Solid State Lighting in Xiamen on April 12–15. At the same time, lighting contracts for the 2008 Olympic Games are expected to be announced, as well as a tripartite collaboration between Taiwan, China and Hong Kong.

LED market grew by 37% to reach $3.7 billion in 2004

White LEDs and mobile phone applications dominated the high-brightness LED market in 2004, but growth is likely to slow as the handset market becomes saturated.

At Strategies in Light, the annual LEDs conference organized by Strategies Unlimited, market analyst Bob Steele presented his most recent market numbers. Steele's estimate for the total market for packaged high-brightness LEDs in 2004 was $3.7 bn, an increase of 37% over the previous year.

InGaN-based devices, comprising blue, green and white LEDs, were the dominant material. Steele's estimate does not include AlGaAs devices, or LEDs manufactured and sold within China. A surprising fact was that white LEDs accounted for exactly half of the total 2004 market.

With a 58% share, the mobile appliance segment dominated the high-brightness LED (HBLED) market once again. Price erosion in this segment had a constraining effect on overall market growth, which was also affected by the weakness of the dollar against other relevant currencies.

Looking ahead, Steele said that growth will slow significantly as the mobile appliance market saturates. Even so, the market is set to move smoothly past the $4 bn mark in 2005, and growth is expected to accelerate in 2007–9 as new applications such as automotive headlights and large-area LCD backlights start to kick in. The current forecast shows the market exceeding $5 bn in 2007 and topping $7 bn in 2009.

Mobile appliances dominate growth

Shipments of mobile phone handsets, the leading application for HBLEDs, grew by 28% in 2004 to reach 670 million units. Around 75% of new phones had full-color displays, which use white LED backlights. Many handsets also have a secondary display, and there was a threefold increase in handsets with camera phones, some of which use white LED flash units.

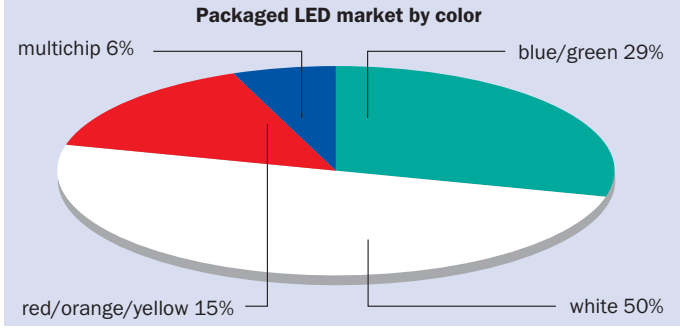
Keypad backlights, which are predominantly blue for the Asian market and white in Europe, represented 38% of the total mobile appliance market of $2.15 bn. This figure has tripled in two years from around $700 m in 2002.

Prices for keypad backlights have undergone severe price erosion, but this has started to level off. Steele suggested this might be because prices cannot fall any lower without companies going out of business.

Signage and automotive

Signage represented 13% of the total HBLED market in 2004, or just over $500 m, of which more than two-thirds was for full-color video displays. In terms of total area, there was 20% growth in displays for sports stadiums, retail and general advertising.

The automotive segment also represented 13% of the total, with interior lighting applications, such as instrument panel backlighting, dominating. Europe has more than 80% penetration, while adoption is taking off rapidly in Japan. Emerging opportunities include dome lights on car ceilings, and backlights for LCD navigation system displays.



White LEDs accounted for half of the 2004 LED market, owing to the demand for full-color handset displays. Credit: Strategies Unlimited

The situation is similar for center high-mounted stop lamps, with near saturation in Europe and rapid adoption in Japan. Only 4% of cars have LED stop-turn-tail lamps but growth is high. The fastest growing application is in side-mirror turn-signal repeaters, which were used in more than 4 million light vehicles out of a total of 59.5 million.

Lighting

Although still only representing 5% (approximately $185 m) of the market, solid-state lighting represents the segment with the most rapid growth after mobile appliances. Most applications are for colored light, and range from very small (flashlights and reading lamps) to multimillion-dollar projects.

Links

Strategies Unlimited: www.strategies-u.com

On our website

"Panel points to developments in high-power LEDs"
The big five LED manufacturers, otherwise known as "the usual suspects" – Cree, Lumileds, Nichia, Osram Opto and Toyoda Gosei – were assembled for a panel session at the Strategies in Light conference to discuss advancements in, and new applications for, high-power LEDs. The panel also featured lively discussions on LED manufacturing in Asia and intellectual property. See www.ledsmagazine.com/articles/features/2/2/6/1.

LEDs MAGAZINE

Implementing LED flash in camera phones

Several thermal, optical, mechanical and electrical criteria should be considered when designing an LED flash for a camera phone, according to **Yeoh Boon Keng**, **Ko Choon Guan** and **Shereen Lim** of Agilent Technologies.

The first camera phone was introduced in Japan in November 2000. In the first half of 2003, 25 million camera phones were shipped worldwide, for the first time beating the number for conventional digital cameras (20 million), according to American Technology Research. The firm predicts that camera phones will continue to outsell digital cameras from now on.

Today's "standard" camera phones offer 640 × 480 pixel resolution for a 0.3 megapixel image size. At the beginning of 2004, state-of-the-art camera phones featured a 1600 × 1200 pixel image (approximately 2 megapixel image size) along with the capability of taking short video clips and the use of removable memory cards. Some 2 megapixel phones also include features such as autofocus. One manufacturer has announced that it will be introducing a 7 megapixel camera phone in mid-2005.

Since camera phones are now being used as "serious" digital cameras, users are expecting to be able to take quality pictures in low-light-level conditions. This is where adding a small illumination source that won't rapidly drain the cell phone's battery comes into play.

Why choose LED flash for camera phones?

Today there are two available choices for digital camera photoflashes: the xenon flash tube (which is used widely in all forms of photography) and white LEDs. Each offers unique features and benefits, and each possesses advantages in different segments of the digital camera market. The xenon flash is practically universally used for both film cameras and stand-alone digital still cameras (DSCs) because of its high brightness. White LED illumination is the choice for most camera phones.

Basically, a xenon flash is a cylindrical glass envelope filled with xenon gas. Multikilovolts are needed to reach the gas breakdown potential, before generating a high current surge through the xenon gas, producing intense light.

On the other hand LEDs are current-driven devices in which the light output depends directly on the forward current passing through them. LEDs can be strobed faster than any other light source, including xenon, and have very short rise times, in the range of 10 to 100 ns. The white light is produced by the combination of the blue photons emitted from forward biasing an InGaN chip, and yellow light, a result of phosphor excitation by blue photons. The resulting lighting quality is comparable to that of cool white fluorescent lamps, with a color rendering index near 85.

The maximum light output from an LED is in most cases limited by the maximum average forward current it can handle, which is determined mainly by the combination of the power dissipation capability of the LED chip/package combination and the performance of any heat sink to which it is attached. In flash applications the LED may be

Differences between xenon and LED flash technologies

Performance	Xenon flash	LED flash
Light output	High, suitable for digital still camera	Relatively low, sufficient for camera phone
Illumination versus time	Pulsed, good for still pictures	Continuous or pulsed, good for still pictures and video
Color	Close to natural light	Blue component of light output requires color correction. The camera software can handle this
Solution size	More space needed for circuitry, especially the big capacitor and transformer. Approximately 3.5 × 8 × 4 mm for the optical assembly and 27 × 6 × 5 mm for circuitry	Small size due to miniature circuitry. Approximately 2.2 × 7 × 1.7 mm for the optical assembly and 7 × 7 × 5 mm for circuitry
Charge time	Approximately 3–5 s	None
Operating condition	Charging current ranges from 100 to 300 mA. 300 V for flash tube, high-voltage pulse to initiate	3.5 V to 4.5 V. Maximum average current is 80 mA
Battery power consumption	Around 1500–2000 mA while charging	Maximum 350 mA during the actual flash
Package robustness	The glass tube is relatively fragile	The LED chips are covered with epoxy, and are robust
EMI	Yes, due to the transformer	Insignificant

operated from a pulsed current with a very short duty cycle. This allows the current and hence the light output to be increased significantly during the actual pulses, while still keeping the LED's average current level and power dissipation within its safe ratings.

In DSCs a high-brightness flash is needed, and the size and power consumption are less significant because a DSC can provide more room for the required drive circuit, and its battery capacity is devoted entirely to operating the camera and flash. Undoubtedly a xenon flash is the best choice for a DSC.

On the other hand, an LED flash offers lower power consumption with drive circuitry that takes up little room. Additionally, no significant electromagnetic interference (EMI) is generated from driving an LED flash.

These advantages help push the use of an LED flash in camera phones. And, of course, the same LED flash can also be operated as a continuous light source, making it suitable for video applications and as a free flashlight incorporated in the phone. The table (on p19) summarizes the differences between xenon and LED flash units.

Selecting LEDs for camera phone flash applications

There are several different LED assemblies that manufacturers specify for camera flash operation, and there are no packaging or electrical standards in the flash LED market. Designers who are not familiar with LED flash design might find themselves having difficulties in selecting an appropriate LED assembly and may discover later problems if they design-in an unsuitable assembly.

A number of criteria should be considered when designing an LED flash into a camera phone. They are:

- optical characteristics;
- electrical design simplicity and flexibility;
- pulsing capability;
- ability to effectively cascade modules for higher light output;
- thermal considerations; and
- manufacturing and assembly considerations, particularly the compatibility of an LED module with manufacturing processes.

Optical characteristics

Most of the digital camera modules currently being used in camera phones have a 50° to 60° field of view and need a minimum of 3–5 lx to capture a good picture. Hence, a camera flash with a 50° to 80° illumination angle is optimal. An illumination angle wider than 80° will cause a portion of light to fall outside the camera's coverage, underutilizing the light output from the LED. Conversely a flash with a smaller illumination angle might cause dark areas on the corners of the captured image.

The majority of LED assemblies intended for camera flash applications on the market now have wide illumination angles. There are techniques for fine-tuning the illumination angle through the use of secondary optics; however, there are several main drawbacks to adding optics for this purpose. First, secondary optics will cause a loss of approximately 12% of the light due to conversion efficiency. The use of secondary optics also adds to the cost of the camera phone, takes up additional space, and complicates the manufacturing and design process.

Agilent has developed high-brightness white LED light sources, the HSMW C830/C850 Agilent flash modules, which are specifically designed to suit the actual requirements of camera phone camera modules. Their unique dome design concentrates the light output from the LED die to form a 60° Lambertian radiation pattern, maximizing the light output that falls within a typical camera's field of view. No secondary optics are needed to redirect the light output. Both major and minor axes produce similar radiation patterns.

Agilent flash modules (HSMW C830/C850) contain three LED die connected either in series or in parallel.

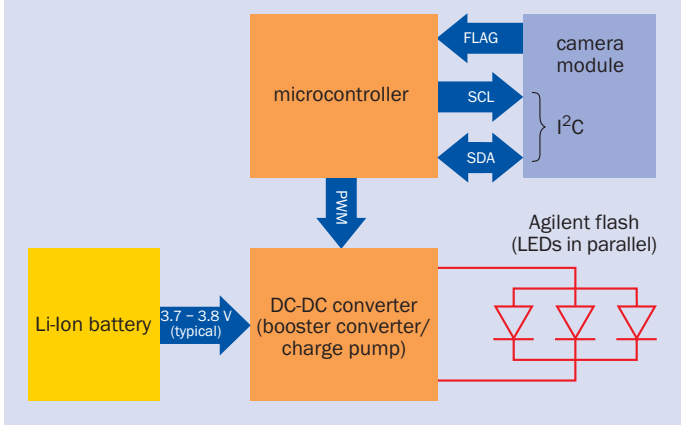


Fig. 1. Camera phone system diagram (PWM = pulse-width modulation, SCL = I2C clock line, SDA = I2C data line, FLAG = synchronize flag).

The majority of LED flashes today have more than one LED die in a single package. It is common that the dice will degrade over time, with individual die degrading at different rates. This phenomenon can alter the radiation pattern of the flash.

The Agilent flash module has this characteristic factored into its optical design. The dome design ensures that the overall package radiation pattern remains consistent, regardless of any change in the relative brightness of any of the individual domes.

The flash module has only two terminals, anode and cathode. Each module incorporates three InGaN LED die; the dice are either connected in parallel (HSMW-C830) or in series (HSMW-C850) within the module. Figure 1 shows how an LED flash can be integrated into a camera phone.

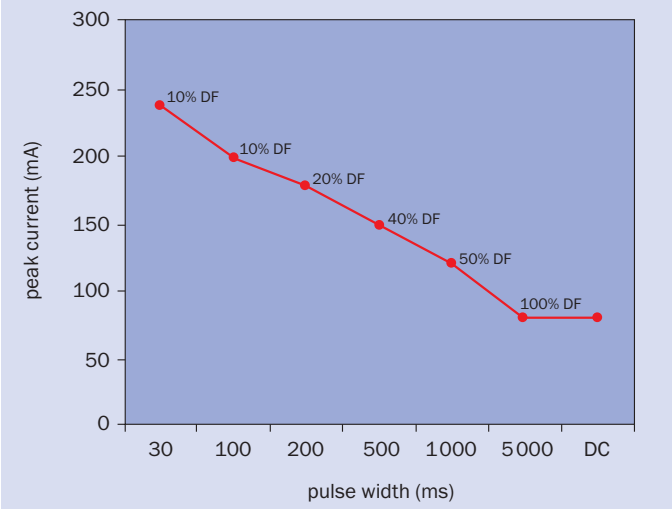


Fig. 2. The relationship between maximum peak current and pulse width (DF = duty factor) for an Agilent flash module.

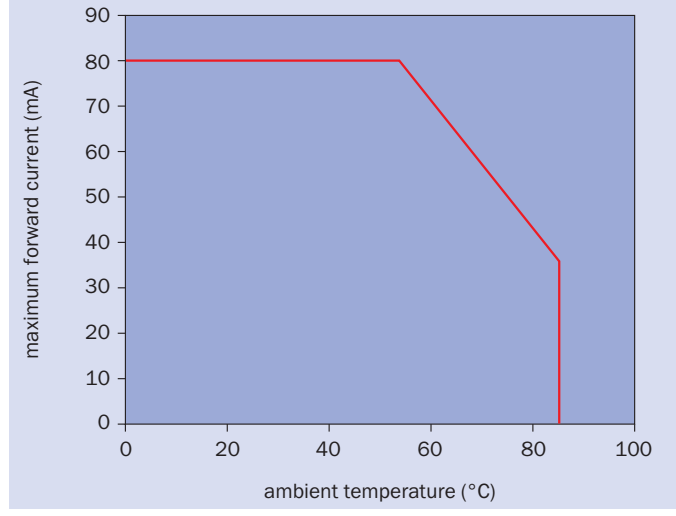


Fig. 3. The derating curve for Agilent flash modules. They can be illuminated for 5 s at 80 mA at an ambient temperature of +55 °C.

Electrical design of an LED flash

The lithium ion battery in mobile phones is a voltage source with a voltage output that varies with the amount of energy it holds (usually between 2.8 V and 4.2 V).

Since the LED is a current-driven device, it is highly recommended that it be driven with a constant-current source in order to obtain consistent light output. Integrating a DC-to-DC converter between the battery and LED flash is a good solution for this. The charge pump converter and voltage boost converter are two possible DC-DC converter topologies suitable for driving an LED flash.

Pulsing capabilities

The length of flash illumination varies depending on the requirements of specific camera modules. As long as the illumination is provided for no less than the module's image-framing period, it will not degrade image quality. Typically, 200–300 ms of illumination is sufficient.

An Agilent flash module can be driven at up to 180 mA for a pulse width of less than 200 ms, providing a brightness of 10 lx. Under continuous operation the maximum allowable current is 80 mA, producing a brightness of around 6 lx. Figure 2 shows the relationship between the maximum peak current and pulse width.

Cascading facility

Agilent has designed the HSMW-C850 so that it may be cascaded both mechanically and electrically. The package is purposely designed to be slim so that if the designer wants to cascade two modules together to double the available light output, the combination will occupy a minimum of space. If the modules are cascaded vertically, the combination is only 7.0 × 4.4 mm. Some LED flash modules on the market have dimensions of 5.0 × 5.0 mm, so that cascading two will occupy about 10.0 × 5.0 mm.

Most LED flash modules have the LEDs connected in a common-anode configuration. Cascading them in series will require that the driver handle both high current and high voltage, while cascading them in parallel will cause potential problems with variations in their light output due to uneven current splitting between the two modules. The HSMW-C850 has all three chips connected in series. If it is being cascaded, only the voltage needs to be adjusted; there is no need to change the drive current, and there is no question of two modules receiving different currents. Additionally, the booster converters available in the market favor low-current drive with high-compliance voltage rather than high-current drive with low-compliance voltage, due to the savings in overall power.

Thermal considerations

Flash modules may generate a lot of heat during operation, so thermal handling must be considered during the design process. Most handset designers prefer using a flexible printed circuit (which is a poor heat dissipater) instead of FR4 PCB material owing to the space constraint.

The Agilent flash module has a low package thermal resistance that can effectively dissipate heat generated by the LEDs. The module can be illuminated for up to 5 s continuously at 80 mA under an ambient temperature of +55 °C. Figure 3 shows the derating curve for Agilent flash modules.

The last consideration for choosing an LED flash is to make sure it is compatible with the IR solder reflow process. A device that cannot be reflow soldered requires manual soldering, which will increase the manufacturing cost and time.

About the authors

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Links

Agilent Technologies: www.agilent.com/view/led

On our website

An extended version of this article can be viewed at www.ledsmagazine.com/articles/features/2/4/1/1.

台北光電週

Photonics Festival in Taiwan since 1984

系列活動

Exhibits / 展出項目
Compound Semiconductor
Precision Optics / Laser
Optical Storage & I/O Device
Vacuum Coating
Measuring, Inspection
Facility / Equipment

OPTO TAIWAN 2005

國際光電大展
The 14th Int' l Optoelectronics Exposition

Exhibits / 展出項目
LED (Display, Signal, Lighting)
Laser Diode, VCSEL
Package / Module
Chip, Epi Wafer, Ingot
Manufacturing Equipment

LED LIGHTING 2005 Taiwan

LED照明展
The Int' l LED Lighting Exposition

Exhibits / 展出項目
Optical Fiber & Cable
Optical Passive Components
Optical Active Components
OFC Module / Package
OFC System / Equipment

OptoCom TAIWAN 2005

光通訊寬頻展
The Fiber Communication & Broadband Exposition

JUNE 08-11, 2005

Taipei World Trade Center 台北世界貿易中心

Advisory

國家科學委員會 National Science Council
經濟部工業局 Industrial Development Bureau

Orangizer

PIDA
財團法人光電科技工業協進會
Photonics Industry and Technology Development Association
台北市100羅斯福路二段九號五樓
5F, No.9, Roosevelt Road, Sec.2, Taipei 100, Taiwan
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Orangizers

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LEDs find their niche in architectural lighting

Lighting designer **Iain Ruxton** thinks that LEDs are "still a bit of a gimmick", although the technology has great potential provided that certain inherent problems can be ironed out.

At the LEDs conference held in Brussels last November, several speakers offered some forthright views on the LED industry and its shortcomings (see Links, p24). *LEDs Magazine* spoke with one of those presenters, Iain Ruxton, design associate at lighting design firm Speirs & Major Associates, to discuss where LEDs are best used, and how the adoption of LEDs into various markets can be accelerated.

How do you view the status of LEDs?

Right now, LEDs in lighting are still a bit of a gimmick. They are popular and used quite widely, but often they're used just because they're a new technology. Sometimes this can be reflected in the marketing approaches of LED lighting equipment makers, which focus on the funky color-change effects that can be achieved rather than addressing the needs of the professional lighting market.

Even so, there are already many examples where LEDs have been used in the retail and leisure markets, and of course we are now starting to see substantial LED installations in architecture.

What is the difference between these markets?

With architecture the projects are usually long-term installations, whereas you can sell LED lighting into retail and leisure markets on the basis of the products being relatively disposable. For example, bars might be completely refitted every two years. In such cases there are no requirements for longevity, and the issue of whether LEDs are really "no maintenance" is largely irrelevant. However, this can mean that lifetime issues are overlooked because they don't need to be addressed.

What are these lifetime issues?

LEDs are often sold as "fit and forget", but this usually means that if the fitting has to be replaced there is no option but to throw the whole thing away. With most other technologies you can just replace the lamp. If LED products can be designed to be more modular, perhaps you could replace the board containing the LEDs but keep the case and perhaps the electronics. Throwing the whole product away doesn't sound good to a customer from either a cost or an environmental point of view.

"If LEDs are going to be a long-term proposition as a serious lighting tool, the industry has to find ways to create longevity, consistency and replaceability."

If, however, you do throw the fitting away, it's not certain that you will be able to replace it with the same fitting, which has the same light output, the same electrical load, and even the same physical size and shape. You could run into problems, for example, just trying to replace a fixture in a recess in a wall, let alone matching the amount and color of light it produces with older adjacent fixtures.

What do manufacturers need to do?

I think manufacturers have to make the units modular and repairable, or they have to make the same products for a long time so that they have the inventory to offer replacements. Unfortunately the rate of technological development is currently preventing this from being a long-term reality – in even five years' time, manufacturers will simply not be able to source the same diodes as they are buying today.

For other lighting technologies things are not moving as rapidly as with LEDs, and there is also a large installed base. LED technology is moving so fast that there's little stability in anybody's product range. Manufacturers of the diodes themselves are still finding their feet and figuring out what products to offer. They need to develop core products, so that customers of original equipment manufacturers can be certain of achieving reasonable lifetimes and product ranges which can serve the marketplace in the long term. If Osram or Philips introduced a lamp this year, sold loads of them, and took it off the market next year, it would cause them some commercial embarrassment.

How do customers view these problems?

It would be interesting to see the reaction if an LED fixture manufacturer were to say, upfront: "Once this product runs out after a certain amount of time, you'll have to throw it away and we don't guarantee to still be making the same product." In the example of the bar that will get refitted within a couple of years, this wouldn't be an issue. On other projects, it's simply not acceptable.

Speirs & Major Associates are currently involved in the project to build Terminal 5 at London's Heathrow airport. The requirement for everything – lighting, mechanical plant and so on – is to have a 25-year design life, which means it will either last that long or that spares will be available ex stock.

Are you using LEDs on that project?

LEDs are not yet mature enough as a lighting product for anyone to meet such requirements, but that's what they must aim for. If LEDs are going to be a long-term proposition as a serious lighting tool, the industry has to find ways to create longevity, consistency and replaceability.

If any LEDs are used at Terminal 5 they will probably be part of the advertising and media systems rather than "architectural" lighting.

What is required in terms of lifetime standards?
LEDs don't fail in the same way as other lighting technologies, so the same definitions are not necessarily relevant. What needs to happen is for the industry to arrive at something consistent and for everyone to agree on it and sign up to it. Then, it needs to be widely publicized so that everyone can understand what information they're being provided with. If it's not the same measure as other technologies, that doesn't matter too much. At least everyone will have something they can work with.

Of course it's vital to look at the whole product. LED manufacturers provide data, then the luminaire maker needs to take that data and look at anything that might affect the performance, such as the thermal system or the driver. Once the LED is inside a luminaire, the data from the LED maker is not necessarily relevant or helpful any more. This doesn't apply to any other type of lighting product – the lamp manufacturer's data is typically going to be correct in anybody's fitting.

Where should people be using LEDs for lighting?
As Kevan Shaw said at the Brussels conference, anyone who specifies LEDs right now is an early adopter. White LEDs are not good for general lighting; many LEDs are required and the spectral distribution is not good enough. However, they are good for certain things, for example for saturated colors, or where small points of light are required. The successful lighting applications for LEDs at the moment are typically more decorative than functional.

What about emergency lighting?
This has great potential, it's almost the perfect application for LEDs. The requirement is for very small unobtrusive fittings that don't consume too much power since they'll be running from batteries in an emergency situation. Tungsten sources consume too much power, while discharge sources take too long to fire up. Fluorescent and compact fluorescent sources are electrically ideal but bulky. A single high-intensity LED might only provide a few lux on the ground, but that's sufficient to meet the regulatory requirements and help people get out of the building. Color quality is irrelevant, as are lifetime issues since the source is used so infrequently.

"If LED products can be designed to be more modular, perhaps you could replace the board containing the LEDs, but keep the case and perhaps the electronics."

Any other compelling applications?
There are some excellent external applications, where fixtures are built into handrails, steps or balustrades – the main benefit is size. Others tend to be marker applications where large amounts of light are not required. Again there are lifetime issues – what happens in 10 years' time, when you have to replace a fitting recessed into the beautifully engineered stainless steel handrail of a bridge? ●

Links

Speirs & Major Associates: www.samassociates.com

On our website
"Brussels conference sprouts better understanding of LEDs" Interaction between lighting designers, luminaire manufacturers and LED suppliers should help the LED industry to focus on its strengths and continue to develop. See www.ledsmagazine.com/articles/features/1/11/7/1.

RETAIL

LED PixeLines illuminate Harrods' windows

Harrods, the world-famous department store in Knightsbridge, London, has benefited from the use of LED lighting fixtures in its display windows, using 26 PixelLines from James Thomas Engineering. The battens run the width of the rear of the windows, washing the back walls and creating an extensive range of colors, from dramatic saturates to delicate pastels. They emit a smooth, uniform coverage up to 3 m high.

The LED fixtures offer considerable improvements compared with the incandescent linear fixtures with color gel filters that they replaced. First is energy savings; the LED battens consume 2.86 kW of electrical power, while conventional lights consume 23 kW. This could save around $40 000 over a two-year period. Also, the LED fixtures produce less heat, which reduces the demand on air conditioning.

Further savings are associated with maintenance and downtime. Color filters absorb white light, allowing only the desired color to pass through, which is extremely inefficient in permanent installations like this, and the gels would have needed to be replaced constantly. The maintenance on conventional 20-cell battens would have included changing around 500 MR16-type lamps as frequently as once every six months. ●

PixelLines create a range of colours. Credit: Mervyn Vincent

● James Thomas Engineering: www.pixelpar.com

LEDs MAGAZINE

Solid-state lighting in the automobile: concepts, market timing and performance

Despite the advantages offered by LEDs in automotive front lighting, the technology should not be considered a "plug and play" replacement for either tungsten-halogen or HID lamps, write **Tom Pearsall**, **Eric Mounier**, **Jean-Christophe Eloy** and **David Jourdan**.

The remarkable improvement in the performance of LEDs is clearly presenting some substantial business opportunities in the car (see Links on p27), but the automotive industry is a demanding customer. Car manufacturers are exerting a strong technology pull both to improve performance and to reduce the cost of optoelectronic components.

Lighting and vision play key roles in the automobile. Most of the information that the driver uses comes through the windscreen of the car as visual data. Additional important information comes from interior lighting and from the instrument panel. Many newer models are also wired with an optical fibre multimedia communications network that links devices such as sensors, radio, DVD player and navigation system.

It is clear that in the context of the automotive industry, which manufactured over 40 million vehicles in 2004, there is a major commercial opportunity for photonic components and systems that meet the performance and cost targets of the car makers. In this article we focus on the situation regarding LEDs for front lighting. The interaction between performance, cost, regulations, and competing technologies gives a good introduction to the conditions that need to be met if LEDs are to become the preferred choice for exterior lighting.

The automotive industry predicts that it will manufacture 60 million cars in 2010. If each car is equipped with 150 high-brightness LEDs (HBLEDs), manufacturers will need to produce more than 10 billion HBLEDs for this application alone. Lighting system suppliers such as Hella and Valeo expect to pay no more than €0.10 per HBLED, making the business worth €1 bn at the component level.

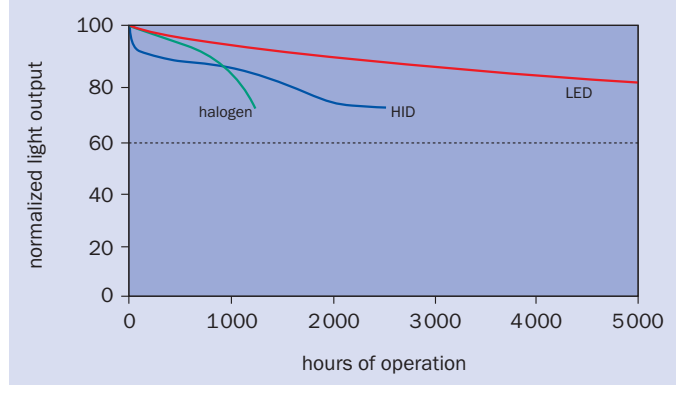

Fig. 1. LED headlamps provide the best technology for maintaining output intensity over time. The average car lifetime is about 5000 operating hours. Credit: Luca Sardi, Automotive Lighting.

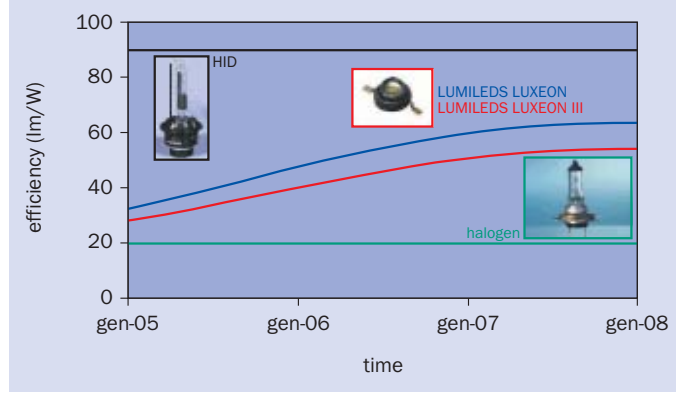

Fig. 2. The efficiency of LED sources is gradually improving, while the efficiency of tungsten-halogen and HID light sources remains constant. Credit: Luca Sardi, Automotive Lighting.

Front lighting

There are three main application areas for front lighting: daytime running lights, signaling units and headlamps. LED solutions have been developed and demonstrated for all three applications. However, only LED signaling units have been widely commercialized. Daytime running lights are available on only a few models, and LED headlamps are still in the development phase.

Three types of component lamps are used in front lighting applications: tungsten-halogen, high-intensity discharge (HID), and LEDs. Tungsten-halogen lamps have the greatest share with about 90% of the market. The HID lamp has about 10% market share and is used most extensively in Japan, with some presence in Europe and almost no presence in the US. LEDs have a long lifetime and high efficiency, and are the performance leader in maintaining output intensity over time (see figure 1).

Headlamp output efficiency is measured in lumens per watt (lm/W), and, as shown in figure 2, the efficiency of LED sources lies

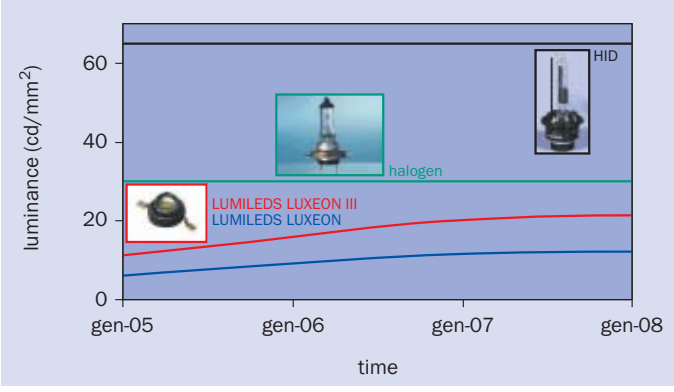

Fig. 3. Luminance output of headlamp sources. LEDs put out significantly less light per unit than either tungsten-halogen or HID lamps. Credit: Luca Sardi, Automotive Lighting.

Fig. 4. The lower output power of LEDs dictates a multi-element headlamp design. Credit: Fausto Bigi and Jean-Paul Charret, Valeo Signals and Lighting.

between that of tungsten-halogen lamps (20 lm/W) and HID lamps (90 lm/W). The most important source of lower efficiency in LED lighting is the package design. Much work still needs to be done to achieve more efficient heat removal and more effective light extraction from the chip. It can be seen in figure 2 that the efficiencies of HID and tungsten-halogen lamps are stationary reference points, while LEDs are improving every year. This trend must continue if LEDs are to be widely used.

Although some properties of LEDs appear to be quite competitive when compared to tungsten-halogen and HID lighting, the output per component still remains relatively low. The output of the best HBLED is only about 10% of that from an HID source and about 20% that of a tungsten-halogen lamp (figure 3).

This does not exclude LEDs from being used, but it does mean that many LEDs will need to be used per lamp. Legal regulations require that headlamps project 300 lm on the road, and HID lamps can project 1000 lm. If LED lamps are going to be used at all, then a headlight fixture will need to contain at least nine LEDs to achieve 300 lm. But to be competitive with HID lighting, each fixture will need at least 30 diodes. Figure 4 shows some proposed designs for this kind of multi-element lamp.

Multiple-element headlights have to meet an additional style requirement: the "white" color for each lamp should look the same. White LEDs use a down-conversion phosphor, and the color-rendering index of the emitted white light varies from diode to diode. Uniform color is obtained at present by discarding the diodes, but this is hardly a high-tech solution. Clearly there is still work to be done on this issue.

Daytime running lights

Daytime running lights are beginning to make an appearance in commercial automobiles following tests which have shown that using these lights can reduce the number of accidents on the highway. The minimum lighting requirement is 30 lm, or 10 times less than the requirement for headlamps, and this level can be reached with only a few LEDs.

Hella has supplied a daytime running light for the Audi A8 model that consists of a cluster of five LEDs (shown in figure 5on the right-hand side). The main headlamp is an HID source (see the left side of the figure). This configuration is a promising example of how LEDs

Fig. 5. LED and HID lamps complement each other in this headlight (left) and daytime running light (right) fixture. The configuration was designed and manufactured by Hella and is installed in the Audi A8 sedan. Credit: Karsten Eichhorn, Hella.

are likely to appear in front-lighting applications. Rather than replacing the HID source, which is a high-efficiency, high-luminance lamp, the LEDs can be used as a complementary source of light in daytime running lamps and also cornering lamps, turning signals and design lighting.

From a marketing and from a regulatory point of view, complementing rather than replacing HID lamps will probably lead to an earlier presence of LED front lighting in commercial vehicles. The LEDs can establish a track record for reliability and performance, and this should then make it easier for them to be integrated into full headlight structures.

Cornering and running lights

LEDs are already used in signal lamps or as a design feature. The compact form of LEDs compared to other lighting sources is a particularly attractive feature for these applications. DaimlerChrysler is one of several manufacturers that are using LEDs for turn-signal indicator lamps, mounted in the rear-view mirror. Luminance requirements are modest and easily met by a few LED chips. The electronics and the space required to implement this functionality easily favor LEDs over other lighting sources.

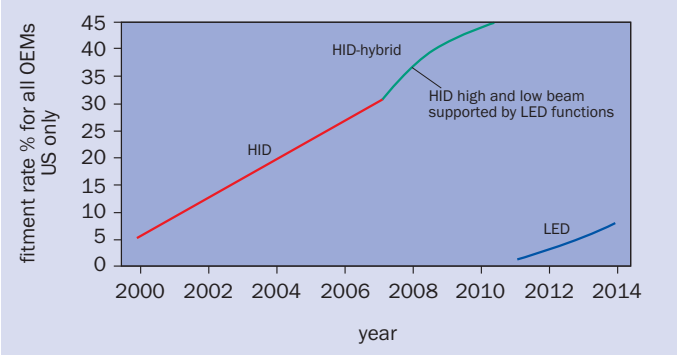

Fig. 6. Two scenarios for introducing LEDs in front lighting. In the hybrid scenario (green) LEDs are used to support HID headlighting functions. LEDs enhance signaling and provide daylight running lamp capability. Regulatory approval is gained gradually. In the second scenario (blue) LEDs are introduced directly in headlighting applications. Solutions to issues like lighting power and thermal management need to be solved first, and regulatory approval must be obtained before commercial application. Such concerns will delay the appearance of LEDs in front lighting by four years compared to the hybrid approach. Credit: Stephan Berlitz, Audi.

Conclusions

The most likely scenario for introducing LEDs in front lighting is an initial use in a complementary function where less stringent regulatory approval is required. Rather than displacing the HID lighting business, which is dominated by Europe and just beginning to gain acceptance, LEDs can be used to enhance and complement these lights. The synergies which will develop through this co-operative activity are likely to benefit both businesses.

A possible co-operative scenario is shown in figure 6. This approach appears to advance the introduction of LEDs into front-lighting applications by four years compared to the scenario where LEDs are used as the sole lighting technology.

LEDs are already present in some front-lighting applications in certain cars. However, the widespread penetration of LEDs into headlights will require some important technology challenges to be resolved. These include increasing the light output per LED, solving thermal management problems on the chip, and achieving uniform color and brightness from one LED unit to another.

Regulatory approval will be needed for LEDs to be introduced into headlight applications. Approval always comes faster when safety advantages can be proven, and this avenue has been exploited skilfully for the daylight running lamp application. These considerations emphasise that the LED is not a "plug and play" replacement for either tungsten-halogen or HID lamps. Using LEDs will require design changes in both the "look" and the operation of the car. Of course, this is not necessarily a drawback. Many of these design changes will enhance both the appearance and the performance of the car.

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Links

EPIC: www.epic-assoc.com
Yole: www.yole.fr

EPIC and Yole Développement have completed a study entitled *Photonics in the Automobile*, covering the opportunities for innovations in lighting, displays and sensors in the car. To find out more, contact David Jourdan (jourdan@yole.fr) at Yole.

On our website
Vehicles channel: www.ledsmagazine.com/articles/features/1/5/4/1.

"Visteon LED innovations improve automotive visibility"
Automotive lighting suppliers such as Visteon are working towards all-LED solutions for automotive lighting. See www.ledsmagazine.com/articles/features/2/3/3/1.

"LEDs for heavy trucks and commercial vehicles"
The proportion of LED lamps used in commercial vehicles continues to increase and LEDs will largely replace incandescent lamps in a few years' time. See www.ledsmagazine.com/articles/features/2/2/4/1.

Click-in track spotlights illuminate cabinets

Crescent Lighting

This new miniature track system is designed for use in cabinets and display areas. The track has a click-in system (patent applied for) comprising sockets and jack plugs, allowing spotlights to be added at regular intervals along the track as required.

The maximum number of spots is determined by the power supply, which provides a constant 350 mA to each of the LEDs in series.

www.crescent.co.uk

High-power device can operate at up to 185 °C

Lumileds Lighting

A new version of the Luxeon high-power LED, which is scheduled for summer release in white and seven colours, should allow operation at a junction temperature of up to 185 °C, following a complete redesign of the package.

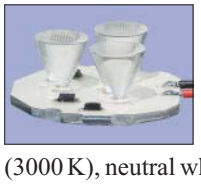
The product should simplify and reduce the cost of system thermal designs, lowering total-solution costs as well as reducing the size of the required heatsink. In addition, the allowable drive current will be increased to 1500 mA with 130 lm of light output, thereby further reducing the cost per lumen by delivering more light from the same package.

Lumileds says that the new Luxeon can be mounted on an FR4 PCB and driven at 400 mA in an ambient environment of up to 40 °C without a heatsink.

www.lumileds.com

White LEDs come with varied phosphor doses

Tridonic.Atco



The powerLED range of white LEDs is available in three colour temperatures. These are warm white (3000 K), neutral white (4200 K) and daylight white (6500 K).

Tridonic has developed a manufacturing technique that accurately measures the wavelength of the LED chip and then adds a precise and individual amount of phosphor to ensure colour consistency from device to device. The company claims to be unique in calculating the phosphor dosing for each LED and says that different batches are guaranteed to offer the same colour temperature, so there should be no need for customers to keep a record of bin numbers.

The P212 chain consists of five 18 × 10 mm modules each containing a 1 mm^2 high-power LED, providing 30 lm per module. The P213 spotlight contains three 1 mm^2 high-power LEDs mounted on a 30 mm diameter board and providing a total luminous flux of 90 lm. Specially developed 8 mm high lenses with beam angles of 10° or 40° can be mounted directly above each LED to provide a homogenous white appearance.

Tridonic says that the use of metal-core boards has resulted in improved thermal management and that the lifetime of the products is 30 000 h.

www.tridonicatco.com

Lighting system offers look of exposed neon

GELcore, LLC

The Tetra Contour LED Lighting System is made to resemble and replace exposed neon in a variety of signage, architectural and accent-lighting applications.

The system provides the appearance of neon as well as light output comparable to that of neon. It offers robustness, low-voltage operation, long life, unmatched cold-weather operation, and ease of installation and maintenance. Cool to the touch, the system also provides a bright, uniform appearance and a wide viewing angle.

The weather-resistant system comprises a rigid, optically diffuse extruded-plastic light guide (8 ft lengths) that can be heated and formed in a shop or on the job site, and a flexible GELcore LED light engine (also 8 ft lengths) that fits snugly inside the guide.

Installation of the two-part TetraContour LED Lighting System is fast and simple – installers use standard neon mounting hardware and GELcore accessories (light-guide connector, end cap and light-engine splice connector) to create a neat, finished appearance. Current colors are red and red-orange, with amber, blue, green and white available later in 2005.

www.gelcore.com

Family of emitters break lumen records

Lumileds Lighting

New Luxeon III high-power LEDs offer 110 lm for amber, 140 lm for red and 190 lm for red-orange. Available immediately, the new emitters offer 50% lumen maintenance at 20 000 h of operation at a 1400 mA forward current.

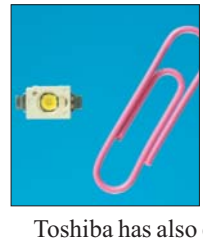
Lumileds says that in the automotive market the new products will enable a single LED to power stop lamps, rear combination lamps and rear fog lamps. This will lower system costs by allowing simpler optical designs and less costly packaging, and it will also reduce space requirements.

The emitters will also be useful for power signaling for traffic, airfield and marine navigation systems; strobe and warning lights for municipal and construction vehicles; marker lights for aircraft exteriors; architectural lighting, particularly in pools and spas; and machine vision systems used for quality assurance in manufacturing.

www.lumiledsfuture.com

Low resistance results in higher luminosity

Toshiba



A new white LED, TL10W02-D, has a luminosity of 60 lm at approximately 2 W (500 mA), thanks to a low-thermal-resistance package.

Toshiba has also enhanced the optical efficiency of its package by optimizing the design of the reflector. The company will ship samples from July, with mass-production starting in October at an initial volume of 1 million units per month.

The 30 lm TL10W01-D will be sampled from June and mass-produced from July, in similar volumes. Both new LEDs come in a

compact package measuring 10.5 × 5.0 × 2.1 mm, with lead-free reflow soldering. The chromaticity co-ordinates of both devices are C*x*: 0.33 and C*y*: 0.32. Samples of Toshiba's TL10W02-D and TL10W01-D white LEDs cost ¥700 ($6.50) and ¥500, respectively.
www.toshiba.co.jp

Ultra-thin marker lights are ideal for flooring

Eyeleds

A range of LED marker lights has been specifically designed to be integrated into all types of flooring.

The key feature of these lights is their ultra-flat construction, with a recess depth of only 6.5 mm. The circular lights contain three SMD devices. Square fixtures containing four LEDs are also available.

Eyeleds are dust-proof and water resistant with an IP67 rating, and they have a solid walk-over construction that is capable of handling loads of up to 285 kg.
www.eyeleds.com

Drivers serve needs of large color displays

Texas Instruments

Two 16-channel, constant-current sink LED drivers support complex power requirements in large form-factor color displays.

The drivers give designers increased system reliability and dynamic brightness control to enhance both resolution and power efficiency.

Each channel on the TLC5940 has an individually adjustable 4096-step grayscale pulsewidth modulation (PWM) brightness control and a 64-step dot correction that allows the display to select from up to 68.7 billion colors to enhance color resolution. Dot correction on the device compensates for the brightness variations between individual LEDs in the system.

TI also offers a more cost-sensitive TLC5923 driver without grayscale PWM functionality. The TLC5940 is available in a 28-pin HTSSOP, PDIP or small QFN package, and the TLC5923 comes in a 32-pin HTSSOP package. Suggested resale pricing in quantities of 1000 is $2.90 for the TLC5940 and $1.90 for the TLC5923.
www.ti.com/sc05076

Thermal management maximizes output

Harvatek

The HarvaLED HT-PX76 and HT-PX78 series are available in three watt sizes.

HT-P176TW and HT-P178TW are 1 W, white LED devices that deliver a typical output of 30 lm at 350 mA. HT-P276TW and HT-P278TW are 2.5 W devices that deliver 60 lm at 700 mA. HT-P376TW and

HT-P378TW are 3.5 W LEDs that deliver 100 lm at 1.05 A. Harvatek has licensed its white-LED technology from Osram Opto Semiconductors.

Both HT-PX76 and HT-PX78 packages feature an integrated thermal management design that allows maximum luminous output over time. HT-PX78 is only 3.30 mm thick, while HT-PX76 includes a lens that collimates the light output. Both packages are fully surface-mountable and comply with industry lead-free initiatives.

Conventional LEDs typically require an external lens or optics to achieve a performance similar to that achieved by HarvaLED products, which have a thermal resistance of 22 °C/W.

www.harvatek.com.tw

High-brightness unit is supremely compatible

Edison Opto Corporation

Edi-Power, an ultrahigh-brightness LED light engine, is available with powers ranging from 5 to 40 W with either monochrome or RGB output.

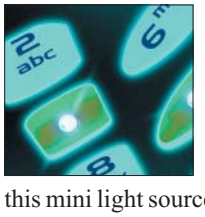
The 1200 lm output of the 40 W instrument is suitable for general illumination, and its small dimensions allow it to be compatible with any kind of lighting application.

In 2004, Edison Opto successfully developed the Edixeon series of high-power 1 and 3 W LEDs. The 1 W Edixeon provides 60 lm and is available in varied colors and emitting angles from 60 to 160°.

www.edison-opto.com.tw

Small PointLED source offers high efficiency

Osram Opto Semiconductors



The 2 mm diameter PointLED has an efficacy of 38 lm/W. The package is round and flat, measuring only 0.775 mm high, so this mini light source can be sunk completely into the printed circuit board. It is ideal for applications where space is at a premium, such as low-profile backlighting.

The typical brightness of the miniature white LED is 800 mcd at a beam angle of 120°. The high efficiency of the LED results from the use of a ThinGaN chip produced using Osram thin-film technology.

Osram Opto says that the PointLED is the smallest LED with an integrated reflector and is suitable for both surface mount technology and zero height mounting.

www.osram-os.com

Low-profile devices fit into crowded PCBs

LEDtronics

Series SML070 LEDs have a footprint of only 2.4 × 3.3 mm, which is ideal for placement on a printed circuit board (PCB) where components are densely packed.

Single-colored LEDs currently available are yellow (590 nm), green (570 nm) and red (620 nm), all with clear lenses. Bicolor LEDs come in green-red with a milky-white lens. Depending on the color, luminous intensities range from 1.2 to 2.3 mcd at 20 mA current.

The Series SML070 LEDs can be used with LEDtronics OptiLED light pipes to simplify the spatial relationship between the PCB and the remote indicator illumination points. Light pipes channel all of the LED-generated light to the exact location where the light is required.

Series SML070 LEDs cost $0.95 each for single color and $1.42 each for bicolor.

www.ledtronics.com

Pair of three-pin LED driver ICs save space

Supertex

The HV9921/22 family allows for the high-efficiency driving of low-current LEDs in signage or general lighting applications.

The regulated LED current is internally fixed at 20 mA for the HV9921 and 50 mA for the HV9922. The drivers have an operating range of 20–450 VDC, which allows for universal AC input operation of 85–265 VAC.

The HV9921/22 is a PWM controller and driver IC used in a buck (step down) converter topology. It utilizes peak current-mode control to allow ease of use, requiring no compensation. It also uses fixed off-time operation of the MOSFET, which allows the HV9921/22 to drive LED string voltages to approximately 80% of the input voltage.

In a space-saving three-pin TO-92 or SOT-89 package, HV9921/22 requires a small circuit board area with very few external components.

www.supertex.com

Compact stud bumper breaks speed record

Kulicke & Soffa Industries

The K&S ATPremier wafer level stud bumper is ideal for LED flip chip applications. The machine, which is rated at 30 AccuBumps per second and 36 Standard bumps persecond, is the fastest stud bumper currently on the market.

Matched with the smallest footprint, the ATPremier maximizes its use of resources and cleanroom space. Stud bumping on the ATPremier is flexible enough for rapid prototyping and is scalable for production.

Operators can create new bond programs using Circle Teach and Step-and-Repeat features. A flexible wafer-mapping interface enables bumping of known good die.

A major benefit of stud bumping technology is that it does not require under bump metallurgy and bonding can be completed at much finer pitch than with solder. The speed and superior technological capabilities of the ATPremier contribute to its low cost of ownership.

www.kns.com

Module provides light in case of emergency

ETAP Lighting

The K9 LED module and luminaires are designed to provide anti-panic and escape-route lighting in the event of an emergency.

The luminaires are surface mounted or recessed, while the single-LED module is designed to be unobtrusively built into an existing lighting luminaire. For anti-panic lighting, a specially shaped lens spreads the light and provides 0.5 lux over an area of 81 m^2 from a mounting height of 3 m. For escape-route lighting, a reflector in combination with a lens enables 1 lux to be achieved with a spacing of up to 11 m (for the same mounting height).
www.etaplighting.com

Recessed luminaires offer range of shapes

Advanced Fiber Optics

The Lofoten Collection of outdoor lighting products includes square, circular, linear and triangular models.

The latter two are designed as in-ground pavers, while the former two can be recessed into surfaces, mounted on surfaces as cubes or mounted on top of bollards. The in-ground luminaires feature 2 cm thick glass and can withstand heavy traffic. They also have an IP68 rating. All of the luminaires incorporate SMD LEDs and work from a 10 V power supply.
www.lofoten-collection.com

LEDs are safer option than traditional flares

Keystone Group

Incendiary flares, which are found in many roadside safety kits, have burn temperatures of 5000 °C and an ingredients list full of toxic chemicals.

FlareAlert, a battery-operated electronic safety flare, contains 12 high-output LEDs and is crush resistant. It has a built-in magnetic base, allowing it to be mounted on a vehicle in case of an accident, or on a mailbox when emergency personnel need to find a house quickly.

One FlareAlert will burn for as long as 80 incendiary flares before needing new batteries, making the operating cost just 3c per hour, compared with the average cost of incendiary flares, which is $4 per hour.

The product is currently available in red; blue, green, yellow and white versions will be available later this year.
www.flarealert.com

Fanless video screens keep the noise down

Lighthouse Technologies

Two new fanless 10 mm pixel pitch indoor LED video screens, the P10 and R10, have been created for environments where noise levels need to be kept to an absolute minimum, such as concerts, corporate lobbies, studios and broadcast events.

Designed for permanent installations, the P10 is lightweight for ease of installation, weighing only 9.6 kg. The R10 rental product features a fast rig single kingpin design for quick set-up and strip-down of the screen.

Both models have been designed for easy maintenance with a clip-on intelligent module feature, which provides screwless maintenance on LED modules and ultra-low power consumption of 100 W/panel (average power consumption) at 2000 nit brightness. Other features include a 140° horizontal and vertical viewing angle, 10 000 pixels/m^2 and a lifetime of 50 000 h to half-brightness.
www.lighthouse-tech.com

High-power RGB LEDs can be driven harder

Marktech Optoelectronics

The LP6-TPP1-01 six-lead, RGB product features a 120º viewing angle in a 6.0 × 5.0 mm surface-mount package that's been designed specifically for accent and color-changing lighting applications.

The device can be tightly arranged on a single plane, which results in an even distribution of color and light. It features close chip density and brightness for excellent color mixing. The unit's six-pin SMT package allows for the individual control of each red, green and blue chip, allowing users to produce a complete color spectrum to help to achieve specific and more uniform lighting architecture.

The LP6-TPP1-01 offers a low thermal resistance of 130 °C/W for increased package efficiency and improved heat dissipation, allowing the LED to be driven up to three times as hard as a standard full-color SMT package.
www.marktechopto.com

Modular optical array shapes beams of light

Optiled

Each hexagonal High Intensity Vorticular Enclosure (HIVE) contains three high-power LEDs, one in each primary color.

The units have a simple slot-in design and can be assembled into a variety of shapes and sizes, with each unit passing power and data to the other units. In the event of failure a single module can be replaced. The S-7 unit contains seven HIVE modules within a water-resistant housing and it creates a beam of light that can be shaped with any of six diffusion optics.
www.optiled.biz

Durable stage lighting comes in many colours

Coemar

Riga LED provides an efficient and reliable solution for stage lighting (film sets, TV studios, theatres) and architectural applications. The glazed aluminum LED bar houses a powerful light source (300 LEDs/m, 100 for each colour) with almost unlimited durability.

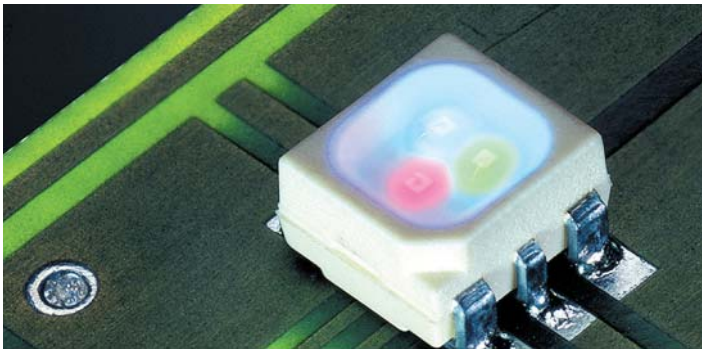
Riga LED is available in two lengths (0.5 and 1 m) with symmetrical (projection angle 74°) or asymmetrical (96°: 56° + 40°) parabola. The asymmetrical version is able, from a distance of only 2.5 m, to provide large-scale stages and backdrops with light of outstanding quality and an infinite variety of colours, including white, with colour temperature correction, thanks to the variable intensity of the RGB component.
www.coemar.com

LEDs MAGAZINE

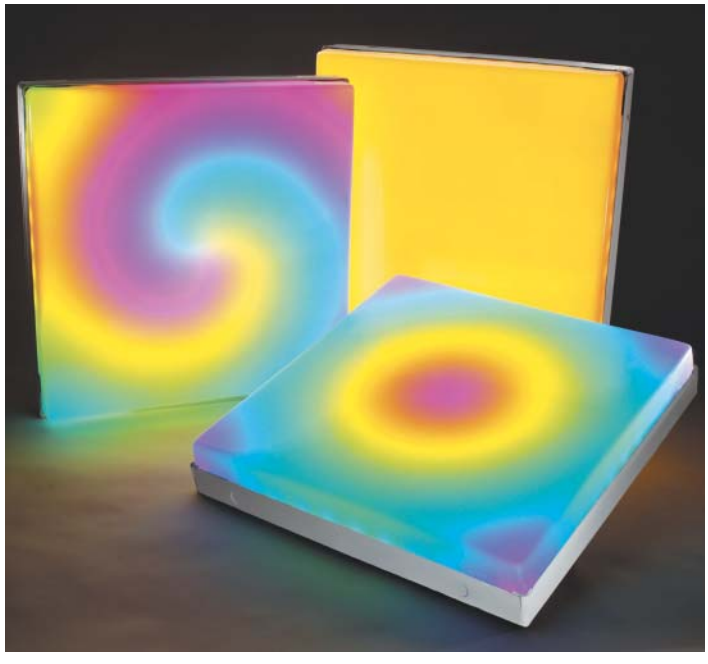
Technology and applications of light emitting diodes

LEDs Magazine provides a unique resource for the LED industry, combining technical articles, case studies, interviews and conference reports with news, product and event information and technical resources.

It is designed for individuals who are involved in the specification, design and manufacturing of LED-based products for a wide range for end-use applications.



Osram Opto Semiconductors



Color Kinetics

LEDs Magazine is an electronic publication comprising:

- **a website** (www.ledsmagazine.com)
  Send news & product information, or submit a free company entry in our Buyer's Guide
- **a FREE weekly Email Update service**
  Sign up for a free subscription via our website
- **a quarterly electronic magazine**
  Download the launch issue from our website

In-depth editorial coverage

LEDs Magazine is the only publication providing dedicated, in-depth, technical coverage of LEDs and their applications.

- **Technology**
  White LEDs & color mixing, drivers & control, packaging & optics, high-power LEDs, testing & standards, patents, modules & arrays...and more
- **Applications**
  Solid-state illumination, architectural lighting, displays, signals, automotive lighting, mobile appliances, machine vision, medical...and more

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LEDs – Lighting the Way Forward!
20–21 April
Birmingham, UK
Organized by Photonics Cluster (UK), in association with *LEDs Magazine*, this is a follow-up to last year's highly successful two-day LED seminar. This year the focus is on technology and applications of LEDs, and will bring together leading manufacturers, component and equipment suppliers, lighting designers and major end-users to discuss the latest opportunities and advances in LED technology.
www.ledsmagazine.com/articles/news/2/3/18/1

LED Lighting Institute
27–29 April
New York, USA
At the Rensselaer Polytechnic Institute's LED Lighting Institute, lighting research experts will help you learn more about this quickly evolving lighting technology in a small-class setting. You will learn how to incorporate LED technologies into the design of architectural lighting fixtures, how to develop optical components that will best take advantage of the small size and compact beam spread of LEDs, and how to design lighting applications using LEDs. You will also be able to compare LED technologies from various manufacturers and learn about operating characteristics, average-rated-life, lumen output, and other specification factors.
www.lrc.rpi.edu/education/outreachEducation/LEDInstitute.asp

Right Light 6 / ILE China 2005
9–11 May
Shanghai, China
Right Light 6 is the Sixth International Conference on Energy-Efficient Lighting, held for the first time outside western Europe. The event is organized by the International Association for Energy Efficient Lighting, in association with the internationally supported China Greenlights Project.
ILE China 2005 is the annual exposition and trade show of the China Association for the Lighting Industry.
www.ilechina.com/english/index.htm

Blue 2005 / Advanced LEDs
16–18 May
Hsinchu, Taiwan
The third international industry review for LED technologies driving the solid-state lighting revolution.
www.blue2005.com

World Light Show 2005 (part of INTEL)
17–21 May
Milan, Italy
Major European lighting trade show.
www.intelshow.com/fi/sezioneintel05/1,4959,e|WLS,00.html

International LED Expo 2005
25–28 May
Kintex, Korea
The event combines an exhibition with an LEDs seminar.
www.ledexpo.com/eng/expo/welcome.asp

Workshop on Building European OLED Infrastructure
6–7 June
Cambridge, UK
Europe is playing a unique role in the development of OLEDs and the enabling technologies that are necessary to manufacture OLED displays panels on a commercial basis. The workshop will focus on the business case for a sustainable European OLED industry.
Spie.org/events/eol

LED Lighting Taiwan 2005
8–11 June
Taipei, Taiwan
Part of Photonics Festival 2005, which incorporates the Opto Taiwan event as well as FPD Taiwan and OptoCom Taiwan.
www.optotaiwan.com

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

PLASA 2005
11–14 September
London, UK
If you work professionally with lighting, sound, rigging or staging, then PLASA 2005 is a key event. The show attracts visitors from all over the world and is Europe's definitive exhibition for professionals and decision-makers within the entertainment, event, corporate, architectural or installation industries.
www.plasashow.com

Light Emitting Diodes 2005
17–19 October
San Diego, CA, USA
The show will feature more than 25 expert speakers, a panel discussion, and an exhibit area. It will bring together key users, component suppliers, and manufacturers of high-brightness LEDs. Participants will receive a thorough assessment of LED markets, while having ample opportunity to discuss industry issues and network with experts, key LED executives and end-users in a three-day open-forum format.
www.intertechusa.com/conferences

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

DECORATIVE

Ambisol lights up film company headquarters with LED panels

Slablight from Ambisol is available in panels up to 3 m high.

Ambisol Signage and Lighting has installed its Slablight LED lighting system in the London headquarters of a global media and film company. Thanks to a unique light-distribution technology and specially designed optics from Polymer Optics, Slablight provides up to 120 cd/m^2 without hotspots or darkspots over panels up to 3 m in height. The system is 30 mm thick for white and single colours, and 100 mm thick for RGB. In this application, Ambisol manufactured and installed separate 11 m and 3 m runs of 1.2 m-high wall, all within a four-week period, after the previously proposed lighting system was deemed too heavy to be supported by the existing floating floor.

- Ambisol: www.ambisol.co.uk
- Polymer Optics: www.polymer-optics.co.uk

ARCHITECTURE

Largest LED building lighting scheme is complete

The new $53 m headquarters building for the Public Institute for Social Security (PIFSS) in Kuwait is at last fully operational. The project, described by Kevan Shaw Lighting Design as "the world's largest LED building lighting scheme", uses nearly a quarter of a million LEDs in 800 fittings distributed around the edges of the building. LED lighting products from Super Vision, TIR Systems and Color Kinetics were used on the project, which is controlled by an Expression 3 lighting control console from ETC.

- Kevan Shaw Lighting Design: www.kevan-shaw.com

SIGNS

CAO Group exhibits bus stop signs for 2008 Beijing Olympics

At the recent International Sign Expo in Las Vegas, CAO Group (see p12) exhibited bus stops that will be installed in Beijing, China, in time for the 2008 Olympic Games. The equipment features RGB and white backlighting illumination, as well as LED alphanumeric displays.

- CAO Group: www.caogroup.com

SPORT

LEDs transported to Australian games in Queen's Baton

In preparation for the 2006 Commonwealth Games in Melbourne, the Queen's Baton, containing an array of 200 LED indicator lights, is being relayed throughout all 71 Commonwealth countries before ending up in Australia. The LEDs perform a sequence of visual effects during exchanges in the relay. The baton was designed and manufactured by Melbourne-based Charlwood Design.

- www.melbourne2006.com.au