

# LED workshop identifies business and technical opportunities for Europe

A recent workshop allowed industry experts to discuss opportunities and challenges facing the LED marketplace, writes EPIC's Tom Pearsall.

A recent workshop organized by the European Photonics Industry Consortium (EPIC) brought industry experts together to identify challenges that need to be addressed by stakeholders in the European LED industry. The Workshop on LED Manufacturing for Lighting & Displays was held in Berlin, Germany on September 10-11, 2007. To support the widespread adoption of LEDs in general lighting applications, the LED industry must be able to generate revenues and profits to support the R&D required to improve LED performance and reduce costs. Significant advances in performance will be needed to realize these expectations, as follows:

- Output of a single white LED to exceed 200 lumens
- Radiant conversion efficiency to exceed 150 lm/W
- Luminescence greater than 50 Mcd/m<sup>2</sup>
- Lifetime greater than 50,000 hours
- Integration into large-area panels
- Integration with driving electronics
- Resistance to harsh weather conditions

## Performance improvements

The synthesis of LED materials is well-advanced and has already produced LED chips with near 100% quantum efficiency. Further improvements in performance must come from innovations in color quality, and thermal and optical performance. For color quality, areas such as phosphors, down converters, and color rendering are all important. Lifetime, packaging materials and processes and thermal management all require further innovation, and the same applies to reflector designs, optics, and designs for 3D imaging, beam steering and adaptive optics.

Lowering the cost of production will be the key driver for every application. Production yields for white LEDs with specified color temperature, output power and forward voltage are low, and currently binning has to be used to create useable product inventories. Added value can be gained by integrating LEDs into more complex systems such as arrays, panels, or more complex arrangements. Innovations at this system and sub-system level are vital to maintaining such advanced technology and manufacturing in Europe.

## Market sector development

Major markets for LED lighting in 2012 will be automotive lighting, architectural lighting and backlighting of flat panel displays (see chart). Research shows modest growth for general lighting with LEDs due to the aggressive installation of compact fluorescent lamps (CFLs) in place of incandescent bulbs in many lighting applications. New and popular applications and luminaires require LEDs would need to be developed to change this picture.

Lighting an automobile uses petrol. In 2006, 200 billion liters of petrol were burned just for lighting in cars. This amounts to 1 million barrels of

oil every day, and half of this amount could be saved by moving to high-efficiency lighting. Approximately 50 million cars were manufactured in 2007, and a substantial proportion of the world's automobile inventory will be replaced by 2012. Deployment of LEDs in front lighting will be widespread by this date.

LEDs are well-suited for architectural lighting, enabling energy-efficient generation of both colored and white lighting with excellent directional control. There will be competition between discharge lamps and LEDs only for high-color-temperature white. In all other situations, lighting solutions by LEDs have significant advantages over other known light sources.

LEDs will displace fluorescent lamps for flat-screen backlighting. While the energy consumption of the two approaches is similar, LEDs have acceptably low levels of hazardous materials, while fluorescent lamps contain undesirable levels of mercury. Environmental pressure to ban mercury altogether will stimulate fluorescent manufacturers to consider other, less satisfactory metals which lead to lower light output efficiency, at higher cost, and with some environmental impact.

## Workshop objectives

Oral and poster presentations at the workshop gave an overview of both opportunities and challenges facing the LED and solid-state lighting businesses. Several break-out sessions were held, and the debate in these groups developed conclusions and recommendations that are anticipated to influence directions in business and technology development. The goal of the workshop was to answer the following questions:

### 1. How can companies make money with LEDs that have nearly infinite device lifetime?

The break-out groups explored business models that are appropriate to LED lighting, and determined that the use and commercial appeal of LEDs is not strongly lifetime-dependent. Instead, the value proposition of LEDs is based primarily on style and performance rather than lifetime. Customers will purchase new products based on LEDs (for example an LED beamer integrated into a mobile telephone) in order to use the capability, and they will discard the product when a new and improved version becomes available. In comparison, the market for incandescent lamps is almost entirely based on replacement of burned-out light-bulbs, and is highly dependent on lifetime. Therefore, the business models for LEDs and incandescent lamps are very different.

The development of standards for these new applications is seen as enabling. Standards for lighting applications are needed as a basic point of departure, and will be an important part of building market volume and lowering costs in more complex systems employing LED functionalities.

## 2. What are the key patents that can enable long-term presence in the LED business?

Patents are an important way to control intellectual property diffusion. In the past, patents have been a crucial barrier for companies seeking to enter the field. Since 2000, licensing has been the rule in the LED industry. The annual expenditure on filing and maintaining patents for any of the major LED makers is a multi-million euro expense. Licensing is a way to cover some of this expenditure.

The value of patents is greatest when the development time is long (i.e. greater than 10 years), for example in the pharmaceutical industry. In the electronics industry, where product lifetime is short (i.e. less than 5 years), the value of patenting is less clear. It may make more sense for companies to keep their developments and know-how as company secrets. Phosphor development is longer term, and aspects may be suitable for patent protection, while LED device developments are short-term and might better be protected by a company secrets policy. A patent survey of 2004 supports this analysis, showing that the largest sector for patent filings occurs for the chromophore chemicals being developed for OLEDs.

## 3. Will warm-white solid-state lighting come from RGB LEDs or from combining blue LEDs with a phosphor?

The working group emphasized that the choice will be made by consumer preference. Consumers in the domestic market show a strong preference for the lowest cost of acquisition, while businesses will pay more attention to the total cost of ownership. The RGB solution is more complex and the acquisition cost is higher, but it permits complete control of the color temperature over the lifetime of the luminaire. The blue LED + phosphor approach is lower cost and simpler to implement, and appears to be the preferred solution for general lighting.

A third solution is UV LED + multiple phosphors, where the UV light is completely converted to visible radiation by the phosphor. Hence, any change in the LED emission wavelength does not affect the color temperature, which is completely determined by the phosphor properties. At the present time UV diodes show lower efficiency than their blue counterparts. Some skepticism was expressed that UV LEDs can be improved further without substantial R&D investment. On the other hand, there is a much larger choice of suitable phosphors, and these could give access to a wider and more controllable range of color temperature for white LEDs.

## 4. What light sources will be used for projection displays: LEDs, lasers or plasma lamps?

This question was considered in the context of several application sectors: rear-projection TV (RPTV), integrated micro-projection systems, portable batter-powered projectors, desktop projection systems, portable battery-powered projectors, desktop projection systems for business, and laser-based large-screen detectors. LEDs can only find applications in the first three, while lasers can be used in all applications sectors, but cost is an important factor.

Laser-based RGB displays are under development in the laboratory. The major hurdle is developing a compact and low-cost green laser. At the present time the only viable solution appears to be frequency-doubling. Quasi phase-matching is used to create efficient and practical frequency-doubling components.

The most significant market opportunities appear to be integrated micro-displays. To be successful, these must be affordable units, for example no more than the cost of an i-Pod music player. Product volumes will have to be very high, but the market volume could exceed 5 billion euros. The second promising market opportunity is for large-scale laser displays to implement digital cinema. Digital cinema would enable a revolution in marketing and distribution of video products. Market volume could exceed 10 billion euros.

## 5. Is binning part of a realistic mass manufacturing process?

Binning is a way of sorting nominally identical LEDs into performance categories based on color coordinates, power, flux and voltage. All manufacturers use binning during production, and their binning parameters are different. Binning means that lots with particular properties can be sold at a premium, while other, less-desired lots are sold at reduced prices.

Binning is required because there is uncontrolled variability in the wavelength of blue LEDs and uncontrolled deposition properties of yellow phosphors. It is reasonable to expect continued improvements in wavelength control. During the last 5 years the wavelength spread across a typical LED wafer has decreased from 20nm to 5nm, but more improvement is needed.

Philips Lumileds has recently introduced the Lumiramic process, in which the phosphor is manufactured and characterized as a separate component from the blue LED. The phosphor component can be selected to compensate for the variation in blue wavelength. When the two are combined to make a white LED, the resulting range of color temperature can be significantly reduced. These improvements will help to reduce the bin size by limiting the color coordinates of the bin.

Standardization procedures need to be introduced in measurement and characterization under manufacturing conditions and the binning structure for color temperature, power, forward voltage and wavelength (for colored LEDs). The standards will be developed by customers. In the automotive lighting market for white LEDs, the principal customer is Audi. Since Audi cannot impose standards on its own, the development of standards will have to wait until other competitors contribute to automotive front-lighting product offerings.

