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Introduction

The revolution in automotive vision systems continues today at a furious pace, driven not only by safety and design, but innovation across the wider photonics arena. Today the sector can be seen to include not only lighting as we conventionally understand it, but also a wide range of technologies designed to enhance the visual information conveyed to the driver. This might range from including illumination through infrared sources as an integral part of driver assistance systems to the enhancement of head-up display information. Automotive lighting has moved a long way from simple incandescent and gas discharge based light sources in the search for solid-state technology in the form of light emitting diodes (LEDs) and organic light emitting diodes (OLEDs) and laser technology, and much of this progress can be attributed to the pace of scientific innovation in materials technology.

For instance the price of LEDs has come down rapidly over the past three to five years, and this trend is expected to continue over the next couple of years until LED lights reach a true mass adoption cost. Essential research into better materials is crucial for reaching this price goal, but beyond that, advances in materials will also broaden LED consumption through improved performance in terms of brightness, lifetime (concerning brightness and colour maintenance), and colour homogeneity or colour rendering. Some of the main challenges are being addressed by innovative materials research.

Perhaps the biggest burden facing LED makers is a property referred to as droop: a curious performance glitch that causes an LED’s efficiency to decline as the current that passes through it is increased.

Materials that promise to alleviate the problem are semipolar GaN (gallium nitride) and nonpolar GaN. The hope is that these substrates will enable improved efficiency under typical (>350 mA/mm²) or higher-power conditions and result in a significant reduction in the overall cost of light.

“It is essential to eliminate or minimize droop so that LEDs can be operated at high current density, so that fewer LEDs are needed per package. This ultimately drives down the dollar-per-lumen value,” commented Dr. Bedwyr Humphreys, chief technology officer at Seren Photonics of Bridgend, Wales. “Semipolar and nonpolar materials also have the potential to enable new devices such as GaN VCSELs [vertical-cavity surface-emitting lasers] and normally off GaN HEMTS [gallium-nitride-based high-electron-mobility transistors].”

New phosphor materials, specifically, narrowband reds, will be needed to derive the same performance when increasing the CRI (colour rendering index) to 90, according to Dr. Jy Bhardwaj, senior vice president for research and development at Philips Lumileds.

For performance enabling greater than 10% efficacy improvement at the same CRI, Bhardwaj said that new narrowband red phosphor materials would be needed.

Furthermore, LEDs are subject to Haitz’s Law, which is something like Moore’s Law, in that it states that every decade, the cost per lumen (unit of useful light emitted) falls by a factor of 10, the amount of light generated per LED package increases by a factor of 20, for a given wavelength (colour) of light. Haitz’s Law predicts an exponential improvement in the semiconductors used in LED technology.

With current LED performance nearing or surpassing that of most traditional light sources, LEDs are now addressing most lighting applications (indoors, outdoors, transportation vehicles and so on). However, changing the existing installed base is costly – one reason every application is not rapidly changing to LED.

“Automotive headlights have [been] the last automotive application to transition to LEDs,” Bhardwaj said. “High-power, high-luminance LEDs are now being designed into luxury and midrange vehicles, and new technologies and materials will expand this to the high-volume entry-level vehicles sector in the next few years.”

The industry-wide move to solid-state light sources brings a number of clear advantages, not least a significant reduction in energy use. Illumination has accounted for a significant proportion of energy use, and a 50% reduction by 2025 over 2005 through solid-state light sources is a significant achievement. Within the automotive sector solid-state light sources allow an overall reduction in CO₂ emissions, and light sources have a significantly longer working lifetime. Beyond the
LED and, now close to production, OLED light sources that are being incorporated in vehicles today, new light sources in development include digital micro-mirror devices (DMD) and laser technology.

Although reducing CO₂ emissions is a key goal in automotive development today, lighting has equally been a focus of intense development for reasons of product differentiation. Led by the European OEMs there has been a revolution in optics and photonics that allows unique design elements. Signature shapes and designs for both rear and front lighting including daytime running lights have become a feature for a wide range of OEMs.

In addition to energy and design benefits, vision technology has become an integral component of driver assistance systems, promoting a safer driving environment altogether. Innovations such as curve adaptive lighting (CAL), progressive bright light warning systems (PBLWS), vision enhancement systems (VES) which utilise a wide range of illumination wavelengths into the infrared and ultraviolet, and active and passive night vision systems (NVS) all have a part to play in making the driving environment safer.

Figure 1: Hella ambient lighting in the new BMW X5

Source: © Hella KGaA Hueck & Co.

An important contribution to product differentiation can also be made by interior lighting that can enhance the ambience of the driving experience, and even go as far as altering the interior illumination for a number of given scenarios.

An additional feature of the new design freedom within the lighting sector is the ability to offer customer choices in headlights systems, or indeed interior or rear lighting systems if appropriate. The ability to offer more sophisticated lighting systems, improved design features and driver assistance system integration brings additional value to the lighting sector. Headlights and indeed being able to see forwards, rear lights and indicators showing position or indeed braking were pre-competitive with very little opportunity for OEMs to realise additional value. Design freedom and a range of options means that today lighting systems can add significant value and bring additional revenue.

Key drivers

Naturally the most important considerations within the lighting and vision sector are associated with safety and the ability to see, albeit by one means or another. However, today these fundamental requirements governed by regulation can be seen as being driven by three distinct sets of issues: