LED headlamps illuminate the way forward

Cadillac has joined Lexus and Audi by introducing a new car that uses white LEDs for forward illumination, reports **Tim Whitaker**.

Toyota, Audi and General Motors are all at the forefront of developments that have seen the launch of the first production cars to use LED headlamps for forward lighting. At the biannual Frankfurt Motor Show (IAA) in September, a number of car manufacturers exhibited concept vehicles using LEDs for all the exterior lighting functions. Some examples can be seen on page 22. Nothing new there, the same thing was seen in 2005. But the big difference this year is that white LEDs are now considered viable for use in forward lighting, and there are real cars on the road to prove the point.

Early next year, Audi is expected to sell the first production car that uses white LEDs for all forward lighting functions. The German company will offer LED headlamps as an optional extra on the R8, a luxury sports car, which has white LED daytime running lights (DRLs) as standard. Audi already has at least fie models with LED-based DRLs in different configurations, but the R8 will be the first to use white LEDs for both high- and low-beam functions. The headlamps are supplied by Automotive Lighting, a German lighting manufacturer, using power LED chips supplied from Lumileds.

However, Toyota Motor Corporation has already stolen some of Audi's thunder by launching the Lexus LS600h. This luxury hybrid wins the title for the first car to use white LEDs in headlamps, - but only in the low-beam function. The LED lights are manufactured by Japan-based Koito Manufacturing Co. Ltd, and contain LEDs supplied by Nichia. The LS600h is already available in the USA and also in Europe.

General Motors is also getting in on the act. As this issue went to press, GM brand Cadillac unveiled at auto shows in the US the Escalade Platinum, a special edition of its luxury SUV (see figures 1 and 2). Escalade Platinum goes into production in the middle of 2008, and features all-LED headlamps supplied by Hella that use LEDs from Osram Opto Semiconductors.

Fig. 1. Hella has supplied all-LED headlamps for the Platinum Escalade luxury SUV, recently unveiled by Cadillac

Advantages of LEDs

Audi says that the main benefits of LED technology include low energy consumption (50 watts for the dipped beam headlights, 6 watts for the DRLs), which together with associated reduction in CO2 emissions will become a major selling feature of cars in the future. Also, LEDs provide a color that is similar to daylight for enhanced contrast and more pleasant visual perception, long lifetime, lower voltage requirements, compact dimensions and the increased freedom of design.

Approvals

Lexus and Audi received special permits from the EU to use frontlighting LED technology in series production. In Europe and other regions covered by ECE regulations, regulations permitting the use of LEDs in headlamps are expected to come into force in Q3 2008. In the USA and other areas covered by SAE standards, headlamps with LEDs for the main lighting functions are already permitted. However, in both ECE and SAE regions, signal functions in the headlamp (direction indicators, side marker lights, position lights and DRLs, cornering light) are already permitted to use LEDs.

Fig. 2. LED headlamps for the Platinum Escalade, shown with (a) LEDs off, (b) daytime running light on, (c) low beam headlamps on, with position light and side marker, and (d) main beam headlamps on. The headlamps from Hella use LEDs from Osram Opto Semiconductors.

Fig. 3. LED headlamps for the Audi R8 are manufactured by Automotive Lighting using LEDs from Philips Lumileds.

Fig. 4. The Lexus LS600h uses LEDs for the low-beam function only.

LED headlamps on the Audi R8

The headlamp that will be offered as an option on the Audi R8 will be the first unit in the world to deploy LEDs for all of the front lighting functions (see figure 3). As well as the DRLs, these functions comprise the turn signals, and the dipped beam and main beam headlights. Each headlight unit contains a total of 54 LEDs.

A total of 24 closely-spaced white LEDs (Advanced Power TopLEDs from Osram) form a wing-shaped linear feature that follows the curved lower contour of the headlamp. These LEDs comprise the DRL, or alternatively act as a position light when the headlights are on. The turn signal contains 8 yellow high-brightness LEDs placed on the top inner edge of the headlight unit, and combines with the DRL to form a frame around the headlight.

Automotive Lighting and Audi say that the design of the lowbeam module is reminiscent of an open pinecone. The basic light distribution for low beam is produced from two half-shell, free-form reflectors, positioned towards the inner front of the headlamp. Each reflector contains an array of four LEDs. A high-performance lens system is positioned towards the outside rear of the headlamp. Three two-LED arrays are located behind the lens, and provide light in the region of the light-dark boundary and for the headlight range, to complete the distribution pattern for low beam. Directly adjacent to the lens is the main beam headlight, comprising one four-chip LED array inside each of the two shell-shaped reflectors

Ralf Ackermann of Automotive Lighting explains that the company has worked with packaged LEDs from Lumileds. “This is a new package that will be introduced by Lumileds next year,” he says. The four-chip arrays have a linear (1 x 4) format. The chip size is 1 x 1 mm and the drive current is 1 A. The color temperature of the white LEDs is around 5000 K.

Electric ventilators ensure effective heat dissipation and also defrost the headlight units. To protect the LEDs, cooling elements with a controlled air transportation system have been developed. Warm air is directed to the bezel of the headlamp where it can be used for de-icing and removal of condensation.

Koito lighting for Lexus

LEDs provide the low-beam functionality for the Lexus LS600h, in conjunction with an HID projector for the high beam (figure 4). In the Koito headlamp, three compact projectors are arranged next to one another, with each containing a single LED. There are two further LEDs in a small reflector below the projectors that produces the remainder of the beam distribution pattern. The LEDs are driven at 700 mA. In order to prevent performance degradation caused by temperature rise in the LEDs, Koito has employed for the reflector portion a proprietary cooling structure based around a heat pipe concept. Some details of this technology are described in US patent number 7,114,837.

Hella and Cadillac

The latest vehicle to use full LED headlamps is the Cadillac Escalade Platinum. GM says that LED headlamps will be an enhancement added to the Escalade Platinum in the summer of 2008, shortly after the start of production of the Platinum model itself in the spring of 2008. The LED headlamps are supplied by German lighting manufacturer Hella, and use a modular approach derived from the prototype described on page 20. “Hella is using customized multichip LED light sources from Osram,” says Daniel Veitner, Hella’s director of marketing for lighting. “These LED light sources have been developed together during the last two years.”

The headlamp (see figure 2) has a vertical yellow side marker on its outer edge, next to which is a white LED-based light-guide that acts as the position guide. The turn indicator for the vehicle is located in the bumper. The low-beam is provided by five lenses, one above the other, each of which generates a specific part of the light distribution pattern. The same LEDs also provide the DRL when operated at lower power. This vertical arrangement of LEDs provides strong and dist inct ive branding for Cadillac that mirrors the vertical arrangement of red LEDs for the rear lights. A further two optical modules are illuminated to provide the main beam.

Lighting manufacturer Hella recently shared details of its full-LED headlamp prototype that uses different transmissive optical elements. Each module in the headlamp contains a multi-chip LED array. Special chip arrangements and housing geometries make it possible to produce the cut-off line without additional mechanical shading. As a result, compact headlamp systems can be realized.

The light distribution pattern is generated in a modular manner. A symmetrical basic light distribution with large dispersion provides homogeneous illumination in the near-field range in front of the vehicle. In the central area close to the cut-off line, an area with high illuminance overlaps this basic light distribution and generates the range of the low

Fig. 5. Hella's full LED headlamp prototype. Low beam is generated by six optical modules, with an additional three for high beam. The cornering light and the dual-function DRL/position light are also realized using white LEDs, with amber LEDs for the flashing direction indicator

beam on the left-hand side of the road (oncoming traffic). The long-range asymmetrical "light finger" on the right hand side of the road provides the necessary long-range orientation for the driver.

The different light distributions are produced by means of differed optical modules that are matched to one another. Varying the arrangement and number of modules provides automakers with many styling options and the potential for product differentiation. In Hella's prototype (see figure 5), the low beam is produced by six optical units. A further three modules are also turned on for high beam, and a single module provides the cornering light. A thin LED strip acts as either the daytime running light or the position light, and three units containing yellow LEDs act as the direction indicator. Daniel Veitner, Hella's director of marketing for lighting, told LEDs Magazine that the six modules for low-beam have different optics in order to create together the required asymmetric light distribution. "Each optic creates a specific part of the light distribution," he said. "The modules all use the same multichip LED packages, with five chips per package."

LED performance

The LED prototype is designed to accommodate future increases in LED performance, but the overall system already rates very well in comparison with current xenon systems. "The prototype was rated subjectively as good as or as superior to today's xenon systems," says Veitner. "In the near future, LED headlamps will also show the same objective performance as xenon headlamps – for both low beam and high beam.

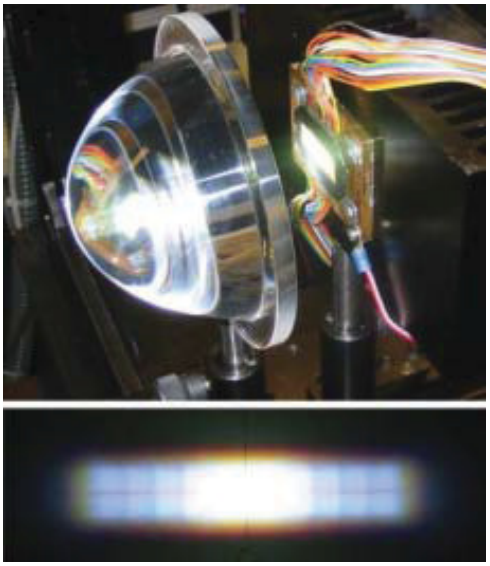
A number of performance parameters are important when designing with white LEDs, says Veitner. Luminance (brightness) is very important to obtain high illuminance (lux) values at a long distance from the vehicle. The parameter efficancy (lm/W) describes the technical development and potential of white LEDs, and luminous flux (lumens) and lumens per dollar are also very important. "However all five parameters are important, and in the development process of a full LED headlamp they are linked with each other," says Veitner. "For example, an LED with higher lm/W can save some cost in the thermo-management of the headlamp, and therefore justify higher cost of the LEDs in terms of lumens per dollar. Hence the holistic view of the overall concept is important.

In terms of thermal management, the Hella prototype uses active cooling by means of a fan, and this will be the case for LED headlamps in series production for several years, says Veitner. The fan itself is a state-of-the-art component that has been the subject of extensive testing and is fully qualified for the automotive market.

In addition to the optimization of the parameters mentioned above, two other improvements are required by LED makers, according to Hella. One is to deploy binning concepts to provide LEDs with identical color temperatures. Another is to provide supply availability to meet automotive requirements (>5 years for series production of the vehicles and >15 years for spare parts).

Adaptive lighting with LEDs

Hella says that it is also working with LED arrays as light sources for future headlamps. Here, individually addressable LED chips are arranged on a carrier substrate and are controlled by pulse width modulation. This allows the LEDs to be switched on and off individually to generate different distribution patterns, and also enables intensity modulation (see figure 6). This will enable intelligent AFS (adaptive front-lighting system) lighting functions such as static or dynamic bend lighting without the need for mechanically moving components, Veitner expects to see such systems by 2010, while fully adaptive LED headlamps (in conjunction with forward- looking vehicle sensor technology and intelligent triggering electronics) featuring new functions such as glare-free high beam will probably wait until around 2013.



(top)A freely addressable LED array and (bottom) an intensity-modulated light distribution generated by the array.