The Advanced Automotive Lighting Systems Report

2013 Edition
CONTENTS

Introduction .............................................................................................................. 7
Key drivers ................................................................................................................ 9
Safety ........................................................................................................................ 9
Regulation .............................................................................................................. 12
Contribution to CO2 output ..................................................................................... 14
Design freedom ....................................................................................................... 16
Lighting Technology .................................................................................................. 19
Light sources ........................................................................................................... 19
  Xenon High Intensity Discharge (HID) systems .................................................... 21
  LED technology ................................................................................................... 23
  Organic LED (OLED) .......................................................................................... 33
  AMOLED and PMOLED .................................................................................... 34
  Laser technology .................................................................................................. 35
Optics technology .................................................................................................... 38
  Lens optics ........................................................................................................... 38
  Reflector optics ..................................................................................................... 38
  Projector optics ..................................................................................................... 39
Distributed Lighting Systems ................................................................................ 40
Applications: Exterior .............................................................................................. 40
  Headlamps ........................................................................................................... 40
  Daytime running lights (DRL) .............................................................................. 41
Position lamps ....................................................................................................... 45
  Front position lamps ............................................................................................ 45
  Rear position lamps ............................................................................................. 45
Fog lamps ................................................................................................................. 45
Side-marker lamps ................................................................................................. 46
Turn signal lamps .................................................................................................... 46
Reversing lamps ...................................................................................................... 47
Rear combination lamps ......................................................................................... 47
Centre high-mounted brake lamp ......................................................................... 47
Licence plate lamps ................................................................................................ 48
Applications: Interior .............................................................................................. 48
  Ingress/egress lighting ........................................................................................ 50
  Instrument panel and switch lighting ................................................................. 51
  Ambient lighting .................................................................................................. 51
  Colour ................................................................................................................ 52
  Head-up display .................................................................................................. 53
Advanced lighting and vision systems ..................................................................... 55
  Mechanical Curve Adaptive Lighting (CAL) ....................................................... 55
Figure 12: Audi R8 all LED front light cluster [Source: Audi] .................................................. 18
Figure 13: Xenon HID headlights combined with LED daytime running lights [Source: Audi] ........................................................................................................................ 18
Figure 14: Xenon HID headlights – Lexus RX 450h [Source: Lexus] .................................. 19
Figure 15: Active LED headlights Mercedes-Benz CL550 [Source: Daimler] ...................... 21
Figure 16: Combined Xenon HID and LED headlamps BMW 6 Series [Source: BMW] ........ 21
Figure 17: Xenon versus halogen beam patterns [Source: BMW/ IHS] .............................. 22
Figure 18: Audi A8 LED headlamp (DRL, low beam, high beam, turn) [Source: Audi] ......... 23
Figure 19: Osram’s Joule LED module [Source: Osram] ..................................................... 24
Figure 20: Osram’s award winning ThinGaN LED [Source: Osram] .................................... 25
Figure 21: Citroen’s DS9 concept features a full LED system from Valeo [Source: Citroen] ....................................................................................................................... 25
Figure 22: The Audi S7 as featured in the 2012 US Super Bowl advert with full LED headlights [Source: Audi] .......................................................................................... 26
Figure 23: Ford’s latest generation Mondeo with full LED headlamps [Source: Ford] ......... 27
Figure 24: Osram’s Olson Black Flat LED [Source: Osram] .............................................. 28
Figure 25: Philips LuxeXeon Altilon LED for forward lighting [Source: Philips Lumileds] .... 29
Figure 26: Ambient LED lighting [Source: Hella] ................................................................. 29
Figure 27: Audi R8 full LED module headlamp [Source: Audi] ................................................................. 30
Figure 28: Global penetration of LEDs in vehicle production [Source: Osram] .................... 31
Figure 29: Audi prototype with OLED ‘covering’ [Source: Audi] ......................................... 32
Figure 30: Epson’s OLED used for a dashboard application [Source: Epson] ....................... 32
Figure 31: OLED rear lighting prototype [Source: Osram] ...................................................... 33
Figure 32: OLED steering wheel prototype [Source: CARO] .............................................. 33
Figure 33: Audi R18 AMOLED rear view display [Source: Audi] ........................................ 34
Figure 34: The Smart Forvision with hybrid OLED roof panels [Source: Daimler] ............. 35
Figure 35: Laser diode based headlight units [Source: BMW] ............................................. 37
Figure 36: Typical sealed beam lens optics, side view. Light is dispersed vertically (shown) and laterally (not shown) ................................................................................................. 38
Figure 37: Typical reflector optics, side view ....................................................................... 39
Figure 38: Typical reflector optics, side view ....................................................................... 39
Figure 39: Hella concept DLS optic fibre headlamp module [Source: Hella] ....................... 40
Figure 40: LED DRL [Source: Audi] ..................................................................................... 40
Figure 41: Reduced voltage low beam used as DRL [Source: Volkswagen] ...................... 43
Figure 42: Interior lighting variety ......................................................................................... 49
Figure 43: Interior OLED ambiance lighting in Smart’s Forvision prototype [Source: Daimler] ......................................................................................................................... 50
Figure 44: Light piping through moulded plastic pipes [Source: Hella] ................................ 50
Figure 45: Light piping highlights a floating island bezel in the 2013 Dodge Dart [Source: Sabic] ................................................................................................................ 51
Figure 46: Innovative interior lighting for ambiance [Source: Johnson Controls] ............... 52
Figure 47: GM head up display [Source: GM] ....................................................................... 53
Figure 48: A schematic of a HUD system [Source: Continental] ........................................ 53
Figure 49: Adaptive front lighting delivers increased safety [Source: Daimler] .................... 55
Figure 50: An illustration of a curve adaptive lighting installation [Source: Ford] …… 56
Figure 51: Hella's swivelling light module. ................................................................. 57
Figure 52: Varroc's Advanced Front Lighting System [Source: Visteon] ...................... 58
Figure 53: Mercedes-Benz Adaptive Dipped Beam system [Source: Daimler] .......... 59
Figure 54: Partial main beam use with Mercedes-Benz's Adaptive Main Beam. [Source: Daimler] ................................................................................................................... 60
Figure 55: A schematic of Hella’s VARILIS system [Source: Hella] ......................... 61
Figure 57: Hella’s VarioX module ............................................................................. 62
Figure 56: LED light cluster as used in the Lexus LS600h [Source: Koito Manufacturing/ Nikkei Electronics] ......................................................................................... 61
Figure 58: Advanced SmartBeam [Source: Gentex Corp.] ...................................... 62
Figure 59: Advanced SmartBeam [Source: Gentex] .................................................. 63
Figure 60: Gentex’s SmartBeam Dynamic Forward Lighting (DFL) view and mirror fitment [Source: Gentex] ............................................................................................. 64
Figure 61: Continental’s intelligent lighting controller [Source: Continental] ............ 65
Figure 62: Advanced anti-glare control using LED for dynamic light functions [Source: Hella] ............................................................................................................................................................ 66
Figure 63: FLIR VES System [Source: FLIR] ................................................................ 69
Figure 64: Night View as fitted to the 2003 Lexus 470 [Source: Toyota] ................. 71
Figure 65: Hella's active night vision system [Source: Hella] ...................................... 72
Figure 66: BMW’s FLIR based VES system [Source:FLIR] ....................................... 73
Figure 67: Mercedes-Benz Active Night View Assist [Source: Daimler] ................. 74
Figure 68: Mercedes-Benz Active Night View Assist with Spotlight Function [Source: Daimler] ................................................................................................................... 75
Figure 69: Oerlikon Optics active night vision system using its NightVision filter [Source: Oerlikon]................................................................................................................. 76
Figure 70: Night vision systems with pedestrian warning symbols [Source: Karlsruhe University] .......................................................................................................................... 76
Figure 71: Possible forms of third generation system warnings [Source: Karlsruhe University] .......................................................................................................................... 77

Table 1: European legal regulations for lights and headlamps [Source: Hella] …… 12
Table 2: Power consumption for conventional versus LED lighting [Source: Hella] … 13
Table 3: Daytime running light power consumption and equivalent CO2 emissions per vehicle [Source: Automotive Lighting] ................................................................. 14
Table 4: Fuel economy potential and cost for non-engine based improvements [Source: IEA] ................................. 15
In the future OLEDs hold the opportunity for lower costs because of the ability to use relatively simple printing type technology to deposit the films, they are extremely lightweight and flexible. They also have the potential for considerably lower power usage in the future. A number of commercial manufacturers are now actively manufacturing robust OLED panels and automotive uses might include:

- Dashboard displays (Figure 30);
- Windshield transparent OLEDs
- Internal lighting;
- External lighting;
- Digital rear view mirrors (Figure 33); and
- Back window alerts or messaging.

Advantageous characteristics that would seem to ensure that OLED technology is predestined to be used in a number of automotive applications can be found both inside the passenger compartment e.g. ambient and orientation lighting, and in the area of signal lights. OLEDs are well-suited to functions that involve low luminous flux and a uniform distribution of light intensity e.g. side lights. For instance, a taillight or a front navigation light could be implemented as a single function light with corresponding microstructures as secondary optical systems.

**AMOLED and PMOLED**

Active-Matrix OLED (AMOLED) is a further enhancement of OLED where the 'active-matrix' part refers to the driving electronics, or the TFT layer. When the image is displayed line by line (sequentially), changing one line at a time. An AMOLED uses a TFT, which contains a storage capacitor that maintains the line pixel states, and so enables large size (and large resolution) displays.

*Figure 33: Audi R18 AMOLED rear view display [Source: Audi]*

A PMOLED uses simpler driver electronics without a storage capacitor so that each line is turned off when moving to the next display line. Thus with a 10-row display each row
will only be illuminated 1/10 of the time. Thus the brightness of each row has to be 10 times the brightness of an AMOLED, using higher voltage resulting in a less efficient display with shorter life. However, PMOLEDs are cheaper to make than AMOLEDs but are limited in size and resolution (the largest PMOLED is only 5 inches, and most of them are around 1-inch to 3-inch). Most PMOLEDs are used for character display, and not to show photos or videos.

**Figure 34: The Smart Forvision with hybrid OLED roof panels [Source: Daimler]**

Several German companies are working on a project called CARO (CAR-OLED). The aim of this project is to develop OLEDs specifically for the car industry. Recently they have shown an interesting steering-wheel concept that includes a white OLED. The OLED is so thin that it does not affect the basic design of the wheel, so even the airbag stays the same (Figure 32).

Daimler recently unveiled a new concept EV (the Smart Forvision) featuring a transparent roof, see-through dashboard and transparent OLEDs for internal lighting. The transparent hybrid solar-OLED roof panels generate energy during the day and provide internal lighting during the night (Figure 34).

**Laser technology**

Some OEMs manufacturers are currently looking at fitting laser diode headlamps that require less energy than HB LEDs, further lowering power requirements. Laser diode applications consist of monochromatic wavelengths spread with phosphor, which create a more natural lighting than laser alone. Laser diode light fixtures create a more targeted point of light.

A laser could emit headlight beams from a 0.4-in. slit in the front of the car, according to Valeo, bringing additional freedom for vehicle designers.
Laser lighting is next for forward lighting, according to Nadine Leclair, Senior VP Engineering at Renault and Jean-Paul Ravier, Advanced Development Director at Valeo Lighting Systems, who says OEMs already are preparing such applications.

“After LEDs, there will be laser beams,” Ravier says. “It will be part of the market in the future, but LEDs will remain dominant.”

Laser headlamps will offer better performance and new styling features, according to Leclair, but LEDs already have a longer lifespan than required. The strength of LEDs is that they already are competitive with xenon high-intensity-discharge lamps and will become less costly in the years ahead.

“We can forecast a quick replacement of HID in the next three years and a more progressive replacement of halogen in the next 10 years,” says Ravier

“LEDs will be used intensively for mass markets, becoming the dominant source, but laser beams will be introduced for premium cars, as is often the case for new technologies, where performance and style are much more important than costs.”

Systems using laser diodes would put more light on the road in very interesting ways: employing a layer of phosphorous where several blue laser beams intersect, a secondary white light can be created with a potential for luminance about five times greater than the best current LED headlamps. Used in automotive applications this high luminance source can allow new functions such as picture beam, or lighting systems with very compact output for very thin styling requests.

Lasers are already used at concerts, for example, to project images on a wall. Fast-moving microelectronic-mechanical systems make a pattern appear fixed, although it is a light beam moving very fast. Thus, lasers could shine around the corner, automatically dim so as not to glare on an oncoming car and produce both low and high beams.

Lasers could therefore handle more complex functions, for instance:

- An adverse-weather beam that reduces the light relatively close to the car to cut glare for opposite drivers due to the reflection on a wet road;
- A high beam that extends further as vehicle speed increases;
- A marking light that illuminates a pedestrian standing by the road but doesn’t glare on his face;
- Road marking that puts extra light on the edges of the road; and
- a navigation beam that casts a shadowy arrow in the light beam on the road to indicate the driver should change lanes or take the next exit.

“To make laser front light systems reality requires work on thermal properties, which now limit laser lifetime to 3,000-10,000 hours, and in addition”, Ravier says, “automotive applications are very demanding for colour shifts with temperature, and the