Active Vehicle Frontlighting Systems based on Innovative LED and Laser Head-lamps

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Active vehicle frontlighting systems have made important progress during the past years. Many of these systems require high resolution optical concepts. LED or laser based solutions are promising. The present paper provides a benchmark of these concepts. Different solutions will be discussed, rated and compared.

1 Introduction into active vehicle frontlighting systems

During the last two decades vehicle frontlighting systems became more and more intelligent. First Adaptive front lighting was introduced in 2006 [1]. Six different light distribution town light, cornering light, dynamic bend lighting, country light, motor-way light and adverse weather light were realized and used to enhance the functionality of the head-lamp. Vehicle speed, activation of the direction indicator, turning of the steering wheel and the signal of rain sensors provide the information which is the input for the intelligent control of the system.

In 2011 the first version of glare free high beam also called adaptive driving beam was introduced onto the market [2]. First headlamps were based on a projection module where a rotating, absorbing drum in the focal plane of the projecting lens de-fines the profile of the cut off line. The shape of the drum changes circumferential from a horizontal cut off to a combination of a horizontal and a vertical cut off. A camera detects the position of the on-coming and ongoing traffic. By swiveling and level-ing the whole projection module and adapting the drum other drivers will not be glared. The general system structure of active lighting systems and some more other system structures are described in [3].

In the last three years first adaptive driving beam frontlighting systems without mechanical actuators were developed. The light distribution is divided into a row of beams each illuminated by a separate LED. Using a matrix of such high luminance LEDs allows traffic dependent switching of each beam [2]. A different system is used in the new Mercedes E-Class [4]. Close to each LED a silicone light guide is placed and then combined with the others to a single primary optic. The outcoupling facets of the primary optic are projected on the street via a lens. Switching of the light beams is realized by switching the LEDs. Due to the use of the light guide the space between the LEDs can be en-larged. Thus cooling of the LED becomes easier and more than one column in light distribution is possible. More light on the street without glaring other drivers is the target.

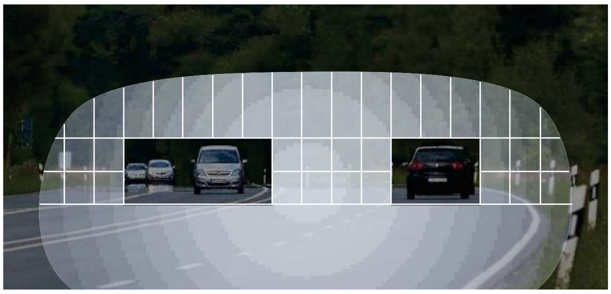

Fig. 1 *Principle of the Mercedes E-Class light distribution separated in three columns.*

2 Towards higher headlamp resolution

The trend towards a more dynamic functionality and towards light distributions with even higher resolution is recognizable in automotive lighting research. In the last years the BMBF founded pro-jects µAFS [5], iLAS [10] and VoLiFa [7] started with the target to enhance the resolution of glare free high beam. All approaches are based on the imaging of a field plane, enabling a variable lumi-nance distribution on it, by an objective. They can be classified in two groups called additive and subtractive image generation [11].

The solution which is in the focus of the µAFS pro-ject consists of three LED chips each divided into 1024 separate switchable pixels. The field plane here consists of the LED array itself. Thus the light distribution can be changed additively. One ad-vantage of this technology is that energy is con-sumed only in those pixels which are switched on. A first headlamp prototype was build and success-fully tested in spring 2016.

The solution which is in the focus of the iLAS pro-ject is based on a blue high power laser diode which is collimated onto a phosphor element. By

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scanning the laser beam in two dimensions with high velocity a defined shape of the light distribution is generated on the phosphor and projected to the traffic space by an optical lens system. By scanning the phosphor in combination with switching of the laser diode a wide variety of light distributions can be generated. A drawback of this solution is the high optical power necessary for the scanning laser beam and the very high irradiance on the phosphor.

The system which is developed in the VoLiFa project consists of several LEDs which illuminate a LCD by a primary optic. The LCD is positioned in the focal plane of the objective. In combination with a polarisator in front and an analysator behind the LCD every pixel can be swiched between transparent and absorbing. Thus this concept generates the image in a subtractive-way. The energy of the switched off pixels will be absorbed and is lost, so that the overall efficiency is poor. An Advantage of this system is that the LCD size (high Étendue) allows a homogeneous illumination by a plurality of LEDs.

A fourth approach is the use of a DLP (digital light processing). The DLP is a micro mirror array with two switching states. One state reflects the light to an absorber the other state will image light to the street. A high luminance LED is projected onto the DLP. The DLP is placed in the focal plane of the optical system. Thus all micro mirrors in the on-state are imaged on the street. The other light beams will be absorbed. The light has to be focused on a DLP size of 1-2 cm (small Ètendue) but allows a resolution of a million pixels.

3 Benchmark

The different approaches for high resolution headlamps are compared in Tab 1 with respect to their most important system properties. The most limiting factor in terms of luminous flux is the surrounding temperature because of a restricted cooling.

	µAFS [5]	iLAS [6]	VoLiFa [7]	DLP [6]
Image	additive	additive	subtractive	subtractive
Light source	LED	Blue Laser	LED	LED
Optical efficiency	50 %	15-27 %	30 %	12,1 %
Luminous flux	1400 lm	~1300 lm	1800 lm	~1300 lm
Pixel	1024	scanning	30.000	> 1 mio.[8]
Optics	4 lenses	1 lens	1 lens	5-6 lenses

Tab. 1 *Comparison of different technologies for high resolution headlamps. Values are representative for high beam mode.*

4 Summary and Outlook

Four different concepts for active lighting systems which are under development in public research projects have been presented and compared in the present paper. The optimal solution would provide a plurality of white light beams into small solid angles. In addition to the solutions presented here, this could be realized in future by using red, green and blue laser diodes whose beams are superposed into a white ray [9].

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