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ABSTRACT

In most cases of night time driving the low beam light function is used for the road illumination in front of the car. This conventional low beam function has a constant light pattern: no matter whether the driver is actually driving on a straight or curvy road, whether the road is wet or dry, always the same beam pattern is applied. Test experiences of the last years prove that a headlamp with an ,,adaptive light pattern" having different optimum light pattern adapted to different driving situations should give a better illumination than the conventional constant low beam pattern which can only be a compromise.

In this paper an outline of the basic idea of the ,,adaptive light pattern" is given. Different driving situations and their corresponding optimum light pattern, basic technical concepts and the legal situation regarding homologation of such an advanced lighting system will be discussed.

INTRODUCTION

Automotive headlamps provide for each of the basic light functions (low beam, high beam and fog beam) a fixed static light pattern. Some thirty years ago 200-300 lumen were a good total luminous flux for a low beam headlarnp. This amount of light was at best enough to illuminate the most important parts of the driver's night time viewing zone.
All lighting regulations and techniques were set up to ensure a minimum light quality using available light sources.

The introduction of halogen bulbs around 1965 greatly improved the light quality. In the eighties two-reflector-headlamps for separate low and high beam and advanced reflector technologies further increased the amount of light available for the street illumination.
Now, a low beam light volume of 500 lumen and more can be achieved using halogen bulbs in combination with advanced reflector techniques or even 1000 lumen using gas discharge lamps (HID). Having reached this state of lighting performance the question arises, in which direction further development should be continued. Shall we add, as in the past, more and more light - if technically available - into the static light pattern giving more and more intense illumination in the hot spot or broader side illumination? Recent HID-light pattern applications have shown very good results on this way (Ref. 1, 2).
Another very promising alternative is to direct the available light dynamically into the direction where it is actually needed. Why illuminating the hot spot with full power while driving with low speed on a windy road? Why wasting many lumen on large lateral side illumination while driving with high speed on a straight highway? Hence, the idea is to have a dynamic or ,,Adaptive Light Pattern" (ALP) which always supplies an adapted, optimal light performance for the actual driving situation.
The legal regulations are not yet completely ready for this innovative concept but the technique is now under full development. The ALP topic can cover a wide range of lighting aspects. We want to concentrate here mostly on the main headlamp functions, especially the low beam, because there seems to be the highest potential for improvement of night time traffic safety.

ALP - AN INNOVATIVE LIGHTING CONCEPT

During night time driving the automotive lighting equipment is responsible for illuminating the driver's viewing field under many different driving situations, street and traffic conditions. The following parameters characterize most of these situations:

- Speed:	low - medium - high
- Road condition:	dry -wet - slippery
-Course of the road:	straight - curvy - intersection...
- Road topography:	flat - hilly
- Road type:	highway -country - city...
-Viewing conditions:	clear - rain -fog -snow
- Ambient illumination:	dark - street lights...
- Traffic density:	low - medium - high
- Driver:	age - driving skills...
- Other parameters:	country, tunnel...

At the same time the car must be visible to other traffic members without causing glare or other irritations. Regarding this complex task the conventional static headlamp light pattern can only be a compromise. Usually most of the flux available for static illumination is directed to the central parts of the viewing zone including the range zone of the low or high beam (approx. ± 5" hor./vert. of driving direction). In this zone we certainly have the highest demand for good illumination and therefore also the highest requirements by current ECE and SAE standards.
The rest of the available static beam flux is more or less scattered to the left and right sides of the viewing zone. This light pattern is a compromise in the sense that it fairly covers the most important viewing zones but only to some extent the special zones needed for example for curve illumination, fog conditions, etc. This compromise is only for those headlamps a very good overall solution that have a total flux almost as high as in the case of HID headlamps. But the general idea - even for high flux systems - is, that light (e.g. foreground illumination), which is beneficial in the static beam pattern under normal driving conditions is most likely undesirable in some other situations (e.g. wet roads).
These basic considerations about the static and dynamic light pattern seem to be obvious but they have to be verified by scientific investigations. The goal is to evaluate the potential benefits of a dynamic or adaptive light pattern compared to the conventional static light pattern. Independent from basic research, a few technical realizations using rotatable reflectors have been presented years ago (e.g. Ref. 3, *4).* First internal field tests and other investigations (Ref. 5, 6, 7) now prove that for most of the above mentioned driving situations different light pattern must be required to obtain an optimal illumination.
The finding is, that no static light pattern, even the sum of all individual light pattern, can deliver the overall optimal headlamp beam pattern. The philosophy of ,,Adaptive Light Pattern" can achieve this goal by means of detection of the actual driving condition and subsequent switching to the well-adapted light pattern.

The European ECE regulations do not yet allow the realization of the ALP concept. Both, the application of multiple light sources in one headlamp and moving beams are considered as important technical realization possibilities for ALP as wili be pointed oui in ine nexi seciion. But it is neither permitted to use more than 1 light source for the low beam function within one headlamp (and more than 2 light sources each for high beam and fog beam) nor is it generally allowed to apply a movable or rotatable reflector.
There is an exception of this practice: an additional secondary high beam may be horizontally rotatable. Reflector parts may also be movable as long as their optical axis is not moved. Also, it is not explicitly forbidden to have adaptive low, high or fog beam if the adapted light pattern always fulfills the current regulation.
A European EUREKA project called AFS (Advanced Frontlighting Systems) with all major European bulb, headlamp and vehicle manufacturers participating (Ref. 8) has been established to make studies and proposals for new regulations to overcome the current restrictive ECE homologation practice. In the second phase the AFS working group is now testing the basics and limits of adaptive lighting in order to propose new regulations in the third phase.
The US Federal Register, Part 571 (FMVSS 108), for automotive lighting is not as restrictive as the European ECE regulation but the subject also is not yet explicitly introduced.

Once we have realized the potential of adaptive lighting in general and supposed there will be some regulatory framework in a few years, what

what kind of variations can be introduced by ALP? Various adaptation possibilities can be thought of:

- Adaptation of low, high or fog beam pattern
- Integration or combination of low, high and fog beam into one beam
- Adaptation of a headlamp to different standards: ECE left hand drive, ECE right hand drive, USA, Japan
- Variation of shape of the cut-off of a low or fog beam
- Variation of beam inclination
- Variation of the signal image of a headlamp (the appearance to opposing traffic)
- Variation of brightness or colour
- On/off - automatic switching of beams

The first tests and investigations already mentioned above allow some preliminary conclusions which help to select the most important variations and parameters for „Adaptive Light Pattern" headlamps:

Experimental Experiences:

- Speed is a suitable control parameter
- Distinction between city traffic, 25 Mph-zones, rural roads and highway is meaningful
- Oncoming traffic on rural road: Enhanced SPOT is advantageous
- Turns at intersections: Increased side illumination is very much welcomed
- Driving in convoy: Spot illumination should be reduced in favour of large side illumination
- Wet roads: Reduced foreground illumination helps to reduce glaring reflections to oncoming traffic
- Switching between different light pattern components should be harmonic and not too abrupt

Some of these conclusions are nicely illustrated in Fig. 1 showing schematically different driving situations from the bird eye's view and their adapted light pattern. In the left part of Fig. 1 the corresponding active components of a multi-segment headlamp - one realization technique for ALP - are indicated. The most important control parameter, which is quite easily accessible in a modern car, is the driving speed. Driving with high speed requires the attention of the driver to be directed to the far field in the direction where the car is heading instead of being distracted by the foreground scenery or the outer left and right sides of the total viewing zone. It is well known that the driver's view is attracted by those parts of the scenery that have the highest luminance (Ref. 9). Hence, the adaptive light pattern should support to direct the concentration to the most important zone for the current driving situation. Therefore, at high speed, an additional far field spot illumination should be added, accompanied by reduced or normal side and foreground light.

When driving at low or medium speed usually the spot is not needed any more. In this case, the adapted optimum light pattern depends on other parameters: When there is an intersection ahead, a curve or a broad street in an urban area then an enhanced lateral side illumination to the left and/or right is needed. In

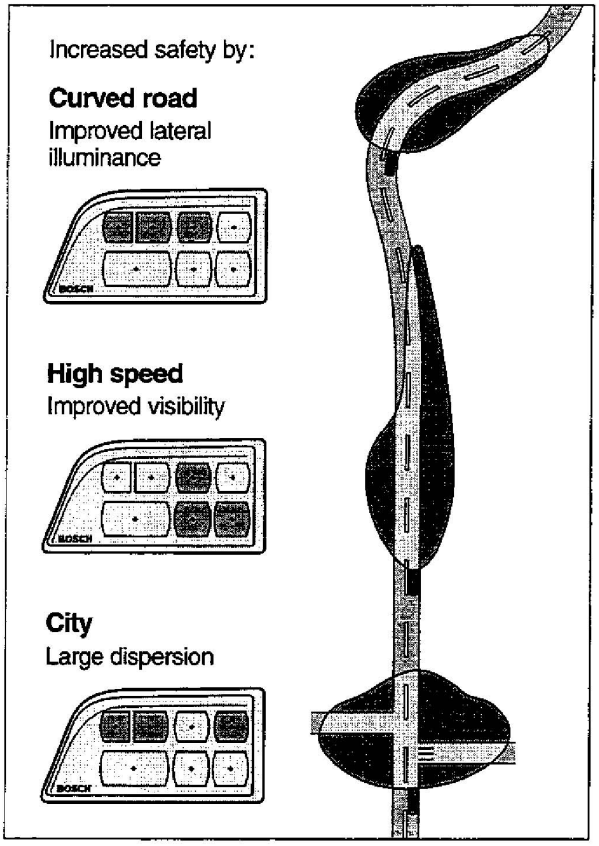

Fig.1: Three standard driving situations with adapted light pattern seen from the bird eye's view.

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