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Giorgio Manassero and Maria Teresa Dalmasso
Magneti Marelli - Lighting Division

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Adaptive Headlamp: A contribution for Design and Development of Motorway Light

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ABSTRACT

A major breakthrough in improving visibility, safety and comfort under all driving conditions is given by a headlamp with adjustable light intensity and beam pattern according to the vehicle speed, steering wheel angles and different driving conditions.

The configuration of this adaptive or intelligent headlamp will be achieved in two phases, by implementation of simple functions, i.e. motorway beam pattern, followed by a combination of them in a second phase. For the new adaptive headlamp one should make use of powerful light sources like the Gas Discharge Bulb and of sensors for road surface status, speed and steering wheel angle. The optical design of the adaptive headlamp is more complex than for conventional headlamps and must take into account new requirements like the continuous transition between the low and high beam positions.

In this paper we describe the design and prototyping phases for an adaptive headlamp whose beam pattern and aiming condition can be varied by the use of actuators. The results of the optical simulations are given and compared with the corresponding prototype measurements.

INTRODUCTION

The problem of visibility during night driving conditions is not always considered as an important constraint during the design and development of new vehicles. Very often car-makers reduce the space allocated to the lighting components and define them for design requirements only. Therefore for component suppliers it is difficult to achieve high photometric performances. Under these strict conditions, car suppliers can achieve good performances by means of new lighting techniques (e.g. numerically calculated reflectors) and light sources (e.g. HID bulbs and systems): the new products guarantee a good light flux, as requested by international regulations, but the beam pattern and aiming are fixed. Therefore

For an overall improvement, it is necessary to dynamically modify the beam pattern and light intensity during driving, and to account for road and weather conditions by means of a wide variety of sensors. A first step in the aforementioned direction is to develop a headlamp which is able to improve visibility during one of the following conditions: rain and fog, on curves, on motorways and in town [1]. The following step will be to implement more than one function, to suit more than one driving condition, and offer a good comfort during transition between driving situations, i. e. transition between low speed and high speed.

This paper will describe the development of a Motorway headlamp able to vary its photometric characteristics with speed. The headlamp will try to reduce the aiming angle and the width of the beam as the vehicles speed increases. These operations will be automatic with the aid of sensors, actuators and electronic boards. The purpose, as for all adaptive functions, is to always provide an optimal beam. This will increase driving safety and comfort. The best visibility characteristics should be obtained without causing dazzling of the oncoming vehicles. Several numerical simulations, laboratory and road tests are being performed to identify the best strategy to achieve the proposed goals.

FUNCTION DESIGN

While driving on a Motorway the high speed and low road lighting require better visibility. In particular when driving at high speed, foreground illuminance is less important, while a high light depth is very useful to detect vehicles running ahead.

Beam modifications must be implemented without dazzling oncoming vehicles: this paper examines the possibility of varying the low beam distribution without trespassing the horizontal line.

It is possible to obtain an increase of illuminance in two ways. The first is to decrease the aiming angle of the light beam and the second is to change the beam shape, to

Research and experimental activity were divided into two parts:

1. The study and set-up of a system capable of changing the aiming of the beam depending on the car speed.
2. Computer simulations and analysis of optical solutions capable of changing beam shape with the car speed.

VARIABLE AIMING

In varying the beam aiming angle, the attention was focused in the mechanical movement of the reflecting surface. The angle was varied from -1% to 0%.

To test this solution, a prototype was set up, where the reflector movements were implemented by means of stepper motors. The relationship between speed/movements is a linear one: the starting speed was fixed, and several slope parameters were adopted to identify the optimal value.

The system was assembled onto a vehicle and some road testing was carried out. The following variables were chosen in order to carry out a preliminary Design Of the Experiment.

- starting speed
- slope of the movement
- dynamic leveling.

The set parameters are adjustable by acting on the electronic control unit, which was positioned in the vehicle. At this stage, the optical part analysis was ignored and an elliptic headlight with a gas discharge lamp was chosen.

The goal is to establish which starting speed and slope would increase the driver's comfort. The influence of dynamic leveling on the variation of aiming due to speed increase was also investigated. In some configurations it may happen that dynamic leveling cancels the effect of the applied correction for the speed increase.

Tests were carried out on a two lane track. The participants were divided into drivers, static observers, and dynamic observers (driving a crossing car). All participants were asked to evaluate three different parameters: illuminance, glare and comfort.

According to our test results the best configuration has a starting speed of 90 km/h and a slow variation of aiming, slope = 0.125 (% / 10 km), in order to achieve the 0 % aiming when speed is increased up to 170 km/h: Fig. 1 shows the slope diagram, with four different speeds. The dotted one is the slope that the participants have considered the best, from the point of view of comfort and visibility.

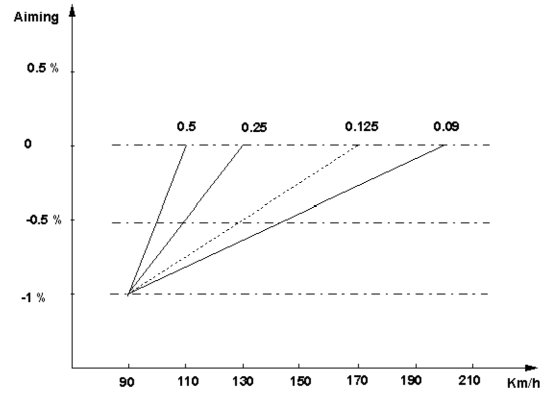

Figure 1. Slope diagram for a starting speed of 90 km/h.

The interaction of this system with dynamic leveling was considered useful in increasing driver's comfort.

VARIABLE BEAM SHAPE

According to the tests carried out on the system described above, the change of aiming is neither optimal nor sufficient yet if we want to obtain a real increase of the driver's comfort.

Further actions are necessary to improve illuminance distribution and the cut off line: a variable beam shape could enhance visibility, together with a variable aiming.

The goal is to obtain a gradual change of the beam shape, starting for example from a low beam configuration. As an example, it is useful to decrease the horizontal divergence and increase illuminance in HV, while the car speed increases. This is because it is demonstrated that at high speed foreground light is irrelevant for safety, while concentrate light in the central part of the screen increases visibility.

As a constrain on this procedure the redirected light shouldn't go above the horizontal line not to dazzle oncoming vehicles.

A preliminary analysis of different procedures was performed taking into account, for instance, the possibility of changing the beam shape with the movements of parts in the reflector structure.[2] [3]

Fig. 2 and 3 represent two different reflectors a parabolic and a segmented one that we simulated with an optical design and analysis software.

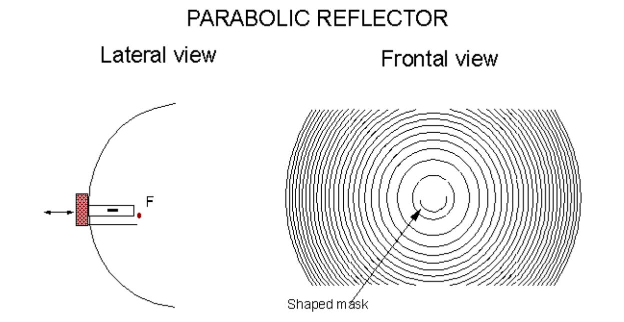

Figure 2. Parabolic reflector.

The low beam configuration for the parabolic reflector was obtained with a shaped mask, fixed to the reflector, that cuts rays from the lower part of the parabolic and models the 15 degree cut-off line. The idea was to reproduce the H4 configuration with a monofilament lamp.

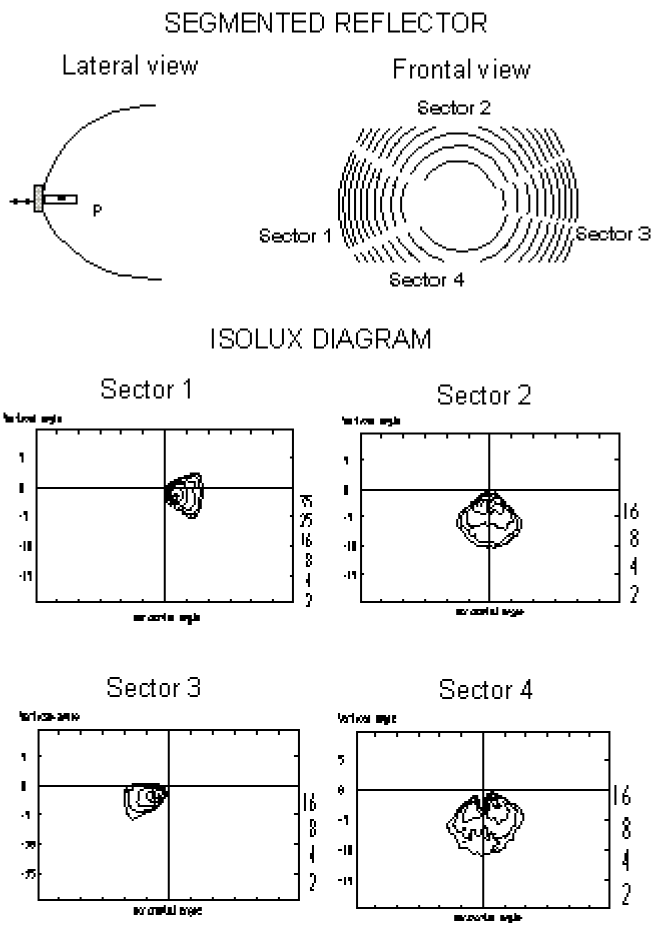

Figure 3. Segmented reflector

Simulations were performed in both cases with a gas discharge bulb D2S because of its high efficiency and low heating. Fig. 4 shows the D2S apodization diagram.

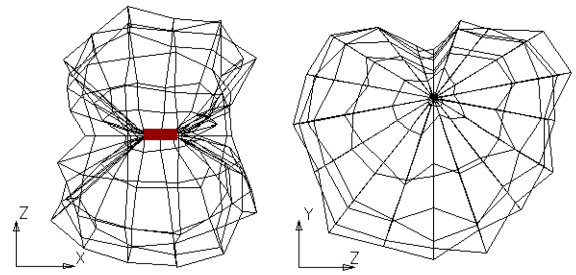

Figure 4. Apodization diagram of the Gas Discharge Lamp D2S (x axis is the optical axis)

A large diameter was chosen for the parabolic reflector to increase the luminous intensity.

Dimensions of parabolic reflector (focus=26 mm):
diameter: 165 mm

Dimensions of segmented reflector:
front section: 150 x 80 mm.

In the case of the parabolic segmented reflector, sector 1 and 2 were tilted around the y axis, with a rotation angle of 1.5 degrees. P1 and P2 are the points about which reflector sectors were rotated as shown in Fig. 5.

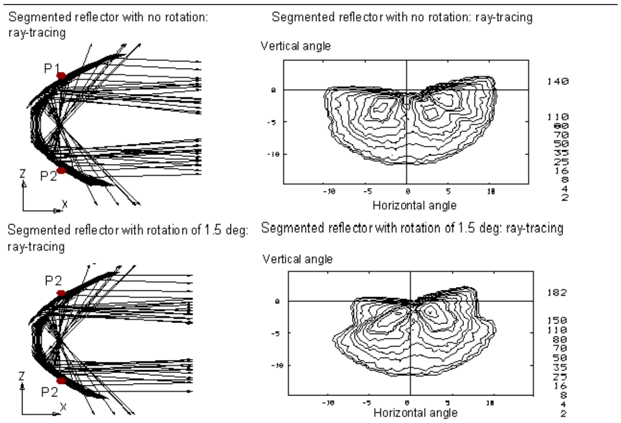

Figure 5. Ray-tracing and isolux diagram of the segmented reflector.

In the case of the parabolic reflector, the reflector lateral segments were rotated around the y axis about points T1 and T2, with a rotation angle of 1.5 degrees, as shown in Fig. 6.

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