Design and evaluation of adaptive optical systems

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Due to the growing demand for systems based on adaptive optics in the automotive industry, new optical devices are developed. These novel systems allow to implement lighting functions with a higher versatility, but also have to be very robust to meet the special requirements of this sector of industry. Therefore, they have to pass careful tests at our research and test facilities.

1 Introduction

The bending light of modern cars is a well-known example of an automotive illumination system that can be adapted to the traffic situation that is encountered on the street. An optical unit that will be presented here serves to expand or reduce the light distribution of a projection system in a controlled way.

In general, projection-type headlamps consist of a gas discharge lamp, a free-form reflector that concentrates the light in an intermediate plane, a shutter device in an intermediate plane, and a lens that projects the light distribution created in the intermediate plane onto the road.

Here, the light distribution of a projection-type headlamp is adapted by changing a lens system.

2 Mechanical and optical requirements

The end-use in the automotive sector imposed several requirements on the optical design of this lens system: The set-up has to be realized with a minimum number of lenses. Another restriction was that the number of movable components, which are necessary to implement an adaptive function, should be as small as possible.

To avoid glare, it is important to have a sharp cut-off line. The position of this cut-off line in angular space has to be stable with respect to changes of the variable optical device.

In addition to an optimization of details in the light distribution in different positions, the light flux of the optical system has to be maximized.

It is also of importance that the design is robust, i.e. relatively insensitive to other influences.

3 Design

The optical design was performed in several steps: First, a basic layout was determined using a matrix method. For the purpose of aberration control and optical optimization of the start configurations, the optics software ZEMAX was applied. In this way, data sets for the lens aspherization were obtained.

To evaluate the performance of different designs, simulations were performed using Hella's proprietary HELIOS software. The opto-mechanical hardware design was then refined and finalized by making use of the commercial CAD tool CATIA V5.

It turned out that the light distribution can be adapted in the desired way by moving one lens of a highly aspherized two-lens unit.

Several set-ups were built and their characteristics were evaluated experimentally, also in conjunction with varying additional optics.

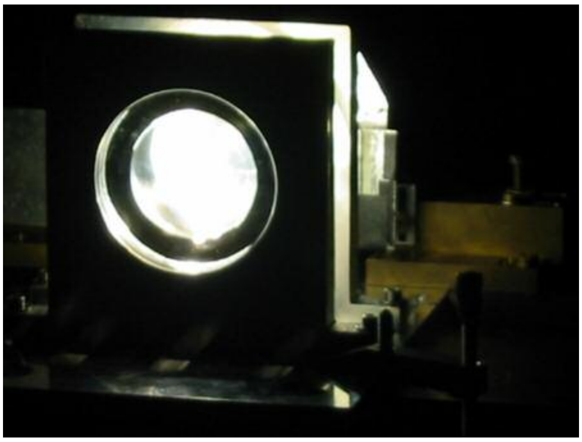

Fig. 1 *Front view of the lens system*

4 Experimental verification

To verify and demonstrate the features of the new devices, they were measured using an automated photogoniometer. This instrument scans the angular distributions accurately that are representative for the different states in which the adaptive optical systems can be operated. Results for an adaptive device with a restricted angular distribution are given in Figs. 2 and 3. Measurement results obtained with a device for a broader angular distribution are shown in Figs. 4 and 5.

To refine the interpretation of the angular light distributions, glare analysis for chosen angular domains was helpful (Fig. 6), because it complemented the picture given by the photogoniometric measurements.

For additional tests, the optical systems were then brought to the so-called light channel, which is probably the biggest facility of its kind in Europe, and evaluated experimentally. The desired adaptive function was successfully demonstrated.

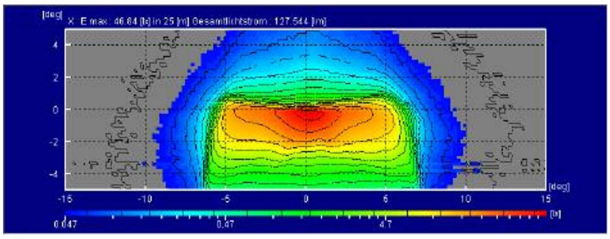

Fig. 2 *Light distribution in angular space measured with an automated photogoniometer: Setting A of an adaptive device*

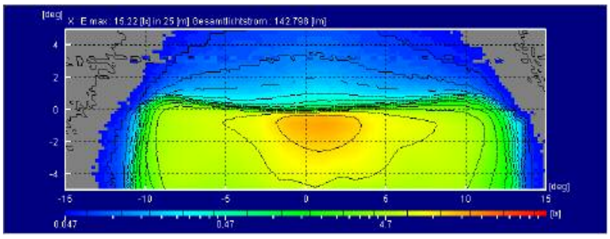

Fig. 3 *Light distribution in angular space measured with an automated photogoniometer: Setting B of the same device as in Fig. 2*

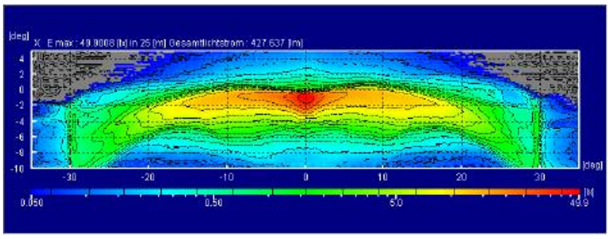

Fig. 4 *Light distribution in angular space measured with an automated photogoniometer: Setting A of another adaptive device*

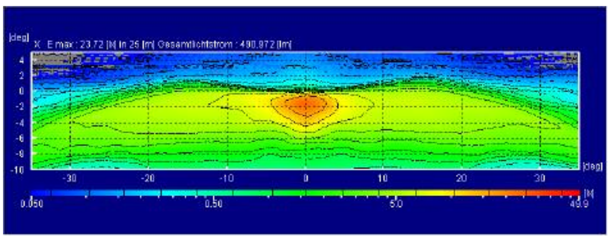

Fig. 5 *Light distribution in angular space measured with an automated photogoniometer: Setting B of the same adaptive device as in Fig. 4*

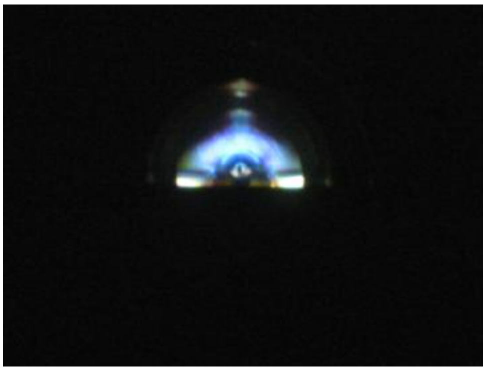

Fig. 6 *Glare analysis at a given angular position*

5 Other adaptive systems

For other applications, the implementation of fluid lenses developed by other laboratories [1] is under investigation. These novel devices allow for a continuous change of the focal length as a function of an applied electric field and were implemented in different experimental set-ups to evaluate their potential for our applications. The results obtained so far seem promising.

6 Conclusion and outlook

It has first been shown by simulations that a solution can be found that fulfills the requirements on the adaptive system with a minimum number of components. This layout has then been realized and verified experimentally. The recorded photogoniometric measurements and tests performed at Hella's light channel demonstrate that the adaptive functionality is obtained.

As a refinement step, the use of alternative shutter devices is considered. It is intended to optimize their geometry for the given application.

References

[1] B. Berge, J. Peseux: „Variable focal lens controlled by an external voltage: An application of electrowetting“ in *European Physical Journal E – Soft Matter* **3** (2): 159-163 (2000)