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Department of Lighting Technology

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Herbert Utz Verlag GmbH, München
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utz@utzverlag.com
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Adaptive Frontlighting – Experimental System Development and Functional Evaluation

Bernhard Wörner

Automotive Lighting

Background

The driver's comfort and safety can be improved considerably by adaptive motor vehicle headlighting, with the today's technical means in lighting design and manufacturing, as well as sensors and communication systems in cars. The actual requirements for frontlighting devices, being established decades ago, do not permit for such variable devices. Therefore, within the frame of the Eureka project AFS[1)] the European car and headlighting manufacturers studied the possible specifications for such advanced requirements with the goal to submit a proposal for a draft Regulations.

Within this project studies for adaptive headlighting requirements, practical tests with such variable headlighting devices had to be performed on the road and under real ambient and traffic conditions, as a sound base of experiences for the definitions - besides theory and laboratory investigations.

Mainly for this purpose Automotive Lighting developed an experimental system of variable headlamps. It's design, the device capabilities, the experiences and conclusions gained up to now with this system shall be discussed here.

Experimental System Design

The first goal was to realize an as large as possible span of passing lighting variations and transitions between the different states, including possible limiting values of luminous intensities. A boundary condition was the integration of the experimental devices in a realistic size of construction as for a conventional headlamps, and full ability for road testing use.

These considerations were made in close cooperation with Daimler-Chrysler lighting experts. The vehicle for the design base and road tests was chosen a Mercedes S-Class car (W140).

The main functional targets were the adaptive passing lighting a) for general purpose as e.g. country road, b) for town conditions and, as the most challenging task, c) for adverse weather conditions.

The design of the adaptive country road passing lighting is derived and followed up directly from different road geometry, vehicle speed and drivers need: on straight roads and at higher speed a rather narrow pattern but a long reach is needed; for bended roads and at lower speed wide lighting is necessary and a combination of both is adequate on roads with more than two lanes often.

Realizing well the former discussions in Europe of a dimmed passing lighting, to be applied in towns for optimum use of the public lighting, a spectrum of such patterns was created for studies of this matter, including the conspicuity question and optimized wide illumination for crossings and when passing parked cars.

The interaction to the opposing traffic is quite different in the case of the adaptive passing lighting for wet road conditions, – a situation which in our regions is the far most frequent form of adverse weather and which – from the visibility point of view – is feared by the drivers, even young drivers, or well experienced ones.

The reasons behind this difficult situation shall be pointed out here briefly: the most relevant factor is the changed scattering of light at the road surface, caused by the increasing filling up of the roughness recesses of the road pavement with water, during rainfall; as a consequence the back scattering is reduced: the driver does not any more see whether and where his headlamps bring light on the road; the light is instead - due to the higher degree of specular reflection - rather guided to the trees, but also to the the opposing traffic. In case of a plane and inundated road, this leads for the opposer to the visual impression as to oppose two pairs of headlamps, one of them above the road and a second below the road. The luminance intensities emitted from the latter are far higher than that of the first one, leading to illuminations at the eye much

higher than that coming directly from the headlamps. If the road is somewhat wavy, even more than one such disturbing pairs of reflex centres can occur.

The draft of the adaptive passing lighting investigated here for the described adverse weather situation is as follows: those areas of the road surface where the opposing situation relevant reflexes are generated, shall be illuminated less; they are anyhow rather close to the vehicle (below 25 m when a critical distance of some 50 or 60 m is supposed). This does not interfer with recognition of a possible obstacle on the road: it can be realized at a much greater distance; whereas, if a laterally moving subject will be made visible by the side illuminations. Therefore, to the drivers benefit, a more intensive illumination is directed to the left curb as well as to the zones directly below the horizon and, especially, to the right curb of the road, being supported by a somewhat higher adjustment of the lamps than for conventional passing lighting, e.g. to H-0.3%.

This lighting draft had led in proving ground tests to significant positive judgements of both, drivers and opposers. We expect here a real gain in safety related aspects in addition to the drivers comfort improvement.

Optical Elements Design and Capabilities

The Headlamp system is built up of each three optical elements or units per side of the vehicle, as shown in **fig.1**.

The "basic module" is a modified ellipsoidal lamp with 70 mm lens, equipped with a 65W halogen bulb. The light distribution is fixed but the luminous flux can be changed in three steps, starting from a standard E_{max} of some 25 lx, it can be pushed to 45 lx, or dimmed to 17 lx. The booster stage is intended for shorttime operation, the lower, economizing stage is thought for the town application.

The cut off is controlled by a multifunctional shielding device. It can be set in two fixed stages at the right hand side of V-V, corresponding to a horizontal cut off line there, limiting the well known 15 degrees asymmetric slope either 0.3° or 1.2° above the left side horizontal cut off. And, it can be further set quasi continuously to fully open aperture. The latter can allow for a) providing a main beam lighting, or b) for control of the cut off as an alternative to the levelling device with very low mass movement – ideally for a dynamic cut off control with

high wearing resistance. In combination with the levelling, the variable shielding can also allow c) for a lower aimed beam with maintained cut off position.

Whereas the zone III control is performed by the rather fast "cut off machine" (some 1/10 of a second reaction time), the lower foreground zone control is achieved by an additional shield, moved slowly (2 seconds for full range) and can be activated right and left separately to an arbitrary state. It is foreseen for performance of the adverse weather passing lighting in case of road wetness being signalized.

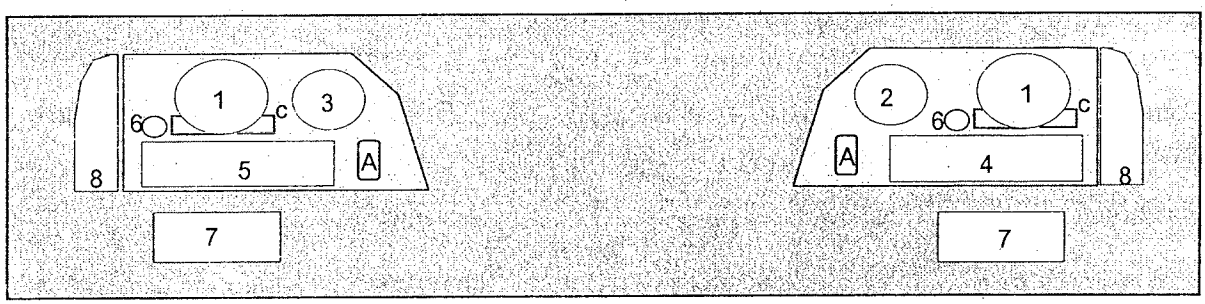

Fig.1: Experimental headlamp system devices with optical modules providing basic passing lighting (1), side illuminations to left side (2) and right side (3), wide band spot (4), narrow spot (5), position lighting (6), main beam lighting (7), direction indicator (8); devices for aiming & adjustment (A), and cut off modification (c).

The "side illumination modules" for the right and left side consist of a second pair of halogen ellipsoidal lamps, yet with very small construction dimensions in length and lens diameter, being designed illuminate the curbes intensively on a distance of some 25 meters. The illumination lateral extension (1 lx) is about 50° each, and the E_{max} is some 20 lx. The cut off is a pure horizontal. In the right headlamp this module's axis is directed by some 20° to the right, in the left headlamp it is some 25° to the left.

So, this lamp element provides not only a good illumination of the curb (respectively adjacent areas) as desired for the adaptive adverse weather passing lighting. Moreover, due to it's light volume and a reach of some 40 meters it is

capable for good illumination in bended road situations too, or, when turning off, in town areas, and it may serve for a fog light.

The modules were provided to be horizontally turnable, but the illumination width is large enough so that this was not deemed necessary.

The two "spot modules" are specially designed on base of wide reflection type halogen lamps (210 x 55 mm) and are equipped with H7 bulbs. They provide two different kinds of punctually enhanced illumination: the element in the right hand side headlamp emits an asymmetric spot of some 6 x 2 degrees with a cut off to the left and upwards. It's max intensity, close to the left upper edge roughly at 75R provides some 180 lx (once for the system, so corresponding to 90 lx per vehicle side), but the value in HV is only a fraction of one lx. It can illuminate perfectly the right curb on a straight road. But even in wide right hand bends it fits well and can be used since it's upper cut off is always below the critical directions for oncomers eyes or rear mirror positions.

The corresponding unit at the left side of the car provides a band of light, 1.4° high and 25° wide, with a very constant illumination of some 5 lx. It supports the reach without contribution to the foreground; additionally a much wider reach zone is created compared to the standard lamps. The effect is not that obvious as that from the right side spot, but, nevertheless useful enough for the composition of the desired spectrum of light patterns.

Adjustment

All of the above lamp elements are contributing to the passing lighting and have a horizontal cut off. For variable vertical adjustment they were equipped with a dynamic levelling device, acting to the whole cluster of lamp elements. This device allows for right and left side separate preset adjustment changes when necessary for the adaptive illumination task.

Lighting Functional Performance

The system allows for a lot of different beam patterns by activation of the ten independent control switches available on the manual operation board.

The following patterns were most used during the tests: starting from the standard passing lighting (**fig. 2a**) two different stages of the adaptive passing lighting for adverse weather / wet road conditions are shown in (**fig. 2b and 2c**).

The adverse weather lighting stage 1, as designed for a damp road, shows the required lower foreground illumination and the much stronger illumination of a very wide and longer range when compared to the standard distribution. The

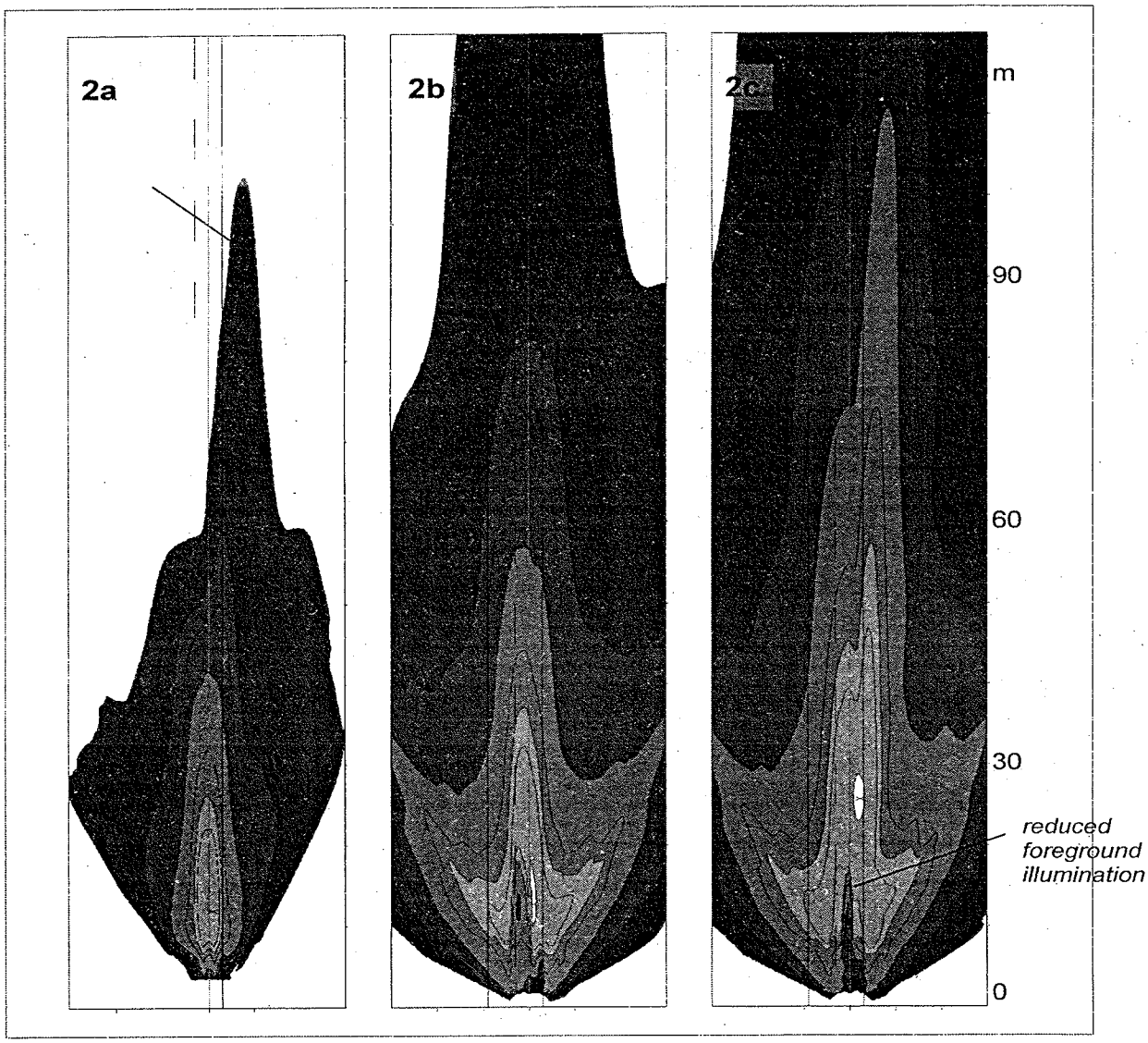

Fig.2**: Experimental headlamp system adaptive passing lighting; vertical illuminance (at 12V) on the ground; grey key steps, in lx: >1; >4; >10; >30; >80; a)* ***standard pattern *(basic modules only) b)* ***adverse weather lighting stage 1, for damp road*** *and c)* ***stage 2, for wet road***

second stage of the adverse weather lighting – designed for conditions of a rather wet road – has the same characteristics yet even more intensively performed either.

Fig.3 shows some of the numerous possibilities of the experimental adaptive lighting for dry conditions: the beam can be made wider in two steps when

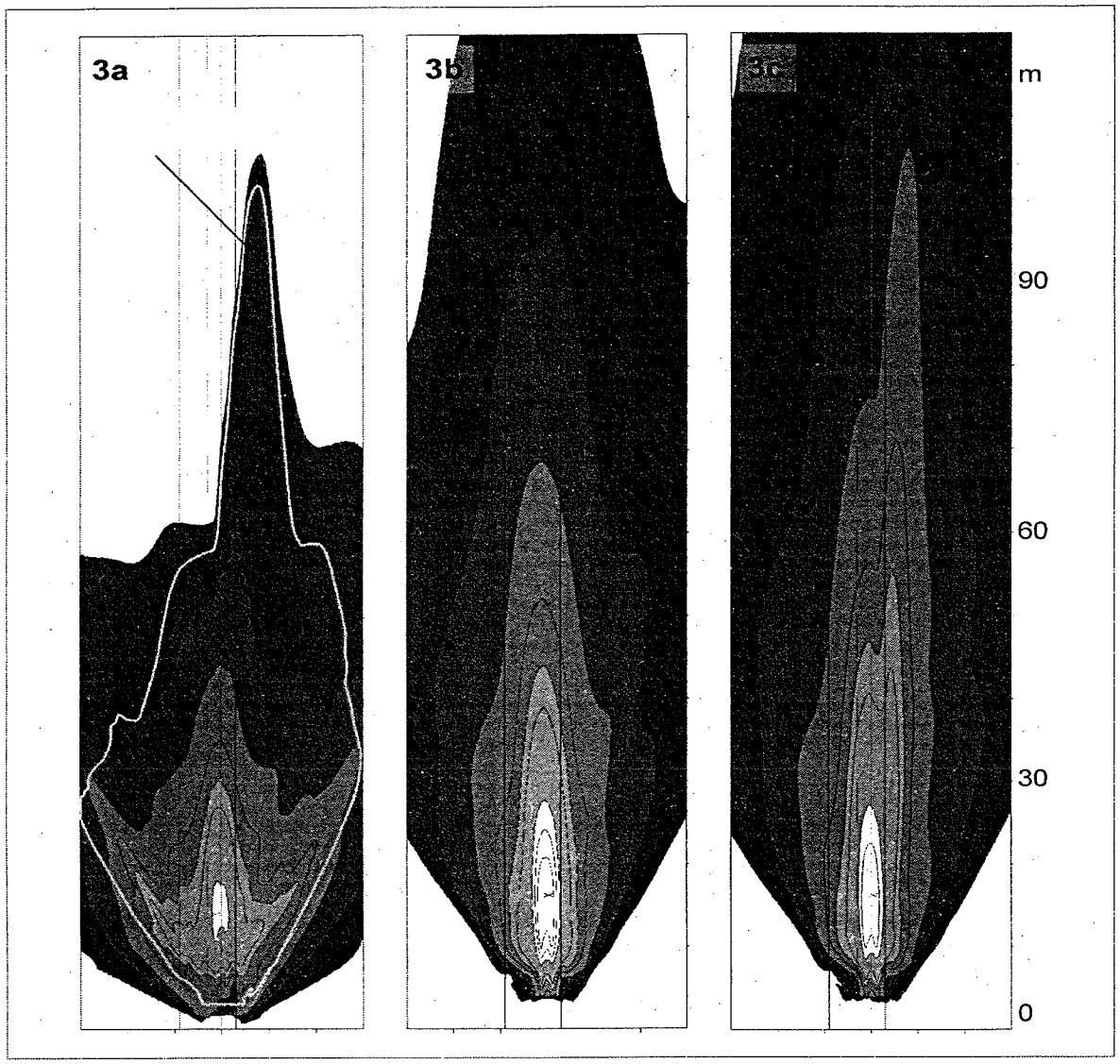

Fig.3: *Experimental headlamp system adaptive passing lighting; vertical illuminance on the ground; a) wide illumination for* ***country road*** *with bends, b) long reaching illumination for* ***main country roads*** *and c) higher aimed lighting for* ***motorway situations***

adding the left side "wide spot" and the side illuminations (**fig 3a**); it can get a longer range with unchanged beam width when boosted and added the right side spot (**fig 3b**). When in addition higher adjusted, this latter beam may also serve as a good passing lighting for motorway situations(**fig 3c**); here the reduced cut off step is applied for avoiding of dazzle in rear mirrors, despite the rather high adjustment to H-H. When the wide distribution is applied to one side

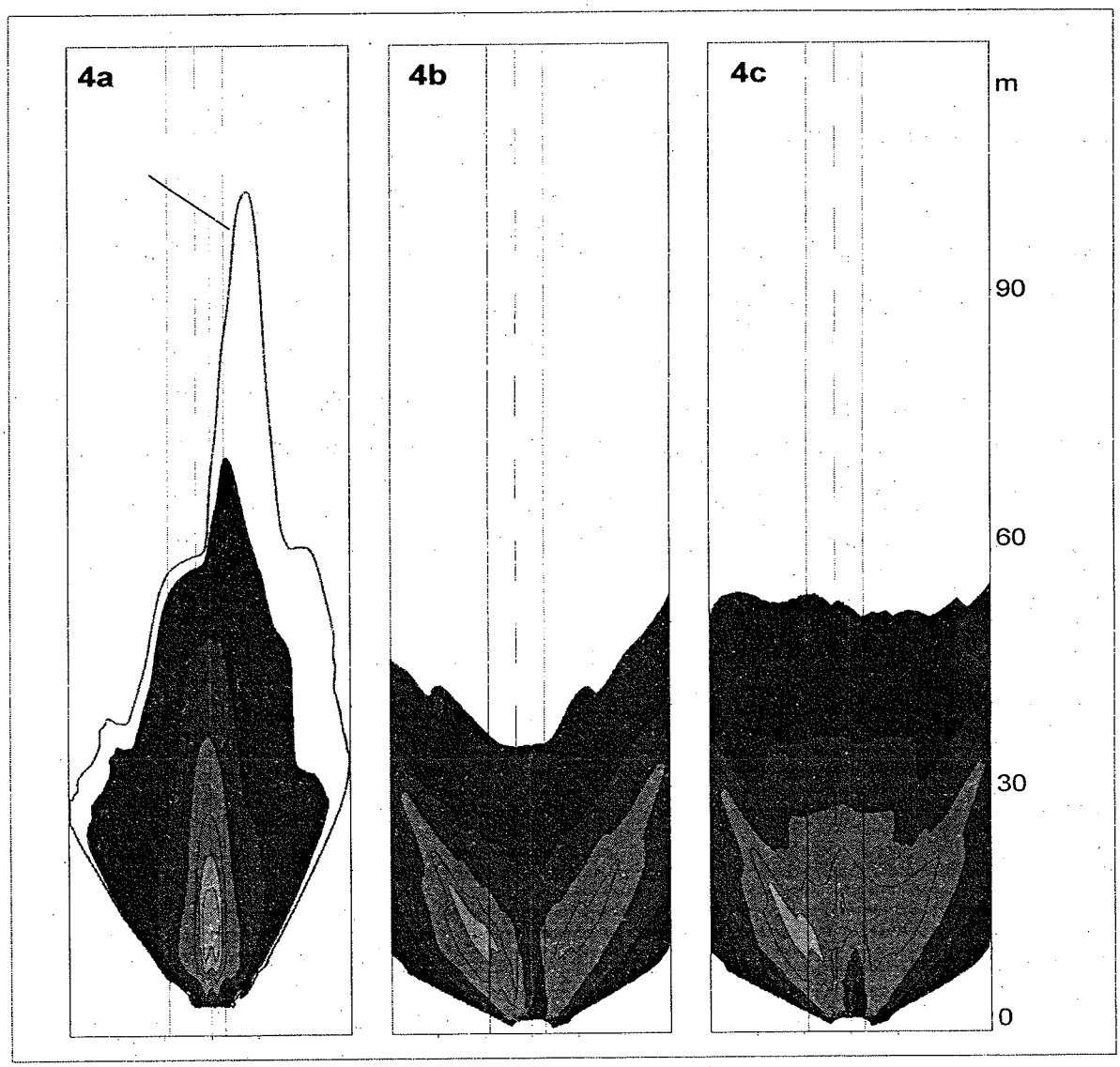

Fig.4: *Experimental headlamp system* ***adaptive passing lighting for town areas****; vertical illuminance on the ground; a) standard illumination dimmed and with reduced asymmetry, b) widespread illumination only and c) with wide spot added*

only, it can serve well for adaptive lighting in bending road situations too; for curves with a larger radius an additional higher adjustment plus the reduced sector application provides a good visual range there.

For application in town conditons, characterized by lower speed and public lighting, the conventional light distribution can be dimmed and reduced in the symmetric part (**fig 4a**), or, depending on speed and ambient light conditions a very wide illumination only can be chosen which do not interfer with the contrast, provided by the public illumination (**fig 4b and c**).

System Performance Evaluation and Experiences

The system was tested on proving grounds too, but extensively and mainly in more than six months test use on public roads of all kinds. Here it payed out that with this system all types of variable passing lighting could be performed as discussed. The functional changes at this time were operated manually by a second person in the test car. This resulted in an interesting and very effective learning process about possible switching criteria and threshold availability or combinations. So, e.g. the public lighting levels for town-adapted passing lighting and the correlation of wiper operation to reflex glare conditions on the road were figured out.

The functional units "boosting", "side illuminations", "spot lightings", "vertical preset adjustment capability" and last not least the upper and lower "cut off machine" were found to be all very useful even when the frequency of use, according to the local and ambient or traffic situation differed considerably.

The higher adjusted and boosted light patterns for adverse weather and motorway situation were mostly used with the reduced right side cut off step; the adjustment optimum was found at some 0.4 degrees above standard aiming; higher aiming reduced the positive effects. Boosted lighting and spot were favorites too on main country roads; the strong side lighting was applied frequently on country roads of lower categories but also as bending and very wide road lighting support. Dimmed lighting for public lit areas was applied for experimental purpose only. It was found to be fully sufficient, and the conspicuity to other traffic participants was felt quite good, especially with the

pair of small ellipsoidal H7 lamps (side illuminations) used. Finally, the missing foreground illumination of the adverse weather passing lighting was in no case a problem; on wet roads anyhow; on dry roads it was well realized, but, the drivers visual task was not affected even then.

All passing lighting performances, as provided and tested were very usefull; and the opposers - in arranged meeting situation conditions - did not complain. Zone III -changes due to additional lamps, being switched on or off, did not bother the opposer in a single test case. This was found despite provocating frequent changes in some tests. The asymmetric appearence of the car, as caused by any switched off lamp modules on one side only, if not needed for a specified function, had no disturbing effect.

Conclusions

The goal of the experimental system was fully reached. It could be shown that the lighting principles for the passing lighting modes as well as their combinations – despite being not performed that perfectly in all details as it would be done with serial products – have a very high acceptance from drivers as well as from opposers side. Even the famous additional 2 x 90 lx right side spot did not lead to a problem or complaints. This means, that the limitating values as choosen for illumination levels as well as for adjustment positions seem to be well tolerable. The rule "more light – more shadow" (in this case: more dazzel) do not apply here if the adaptive passing lighting design strategy as described and tested is followed – a strategy, which, among other informations and data, may contribute to a base for the future approval scheme of such systems as to be proposed.

Acknowledment

Daimler Chrysler AG provided not only the test vehicle and realized the switching devices, but contributed considerably to system development and gaining the test experiences.

1) Eureka Project EU1403 Advanced Frontlighting Systems (AFS)