ADAPTIVE DRIVING BEAM –
– NEW CONCEPT OF VEHICLE FRONT-LIGHTING

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Abstract

Vehicle front-lighting is essential for road traffic safety during night-time. It is a subject of continuous changes following the progress in technology. After the introduction of gas-discharge (xenon) light sources in 90-ties of the last century, in the recent years there were adaptive front-lighting systems (AFS) allowed to be used. This kind of front-lighting with significant complexity of functions and control, relatively limited lighting improvement and high costs, does not spread as quickly as it was predicted. For these reasons, the last two years saw automatic and adaptive driving beam offered, with electronic control based on the video camera image processing. It is done referring to the present in force, static technical requirements. But the automatic control of these lights as well as reactions of other roads users could have wide spread implications for the night-driving comfort and safety. On one hand it should create much better road illumination, as it leads in many cases to road illumination closer to the standard driving beam, when at present the passing beam would be used. On the other hand, there is a significant risk of glaring other road users as a result of their improper recognition or erroneous activation/deactivation of these lights. It could be a result of imperfections in sensors, algorithm and devices controlling light beam changes. This could lead to lack of light reaction and glaring of improperly indentified objects e.g. bicycles, pedestrians and to illumination deterioration in response to retro-reflectors (road signs). This paper describes most important issues concerning advantages and risks of introducing this kind of lights to the market and ways of defining requirements.

Keywords: *road transport, road illumination, headlamps, traffic safety*

1. Introduction

In last year's significant progress in vehicle front-lighting is observed. It concerns optical construction as well as light sources and finally methods and devices of control of light beam directing and intensity.

After the introduction of gas-discharge (xenon) light sources in 90's of the last century, in the recent years there were adaptive front-lighting systems (AFS) allowed to be used. This kind of front-lighting with significant complexity of functions and control, relatively limited lighting improvement and high costs, does not spread as quickly as it was predicted. The main reason is the restricted range of road illumination which is result of assumption for static passing beam. Passing beam is designed in a way that no relatively high illuminance level can occur over horizon. Practically it is realised by cut-off line, which is inclined down more than 1%. As a result nominal range of good road illumination cannot be further than 75 m straight before vehicle. On the right side of the road this range could be longer (practically to 100-200 m) as a result of asymmetry of cut-off allowing higher light position on the right side. Nevertheless it is only side effect which helps in observation of area where relatively often pedestrians can occur. From the other hand this can cause excessive glaring of other road users, especially on the right curves.

Throughout decades numerous studies showed that passing beam headlamps do not provide sufficient illumination on the road. Thus, obstacles can hardly ever be detected within stopping distance [1, 4, 6].

Adaptive Frontlighting Systems (AFS) [11] are intended basically to move beam pattern left and right accordingly to bending direction ("bending" mode of AFS) as well as slightly increase inclination of cut-off alignment by higher speeds during motorway driving conditions ("motorway" mode). Two additional functions of AFS are the "bad weather" mode activated during raining, snowing or fog and "town" mode which allow illuminating in closer distances but wider angles. Complete AFS is complicated and expensive solution. The bending function which was allowed also in standard passing beam is relatively simple solution giving "near" AFS quality inside passing beam.

Finally advantages of AFS remain restricted, comparing to standard driving beam which is the cheapest and well known head-lighting function. Main disadvantage of passing beam is glaring oncoming road users in certain conditions. However driving beam cannot be used when glare exposed eyes can occur. Practical observations and recent research shows that drivers have a reluctance to operate the driving beam and frequently switch the driving beam to the passing beam too early with the consequence that forward vision is restricted [5,10]. It leads to conclusion that significant head-lighting improvement can be achieved by appropriate using standard driving beam and/or to control it automatically.

The next step is idea to adapt driving beam to road condition, eventually in connection with adaptation of passing beam. This adaptation is based on different philosophy than AFS because the main concept is to avoid high illumination of areas where glare exposed eyes could appear.

2. Driver assistance in driving beam use

As it was found that driving beam is used not often enough in relation to driving conditions sensors were introduced to detect the presence of other power driven vehicles in illuminated areas to assist the driver. It could significantly improve not only driving comfort but also safety. Control system for switching between passing beam and driving beam was based on camera system "recognizing" other road users. To work properly the sensors and software should be able to detect surroundings, position of other vehicles and other road users. But this process of machine recognition is the main difficulty. It is possible to detect given level, colour and/or size of light which can be interpreted as oncoming or preceding vehicle. It is done by reacting to the light emitted by the front lighting devices of an oncoming vehicle and the rear lighting devices of a vehicle. Much more difficult is to recognize pedestrians as they can have no lights. Present laws require not glaring them and cyclists by driving beam [12, 13]. Machine camera detection should not be limited to the vehicles only but rather should detect and properly react to "other road-users". Otherwise this will cause changes in road traffic rules and habits of millions road users. It could have significant impact for traffic safety.

In fact this kind of automatic control should be subject of requirements to ensure that different interpretations of its functionality are avoided. Till now no such provisions are ready.

3. Automatic activation of driving beam

Due to a lack of clarity and consistency in the interpretation of the current provisions of UN ECE Regulation No. 48 [12], some national road administrations have already granted type approvals for vehicles equipped with automatic activation and deactivation of the driving beam.

Experts of international vehicle lighting community had possibilities to test and compare some existing and prepared for future automatic driving beam solutions. On Fig. 1 [3] is shown idea of Mercedes-Benz Class E "Automatic High Beam Assist with Adaptive Low Beam". It is realized by automatic soft switching between low and driving beam and by increasing the range of the passing beam light up to the next vehicle on the road.

Used in Opel Astra system "High Beam Assist" switches on driving beam automatically at night when vehicle speed is above 40 km/h, then is switching automatically to the passing beam when

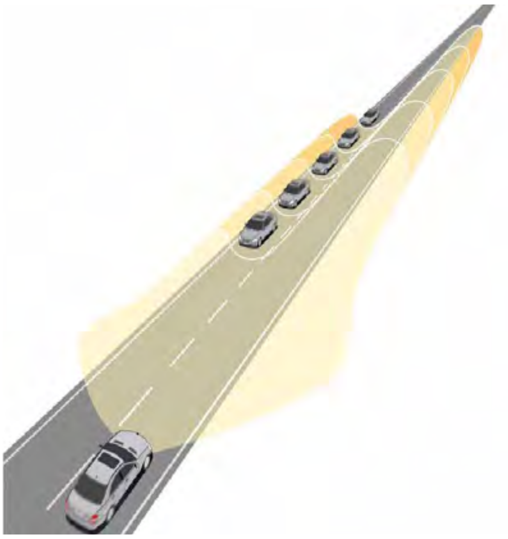

Fig. 1. The passing beam light is automatically reduced by an approaching vehicle [3]

the camera detects lights of oncoming or preceding vehicles, vehicle speed gets below 20 km/h, or if it is foggy or snowy [3].

Similar to Mercedes "High Beam Assist Plus" in the new driving beam system of Audi A8 automatically switches between low and driving beam and in addition the headlight range on the left side is adapted to the next vehicle on the road (Fig. 2).

Fig. 2. Audi A8. The passing beam light is automatically reduced by an approaching vehicle [3]

Above presented systems are really not fully in line with current requirements. As a result presently all the time the driver remains responsible for deciding whether it is appropriate to operate the automatically activated driving beam and if necessary to switch the driving beam off manually.

Such situation cannot be acceptable and should be resolved relatively quickly. It is subject of intensive work of UN ECE GRE experts.

4. Adaptive driving beam (ADB)

The main difference between "Automatic" and "Adaptive" Driving Beam is that ADB changes driving beam pattern during driving when recognized object sensitive for glare appears in light beam, especially vehicle but also "other road user". This adaptation should be such that when glare sensitive object is located in light beam this beam should be restricted to accepted level only in area where it appears. Practically it means that kind of shadow should be generated in this area. It allows keeping better visibility in other areas where other safety important objects could appear. The area and values of light restriction should be controlled using sensor signals and appropriate software controlling light beam "shape".

Below are presented examples of practical realisations of such systems (Fig. 3.)

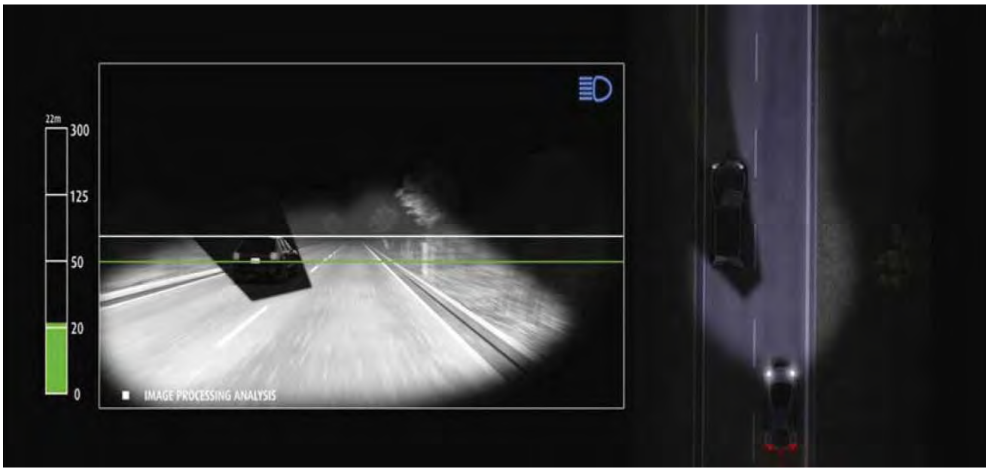

Fig. 3. Valeo. "Xenon Glare Free High Beam". Example of "cutting" light in place of presence of other vehicle [3]

Used in Volkswagen Touareg 2 "Dynamic Light Assist" adapts distribution to the actual traffic situation via a camera signal. It uses partial driving beams as shown on Fig. 4 and 5.

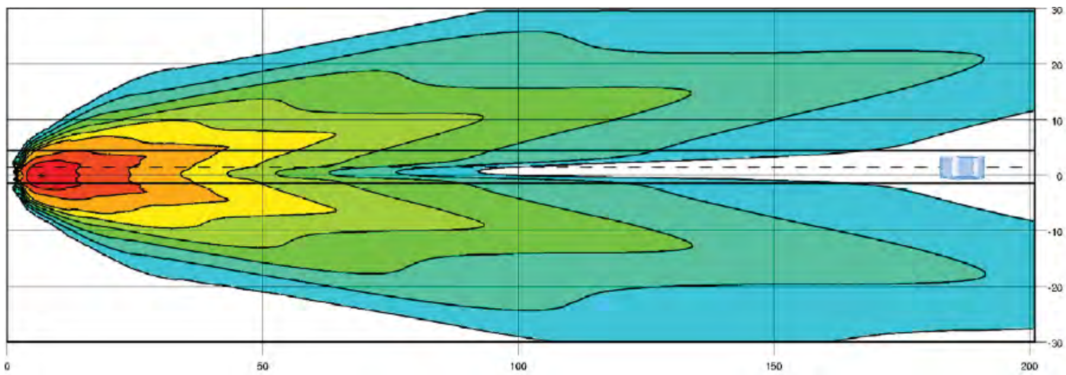

Fig. 4. Touareg 2. Partial high beam, driving behind a car [3]

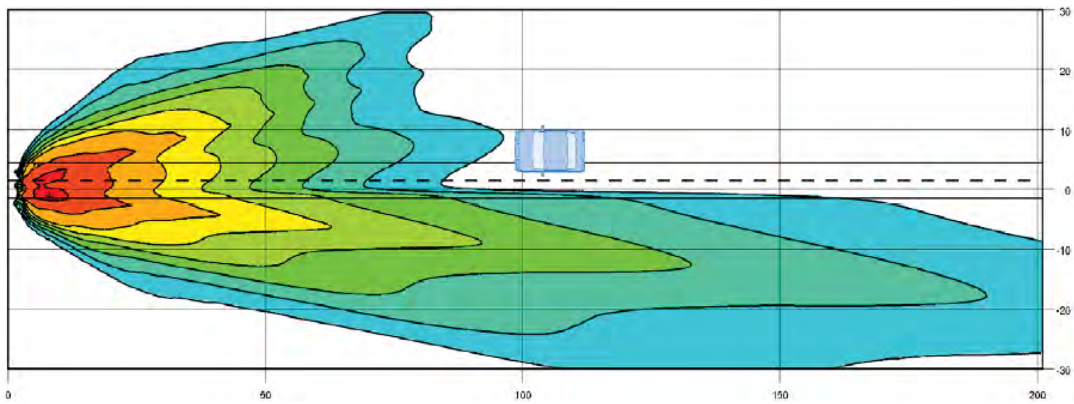

Fig. 5. Touareg 2. Partial high beams, with driving beam on the right lane passing oncoming traffic; when overtaking the beam is mirror-inverted [3]

More detailed description of ADB and experiments on the road can be found in [2, 9]. Idea and examples of isolux lines for “VarioX-module” headlamp are presented on Fig. 6.

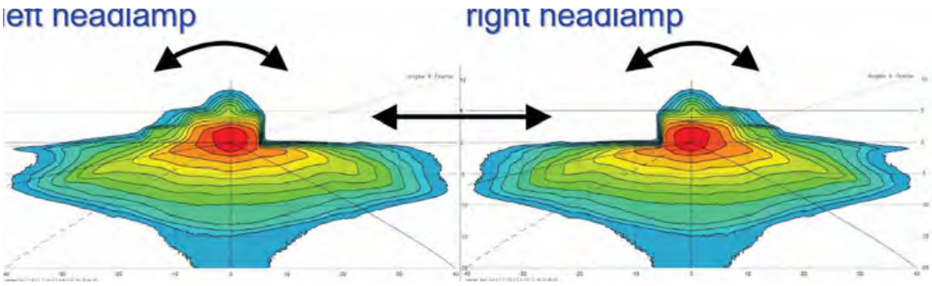

Fig. 6. Principal depiction of vertical Cut-off line beam pattern [2]

5. Open questions regarding disadvantages of ADB

It is easy to see that information provided by manufacturers is very modest and have impressive but rather advertising character. The practical test of presented systems shows that these systems react to front and rear lights of other vehicles but such reactions are not always in line with declarations of manufacturers and expectations of drivers. The basic impression is that there is much more illumination on the road and the driving beam is switched on significantly more often than the driver would do manually.

But it is observed that these lights react to retro-reflective materials, especially to some road signs with high reflectivity, or small retro-reflectors placed on posts, barriers or in pavement switching to passing beam when there is no need. Reactions to bicycle depend on light intensity of their headlamp, and finally these systems do not react to pedestrians. Reactions of ADB systems looked subjectively as not highly repeatable comparing driver reaction in similar situations. Also, there were subjective feelings that this kind of lights in some situation glares much more than expected.

Even though reservations these feelings lead to conclusion that advantages of such systems should dominate over disadvantages. The most important advantage is the possibility to overcome limitation of passing beam short range visibility. Present passing/driving beam system is the result of imperfect assumptions and technical possibilities of 50’s of the 20 century which were the backgrounds for present vehicles illumination system. This short range of passing beam is often insufficient to detect many objects on the road when driving with speeds that are legal and common-sense during night time.

But important is that there is a possibility to decrease comfort and - probably - safety in some situations, especially when driver of such ADB equipped expensive vehicle relays on manufacturer’s assurance that the system works automatically and properly. Such situations depends on imperfection of machine object recognizing and beam pattern control regarding driver sight, knowledge, experience and driving style, which are very individual and change with time.

The driver could be not expected to concentrate on rare situations where the automatic system could not work like intended, potentially lowering his/her attention in dangerous situations as well as to detect situations where ADB is either not working properly and needs to be overridden or may not illuminate whole expected area forcing driver to quickly adapt the speed or to do other unpredictable manoeuvres.

6. Regulations for ADB

Above examples shows that there are different technical conceptions of realizing function called “Adaptive Driving Beam” which manufacturers try to include in one of the following: standard driving beam (automatic switching), AFS (adaptive cut-off line) or “true” ADB. The latter currently cannot be type approved according to existing headlight regulations but also the first two introduce doubts.

Details of ways of machine recognizing objects and control algorithms for ADB are treated confidentially by their manufacturers. On the other hand they put pressure on experts preparing regulations to allow such systems on the market. It results in proposal of requirements which are subjective and very general. In practice it is rather really impossible to verify it in a repeatable way. Some examples of proposed description:

"The system may gradually adapt the complete driving beam, or alternatively may selectively and gradually adapt the driving beam only in the zones corresponding to the presence of oncoming and / or preceding vehicles without causing discomfort to other road users" [8].

"Under the conditions of gradual adaptation, the main-beam function shall meet the requirements this Regulation. These requirements shall be verified during the type approval testing in conjunction with a signal generator to be provided by the applicant. This signal generator shall reproduce the signals provided by the vehicle and cause the gradual adaptation of the main-beam and in particular shall represent the settings so that the photometric compliance can be verified" [8].

"*Gradual adaptation of the driving beam*" means a driving beam that adapts to the presence of oncoming and preceding vehicle in such a way that improved visibility is achieved for the driver without causing discomfort to other road users" [8].

"To verify, that the automatic gradual adaptation of the driving beam does not cause any discomfort (e.g. excessive glare) to oncoming and preceding drivers, the technical service shall perform a test drive which comprises any situation relevant to the system control on the basis of the applicants description; it shall be notified whether the adaptive driving beam is activated, performing and de-activated according to the applicant's description. Obvious malfunctioning shall be contested" [7].

"The correct reaction of the system shall be demonstrated by a test drive in clear atmosphere with a speed of 70km/h ±10 km/h" [7].

Proposed definitions of photometrical requirements for ADB similarly describe relatively simplified and small area of road possible glare exposure (Tab. 1) [8].

Tab. 1. Proposed photometrical requirements for ADB for glare

Test Point	Position / deg.		Max. Intensity	
	Horizontal	Vertical	(cd)	(lx)
Line 1 - Oncoming vehicle at 50m	-4.8°L to -2°L	0.57°Up	440	0.7
Line 2 - Oncoming vehicle at 100m	-2.4°L to-1°L	0.3°Up	1300	2.0
Line 3 - Oncoming vehicle at 200m	-1.2°L to -0.5°L	0.15°Up	3800	6.0
Line 4 - Preceding vehicle at 50m	-1.7°L to 1.7°R	0.3°Up	1320	2.1
Line 5 - Preceding vehicle at 100m	-0.9°L to 0.9°R	0.14°Up	3900	6.2
Line 6 - Preceding vehicle at 200m	-0.45°L to 0.45°R	0.1°Up	11400	18

It is important that there is no description on how to check that a vehicle (other road user?) was recognized in given place and direction. It is proposed to be left for manufacturer and to be tested subjectively or by simulation.

Image processing and generation of appropriate control signals is based upon algorithms developed by the vehicle manufacturer in conjunction with vehicle suppliers. These algorithms are the result of extensive testing in real-world conditions. But they remain proprietary and confidential.

For these reasons there are many doubts how the requirements should be described to assure that illumination on the road will be safe enough independent of manufacturer solutions. Leading manufacturers that are interested in introducing new ADB systems declare that they are tested during thousands km of driving and are safe.

When such systems will be type approved (some are for today) drivers will become confident of automatic systems and will rely on them to work properly. And this assumption is very understandable.

So these systems should work correctly and should be reliable. But it is easy to imagine that when this solution (ADB) will be legal other manufacturers will try to introduce to market devices which will be as cheap as possible and meet minimum legal requirements. When requirements are checked in significant part subjectively the real performance could be unpredictable, especially performance of detection of objects infrequently occurring on the road. It is important in regard to "other road-users" described in [12] already for many years as well as in [13].

Such situation could cause equipping vehicles with ADB systems which performance will be not satisfactory. It could concern especially aftermarket sets.

7. Conclusions

New ADB systems could be the advanced step forward in way of improving night time road illumination. The main new rule is "active, selective glare avoidance" in place of present passing beam "fixed shadow" (glare risk) zone. As a consequence excessive glaring of passing beam presently is observed as well as usage of driving beam much less then possible.

Common use of ADB systems could be real breakthrough in philosophy of road illumination and could cause significant consequences concerning better road illumination, improved strategies of night driving and all road user behaviour. Introducing ADB systems means agreeing to change in definition of legal requirements in direction to partial replacement of human perception by high level of machine vision.

Till now presented versions of ADB are questionable mostly because there do not react properly to some objects which present driving beam could glare. The most important are cyclists and pedestrians. There were also observed false reactions caused by retro-reflective materials. There are observed different strategies of illumination reduction, what means that in some realisation significant reduction of illumination occurs by small area where it is really needed when in other could be big shadow areas decreasing illumination in needed place. Current proposal of formal photometrical requirements [8] looks very simple, regarding possibilities and needs.

As a consequence there should not be the place for ambiguities and imperfections in requirements and testing methods because main goal is traffic safety. Present works in this subject show significant difficulties in agreement between international experts, as the matter is complicated. The main question is how far it is possible to go in subjective testing direction when photometric objective tests seem to be complicated and expensive.

Regulations should be written clear, precise and detailed. ADB functioning should be transparent and clear-cut. This requires manufacturers to be open and treat their solutions as contribution to common work. Commercial success looks to be possible on condition that will include more cooperation than competition.

Very important issue is that system behaviour should be clearly defined understandable and driver friendly. ADB systems should be reliable enough that at least system error should not result in serious danger keeping in mind real driver possibility and responsibility.

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