Innovative Lighting Systems Enhance Road Safety

In the last twenty years, significant progress has been made in the field of headlight technology. Today's systems are making driving at night much safer. Future intelligent lighting systems, which make use of computer-aided image processing sensors, will bring further safety benefits. Automotive supplier Valeo is currently developing such lighting systems.

1 Introduction

Despite the fact that traffic volume at night is much lower, a recent study by TÜV Rheinland has shown that the risk of accidents and, in particular, of fatal accidents during the night-time hours is relatively high. The TÜV analysis indicates that if all the vehicles on the road in Germany had xenon instead of conventional halogen headlights, serious accidents on rural roads would be reduced by more than 50 % each year and on motorways by more than 30 %. As a result, there would be 6 % fewer accidents resulting in injuries and 18 % fewer with fatalities. The study compared the number of accidents involving luxury ve-

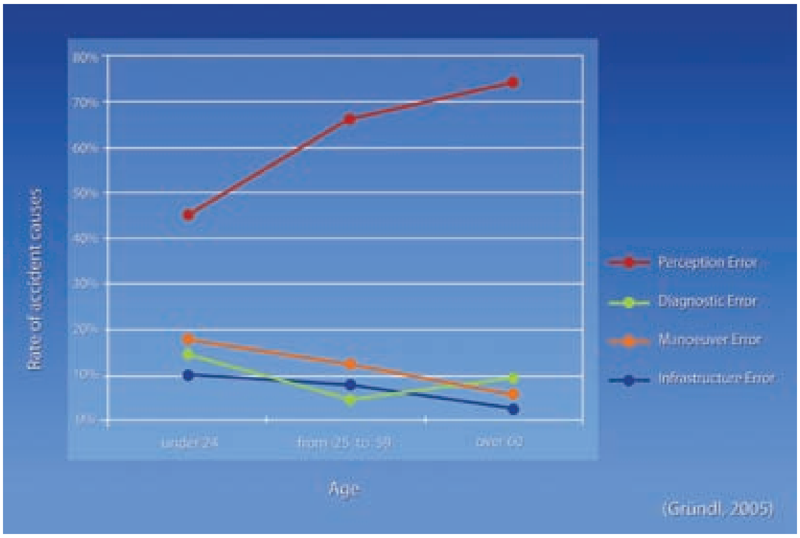

Figure 1: Driver errors as the cause of accidents

hicles with a high proportion of xenon lighting and vehicles from segments with a negligible proportion of xenon headlights. This showed that xenon lighting has a statistically significant influence on the number of accidents on rural roads and on motorways. The result is not dependent on other technological improvements, such as ABS or electronic stability control systems. Currently, around ten percent of all the vehicles registered in Germany have xenon headlights.

A study carried out in 2005 considered the age of the driver involved in the accident in relation to the cause of the accident, **Figure 1**. Amongst younger drivers, perception errors were the most frequent cause of accidents, while the proportion of this type of error amongst drivers over the age of 60 was more than 70 %. By 2025, there will be more than 100 million people in Europe (EU25) over the age of 64 and a large proportion of them will still be driving.

In addition to these investigations, Valeo regularly analyses the acceptance and expectations of car buyers in relation to driving assistance systems. These studies are carried out annually throughout the world and consist of a combination of socio-cultural trend analyses, internet surveys and evaluations of end customer interviews.

One important result of the surveys is the requirement for improved visibility. This applies to all market segments, not only the premium car segment. In addition, it is clear that there is significantly more interest in and a greater readiness to buy lighting systems than other types of driver assistance systems, **Figure 2**. This finding has been confirmed by a study on the acceptance of driving assistance systems carried out this year in Cologne by independent market researchers who interviewed drivers of vehicles from the segments B, C and D.

Visibility was regarded as the most important area for improvement. The drivers' expectations for improvements to lighting systems included an automated high beam system and adaptation of lighting to road and traffic conditions. A further study, carried out in Detroit in 2006, highlights the significance of automatic switching between low and high beam. This indicated that the average use of high beam represented only 3.1 % of travelling at night time. Even in conditions with no other traffic on the road and in rural areas where high beam could be used for 100 % of the time, it is only used for 25 % of each journey.

A survey carried out by Valeo in Heidelberg produced similar results. In this investigation, the average use of high beam was 8 % (60 drivers over a distance of 3400 km). At the same time, the study showed that a well-designed automatic high beam system can increase the use of high beam by a factor of 4.7. A US study of 54 drivers last year indicated the reasons behind the unwillingness to use high beam. The study indicated that:

- 50 % of the drivers were aware that they do not use high beam effectively
- 79 % recognised that it is easy to switch from low to high beam
- 87 % indicated that they were prepared to accept an automatic system for switching from high beam to low beam.

The number of drivers prepared to buy a high-beam assistant is similar in both the US and Europe. Systems of this kind would sell well at a price of 250 euros. In addition, the studies have demonstrated that drivers' readiness to buy increases significantly after taking a test drive. The test drivers would even be prepared to pay up to 500 euros for the increase in safety.

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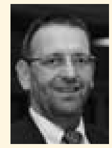

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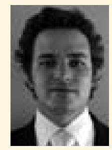

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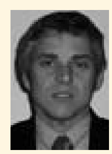

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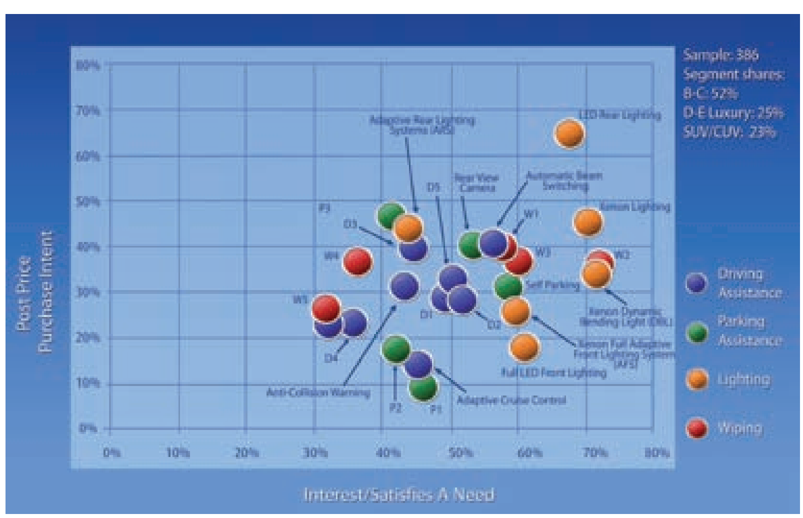

Figure 2: The results of an internet survey indicate the level of acceptance of driver assistance systems, including lighting solutions

2 Light and Sensor Technology – The Limitations of Current Systems

2.1 From Xenon to Adaptive Headlights

There have been major changes in headlight technology since the start of the 1990s. The introduction of gas discharge lamps (xenon) has doubled or trebled the light output of both low and high beam headlights. The introduction of static and dynamic bend lights in 2003 has allowed vehicle lights to adapt to the circumstances on the road. New legislation permits the use of adaptive front lighting systems with motorway, adverse weather and town lighting functions, in addition to the standard low beam and high beam, **Figure 3**. The ability to adapt to different weather and traffic conditions is based on a relatively simple sensor system. The essential input data already available on vehicles includes speed, steering angle and windscreen wiper operation. Using this information, the system can evaluate the road category or traffic situation and select the most suitable type of lighting. However, the system does not always choose the correct beam. As a result, the different beams are designed to ensure that other road users are not dazzled.

The performance of the system can only be improved further by integrating a camera. This removes one of the current limitations, as anti-dazzle protection is no longer provided by the beam. Instead, an accurate analysis of the traffic situation allows the high beam to be modified. The resulting increase in visibility and safety is significant and, at the same time, there is no possibility that other road users will be dazzled.

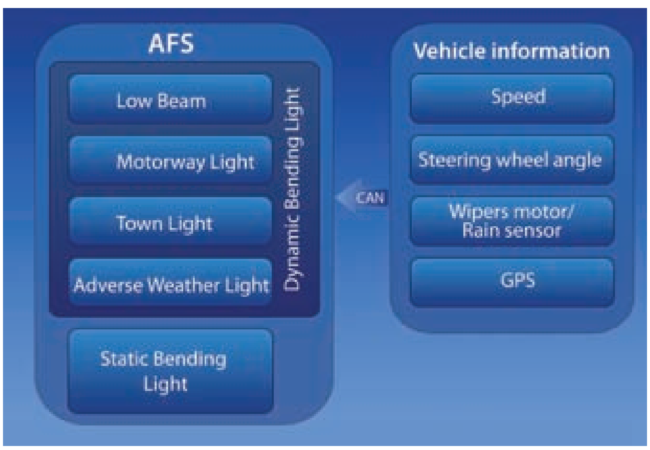

Figure 3: The selection algorithm for AFS

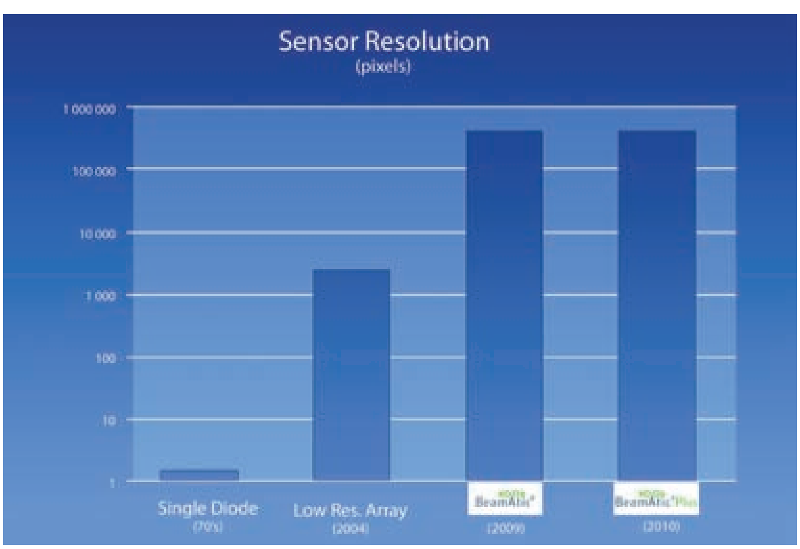

Figure 4: The rapid development of sensors for lighting automation

2.2 From Automatic Low Beam to the High-beam Assistant

Automated vehicle lighting has a long tradition. The first trials took place in the 1960s and 1970s in the US and Europe, but had only limited success. The sensor systems of that time were not sufficiently advanced and were not able to clearly identify the vehicles ahead of or approaching the car. In addition, a large number of false identifications had a major impact on the usability of the system.

The first high-beam assistant based on a sensor with 2500 pixels represented a significant improvement in functionality. However, the system still had obvious limitations: incorrect recognition of objects, high activation and deactivation thresholds, recognition difficulties in fog and, as a result, drivers being dazzled by their own lights in foggy conditions.

Since 2004, Valeo has been using a new generation of complementary metal-oxide semiconductors (CMOS) for its lane departure warning systems in the Nissan Infiniti models. These sensors also offer a wide range of opportunities for developing new automatic lighting systems. The resolution of this new generation of sensors has reached a level, **Figure 4**, which allows the entire vehicle environment to be accurately represented. The Valeo systems are called BeamAtic and BeamAtic Plus.

3 New Lighting Assistance Systems

3.1 Automatic High Beam

Depending on the traffic conditions, the BeamAtic system switches automatically from low beam to high beam and vice versa. The video data is passed to the ECU, which calculates the necessary information for the lighting control unit. The BeamAtic software uses the camera as if it were a light sensor with fixed settings. During the first phase, the software analyses all the light sources within its visual range using a variety of processes, such as pattern recognition, curve recognition and threshold identification. The analysis breaks the objects down into different categories, such as rear lights, headlights or street lights. Once the objects have been classified, the tracking software filters out all the information that is not related to the movement of the vehicle. At the same time, roads with permanent street lighting are identified, in order to avoid high beam being used in inner cities. Two sub-algorithms are used to detect these lighted areas. The first identifies street lighting in specific regions of interest. The second measures the brightness of the image. By coupling these two items of data, it is possible to determine the status of the lighted areas. As soon as the software identifies a lighted area, it switches the car headlights to low beam. When the car leaves the lighted area, the BeamAtic system automatically switches to high beam if there is no vehicle nearby.

3.2 Variable Lighting

The next level of automated lighting system controls the headlight beam, depending on the other road users approaching or ahead of the car. This system is called BeamAtic Plus and is based on two main functions: progressive lighting and predictive headlight levelling, **Figure 5**. If the two functions are used simultaneously, the lighting of the vehicle can be adapted to the position of other road users, either approaching or ahead of the vehicle. The progressive lighting function provides a continuous transition between low and high beam, depending on the position of the vehicle. The range of the beam is controlled on the basis of an evaluation of the distance between the vehicle itself and the vehicle identified by the system. The objective is to provide the driver with as much light as possible without dazzling other road users. The predictive headlight levelling system allows the headlights to be used dynamically on the basis of the vertical position of the other road users in the vicinity. This dynamic headlight setting increases visibility when the vehicle is approaching a hill without dazzling drivers travelling down the hill. This system also avoids dazzling at the top the hill. The system places specific requirements on components, image recording and image processing functions and algorithms. In order to ensure that the systems and subsystems are compatible with one another, a specific system methodology was introduced during the process development phase, **Figure 6**.

In order to provide progressive headlights and predictive headlight levelling, Valeo has developed a system consisting of three functional blocks: image processing, lighting control and the headlights themselves. The system can be described in terms of the detection range, the precision of the predictive function or the response time. Starting from the overall system performance specifications, the dedicated requirements for each individual subsystem can be defined.

3.2.1 Image Processing

The image processing system consists of two components: the sensor and the ECU (Electronic Control Unit). They can be installed in one housing to save space or in two separate housings, depending on the requirements of the vehicle manufacturer. The BeamAtic Plus and BeamAtic systems use identical sensors, as the systems are modular and based on one another, **Figure 7**. Firstly, the vehicles are detected by BeamAtic. Secondly, the BeamAtic Plus software computes the distance. Then the horizontal and vertical angle between the vehicles identified by BeamAtic is calculated.

Additional vehicle data, such as the speed, is primarily used for strategic coordination. The light source identification and the information about whether a vehicle is moving towards or away from the vehicle in question allows pairs of lights to be allocated to a vehicle. Red rear lights represent a vehicle in front and white headlights represent an oncoming vehicle. This is a decisive consideration as the functional safety of all the BeamAtic Plus strategies is based on this information.

If the information were incorrect, the headlight control system would be unreliable and may dazzle other road users. As soon as the vehicle ahead or the oncoming vehicle has been identified, the distance to this vehicle is calculated. The distance is calculated by measuring the number of pixels between the right-hand and left-hand light source. Once this figure is known, the actual distance between

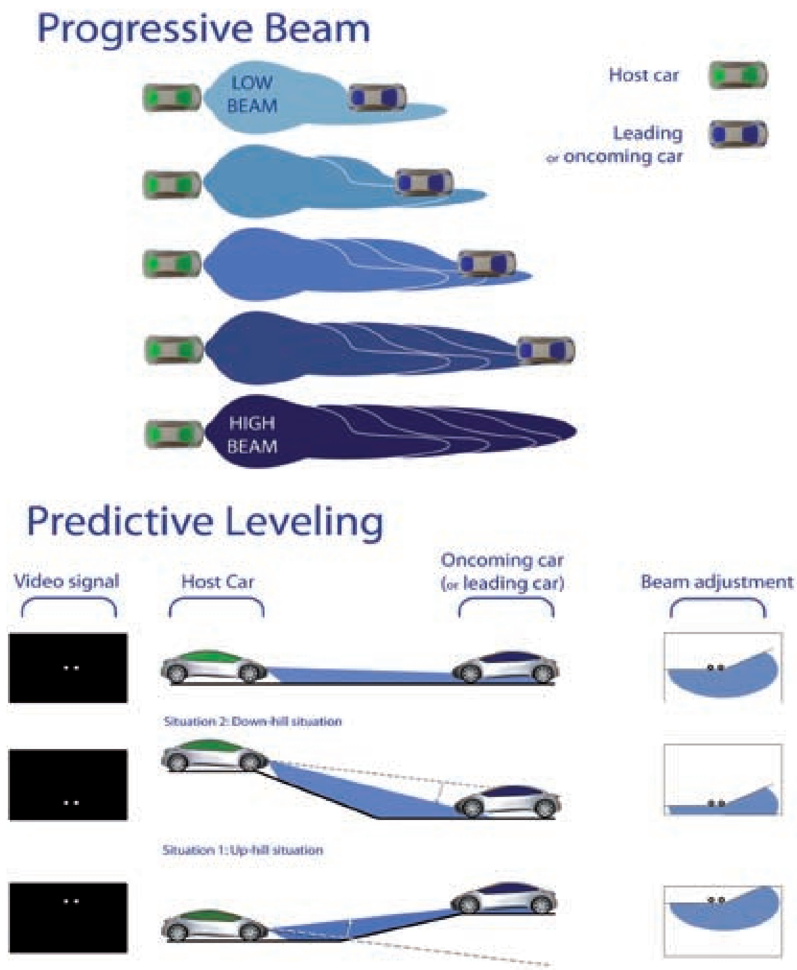

Figure 5: BeamAtic Plus adapts to the situation on the road. The changes made to the light beam increase visibility

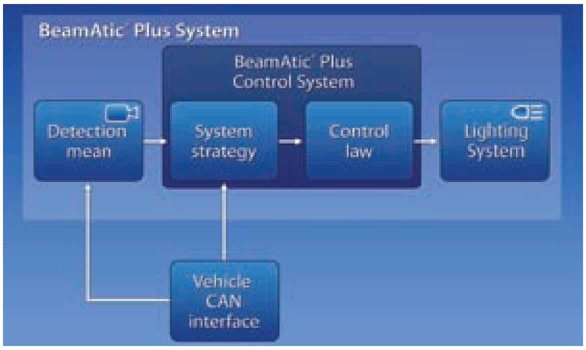

Figure 6: The methodology introduced during the process development phase ensures that the different components and subsystems are fully compatible

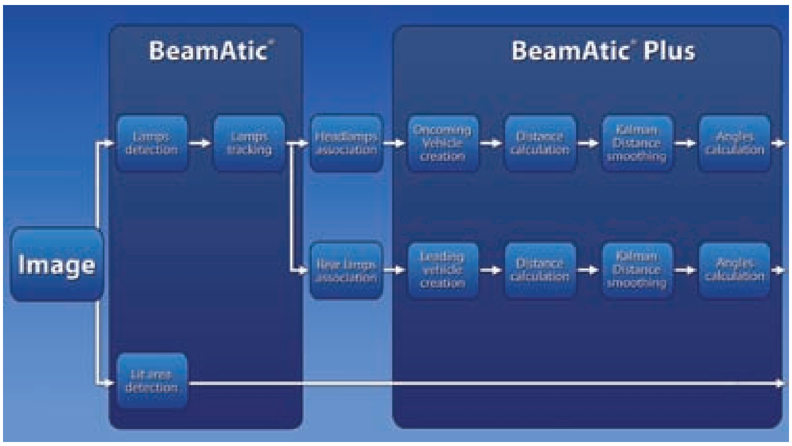

Figure 7: The BeamAtic Plus system is based on the BeamAtic software

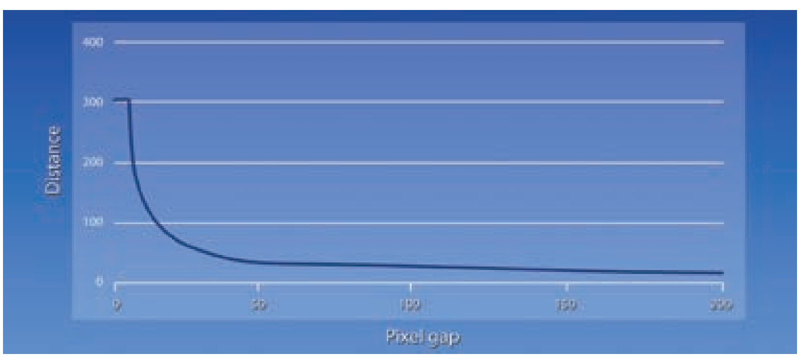

Figure 8: The Kalman filter allows the distance to the next vehicle to be calculated

the vehicles can be evaluated, **Figure 8**. The light strategy is based on the following data:

- Headlight status: low/high beam
- Street lighting
- Distance from the oncoming vehicle
- Angle to the oncoming vehicle
- Distance from the vehicle ahead
- Angle to the vehicle ahead

All this data is sent via the CAN bus (controller area network) to the lighting control system and forms the basis for the lighting strategy.

3.2.2. The Control System

The BeamAtic Plus control system is the link between the camera and the headlights. The camera provides the following information about the surroundings: distance and angle of the object, low or high beam status and street lighting. In addition, the following vehicle data is processed: steering angle, speed, wiper and turn indicator information. All the system strategies are stored in the control unit. The data recorded is subjected to a plausibility check and, if it differs from the expected interval, a lighting position that will not dazzle other road users is selected. The control unit also calculates the specifications for the predictive headlight levelling system and the adaptive light beam function. The objective of this control strategy is to position the stepper motors accurately on the basis of the data provided.

3.3 The Lighting Module

Two headlight systems are used with the BeamAtic and BeamAtic Plus lighting automation modules. The tri-xenon headlights are compatible with BeamAtic and have three beam options (low beam, motorway and high beam). The progressive beam modules create a continuous transition between low and high beam. This function is used with the BeamAtic Plus system.

3.3.1 TriXenon Module

Several different attempts have been made to improve the efficiency of xenon headlights. One of the most widely used concepts is a two-function projection module that produces both low beam and high beam. This consists of an elliptical reflector, a shutter that provides anti-dazzle protection for low beam and a lens that creates the light beams. The lens gives the headlight its characteristic appearance, as the majority of xenon headlights use optical projector modules. The modules are so compact that the necessary mechanical system for the different functions can easily be integrated. This is particularly beneficial for bend lights as the light module swivels by +/- 15°. Recent studies confirm the fact that bend lights improve safety, particularly on bends. The combination of dynamic bend lights and xenon improves visibility by up to 40 % on average bends. New regulations from the Economic Commission for Europe (ECE) describe the requirements for adaptive front lighting systems (AFS). Recent regulations allow for new light functions, such as motorway, adverse weather and town lighting. The lighting concept is already in use in the Mercedes E-Class and will soon be introduced into other models. Valeo's technical solution is a compact xenon module, referred to as TriXenon, **Figure 9**, which is a logical development of the current bifunctionnal xenon modules. In this case, there are three possible shutter positions. In the motorway position, the module produces a beam with a length of up to 160 m.

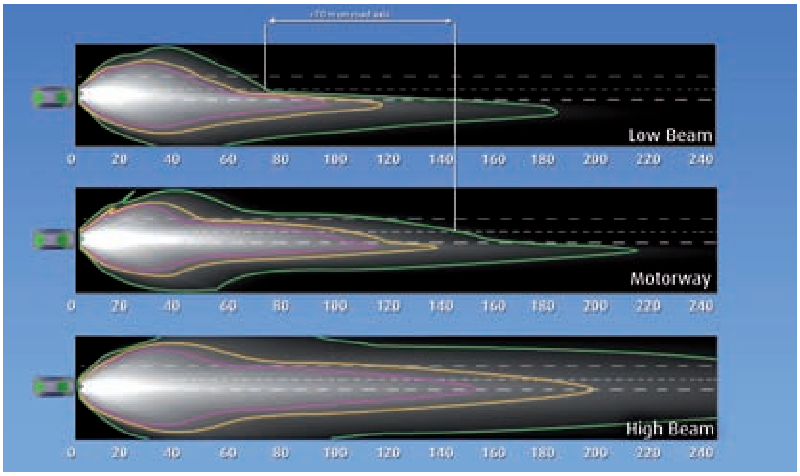

Figure 9: TriXenon module

3.3.2 Progressive Beam Module

Valeo is developing a module for a camera-based automated headlight system that will adjust the visibility according to the situation on the basis of information supplied by the camera. The anti-dazzling shutter is powered by a stepper motor and is designed in such a way that a continuous movement results in a progressive change in the light intensity. At the same time, the position of the boundary between light and dark is moved. The driver perceives this combination of effects as an extension of visibility, which makes driving both easier and safer. The new module will become part of the Valeo xenon family, **Figure 10**, and will keep the dimensions of the existing bifunctionnal xenon and TriXenon modules, which means that it can easily be integrated into existing headlight systems.

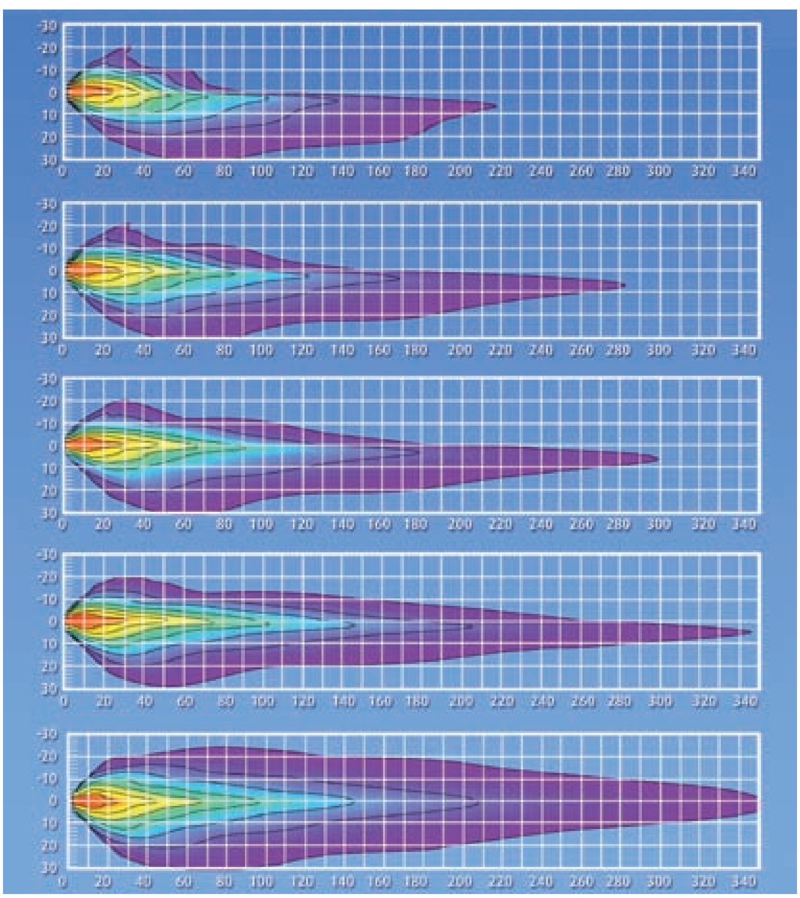

Figure 10: Progressive beam module

4 Future Prospects

Interdisciplinary cooperation across a number of different specialist areas is an essential part of the development process for the systems described here. Only an end-to-end development approach will allow the systems to achieve maximum efficiency and make use of all the possibilities for improvement. Bringing together lighting and sensor expertise for the preliminary development of driver assistance systems in Valeo's Driving Assistance Domain is a decisive factor in the overall understanding of the systems. The next developments in the field of lighting will involve the introduction of LEDs (light emitting diodes) as a light source. This technology opens up new opportunities that are not currently available with conventional technologies. LEDs are a solid state light source and their intensity can easily be modified. This makes it possible to switch off specific areas of a light system or to alert the driver to potential dangers using a spot light. This functionality will be based on new software modules for the camera, such as obstacle and pedestrian recognition. The two systems must be perfectly coordinated in order to provide the driver with the maximum possible amount of light and, at the same time, to prevent other road users from being dazzled.

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