ACTIVE NIGHT VISION - ENHANCEMENT OF THE DRIVER'S VIEW BY INFRARED HEADLAMPS

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ABSTRACT

The visual range when driving a car with dipped beam is limited by the statutory beam pattern and often is not sufficient. Given today's traffic volume, the main beam can only rarely be used.
Active Night Vision systems based on infrared (IR) lighting provide an opportunity to increase the visual range without dazzling oncoming traffic.
The system consists of an IR headlamp, a camera and a man-machine interface, e.g. a display.
In the following, the system concept will be presented and the possibilities of infrared lighting and its integration in modern headlamps will be discussed.

INTRODUCTION / MOTIVATION

Driving a car at night is dangerous as studies by *Statistisches Bundesamt* [Federal Department of Statistics] show. Over 40% of fatal accidents happen during the night despite a traffic volume of only 20% at that time.

The reasons for this include overtiredness and alcohol but the driver's limited visual range is a main cause. The lighting range of 60 to 120 m is a compromise between what is technically feasible or legally admissible and avoidance of dazzling of oncoming traffic.

To improve visibility and provide additional information, illumination of roads with polarized light or additional ultraviolet light have been discussed recently. However, series production never started because efficiency is poor and UV-fluorescent marks are needed in road traffic.

More promising is the approach to detect infrared light, for which process passive systems based on the heat emitted by all bodies and active systems with additional near-infrared illumination of the scene are used.

In the following, the active IR Night Vision System is explained in more detail.

Active Night Vision System

The principle design of an active night vision system with infrared headlamp is shown in Fig. 1.

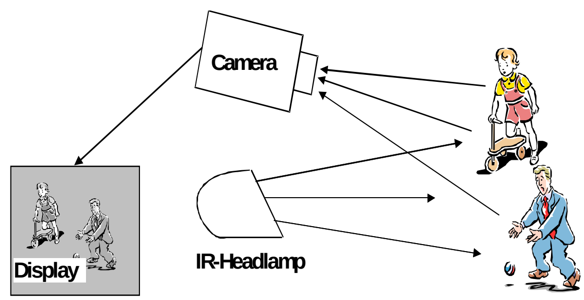

Figure 1.

Block diagram of an active night vision system.

Invisible to the human eye, the IR headlamp illuminates the scene in the infrared spectral range. The IR light reflected by objects is detected by the camera and the information is shown on a display.

Particularly suitable is lighting with near-infrared radiation (NIR) with wavelengths between 780 and 1,100 nm, i.e. directly beyond the visible spectrum. The reasons for this are:

- There is a number of commonly used light sources for the generation of NIR.
- Many of the materials visible light travels through are also transparent to NIR.
- Detection can be by means of conventional silicone chips (CCD or CMOS cameras).

Furthermore, the reflection behaviour of many materials is at least similar in NIR and the visible range because of the closeness of the spectral areas. Nevertheless, there are some differences some of which are even favourable for IR picture recording. For example, the degree of reflection of black clothes is much higher in NIR light which suggests that such clothes are black only in visible light. Vegetation is a little brighter in IR, snow a little darker than in the visible range /1/.

Light Sources for Infrared Headlamps

There are several options for the generation of NIR light, e.g. halogen bulbs, gas discharge bulbs and light-emitting or laser diodes. Halogen bulbs will be examined in more detail.

Halogen bulbs

Fig. 2 shows the spectral emission of various halogen bulbs for motor vehicles. The curve is typical for full radiators with colour temperatures of about 3,000 K.

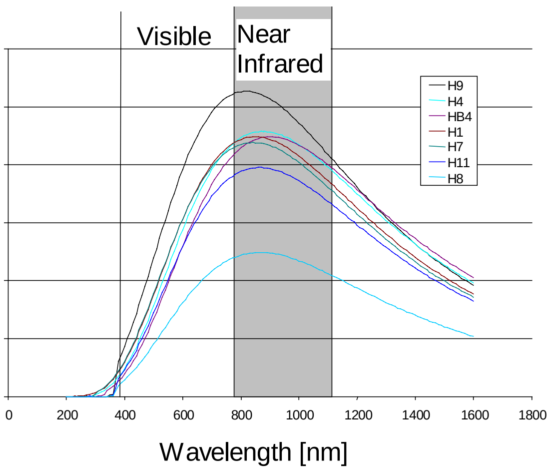

Figure 2.

Spectral emission of different halogen bulbs for motor vehicles.

The shaded area indicates the sensitivity range of a silicon detector beyond the visible spectrum. One can see that the emission maximum of all bulb types is within that range. The energy sum of the radiation emitted between 780 and 1,100 nm is on average 1.3 times higher than in the visible range and is about a third of the total energy, i.e. approximately 20 W for the H7 halogen bulb. Therefore, halogen bulbs are very well suited for active night vision applications.

Gas discharge bulbs

In contrast to the halogen bulb, the spectrum of the gas discharge bulb is a mixture of continuous and discontinuous emission, due to the light generation process (Fig. 3).

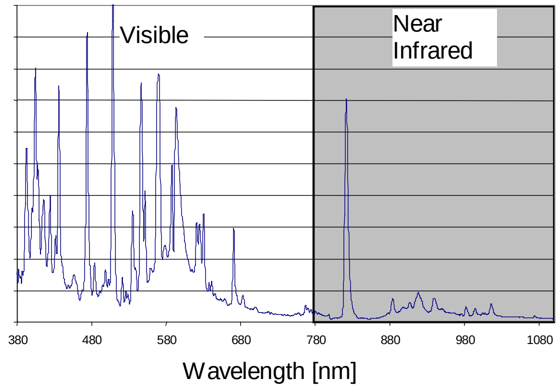

Figure 3.

Spectral distribution of a of the gas discharge bulb type D2S.

The spectrum above 780 nm shows a marked spectral line at about 830 nm and a low continuous portion. Only 15% of the total energy are emitted above 780 nm, so gas discharge bulbs emit considerably less NIR than halogen bulbs.

Due to their spectral emission characteristics halogen and gas discharge bulbs have a potential for active night vision systems in addition to the use for conventional lighting.

For exclusive IR application, the infrared radiation has to be separated from the visible light. This is done with the help of filters which absorb the light up to about 780 nm but let infrared light pass. Such filters are available made of tinted polycarbonates and glass.

Light-emitting and laser diodes

Light-emitting and laser diodes emit a narrow spectrum thus allowing the generation of “pure“ IR radiation. Therefore, additional separation of visible and infrared light is not necessary /1/. Other important aspects such as achievable output, electric resistance, eye safety, electromagnetic compatibility, cost etc. are currently examined in more detail.

Designs of infrared headlamps

Auxiliary lamps

The most simple form of an IR headlamp is a headlamp with main beam characteristics with an IR-transmissive filter before it. Tests have been performed with Hella‘s Micro FF auxiliary lamps (Fig. 4). This headlamp is equipped with a 55 W H3 bulb and thus achieves a maximum radiant intensity of about 190 W/sr in the wavelength range 800 - 1,000 nm.

Figure 4.

Hella Micro FF auxiliary main beam.

Two headlamps with appropriate filters have been tested in the Hella light tunnel to establish their suitability. Fig. 5a-d show the information content in the IR range for different situations. No visible light has been used to take these pictures.

Figure 5a.

IR illumination with two Micro FF main driving lamps with IR-transmissive filter; a person on the right side and a wooden figure painted grey on the left 80 m away.

Figure 5b.

As Fig. 5a but with counter light.

Figure 5c.

As Fig. 5a but at a distance of 120 m from the test objects.

Figure 5d.

As Fig. 5c but with counter light.

Fig. 5a-d show that persons are clearly visible even from a relatively great distance—they were visible at even greater distances. At the same time, the problem of counter light sources becomes clear. Irradiation of the picture as seen here has to be avoided. In our tests we have used a frame interline transfer camera which partially suppresses this effect. Conventional CCD cameras would yield a completely irradiated picture (also see Section "Camera and Reproduction of the Picture").

It is difficult to specify the radiant intensity required for an IR headlamp because a multitude of parameters have an influence on the brightness. For example, even a change of the camera aperture by one step, e.g. from f2.8 to f2, results in the duplication of the incoming light which means that the requirements on the headlamp could be halved. The sensitivity of the camera can have a similar effect. If the camera is installed behind the windscreen, the transmission behaviour of the windscreen has to be taken account of as well. As many windscreens are equipped with a heat insulation foil to counteract heating of the passenger compartment, this fact has to be given special attention.

The optimal beam pattern of the infrared headlamp can only be determined in the context of the entire system. Among other things, the image angle detected by the camera and the desired maximal range as well as the adjustment to the dipped beam pattern have to be taken into account.

IR Projection Lamps with Halogen Bulb

The use of a projection lamp with IR-transmissive shield provides the possibility of building a headlamp which at the same time generates dipped beam and infrared main beam.

A projection lamp functions like a slide projector with the slide being replaced by a metal shield /2/. The metal shield has an edge with a shape adapted to the cut-off to be generated. The edge is projected on the road via a lens. The metal shield shades the light from the area above the cut-off to prevent dazzling of oncoming traffic.

In an IR projection lamp, part of the metal shield is replaced by a filter which is opaque to visible light but lets infrared radiation pass (Fig. 6). Thus the required cut-off is still produced for the visible light while infrared light is not shaded resulting in a permanent light distribution of the main beam in the IR range.

Figure 6.

Prototype of projection module with IR-transmissive shield equipped with an H7 halogen bulb.

Figure 7.

Projection lamp with IR portion recorded with an IR-sensitive camera, distance 60 m.

Figure 8.

Same situation as in Fig. 7 but with a conventional headlamp without IR portion.

The additional information gained when using an IR projection lamp is shown in Fig. 7 and 8. The test person is standing at a distance of 60 m from the headlamp which corresponds to the range of the headlamp adjusted in accordance with the legal requirements. Fig. 8 shows that with a conventional headlamp without IR portion only the shoes of the person can be seen. In contrast to this, the person is clearly visible in the light of the IR projection lamp as recorded by an IR-sensitive camera (Fig. 7). The naked eye can in any case only see the picture shown in Fig. 8.

It is conceivable to extend the principle to bi-functional headlamps (Bi-Xenon) which switch between dipped and beam by means of a turn-around shield /3/. In the case of the IR headlamp this would mean change-over from permanent infrared light to visible main beam.

Camera and Reproduction of the Picture

IR radiation up to a wavelength of about 1,100 nm can be detected by silicon detectors as used in CCD and CMOS cameras.
Fig. 5b and 5d show an effect CCD camera sensors show if there are strong counter light sources. The camera no longer resolves the light sources but yields an irradiated picture. A CMOS sensor with a dynamic range of up to 120 dB can be a solution /4/. CMOS sensors for application in motor vehicles are still in the development stage.

There are other possibilities for pictorial reproduction, e.g. playback via a head-up display (HUD) or an LCD monitor.

An HUD functions like a projector. An LCD is projected to the driver's eye like a slide by a lens in such a way that ideally it will appear as being congruent with the outside world. The advantage is that the driver doesn't have to look away from the road to see the infrared picture. Additionally, the position of objects detected by the IR camera can be assigned directly. A drawback is that the driver's eyes must not be moved too much because otherwise the area of visibility is left.

The LCD monitor is a more simple alternative but like a rear mirror it requires constant changing of the line of vision.

Instead of on a display, the information could also be represented via an information and warning system giving an acoustic-optical signal when an obstruction is detected.

Summary / Preview

Night vision systems based on IR illumination can make an additional contribution to traffic safety at night.

These systems are assistance systems providing the driver with additional information on the traffic situation especially in the far range in addition to the dipped beam.

Light sources used in headlamps today such as halogen and gas discharge bulb can also be used for IR illumination. In particular, the NIR spectral portion of halogen bulbs is high.
The use of IR-transmissive filters in projection lamps allows integration of IR illumination in modern headlamps.
CMOS cameras are interesting with regard to picture recording. Their further development will be crucial for the progress of the active night vision systems discussed here.
The reproduction of the pictures, i.e. information transmission to the driver, will play a key role with regard to acceptance of the system. Apart from simple acoustic and visual warning signals, representation by means of LCD and HUD is also discussed.

"Simple" passive systems based on heat radiation detection are already being produced in series today /5/.

Active night vision systems in private cars will probably be used in the near future.

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