

Technical Information

Light – ADILIS® Night Vision System



*Ideas today for
the cars of tomorrow*

**Peering into the dark –
or perhaps not?
Night Vision systems are
almost ready for series production**

If visibility still isn't sufficient in unclear traffic situations at night despite good headlamps, the time for a Night vision system has come. The display provides information drivers cannot receive with their limited natural visual ability and one glance is all drivers need to recognize the context of the traffic situation and drive on safely. The following brochure explains how such innovative systems work and describes a few of the components currently being readied for series production under the product name ADILIS® at KGaA Hueck & Co., Lippstadt.

Illuminating the traffic space with visible light has been achieved already, yet limited visibility is still one of the most important causes of serious accidents at night. Accident frequency can certainly be reduced because drivers will have a better view of the overall situation if they have access to information about the traffic space they cannot normally see. The basic idea behind this approach is to extend the traffic space that can be recorded visually (approx. 60 m) to up to around 150 m using an infrared imaging system.

This system illuminates the traffic space beyond the low beam range using infrared radiation, providing the same effect as a high beam, but oncoming traffic is not dazzled. The scenario is recorded by a camera sensitive to infrared light, then processed and displayed using a suitable medium (such as a Head-up Display, for example). The cover picture demonstrates just this gain in information.

In this situation drivers must utilize the high beam due to the glare perceived by oncoming traffic and the vehicles in front. On the other hand, the possible adaptation of the actual driver's eyes to the increased luminances from the headlamps of oncoming traffic means that he is actually "peering into the dark." In such a scenario, an overall view of the traffic situation gained with the aid of a night-vision system is significantly better than the natural, purely visual information available. This system makes it possible to clearly recognize that the vehicle in front is not only at a standstill but that there is someone on the road collecting lost pieces of luggage as well.

**Structure of a
Night Vision system**

A system that is in a position to fulfill the function described above consists of mainly the following components:

- Infrared headlamps
- Camera
- Display

The image-processing process also has to be given some thought, of course, but that would be beyond the scope of this brochure. Our list follows the natural topology of the system which also characterizes the signal-processing chain. Before more details are given about the various system elements, it has to be shown first why such a system with the structure mentioned can function at all.

The answer to this question is provided by two sensitivity curves. The first of these is the so-called $V(\lambda)$ -curve, which specifies the relative spectral sensitivity of the human eye as a function of wavelength (greatly simplified of the color) of incident light. The second is the spectral sensitivity of the CCD or CMOS camera used, which is analogous to the $V(\lambda)$ -curve for such an image sensor. Figure 1 shows a comparison of the two curves. It clearly illustrates that a camera chip is still sensitive at long wavelengths whereas the human eye does not perceive anything under normal conditions at these wavelengths.

Image sensors made of semiconductor materials such as silicon can thus still detect electromagnetic radiation of near-infrared while the human eye (or to be more exact, the receptors on the retina) can no longer achieve this. The window formed by the two descending flanks of the two sensitivity curves is quite small. In other words, the capacity used in the system concentrates on a comparatively narrow range of the electromagnetic spectrum between approx. 800 nm and 1000 nm wavelength. The human eye is already very insensitive in this wavelength range, but with the high capacities used (radiance) it can still recognize red "light". This effect is indicated in **Figure 1** as a border area of perception. It restricts the useful wavelength range even further.

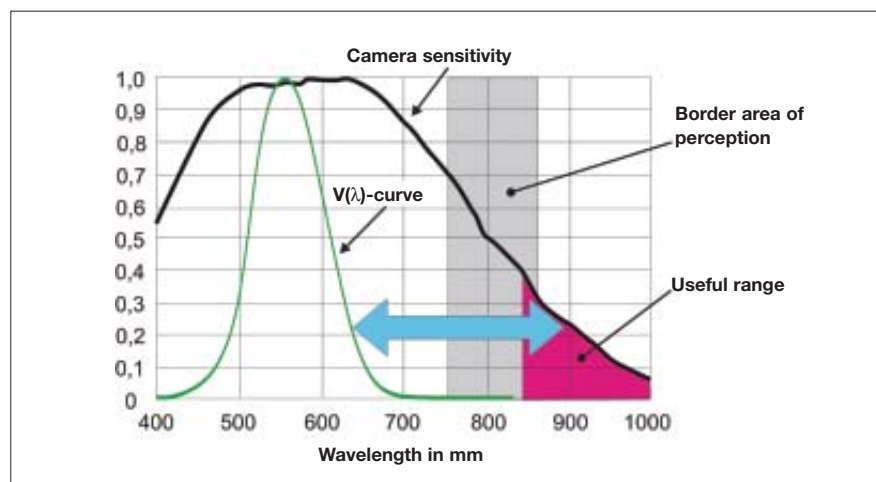


Figure 1:
 The sensitivity of the human eye for light declines drastically as wavelengths increase (>700 nm) whereas a typical camera using a silicon chip still shows considerable sensitivities in these ranges. This is why and how active night vision systems work.

Infrared headlamps

The near-infrared optical radiation required for an active Night Vision system can be generated in different ways. At the moment, radiators using halogen bulbs, infrared emitting LEDs (IR-LED or IRED) and infrared lasers are all under development.

The halogen bulb mainly behaves like a Planckian radiator with a color temperature in the 3000 K range and emits a large share of its electromagnetic radiation not in the visible range of the spectrum but rather in the infrared range. This fact can be exploited and a halogen bulb used as a source for an infrared headlamp. To do this, the visible share of the spectrum emitted by the bulb is suppressed with the aid of a filter, so that only the infrared radiation share is projected by the headlamp. The principle is shown in **Figure 2**.

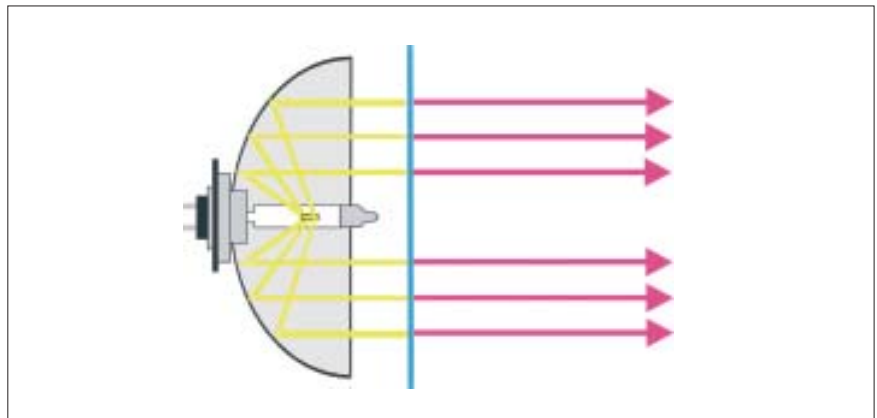


Figure 2:
Principle of generation of infrared radiation in an infrared headlamp using a halogen bulb and a filter.

What makes this technique difficult are the power ratios which typically create a red impression when a simple red glass filter is used in this arrangement, for example. The reason for this effect is the fact that the sensitivity of the human eye is not reduced to zero in the near-infrared range. This was mentioned briefly above as the border area of perception (**refer also to Figure 1**).

Since we are talking about a headlamp here, the following problem occurs: Red light is produced at the front of the vehicle, and that is prohibited. The technical solution is to exchange the filters made of solid materials for so-called interference filters. This makes it possible to adjust the appearance of the beam or its color within certain limits. Development stages have to be passed here, too, of course, **Figure 3** shows initial early samples whereas **Figure 4** presents the current status.



Figure 3:
Initial samples of an infrared headlamp using a halogen bulb and interference filter.
The typical angle-dependent color play of such filters can be seen.



Figure 4:
Current status of infrared modules (on the left each time) integrated in a prototype on the basis of a Bi-Xenon series device.

Infrared headlamps which use semiconductors as sources of radiation are of a different nature. Let us address infrared emitting LEDs (IRED) first. The major difference to (polychromatic) halogen bulbs is that with these sources, the radiation emitted is more monochromatic. The distribution of the spectral power curve is approximately Gaussian around one central wavelength. For Night Vision systems with commercially available components this is at 850 nm, for example. This is an advantage because the comparatively expensive filter required for a filament bulb solution is no longer required. Technically more important, however, is the fact that light sources based on semiconductors can be operated in pulses. This results in system-specific advantages when the radiation impulses of the IREDs are synchronized with the temporal exposure window of the camera. The image is improved in relation to continual operation because during the pulse, less interference radiation can affect the image sensor, in other words, the signal-to-noise ratio increases. This type of operation presupposes infrastructure, however, since such improvements are only possible when camera and IREDs are operated synchronously, as mentioned before.

At the moment IREDs are available as dies, as SMDs or as 3 or 5 mm plastic components. Which type of component is actually used is more a question of the concept involved, although the plastic components known from visible LED technology are not suitable. The capacities required here are so great that the thermal management necessary to dissipate the heat loss cannot be achieved with these designs. During the technical design of the optics, the demanding part is the focusing of the beams from singular sources into one overall effective beam pattern.

Figure 5 shows a current sample status.



Figure 5:
Infrared module with infrared emitting LEDs (IR-LED or IRED) as sources of radiation.

A further alternative is the use of lasers, which have a significantly tighter bandwidth than even IREDS of approx. 2 nm half-width in comparison with 20 nm for IREDS. This, together with the possibility of operating lasers as pulsed, has system-related advantages. In combination with an optical filter adjusted to the laser in the beam path of the camera lens, a large share of interference radiation is suppressed, resulting in an extremely clear image. The disadvantages of this solution are the (still) comparatively high costs of the laser and the fact that the high energy densities of the optical radiation enforce compulsory classification in the so-called laser protection classes.

The legal ECE regulations prescribe that an infrared module may generally be installed only in the main headlamp. It also be operated only when the low beam is switched on. In addition to these legal regulations, infrared headlamps of a Night Vision system are only in operation when the vehicle has exceeded a minimum speed. This prevents people (at pedestrian crossings, for example) from looking into the radiators at close range for too long.

Camera

The second component in a Night Vision system such as ADILIS® (Advanced Infrared Lighting System) is the receiver of the radiation reflected from the traffic space – the camera with the lens in front of it.

The lens maps the scenario onto the actual image sensor and is responsible for the aperture of the system. At the moment, angles of $\pm 8.5^\circ$ to $\pm 11^\circ$ in the horizontal are becoming established for Night Vision systems. Smaller angles (i. e. larger focal lengths) lead to a zoom effect and the further-away scene being brought nearer. This is just the point of a Night Vision system, because it is exactly this range (further than approx. 60 m), otherwise invisible, that we are interested in. It must be said, however, that the overlap range becomes too small. The term overlap is used to describe the area that is accessible both to the driver's natural vision as well as on the system display. For a Night Vision system it is very important that this area exists, because it is only through this that users can integrate the information on the display in their visual world. In addition, the edge areas are mapped better in the system at larger apertures. This means of course that with greater apertures, objects farther away appear smaller again in the display and cannot be perceived as well. This is more or less a problem of optimization.

The real crunch of the Night Vision system at the current point of technical development are two image sensor (and thus camera) parameters which play a major role in determining the suitability of the whole system. These two parameters are the sensitivity of the image sensor (in the near-infrared range) and its dynamics.

The current situation is as follows: The long known and mature technology of CCD image sensors enables cameras to be produced with large sensitivities of around $50 \text{ V}/(\text{lx s})$ but limited dynamics of around 50 dB. On the other hand, we have the comparatively young technology of CMOS image sensors which became available in the mid-1990s. Typical for this system are sensitivities in the range of $5 \text{ V}/(\text{lx s})$ and an extended dynamic range of up to 120 dB. With the sensitivities, values from the photometric range have been used which can be accessed more quickly. It must also be noted that CMOS sensors do not have these dynamics naturally, but that they are achieved through modifications to characteristic curves. Examples are partly linear characteristics, logarithmic or linear-logarithmic sensors.

These values dictate the performance capacity of the whole system in a very simple form. The sensitivity is mapped on the visible range, the dynamics of the image sensor on the ability to deal with glare caused by oncoming traffic.

Drawing conclusions about qualities from theoretical values is always very difficult. For this reason, the subject of glare and dynamics is illustrated again in **Figure 6**. This series of images taken in the Hella light testing facility makes clear the influence different dynamics have on the image. In theory, dynamics of approx. 130 dB are required; in **Figure 6** a sensor was used which has dynamics of only approx. 50 dB. In this respect a gap still has to be closed here. If several vehicles come one after the other, glare will also be greater than can be recognized in **Figure 6**. In such scenarios, CMOS sensors can reveal their strengths. Unfortunately, the sensors are not sensitive enough to be used in a Night Vision system at the moment. This technology is under development, however, so that it is only a matter of time before such sensors will be able to be used. Current systems use CCD cameras which have the required sensitivity.



Figure 6:
Series of images with dynamic scope in the image reduced in steps of 3 dB. It can be seen clearly that the corona around the headlamp and its reflection in the asphalt increases in stages. The dynamics as a system property thus directly correlate with the ability to process such glare situations.

Display

The increase in information existing as image data now has to be made available to the driver using an appropriate image reproduction unit. In other words: A display has to be mounted in the driver's field of vision. One possible solution is to feed the video data into a Head-up Display (HUD). HUDs have a major advantage in comparison with directly visible displays e.g. Central Information Displays (CID) in the dashboard area, in that drivers only have to take their eyes off the road, momentarily. Usually, the virtual image of an HUD is positioned below the horizontal line of the field of vision so that the driver can acquire the information available simply by moving his eyes.

The virtual distance of the image to the eye of the viewer with such systems is around two meters, with directly visible displays around 60–80 cm. Since the focal point of human visual systems for objects two meters away is about the same as at infinity, the eye can record objects on an HUD more quickly since the eye has less accommodation work to do. The read-off process is thus significantly less tiring than when reading off displays in the close-up range of the dashboard. Thanks to the increased distance of the viewer to the virtual image, a resolution of more than 60 pixels per-angular-degree is achieved. Since this value is greater than the resolution limit of the human eye, higher resolution for such a 2:1 image format as discussed below is not required. If a wider image representation is required for ergonomic/physiological reasons, the horizontal resolution must be increased accordingly.

Today's HUDs have a local resolution of 360 x 180 pixels (aspect ratio 2:1). The TFT displays suitable for and often found in vehicles due to design space and cost reasons usually have a resolution of 320 x 240 pixels (aspect ratio 4:3). 3).

One critical characteristic of current automotive displays is the low dynamics, which are seldom above 36 dB (6 Bit = 64 gray stages). This shows that the highly dynamic image recorded initially has to be processed accordingly before it can be displayed.

Summary & outlook

Lighting technology, electronics, camera, lens, image processing, Human Machine Interface – the many disciplines and components involved make a Night Vision system into an interesting assistance system from a technical point of view. The significant increase in the overall picture of the traffic space in unclear traffic situations not only increases the feeling of comfort during driving, it also results in increased safety, making the system extremely interesting for users.

Till recently, the basic problems of such Night Vision systems were the subject of discussion, though mature solutions are now available in many cases which are awaiting use in the market. This brochure presents the current technical status and illustrated samples as well as development trends. In addition to these, systems which make pedestrian recognition possible in Night Vision systems will certainly be under discussion in the future as well. Just as the increase in image quality depends on improvements in semiconductor sensors, this is a question of software and the relevant hardware required. Progress is to be expected in this area, too.

The complete system still offers considerable potential. In its current form, however, it is already far enough developed to be launched onto the market in the next vehicle generation.

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