# On infrared alert

## Infrared technology is making a valuable contribution to realising the goal of seeing what is there, even in 'zero vision' environments: in dark nights on the road

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**IMAGES** COURTESY OF XENICS

The effectiveness of infrared (IR) imaging technology has been proved in numerous scientific fields as well as in public security and military applications, and can substantially lower the rate of traffic accidents and the numbers of injured and dead. Current IR trends are for higher resolution, sensitivity and speed, as well as multispectral data acquisition.

The IR spectrum can be subdivided into three sections: near infrared (NIR) at wavelengths of 0.8-1.7µm, which is in the direct neighbourhood of the visual spectrum (VIS); medium infrared realm (MWIR) at wavelengths of 3-5µm; long-wavelength infrared (LWIR) at 8-15µm.

Driver assistance systems should improve drivers' sight at night (three times as many accidents happen in the hours of darkness than in daytime), when night vision systems based on NIR image capturing operate as active sensors using the car's headlights. Such active systems used in conjunction with headlights give a much better depiction of the scene ahead than mere visual observation. Passive LWIR technology captures the temperature radiation of warm-blooded living creatures (humans as well as animals), and can look four times further ahead, providing images from much larger distances.

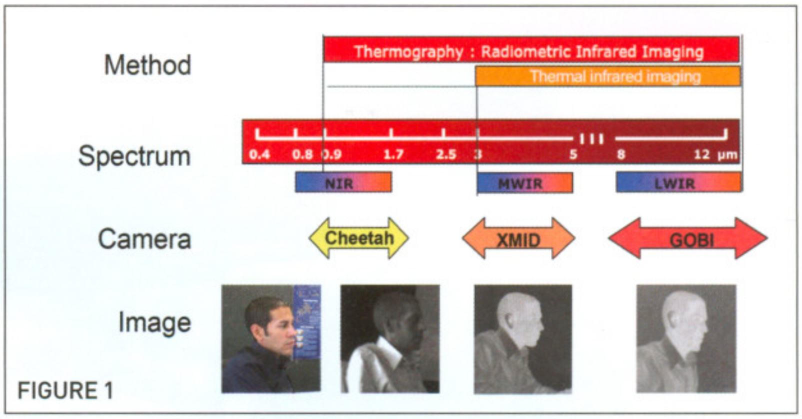

FIGURE 1

**FIGURE 1:** Three spectral areas are of special interest: near-infrared (NIR), medium-wave infrared (MWIR), and longer-wave infrared (LWIR)

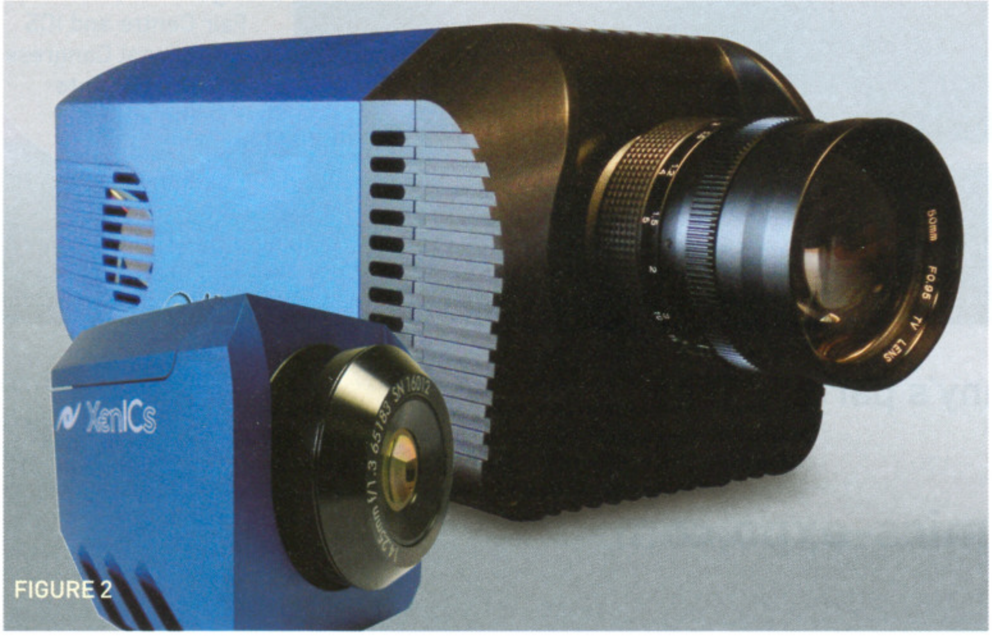

FIGURE 2

**FIGURE 2:** Two cameras – Cheetah in InGaAs technology for the NIR, and GOBI equipped with micro-bolometers for long-wave infrared – cover wide areas in road traffic management

NIR imaging systems' high sensitivity and large dynamic range based on InGaAs technology make them ideal for mobile or stationary cameras, even when the light level is too low for normal cameras. Capturing any available residual light, the system uses sensors to detect the presence of vehicles and other objects at night and in twilight, even if driving without lights, as is frequently the case with cyclists and pedestrians.

If there is no other light source available, these systems can exploit the phenomenon of night-sky or airglow, which is emitted equally by the entire sky, and at all geographical latitudes. At night, the intensity of this residual atmospheric sky light exceeds the intensity of starlight by a factor of five to six. It almost completely covers the entire NIR wavelength area from 1.0-1.7µm.

NIR cameras based on InGaAs technology – with their highest sensitivity at 0.9-1.7µm – are perfectly suited for using the airglow phenomenon. They can even 'see' objects with great clarity when there is no moonlight.

Image capturing in NIR is carried out in a similar way as in the visual realm, because it uses the light reflected to the camera by the observed object. The evaluation and analysis of scenes observed is much easier with NIR than with purely thermal detection. As a result, images obtained via the reflective method also reveal shadows, with contrast, resolution and details

FIGURE 3

**FIGURE 3:** Comparison of an imaging application for the surveillance of a tunnel, on the left taken in the visual realm, on the right in the infrared. Clearly recognisable in the IR depiction – approaching car in the dark section of the tunnel.

comparable to regular images taken in the visual realm.

For applications that must yield particularly meaningful night vision results, it can make sense to complement NIR imaging based on InGaAs technology with thermographic imaging in MWIR and LWIR. Such thermographic cameras, either uncooled microbolometer or cooled infrared cameras, use thermal detectors that indicate only the presence of warm objects appearing before a cooler background. In combination with thermal imaging, NIR cameras greatly simplify the identification of objects that would be difficult to detect by thermal imaging.

## Sensor anatomy

The sensors of LWIR microbolometer cameras such as the Gobi consist of IR-absorbing semiconductor structures, the radiation-dependent resistance of which is measured and tracked. Because poly-silicon is suited as an absorber, LWIR microbolometers are manufactured as MEMS (micro electromechanical system), and are combined with readout circuits in CMOS technology.

Real-time images yielded from both spectral bands can then be processed and – crucially – digitally superimposed. Therefore, the systemic fusion of NIR and LWIR enables the user to select the most appropriate representation in a given application.

Standard imagers based on readout circuits should suffice in most infrared traffic management applications, but there is a growing number of applications that require customer-specific solutions. As well as developing application-specific sensor arrays, Belgium-based IR technology provider XenICs is prepared to specifically design ROICs for InGaAs, QWIP, MCT, bolometer and hybrid (in the visible realm) sensors based on advanced technologies. Design of complex high-performance, analogue and digital custom CMOS-integrated circuits is one of XenICs' core capabilities, providing customer advantage in gaining market share and competitiveness.

Infrared technology is not limited to use in information systems for car drivers, but also for operators of revenue-based traffic management systems. They are most interested in automatic incident detection (AID) through the collection of traffic data and by video surveillance, and infrared technology is equally well suited for infrastructure analysis and maintenance tasks. A typical example is the design of appropriate opto-electronic sensors that require special capabilities in terms of sensor and ROIC technologies. XenICs has developed, in cooperation with Belgian fibre metrology specialist FOS&S, an evaluation system for fibre Bragg gratings (FBGs). The system can survey extended three-dimensional, flat or linear structures, such as roads, bridges and tunnels.

FBGs are among the most important fibre-optic sensors today. They exhibit periodically fluctuating values of the refractive index over a certain length of glass fibre. Light thrown into the fibre is partially reflected at each of these boundaries. This causes a superimposition of backwards travelling waves. Depending on grate period and refractive index, at a certain wavelength (the Bragg wavelength) the waves are all in phase, and amplify each other. At the Bragg wavelength, the reflected spectrum shows a maximum. Such gratings can be manufactured with high precision and repeat accuracy, and most importantly, their properties won't change over time. This enables the production of sensors that have no offset or drift.

When FBGs are operated in reflection mode, the fibre must be accessible from only one side, which is illuminated by a sufficiently broadband light source radiating in the NIR (1,530-1,610nm). The medium wavelength of the reflected light fulfils the Bragg condition:

$$\lambda\text{Refl} = 2\, n\, \Lambda$$

where n is the refractive index, and Λ is the grating period. Because both values are dependent on the temperature and

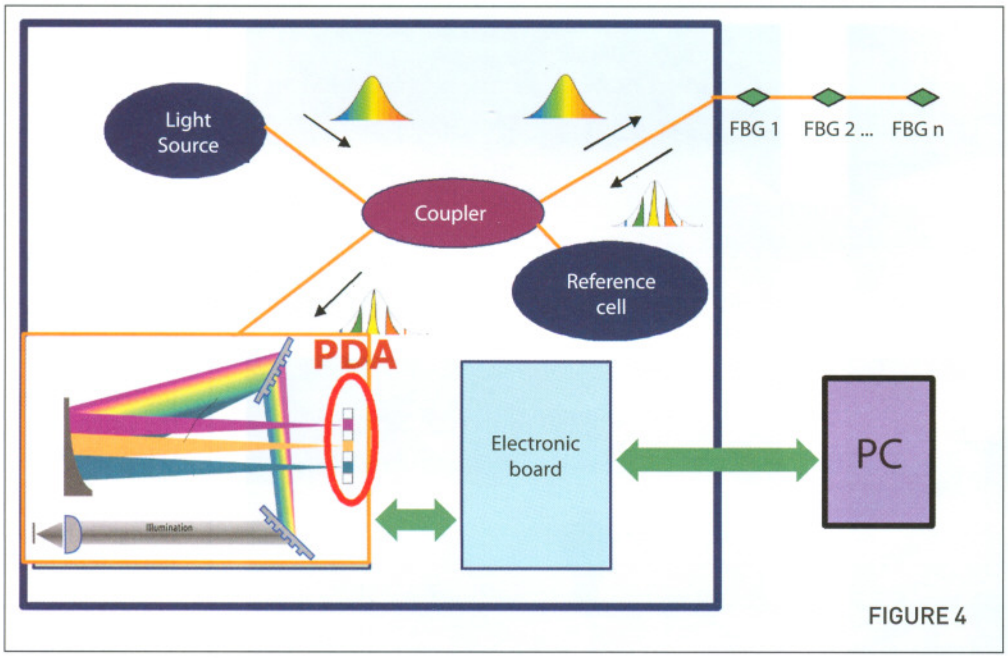

FIGURE 4

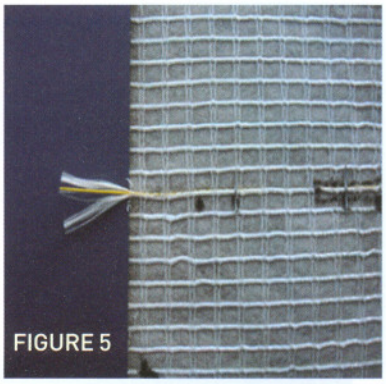

FIGURE 5

FIGURE 7

**FIGURE 4:** Setup for strain and temperature measurement based on Bragg gratings

**FIGURE 5:** Polyfelt Rock fabrics with optical sensor fibre interwoven

**FIGURE 6:** The Geodetect system of Polyfelt Geosynthetics reveals critical shifts and structural changes within the road foundation

**FIGURE 7:** IR-based traffic monitoring system for vehicle density and speed on a major motorway

strain force acting on the fibre, the resulting wavelength will vary as a function of temperature and/or strain. Therefore, with dependence of refractive index and grating period precisely known as a function of temperature and strain, the observed wavelength shift of the reflected light serves as a measure of temperature and/or fibre elongation. Typical sensor sensitivity is in the range of $d\lambda/dT$ ~12 pm/K for temperature, and $d\lambda/(dL/L)$ ~1.2 pm/(µm/m) for strain.

FBGs are virtually transparent for all wavelengths except their own Bragg wavelength. As a result, they can be established at several locations along a fibre, which all have different Bragg wavelengths. They are coupled, without any wiring expense, to the evaluation and readout unit, where they can be separated via wavelength multiplex and individually analysed. This way, whole lines of sensors can be realised, which are well suited for longitudinal structures such as roads, bridges and tunnels.

The application of such novel sensor principles stands and falls with the availability of application-friendly evaluation methods and systems. The evaluation system DynoSense 300, jointly developed by FOS&S and XenICs, contains an optical 2 x 2 coupler that feeds the energy of a broadband light source to the sensor fibre. The coupler guides the reflected radiation to a polychromator, which projects, by means of its concave mirror grating, the received spectrum onto a high-resolution IR line sensor. The line sensor, made by XenICs, increases the wavelength resolution across the entire measurement range (1,520-1,580nm) to better than 1pm. At this high precision the DynoSense 300 can control up to 40 sensors on one fibre – an excellent precondition for tightly knit surveillance of widely distributed infrastructure nodes.

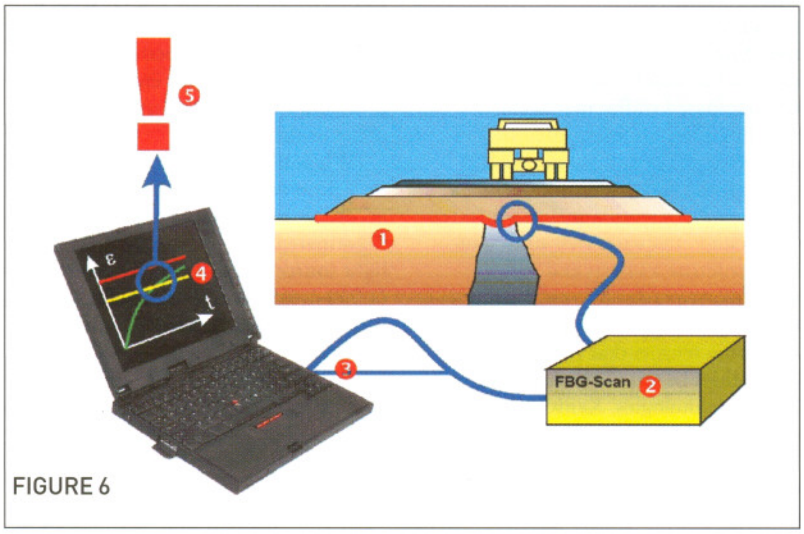

FIGURE 6

## Structural integrity

Because of their structure, FBG sensors can be easily integrated in fabrics, such as geo textiles, which help to strengthen roads that are in danger of collapsing, such as in former mining areas. At the same time, they can serve the useful function of sensor carriers for preventive maintenance of critical underground structures.

A measurement setup has a fibre-optic sensor embedded in the geo textile structure of the road foundation, as well as the FBG evaluation unit and a computer that will trigger an alarm if a permissible elongation is exceeded. This way, structural safety conditions along the road can be greatly improved.

Improving the safety of road traffic pays off in any regard and on any level, because it can save lives and prevent valuables being destroyed. Infrared sensor technology has proved to be an eminently viable tool. In the future, it is sure to further increase its contribution to this worthy goal. ❮