KEYWORDS ● Optics ● Imaging ● Semiconductors

VisGaAs Camera Sees RED...and More

Seeing both infrared and visible light creates new opportunities for infrared cameras.

Images from nightly news broadcasts are striking; stilted video of gray-green vehicles and soldiers moving stealthily through the desert night, or the sudden bloom of an explosion that whites out the screen as a laser-guided missile finds its target. To most people, these are the images that define what they think of as infrared (IR) technology. Based on near-IR image intensifiers and long-wave IR cameras, night vision systems and thermal imagers have changed the way warfare is waged.

As with many other technologies that were developed primarily for the military, IR camera technology is now being used in more mainstream applications as well. The advent of uncooled detector technology is a main reason for the technology's proliferation into areas such as security surveillance, fire fighting, and vehicle collision avoidance.

New, uncooled IR detectors are lighter, cheaper, less complex, and consume less power than their predecessors, which makes them more feasible for common use. Gone are the heavy, high-current-consuming thermo-electric coolers, and the result is IR cameras that are nearly equivalent to visible-spectrum cameras in ease-of-use, size, and weight.

Infra-red detectors

In the IR-camera community, the term "uncooled" is usually associated with long-wavelength-sensitive cameras based on detector arrays composed of bolometers—elements that undergo a resistance change in response to absorbed radiation. However, in addition to bolometers, there are other technologies for uncooled IR detectors, such as photodiodes, which can be fabricated from a variety of semiconductor materials. Collectively, these materials provide sensitivity over a broad range of wavelengths.

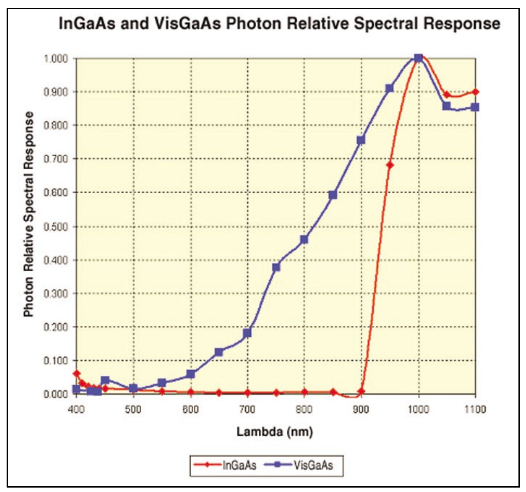
For a given application, the appropriate detector technology is determined by a host of factors, such as the amount of ambient light, the temperature of the object or area of interest, and environmental factors such as smoke, fog, or dense foliage. Long wavelength (>6 µm) detectors made of arrays of titanium oxide or vanadium oxide micro-bolometers, for example, can see through dense smoke or fog, which makes them particularly useful in fire-fighting and collision-avoidance schemes.

This versatility extends into the telecom, biomedical, and agriculture arenas, which require sensitivity to wavelengths in the near-IR (NIR, 1-3 µm). Since these applications tend to have a low level of IR light, a single detector array with the ability to simultaneously image visible light and NIR (i.e., multi-spectral imaging) can offer better images without the need for additional image enhancement.

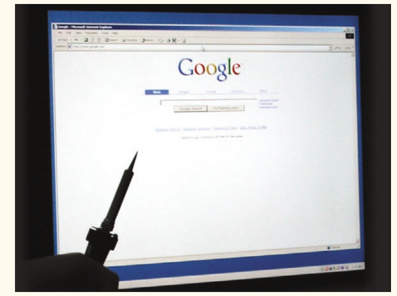
Dual capabilities

Near-IR cameras are available based on any of several technologies, but focal plane arrays of indium-gallium-arsenide (InGaAs) photodetectors offer a direct, high-speed response, which results in significant advantages in quantum efficiency, dynamic range, and cost. But the typical responsivity of InGaAs drops off at around 0.9 µm, which is well above the visible spectrum. Indigo Systems, Goleta, Calif., which recently merged with FLIR Systems, Inc., Portland, Ore., has developed a multi-spectrum InGaAs detector technology, VisGaAs, which shows direct responsivity in both the near-IR and visible spectra, down to wavelengths as short as 600 nm. According to Austin Richards, Indigo research scientist, while the technical impact of VisGaAs won't be fully understood for some time, he expects to see initial application of VisGaAs technology in such areas as through-wafer IC inspection, chemical imaging, fiber-optic spectrometry, and laser designators for weapons targeting systems.

Fabrication of the VisGaAs detector array, which begins with standard InGaAs material, includes proprietary processing methods that are the key to the broadened responsivity spectrum. Ted Hoelter, Director of Systems Engineering at Indigo, characterizes the process as being complementary to that used to produce conventional lead-antimonide detectors.



Comparing the spectral response of VisGaAs test run chips to standard InGaAs detectors reveals the enhanced sensitivity of VisGaAs as being well below the drop-off of standard InGaAs detectors. Standard InGaAs has zero sensitivity throughout the entire visible range (~400 to 750 nm), while VisGaAs has sensitivity through the upper half of the visible spectrum.



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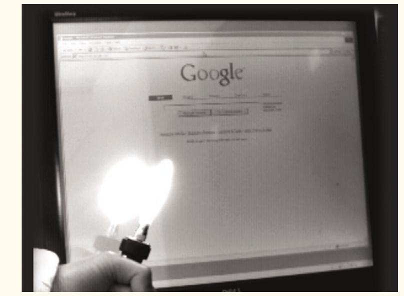

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Images of an identical scene taken with a) a conventional visible-light camera, b) a NIR-only camera, and c) a VisGaAs camera. In (a), the visible-light camera clearly shows the projection of the Google homepage, but there is no indication that the soldering iron tip is hot. In (b), the standard InGaAs camera shows heat emanating from the soldering iron tip against what appears to be a blank screen due to the inability of InGaAs to detect visible wavelengths. In (c) the VisGaAs camera reveals the heat of the soldering iron tip as well as the projected Google image on the screen, thus demonstrating the multi-spectral response of the VisGaAs detector array.

Integrated packaging

To expedite the testing and development of VisGaAs, its focal plane array was designed and constructed with the same form factor as that of Indigo's commercially available Phoenix camera system. In the Phoenix system, the imaging optics direct incoming radiation from the observed scene onto a 320 x 256 array of detectors located in the focal plane of the optics. Front-end electronics, (i.e., the readout IC), digitize the output of the detectors and interface to the back-end video electronics, which prepare the signals to be displayed. Once digitized, sophisticated signal conditioning is performed, which includes non-uniformity correction, noise-cancellation, and the elimination of bad pixels through signal interpolation.

The combination of the focal plane array and the readout IC substantially impacts the camera's performance. Due to the high fill factor and large number of electrical connections (>160,000) associated with the plane array, conventional wire bonding cannot be used to interconnect the two die. Instead, a variation of ball-grid array (BGA) technology is used wherein the BGA technology employs high-density indium solder bumps and a focal plane array with coplanar contacts that enable direct bonding to the readout IC.

Performance trial

But the question remains, how well does this camera perform? Typically, thermal imaging tends to provide a binary view of the world, with only modest gray-scale response. VisGaAs, on the other hand, provides the user with a view that more closely resembles the visible world. Case in point, the simple imaging demonstration of a hot soldering iron and a video screen in the attached photos and caption illustrate how the response of VisGaAs detectors bridges that of conventional visible light detectors and standard InGaAs detectors. Critical camera requirements include high per-pixel sensitivity, pixel-to-pixel uniformity, and high dynamic range to avoid blooming and washed-out areas from hot spots while still seeing cooler areas.

What's next for VisGaAs?

Further development of VisGaAs is expected to yield improved performance. An enhanced anti-reflection coating, designed to cover the broader spectral range, and an optimized lens are being developed and it is hoped that future VisGaAs focal plane arrays can be made to show further enhancement in the shorter wavelengths, perhaps even extending into the ultra-violet.

According to Richards, VisGaAs offers the first truly multi-spectral camera with responsivity across the entire visible and NIR bands, and sees near-term application in high-temperature thermography and wafer inspection as just the beginning.

—James Walker

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IR technology hopes to NOT make an impact

Collision avoidance initiatives based on IR sensors are in the works at several major automakers. Ford Motor Company, Dearborn, Mich., for example, is featuring "Active Night Vision" based on IR detection in their S^2RV (Smart Safe Research Vehicle) concept SUV. In the S^2RV, an infrared sensor system mounted above the rear-view mirror is able to "see" objects further out than with normal high-beam headlights. The infrared imager views the scene ahead of the car and projects a real-time image onto a heads-up display on the dashboard. Toyota Motor Corp., Torrance, Calif., offers an alternative system called "Night View" on select 2004 Lexus models, in which NIR light is projected from lamps located in the front bumper. The reflected NIR radiation from oncoming objects is then detected by a CCD camera, processed, and projected onto the lower half of the windshield, in front of the driver. The resulting image enhancement affords the driver a forward view nearly four times the range of conventional low beam headlights.

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