UTC Aerospace Systems

Why SWIR & InGaAs?

Why is it Uselful?

High Sensitivity

High Resolution

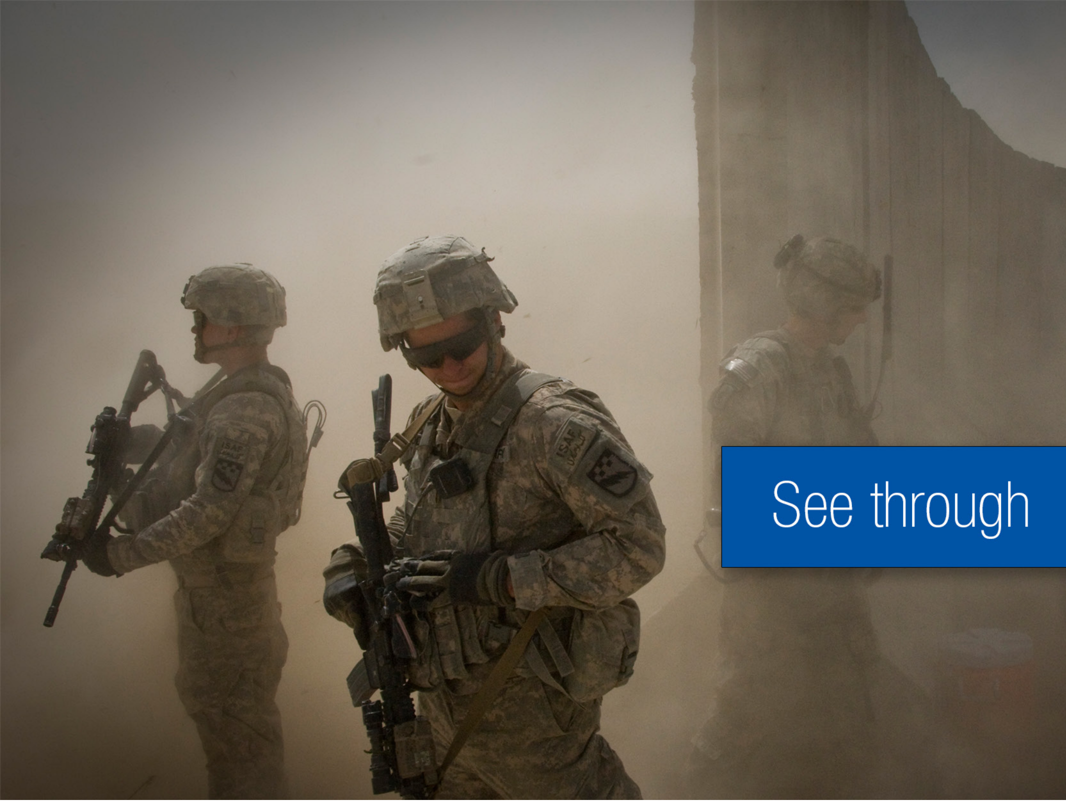
Covert Illumination

See Lasers/Beacons

Compact/Low Power

SENSORS UNLIMITED

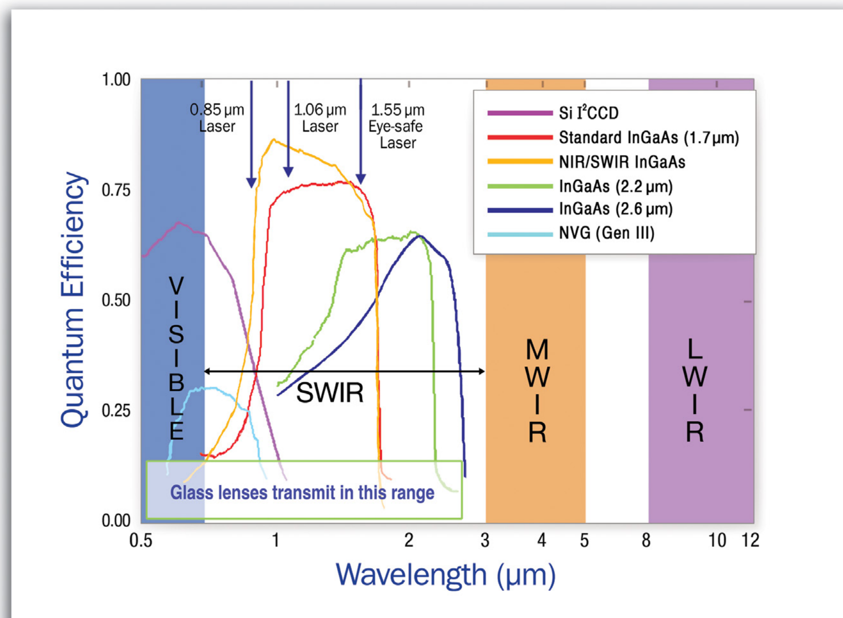
For over 25 years we have lead the SWIR and InGaAs technology industry by designing and manufacturing integrated solutions to the military, business and commercial industries. Our products are globally available and we are a major supplier to the international space programs.



See through Dust, Smoke & Haze

What is the Value of Shortwave Infrared?

Sensing in the shortwave infrared (SWIR) range (wavelengths from 0.9 to 1.7 microns) has been made practical by the development of Indium Gallium Arsenide (InGaAs) sensors. Sensors Unlimited, Inc., part of UTC Aerospace Systems, is the pioneer in this technology and clear leader in advancing the capability of SWIR sensors. Founded in 1991 to create lattice-matched InGaAs structures, Sensors Unlimited, Inc. quickly grew as the telecom industry recognized the exceptional capabilities of this remarkable material.



Sensors Unlimited has continued to push InGaAs technology forward, today producing InGaAs one-dimensional linear arrays, two-dimensional focal plane array cameras and SWIR Systems. But why use SWIR?

First, a basic fact: light in the SWIR band is not visible to the human eye. The visible spectrum extends from wavelengths of 0.4 microns (blue, nearly ultraviolet to the eye) to 0.7 microns (deep red). Longer wavelengths can only be seen by dedicated sensors, such as InGaAs. Although light in the short-wave infrared region is not visible to the eye, this light interacts with objects in a similar manner as visible wavelengths. That is, SWIR light is reflective light; it bounces off of objects much like visible light. As a result of its reflective nature, SWIR light has shadows and contrast in its imagery. Images from an InGaAs camera are comparable to black-and-white visible images in resolution and detail. This makes objects easily recognizable and yields one of the tactical advantages of the SWIR, namely, object or individual identification. That makes InGaAs interesting, but what makes it useful?

What Makes InGaAs Useful?

InGaAs sensors can be made extremely sensitive, literally counting individual photons. When built as focal plane arrays- with thousands or millions of tiny point sensors, or sensor pixels-SWIR cameras will work in very dark conditions. Night vision goggles have been around for several decades and operate by sensing and amplifying reflected visible starlight, or other ambient light, in what are called image intensification (I-Squared) tubes. This technology has worked well for direct view night vision goggles. But when an image needs to be sent to a remote location (an intelligence center, for example), there is no practical method which does not introduce reliability and sensitivity limitations (e.g. I2CCD). Because all of SUI's SWIR sensors convert light to electrical signals, they are inherently suitable for standard storage or transmission.

Using SWIR at night has another major advantage. An atmospheric phenomenon called night sky radiance emits five to seven times more illumination than starlight, nearly all of it in the SWIR wavelengths. With a SWIR camera and this night radiance - often called nightglow - we can "see" objects with great clarity on moonless nights and share these images across networks as no other imaging technology can do. But aren't there other cameras that operate in the shortwave infrared range? Yes, Sensors constructed from materials like mercury cadmium telluride (HgCdTe) or indium antimonide (InSb) can be very sensitive in the SWIR band. However, in order to increase their signal-to-noise ratio to usable levels, these cameras must be cryogenically cooled. In large military aircraft designed for large surveillance and reconnaissance, cooling is an option as these platforms can provide space and power to run mechanical cooling systems. However, mechanical cooling devices have limited lifetimes and, as these platforms are miniaturized, size, weight, and power constraints can limit the deployment of cooled camera systems. In stark contrast, similar sensitivity can be achieved at room temperatures using long-lifetime components in a and small size, weight, and power (SWaP) package with a Sensors Unlimited InGaAs camera.

Essentially, InGaAs cameras can be small and use very little power, but give big results. Sensors Unlimited InGaAs cameras offer VGA resolution in a tiny 1.25"x1.25"x1.10" package and just 1.5W power draw at steady state. We also offer HD (1 Megapixel) resolution in a 2"x2"x2.43" package with ≤3.0W power draw at steady state.

By using SWIR illumination like 1.55 micron lasers or LEDs, it is possible to covertly illuminate a scene that can only be viewed with SWIR cameras. A military vehicle vehicle equipped with SWIR illumination and a SWIR imaging system is able to illuminate its surroundings when nightglow is not available, as maybe the case under thick tree cover or in a tunnel, in order to safely navigate a route in hostile territory. SUI InGaAs cameras are of great value in such applications. And because such illuminators are eye safe, there are few restrictions on how they are used.

SWIR and Thermal Imaging

Thermal imagers are another class of camera with excellent detection abilities. These imagers are a good compliment to SWIR imaging in many applications. While a thermal imaging can detect the presence of a warm object against a cool background, a SWIR imager can provide recognition and identification as well as depth perception with contrast and shadow. The determinatio of whether a vehicle is a civilian truck or a military tank is crucial. SWIR can help with this friend-or-foe determination by providing context to the image that no other technologies can provide.

CMOS and CCD imagers continue to evolve to meet military needs, but such sensors are typically daylight-only sensors. On the other hand, a single SWIR camera can be used for both day and night imaging, and can cover the visible, NIR, and SWIR spectral regions in a single device. In an Unmanned Aerial Vehicle (UAV), for example, a single Sensors Unlimited SWIR camera can operate over the full duration of typical day/night mission profiles.

Image Through Glass

Finally, one major benefit of SWIR imaging that is unmatched by other technologies is the ability to image through glass. Sensors Unlimited's cameras can use conventional, cost-effective visible camera lenses for all but the most demanding applications. Special expensive optics or environmentally hardened housings are mostly unnecessary, making them available for a wide variety of applications and industries. This also allows for the SWIR camera to be mounted behind a protective glass window, providing extra flexibility when positioning the camera system on a potential platform.

Enhance Battle

Damage Assessment

So, Why SWIR?

- High sensitivity
- High resolution
- Nightglow (night sky radiance)
- Day-to-night imaging
- Covert illumination
- See covert lasers and beacons
- No cryogenic cooling required
- Conventional, low-cost visible spectrum lenses
- Small size
- Low power

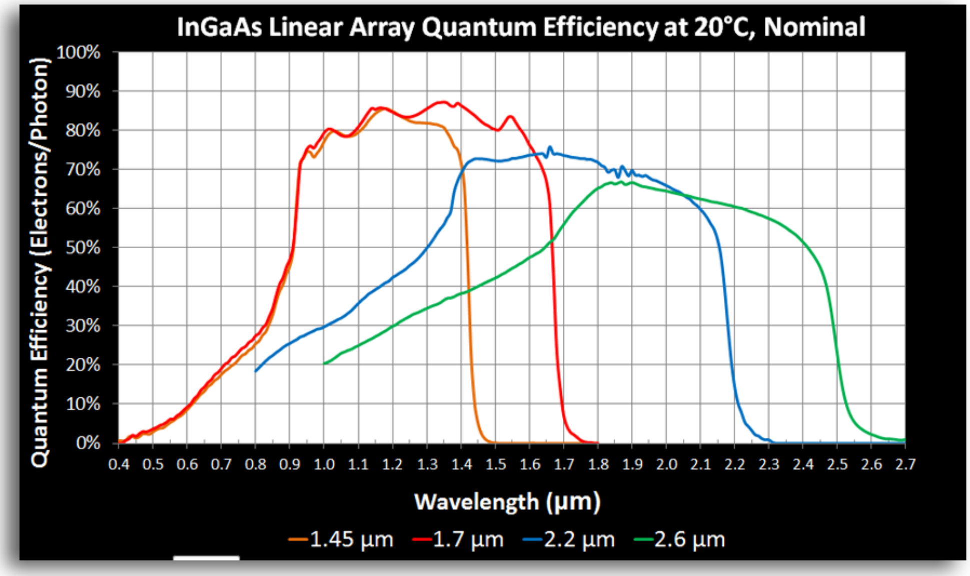
What is InGaAs?

InGaAs, or indium gallium arsenide, is an alloy of gallium arsenide and indium arsenide. In a more general sense, it belongs to the InGaAsP quaternary system that consists of alloys of indium arsenide (InAs), gallium arsenide (GaAs), indium phosphide (InP), and gallium phosphide (GaP). As gallium and indium belong to Group III of the Periodic Table, and arsenic and phosphorous belong to Group V, these binary materials and their alloys are all III-V compound semiconductors.

Why go to all the trouble?

To a large extent, the electrical and optical properties of a semiconductor depend on its energy bandgap and whether the bandgap is "direct" or "indirect." The energy bandgaps of the four binary members of the InGaAsP quaternary system range from 0.33 eV (InAs) to 2.25 eV (GaP), with InP (1.29 eV) and GaAs (1.43 eV) falling in between. At SUI we emphasize photodetectors, so we care most about the optical properties of semiconductors. A semiconductor will only detect light with photon energy larger than the bandgap, or put another way, with a wavelength shorter than the cutoff wavelength associated with the bandgap. This "long wavelength cutoff" works out to 3.75 µm for InAs and 0.55 µm for GaP with InP at 0.96 µm and GaAs at 0.87 µm.

By mixing two or more of the binary compounds, the properties of the resulting ternary and quaternary semiconductors can be tuned to intermediate values. The challenge is that not only does the energy bandgap depend on the alloy composition, so also does the resulting lattice constant. For our four binary members, the lattice constants range from 5.4505 Å (GaP) to 6.0585 Å (InAs) with GaAs at 5.6534 Å and InP at 5.8688 Å. The relationship between the lattice constant and the long wavelength cutoff of the four ternary alloys in the InGaAsP family are shown in the below graph.



Let's get back to InGaAs

The InAs/GaAs alloy is referred to as InxGa1-xAs where x is the proportion of InAs and 1-x is the proportion of GaAs. The lattice constants and long wavelength cutoffs of these alloys are depicted as the red lines in Figure 1. The challenge is that while it's possible to make thin films of InxGa1-xAs by a number of techniques, a substrate is required to hold up the thin film. If the thin film and the substrate do not have the same lattice constant, then the properties of the thin film will be severely degraded.

For lots of reasons, the most convenient substrate for InxGa1-xAs is InP. High quality InP substrates are available with diameters as large as 100 mm. InxGa1-xAs with 53% InAs is often called "standard InGaAs" without bothering to note the values of "x" or "1-x" because it has the same lattice constant as InP and therefore the combination leads to very high quality thin films.

Standard InGaAs has a long wavelength cutoff of 1.7 µm. Meaning, it is sensitive to the wavelengths of light that suffer the least signal dispersion and transmit furthest down a glass fiber (1.3 µm and 1.55 µm), therefore detecting "eye-safe" lasers (wavelengths longer than 1.4 µm). It is the optimum wavelength band for detecting the natural glow of the night sky. SUI's core product lines are based on PIN and avalanche photodiodes and photodiode arrays made from standard InGaAs. Take the time to browse through the rest of the site to learn about SUI's many offerings including area and line scan cameras, one- and two- dimensional focal plane arrays, and complete SWIR imaging systems.

So what is "extended wavelength" InGaAs and why bother?

Standard InGaAs has a long wavelength cutoff of 1.7 µm. Many applications require the detection of light with longer wavelengths. An important example is the ability to measure moisture content in agricultural products by measuring water absorption at 1.9 µm. Another example is light detection and ranging (LIDAR), used in airplanes to detect clear air turbulence. LIDAR systems often use lasers that emit light with a wavelength of 2.05 µm. InxGa1-xAs with a longer cutoff is called "extended wavelength InGaAs."

It seems as if all one would have to do is add a little more InAs to the mix, but it's not so easy. This increases the lattice constant of the thin film, which causes a mismatch with the substrate, and this reduces the quality of the thin film. SUI has put a lot of work into learning to grow high-quality extended wavelength InGaAs, and this is reflected in our product offerings. The results of our efforts are summarized in the second figure. The quantum efficiency of standard InGaAs in blue together with the quantum efficiencies of two extended wavelength alloys, X=0.74 (green) and X=0.82 (red). The spectral response of silicon is also shown. As we like to say, "InxGa1-xAs starts where silicon leaves off."

Third infrared window

Uncooled Short Wave Infrared (SWIR) cameras open up the third and final window in the infrared spectrum. For the last few decades, the military has used long wave infrared (LWIR) and mid wave infrared (MWIR) sensors and cameras for detecting human activity by thermal emissions. Humans, vehicles and other equipment stand out strongly when the environment is at a different temperature.

The short wave infrared (SWIR) portion of the spectrum offers unique capabilities, often complementary to LWIR and MWIR imaging. Imaging in SWIR uses reflected light, much like the slightly shorter wavelengths of the visible spectrum. Until recently the only way to see in this part of the spectrum was to use large, cryogenically cooled sensors. But beginning in 2003, Sensors Unlimited of Princeton, New Jersey began to produce small, uncooled cameras using a new semiconductor material, indium gallium arsenide (InGaAs). This remarkable material has peak sensitivity in the SWIR band, from 900 to 1700 nm.

SWIR for Military Applications

For military applications, SWIR cameras open the third and final window in the infrared spectrum. Long wave (LWIR) and MWIR sensors have long been a staple of military applications. Both are thermal sensors which do an excellent job of sensing human activity when that activity is warmer than its surroundings. Unlike LWIR and MWIR, SWIR sees in reflected light, so objects and persons look very similar to how they look in visible light, giving the military an all-new capability.

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