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IMAGING

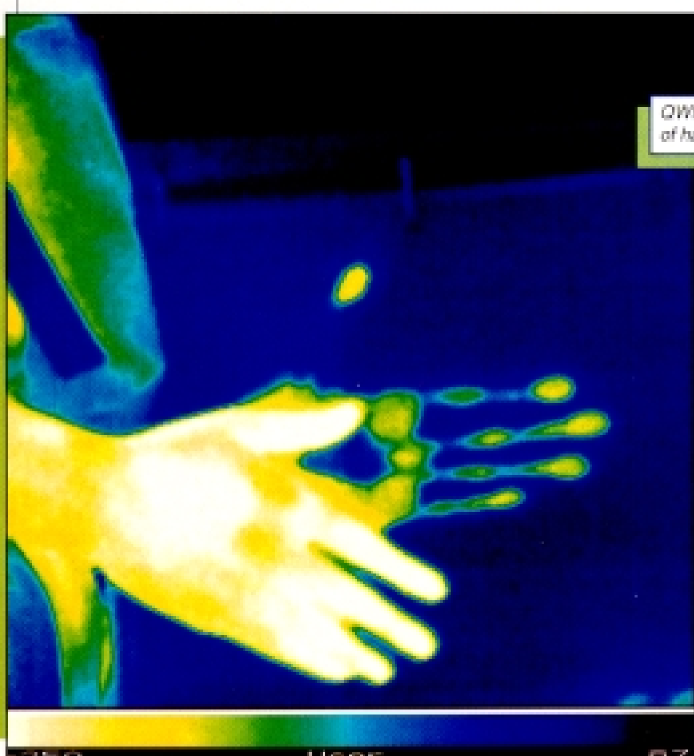
IR imaging arrays Turn to quantum wells

A new semiconductor-based technology gets ready to invade the marketplace.

by Manijeh Razeghi, Walter P. Murphy Professor and Director of the Center for Quantum Devices
Robert R. McCormack School of Engineering and Applied Science at Northwestern University

A new semiconductor-based infrared detector technology for mid- and long-wavelength instruments is ready for the marketplace. The quantum-well infrared photodetector (QWIP) is based on absorption by confined carriers in multiple quantum wells. QWIPs have a narrow absorption spectrum that can be tailored to match any transition in the 3- to 20-μm wavelength range by adjusting the quantum well width and barrier layer composition. More important, it can be made using III-V semiconductors based on gallium arsenide (GaAs) or indium phosphide (InP).

This new detector promises major advances for infrared focal plane arrays:



QWIP image of hands.

• Standard III-V Technology. Production technology for GaAs and InP microwave devices, lasers and digital circuits already exists. The use of GaAs allows large wafers (up to 4 in.) to be grown and processed with excellent uniformity and large-scale integration type yields. In addition to low development costs, QWIPs have excellent thermal stability and radiation hardness.

• Multispectrality. A series of QWIPs peaking at different wavelengths can be grown on one wafer. After separate contacts are made to each, it is possible to detect, on one pixel, signals originating at two different wavelengths. Such multiband detectors can use noise-reduction algorithms to improve performance and enable all-weather operation and flexible multipurpose imaging arrays.

• Tunability. Asymmetric quantum wells exhibit a Stark effect when under an applied electric field, resulting in a tuning of the peak detection wavelength across several microns as a function of bias. Solid-state spectrophotometers can be based on such asymmetric QWIPs.

• Saturation. QWIPs employ inter-sub-band absorption (which depends on the finite carrier density in the quantum well) and saturate when all the carriers have been excited. Therefore, QWIPs have an intrinsic resistance to "blooming," which leads to an extremely high resistance to laser aggressive countermeasures in military infrared imaging systems.

These attributes make QWIPs potential replacements for other detector materials such as mercury cadmium telluride (MCT) in certain

applications. MCT's performance is reduced beyond approximately 11 μm because of the detrimental effect of tunneling currents in the PIN diodes and the difficulty in controlling the composition of MCT for very long wavelengths.

Results for mid-wavelength infrared QWIPs developed by the Center for Quantum Devices and other groups show background-limited photodetection temperatures (T_{BLIP}) ~130 K and BLIP detectivity ~3 × 10^{11} √Hz/W at ~ 4 μm. T_{BLIP} for 8- to 12-μm detection is 80 K. Nonetheless, operating temperatures of 80 to 130 K are well within the range of commercial focal plane array cryocoolers. Several companies, including Amber, JPL and Lockheed Martin, have demonstrated IR cameras based on QWIP focal plane arrays with ~25 mK sensitivity at 9 μm.

Improvements in the operating temperature and detectivity will come from optimization of the device design for increased absorption and the use of aluminum-free materials. Research on QWIPs has focused so far on the GaAs/AlGaAs system because of the maturity of the techniques for growth of these materials.

However, evaluation of semiconductor lasers developed using AlGaAs material has shown that the reactive aluminum atoms create defects that result in shorter lifetimes and lower peak power levels compared with equivalent GaAs/GaInAsP-based lasers.

In addition to lower reactivity, GaInAsP has lower surface recombination, higher mobility and smaller interface roughness. It is for this reason that we believe the use of aluminum-free material will reduce dark currents and increase T_{BLIP} for QWIP focal plane arrays.

These new GaInAsP detectors should be commercially available within one year. □