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New Generation of Superlattice Cameras Add More 'Color' to Night Vision

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Recent breakthroughs have enabled scientists from the Northwestern University's Center for Quantum Devices to build cameras that can see more than one optical waveband or "color" in the dark. The semiconducting material used in the cameras – called type-II superlattices – can be tuned to absorb a wide range of infrared wavelengths, and now, a number of distinct infrared bands at the same time.

The idea of capturing light simultaneously at different wavelengths isn't new. Digital cameras in the visible spectrum are commonly equipped with detectors that sense red, green, and blue light to replicate a vast majority of colors perceived by the human eye. Multi-color detection in the infrared spectrum, however, offers unique functionalities beyond color representation. The resonant frequencies of compounds can often be found in this spectral range, which means that chemical spectroscopy can be relayed in images real-time.

"When coupled with image-processing algorithms performed on multiple wavebands, the amount of information rendered in a particular scene is tremendous," said Manijeh Razeghi, Walter P. Murphy Professor in Electrical Engineering and Computer Science at the McCormick School of Engineering and director of the Center for Quantum Devices.

Razeghi's group engineered the detection energies on the cameras to be extremely narrow, close to one-tenth of an electron volt, in what is known as the long-wave infrared window. Creating the cameras was difficult, however, because the light-absorbing layers are prone to parasitic effects. Furthermore, the detectors were designed to be stacked one on top of another, which provided spatially coincident pixel registration but added significantly to the growth and fabrication challenges. Nevertheless, a dual-band long-wave infrared 320-by-256 sized type-II superlattice camera was demonstrated for the first time in the world, the results of which were published in the July 2011 issue of Optics Letters.

Such infrared photon cameras based on another material called HgCdTe were used in disaster relief in March 2011 when a catastrophic tsunami damaged Japans' nuclear reactors. These cameras provided accurate temperature information about the reactors from unmanned aerial vehicles, providing officials the information they needed to orchestrate cooling efforts and prevent nuclear meltdown.

HgCdTe, however, is considered to be an expensive technology in the long-wave infrared due to its poor spectral uniformity and therefore yield – areas in which type-II superlattices may prove more efficient.

"Type-II superlattices can be grown uniformly even at very long-wavelengths because its energy gap is determined by the alternating InAs and GaSb quantum well thicknesses, rather than its composition as is the case with HgCdTe," Razeghi said. The high-resolution multi-band type-II superlattice camera also offered very impressive performances, requiring only 0.5 milliseconds to capture a frame with temperature sensitivities as good as 0.015°C. "The high-performance, multi-functionality, and low cost offered by type-II superlattices truly make it an attractive infrared technology," she added.

Above: Center for Quantum Devices graduate student Edward Huang holds a lighter and a narrow-band filter centered at 11.3μm. The flame can only be seen when imaged with the band-pass detectors sensitive up to 13μm (right) but not in the ones with shorter detection wavelength up to 9.5μm (left).