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Researchers Realize High-Power, Narrowband Terahertz Source at Room Temperature

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Researchers at Northwestern University have developed a simpler way to generate single-chip terahertz radiation, a discovery that could soon allow for more rapid security screening, border protection, high sensitivity biological/chemical analysis, agricultural inspection, and astronomical applications.

The work, headed by Manijeh Razeghi, Walter P. Murphy Professor of Electrical Engineering and Computer Science in the McCormick School of Engineering and Applied Science, was published Monday in the journal *Applied Physics Letters* and was presented in August at the SPIE Optics + Photonics conference in San Diego.

Terahertz radiation (wavelength range of 30 – 300 microns) can be used to see through paper, clothing, cardboard, plastic, and many other materials, without any of the health risks posed by current x-ray based techniques. This property has become extremely valuable for security screening, as it is safe to use on people and can detect metals and ceramics that might be used as weapons.

In addition, a scanning terahertz source can identify many types of biological or chemical compounds due to their characteristic absorption spectra in this wavelength range. Sensitivity to water content can also be utilized to study agricultural quality. Finally, through mixing with a compact coherent terahertz source, very weak terahertz signals from deep space can be detected, which may help scientists understand the formation of the universe.

Coherent terahertz radiation has historically been very difficult to generate, and the search for an easy-to-use, compact source continues today. Current terahertz sources are large, multi-component systems that may require complex vacuum electronics, external pump lasers, and/or cryogenic cooling. A single component solution without any of these limitations is highly desirable to enable next generation terahertz systems.

One possible avenue toward this goal is to create and mix two mid-infrared laser beams within a single semiconductor chip in the presence of a giant nonlinearity. This nonlinearity allows for new terahertz photons to be created within the same chip with an energy equal to the difference of the mid-infrared lasers’ energies. As mid-infrared lasers based on quantum cascade laser technology are operable at room temperature, the terahertz emission can also be demonstrated at room temperature.

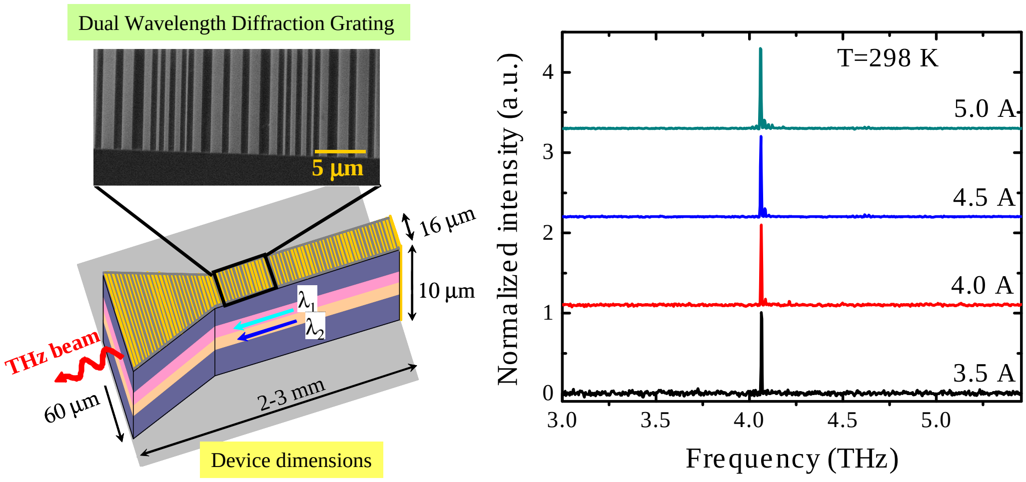
Razeghi and her group at the Center for Quantum Devices have taken this basic approach a step further by addressing two key issues that have limited the usefulness of initial demonstrations. Razeghi's group currently leads the world in high-power quantum cascade laser technology; by increasing the power and beam quality of the mid-infrared pumps, the terahertz power has been significantly increased by more than a factor of 30 to ~10 microwatts.

Additionally, the researchers have incorporated a novel dual-wavelength diffraction grating within the laser cavity to create single mode (narrow spectrum) mid-infrared sources, which in turn has led to very narrow linewidth terahertz emission near 4 terahertz. Further, due to the novel generation mechanism, the terahertz spectrum is extremely stable with respect to current and/or temperature. This could make it valuable as a local oscillator, which can be used for low light level receivers like those needed for astronomical applications.

Razeghi said her group will continue in hopes of reaching higher power levels.

"Our goal is to reach milliwatt power levels and incorporate tuning within the device," Razeghi said. "Theory says that it is possible, and we have all of the tools necessary to realize this potential."

Razeghi's work in this area is partially supported by the Defense Advanced Research Projects Agency (DARPA), and she would like to acknowledge the interest and support of Dr. Scott Rodgers of DARPA and Dr. Tariq Manzur of the Naval Undersea Warfare Center.



Device schematic and THz output spectrum at room temperature as a function of current.