Single-pixel 'multiplex' captures elusive terahertz images

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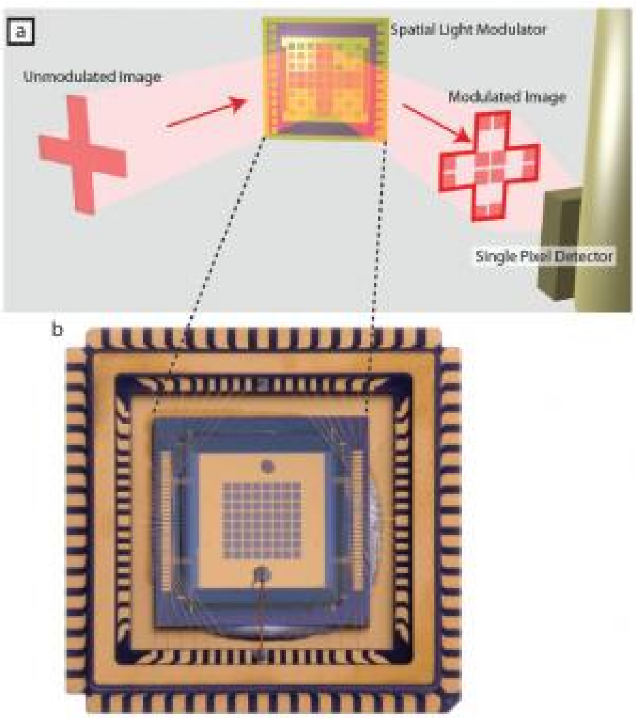

Developed by a team of researchers from Boston College, the University of New Mexico and Duke University, a "multiplex" single pixel imaging process effectively tames stubborn terahertz (THz) light waves with electronic controls in a novel metamaterial. As the graphic shows, THz image waves are received by a metamaterial spatial light modulator, which in turn sends multiple data points from the THz scene to a single-pixel detector, which computationally reconstructs the image faster, more efficiently and with higher-fidelity than conventional THz imaging technology. Credit: *Nature Photonics*, 2014.

A novel metamaterial enables a fast, efficient and high-fidelity terahertz radiation imaging system capable of manipulating the stubborn electromagnetic waves, advancing a technology with potential applications in medical and security imaging, a team led by Boston College researchers reports in the online edition of the journal *Nature Photonics*.

The team reports it developed a "multiplex" tunable spatial light modulator (SLM) that uses a series of filter-like "masks" to retrieve multiple samples of a terahertz (THz) scene, which are reassembled by a single-pixel detector, said Boston College Professor of Physics Willie Padilla, a lead author of the report.

Data obtained from these encoded measurements are used to computationally reconstruct the images as much as six times faster than traditional raster scan THz devices, the team reports. In addition, the device employs an efficient low power source, said Padilla, whose research team worked with colleagues from the University of New Mexico and Duke University.

"I think we were surprised by how well the imaging system worked, particularly in light of the incredibly low power source," said Padilla. "Traditional THz imaging systems use sources that demand much more power than our system."

Metamaterials are designer electromagnetic materials that have tunable optical properties, allowing them to interact with light waves in new ways. Those unique properties have proven conducive to working with THz light waves, which have longer wavelengths than visible light and therefore require new imaging technology.

Padilla said the team set out to use metamaterials to develop an imaging architecture superior to earlier THz camera designs, which have relied on expensive and bulky detector arrays to assemble images.

Central to the team's advanced device is the development of a spatial light modulator constructed from a unique metamaterial structure by researchers at the University of New Mexico's Center for High Technology Materials. The SLM, which deploys a series of masks to obtain select image information from the THz scene, showed it effectively tames the otherwise stubborn THz light waves, which have defied other forms of frequency controls such as electronic sensors and semiconductor devices.

The metamaterial SLM efficiently modulates THz radiation when an electronically controlled voltage is applied between two layers of the metamaterial, effectively changing its optical properties and allowing it to actively display encoding masks designed to retrieve THz images. One such encoding technique allowed the researchers to access negative encoding values, which allow for higher fidelity image reconstruction.

A negative encoding value typically requires phase-sensitive sources and detectors, multiple detectors, or taking twice the number of measurements in order to create the image. The team created its "masks" without additional equipment or measurements, allowing researchers to use a more robust image encoding method that increased image quality while reducing the time needed to acquire the image.

Since it offers improved results without additional equipment, researchers engaged in "multiplexing" THz imaging could quickly adopt the new imaging approach. The findings add to a growing body of research that shows metamaterials are a viable option for the construction of efficient SLMs at THz wavelengths.

"In the long run, I think we set out a new paradigm for imaging at longer wavelengths," said Padilla. "Rather than including an expensive and bulky detector array in an imaging system, high-fidelity images can be obtained with only a single pixel detector and a low power source, allowing for a compact and inexpensive THz imaging system."

Padilla said a new generation of metamaterial THz imaging systems could help realize the potential applications projected by researchers and theorists.

"This type of imaging system has the potential to make a huge impact," said Padilla. "The ability to image a scene with THz could be used to screen for cancerous skin cells, monitor airports and other secure areas for illegal drugs or explosives, and perform personnel screening to look for concealed weapons."

More information: Terahertz compressive imaging with metamaterial spatial light modulators, DOI: 10.1038/nphoton.2014.139

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