

Prototype Terahertz Imager Promises Biochem Advances

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The NIST terahertz imaging system reveals slight temperature differences, as shown in this post-processed image. The color scale ranges from blue indicating 301 K or 28.75 degrees C, to red indicating 302.5 K or 29.35 degrees C. The image was made of the test scene shown in the photo, a room-temperature ring on top of a warmer absorber material. Quantitative analysis shows the current system can distinguish structures with dimensions as small as 4 millimeters, to be significantly improved in the future. Credit: NIST

Researchers at the National Institute of Standards and Technology have demonstrated a new imaging system that detects naturally occurring terahertz radiation with unprecedented sensitivity and resolution. The technology may become a new tool chemical and biochemical analyses ranging from early tumor detection to rapid and precise identification of chemical hazards for homeland security instruments.

Terahertz radiation falls between microwaves and infrared radiation on the electromagnetic spectrum, with frequencies from about 300 million cycles per second to about 3 trillion cycles per second. Biological and chemical samples naturally emit characteristic signatures of terahertz radiation, but detecting and measuring them is a unique challenge because the signals are weak and absorbed rapidly by the atmosphere.

The NIST prototype imager, described in detail for the first time in a new paper, uses an exquisitely sensitive superconducting detector combined with microelectronics and optics technologies to operate in the terahertz range. The NIST system has its best resolution centered around a frequency of 850 gigahertz, a “transmission window” where terahertz signals can pass through the atmosphere. The system can detect temperature differences smaller than half a degree Celsius, which helps to differentiate between, for example, tumors and healthy tissue.

The heart of the system is a tiny device that measures incoming terahertz radiation by mixing it with a stable internal terahertz signal. This mixing occurs in a thin-film superconductor, which changes temperature upon the arrival of even a minute amount of radiation energy. The slight frequency difference between the two original terahertz signals produces a more easily detected microwave frequency signal.

NIST developed the device and antenna, combined with an amplifier on a chip smaller than a penny, in collaboration with the University of Massachusetts. Called a hot electron bolometer (HEB), the technology is sensitive enough to detect the weak terahertz signals naturally emitted by samples, eliminating the need to generate terahertz radiation to actively illuminate the samples. This greatly reduces complexity and minimizes safety concerns. In addition, the NIST “mixer” system delivers more information by detecting both the magnitude and phase (the point where each individual wave begins) of the radiation.

Because passively emitted signals are so weak, the current system takes about 20 minutes to make a single 40 x 40 pixel image. NIST researchers are working on an improved version that will scan faster and operate at two frequencies at once. Future systems also should be able to achieve better spatial resolution.

Citation: E. Gerecht, D. Gu, L. You and S. Yngvesson. Passive heterodyne hot electron bolometer imager operating at 850 GHz. Forthcoming in IEEE Transactions on Microwave Theory and Techniques.

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