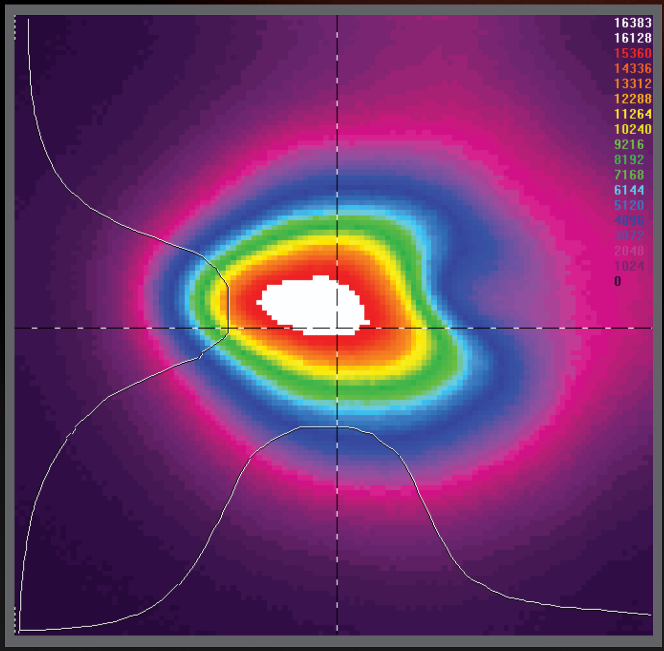
Terahertz Research

At Jefferson Lab

Throughout the centuries, people have harnessed the power of light. Antennae beam light in the radio band to transmit radio and television broadcasts; light in the infrared band enables remote controls; and the X-ray band allows doctors to see inside the human body. But the possibilities afforded by one band of light remain virtually untapped: Terahertz.

The Terahertz light band sits between the infrared and radio bands on the electromagnetic spectrum, with wavelengths between 3 and .03 millimeters. THz light is non-ionizing (doesn't harm living tissue at modest powers). That means THz light may provide medical images that are complementary to and safer than X-rays. It can also penetrate many fabrics and packaging materials and so holds great potential for security fields in detecting concealed weapons, such as a non-invasive airport scanner.

As a research tool, there appear to be many benefits. Thus far, limited research has revealed several unique applications of THz light. Spectral signatures of certain biological and chemical agents have been measured at THz frequencies. Detection of basal cell carcinomas and tooth cavities have been demonstrated. Other applications are only now being discovered, such as protein dynamics, superconductivity, magneto-optics, electro-optics, nonlinear optics and coherent control.



Beam image of Jefferson Lab THz light source.
The center of the pattern reads in excess of 2 watts of THz light.

Although promising, these and other potential applications of THz light have remained largely unexplored or only partially explored with low-power THz, because while both stars and electrical devices can give off THz light in small amounts, there hasn't been a THz light source bright enough for fully testing future applications.

That recently changed with the increased availability of Jefferson Lab's Free-Electron Laser. The Jefferson Lab FEL is a fourth-generation light source and is considered the most powerful tunable laser in the infrared. The FEL also delivers more than 10 Watts of broadband THz light for scientific studies—at least 10,000 times brighter than THz light produced anywhere else.

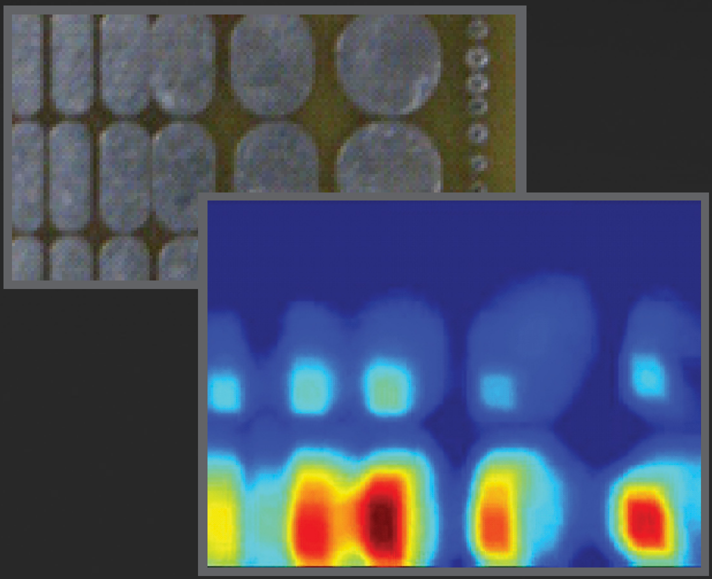
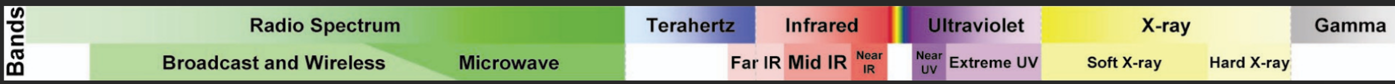


Photo and THz image of a cloth-covered
test pattern target shows a sensitivity to ~1 mm.



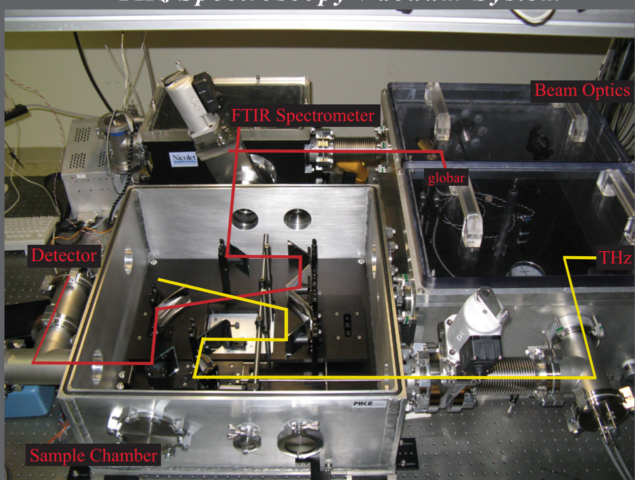
Request for Proposals

In the near future, Jefferson Lab will issue requests for proposals regarding research with its THz light source. The laboratory is seeking partnerships for the development of high-power THz active imaging for both security and biomedical applications.

The THz source is fed into a facility that permits a variety of tests to be safely performed. The source can provide high-power broadband light of at least 10 Watts of average power, 0.1 to 1.5 THz. Narrow-band THz is also available.

In addition, the facility has a THz imaging system capable of sensing a nanoWatt of light per pixel, which has been used to observe objects in real-time with a signal to noise of over 100, and with high resolution. In parallel, the laboratory is participating in a program to establish safe exposure limits of high-power THz light to humans.

THz Spectroscopy Vacuum System



The Jefferson Lab FEL generates the broadband high-power THz light in ultrashort pulses due to the bunching of the electrons in the FEL accelerator. The THz spectrum is frequently used to characterize the accelerator performance and for developing THz-based instrumentation for accelerator diagnostics.

The ultra-short pulses of THz light also provide a tool with extraordinary temporal resolution. The THz lab is equipped to perform single-color and two-color pump-probe experiments using THz pulses, synchronized table-top pulsed lasers and FEL beam (IR and soon UV). These types of measurements can be performed on solid-state, gas-phase, and even liquid-phase systems, with the sample in purged or evacuated chambers.

The FEL team is currently building a beam transport system in the THz lab to deliver any of the possible sources into a 16 T superconducting magnet. The magnet has been commissioned and provides another excellent tool for the study of highly correlated and magnetically active systems. The team will soon also begin a study to examine the use of THz as a probe in extreme high-pressure experiments.

Many more applications are possible with the JLab THz source and extensive testing equipment available in the THz lab. Please contact Gwyn Williams (gwyn@jlab.org) with inquiries and proposals.

DOE's Jefferson Lab, a nuclear physics research laboratory located in Newport News, Va., is a facility used by scientists worldwide. Its primary mission is to conduct basic research of the atom's nucleus at the quark level. Partnering with industry, universities and defense agencies, Jefferson Lab also pursues applied research with its free-electron laser and medical imaging programs. Jefferson Lab also reaches out to help educate the next generation in science and technology.

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