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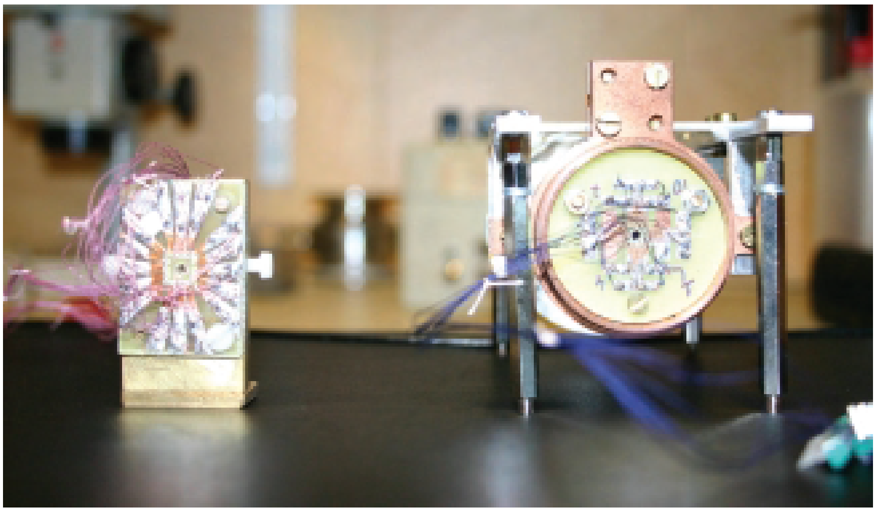
The evolution of THz sensor technology - from dark matter astronomy to security imaging

Invisible, safe, and capable of detecting concealed weapons as well as poisonous and explosive materials in the air, Terahertz (THz) technology will be at the heart of tomorrow's defence and security sensors.

The frequency region of 0.3 to 10.0 THz, also known as the far infrared or submillimeter range, is at the core of an explosion of research in the field of terahertz imaging and detection. This has been largely driven by the versatility of the technology and its possible use in applications that would otherwise prove to be impractical, if not impossible, with conventional technologies. One of the first uses of THz imaging, for example, was for the detection of dark matter in the demanding field of astronomy. This area requires tools of tremendous sensitivity with a Noise Equivalent Power (NEP) down to $NEP<10^{-19}$ W/Hz$^{1/2}$. Such sensitivity requires low noise detectors for which the only solution is to use cryogenic detectors cooled below 300 mK. Similarly, THz spectroscopy has the potential to become a powerful tool for the investigation of DNA and RNA topology. The far infrared absorption spectra of nucleic acids reflect low-frequency internal molecular motions that are dependent upon the weak hydrogen bonds of the double-helix base-pairs and non-bonded interactions between different functional groups. This could, in turn, provide information on the structure, flexibility and function of the examined molecule.



Josephson oscillator and cold electron bolometer units for the THz transmission spectrometer

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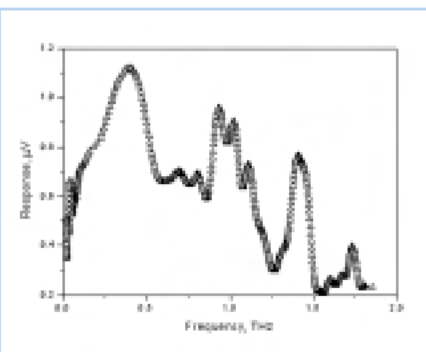
Given the global political climate, however, one of the most interesting and rapidly evolving fields for the application of THz technology is in the area of defence and security imaging. Here, the important feature of THz radiation is that clothing, unlike weapons and explosive materials, is transparent to such wavelengths. This leads to natural applications in the development of security control scanners that would not require individuals to be exposed to potentially harmful x-rays. In addition, the THz spectra of explosives and poisons contain specific spectral lines that can be detected from air probing in defended areas and objects.

Overcoming obstacles with ActivelyCooled Heliox AC-V™

The primary obstacle to the development of THz cryosensors, regardless of their purpose, has been in the cost and complexity of handling the liquid helium and cryostats used to cool sensors. The advent of the HelioxAC-V™ from Oxford Instruments, however, has brought a new approach to this problem with a breakthrough in ultra-low temperature cold stage technology. This closed-cycle cryostat features an ActivelyCooled™ unit that provides cooling power down to 300 mK. Uniquely, ActivelyCooled systems do not require servicing or replenishing of liquid cryogens, making the HelioxAC-V significantly easier to use and far less costly to operate than conventional ^{3}He refrigerators.



Applying these advantages, a team of researchers from the Microtechnology Department of Chalmers University of Technology (Göteborg, Sweden) has designed a prototype Terahertz Transmission Spectrometer (TTS) in the 0.2 to 2.0 THz frequency range, with a resolution down to 1.0 GHz. Importantly, the prototype also comprised a cold electron bolometer (CEB) detector and broadband, narrow line width oscillator employing superconducting nanotechnology. Through a mechanism similar to the Peltier effect, superconductor-insulator-normal (SIN) tunnel junctions contained within the CEB provide the system with further electron cooling, down to just 100 mK when a simple 0.5 mV dc bias voltage is applied. This creates the basic model for a gas analyser capable of detecting trace amounts of poisonous or explosive materials in the air of security risk areas such as airports and government buildings. In addition, the system could be used for applications in security imaging, including the detection of concealed weapons in an active or passive manner.

Possibilities on the horizon

To further broaden the application of THz systems, the Chalmers' team is currently working on the development of ultra high sensitive detectors of sub-mm wave radiation. They have developed cold electron bolometers with sensitivity down to 10^{-18} W/Hz$^{1/2}$ at frequencies of up to 2 THz. To this end, the group is using the unique technology facilities at the Microtechnology Center (MC2) process lab for the fabrication of nanobolometers and nanometer Josephson junctions. Future THz imaging systems equipped with CEB arrays could be used for a highly diverse range of purposes, from battlefield imaging to the remote measurements of ozone and atmospheric pollutants. Regardless of their application, however, the efficient, cryofree operation of ActivelyCooled™ is set to play key role in the ongoing development of THz systems.

The HelioxAC-V

References:

M. Tarasov, L. Kuzmin, T. Claeson et al. Terahertz spectrometer comprising Josephson oscillator and cold-electron bolometer, Proc. of SPIE "Optics/Photonics in Security and Defence", vol. 5619, Oct. 2004, p.19

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