Opening up the last part of the spectrum

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(PhysOrg.com) -- New European research on the last, hidden part of the electromagnetic spectrum is producing new, safe and non-destructive tests for medicine, security and industrial quality control.

Terahertz waves occupy the part of the spectrum between light and radio, specifically between infrared and millimetre waves. With wavelengths of 0.1-1mm, THz waves can be used like light or x-rays to create detailed images of solid objects. They have the useful property of passing easily through packaging and clothes, and since they are non-ionising they are safer than x-rays.

But THz waves can probe the content of objects as well as their shapes, thanks to their ability to respond to chemical properties. This is because their frequency range of 0.3-3THz matches the natural molecular vibrations of many common substances and biological materials.

Add these two properties together and you have a scanner that can not only detect a hidden package, but also show what is inside. New European research on THz waves could enable applications that include detecting tumours beneath the skin, a new and powerful kind of microscope for biological research, and quality control in semiconductor and pharmaceutical factories, as well as smart security scanners.

No man's land

Scientists have known the potential of THz waves for many years, and some THz instruments are already available commercially – though the new 3D scanners found in some airports mostly use the adjacent millimetre waveband. So why the need for more THz research?

One answer, according to THz expert Martyn Chamberlain, is that THz radiation is hard to generate, lying as it does in the "no-man's land" between electronics and optics. Electronic generators cannot yet operate at frequencies above 0.3THz, Chamberlain explains, while traditional THz lasers are too bulky for most practical applications. As a result, THz radiation has been comparatively neglected.

This is set to change following the results of an EU-funded research project called TeraNova, for which Chamberlain is a spokesperson. The 18 TeraNova partners include French electronics giants Thales and Alcatel, BAE Systems of the UK, and German drug discovery company Evotec. The four-year project is in its final stage and its partners have made several important developments in generating, using and detecting THz waves.

One big step forward was in quantum cascade lasers (QCLs): semiconductor devices that take advantage of quantum effects to operate at frequencies in the THz range. The researchers were able to extend the range of operating frequencies down to 850GHz, and are on the brink of producing QCLs that operate with simple solid-state cooling instead of the liquid nitrogen previously required.

The project also developed lasers that produce intense pulses of near-infrared light lasting as little as one femtosecond (a thousandth of a trillionth of a second!). When these extremely short pulses hit a special semiconductor target they produce "broadband" THz radiation, which has great potential for a range of new research tools in chemistry, biology and basic physics.

To complement their improved THz sources, the researchers developed new amplifiers and detectors. They have combined these in modular chips that have world-leading potential to create new low-cost analytical devices for biological research where, says Chamberlain, the very low energy of THz radiation ensures that fragile biological samples are not damaged.

From semiconductors to sperm cells

Passing easily through containers, clothes and packaging, THz waves can be used to measure the strength of alcoholic drinks or check the composition of foodstuffs or industrial raw materials, as well as identifying explosives and contraband. In the life sciences, THz technology is a highly sensitive way to detect genetic mutations and probe the structure and function of living cells, including the detection of cancers. In manufacturing processes, THz waves can check the integrity of multi-layer tablet coatings and control the quality of semiconductor wafers.

The TeraNova partners used their new THz sources and detectors to create prototypes of two practical THz devices: one aimed at electronics manufacturers and the other at animal breeders.

The first device relies on the ability of THz waves to measure the concentration and mobility of charge carriers in semiconductor wafers, especially those created using a technique known as molecular beam epitaxy (MBE). Traditional measurements of these properties require wafers to be sacrificed, so the non-destructive nature of the THz scanner is a real step forward.

The other demonstration device provides a way to identify individual biological cells without the need to "label" them with toxic dyes or radioisotopes. The Micro-integrated Single-cell THz Spectroscopic Sensor (MIST) will detect the X and Y chromosomes in sperm cells, and might form the basis for an automatic sex-selection system that would be useful to livestock breeders.

At a less commercial level, the project developed a number of “proof-of-principle” demonstrators for biological research. These include sensors that can identify the motion of groups of molecules in biological materials, and the binding state of biomolecules without the use of chemical labels. The researchers also developed a THz microscope, and performed much basic research on signal processing and the properties of materials at THz frequencies.

These more fundamental activities pave the way to new practical applications for the last part of the spectrum.

Provided by ICT Results

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