



An image made from a camera sensitive to terahertz frequencies reveals objects under clothing and paper.

## TAMING THE TERAHERTZ

### T-rays could be more versatile than x-rays

**IMAGING** | Just as x-ray technology came along in the 1890s—allowing doctors to peer beneath flesh to see bones and organs—another promising imaging technology is now emerging from an underused chunk of the electromagnetic spectrum: the terahertz frequencies. These so-called t-rays can, like x-rays, see through most materials. But t-rays are believed to be less harmful than x-rays. And different compounds respond to terahertz radiation differently, meaning a terahertz-based imaging system can discern a hidden object's chemical composition. Thanks to this power, “terahertz imaging is getting hotter and hotter,” says Xi-Cheng Zhang, a terahertz pioneer at Rensselaer Polytechnic Institute. Potential applications range from detecting tumors to finding plastic explosives. And since t-rays penetrate paper and clothing, a terahertz camera could detect hidden weapons.

Terahertz frequencies are tough to produce and detect. They're higher than microwaves but lower than infrared light. “You're never sure whether to use electronics-based or optics-based” technology, says Martyn Chamberlain of the University of Leeds in England, a leading terahertz researcher. The terahertz sources now on the market tend to emit many frequencies at once, limiting their utility. In the past year, however, several research projects have made substantial progress in developing devices that produce t-rays within a narrow frequency band—a requirement for precise chemical sensing and medical imaging.

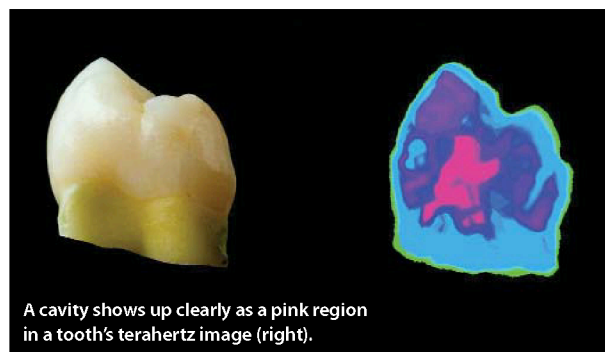
One such system, made by Brattleboro, VT-based Vermont Photonics, works by sending an electron beam across the microscopically rippled surface of a conductor, such as aluminum; the beam causes electrons in the conductor to move up and down the undulations, a motion that shakes loose t-rays. Changing the

energy of the electron beam also changes the terahertz frequency generated, says Vermont Photonics cofounder Michael Mross. The company is targeting its instrument primarily at observing interactions involving biomolecules for applications such as drug discovery. Another approach is something called the “quantum cascade laser,” a neat bit of semiconductor engineering used to produce infrared light. Moving the technology into the terahertz range requires exquisitely precise control over the materials. Last year, Qin Hu, an MIT electrical engineer, demonstrated a quantum cascade laser that produces a continuous terahertz beam at a well-defined frequency.

The most near-term application for terahertz technology is in medical imaging. In one ambitious effort, TeraView, a Cambridge, England-based startup, has used terahertz imaging to detect skin cancers that elude other imaging technologies—in particular, tumors that form invisibly beneath the surface of the skin. T-rays could also identify unknown biological materials, since biomolecules naturally vibrate at terahertz frequencies, and each has a distinct terahertz “fingerprint.” In other words, specific proteins absorb certain characteristic t-ray frequencies, which change their molecular arrangement, or conformation; sensors can then monitor this absorption to indicate the identity of the protein. “Life is a terahertz process,” says Chamberlain. One potential application is automated identification of biological warfare agents, such as anthrax. Another is a t-ray chemical sensor, which would take advantage of the fact that other large molecules, such as polymers, also respond to terahertz waves in characteristic ways. A terahertz camera built by QinetiQ of Farnborough, England, takes eerily invasive pictures of people through their clothes.

But the interaction of t-rays with proteins raises the question of how safe human exposure is. The European Union is sponsoring a program, called Terahertz Bridge, to study just that. Preliminary results have been encouraging; researchers have seen no evidence of irreversible, x-ray-like tissue damage from the doses of t-rays that would be used for bodily imaging. “So far, it's safe,” says Gian Piero Gallerano, coordinator of Terahertz Bridge.

While scientists go through contortions to produce t-rays, nature has it much easier. Terahertz radiation continues to propagate throughout space from its origin in the Big Bang. Says Chamberlain, “The universe is full of this stuff.” Before long, humans may begin putting it to practical use. —Herb Brody



A cavity shows up clearly as a pink region in a tooth's terahertz image (right).