Unexpected Plasmonic Discovery: Terahertz Waves Travel Slower When Sent Down Smaller Wires

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Frequently, the unexpected results in science are the most exciting. That's the case with the latest findings from the lab of Rice University's electrical engineer Daniel Mittleman, who was trying to find new ways to use terahertz energy, or T-rays, for chemical sensing when he noticed a strange tendency of the signals to travel slower if they were sent down smaller metal wires.

Mittleman and graduate student Kanglin Wang reported their findings in the April 21 issue of *Physical Review Letters*. Their explanation for the odd phenomenon arises from the unique way that T-rays interact with the sea of electrons flowing across the surface of the metal wire.

"A similar variation in wave velocity is well-documented for higher frequency radiation in the visible portion of the spectrum, but this was a real puzzle because no one had predicted it for such low frequencies," said Mittleman, associate professor of electrical and computer engineering.

Mittleman and Wang discovered the phenomenon during follow-up experiments to last year's groundbreaking development of the first T-ray wire waveguides. Their discovery that T-rays propogate down bare metal wires has allowed them to make T-ray endoscopes that can carry T-rays around corners and into tight places – like pipes and metal containers – where it hasn't been feasible to place a T-ray generator. Mittleman hopes to use the technique to design a new class of chemical sensors that port security officers can use to quickly determine whether explosives are hidden inside shipping containers.

That kind of sensing is possible because of the unique properties of T-rays, which fall between microwaves and infrared light in the least-explored region of the electromagnetic spectrum. Metals and other electrical conductors are opaque to T-rays, but like X-rays, T-rays can penetrate plastic, vinyl, paper, dry timber and glass and unlike X-rays, T-rays pose no health hazards.

The reason bare metal wires can be used as T-ray waveguides has to do with the way that light from the terahertz frequency interacts with the sea of electrons flowing over the surface of the wire. When a wave of light strikes the wire, it creates a corresponding wave, called a plasmon, in the electrons flowing over the wire's surface.

A new field of optics dedicated to the study of plasmons has sprung up within the past decade, and Rice boasts at least a half-dozen leading plasmonics labs, most of which are dedicated to the design, testing and use of metallic nanoparticles that are tailored to interact in particular ways with specific wavelengths of light.

Mittleman said plasmonics is the key to understanding the movement of T-rays down metal wires. When T-rays strike the metal wire, they create plasmons, and it is via these electron waves that the T-ray energy propogates down the wire. As the diameter of the wire gets smaller, the curvature becomes more pronounced, and this changes the plasmonic properties of the wire. It is this curvature, coupled with properties of the metal itself, that causes the T-rays to move slower.

"This is but one example of the interesting new physics that coming out of T-ray labs across the country, and with more researchers taking an interest in T-rays I think we're well on our way to answering some of the fundamental questions that must be addressed for the field to progress," Mittleman said.

Source: Rice University