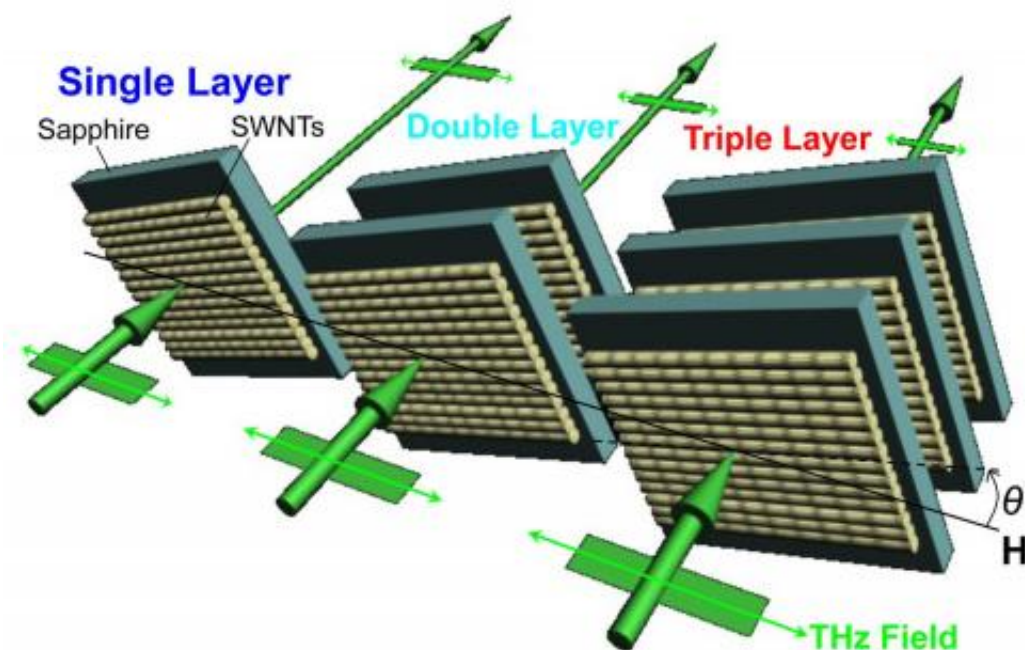


Nanotube-based terahertz polarizer nears perfection

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A triple layer of carbon nanotube arrays on a sapphire base are the basis for a new type of terahertz polarizer invented at Rice University. The polarizer could lead to new security and communication devices, sensors and non-invasive medical imaging systems. (Credit: Lei Ren/Rice University)

(PhysOrg.com) -- Researchers at Rice University are using carbon nanotubes as the critical component of a robust terahertz polarizer that could accelerate the development of new security and communication

devices, sensors and non-invasive medical imaging systems as well as fundamental studies of low-dimensional condensed matter systems.

The [polarizer](#) developed by the Rice lab of Junichiro Kono, a professor of electrical and computer engineering and of physics and astronomy, is the most effective ever reported; it selectively allows 100 percent of a terahertz wave to pass or blocks 99.9 percent of it, depending on its polarization. The research was published in the online version of the American Chemical Society journal, [Nano Letters](#).

The broadband polarizer handles waves from 0.5 to 2.2 terahertz, far surpassing the range of commercial polarizers that consist of fragile grids wrapped in gold or tungsten wires.

Kono said technologies that make use of the optical and electrical regions of the [electromagnetic spectrum](#) are mature and common, as in lasers and telescopes on one end and computers and microwaves on the other. But until recent years, the terahertz region in between was largely unexplored. "Over the past decade or two, people have been making impressive progress," he said, particularly in the development of such sources of radiation as the terahertz [quantum cascade laser](#).

"We have pretty good terahertz emitters and detectors, but we need a way to manipulate light in this range," Kono said. "Our work is in this category, manipulating the polarization state -- the direction of the electric field -- of terahertz radiation."

Terahertz waves exist at the transition between infrared and microwaves and have unique qualities. They are not harmful and penetrate fabric, wood, plastic and even clouds, but not metal or water. In combination with spectroscopy, they can be used to read what Kono called "spectral fingerprints in the terahertz range"; he said they would, for instance, be useful in a security setting to identify the chemical signatures of specific

explosives.

The work by Kono and lead author Lei Ren, who recently earned his doctorate at Rice, makes great use of the basic research into carbon nanotubes for which the university is famous. Co-authors Robert Hauge, a distinguished faculty fellow in chemistry, and his former graduate student Cary Pint developed a way to grow nanotube carpets and to transfer well-aligned arrays of nanotubes from a catalyst to any substrate they chose, limited only by the size of the growth platform.

While Hauge and Pint were developing their nanotube arrays, Kono and his team were thinking about terahertz. Four years ago, they came across a semiconducting material, indium antimonide, that would stop or pass terahertz waves, but only in a strong magnetic field and at very low temperatures.

At about the same time, Kono's lab began working with [carbon nanotube](#) arrays transferred onto a sapphire substrate by Pint and Hauge. Those aligned arrays -- think of a field of wheat run over by a steamroller -- turned out to be very effective at filtering terahertz waves, as Kono and his team reported in a 2009 paper.

"When the polarization of the terahertz wave was perpendicular to the nanotubes, there was absolutely no attenuation," Kono recalled. "But when the polarization was parallel to the nanotubes, the thickness was not enough to completely kill the transmission, which was still at 30-50 percent."

The answer was clear: Make the polarizer thicker. The current polarizer has three decks of aligned nanotubes on sapphire, enough to effectively absorb all of the incident terahertz radiation. "Our method is unique, and it's simple," he said.

Kono sees use for the device beyond spectroscopy by manipulating it with an electric field, but that will only become possible when all of the nanotubes in an array are of a semiconducting type. As they're made now, batches of nanotubes are a random mix of semiconductors and metallics; recent work by Erik Hároz, a graduate student in Kono's lab, detailed the reasons that nanotubes separated through ultracentrifugation have type-dependent colors. But finding a way to grow specific types of nanotubes is the focus of a great deal of research at Rice and elsewhere.

More information: pubs.acs.org/doi/abs/10.1021/nl203783q

Provided by Rice University

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