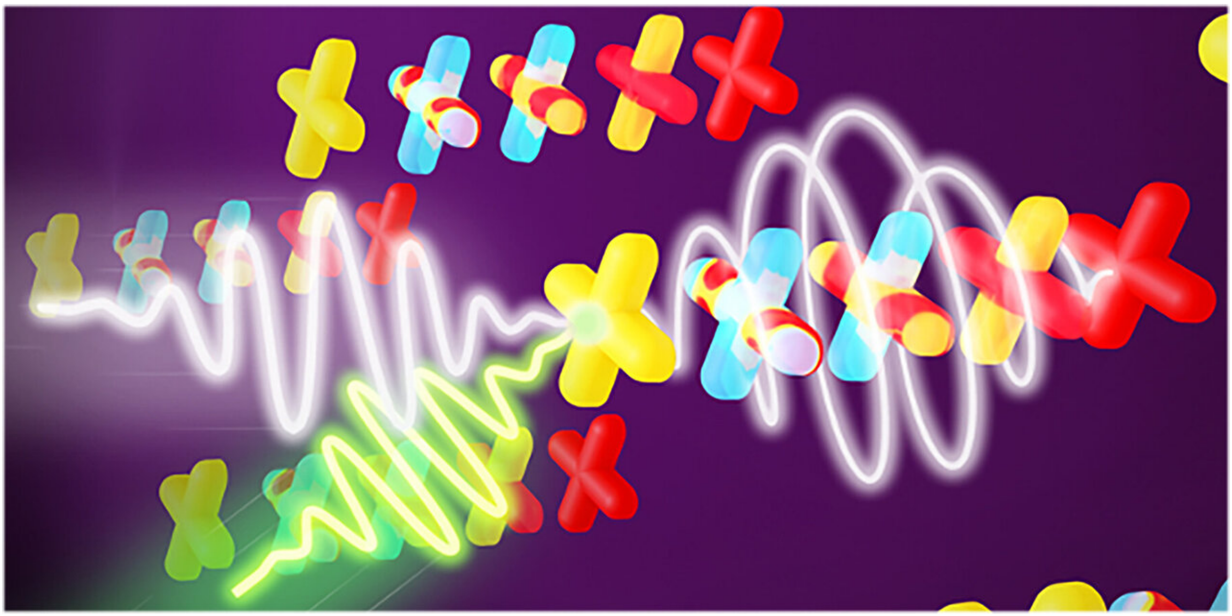
A trillion turns of light nets terahertz polarized bytes

October 19 2020, by Jade Boyd



A pictorial schematic depicts the structure and action of a nanopatterned plasmonic metasurface that modulates polarized light at terahertz frequencies. An ultrashort laser pulse (green) excites cross-shaped plasmonic structures, which rotate the polarity of a second light pulse (white) that arrives less one picosecond after the first. Credit: A. Assié

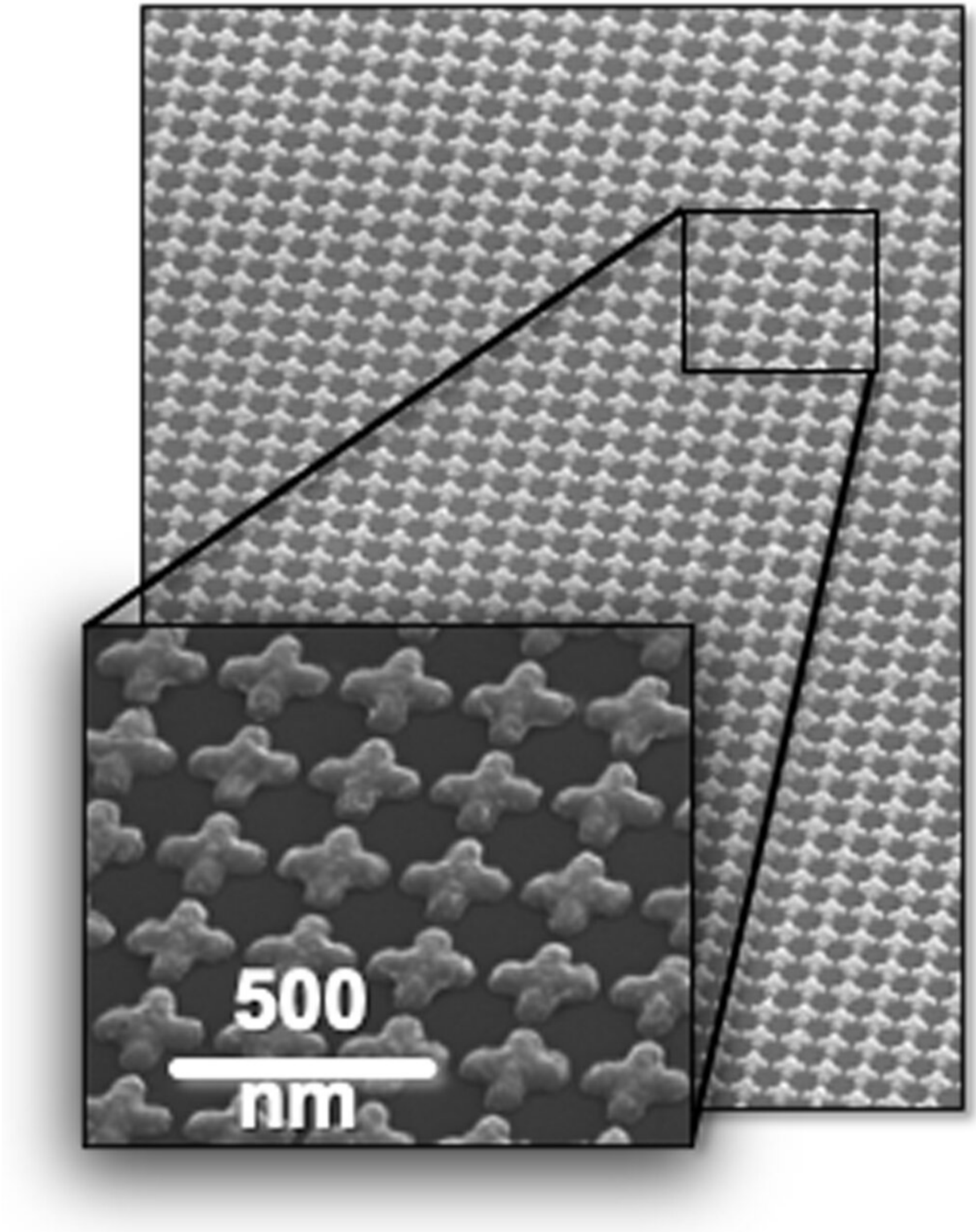
U.S. and Italian engineers have demonstrated the first nanophotonic platform capable of manipulating polarized light 1 trillion times per second.

"Polarized light can be used to encode bits of information, and we've shown it's possible to modulate such light at terahertz frequencies," said Rice University's Alessandro Alabastri, co-corresponding author of a study published this week in *Nature Photonics*.

"This could potentially be used in wireless communications," said Alabastri, an assistant professor of electrical and computer engineering in Rice's Brown School of Engineering. "The higher the operating frequency of a signal, the faster it can transmit data. One terahertz equals 1,000 gigahertz, which is about 25 times higher than the operating frequencies of commercially available optical polarization switches."

The research was a collaboration between experimental and theoretical teams at Rice, the Polytechnic University of Milan (Politecnico) and the Italian Institute of Technology (IIT) in Genoa. This collaboration started in the summer of 2017, when study co-first author Andrea Schirato was a visiting scholar in the Rice lab of physicist and co-author Peter Nordlander. Schirato is a Politecnico-IIT joint graduate student under the supervision of co-corresponding author Giuseppe Della Valle of Politecnico and co-author Remo Proietti Zaccaria of IIT.

Each of the researchers work in nanophotonics, a fast-growing field that uses ultrasmall, engineered structures to manipulate light. Their idea for ultrafast polarization control was to capitalize on tiny, fleeting variations in the generation of high-energy electrons in a plasmonic metasurface.



A scanning electron microscope image of the nanopatterned plasmonic metasurface that engineers from Rice University, the Polytechnic University of Milan and the Italian Institute of Technology created to modulate polarized light at terahertz frequencies. Credit: Andrea Toma/IIT

Metasurfaces are ultrathin films or sheets that contain embedded nanoparticles that interact with light as it passes through the film. By varying the size, shape and makeup of the embedded nanoparticles and by arranging them in precise two-dimensional geometric patterns, engineers can craft metasurfaces that split or redirect specific wavelengths of light with precision.

"One thing that differentiates this from other approaches is our reliance on an intrinsically ultrafast broadband mechanism that's taking place in the plasmonic nanoparticles," Alabastri said.

The Rice-Politecnico-IIT team designed a metasurface that contained rows of cross-shaped gold nanoparticles. Each plasmonic cross was about 100 nanometers wide and resonated with a specific frequency of light that gave rise to an enhanced localized electromagnetic field. Thanks to this plasmonic effect, the team's metasurface was a platform for generating high-energy electrons.

"When one laser light pulse hits a plasmonic nanoparticle, it excites the free electrons within it, raising some to high-energy levels that are out of equilibrium," Schirato said. "That means the electrons are 'uncomfortable' and eager to return to a more relaxed state. They return to an equilibrium in a very short time, less than one picosecond."

Despite the symmetric arrangement of crosses in the metasurface, the nonequilibrium state has asymmetric properties that disappear when the system returns to equilibrium. To exploit this ultrafast phenomenon for polarization control, the researchers used a two-laser setup. Experiments performed by study co-first author Margherita Maiuri at Politecnico's ultrafast spectroscopy laboratories—and confirmed by the team's theoretical predictions—used an ultrashort pulse of light from one laser to excite the crosses, allowing them to modulate the polarization of light in a second pulse that arrived less than a picosecond after the first.

"The key point is that we could achieve the control of light with light itself, exploiting ultrafast electronic mechanisms peculiar of plasmonic metasurfaces," Alabastri said. "By properly designing our nanostructures, we have demonstrated a novel approach that will potentially allow us to optically transmit broadband information encoded in the polarization of light with unprecedented speed."

More information: Andrea Schirato et al, Transient optical symmetry breaking for ultrafast broadband dichroism in plasmonic metasurfaces, *Nature Photonics* (2020). DOI: 10.1038/s41566-020-00702-w

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