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Cascaded metasurfaces for dynamic control of THz wavefronts

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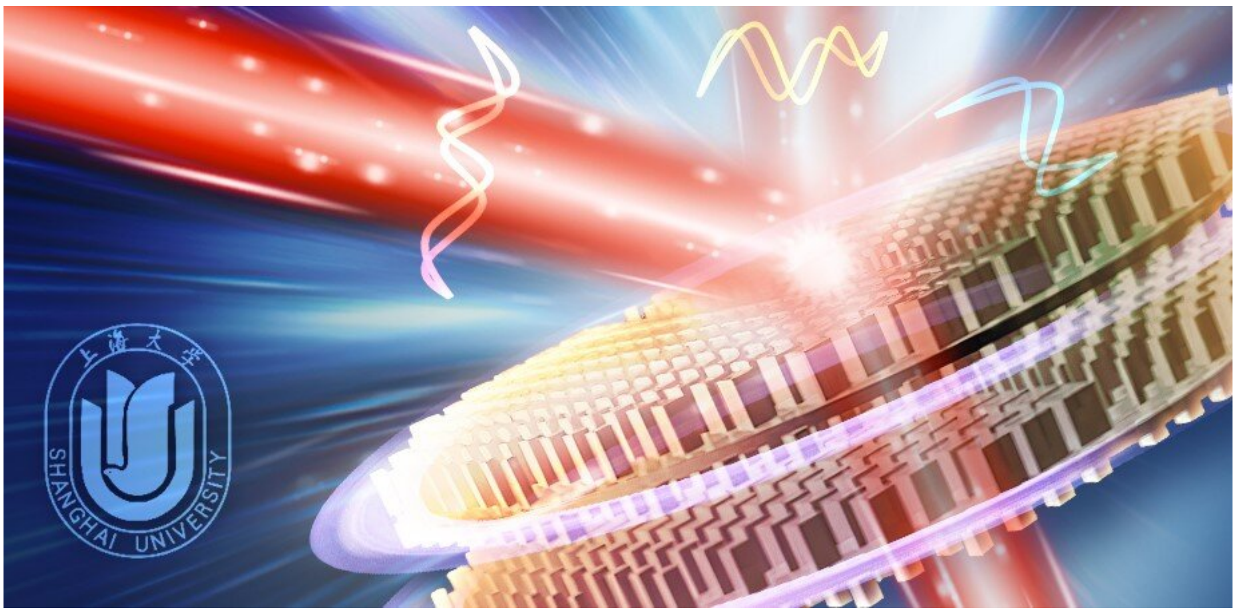
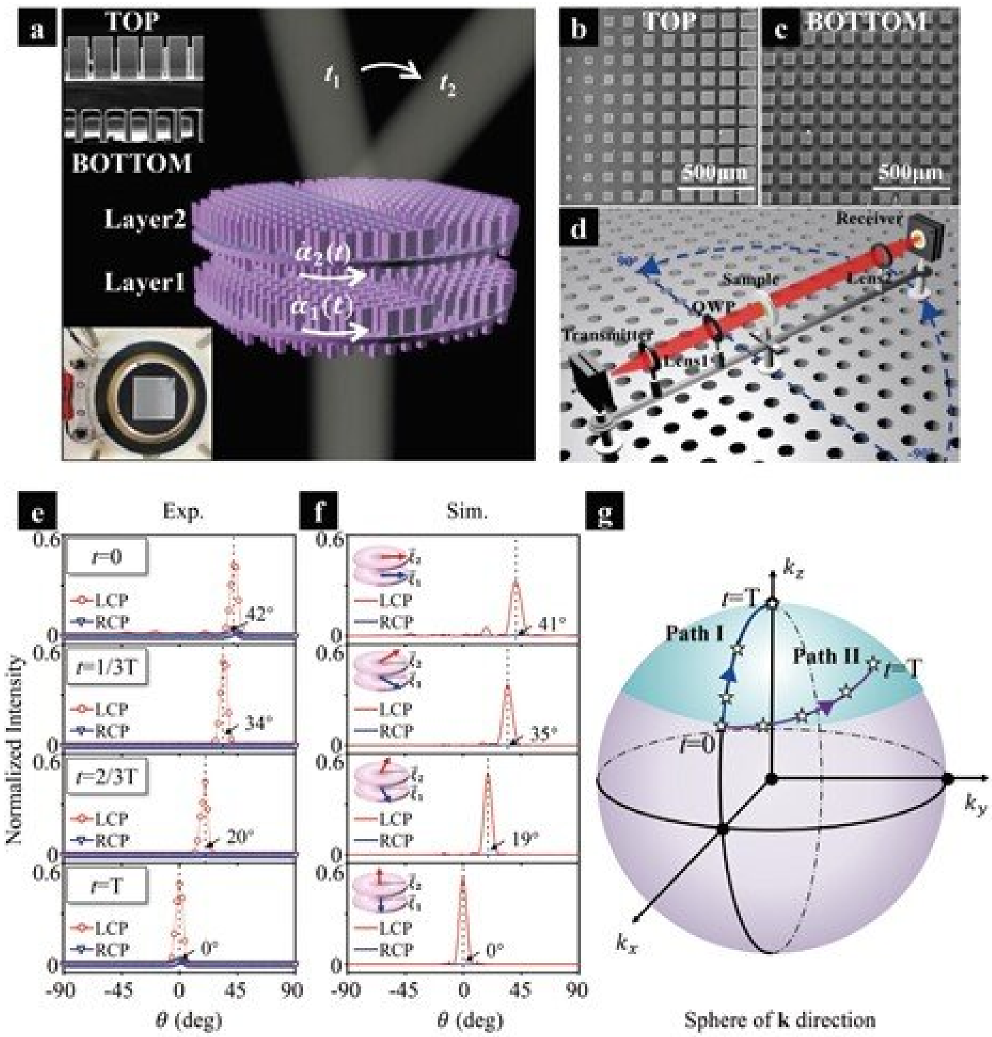


A metadevice for dynamically controlling THz wavefronts by rotating layers of cascaded metasurfaces. Credit: Shanghai University

Electromagnetic (EM) waves in the terahertz (THz) regime contribute to important applications in communications, security imaging, and bio- and chemical sensing. Such wide applicability has resulted in significant technological progress. However, due to weak interactions between natural materials and THz waves, conventional THz devices are typically bulky and inefficient. Although ultracompact active THz devices do exist, current electronic and photonic approaches to dynamic control have lacked efficiency.

Recently, rapid developments in metasurfaces have opened new possibilities for the creation of high-efficiency, ultracompact THz devices for dynamic wavefront control. Ultrathin metamaterials formed by subwavelength planar microstructures (i.e., meta-atoms), metasurfaces enable tailored optical responses for control of EM wavefronts. By constructing metasurfaces that possess certain predesigned phase profiles for transmitted or reflected waves, scientists have demonstrated fascinating wave-manipulation effects, such as anomalous light deflection, polarization manipulation, photonic spin-Hall, and holograms.

Moreover, integrating active elements with individual meta-atoms inside passive metasurfaces allows for 'active' metadevices that can dynamically manipulate EM wavefronts. While active elements in deep subwavelengths are easily found in the microwave regime (e.g., PIN diodes and varactors), and successfully contribute to active metadevices for beam-steering, programmable holograms, and dynamic imaging, they are difficult to create at frequencies higher than THz. This difficulty is due to size restrictions and significant ohmic losses in electronic circuits. Although THz frequencies can control THz beams in a uniform manner, they are typically unable to dynamically manipulate the THz wavefronts. This is ultimately due to deficiencies in the local-tuning capabilities at deep-subwavelength scales in this frequency domain. Therefore, developing new approaches that bypass reliance on local tuning is a priority.



Demonstration of the dynamic beam-steering metadevice: (a) Schematics of the metadevice, which consists of two layers of transmissive metasurfaces aligned by a motorized rotation stage. (b) Top view (left) and (c) bottom view (right) SEM pictures of the fabricated metadevice. (d) Schematics of the experimental setup shown to characterize the meta-device. (e) Experimental and (f) simulated far-field scattering power distributions with the metadevice illuminated by an LCP light at 0.7 THz, and evolving along Path I at different time instants. (g) Evolution of transmitted wave directions on the sphere of k direction as the metadevice moves along Path I and Path II, with solid line (star-symbols) denoting the simulated (experimental) results. Here, the blue region denotes the solid angle for beam-steering coverage. Credit: X. Cai et al.

As reported in *Advanced Photonics*, researchers from Shanghai University and Fudan University developed a general framework and metadevices for achieving dynamic control of THz wavefronts. Instead of locally controlling the individual meta-atoms in a THz metasurface (e.g., via PIN diode, varactor, etc.), they vary the polarization of a light beam with rotating multilayer cascaded metasurfaces. They demonstrate that rotating different layers (each exhibiting a particular phase profile) in a cascaded metadevice at different speeds can dynamically change the effective Jones-matrix property of the whole device, achieving extraordinary manipulations of the wavefront and polarization characteristics of THz beams. Two metadevices are demonstrated: the first metadevice can efficiently redirect a normally incident THz beam to scan over a wide solid-angle range, while the second one can dynamically manipulate both wavefront and polarization of a THz beam.

This work proposes an attractive alternative way to achieve low-cost dynamic control of THz waves. The researchers hope that the work will inspire future applications in THz radar, as well as bio- and chemical sensing and imaging.

More information: Xiaodong Cai et al, Dynamically controlling terahertz wavefronts with cascaded metasurfaces, *Advanced Photonics* (2021). DOI: 10.1117/1.AP.3.3.036003

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