Optically controlled metasurfaces for dynamic dual-mode modulation

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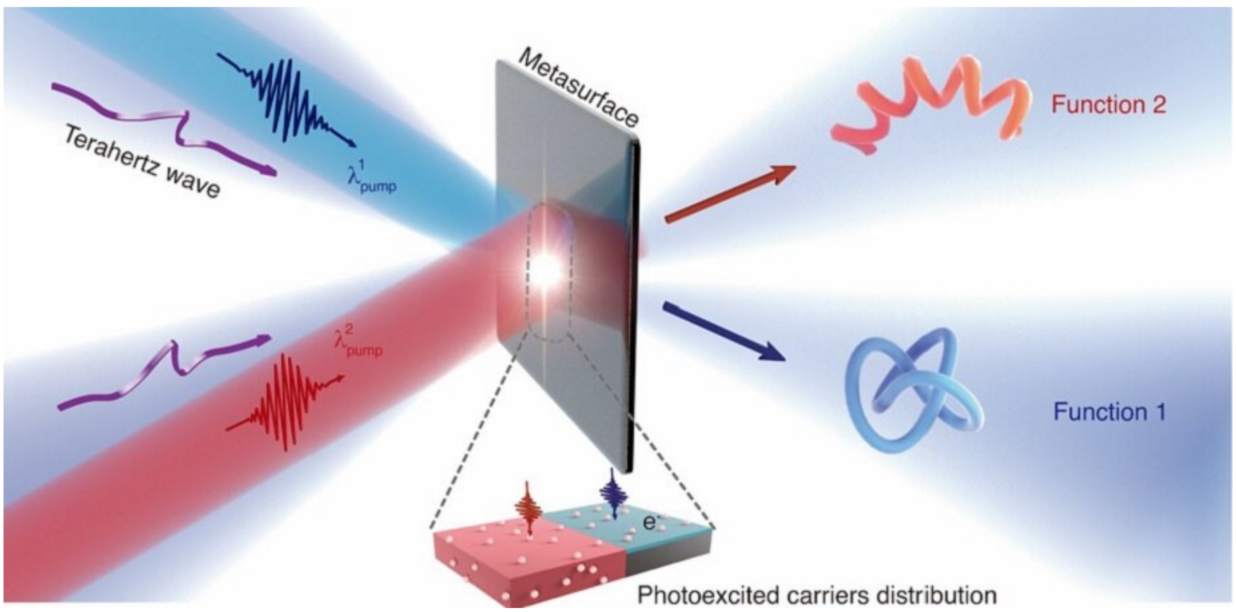


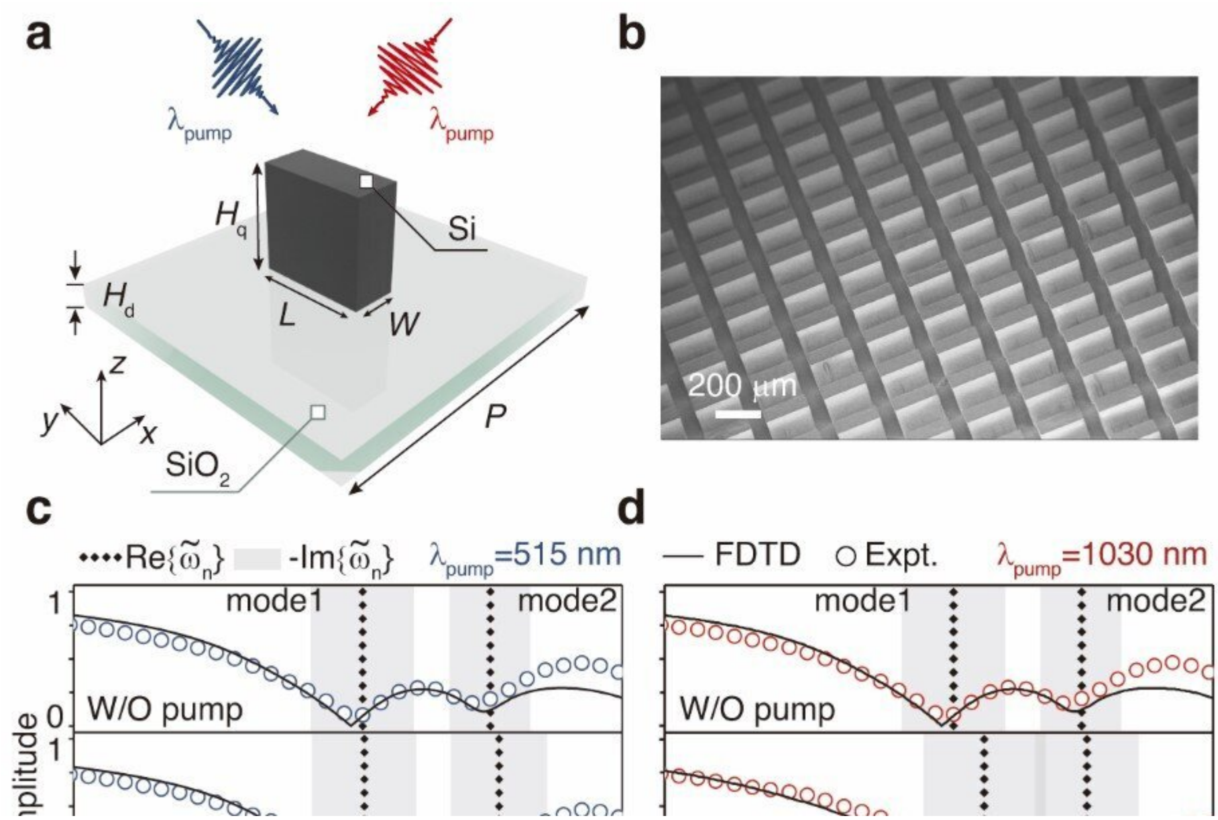
Optically controlled metasurfaces achieve dynamic dual-mode modulation by varying the wavelength of pumping light. Credit: *Advanced Photonics* (2023). DOI: 10.1117/1.AP.5.2.026005

Dynamic control of terahertz (THz) waves at will with an ultra-compact device is important for THz technologies in biomedical imaging, telecommunications, detection, and beyond. However, tunable THz devices made of conventional materials are usually bulky, and they tend to have limited modulation depths and functionalities, due to weak interactions between naturally existing materials and THz waves.

Metasurfaces—functional materials endowed with unparalleled flexibility to manipulate light at the deep-subwavelength scale—provide a powerful platform for dynamic control of THz waves.

Combining passive metasurfaces with different external-stimuli-controlled materials, optically controlled metadevices have attracted attention in this regard. Their attractive properties include ultra-fast modulation speed and high modulation pixel resolution. Most optically controlled metadevices can achieve light modulation that is either selective or unselective of frequency. Dual-mode yet distinctly tunable light manipulation—say, upon adjusting an external knob in a simple device—is highly desired for applications in integrated optics.

As reported in *Advanced Photonics*, researchers from Fudan University's Department of Physics recently established a novel metasurface-based approach that achieves dynamic dual-mode modulation of THz waves by varying the wavelength of pumping light with an additional knob. Specifically, their experiment demonstrated that a pre-designed dielectric metasurface can realize mode-selective or mode-unselective modulations on incident THz waves, by switching the wavelength of the pump wavelength (e.g., 515 nm or 1030 nm). Their theoretical analyses revealed that such dual-mode modulation can be effectively controlled by carefully designing the spatial overlap between the wave-functions of the metasurface's resonant modes and the regions perturbed by the pump-laser excitation at different wavelengths.



Experimental demonstration of the dynamic dual-mode THz wave modulation. (a) Schematics of the basic meta-atom consisting of a quartz substrate and silicon pillar. (b) Tilt-view SEM image of the fabricated sample. (c, d) Measured (open circles) and simulated (solid lines) transmission-amplitude spectra of the fabricated metasurface, under external pumping at (c) 515 nm and (d) 1030 nm with different pump fluences. Credit: *Advanced Photonics* (2023). DOI: 10.1117/1.AP.5.2.026005

Inspired by their discovery of the mechanism, the research team further demonstrated two active metadevices with distinct light-modulation functionalities. In experiments and simulations, they first presented a device that can dynamically change the polarization state of incident THz waves dictated by both pump wavelength and pump fluence. Then, they presented a device that can encrypt optical information so that it displays a pre-designed holographic pattern only when excited by a pump beam at a pre-determined correct wavelength.

According to corresponding author Qiong He, Professor of Physics at Fudan University, "We anticipate that this work will stimulate many new tunable devices with distinct light-modulation functionalities." He adds, "These functionalities may be useful for numerous applications, such as sensing, security, and next generation wireless communications."

More information: Haoyang Zhou et al, Optically controlled dielectric metasurfaces for dynamic dual-mode modulation on terahertz waves, *Advanced Photonics* (2023). DOI: 10.1117/1.AP.5.2.026005

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