Nanomechanical Metamaterial Light Modulators

Eric Plum[1,*], Jun-Yu Ou[1], João Valente[1], Pablo Cencillo[1], and Nikolay Zheludev[1,2]

[1]Centre for Photonic Metamaterials and Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ, UK
[2]Centre for Disruptive Photonic Technologies, Nanyang Technological University, 637371, Singapore
*corresponding author, E-mail: erp@orc.soton.ac.uk

Abstract

Reconfigurable photonic metamaterials provide a flexible platform for thermo-optical, electro-optical, magneto-optical and all-optical modulation of metamaterial properties. We provide an overview from fundamental physics to practical metadevices for high-contrast light modulation.

1. Summary

Metamaterials offer a large range of novel or enhanced optical properties, however, they are usually narrow-band and fixed. Thus, dynamic control over metamaterial properties has become a major challenge. Practical solutions for controlling metamaterial optical properties will greatly increase their application potential and open up novel opportunities from fundamental physics to programmable transformation optics devices.

Reconfigurable photonic metamaterials achieve large-range tuning or switching of optical properties by rearranging the metamaterial structure on the nanoscale. Exploiting weak elastic forces in materials of nanoscale thickness and large mechanical eigenfrequencies of nanoscale structures, we demonstrate metamaterials that can be reconfigured at up to megahertz frequencies. Our nanostructures reconfigure in response to heat, electrical currents and voltages, magnetic fields and optical signals, exploiting different driving mechanisms based on differential thermal expansion [1], electrostatic forces [2], resistive heating, the Lorentz force (Fig. 1) and optical forces (Fig. 2). Beyond fully reversible modulation of metamaterial optical properties with contrast on the order of 50%, we find giant electro-optical and magneto-electric optical effects and evidence of forces associated with the optical excitation of plasmonic resonators (Fig. 2).

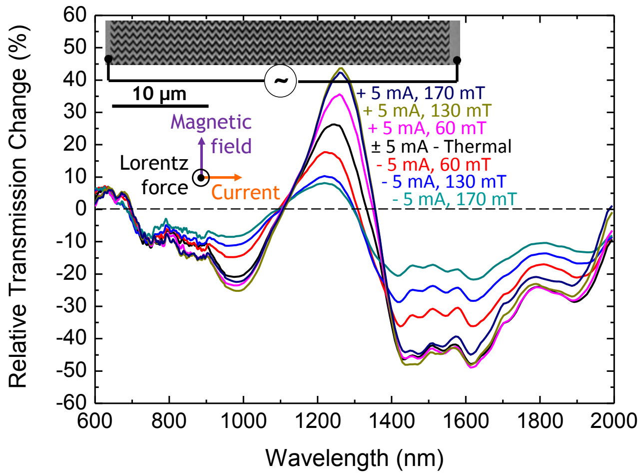

Figure 1: Electrically and magnetically reconfigurable photonic metamaterial. Transmission modulation measured as a function of applied currents and magnetic fields. The inset shows a scanning electron micrograph of part of the metamaterial structure consisting of free-standing gold on silicon nitride bridges.

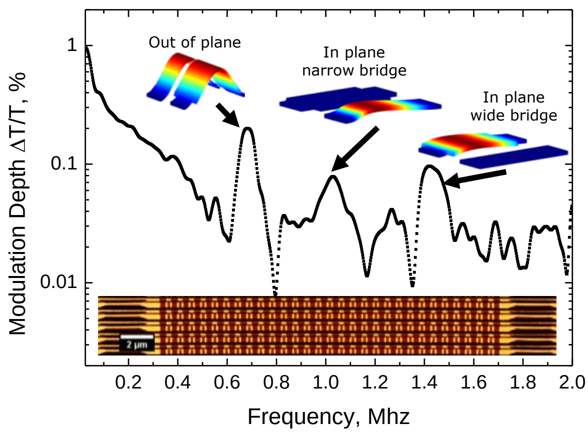

Figure 2: All-optically reconfigurable photonic metamaterial. Transmission modulation measured as a function of modulation frequency with a 1550 nm wavelength pump beam (intensity 265 W/cm^2) and a 1310 nm probe. Insets show mechanical eigenmode simulations and a scanning electron micrograph of part of the metamaterial structure consisting of free-standing silicon nitride bridges supporting gold plasmonic resonators.

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References

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