Nonlinear Nanomechanical Photonic Metamaterials

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Abstract

By harnessing mechanical and optical resonances in tandem one can enhance the magnitude of actuation and optical response in dynamically reconfigurable nanostructures driven by microwatt optical signals and low-intensity acoustic vibrations. We review recent work on structures exhibiting profound opto-mechanical nonlinearity and bistability.

Summary

Nanomechanical metamaterials represent a highly adaptable platform of the engineering of profound electro-, magneto- and acousto-optic switching coefficients, and a range of optical phenomena that are vanishingly small, rare or non-existent in natural media. Here, we demonstrate systems in which coupling of near-infrared electromagnetic and MHz-frequency flexural resonances delivers strongly nonlinear optical properties.

Ponderomotive, non-thermal optical forces can control the structural configuration and thereby the optical response of an all-dielectric nanowire metamaterial, enabling all-optical transmission modulation at in a structure $<{}^{1}/_{3}$ of a wavelength thick, at low ($\mu W/\mu m^2$) intensities. This optomechanical nonlinearity is, moreover, strongly directionally asymmetric – i.e. dependent upon the direction of light propagation through the nanostructure.

Nanowires decorated with plasmonic resonators can be driven to provide a bistable optical response by acoustic signals modulated at their natural mechanical frequencies.

These hybrid nano-opto-mechanical systems opens new opportunities to develop low-power photonic switching devices.

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