Light Driven Nonlinear Plasmonic Optomechanical Metamaterials

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The realization of integrated optical system on a chip requires extreme miniaturization functional elements. To reach this objective, novel approach must be developed to manipulate light with light in small areas and interaction lengths. Here we experimentally demonstrate optically driven mechanically reconfigurable photonic metamaterial exhibiting an extraordinarily large optical nonlinearity. With nonlinear absorption of β~0.8 cm/W, the nanostructure is 7 orders of magnitude more nonlinear than nonlinearity of semiconductors such as *GaAs* at optical frequencies.

Fig. 1(a) shows a nonlinear reconfigurable array of Π-shaped plasmonic resonators sitting on double clamped silicon nitride bridges fabricated by focused ion beam milling from a 50 nm thick gold layer covering a 50 nm thick silicon nitride membrane. In order to manipulate the metamaterial's optical properties by light, a modulated laser beam was pumped at 1550 nm, where simulations predict significant relative optical forces on the bridges. The modulation of the metamaterial's transmission was probed at 1310 nm and detected using a photorecIver and a lock-in amplifier. At modulation frequencies of 10s of kHz, the optical pump leads to pronounced modulation of the structure's transmission characteristics at the probe wavelength, see Fig. 1(b). For a pump power of 2 mW (peak intensity I =206 W/cm^2) a modulation amplitude on the order of 1% is detected at 25 kHz modulation. As the modulation frequency increases, the out-of-plane and in-plane mechanical resonances are observed optically. While optically induced differential thermal expansion contributes to the mechanical nonlinearity at low frequencies, the in-plane mechanical modes (1.2 MHz and 1.4 MHz) cannot be directly excited by thermal effects but can be explained by near field optical forces.

In summary, optically actuated plasmonic optomechanical metamaterials offer an opportunity to achieve precise control of metamaterial properties through optically induced mechanical deformation of nanoscale metamaterial structures by electromagnetic near-field interaction and thermo-optical effects. With light intensity of few μW/μm^2, metamaterial arrays can be sufficiently actuated leading to light-by-light modulation with MHz bandwidth.

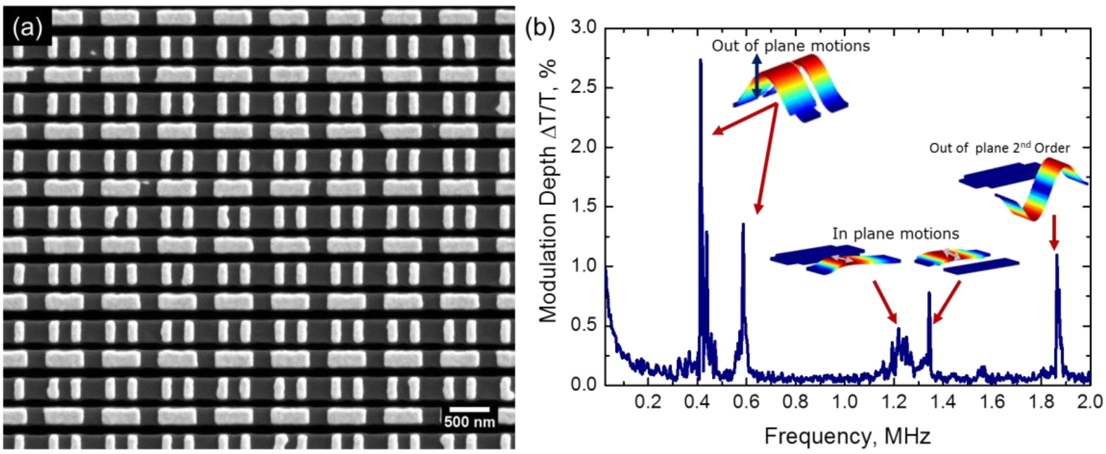

Fig.1: Optically reconfigurable photonic metamaterial. (a) SEM micrograph of the metamaterial consisting of a Π-shaped gold resonators fabricated by focused ion beam milling on a free standing silicon nitride membrane. (b) Modulation depth as a function of modulation frequency for a pump power of 2 mW, where simulations of the mechanical eigenmodes are shown as insets.