Nano-mechanical dielectric, plasmonic and phase-change metamaterials switchable with light

K. F. MacDonald[1*], E. Plum[1], and N. I. Zheludev[1, 2]

[1] *Optoelectronics Research Centre & Centre for Photonic Metamaterials, University of Southampton, UK*
[2] *TPI & Centre for Disruptive Photonic Technologies, Nanyang Technological University, Singapore*
** kfm@orc.soton.ac.uk*

Nonlinear and switchable metamaterials, with properties surpassing those of natural media, offer a functional platform for future, nanoscale 'meta-devices', and it has been seen recently that all-dielectric architectures can deliver metamaterial functionalities free from the high resistive losses inherent to noble metal frameworks. We report here on recent advances in the development of planar, nano-optomechanically reconfigurable metamaterial and re-writable all-dielectric metasurface solutions to provide a new generation of flat-optics, sensor, optical switching and memory devices.

We report on the realization of plasmonic and all-dielectric nano-membrane metamaterials that may be dynamically reconfigured by optical forces at low (µW per unit cell) illumination intensities (Fig. 1).[1, 2] Such structures provide extremely large optomechanical nonlinearities, operating at intensities of only a few µW per unit cell and mechanical eigenfrequencies extending to hundreds of MHz.

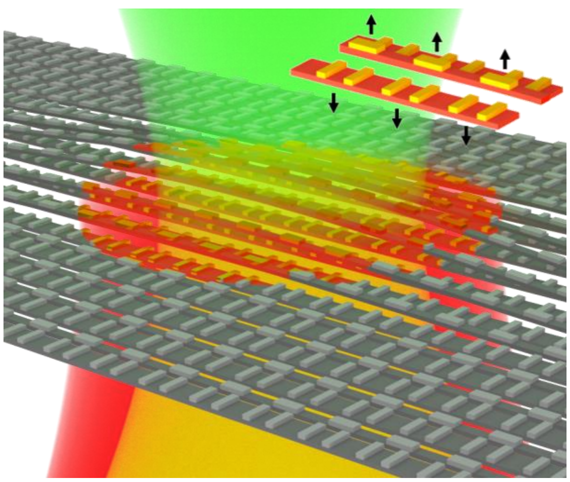

Fig. 1: Artistic impression of a plasmonic (Au on Si_3N_4 membrane) optomechanically reconfigurable metasurface. Optical forces drive mutual displacement between neighboring elements.

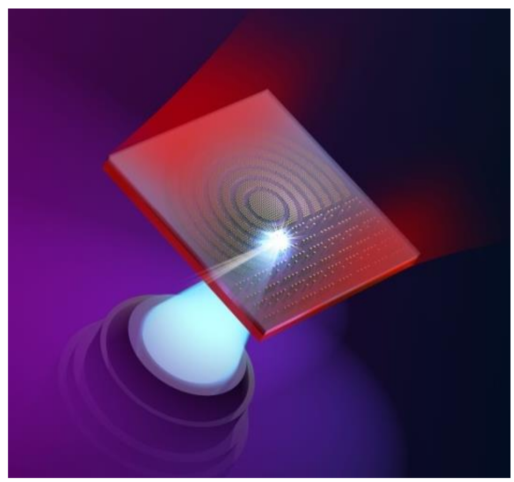

Fig. 2: Artistic impression of chalcogenide direct laser-write reconfiguration – a Fresnel zone plate being erased and replaced by a metamaterial.

We also describe how femtosecond-laser-induced, non-volatile, 'greyscale' phase changes in chalcogenide thin films enable allow for the writing and erasing of arbitrary, spatially multiplexed flat optical elements and metasurface patterns (Fig. 2).[3] Trains of low energy (<0.3 nJ) femtosecond pulses define sub-micron pixels of variable partial crystallinity in a nanoscale layer of amorphous Ge:Sb:Te, which may be selectively erased (re-amorphised) by higher energy (~1 nJ) pulses. The technique is employed to create re-focusable, chromatically correctable and super-oscillatory lenses, and near-infrared-resonant photonic metamaterials.

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3. Q. Wang, E. T. F. Rogers, B. Gholipour, C. M. Wang, Y. Guanghui, J. Teng and N. I. Zheludev, Nat. Photon. (in press).