Reconfigurable Nanomembrane Metadevices

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Abstract: Dynamic control over metamaterial optical properties enables active metadevices. Here we demonstrate optically, magnetically and electrically actuated metadevices providing functionalities from giant nonlinear and magneto-electro-optical effects to on-demand gratings, phase gradient surfaces, beam steering and focusing of light.

The broad range of enhanced and novel functionalities that conventional metamaterials can provide are usually not only resonant and therefore narrow-band, but also fixed. Dynamic control over metamaterial functionalities enables much more flexible active metadevices and is possible through coherent optical control over the light-matter interaction, phase transitions of constituent materials and – as discussed here – actuation of metamaterials on the nanoscale.

Metamaterials and metasurfaces are arrays of coupled resonators and therefore their optical properties are sensitive to rearrangement of their building blocks on the nanoscale. Such actuation of thousands of metamolecules is enabled by dielectric nanomembranes, which are strong enough to support metamaterial nanostructures, yet flexible enough to allow their actuation by thermal, electrostatic, magnetic and optical forces – so far with up to 50% optical contrast and at modulation frequencies from kHz to 100s of MHz. We show experimentally that optical actuation of plasmonic and dielectric nanomembrane metamaterials gives rise to an exceptionally large optical nonlinearity [1, 2]. We demonstrate experimentally that nanomembrane metamaterials can be actuated by the magnetic Lorentz force acting on electrical charges moving in a magnetic field, and that this gives rise to a novel, giant magneto-electro-optical effect [3, 4]. Furthermore, we report on the development of first random access reconfigurable metamaterials, where the optical properties of the metamaterial nanostructure can be controlled with sub-wavelength resolution in one spatial dimension. We show numerically that such metadevices enable on-demand gratings, phase gradient surfaces, beam steering and focusing of light.

In summary, reconfigurable metamaterial nanostructures allow the realization of active metadevices providing the optical properties that we want, where we want and when we want.


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