Active metasurfaces: Optical properties on demand

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Dynamic control over metamaterial optical properties with high spatial and temporal resolution is the key to a broad range of novel functionalities from spatial light modulation without pixelation artefacts to parallel all-optical information processing. Here we explore two complementary approaches based on (i) mechanically reconfigurable nanostructures and (ii) modulation of light with light without nonlinearity.

The properties of any array of coupled resonators depend on displacement of its components. Mechanical actuation of photonic metamaterial structures cut from membranes of nanoscale thickness can be driven by temperature, electrical currents and voltages, magnetic fields and even light [1], and recently, selective actuation of individual rows of metamolecules has been demonstrated [2]. Such structures can provide giant optomechanical nonlinearities, various types of optical sensors and spatial light modulation with sub-wavelength pixilation, e.g. to provide diffraction, focusing and beam steering on demand [3].

Any functional material of substantially sub-wavelength optical thickness may be placed at a node or anti-node of a standing wave formed by counterpropagating coherent electromagnetic waves. As truly planar structures will only interact with the electric field of a normally incident wave, the light-matter interaction will be switched off at the electric field node, while it is enhanced at the anti-node. This linear interaction can provide all-optical control over intensity, polarization and propagation direction of light with high contrast at arbitrarily low intensities and with many THz bandwidth. By controlling absorption of light with light on a metasurface integrated in an optical fibre network we demonstrate elementary data processing operations. Through two-dimensional all-optical control of absorption on a metasurface with diffraction-limited resolution, we demonstrate novel approaches to all-optical processing of images [4], parallel logical operations between pairs of optical data streams [5], pattern recognition and image analysis.

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