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Shaping the light by nonlinear flat optics

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Classical optical lenses shape the light beam based on gradual phase shifts accumulated during the propagation. This results in devices which are difficult to integrate. In recent years, plasmonic metasurfaces opened the field of flat optics. Abrupt changes in the properties of the light, such as phase and polarization, can be introduced at the sub-wavelength scale by the meta-atoms. These meta-atoms act as Huygen's sources, allowing to shape the beam in the far-field. New thin-film filter and photonic devices can be realized and easily integrated into existing technologies.
We propose a scheme to realize nonlinear flat optics. It uses enhanced nonlinear optics from metasurfaces, where we are able to precisely design not only the enhancement, but also the phase and polarization of emitted nonlinear signals. The meta-atom we use is a novel plasmonic nanoantenna we call the butterfly. This structure exhibits a field enhancement in the gap which can be exploited for nonlinear optics.
The field enhanced in the gap is polarization independent, quasi linearly polarized, and its phase changes as a function of the incident polarization angle. We show a meta-lens made of butterfly antennas, which converts a linearly polarized CW beam into an structured second harmonic beam carrying orbital angular momentum. Nonlinear optics allows us to access a wavelength range otherwise impossible by linear plasmonics, due to the losses in metals.
The idea finds application in spatial multiplexing for optical communications, opto-mechanics, molecule orientation and trapping, nonlinear optics enhancement and light structuring.
The simulations are performed with the finite-difference time-domain (FDTD) method exploiting the IBM BlueGene/Q supercomputer of the Southern Ontario Smart Computing Innovation Platform (SOSCIP).

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