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Symmetry breaking of photonic spin-orbit interactions in metasurfaces

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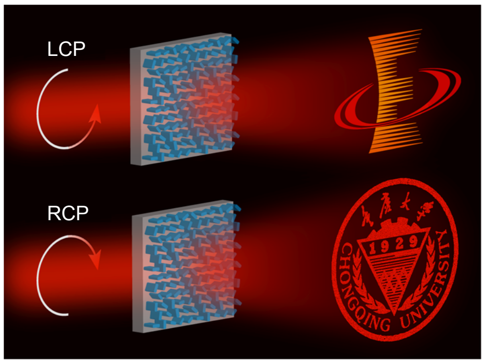

Schematic of the proposed metasurface that produces two asymmetric holographic images for two circular polarizations.

Abstract: The dual-functional and/or multifunctional devices have huge fascinations and prospects to conveniently integrate and miniaturize complex systems with low costs. However, most of such devices based on metasurfaces are composed of several zones or interlaced arrays, with each only constructive contribution to corresponding function, resulting in a decreased efficiency and adding background noise to others. Spin-orbit optical phenomena pertain to the wider class of electromagnetic effects originating from the interaction of the photon spin with the spatial structure and propagation characteristics of an optical wave, mediated by suitable optical media. There are many emerging photonic applications of spin-orbit interactions (SOI) of light, such as control of the optical wave propagation via the spin, enhanced optical manipulation, and generation of structured optical fields. Here, a new method is proposed to achieve independent controls of two orthogonal circularly polarized (CP) incidences by breaking the symmetry of SOI in metasurfaces. As a result, the whole metasurface can simultaneously contribute to two independent controls, leading to a high optical usage and low noise. The proposed metasurfaces are composed of an array of nanofins with spatially varying sizes and orientations. The symmetry breaking of SOI is developed by the absence of inversion symmetry of phase gradient. The required phase for wavefront manipulation is imparted based on both the geometric (spin-dependent) phase via rotation of nanofins and the dynamic (spin-independent) phase via difference of size. Both geometric phase and dynamic phase can cover the entire $0\sim2\pi$ range by rotating each nanofin from $-\pi/2$ to $\pi/2$ and proper geometries of nanofin. Owing to these two phase gradients being independent, the final phase gradients for two opposite spins no longer have inverse symmetry and can be independently manipulated. Therefore, our proposed metasurfaces have the capabilities of producing arbitrary combination of wavefronts for two orthogonal converted CP transmitted lights. The freedom provided by the proposed platform allows a wide variety of asymmetric SOI for two opposite spins. As a proof-of-concept, we apply our proposed design principle to theoretically achieve asymmetric holographic images, spin-selective focusing without the scattered noise, and generation of vortex beams with asymmetric topological charges at visible and infrared wavelengths (λ = 532 nm and 10.6 μm) with high efficiency (the average conversion efficiencies are ~94.2% for λ = 532 nm and ~92.7% for λ = 10.6 μm), showing that our concept may provide new opportunities to realize asymmetric SOI for various practical applications of interest. We believe that our design will find a large amount of applications in novel spin-controlled multifunctional shared-aperture devices, as well as open a new degree of freedom for the photonic applications of SOI.

Keywords: metasurfaces; metamaterials; spin-orbit interactions

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