SPIN OPTICS

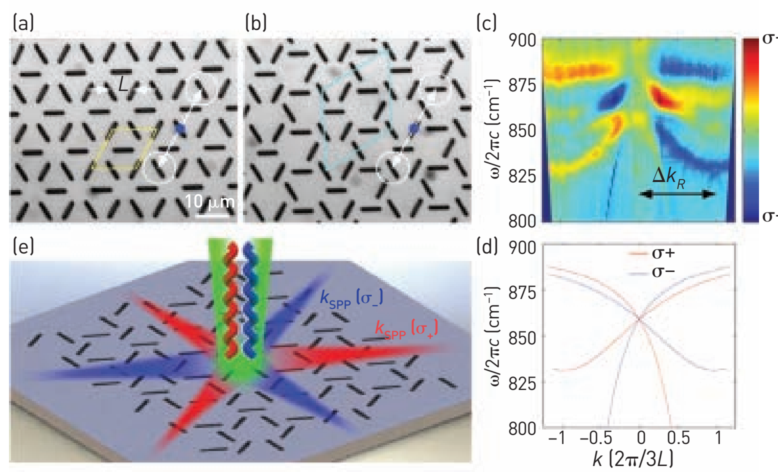
Spinoptical Metamaterials: A Novel Class of Metasurfaces

Photonic metasurfaces are metamaterials with reduced dimensionality composed of engineered subwavelength-scale meta-atoms enabling a custom-tailored electromagnetic response of the medium.[1] These 2-D metastructures are also at the forefront of the physical enigma: What is the effect of surface symmetry properties on light-matter interactions?

The Rashba effect is an illustration for a perturbed interaction as a result of a symmetry violation.[2] It is a manifestation of spin-orbit interaction under broken inversion symmetry, where the electron spin-degenerate bands split into dispersions with oppositely spin-polarized states. Like the role of the symmetry-breaking potential gradient in the electronic Rashba effect, the geometric gradient associated with space-variant orientations of optical nanoantennas induces a spin-split dispersion, where the photon spin corresponds to the circular polarization helicity.[3]

We reported on a novel class of metasurfaces—spinoptical metamaterials—which give rise to a spin-controlled dispersion due to the optical Rashba effect.[4] The inversion asymmetry is obtained in artificial kagome structures with anisotropic antenna configurations modeling the uniform and the staggered chirality spin-folding modes in the kagome antiferromagnet.[5] The geometrically frustrated kagome lattice is a peculiar platform since reordering local magnetic moments transforms the lattice from one with inversion symmetry to asymmetric.

We investigated the light-matter interaction via optical mode measurement of the thermal emission from the inversion symmetric and asymmetric metasurfaces. The dispersion relation of the symmetric structure exhibited good agreement with the standard; however, the dispersion of the asymmetric structure exposes new modes, giving rise to an optical spin degeneracy removal. Circular polarization resolved measurements revealed the optical Rashba spin splitting in the dispersion of the emitted light from the inversion asymmetric structure.



(a,b) Inversion symmetric and asymmetric kagome metasurfaces with corresponding unit cells. Measured (c) and calculated (d) spin-polarized dispersions of the inversion asymmetric structure, manifested by the Rashba spin splitting Δk_R; $\sigma_\pm$ stand for right and left circularly polarized light, respectively. (e) Spin-based surface-wave multidirectional excitation via the optical Rashba effect offers control of propagation direction.

The removal of the spin degeneracy in the inversion asymmetric metasurface arises from a spin-dependent Rashba correction resulting in the spin-orbit momentum-matching condition. This selection rule, generated from symmetry restrictions, is manifested by combined contributions of structural and local field lattices associated with differentiated unit cells of the inversion symmetric and asymmetric structures, respectively.

By controlling the propagation direction of excited electromagnetic waves, metasurfaces with designed symmetries provide a route for integrated spintronic-spinoptical nanocircuits. Optical spin as an additional degree of freedom offers controlled manipulation of spontaneous emission, absorption, scattering and surface-wave excitation. OPN

Researchers

Nir Shitrit, **Igor Yulevich**, **Elhanan Maguid**, **Dror Ozeri**, **Dekel Veksler**, **Vladimir Kleiner** and **Erez Hasman** (mehasman@technion.ac.il)
Technion, Haifa, Israel

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