Chiral Optics of Planar Metamaterials

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Abstract-Any planar structure can be superimposed with its mirror image. Despite lacking conventional chirality, planar metamaterials exhibit stronger and more diverse chiral optical effects than conventional materials. Planar chirality associated with the twist of flat spirals and mirror asymmetry introduced by the direction of illumination give rise to directional transmission asymmetries, giant linear and nonlinear optical activity, circular polarization reflectors and perfect absorbers as well as wavevector selective spectral filters.

It is a common misconception that chiral optical effects require chiral materials, i.e. materials that cannot be superimposed with their mirror image. In fact, chiral optical effects occur in chiral experiments.

A flat spiral does not have conventional chirality as it can be superimposed with its mirror image by flipping it over. Nevertheless, circularly polarized waves of opposite handedness will interact differently with a planar twisted object. As the planar twist reverses for opposite directions of observation, the handedness of the optical effect reverses for opposite directions of illumination, resulting in directionally asymmetric transmission [1]. An effective planar twist can result from oblique incidence onto any planar pattern and thus directionally asymmetric optical properties should be expected for any lossy planar metamaterial [2]. The effect can be engineered to yield perfect absorption for one circular polarization, while the other is reflected without polarization change, providing an opportunity to develop circularly polarized cavities for sensing and lasers [3].

A chiral experiment with an effective three-dimensional twist can result from oblique incidence onto any planar structure lacking two-fold rotational symmetry. For planar metamaterials, this can lead to exceptionally large optical activity for both transmitted [4] and reflected light [5] and exploiting nonlinearity enhancement in plasmonic metamaterials 10-million-fold larger nonlinear optical activity than in natural materials has been observed [6]. The effects are inherently tuneable due to their dependence on the angle of incidence and they allow the realization of switchable circular polarization perfect absorbers [7] as well as resonant spectral passband filters that are directional notch filters [8].

An overview over concepts developed over the last decade and associated experimental breakthroughs will be given.

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