Gyrotropy in Photonic Metamaterials due to Extrinsic Chirality

Eric Plum[1,*], Xing-Xiang Liu[1,2], Vassili A. Fedotov[1], Yifang Chen[3], Din Ping Tsai[2] and Nikolay I. Zheludev[1]
[1]*Optoelectronics Research Centre, University of Southampton, SO17 1BJ, UK*
[2]*Department of Physics, National Taiwan University, Taipei, 106, Taiwan, Republic of China*
[3]*Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, UK*
[*] *Email: erp@orc.soton.ac.uk, web: http://www.nanophotonics.org.uk/niz/*

Abstract: We demonstrate strong circular dichroism for achiral photonic planar metamaterials. The effect arises from extrinsic chirality resulting from oblique incidence of light onto the metamaterial nanostructure.

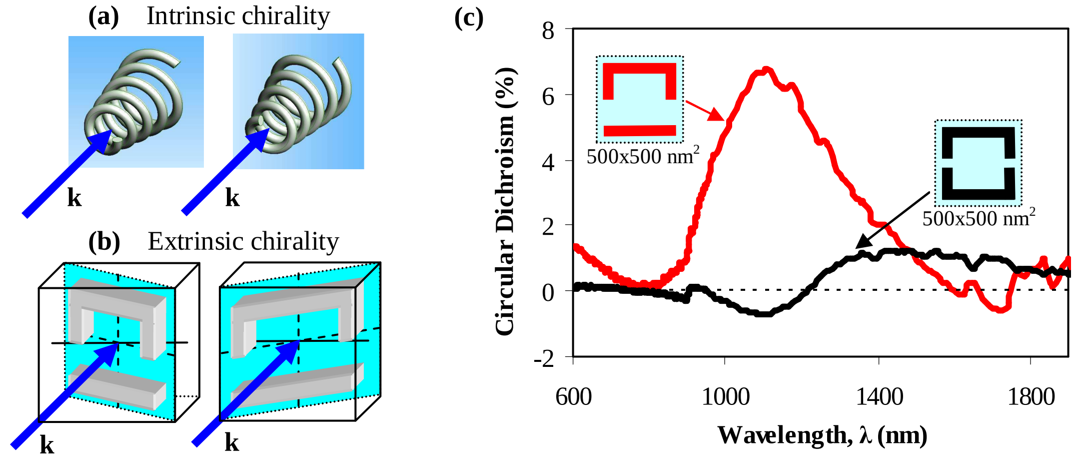

Fig.1: **Gyrotropy due to extrinsic chirality.** (a) Example of an intrinsically chiral structure. (b) Unit cell of an achiral photonic planar metamaterial that can become extrinsically chiral at oblique incidence of light. Two enantiomeric configurations are shown. (c) Circular dichroism measured in achiral photonic planar metamaterials for circularly polarized light incident at 20°. The insets show the unit cells of the metamaterial arrays which have a pitch of 500 nm. The red curve corresponds to extrinsically chiral asymmetrically-split rings, while the black curve was obtained for a reference structure based on symmetrically-split rings which cannot be made extrinsically chiral.

It is widely accepted that gyrotropy, i.e. optical activity and circular dichroism, can only be observed in structures (or molecules) that are intrinsically chiral, i.e. available in two enantiomeric forms interconnected by a mirror reflection (see Fig. 1a). However, as we have demonstrated very recently for metamaterials in the microwave part of the spectrum [1], circular dichroism and optical activity can also be observed for achiral structures if extrinsic chirality is imposed through oblique incidence, as illustrated in Fig. 1b. Extrinsic chirality results from the mutual orientation of metamaterial and incident beam, which can be made chiral for any metamaterial without 2-fold rotational symmetry.

Here, for the first time, we demonstrate the existence of a gyrotropic response in *photonic* planar achiral metamaterials. The metamaterial nanostructures were formed by regular 2D arrays of asymmetrically-split nanorings composed of aluminium wires with a square cross-section of 50×50 nm^2, which were supported by a glass substrate. Our measurements conducted at oblique incidence showed substantial circular dichroism exhibited by the nanostructures, which became stronger with increasing angle of incidence. For example, for 20° incidence the asymmetrically-split ring nanostructure with the pitch of 500 nm was 7% more transparent for one circular polarization than the other (see Fig. 1c). The observed difference is very large considering that the metamaterial nanostructure was only about λ/22 thick. Importantly, the dichroism changed sign for circularly polarized light incident at opposite angles, i.e. when the experimental configurations “metamaterial + beam” are enantiomorphic (as illustrated in Fig. 1b). For reference nanostructures based on symmetrically-split rings of 2-fold rotational symmetry circular dichroism was almost absent, where some residual effect can be attributed to the manufacturing imperfections of the symmetric nanostructures.

In contrast to intrinsic chirality, polarization effects due to extrinsic chirality can be realized in truly planar metamaterials, which are naturally suited for existing planar manufacturing nanotechnologies. Furthermore the gyrotropic response of extrinsically chiral metamaterials is inherently tuneable via the angle of incidence (or tilt of the structures). The strength of gyrotropy due to extrinsic chirality combined with its tuneable nature and low complexity of suitable metamaterial nanostructures may well lead to exploitation of the effect in future nanophotonic polarization control applications.

[1] E. Plum, V. A. Fedotov, and N. I. Zheludev, “Optical Activity of Planar Achiral Metamaterials,” arXiv.org:0807.0523v1 (2008).