Giant intrinsic chirality from planar dielectric nanostructures

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Harvard researchers have developed a metasurface comprising a single planar layer of nanostructures exhibiting strong optical chirality in transmission. This means it can let circularly polarized light of one polarization pass through almost unhindered, while light of the opposite helicity is completely diffracted away. Such capabilities are incredibly useful for a host of applications, including circular dichroism spectroscopy in the analysis of drug samples, and polarization filters in telecommunications.

This work challenges some long-held notions about chiral metamaterials and metasurfaces. "Previously, people thought that to achieve a strong, intrinsic chiro-optical response, the structures had to be complicated three-dimensional shapes, such as corkscrews or helices, in order to break the symmetry ", says Prof. Federico Capasso of Harvard University. "These 3-D metamaterials were extremely difficult to fabricate on a large-scale. With this work, we showed that even a planar layer of dielectric nanostructures whose thickness is on the order of the incident wavelength can exhibit strong intrinsic chirality. This offers a practical way for such devices to be implemented in various applications as they can now be made in a single lithographic step."

The authors were able to achieve this using gammadion-shaped nanostructures made of titanium oxide, a relatively high-index dielectric material. "This allows us to create planar structures with a strong in-plane magnetic moment, without resorting to 3-D geometry. By further optimizing the in-plane parameters of the gammadions, we can achieve the necessary coupling between the electric and magnetic moments to observe strong intrinsic chiro-optical activity," says Alexander Zhu, first author of the study.

The authors experimentally achieved up to 80% circular dichroism in transmission at green wavelengths, with more than 90 percent of light with the correct helicity transmitted at normal incidence. This result is on par with the state-of-the-art 3-D metamaterials and greatly exceeds planar counterparts under similar conditions.

Further analysis points to some rich physics underlying this phenomenon of giant intrinsic chirality in planar structures. The authors found that the optical response of the gammadion structures is dominated by higher-order multipoles, such as the toroidal quadrupole and magnetic octupole. In naturally occurring media, such high orders are vanishingly small, such that only dipole responses are typically observed. However, their existence is critical, since dipole modes radiate primarily along normal incidence, whereas the primary radiation direction for higher-order modes is off-normal. This provides some insight into the design and optimization of these nanostructures. The authors are now seeking to further improve these results and develop a fast, efficient sensor for spectroscopic detection of chiral compounds.

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