

Chiral Self-Induced Nonreciprocity: Breaking Reciprocity with Nonlinear Bilayer Nonlocal Metasurfaces

Yoshiaki Kasahara⁽¹⁾, Pietro Baldin^(1, 2), Giuseppe Della Valle⁽²⁾, and Andrea Alù⁽¹⁾

(1) City University of New York, New York, 10031, USA (aalu@gc.cuny.edu)

(2) Politecnico di Milano, Dipartimento di Fisica, Milano, 20133, Italy

Nonreciprocity enables asymmetric wave propagation, enhancing advanced communication systems and protecting sensitive components. Traditional methods to achieve nonreciprocity often depend on external biases, such as magnetic fields, or complex spatiotemporal modulation. However, recent advancements have harnessed the inherent nonlinear properties of materials, enabling passive, bias-free nonreciprocal devices with high integration potential [M. Cotrufo, A. Cordaro, D. Sounas, A. Polman, and A. Alù, “Passive bias-free non-reciprocal metasurfaces based on thermally nonlinear quasi-bound states in the continuum,” *Nat. Photonics*, vol. 18, p. 81, Jan. 2024]. Thus far, these demonstrations have primarily focused on linear polarization, leaving the exploration of nonreciprocity for circularly polarized waves largely unexplored.

This work introduces the concept of *chiral self-induced nonreciprocity*, where nonlinear material responses are combined with chiral nonlocal metasurfaces to break reciprocity for circularly polarized light. By embedding tailored geometries and leveraging nonlinear interactions, we demonstrate nonreciprocal transmission with polarization-handedness dependent control.

Three key factors are essential to achieve this functionality: (1) realizing high- Q resonators to enhance nonlinear effects, (2) enabling chiral interactions, and (3) inducing asymmetric fields between opposite excitation directions [D. Sounas and A. Alù, “Time-reversal symmetry bounds on the electromagnetic response of asymmetric structures,” *Phys. Rev. Lett.*, vol. 118, p. 154302, Apr. 2017]. The first two goals can be realized using two-interface nonlocal metasurfaces [A. Overvig, N. Yu, and A. Alù, “Chiral Quasi-Bound States in the Continuum,” *Phys. Rev. Lett.*, vol. 126, p. 073001, 2021], which utilize the concept of quasi-bound states in the continuum (q-BIC). To achieve the third, structural asymmetry along the wave-propagation direction is required, which can be implemented by introducing a substrate to break vertical symmetry [M. Cotrufo, A. Cordaro, D. Sounas, A. Polman, and A. Alù, *Nat. Photonics*, vol. 18, p. 81, Jan. 2024], or by employing two metasurface layers with independent resonances [A. Mekawy, D. Sounas, and A. Alù, “Free-space nonreciprocal transmission based on nonlinear coupled Fano metasurfaces,” *Photonics*, vol. 8, no. 5, p. 139, Apr. 2021].

In this work, we will extend these approaches to a chiral bilayer nonlocal metasurface platform. During the talk, we will present updated investigations and demonstrate how these strategies enable chiral self-induced nonreciprocity for circularly polarized light.