Structural Asymmetry Induced Strong Mode Coupling with High Quality Factor and Super-chirality

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Abstract
Optical chirality, which characterizes the handedness of electromagnetic fields, is fundamental to enhancing chiral light-matter interactions and is critical for applications such as enantioselective sensing and quantum photonics.[1,2] However, achieving strong optical chirality while simultaneously preserving high quality (Q) factors remains a key challenge. Photonic crystal (PhC) slabs are known to generate a broad range of polarization states mapped onto the Poincaré sphere, including circularly polarized states.[3] Together with their intrinsic high-Q resonances, PhC slabs have recently attracted increasing attention for their capability to generate and control optical chirality. [4,5] However, chirality engineering in PhC slabs has predominantly focused on manipulating far-field properties. The control of near-field chirality—essential for localized chiral interactions—remains relatively unexplored. In this work, we investigate the generation of near-field optical chirality by constructing PhCs from achiral unit structures. By applying structural perturbations, we induce mode coupling between two orthogonally polarized modes at off-Γ-point, resulting in hybridized modes with intrinsic phase differences. This controlled hybridization leads to the emergence of spin-dependent near-field chirality while preserving extremely high-Q resonances. We experimentally confirm the strong coupling between transverse electric (TE)– and transverse magnetic (TM) -like modes via angle-resolved spectroscopy, enabling detailed characterization of the polarization properties and Q factors of the resulting hybridized modes.

References

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