Intrinsic circularly polarized H1 photonic crystal cavity modes near exceptional points

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Non-Hermitian systems are open physical systems that could exchange energy with their surrounding environment. In such systems, there are peculiar degeneracies known as exceptional points (EPs) at which both the eigenfrequencies and eigenstates become identical. A broad sense of chirality can also be associated with EPs, for example circular polarization, chiral propagation and chiral geometric phase [1]. As photonic systems are naturally non-Hermitian due to the presence of loss, with gain and/or loss engineering, photonic systems are suitable platforms to investigate the non-Hermitian chiral effects [2, 3]. In this work, we propose a scheme which makes use of non-Hermitian effects in a H1 photonic crystal (PhC) nanocavity to achieve intrinsic chiral cavity modes which are circularly polarized.

The H1 PhC cavity could support two degenerate and orthogonal linearly polarized dipole modes which can give rise to circular polarization when driven with a $\pi/2$ phase difference. Fabrication error tends to lift the degeneracy of the modes making them impractical to generate circular polarization. In our scheme, two selected air holes near the cavity (Fig. 1a) are modified to induce non-Hermitian backscattering between the two modes. As the cavity modes approaches the EP with suitable air holes modifications, the modes become highly degenerate as well as chiral in nature. We confirmed such chirality by performing finite-difference time-domain (FDTD) simulations, showing that the dominant field intensity is circularly polarized (Fig. 1b) with the degree of circular polarization approaching unity even in the farfield. The handedness of the chirality can be switched by selecting a different pair of air holes for modifications.

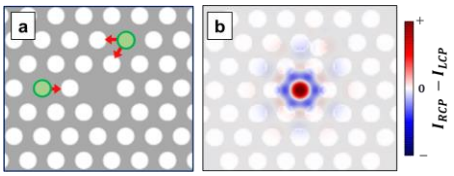

Fig 1. (a) Illustration of modifications on two selected air holes. (b) Circularly polarized field intensity localized at the cavity when near EP.

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