Symmetry of guided mode resonances in 2D nonlocal metasurfaces

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Metasurfaces (MSs) on thin-film waveguide layers have recently received increasing attention due to their potential to achieve high quality-factor nonlocal resonances [1]. Such resonances are essential for various applications, including spatially entangled photon-pair generation through spontaneous parametric down-conversion (SPDC) mediated by enhanced interactions in quadratic nonlinear media [2]. The SPDC rate is proportional to the classical sum-frequency generation (SFG) efficiency and of crucial importance for understanding the SFG response is the overlap between the signal and idler vector fields and the nonlinear polarisation they generate. Previously, coupled mode analyses have been conducted but here we explore the planar vector fields of square [Fig. 1(a)] and hexagonal [Fig. 1(b)] MSs on a thin film and identify the effect of the changing symmetry throughout the Brillouin zone. The dispersions of nonlocal guided-mode resonances for square and hexagonal lattices are shown in Figs. 1(a,b), which show the presence of both linear and nearly flat dispersion regions due to the symmetry of the modes. In addition, there are multiple symmetry-protected and topological bound states in the continuum which can enhance nonlinear frequency conversion and SPDC processes. The symmetry of the MS allows us to identify the allowed spatial mode spectra and the corresponding vectorial electric fields, such as shown in Fig. 1(c), and thereby determine mode coupling and nonlinear polarisation changes over the Brillouin zone. This then allows us to predict which modes can facilitate the quantum process of photon-pair generation. Our results open new opportunities for engineering light-matter interactions in 2D guided-mode metasurfaces.

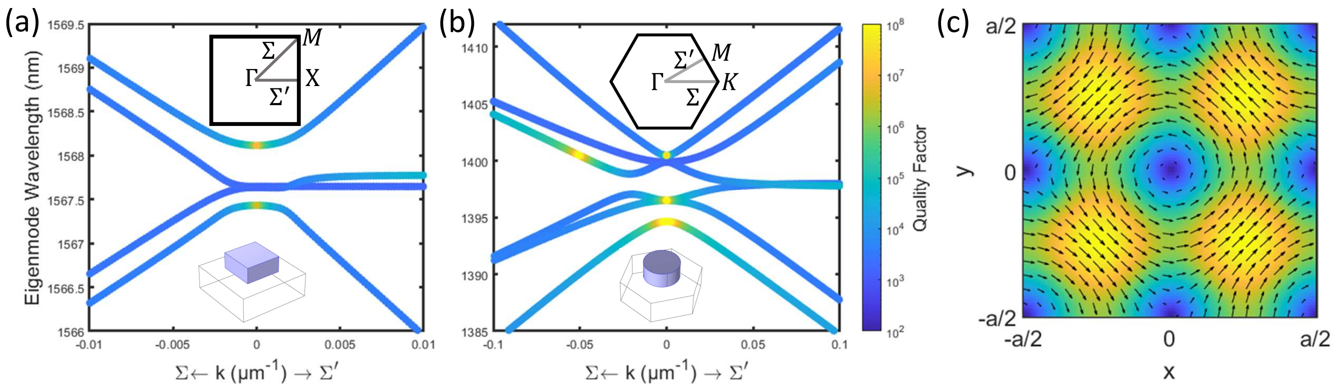

Figure 1: Dispersion of waveguide ($n = 2.21$) modes for (a) C_{4v} and (b) C_{6v} symmetric structures ($n = 1.5$). (c) **E** field of a vector planar harmonic corresponding to the A_2 irreducible representation of C_{4v}.

[1] J. H. Song, J. van de Groep, S. J. Kim, and M. L. Brongersma, Nat. Nanotech. **16**, 1224 (2021).

[2] J. Zhang, J. Ma, M. Parry, M. Cai, R. Camacho-Morales, L. Xu, D. N. Neshev, and A. A. Sukhorukov, arXiv 2204.01890 (2022).