イプシロンニアゼロ材料を用いた磁性フォトニック結晶における トポロジカルバンドギャップ増大の検討

Investigation of enlarged topological band gaps in magneto-optical epsilon-near-zero photonic crystals

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Topological photonic crystals (PhCs) based on magneto-optical (MO) materials enable a photonic analog of quantum hall (QH) effect and backscattering-immune chiral edge states[1]. Unfortunately, extremely weak MO responses in the optical band restrict achievable topological bandgap width[2], hence hindering the realization of robust QH-like edge states in the optical regime. A way to improve MO responses is the use of epsilon-near-zero (ENZ) materials with vanishing ε_{xx} (diagonal element of permittivity)[3]. However, the potential of such materials has not yet been reported in enhancing a topological band gap.

Here, we for the first time report the enhancement of topological bandgap by using MO ENZ materials. Figure 1(a) shows a unit cell of the investigated PhCs of a honeycomb lattice: triangular areas of a Si substrate are filled by MO ENZ materials. Without magnetization (off-diagonal element of permittivity ε_{xy}=0), the ENZ PhC (ε_{xx}=0.01, filling ratio=81%)) exhibits two bands touching at a Dirac point as shown in Fig. 1(b). With magnetization (ε_{xy}=0.1i), the complete MO topological gap is opened as shown in Fig. 1(c) with a 4.5% gap-mid gap ratio ($\Delta\omega/\omega_c$), corresponding to a 69-nm gap at 1.55 μm wavelength, which is 3 orders of magnitude larger than the previous report (42 pm) [2]. Figure 1(d) shows that $\Delta\omega/\omega_c$ remarkably increases as reducing ε_{xx}, highlighting the role of ENZ materials. Our results suggest that introducing ENZ property could boost the performance of topological MO PhCs even in the optical regime.

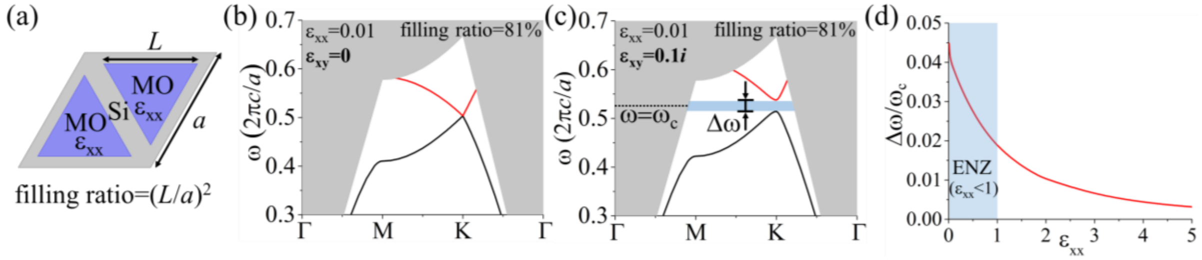

Fig.1 (a) Schematic of a unit cell of the investigated PhC. (b,c) Band structures of the non-magnetized (b) and the magnetized (c) ENZ-MO PhCs, respectively. (d) Variation of $\Delta\omega/\omega_c$ with respect to ε_{xx}. All calculation results in (b-d) were obtained by using the commercial software package COMSOL Multiphysics.

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Reference [1] F.D.M. Haldane, *et al.*, *Phys. Rev. Lett.*, **100**, 013904 (2008). [2] B. Bahari, *et al.*, *Science*, **358**, 636-640 (2017). [3] A. R. Davoyan, *et al.*, *Phys. Rev. Lett.*, **111**, 257401 (2013).