Novel edge electromagnetic transportation in PT symmetric topological photonic crystal

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The discovery of topological insulators, which have insulating bulk and conducting edge states, has open a new chapter of condensed matter physics in recent years. Edge electromagnetic states with topological protection has also been found in photonic crystals. Early approaches to realize photonic topological insulators require external magnetic field [1] or complicated structure [2] which make them hard to be applied.

Wu and Hu demonstrated an approach where one can use only dielectric materials to achieve two-dimensional topological photonic crystals [3]. They arrange dielectric cylinders into honeycomb array, then move 6 cylinders in every hexagonal unit-cell outward (inward) while keeping the lattice constant to obtain a topological (trivial) photonic frequency gap. A pair of edge states carrying opposite orbital angular momenta appear at the interface between these two structures.

The TM mode of the two-dimensional dielectric photonic crystal, which exhibits in-plane magnetic field H_x and H_y and out-of-plane electric field E_z, is described by the master equation

$$-\frac{1}{\varepsilon(\boldsymbol{r})}\nabla^2 E_z(\boldsymbol{r}) = \frac{\omega^2}{c^2} E_z(\boldsymbol{r}),$$

where $\varepsilon(\boldsymbol{r})$ is the position-dependent permittivity and c is the speed of light in vacuum. In our present work, we add gains and losses to the cylinders lying close to the interface between the topological region and trivial region, which can be modeled by the imaginary parts of permittivity $\varepsilon_r = \mathrm{Re}(\varepsilon_r) \pm i\gamma\ (\gamma > 0)$. Gains and losses are assigned at A and B sublattice respectively such that the system holds the PT symmetry.

We found PT symmetry breaking at the topological interface states near the Γ point, associated with the appearance of imaginary part in the eigen frequency, where the real part of the frequency forms a flat band. Due to the broken time-reversal symmetry, all states on the flat band exhibit the same directions of orbital angular momentum and net energy flux. The one-way edge transportation can be applied to develop single-mode topological lasers and circulators.

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References

[1] F. D. M. Haldane, Phys. Rev. Lett. **100,** 013904 (2008).
[2] A. B. Khanikaev, Nat. Mater. **12,** 233 (2013).
[3] L.-H. Wu and X. Hu, Phys. Rev. Lett. **114,** 223901 (2015).