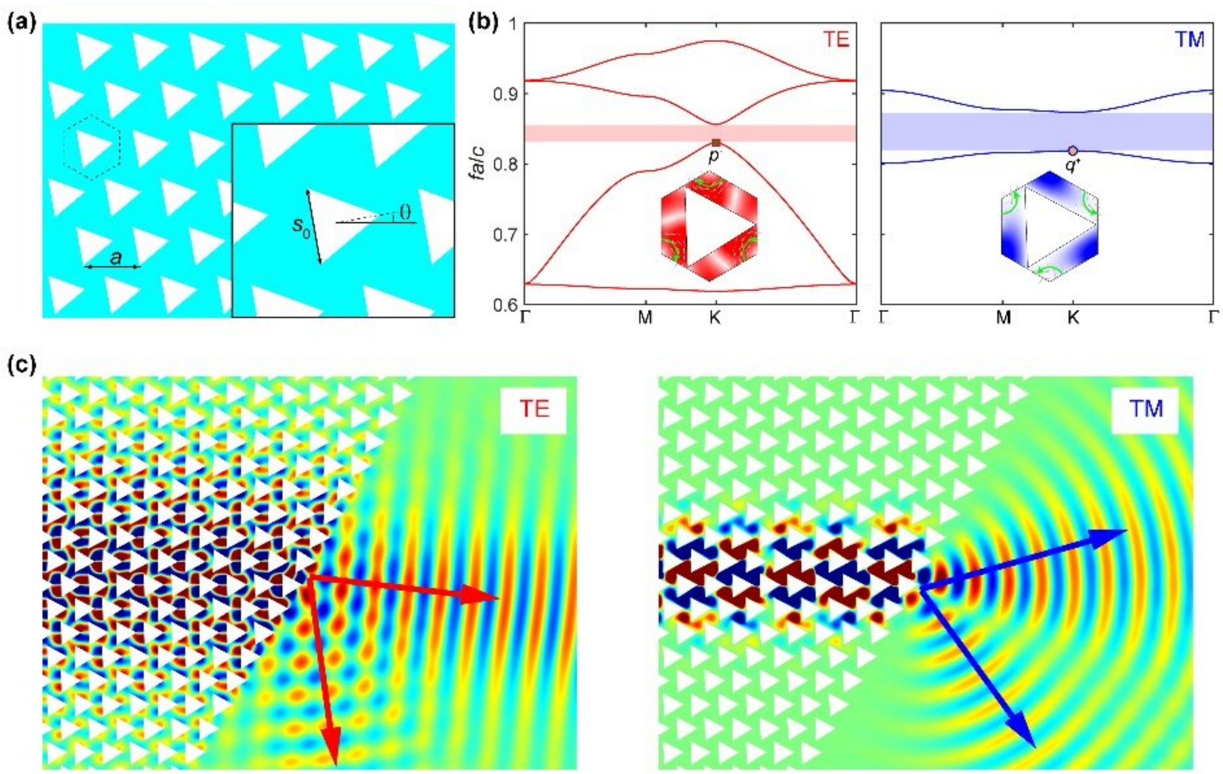
Dual-polarization two-dimensional valley photonic crystals

September 2 2022



Dual-polarization valley photonic crystals. (a) Structure of the valley photonic crystal, (b) Bulk band structure and eigen fields of representative bulk modes at the K point. (c) Polarization dependent refraction of edge modes. Credit: Science China Press

The introduction of topology in photonic systems has attracted considerable attention not only for the elaborate molding of light but also for its practical applications in novel photonic devices. Originally, the quantum Hall effect of light was realized in photonic crystals (PCs) by introducing external electric or magnetic fields to break the time-reversal symmetry (TRS).

Instead of breaking the TRS, the quantum spin-Hall effect of light has been achieved in TRS-preserved systems where photonic pseudospins can be constructed. Recently, the valley Hall effect of light has been realized by introducing the binary valley degree of freedom (DoF) into photonic systems. One of the vital features of the valley Hall effect is the nontrivial photonic band gap, which is characterized by the nonzero valley Chern number.

Furthermore, valley-dependent edge modes are supported at the domain wall which consists of two PCs with opposite-valley Chern numbers. The valley Hall effect of light is commonly realized in a triangular-lattice PC with broken mirror symmetry or in a honeycomb-lattice PC with broken spatial inversion symmetry, and it is compatible with existing nanophotonic fabrication technique.

For these advantages, valley PCs have received significant attention in integrated photonics and are promising in applications including waveguides, beam splitters, ring resonators, etc. On the other hand, as one of the DoFs of light, polarization has been widely applied in multiplexing photonic devices. Exploring the polarization dependent valley Hall effect, which introduces a conventional DoF of light into topological PCs, will further broaden the scope of application in topological photonics.

Recently, Xiao-Dong Chen, Jian-Wen Dong et al. from Sun Yat-sen University proposed the polarization-valley Hall effect of light in a 2D triangular-lattice PC. The research results were entitled "Dual-polarization two-dimensional valley photonic crystals" and published in *Science China Physics, Mechanics & Astronomy*.

The accidental degeneracy of frequencies of Dirac cones with TE and TM polarizations, i.e., accidental dual-polarization Dirac cones, are realized by changing the filling ratio of metallic rods in the dielectric background. The polarization dependent valley Chern numbers are confirmed by analyzing the vortex phase distribution of eigen-fields and calculating the Berry curvature in momentum space.

The resultant TE- and TM-polarized band gaps with opposite-valley Chern numbers lead to the polarization-valley Hall effect of light. A key phenomenon of the polarization-valley Hall effect of light, i.e., polarization dependent refraction of bulk modes into the homogeneous medium, is demonstrated. Such polarization dependent feature is useful in multiplexing photonic devices, e.g. the polarization beam splitters.

Aside from the polarization-dependent phenomena, the polarization-independent topological valley transport is also presented, which fulfills the desire for increasing information capacity in optical interconnection by introducing polarization DoF.

It is noteworthy that the presented results are general because the key requirement is to find two polarization dependent valley photonic band gaps sharing the same frequency range. Moreover, introducing the polarization in other topological phases may result in fruitful intriguing phenomena, including polarization dependent higher-order topological corner states, etc.

This work proposed an approach to apply the polarization DoF in 2D valley Hall PCs. The introduction of polarization DoF in topological photonics has enriched light field manipulation and has offered a deeper application potential for topological photonics.

More information: Xin-Tao He et al, Dual-polarization two-dimensional valley photonic crystals, *Science China Physics, Mechanics & Astronomy* (2022). DOI: 10.1007/s11433-022-1916-7

Provided by Science China Press

Citation: Dual-polarization two-dimensional valley photonic crystals (2022, September 2) retrieved 23 June 2024 from https://phys.org/news/2022-09-dual-polarization-two-dimensional-valley-photonic-crystals.html