Photonic Topological Insulators: Guiding Electromagnetic Waves Around Sharp Corners

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Science thrives on analogies, and a considerable number of inventions and discoveries have been made by pursuing an unexpected connection to a very different field of inquiry. For example, photonic crystals have been referred to as "semiconductors of light" because of the far-reaching analogies between electron propagation in a crystal lattice and light propagation in a periodically modulated photonic environment. However, one aspect of electron behavior, its spin, escaped emulation by photonic systems until recent [1-8] invention of photonic topological insulators (PTIs). The impetus for these developments in photonics came from the discovery of topologically nontrivial phases in condensed matter physics that give rise to topologically protected edge states immune to scattering. The realization of topologically protected transport in simple PhCs would circumvent a fundamental limitation imposed by the wave equation: inability of reflections-free light propagation along sharply bent pathway. Topologically protected electromagnetic states could be used for transporting photons without any scattering, potentially underpinning new revolutionary concepts in applied science and engineering.

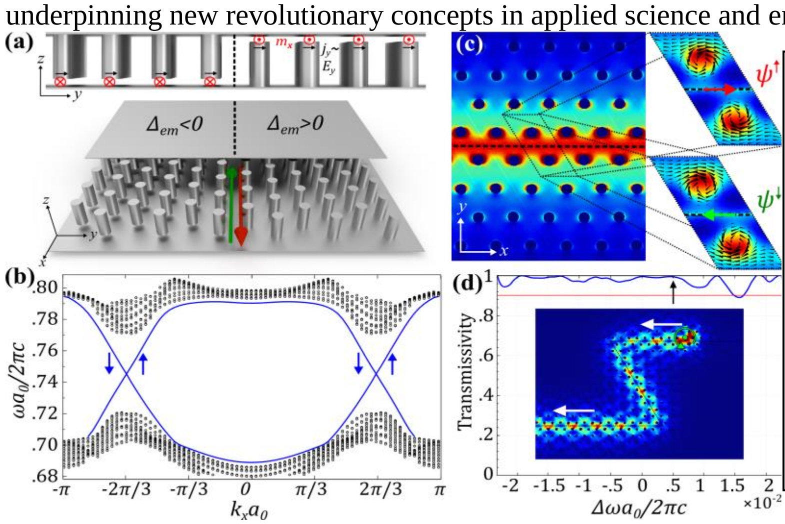

Figure 1: Propagation of topologically protected surface waves (TPSWs) along the interface between two topologically-nontrivial PTIs shown in (a). (b) 1D band structure, black circles: bulk modes, blue lines: TPSW, arrows: spin state. **(c)** Energy density; and Poynting vector of a TPSW at the frequency ω indicated by a black arrow in (d). **(d)** Transmission spectrum $T(\Delta\omega)$ through the zigzag path, where $\Delta\omega = \omega - \omega_G$ is the detuning from the bandgap center. Red line: $T = 0.9$.

I will provide an overview of the exciting field of PTIs, with particular emphasis on reciprocal photonic structures [2-7] that do not rely on magnetic fields. I will also describe a simple photonic structure [6], a periodic array of metallic cylinders attached to one of the two confining metal plates shown in Fig.1(a), that behaves as a PTI: possesses a complete topological bandgap and emulates spin-orbit interactions. An interface between two such structures supports topologically protected surface waves which can be guided without reflections along sharp bends of the interface as shown in Fig.1(d). Perspectives on how photonic topological insulators can emulate condensed-matter phenomena will be presented.

References

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