Photonic Topological Insulator Waveguiding from a Classical Electromagnetics Perspective

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Photonic topological insulators are emerging as an important class of material (natural or meta) that allow for the propagation of unidirectional surface waves, immune to backscattering, at the interface with another medium. The properties of these materials are quantified by the Berry phase, Berry potential, and an invariant known as the Chern number. Here, we are interested in electromagnetic propagation, and the Berry properties of the Maxwell's equations eigenmodes, f_n, which are quantified by Berry potential, $A_n = i f_n . \nabla_k f_n$, Berry phase, $\delta_n = \oint dk . i f_n . \nabla_k f_n$, and Chern number $C_n = {}^1\!/_{2\pi} \int dS . \nabla \times A_n$. Often, Berry properties are obtained using the quantum mechanical derivation based on a Hamiltonian, and making an analogy between Maxwell's equations and the quantum system.

However, for photonic systems the phenomena is purely classical, and in this presentation we derive and explain all Berry properties from a classical engineering electromagnetic perspective, without consideration of the usual quantum mechanics derivation, appealing to analogies between Schrödinger's equations and Maxwell's equations, or invoking gauge theories. We also discuss the implications of backscattering-immune SPP propagation, and the limits of this property for realistic three-dimensional defects/discontinuities. We show that, although backward propagation/reflection cannot occur, side scattering does take place and has significant effect on the propagation of the surface mode. Several different waveguiding geometries are considered for reducing the effects of side-scattering.