Topologically-protected leaky-wave structures

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Photonic topological insulators (PTIs) are emerging as an important class of (meta)materials that support the propagation of unidirectional, topologically-protected, surface waves, immune to backscattering, at the interface with another medium with different topological properties. While PTI-based waveguides have recently been the subject of growing interest and research efforts, less attention has been devoted to their response and functionality in the presence of radiation loss (or material loss/gain), a research direction that may have important practical implications, for example in the context of antenna and nanoantenna technology.

Here, we discuss the general properties of a topologically-protected *leaky* mode at the interface between a photonic topological insulator (for example a biased plasma) and a topologically trivial medium (for example vacuum). We show that the propagation and attenuation constants of the unidirectional leaky mode can be systematically engineered, leading to highly directive and tunable radiation patterns. Taking advantage of the non-trivial topological property of these leaky modes, we demonstrate advanced functionalities, including arbitrary re-routing and re-cycling of the mode energy on the surface of bodies with complex shapes, as well as the realization of leaky-wave antennas with two channels of radiation that are completely independent and separately tunable. We also study the response of the designed open structures when externally illuminated, which may be of interest to realize nonreciprocal receiving antennas, as well as unidirectional light couplers and absorbers. Our predictions and designs are based on analytically studying the complex behavior of topologically-protected modes in closed and open wave-guiding structure, including the effect of loss/gain and the possibility of modal coupling.