Modal interactions and degeneracies in coupled photonic topological insulators with loss and gain

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In recent years, large research efforts have been devoted to *photonic topological insulators* (PTIs), a new class of engineered materials and structures that support unidirectional surface waves at the interface with another medium having different topological properties. These unidirectional edge states are topologically protected, namely, they are associated with topological invariant quantities that do not change under continuous deformations of the structure [S. A. H. Gangaraj, et al., IEEE J. Multiscale and Multiphys. Comput. Techn. 2, 317 (2017)]. As a result, these surface waves are inherently immune to backscattering when interacting with corners, bends, and imperfections on the surface.

While *closed* (Hermitian) PTI-based waveguiding structures have been the subject of several research works, less attention has been devoted so far to photonic topological insulators that are "*open*" (non-Hermitian), namely, they can exchange energy with an energy sink/reservoir in the form of radiation leakage and/or material loss and gain. Within this context, in our talk we will present a complete modal analysis of non-Hermitian photonic topological insulators with gain and loss, based on classical Green's function theory. Our analysis elucidates the nature and modal behavior of coupled topological modes, and the existence of modal degeneracies at specific points of the parameter space. We consider a magnetized plasma as a continuum model for PTIs, but our analysis reveals some general properties of open PTI systems independent of their implementation.

An interface between two oppositely-biased plasmas supports two unidirectional back-scattering-immune surface plasmon polaritons (SPPs), and the coupling between these surface states can be controlled by introducing a thin gap layer between the two biased plasmas. We demonstrate that, in a suitable non-Hermitian PTI system with balanced distribution of loss and gain (a so-called parity-time-symmetric configuration), an exceptional point of degeneracy (EPD) emerges on the wave-number complex plane, where two unidirectional topological modes perfectly coalesce. Based on our analysis, we are able to study, for the first time, *topologically-protected wave propagation in a wave-guiding system operating at an exceptional point,* and we reveal some counter-intuitive propagation effects.

Our findings also unveil potential applications of non-Hermitian topological waveguides with gain and loss, for example in the context of energy extraction and spontaneous emission enhancements from localized sources, and topologically-protected modal interactions and transformations in open waveguiding structures operating near exceptional points.