# Topological electromagnetics in complex scenarios: Non-reciprocal, non-Hermitian, non-linear, and non-local material structures

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Strongly nonreciprocal structures and photonic topological insulators are emerging as an important class of material platforms that support the propagation of robust unidirectional surface waves. In particular, surface modes supported by different forms of topological insulators (either periodic or homogenous) are "topologically-protected", namely, they are associated with topological invariant quantities that do not change under continuous deformations of the structure [see, e.g., L. Lu, J. D. Joannopoulos, and M. Soljačić, Nat. Photonics 8 (2014).; 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 along the surface. However, in most works dealing especially with continuum nonreciprocal materials (e.g., magnetized plasmonic media), the considered material models are often very simplified, and the limits of the assumptions underpinning the unidirectional nature of the modes are not fully discussed. In addition, even more interesting wave-propagation effects may be obtained in more complex structures that include, for example, nonlinearities, loss/gain, or radiation.

In this work, we investigate strongly nonreciprocal and topological platforms, and their supported bulk and surface modes, when more realistic material models and more complex scenarios are considered, including materials with loss (or gain), spatial dispersion, and nonlinear effects. As a model system, we consider a magnetized plasmonic material, which exhibits a typical gyrotropic nonreciprocal response. We discuss the effect of nonlocality and dissipation on the unidirectional nature of the supported nonreciprocal plasmonic modes in different regimes, and the topological transitions that may emerge. We show that the effect of nonlocality strongly depends on the considered structure. While in certain regimes and configurations surface-plasmon-polariton modes clearly lose their unidirectionality due to nonlocal effects, in other scenarios the nonlocality does not prevent the existence of unidirectional topological surface waves, even in the lossless case. In this situation, we also show that by blocking the path of unidirectional waves with suitable terminations, a very high field-intensity enhancement can be achieved where the one-way topological mode is blocked. Due to the strong and localized fields, this behavior is ideal to enhance light-matter interactions, including for enhanced absorption and nonlinear/quantum effects.

Our study reveals limits and potential of unidirectional/topological material platforms in more realistic and more complex scenarios, and may pave the way to novel applications of topological wave-guiding systems.