One-side excited one-way modes in nonreciprocal waveguides

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Manipulation of the flow of light is one of the key issues in photonics. Unidirectional and robust photonic states are found in photonic structures with nontrivial band topologies[1] or strong nonreciprocity[2], which are promising for on-chip integrated photonics. In addition, using phenomena like spin-momentum locking, circular dipole (CD) sources could excite unidirectional and robust surface modes at interfaces of nearby photonic structures[3]. Besides CD, the recently proposed Janus dipole (JD) source, which is composed of ±π/2 out-of-phase orthogonal electric dipole (**p**) and magnetic dipole (**m**), enables switchable one-side excited surface modes[4]. The combination of unidirectional states and polarization-engineered dipole sources would bring new research opportunities in the manipulation of near-field directionality.

Here we propose a way to realize one-side excited one-way surface modes in nonreciprocal metal-dielectric-metal waveguides, which includes the one-side excitation by a JD source[4] and the one-way photonic states in epsilon-near-zero (ENZ) magneto-optical (MO) waveguides[2]. Figure 1(a) shows a dispersion relation of surface modes at the interface between ENZ-MO and metal. A Drude model is applied for the description of metal's permittivity. With magnetization (z-direction), a unidirectional mode is found in a broad frequency range (red line, Fig. 1(a)), due to the strong nonreciprocity enhanced by the ENZ-MO effect[2,5]. Furthermore, when JD sources are introduced to metal-ENZ-MO-metal waveguides, the side-dependent excitation of one-way modes is observed (Figs. 1(b,c)), enabling the specified single port output for near-field photonic routings. Such photonic routings are switchable by flipping the phase difference (Δϕ) in the JD sources (Figs. 1(b,c)). Our results not only enrich the understanding of near-field directionality but also pave the way toward novel applications for on-chip integrated photonics.

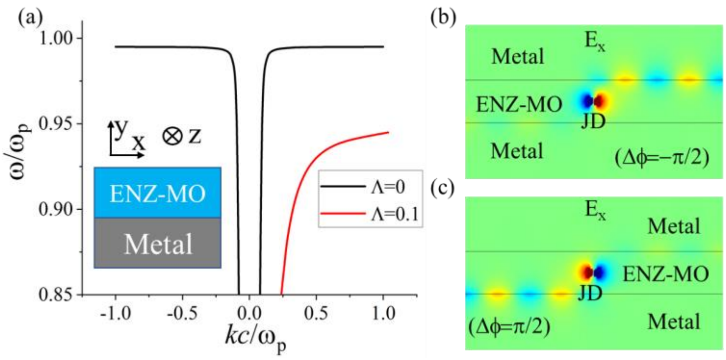

Fig.1 (a) Dispersion relation of an ENZ-MO waveguide with (Λ=0.1) and without (Λ=0) magnetization. ε_{xx} and Λ are diagonal and off-diagonal permittivity of dispersionless ENZ-MO materials. *k* is the wavenumber, *c* is the speed of light, ω is angular frequency, ω_p is plasmon frequency of the metal. (b,c) One-way states excited by side-dependent JD sources (composed of p_x and m_z dipoles) in three-layer waveguides (4 output ports). ϕ=π/2 (b), ϕ=−π/2 (c).

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