

Emulating Modes of a Magnetized Plasma in a Spatially Dispersive Metasurface Waveguide

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Metasurfaces are ultrathin, subwavelength patterned surfaces that can arbitrarily tailor currents. As a result, they can provide extreme control over electromagnetic wavefronts through careful design of their surface properties. Their surface properties are typically modeled using tangential polarizabilities, but the addition of normal polarizabilities can expand their range of wave control.

Here, we report a parallel-plate waveguide that supports a mode which emulates an extraordinary mode supported by magnetized plasma. Specifically, the parallel-plate waveguide has one plate covered by a reciprocal, bianisotropic metasurface with an omega response. The metasurface allows normal magnetic dipoles to couple to tangential electric fields, or equivalently tangential electric dipoles to couple to normal magnetic fields.

Usually, the 3×3 tensor describing the surface properties of such a metasurface is unwieldy for design. However, rewriting the tensor in terms of the tangential wavenumber of an incident plane-wave reduces it to a 2×2 tensor that is spatially dispersive (C. Pfeiffer, A. Grbic, "Emulating Nonreciprocity with Spatially Dispersive Metasurfaces Excited at Oblique Incidence", Phys. Rev. Lett., vol. 117, issue 7, Aug. 2016). In this form, the 2×2 electric admittance tensor of the spatially dispersive metasurface has a form analogous to that of the permittivity tensor of a magnetically biased plasma. The tangential wavenumber of the incident wave is analogous to the DC magnetic bias in the plasma.

Modes of interest supported by the waveguide are rotated by 90 degrees upon reflection from the metasurface. This rotation is possible due to the metasurface's normal polarizabilities. The electric field of the mode is parallel to the axial direction of the waveguide, and its polarization exhibits the same cartwheeling effect as an extra-ordinary mode propagating normal to the magnetic bias in a plasma. One important distinction is that the waveguide is reciprocal, and the magnetically biased plasma is not. If the propagation direction is reversed in the waveguide, the tangential wavenumber that effectively "biases" the metasurface is flipped, ensuring reciprocal propagation.