Gyrotropic Effects in Hyperbolic Metamaterials

Mohamed A. K. Othman*, Caner Guclu, and Filippo Capolino
Department of Electrical Engineering and Computer Science
University of California Irvine, Irvine, CA, 92697
*mothman@uci.edu

Hyperbolic metamaterials (HMs) have recently been one of the most prominent impetus to infrared and optical applications for their broadband spontaneous emission enhancement and super absorption of near fields. It has been shown that plasmonic layers stacked with subwavelength dielectric spacers can be homogenized as a uniaxial electric media, with negative transverse permittivity for a wide range of parameters, which gives rise to a hyperbolic wavevector dispersion characteristics. In this premise, we investigate an HM implementation that utilize thin in-plane anisotropic structures in a multilayer configuration. Such anisotropic materials can be implemented, depending on the desired operating wavelength, using anistropically-patterned metasurfaces, or by exploiting the Hall effect in magnetically-biased metals, semiconductors or graphene sheets. We explore the possibility of observing non-vanishing off-diagonal elements in the effective permittivity tensor, in other words, obtaining an effective gyrotropic and nonreciprocal media with negative transverse permittivity. Moreover, we demonstrate how the propagation wavenumber inside the effective gyrotropic medium can be derived using a transmission line formalism, where a new set of wave solutions is formed as a result of the peculiar coupling between the TE and TM polarizations. We also validate our analysis with the rigorous transfer matrix approach by cascading the multilayers and constructing a four port network that accounts for the mode-coupling, and we show good agreement with the effective medium description in calculating plane wave transmission and reflection spatial spectrum of the multilayer.

As a demonstration, and based upon the derived transmission line theory, extraordinary wavevector dispersion can be engineered to be hyperbolic, which is a clear sign of a substantial enhancement in the local density of states. Also we report a very wide spatial spectrum of waves that propagate inside the gyrotropic HM, with spectral transmission peaks significantly greater than that of a uniaxial HM. This indicates that power radiated by small emitters or scattered by microscatterers are entirely absorbed by the multilayer; a remarkable feature that can be utilized in super resolution imaging and designing ultrathin nonreciprocal absorbers.