Bi-hyperbolic and tetra-hyperbolic isofrequency topologies in a gyroelectromagnetic medium

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Abbreviated abstract: Isofrequency topologies are studied for a gyroelectromagnetic medium obtained by stacking optically thin magnetized ferrite and semiconductor layers into a unified structure. In such a structure, both bi-hyperbolic and tetra-hyperbolic isofrequency contours appear as a simultaneous effect of both periodic arrangement of constitutive layers and external magnetic field influence. It is proposed to consider the obtained bi-hyperbolic and tetra-hyperbolic isofrequency contours as new topology classes of the wave dispersion

Related publications:

– Fesenko, V. I. and V. R. Tuz, Phys. Rev. B, 99, 094404 (2019)

– Tuz V. R. and V.I. Fesenko, J. Appl. Phys., 128, 013107 (2020)

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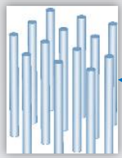
Motivation

Hyperbolic (extremely anisotropic or indefinite) media

Indefinite tensor(s)

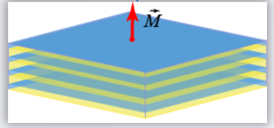
$$\hat{\eta} = [\eta_{xx}, 0, 0; 0, \eta_{yy}, 0; 0, 0, \eta_{zz}]$$

one of the principal components of the tensor(s) differs in sign from other principal components



Metallic wire array (indefinite permittivity tensor)

Metallic split-ring resonators array (indefinite permeability tensor)

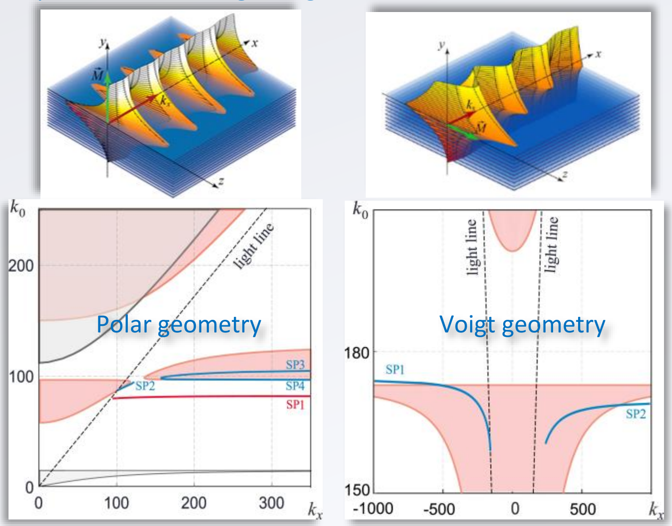


Magnetic-semiconductor superlattice (indefinite permittivity and permeability tensors)

Negative refraction, strong enhancement of spontaneous emission, broadband infinite density of states, light steering, sensing, the photonic spin Hall effect, super-resolution imaging, focusing, signal routing, and abnormal scattering.

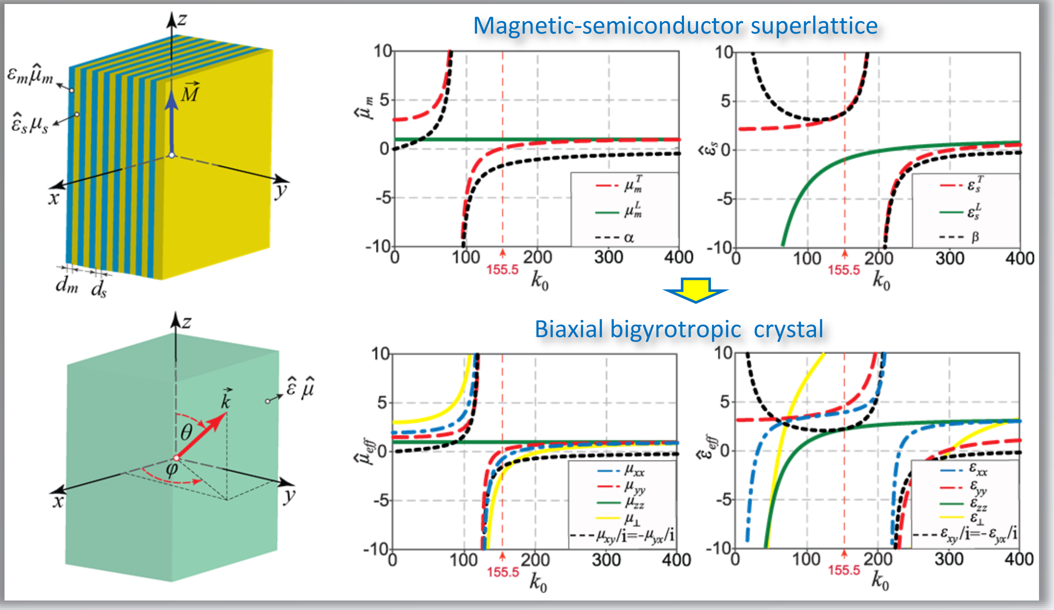
Related previous studies

The **effect of coexistence of bulk and surface polaritons** in a magnetic-semiconductor superlattice, which is influenced by an external static magnetic field in the polar [1] and Voigt [2] geometries, was revealed



Related publications: 1. V.R. Tuz, et al., J. Appl. Phys. 121, 103102 (2017);
2. V.I. Fesenko, et al., Opt. Lett., 41(9), 2093-2096 (2016);

Dispersion relation for bulk waves



Long-wavelength limit

$$d_m \ll \lambda, d_s \ll \lambda, L \ll \lambda$$

Homogenization procedure of the effective medium theory [1]

Superlattice BaCo/Si

Biaxial bigyrotropic crystal

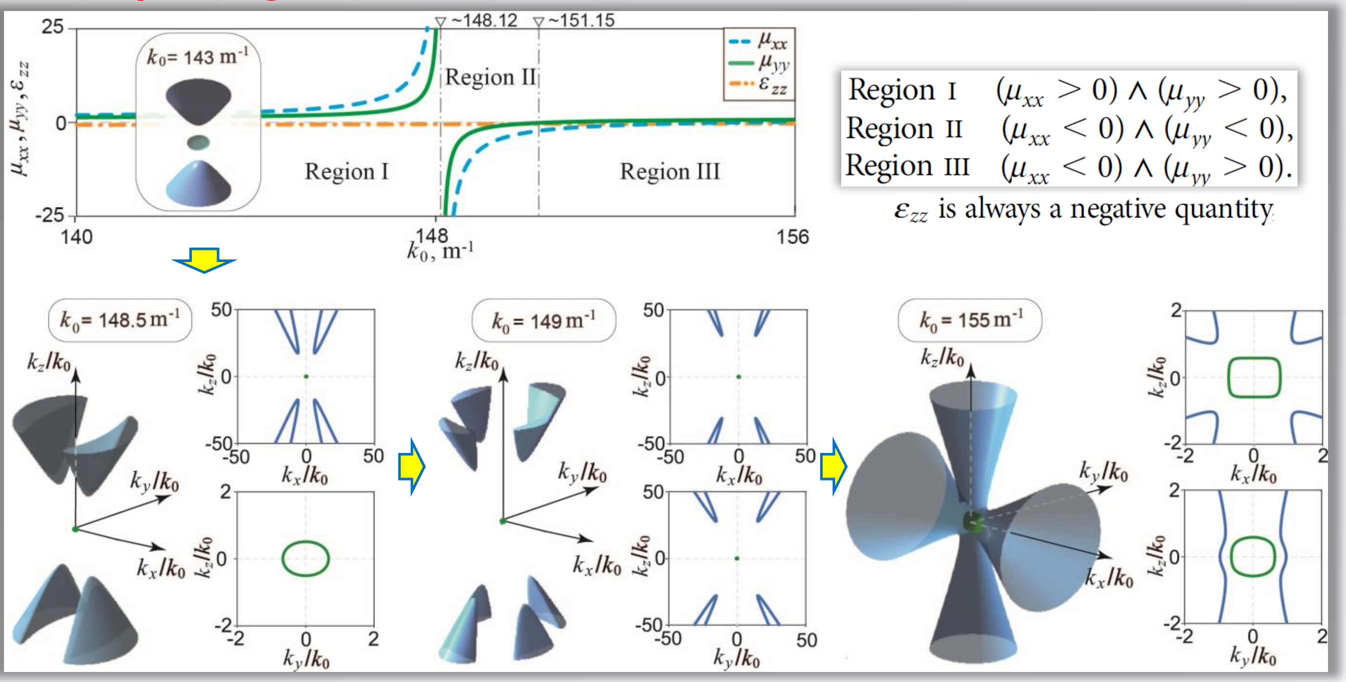
$$\begin{bmatrix} \varepsilon_m, & \hat{\mu}_m \\ \hat{\varepsilon}_s, & \mu_s \end{bmatrix} \Rightarrow \hat{g}_{eff} = \begin{pmatrix} \tilde{g}_{xx} & \tilde{g}_{xy} & \tilde{g}_{xz} \\ \tilde{g}_{yx} & \tilde{g}_{yy} & \tilde{g}_{yz} \\ \tilde{g}_{zx} & \tilde{g}_{zy} & \tilde{g}_{zz} \end{pmatrix}$$

$$\tilde{g}_{xx} \neq \tilde{g}_{yy} \neq \tilde{g}_{zz} \; \tilde{g}_{xy} = -\tilde{g}_{yx} \neq 0$$

$$(\varepsilon_{zz}\mu_{zz})^{-1}\{k_x^4\varepsilon_{xx}\mu_{xx} + k_y^4\varepsilon_{yy}\mu_{yy} + k_z^4\varepsilon_{zz}\mu_{zz} + k_x^2k_y^2(\varepsilon_{xx}\mu_{yy} + \varepsilon_{yy}\mu_{xx}) + k_x^2k_z^2(\varepsilon_{xx}\mu_{zz} + \varepsilon_{zz}\mu_{xx}) + k_y^2k_z^2(\varepsilon_{yy}\mu_{zz} + \varepsilon_{zz}\mu_{yy})$$
$$- k_0[k_x^2(\varepsilon_{xx}\varepsilon_{zz}\mu_\perp + \mu_{xx}\mu_{zz}\varepsilon_\perp) + k_y^2(\varepsilon_{yy}\varepsilon_{zz}\mu_\perp + \mu_{yy}\mu_{zz}\varepsilon_\perp) + k_z^2\varepsilon_{zz}\mu_{zz}(\varepsilon_{xx}\mu_{yy} + \varepsilon_{yy}\mu_{xx} - 2\varepsilon_{xy}\mu_{xy}]\} + k_0^4\varepsilon_\perp\mu_\perp = 0.$$

Related publication: 1. **V.R. Tuz, et al., (InTech, 2018), Chapter 6, pp. 99-125. ISBN: 978-1-78923-063-5.**

Topological transitions



The topological transitions of isofrequency surfaces of extraordinary high-*k* waves from an **open type-I hyperboloid** to the form of **a cone cut into either two or four parts (tetra-hyperbolic)** [1] as well as a **bi-hyperboloid** [2,3] are revealed

Related publications: 1. Tuz V. R. and V.I. Fesenko, J. Appl. Phys., 128, 013107 (2020);
2. Fesenko, V. I. and V. R. Tuz, Phys. Rev. B, 99, 094404 (2019);
3. V.R. Tuz, I.V. Fedorin, V.I. Fesenko, Opt. Lett., 42(21), 4561-4564 (2017).