Towards Hyperbolic Radial Anisotropy using Layered Spheres

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Metamaterials with hyperbolic dielectric or magnetic anisotropy exhibit many exotic properties, as is evident from the recent review by A. Poddubny et al. (*Nature Photonics*, **7**, 2013, pp. 958–967). In this presentation, we continue the work on radially anisotropic (RA) spheres (H. Wallén et al., *Radio Science*, accepted in Dec. 2014) by studying the theoretical performance of a layered metal–dielectric realization, with special focus on the anomalous losses in the hyperbolic case.

The simplest way to implement hyperbolic dielectric anisotropy seems to be arrays of metallic nanorods or alternating layers of metal and dielectrics. We concentrate on the layered approach, as it seems more realizable in spherical geometry. Assuming a sufficient number of thin layers, the effective permittivity components of a silver–dielectric sphere are

$$\varepsilon_{\mathrm{tan}} = p\,\varepsilon_{\mathrm{Ag}} + (1-p)\,\varepsilon_{\mathrm{d}}, \qquad \frac{1}{\varepsilon_{\mathrm{rad}}} = \frac{p}{\varepsilon_{\mathrm{Ag}}} + \frac{(1-p)}{\varepsilon_{\mathrm{d}}},$$

where p is the volume fraction of silver, with permittivity $\varepsilon_{\mathrm{Ag}}$ given by a reasonable Drude-model. We assume that the dielectric is lossless with relative permittivity $\varepsilon_{\mathrm{d}} \geq 1$. Choosing suitable parameters p and ε_{d}, we can get opposite signs of the real parts of $\varepsilon_{\mathrm{tan}}$ and $\varepsilon_{\mathrm{rad}}$ with modest imaginary parts in large regions of the optical domain.

An ideal RA sphere with infinitesimally small losses exhibits anomalous losses when $\varepsilon_{\mathrm{tan}}/\varepsilon_{\mathrm{rad}} < -1/8$. As this effect is not limited to a single permittivity value, it could be a promising route to get broadband absorption instead of narrow-band resonance-based absorption. One key focus of this presentation is to study how well the silver–dielectric layered sphere can approximate the ideal RA sphere and how broadband absorption we can get. Most of the results are based on a quasistatic treatment of the homogenized layered sphere. An actual realization would most likely have a very limited number of layers, and thus we also plan to present some results for layered spheres without homogenization.