Mie Resonances of Radially Anisotropic Dielectric Cylinders

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The research of artificial metamaterials is still under much interest. One of the current directions is the study of all-dielectric metamaterials based on the Mie resonances of high-permittivity objects. In comparison to plasmonic metals, the advantage of dielectrics is that they usually show much more moderate frequency dispersion and lower losses.

In this presentation, we will study the Mie resonances of an infinitely long radially anisotropic (RA) cylinder with radial permittivity ε_ρ and tangential permittivity ε_φ. In the long-wavelength limit, the cylinder can be seen from the outside as a homogeneous cylinder with an effective permittivity $\varepsilon_{\text{eff}} = \sqrt{\varepsilon_\rho \varepsilon_\varphi}$. We note that the choice $\varepsilon_\rho = \varepsilon_\varphi^{-1}$ makes an electrically small cylinder invisible and even suitable for cloaking purposes (H. Kettunen et al., *J. Appl. Phys*., **114**, 2013, p. 044110).

In the dynamic case, we need to solve the scattering problem of a TE_z polarized electromagnetic plane wave from a dielectric RA cylinder, whose axis lies along the z-axis. The incoming and scattered fields are written as series expansions, whose expressions are derived, e.g., in (Y. Ni et al., *Plasmonics*, **5**, 2010, pp. 251-258). The first Mie resonances can be easily spotted by looking at the coefficients a_n of the scattered wave, as the maxima of a_0 reveal the magnetic dipolar resonances and the maxima of a_1 the electric dipolar ones.

Radial anisotropy makes it possible to tune the occurrence of these resonances by adjusting the permittivity components of the cylinder. We could, for example, want to suppress either one of the resonances. It turns out that the coefficient a_0 only depends on the tangential permittivity ε_φ. Thus, by choosing $\varepsilon_\varphi = 1$, we completely cancel out the magnetic dipole term. On the other hand, choosing ε_φ very large and $\varepsilon_\rho = \varepsilon_\varphi^{-1}$, with increasing frequency we first obtain a magnetic resonance, that is, the cylinder exhibits artificial magnetism with almost negligible electric response.

We will also discuss the most intriguing possibility of tuning the magnetic and electric resonances to appear simultaneously. With resonances strong enough, the cylinder could look effectively double negative. Hence, an effective medium consisting of an array of such cylinders could manifest a negative index of refraction.