Optical response of finite hyperbolic metamaterials

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Metamaterials present new possibilities in the world of science, as they exhibit properties unseen in nature, such as negative refraction of light. They are artificially structured materials, which can be designed to control light. Hyperbolic metamaterials (HMMs) are a special case of metamaterials. Thanks to their unique properties (stemming from a hyperbolic dispersion curve), they can find application in subwavelength imaging, photovoltaics or biosensing.

Here, our aim is to study the optical response of finite HMMs in the form of nanodisks consisting of metal – dielectric layers. In order to calculate scattering and absorption cross sections of single hyperbolic nanodisks the Finite-Difference Time Domain (FDTD) method was applied. Hyperbolic nanodisks enable control of light in the visible/near-infrared spectral range owing to their nontrivial, rich modal spectrum. Their optical response consists of a dominant scattering mode, which is a radiative mode characterized by a strong, mostly pure electric dipolar mode, as well as an absorptive mode stemming from an induced coupled magnetic dipole – electric quadrupole (non-radiative mode). By modifying geometric parameters of the structure, such as the disk's radius and height or thicknesses of the metal and dielectric layers, we can control the spectral position, width and intensity of the peaks. In particular, it is possible to spectrally separate scattering and absorption peaks. In our work, we strive to explain the mechanism of induced resonances and find an optimal structure for further applications, such as refractometric sensing. Thanks to the fact, that both scattering and absorption modes of hyperbolic nanodisks are sensitive to the change of the refractive index of surrounding medium, HMMs are potential candidates for bulk refractometric sensors (sensitivity is defined here as the spectral position shift of the absorption/scattering peak divided by the change of bulk refractive index that caused such shift).