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Master 2 internship research proposal

All-Dielectric Metamaterials for Metadevices : Negative Index and Near-Zero Index Materials

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General framework

Metamaterials have opened a new field in physics and engineering. Indeed, these artificial structured materials give rise to unnatural fascinating phenomena such as negative index, sub-wavelength focusing and cloaking. Metamaterials also exhibit near-zero refractive index [1]. These open a broad range of applications, from the microwave to the optical frequency domain. Metamaterials have now evolved towards the implementation of optical components [2].

We consider *All-Dielectric Metamaterials* (ADM) which are the promising alternative to metallic metamaterials, because they undergo no ohmic losses and consequently benefit of low energy dissipation and because they are of simple geometry. They consist of high permittivity dielectric resonators involving Mie resonances. We have experimentally demonstrated negative effective permeability and/or permittivity by the means of all-dielectric metamaterials [3]. Previously, we have also demonstrated a negative index all-dielectric metamaterial [4].

Metamaterials that exhibit Near-Zero Index metamaterials (NZI) have a large number of applications including wavefront engineering, directivity and gain enhancement of antennas, electromagnetic cloaking, phase matching for nonlinear applications, unidirectional transmission, defect waveguides, ZIM cavities, ... [5]

Recently, we have numerically demonstrated a metadevice, namely, a metalens that focuses an incident plane wave and is less than one and a half wavelength thick. Its focal length is only a few wavelengths and the spot in the focal plane is diffraction-limited. [6]. We have also addressed the role of the coupling of the modes of Mie resonances in an all-dielectric metamaterial so as to achieve negative index and Near-Zero Index at terahertz frequencies (see fig. 1) [7].

Work Plan

During this internship, All-Dielectric Metamaterials will be numerically designed ; Negative Index and Near-Zero Index will be addressed. Various devices will be investigated (antennas systems, flat lens, gradient devices, ...) ; in the first instance, antennas systems will be considered. Our aim is to demonstrate that NZI All-Dielectric Metamaterials may be associated to antennas. This work takes place within the framework of a group of scientists of different disciplines (chemists, material scientists and physicists) [8] which deals with All-Dielectric Metamaterials design, hight dielectric material fabrication, structuration and characterization [8].

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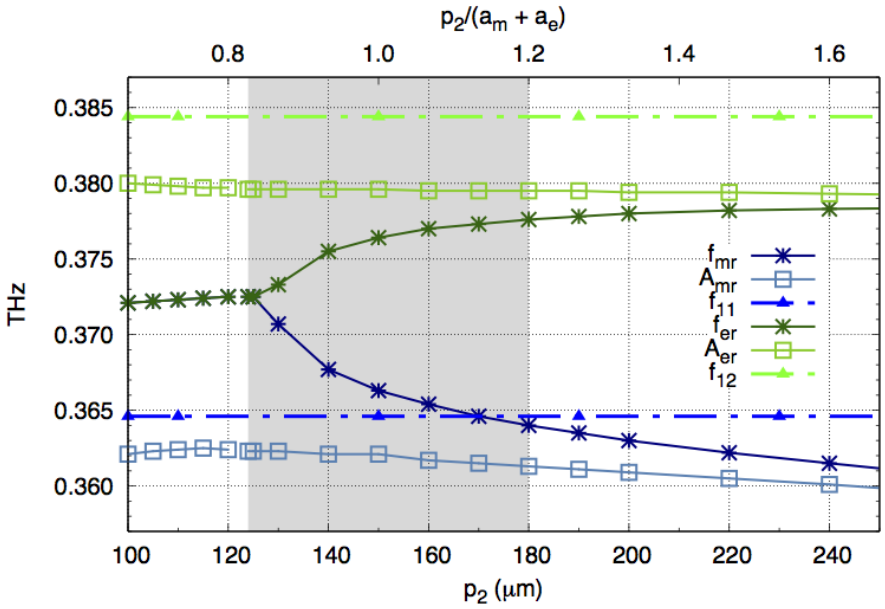

FIGURE 1 – *Spatial* mode coupling : frequency of the first two modes of Mie resonances in function of the distance p_2 between two resonators which is half the lattice period l_p. It shows the mode degeneracy. The shaded area corresponds to negative value of the effective index n_{eff}. near-zero Index is attainable. [7]

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