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M2 internship research proposal

All-Dielectric Metamaterials for Zero-Index-Photonic : Negative Index and Near-Zero Index Materials at Terahertz

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Scientific 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, 2] 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. [3]

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. [4] 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. [5] Previously, we have also demonstrated a negative index all-dielectric metamaterial. [6]

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, Zero-index Materials (ZIM) cavities. [7]

The main feature of Zero Index Materials is that the phase distribution of the EM field is nearly constant, because of the decoupling of the electric and the magnetic fields, that results in the "decoupling of the "spatial" (wavelength) and the "temporal" (frequency)". [2] Zero Index Photonics has consequently fundamental and technological implications on different subfields of optics and nanophotonics. Optical components and antennas systems operating in the terahertz range are the targeted devices.

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. [8] 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. [9]

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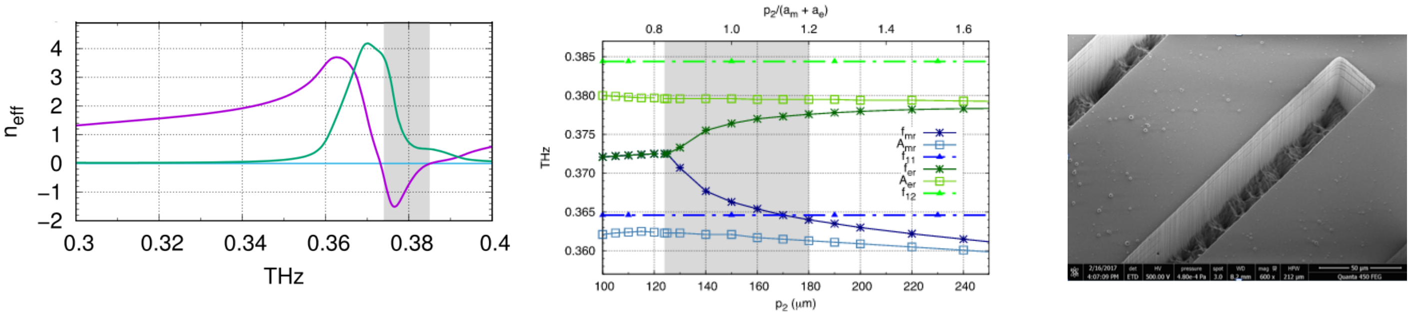

FIGURE 1 – (left) Negative index from an ADM (shaded area) [9], (center) Mode coupling : frequency of the first two modes of Mie resonances as a function of the distance p_2 between the two resonators ; frequency degeneracy is observed [9] ; (right) PMMA mould fabricated by the LIGA process (Lab. Albert Fert)

General framework and work Plan

This work takes place within the framework of the *DisPoNT* ANR ASTRID project. It gathers a group of scientists of different disciplines (chemists, material scientists and physicists), who deal with All-Dielectric Metamaterials design, hight dielectric material fabrication, structuration and characterization [10–12]

During this research project, All-Dielectric Metamaterials and Metadevices will be numerically designed ; Negative Index and Near-Zero Index will be addressed. In the first instance, our aim is to demonstrate near-zero index and negative index. The role of the coupling between the modes will be investigated. Then "metadevices" (e.g., Graded Index Lens based on a metasurface 2D metamaterial) could be considered.

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