LEFT-HANDED META-MATERIALS IN THE VISIBLE

Introduction

For a material to transmit light, it must have a real index of refraction, and therefore its permittivity and permeability (ε and μ) must have the same sign since $n = \sqrt{\varepsilon \mu}$. In all known cases where this is true the material has both positive ε and μ, but theoretically a material in which both ε and μ are both negative would also allow the propagation of electromagnetic waves. It has been predicted that such a material would exhibit several strange properties, including a left-handed vector orientation for E, H and k. Although metals have a negative ε, no known material exists in nature with a negative ε and μ in the same frequency range. Therefore, it is necessary to design and fabricate such a material in order to verify its predicted behavior.

Because the properties of this kind of material have not been thoroughly experimentally explored, there exists an opportunity to verify and extend theoretical predictions, and also to find other non-obvious consequences of left-handedness. Recently, certain structures have been shown to exhibit a negative permeability under at long wavelengths, thus allowing the construction of left-handed “meta-materials” (LHMs). These meta-materials now must be built with lattice constants on the order of centimeters, but could theoretically be scaled to smaller structures in the future for applications in the visible. Experiments confirming theoretical results at long wavelengths are now available, but these experiments have encountered large absorption effects introduced by specific characteristics of the meta-material’s construction.

The purpose of our project is to design and fabricate a LHM in the visible and experimentally verify the effective index of refraction of this meta-material. In this way we also hope to be able find ways to reduce the absorption effects encountered by the experimentalists in the frequency range where the meta-material becomes LHM. Also, we hope to find useful applications of these materials’ strange properties in the visible.

Design and Testing of Negative Index Metamaterials (NIM) in the Visible Regime

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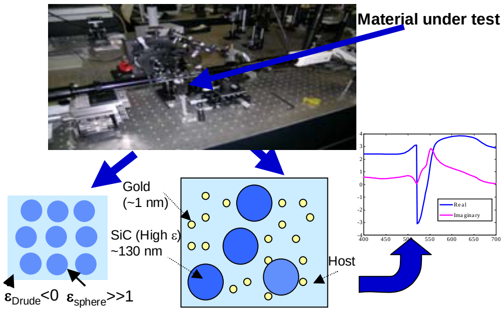

Objectives and Approach

Design and test a new NIM in the visible regime

- **Design NIM using FDTD and analytical electromagnetic analysis methods**
- **Fabricate a device prototype**
- **Establish its NIM behavior**

Design and build Testbed

- **Optimization of Design**
- **Fabrication and Characterization**

DoD Relevance

- **NIM would allow designing new types of optical filters, antireflection coatings, laser cavities, and phase conjugation;**
- **Numerical and analytical modeling of nanoscale devices for the visible regime provide powerful tools that describe the electronic interactions in the bulk material**
- **Testbed under development can be used as an "optical injector" to test and validate NIM behavior in the visible regime.**

Accomplishments

NIM in the Visible

- **Developed 2 methodologies using numerical and analytical methods to design NIM in the visible regime**
- **Fabrication of designed NIM in progress**

Testbed for studying NIM

- **Theoretical optimized design near completion**
- **Initial fabrication procedure developed**
- **Initial characterization set-up complete**