

Negative Index Metamaterials at Optical Frequencies

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Recently, metamaterials with negative index of refraction have been demonstrated for microwave electromagnetic (EM) radiation. It has been anticipated in 1950-60s by Pafomov and Veselago that negative refraction should occur in homogeneous media with simultaneously negative dielectric permittivity and magnetic permeability, $\epsilon < 0$, $\mu < 0$. It has been speculated by Pendry (2000) that the ideal Veselago lens with $\epsilon = \mu = -1$ can produce an image beyond the limits of geometrical optics, with resolution $\Delta x \ll \lambda$. We explore this possibility theoretically and experimentally. We find a strong effect of surfaces on resolution limit and nontrivial relation of subwavelength imaging to EM “softness” of the lens [1]. We have designed the metamaterial by means of FDTD modeling, which is a stack of metallic films with periodic hole arrays separated by dielectric layers (called “fishnet”, FN) to work at IR wavelengths $\lambda = 1.5\text{-}1.6 \mu\text{m}$, and fabricated a few samples by nanoimprint lithography[2]. The FN transmission and reflectance characteristics of the samples have been measured by laser spectroscopic ellipsometry and showed unambiguously that the FN supports the “backward” waves and have overall negative index of refraction at IR frequencies. We also address the questions of countering losses by using gain medium, attainable sub-wavelength resolution, and focusing.

1. A.M. Bratkovsky, A.Cano, and A.P. Levanyuk, *Appl. Phys. Lett.* **87**, 103507 (2005).
2. W. Wu et al., cond-mat/0610352, to appear in *Appl. Phys. A*, Special Issue on Negative Index Metamaterials.