Negative Index Metamaterials and Their Applications to Sub-diffraction Imaging and Infrared Light Harvesting

Gennady Shvets
University of Texas at Austin

A MetaMaterial is a man-made medium constructed out of carefully engineered building blocks (unit cells) that has electromagnetic properties unattainable in natural materials. One such property is the negative refractive index which requires that both the dielectric permittivity and negative permeability turn negative. Negative refractive index dramatically alters many well-known phenomena such as the Snell's Law, Doppler Effect, and the Abbe's Limit on the resolution of a microscope. While the possibility of negative index materials (NIMs) has been theoretically predicted in 1960s by a Soviet physicist Victor Veselago, they were fabricated and tested only during the past decade, and mainly in the microwave part of the electromagnetic spectrum. Because most exciting applications are found in the optical part of the spectrum, there is considerable effort aimed at developing optical NIMs and using them to beat the Abbe's diffraction limit. One of the main challenges is to make a metamaterial exhibiting optical magnetism. I will review the progress in the field and the role of plasmonics in building nanostructured NIMs. Our theoretical and experimental efforts aimed at developing mid-infrared NIMs and superlenses will be described. Experimental demonstration of a near-field super-lens in the mid-infrared (around 11 microns) range will be described. The lens is implemented using crystalline SiC films that have remarkable infrared properties: They support surface polaritons with less damping than most metals. Both amplitude and phase-sensitive imaging is demonstrated. It is also demonstrated that super-lensing can be used for sub-surface imaging with a $\lambda/20$ [1] spatial resolution. Applications to biologically-relevant imaging through water in nanofluidic channels will be discussed, as well as new approaches to imaging the near field using far-field diagnostics (Far-field SuperLens). Applications of metamaterials to harvesting infrared radiation and mid-infrared index sensing will also be reviewed.

[1] T. Taubner, D.Korobkin, Y.Urzhumov, G.Shvets, and R.Hillenbrand, "Near-field microscopy through a SiC superlens", Science **313,** 1595 (2006).