Metamaterials: Mechanisms of Subwavelength Imaging

E. Shamonina[1] and L. Solymar[2]
[1]University of Osnabrück, Germany
[2]Imperial College, UK

Metamaterials are artificial structures comprising of arrays of small resonant elements in which both the size and the distance between the elements are much smaller than the wavelength. A number of metamaterial devices have been designed to manipulate and control the near field following the idea of the perfect lens proposed by Pendy [1]. His idea was to image an object of subwavelength dimensions a distance away from the source plane by a plane parallel slab having a refractive index ?. A silver slab [1] or a multilayered silver metamaterial [2] can serve as a near-perfect lens, with the limit of resolution determined by surface plasmon resonances and by a high-frequency cut-off of the transfer function. There have been imaging experiments with silver slabs (see e. g., [3, 4]), with a single layer of a 2D array of Swiss Rolls [5, 6], and with two or more layers of 2D arrays of split ring resonators [7–10].

The purpose of the present work is to review the mechanisms of subwavelength imaging and discuss the relationship between imaging and focussing. The mechanisms discussed will be the excitation of (i) surface plasmons, (ii) magnetoinductive surface waves and (iii) phase conjugate waves at the outer boundary of the lens. In addition we shall consider microchannelling [11] based on the eigenmodes of the periodic medium and also on a set of magnetoinductive waves evanescent in the transverse direction and propagating in the longitudinal direction. Imaging and focussing will also be described in terms of coupled resonators [7] and finally the general topic of Poynting vector optics [12] will be discussed with indefinite media [8] as one of the examples.

REFERENCES

1. Pendry, J. B., "Negative refraction makes a perfect lens," *Phys. Rev. Lett.*, Vol. 85, 3966–3969, 2000.
2. Shamonina, E., V. A. Kalinin, K. H. Ringhofer, and L. Solymar, "Imaging, compression and Poynting vector streamlines with negative permittivity materials," *Electron. Lett.*, Vol. 37, 1243–1244, 2001.
3. Melville, D. O. S. and R. J. Blaikie, "Super-resolution imaging through a planar silver layer," *Opt. Express*, Vol. 13, 2127–2134, 2005.
4. Fang, N., H. Lee, C. Sun, and X. Zhang, "Sub-diffraction-limited optical imaging with a silver superlens," *Science*, Vol. 308, 534–537, 2005.
5. Wiltshire, M. C. K., J. B. Pendry, I. R. Young, D. J. Larkman, D. J. Gilderdale, and J. V. Hajnal, "Microstructured magnetic materials for radio frequency operation in magnetic resonance imaging (MRI)," *Science*, Vol. 291, 849–851, 2001.
6. Wiltshire, M. C. K., J. V. Hajnal, J. B. Pendry, D. J. Edwards, and C. J. Stevens, "Metamaterial endoscope for magnetic field transfer: near field imaging with magnetic wires," *Opt. Express*, Vol. 11, 709–715, 2003.
7. Maslovski, S., S. Tretyakov, and P. Alitalo, "Near-field enhancement and imaging in double planar polariton-resonant structures," *J. Appl. Phys.*, Vol. 96, 1293–1300, 2004.
8. Smith, D. R., D. Schurig, J. J. Mock, P. Kolinko, and P. Rye, "Partial focusing of radiation by a slab of indefinite media," *Appl. Phys. Lett.*, Vol. 84, 2244–2246, 2004.
9. Freire, M. J. and R. Marques, "A planar magnetoinductive lens for 3D subwavelength imaging," *Appl. Phys. Lett.*, Vol. 86, 182505, 2005.
10. Lin, I.-H., C. Caloz, and T. Itoh, "Near-field focusing by a nonuniform leaky-wave interface," *Microw. Opt. Techn. Lett.*, Vol. 44, 416–418, 2005.
11. Belov, P. A., C. R. Simovski, and P. Ikonen, "Canalization of subwavelength images by electromagnetc crystals," *Phys. Rev. B*, Vol. 71, 193105-1-4, 2005.
12. Russell, P. St. J., "Novel thick grating beam-squeezing device in ta2O5 corrugated planar waveguide," *Electron. Lett.*, Vol. 20, 72–73, 1984.