CANALIZATION OF SUB-WAVELENGTH IMAGES BYELECTROMAGNETIC CRYSTALS

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Abstract:

The theoretical possibility of sub-wavelength imaging by a slab of left-handed medium (LHM) was demonstrated by J. Pendry in his seminal work [J.B. Pendry, ``Negative refraction index makes perfect lens\'\', Phys. Rev. Lett., vol. 85, no.18, pp. 3966-3969, 2000]. The focusing phenomenon in Pendry\'s perfect lens is based on two effects. The propagating modes of a source are focused in the LHM due to the negative refraction and the evanescent modes experience amplification inside the LHM slab. This allows to restore sub-wavelength details in the focal plane. The second effect happens due to the resonant excitation of the surface plasmons at the interfaces of the slab. A flat superlens formed by a slab of photonic crystal was suggested by C. Luo et. al. and the possibility of sub-wavelength imaging was theoretically studied in [C. Luo, S.G. Johnson, J. D. Joannopoulos, J. B. Pendry, ``Subwavelength imaging in photonic crystals\'\', Phys. Rev. B, vol. 68, 045115, 2003]. The principle of Luo\'s superlens is similar to the principle of Pendry\'s perfect lens: negative refraction for propagating modes and amplification due to the resonant surface plasmon for evanescent modes. Both effects are obtained without left-handed properties of a material. Negative refraction is obtained due to a specific form of isofrequency contours (without backward waves inherent to LHM).

In the present paper we propose to use the photonic crystal in a different regime than suggested by C. Luo et. al.. This regime does not involve negative refraction and amplification of evanescent modes, rather, we propose to transform the most part of the spatial spectrum of the source radiation into propagating eigenmodes of the crystal having practically the same group velocity (directed across the slab) and the same longitudinal components of the wave vector. The spatial harmonics produced by a source (propagating and evanescent) refract into the crystal eigenmodes at the front interface. These eigenmodes propagate normally to the interface and deliver the distribution of near-field electric field from the front interface to the back interface without disturbances. The incoming waves refract at the back interface and form an image. This way the incident field with sub-wavelength details is transported from one interface to the other one. We call the described regime as canalization with sub-wavelength resolution. The regime of canalization can be implemented by using the isofrequency contour which has a rather long flat part. Such contours are available for different types of photonic crystals.

We use a two-dimensional electromagnetic crystal formed by capacitively loaded wires [P.A. Belov, C.R. Simovski, S.A. Tretyakov, ``Two-dimensional electromagnetic crystals formed by reactively loaded wires\'\', Phys. Rev. E, vol. 66, 036610, 2002], the so-called capacitively loaded wire medium (CLWM). The canalization regime is implemented at low frequencies with respect to the crystal period by using CLWM. The resolution of one sixth of the wavelength is demonstrated. The thickness of the superlens is not related with the distance to the source and the lens can be made thick enough.