Image Formation Versus Focusing of Energy in Metamaterial Superlenses

Francisco Mesa*[1], Ricardo Marqués[2], Manuel J. Freire[2], and Juan D. Baena[2]

[1] Dept. of Applied Physcis 1, University of Seville, Seville Spain, e-mail: mesa@us.es

[2] Dept. of Electronics & Electromagnetism, University of Seville, Seville, Spain, e-mail: marques@us.es

One of the most promising features attributed to metamaterials has been the fabrication of superlenses that could beat the wavelength restrictions characteristics of dielectric lenses. Sometimes, this effect has been refereed as a sub-diffraction or super- "focusing" by metamaterial superlenses. However, recent detailed studies on the imaging process in planar metamaterial lenses [V.G. Veselago, *Appl. Phys. B*, 81, 403-407, 2005; Mesa et al., to be published in *Phys. Rev. B*, 2006] have put in doubt such interpretation. Basically, what has been found in *perfect* planar metamaterial superlenses is the existence of two conjugate planes; namely, an image plane with exactly the same electromagnetic scene as certain object plane. This property does not necessarily means that the superlens behave as a "focusing" device, as a conventional lens does. It should be recalled that standard "focusing" devices always concentrate the energy in volumetric regions whose dimensions are greater than wavelength. However, the distribution of electromagnetic energy in the conjugate plane of a planar metamaterial slab having details smaller than the wavelength does not implies that the volumetric density of energy overcomes the diffraction limit. In fact, this behavior will be against the well-known uncertainty principle [J.M.Williams *Phys. Rev. Lett.*, 87, 249703, 2001; V.G. Veselago, *Appl. Phys. B*, 81, 403-407, 2005]. Anyhow, there are some reported experiments with planar metamaterial slabs [M. Freire and R. Marqués *App. Phys. Lett.*, 86, 182505, 2005; Z.Lu, et al., *Phys. Rev. Lett.*, 95, 153901, 2005.] whose naive interpretation seems to point out that there is actually a sub-wavelength focusing phenomenon. The physical explanation of these surprising experimental facts has been provided in [Mesa et al., to be published in *Phys. Rev. B*, 2006], where it is discussed that, because of the *near-field* nature of the experiment, the interaction between the measurement setup and the device under study cannot be neglected. When this interaction is properly taken into account, what may be erroneously regarded as a subwavelength focusing effect is readily recognized as a local maximum in the transmission coefficient of the complete physical system (which arises from the coupling between the input and output ports). Thus, the observed three-dimensional sub-diffraction images do not correspond to a real focusing of energy into a spot smaller than the wavelength, but to the *matching* properties [V.G. Veselago, *Appl. Phys. B*, 81, 403-407] of such devices.