Avoiding Imaging Artifacts in Metamaterial Superlenses

Iman Aghanejad*, Kenneth J. Chau, and Loïc Markley
The University of British Columbia, Kelowna, BC, Canada

Left-handed materials with $\epsilon = \mu = -1$ can hypothetically achieve perfect imaging with unlimited spatial resolution by amplifying all evanescent waves which would otherwise be lost. Left-handed plane waves propagating isotropically within the perfect lens focus all the propagating components through negative refraction while coupled surface modes perfectly amplify the evanescent components. Since 2001, many different engineered metamaterials have been presented to mimic a left-handed response. These structures all exhibit circular equifrequency contours (EFCs) that resemble those of left-handed media over the propagating spectrum and therefore have the potential to exhibit superlensing behaviour. In practice, however, their imaging performance has been limited due to high spatial-frequency resonances within the metamaterial lenses.

In this work, we identify imaging artifacts caused by these resonant modes and show how these artifacts can be avoided. Resonant modes cause image degradation by: 1) imposing a spatial frequency upper limit for the reconstruction of an object components in the image plane and 2) over-amplifying the object components corresponding to the resonant modes, often producing high-intensity sidelobes. These artifacts may not be revealed using the standard two-point-source resolution experiment (see Fig. 1(a)) and thus have not been well-studied in the literature. They are readily observed, however, when the superlens is required to image complex objects composed of multiple point sources under varying spatial arrangements (see Fig. 1(b)). We show that in order to achieve robust super-resolution imaging, imaging artifacts due to resonant modes can be mitigated by: 1) adjusting the lateral width of the slab to detune the dominate resonant modes from the operating frequency and 2) introducing vacancy point defects to push the resonant modes to higher spatial frequencies. Full-wave simulations confirm that these strategies yield substantial improvements in both sub-diffractive imaging resolution and robustness (see Figs. 1(c) and 1(d)).

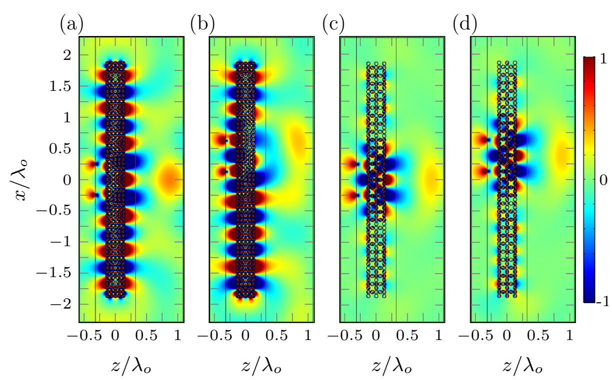

Figure 1: The imaging field distributions for magnetodielectric metamaterial lenses. (a) Two symmetric point sources and (b) two offset point sources illuminate a regular dense five-layer lens. (c) and (d) show the simulation results similar to (a) and (b) when a modified lens with vacancy points is illuminated.