Flat Lenses and Reflectors

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The seminal paper by Pendry proposed a perfect lens in the sense that the complete propagating and evanescent spectra emanating from an object can be faithfully constructed at a distance from the object. The work of Pendry ignited an unprecedented enthusiasm for better optics and better focusing of electromagnetic waves in general. Due to fundamental limitations, the work by Pendry remains a theoretical construction at best. Nevertheless, even if the Pendry lens can be realized physically, it remains of limited utility since reconstructing the full spectrum can only be possible at close distance from the object. More recently, a far field lens, or a *superlens*, was proposed where the Pendry lens was used to enhance the evanescent spectrum coming out of the object and then a grating surface was used to convert the evanescent spectrum to a propagating one that can be detected in the far field. The far field *superlens* introduced for near field microscopy remains limited as it would require a grating structure to be placed in the very close proximity of the object, which precludes full imaging (i.e., reconstitution of both propagation and evanescent spectra) of physically distant objects. In most applications in the microwave frequency regime, minimizing aberration is not the highest concern, as high, but not perfect focusing is what is desired. Focusing can also be achieved using coordinates transformation by bending rays. Wave bending is accomplished by a highly anisotropic medium where the medium material properties depend on its coordinate location. This discrete coordinate transformation technique translates a 2D convex optical lens into a flat lens. Recently two different groups succeeded in creating a lens for focusing the far field. Both groups used metallic inclusions, or very small antennas, to achieve a phase shift profile on the exit side of the lens such that the wavefront converges at a single focal point. These designs have losses and reflections, thus significantly reducing the focusing efficiency. Additionally, the focusing is limited to a very narrow band of frequencies which govern the design of the metallic inclusions responsible for the precise phase shift profile throughout the lens.

In this work, we present theoretical findings behind a focusing technique that is based on dispersion. We limit our work to far-field focusing (i.e., focusing of an incident plane wave arriving from infinity onto a specific focal point in the proximity of the lens). We show that dispersion can be used to design a flat lens with a specific phase profiles necessary to create a focal point in the near field. The practical realization of the flat lens proposed here will largely depend on the promise of metamaterials to realize refractive indices as high as 20.