Optical properties of materials with negative refraction: perfect lenses and cloaking

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It has been shown recently that some photonic crystals might be the left-handed materials with both negative ε and μ for propagating modes.[1] They provide negative refraction at the interface with a regular material and they may be used for creation of the Veselago lens. These negative ε and μ, however, are properties of the separate modes rather than properties of the whole crystal. For example, the amplification of the evanescent waves in photonic crystal does not follow from the fact that propagating modes with the same frequency in this crystal have negative ε and μ. The reason is that the spatial dispersion makes ε and μ for propagating modes completely different from those for the evanescent modes. This is important because, following Pendry,[2] the amplification of evanescent waves provides a possibility of creating a lens with an image much sharper than the wavelength (the so-called "superlens").

We consider the case when evanescent waves do not play any role in creation of the image of the Veselago lens and find some unusual features of this image, including perfect imaging in the lateral direction of the phase-shifted part of the point source. This happens because this part *does not* contain evanescent waves. Simple analytical calculations of the field near focus are in a perfect agreement with the results of computer simulation. On the other hand, in some cases there are surface waves that have nothing in common with the bulk properties of material. Those waves may improve the sharpness of the focus beyond the diffraction limit in the near-field regime.

The construction of the multi-focal Veselago lens predicted earlier is proposed on the basis of a uniaxial photonic crystal consisting of cylindrical air holes in silicon that make a triangular lattice in a plane perpendicular to the axis of the crystal. The object and image are in air. The period of the crystal should be 0.44 μm to work at the infrared wavelength 1.5 μm. The lens does not provide superlensing but the half-width of the image is 0.5 λ.

1. A. L. Efros and A. L. Pokrovsky, *Solid State Commun*. **129**, 643 (2004).
2. J. B. Pendry, *Phys. Rev. Lett.* **85**, 3966 (2000).