Photonic crystals as negative index materials

S. Enoch *, D. Maystre, G. Tayeb

Institut Fresnel, UMR CNRS 6133, Faculté de Saint Jérôme, case 161, 13397 Marseille Cedex 20, France

Negative index materials are the subject of a recent controversy. The first study of negative index materials (NIM) is due to V. Veselago (1964), who showed that a medium with both permittivity and permeability equal to -1 behaves as a medium producing negative refraction for plane waves. Recently, J.B. Pendry proposed a perfect lens using NIM, arguing that evanescent components of the electromagnetic field play a vital role in the perfect focusing process. Assuming that a material with such property exists, one can show that a slab of such a material can make a point image of a point source. This result has raised a polemical discussion.

First, we will show using a simple and rigorous demonstration that a homogeneous material having both permittivity and permeability equal to -1 cannot exist, even at a given wavelength.

On the other hand, it must be acknowledged that experimental results have evidenced the phenomenon of negative refraction in left-handed materials. Furthermore, we have shown from numerical data that purely dielectric photonic crystals can generate the same phenomenon. In these cases, the observed properties can be explained and it can be shown that such materials can be used to elaborate efficient (but not perfect) lenses which can go beyond the usual lenses.

We will give numerical illustrations of these results in the case of a two-dimensional dielectric photonic crystal. The physical insight of negative refraction is provided using dispersion curves of Bloch modes. We also estimate the limitations of a lens made of photonic crystals.

From our theoretical and numerical results, a critical appraisal of the recent results published elsewhere will be carried out.