

# The beauty of anisotropy in extraordinary transmission fishnet metamaterials

Miguel Navarro-Cía, Miguel Beruete, and Mario Sorolla, Millimeter and Terahertz Waves Laboratory, Universidad Pública de Navarra, Campus Arrosadía, 31006 Pamplona, Spain

Tel. +34 948 16 60 44, Fax +34 948 16 97 20, [miguel.navarro@unavarra.es](mailto:miguel.navarro@unavarra.es)

Abstract: In this work, we explore both numerically and experimentally, the possibility to obtain positive and negative refraction regimes that depend on the wave polarization, exploiting the strong anisotropy of extraordinary transmission fishnet metamaterials.

To date, the most successful metamaterial arrangement is a pair of perforated plates, usually referred to as fishnet structure [1, 2]. A careful analysis of its underlying mechanism, shows that metamaterial performance is intimately linked to the extraordinary transmission resonance [2, 3] so it could be properly termed as a extraordinary transmission metamaterial. Due to the structural parameters, this kind of structures has a very complex response that depends strongly on the wave polarization and plane of incidence [4-6], see Fig. 1. In fact, its performance can be approximated by different models of indefinite media [7] as a function of those factors.

In this work we will present a deep study of the different propagation regimes feasible in extraordinary transmission fishnet metamaterials. Negative refraction will be shown for P-polarization whereas positive refraction will appear under S-polarization. Finally, some hints to improve the performance of the structure will be given. All the numerical results will be checked with experiments at millimeter waves.

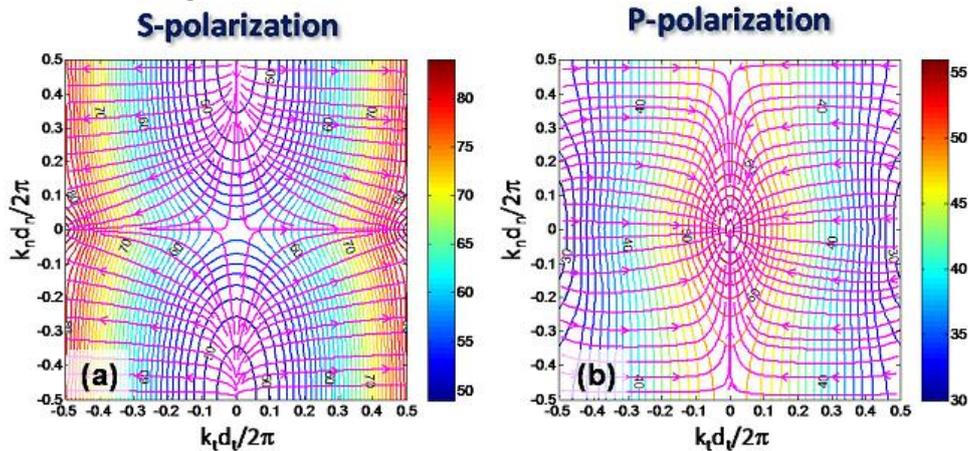


Fig. 1. Isofrequency contours for the case of S-polarization (a) and P-polarization (b).

## References:

- [1] S. Zhang, W. Fan, N.C. Panoiu, K.J. Malloy, R.M. Osgood, and S.R.J. Brueck, "Experimental Demonstration of near-Infrared Negative-Index Metamaterials," *Phys. Rev. Lett.* 95, 137404, 2005.
- [2] M. Beruete, M. Sorolla, and I. Campillo, "Left-Handed Extraordinary Optical Transmission through Photonic Crystal Subwavelength Hole Arrays," *Opt. Express* 14, 5445, 2006.
- [3] T.W. Ebbesen, H.J. Lezec, H. Ghaemi, T. Thio, and P.A. Wolf, "Extraordinary optical transmission through sub-wavelength hole arrays," *Nature* 391, 667, 1998.
- [4] M. Beruete, M. Navarro-Cía, M. Sorolla, and I. Campillo, "Negative refraction through an extraordinary transmission left-handed metamaterial slab," *Phys. Rev. B*, 79, 195107, 2009.
- [5] M. Beruete, M. Navarro-Cía, and M. Sorolla, "Strong lateral displacement in polarization anisotropic extraordinary transmission metamaterial," *New J. Phys.* 12, 063037, 2010.
- [6] A. Mary, S.G. Rodrigo, L. Martín-Moreno, and F.J. García-Vidal, "Holey metal films: From extraordinary transmission to negative-index behavior," *Phys. Rev. B* 80, 165431 2009.
- [7] D.R. Smith and D. Schurig, "Electromagnetic Wave Propagation in Media with Indefinite Permittivity and Permeability Tensors," *Phys. Rev. Lett.* 90, 077405, 2003.