Anomalous dispersion in one-dimensional photonic band gap structures with birefringent layers

C.Sibilia, A.Mandatori, M.Centini, G. D'Aguanno, M.Bertolotti

INFM at Dipartimento di Energetica – Università "La Sapienza" di Roma – Via Scarpa 16, 00161, Roma (Italy),+39 06 49941 6541, fax +39 06 442 40 183, concita.sibilia@uniroma1.it

J.W.Haus

Director Electro-Optics Program University of Dayton

M.Scalora

Weapons Sciences Directorate, Research Development and Engineering Center, U.S. Army Aviation & Missile Command, Building 7804, Redstone Arsenal, AL 35898-5000, USA.

Abstract: Anomalous dispersion in biaxial birefringent one dimensional photonic structures has been studied. This causes the Poynting vector to reverse its direction with respect to the wave vector, with consequent manifestation of negative refraction. Conditions to enhance the effects are discussed.

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Few cases of electromagnetic (e.m.) waves propagation exist where dispersion relation cause the Poynting vector to reverse its direction with respect the wave vector direction. For such kind of waves (so called " backward waves" negative refraction is expected. Negative refraction of e.m. waves was first predicted in materials with simultaneousl y negative permittivity and permeability [1]. Recently it has proposed that negative refraction could be observed in artificial materials, such " left –handed" materials on a microwave scale[2] and in photonic crystal at optical frequencies[3], where results were obtained for 2D and 3d photonic crystal structures. In the present work we discuss how "negative refraction" can be reached in one-dimensional, finite periodical structure.
Let us assume the elementary cell of the structure (first and second layer of the PBG) is birefringent, while the external materials are isotropic. An example is shown in figure 1 where the principal axis x and y of the second layer are rotated by same angle φ with respect to the z axis (biaxial birefringent materials). With this rotation of the principal axis we obtain an exchange of energy from the x and y axis at each interface, which offers interesting optical behavior from the point of view of spectral [4] and dispersive properties, and for the distribution of the electric field inside the multilayer structure. Dispersive properties for the finite structure are expressed by the phase of the complex transmission function:

$$t = x + iy = e^{\ln\sqrt{T}} e^{i\varphi_t} = e^{i\tilde{\varphi}} \; ; \qquad (1)$$

we can equate the phase in the eq. (1) to the effective wave vector by relation $\tilde{\varphi} = kD$, representing the phase of wave travelling through the structure. This " effective" phase gives us the " effective dispersion relation", which lies ω and k, according to the following expression [4]

$\tilde{\varphi} = \frac{\omega}{c}\tilde{n}_{eff} D$. The phase is a decreasing function of the wavelength (including artificial jumps given to a maximum or minimum in the transmission spectrum), however anomalous behavior has been found for biaxial materials . The correspondent transmission values are quite different from zero, giving rise to the possibility of application of this effect, according to the suggestions given in refs. 2 and 3.
An analysis of the spatial behavior of the output field is presented and discussed for different conditions of the parameters involved in the geometry.

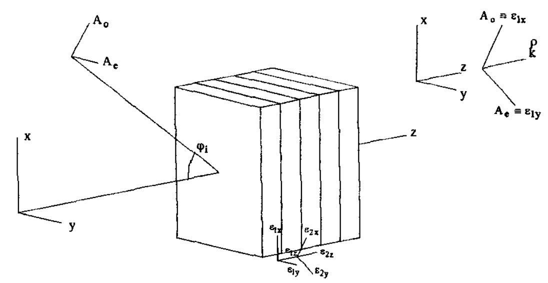

Fig.1 Scheme of the layered structure

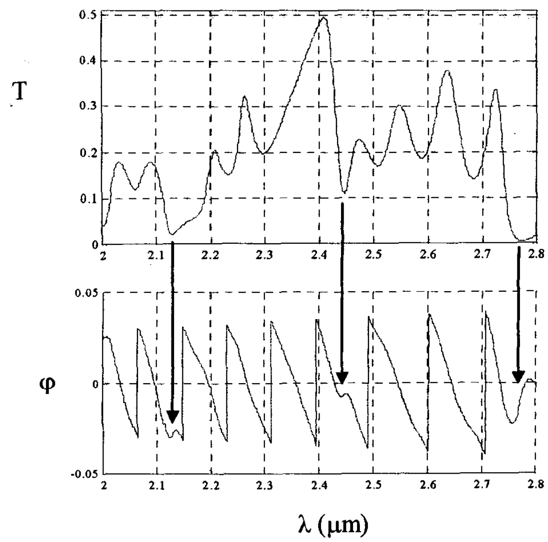

Fig.2 Example of transmission spectrum and anomalous phase for an input angle of 30°,

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