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4D-photonic crystals

Naimi E K
National University of Science and Technology "MISIS", Russia

One of the modern optics directions is the investigation of the so-called photonic crystals (PCs), a new class of ordered optical materials characterized by two main features: the periodic spatial modulation of the refractive index with a period allowing light Bragg diffraction and the existence of band gaps associated with translational symmetry of the refractive index in the spectrum of intrinsic electromagnetic states. The idea of the PC development belongs to E. Yablonovich and S. John (1987). It consists in designing new artificial media whose properties would make it possible to affect photons similarly to the effect of the ordinary lattice on electrons. Similarly to Bloch waves of electrons in ordinary crystals, optical waves in the PC lattice can have states in which the wave vector k (phase velocity) direction and the Poynting vector (group velocity) direction are anti-parallel. In other words, PCs can have a negative refractive index. The phenomenon of negative light refraction was most thoroughly considered by V.G. Veselago (1967). From the general point of view, the PC is a super lattice, i.e., a structure in which an additional field with a period exceeding the period of the basic lattice by several orders of magnitude is artificially induced. For photons, such a field is induced by periodic changes in the refractive index of the medium in one, two, or three dimensions (1D-, 2D-, and 3D-photon structures). The formation of dynamic periodic changes in the PC structure makes it possible to one more dimension, i.e., the time. A crystal obtained in such a way can be considered as a four dimensional (4D) photonic structure where the time is the fourth dimension. Due to the mutual influence of spatial and temporal processes, optical properties of such structures are potentially more diverse than properties of three dimensional crystals. In the present work we consider the conditions of the formation of the dynamic PC based on an optically homogeneous and isotropic medium with space–time modulation of the refractive index, implemented by an ultrasonic wave whose length exceeds the light wavelength by many orders of magnitude. To solve the posed problem in general form, we use Fermat's principle. It has been shown that the excitation of a standing ultrasonic wave in the medium creates a structure consisting of trajectories of separate light beams, which is a super lattice of the dynamic 4D-photonic crystal. The band gaps corresponding to negative light refraction have been revealed in beam trajectories. Possible fields of application of such structures have been discussed.

Biography

Naimi E K received PhD from Moscow State University and Dc. Sc. thesis from Moscow Institute of Steel and Alloys in 1993. In 1994, she worked as a Professor in Department of Physics. Her fields of research interests are solid state ultra-acoustics. She has published more than 50 papers in reputed journals.

e.naimi@mail.ru

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