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DISPERSION CHARACTERISTICS OF THE PHOTONIC CRYSTAL WAVEGUIDES

Photonic crystals are artificial periodic structures with different dimensionality. They are used for numerous applications in microwave and optical bands [1, 2]. Furthermore resonant and waveguiding structures can be developed on the basis of photonic crystals. These structures are formed through the local and linear defects of periodicity in photonic crystal structures. Localization of electromagnetic energy within defects areas is due to photonic band gap mechanism. High efficiency localization can be achieved in this case.

Operation characteristics of photonic crystal waveguides are defined by configuration of guiding structure and material parameters. In this work we consider linear photonic crystal waveguides which channels are filled with different media.

Fig. 1a and 1b shows two schemes of photonic crystal waveguides with dielectric and hollow waveguide channel respectively. It is obvious that a photonic crystal with triangular symmetry is used. It is formed by a system of hollow cylindrical holes in the dielectric medium. The black color in the figures corresponds to the dielectric with permittivity $\varepsilon = 12$, and the white color corresponds to the vacuum. The structure considered in the paper is two-dimensional. All geometric dimensions in the simulation of a photonic crystal waveguide are normalized to the structure period a. This allows us to apply the results of the calculations to the analysis of photonic crystal waveguides in different frequency ranges. Normalized diameter of the hollow holes is equal $r / a = 0.45$.

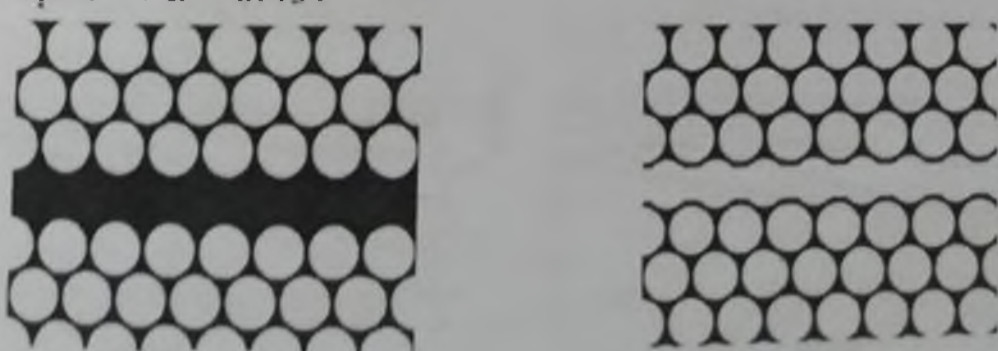

Fig. 1. Schematics of the photonic crystal waveguides

The MIT Photonic Bands computer package was used to determine the photonic bandgaps of the photonic crystal and its dispersion characteristics [4].

Fig. 2a shows the dispersion diagram for a photonic crystal waveguide with a dielectric channel. The shaded area in the diagram shows the photonic band gap. The normalized wave number is postponed along the abscissa axis. The y- axis defines the normalized frequency. There are several dispersion curves in the band gap. These curves correspond to the so-called "defective" modes of the photonic crystal structure. Therefore photonic crystal waveguide is multimode in this case. This is due to the use of a dielectric with a sufficiently high permittivity and the corresponding value of the waveguide channel width.

Let's consider photonic crystal waveguide with hollow channel. The scheme of this waveguide is presented in Fig. 1b. Hollow waveguide channel has several advantages over a dielectric one. First and foremost is the reduction of losses in the respective frequency bands. In addition such a design allows the passing of electron beams through the waveguides or to place in them various investigated elements.

There is only one mechanism for localization of electromagnetic energy in a hollow-channel photonic crystal waveguide. This is a photonic band gap. Total internal reflection is absent because the dielectric constant of the waveguide channel is less than the effective permittivity of the clad. In addition, the electrodynamic characteristics of the structure change significantly. This is due to the fact that the wavelength in the hollow waveguide channel is equal to the wavelength in free space. Therefore, the width of this channel may be increased while maintaining single-mode regime. It should be noted that the wider waveguide channels greatly facilitate the transmission of linear beams of charged particles.

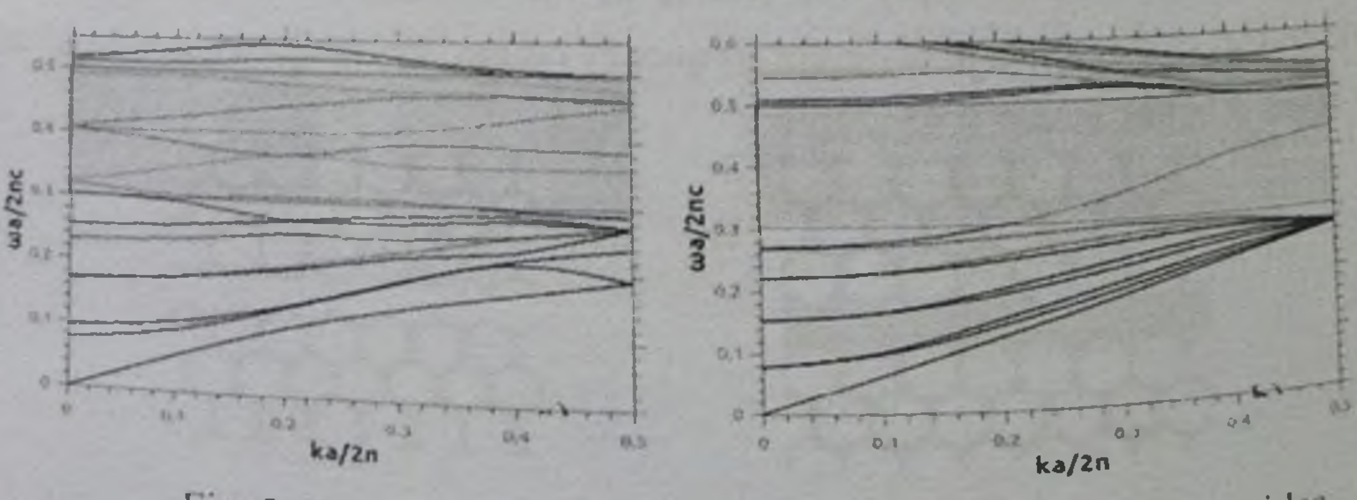

Fig. 2. Dispersion diagrams of the photonic crystal waveguides.

Fig. 2b shows dispersion diagram of a hollow-channel photonic crystal waveguide. There is only one dispersion curve within the photonic band gap in this case. Thus photonic crystal hollow waveguide is single-mode. Moreover waveguide mode in this structure is limited not only by wave number but also by frequency. The bandwidth of the waveguide is in the interval $0.3 < \frac{\omega a}{2\pi c} < 0.43$. This means that the bandwidth of the waveguide is less than the width of the photonic band gap. Therefore, within this zone, the photonic crystal waveguide has an effective critical frequency value. This phenomenon is used in the development of various elements of optical waveguide paths, which requires switching of signal transmission through waveguide channels. The waveguides considered in the work have the same width of the waveguide channel. But they are quite different in the operating regimes. The dielectric channel waveguide is multimode, and the hollow channel waveguide is single-mode. This result must be taken into account when designing devices based on these photonic crystal structures.

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