The Influence of Geometric Characteristis on a Bandwidth of the Photonic Crystal Waveguide

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Abstract – We investigated the influence of GaAs pillars diameter on a frequency band in the case of 2D photonic crystal waveguide. The obtained result show that the bandwidth changes with changing of the pillars diameter. We also have shown that changing of diameter of pillars in the photonic crystal waveguide structure allows us to design optical filters.

Keywords— photonic crystal; telecommunications, waveguide; TE waves.

I. Introduction

The photonic crystals are periodic dielectric structures of alternating layers of materials with different refractive indices that affect the propagation of electromagnetic (EM) waves due to the phenomenon of photonic bandgap (PBG). PBG is defined as a frequency band that characterized by zero density of the electromagnetic states. By removing some of the pillars in the crystal structure, it is possible to create a waveguide for the frequencies within the bandgap. Thus, the light can propagate along the created waveguide structure [1, 2].

The main research tasks are listed as follows:

- study TE waves propagation through the photonic crystal waveguide;
- investigation of the bandwidth variations at a variation of GaAs pillars diameter.

II. Simulation of the TE-waves propagation through the photonic crystal waveguide

In order to simulate the propagation of electromagnetic waves through the photonic crystal waveguide in this work we consider propagation of the transverse component of light (TE wave). The geometry of an investigated photonic crystal waveguide is a lattice of GaAs pillars surrounded by an air (fig.1). The pillars diameter of an investigated photonic crystal waveguide is d = 300 nm and the distance between pillars centers (pitch) Λ = 750 nm. Thus, the ratio d/Λ=0.4. We simulated TE-waves propagation through the photonic crystal waveguide within the infrared spectrum in the wavelength range from 0.8 to 2.5 microns. The calculation performed for 300 values of wavelength.

To study TE waves propagating through the crystal we used a scalar equation for the transverse electric field component E_z, as in

$$-\nabla\cdot\nabla E_Z - n^2 k_0^2 = 0 \qquad (1)$$

where n is the refractive index and k_0 is the free-space wave number.

To model the propagation of electromagnetic waves through the waveguide, we have introduced a plane wave Ez to the left boundary of the structure and made calculations of power outflow P_{out} through the right border of considered structure. In our research, we used finite element method (FEM) [3].

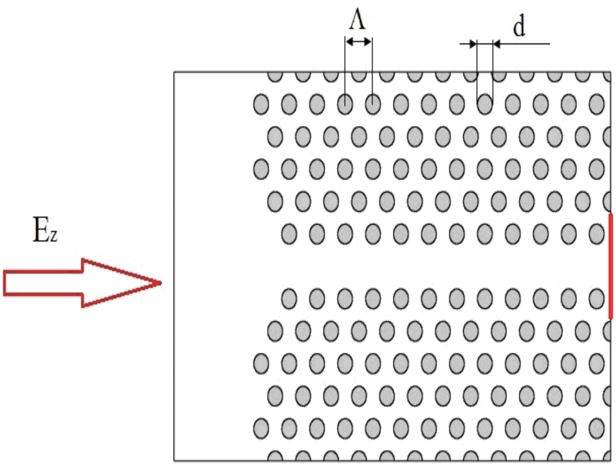

Fig. 1. The geometry of an investigated photonic crystal waveguide

Figure 2 shows the normalized power outflow through the photonic crystal and through a waveguide (Fig. 2 (a)), and it is also represents the TE waves distribution through the photonic crystal waveguide at wavelengths within the PBG (Fig. 2 (b)), and below PBG (Fig. 2 (c)). As you can see from the figure, the bandwidth of the considered waveguide is within 1.58-2.35 mkm.

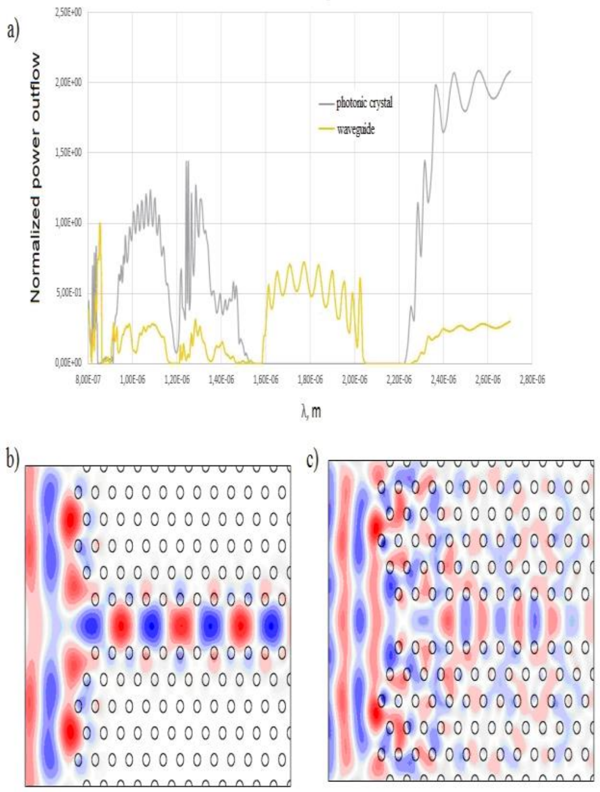

Fig. 2. TE waves propagation through the waveguide a) normalized power outflow versus the wavelength passing through the waveguide; b) TE waves propagation at wavelength within PBG, λ=1770 nm; c) below PBG, λ=1380 нм

III. Investigation of the Bandwidth Variations at a Variation of GaAs Pillars Diameter

To conduct the study, we changed the value of the diameter of the columns from 200 nm to 350 nm with steps of 25 nm (only 7 values). Figure 3 shows the bandwidth of waveguides with a pillar diameter 350, 300, 250, 200 nm.

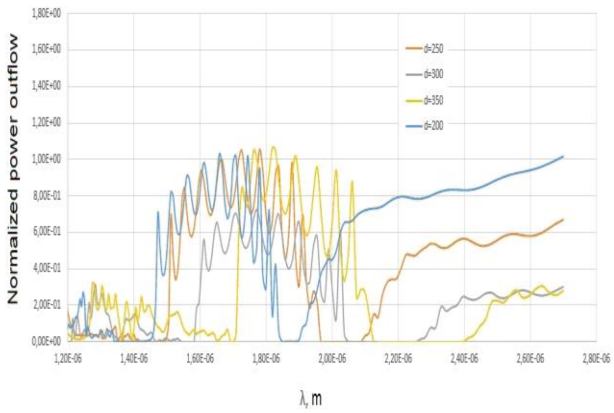

Fig. 3. Bandwidth of considered types of waveguides

Figure 3 also shows, that the waveguide bandwidth shifts to shorter wavelengths with decreasing of pillars diameter and shifted to longer wavelengths with increasing of pillars diameter.

IV. Conclusions

Obtained results show that the bandwidth of the considered types of photonic crystal waveguide shifts to the longer wavelength with the increasing of pillars diameter and shifts to the shorter wavelength with the decreasing of pillars diameter. Note that presented results also in good agreement with the results that we obtained in [4, 5]. We believe that all obtained results will be helpful for creating ultra-compact optical components and can be used to create ultra-compact photonic crystal filters of optical radiation.

References

[1] L. Oyhenart and V. Vigneras, *Photonic Crystals – Introduction, Applications and Theory*. Published by InTech, pp. 267–290, March 2012.

[2] J.D. Joannopoulus, R.D. Meade, and J.N. Winn, *Photonic Crystals*. Princeton University Press, 1995.

[3] Jiaming Jin *The finite element method in electromagnetics*. John Wiley & Sons Inc., pp. 5-9, 2002.

[4] A.I. Filipenko and A.N. Donskov "Influence of Geometrical Structure on the Pass Band of 2-D Photonic Crystal Filter", *Telecommunications And Radio Engineering*, pp. 985-993, Vol. 73, 2014.

[5] A,I. Filipenko and A.N. Donskov, "Investigation of the 2-D Photonic Crystal Filter", in *International Conference on Advanced Optoelectronics and Lasers* (CAOL 2013), pp. 58-59, 2013. ISBN: 978-1-4799-0019-0