SELF COLLIMATION IN PILLAR TYPE PHOTONIC CRYSTAL USING COMSOL

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Abstract- *A photonic crystal provides a possibility to control and manipulate the propagation of light. Many numerical methods have been used to study photonic crystal structures. Among them, comsol multiphysics have been used here to design photonic crystal structure. Also the study of TE and TM waves propagating through the crystal are considered. Electromagnetic waves incident onto such PCs from directions covering a wide range of incident angles become highly localized along a single array of rods, which results in the narrow-beam propagation without divergence. The Self-collimation is dispersion-related phenomenon, which possesses sufficient bandwidth to function as an effective waveguide mechanism through a substantial propagating distance.*

Index Terms: Photonic crystal (PhC), Self-collimation (SC), Transverse Electric waves (TE) and Transverse Magnetic waves(TM).

I.INTRODUCTION

In recent years the devices based on self-collimation of light beams and negative refraction in PhC without geometry variation are proposed. Self- collimation (SC) effect, by which an incident light can propagate with almost no diffraction and no engineered defect in PhCs, has attracted particular attention because of its potential for photonic integrated circuit (PIC). Self-collimation is independent of light intensity, nonlinear propagation and frequency ranges.

Moreover compared with engineered defect PhCs waveguides, self-collimation doesn't required lateral Confinement to prevent either the beam divergence or diffraction broadening and it can release strict alignment for coupling light into narrow waveguide. To use these effects in practical device, it is essential that light can be coupled efficiently into and out of the PhC structure with minimal back-reflection. The self-collimation effect relies on the special dispersion properties in PhC, where the curvature of equi-frequency counter (EFC) departed from the normally circular curvature in free space. Technically speaking, in contrast to the hole-type PCs, the pillar-type structure has significant potential for use with active components because of the possibility of electrical contacting and the heat dissipation capability. Moreover, the rods are more suitable for sensing applications because light interacts with the medium (to be sensed) that surrounds the rods more strongly, and in optofluidics, the rod structure may allow for better fluid penetration than the structure consisting of air holes in a dielectric slab.

II.PHOTONIC CRYSTAL STRUCTURE

A photonic crystal (PhC) is a periodic structure having a refractive index that is modulated with a wavelength-scale periodicity. The crystal can be periodic in one, two, or three dimensions. Instead of using a three-dimensional photonic crystal for wave guiding purposes, one could use a two-dimensional crystal. A two-dimensional photonic crystal responds differently to TE and TM polarization, where TE is the polarization with the E-field component in the plane of the circuits, and TM is the polarization with the E-field component parallel to the rods or holes. The polarization sensitivity of a two dimensional photonic crystal can be used to make micron size polarization filters or

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splitters E.g., a crystal with a TM band gap would filter out this polarization, while allowing the TE polarization to pass through By placing such a crystal under an angle with respect to the incoming waveguide, the reflected TM polarized light can be captured in a second output waveguide and a polarization splitter is created.

III.METHODOLOGY

In PCs, the direction of light propagation completely depends on the gradient direction of the corresponding EFC because the direction of light propagation is identical with the group velocity $v_g = \nabla_k \omega(k)$, where ω is the optical frequency at the wave vector k. Therefore, the SC effect can be considered to be due to the flat part of the EFC. However, this non diffractive propagation is limited to functions using a rather wide beam, with the wave vectors restricted to the local flat portion of the EFC.

In this paper we Design a photonics crystal using RF module using comsol multiphysics simulation software.

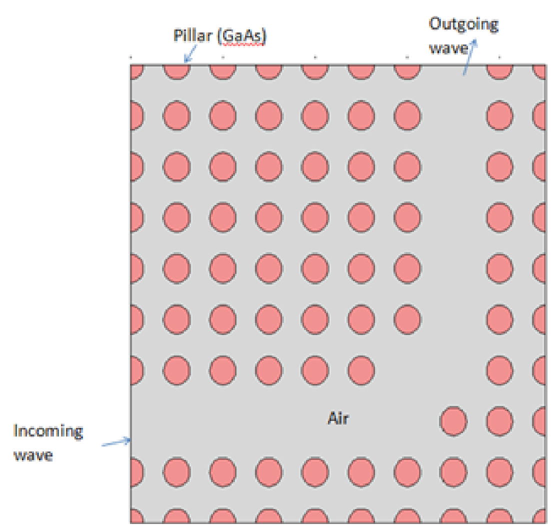

Figure 1: Schematic of a 2-D pillar-type PC consisting of a square lattice

This model describes the wave propagation in a photonic crystal that consists of GaAs pillars placed equidistant from each other. The distance between the pillars prevents light of certain wavelengths to propagate into the crystal structure. Depending on the distance between the pillars, waves within a specific frequency range are reflected instead of propagating through the crystal. This frequency range is called the photonic bandgap. By removing some of the GaAs pillars in the crystal structure you can create a guide for the frequencies within the bandgap. Light can then propagate along the outlined guide geometry.

The geometry is a square of air with an array of circular pillars of GaAs as described above. Some pillars are removed to make a waveguide with a 90° bend. The objective of the model is to study TE waves and TM waves propagating through the crystal. To model these, use a scalar equation for the transverse electric field component *Ez*,

$$-\nabla\nabla Ez - n^2 k0\ ^2 Ez = 0$$

Where n is the refractive index and $k0$ is the free-space wave number. Because there are no physical boundaries, you can use the scattering boundary condition at all boundaries. Set the amplitude *Ez* to 1 on the boundary of the incoming wave. For magnetic field component the scattering boundary conditions *Hz* is 0. In this case a photonic crystal lattice is constructed from gallium arsenide (GaAs) and air holes as rods. The refractive index of the gallium arsenide combination is 3.66 and the refractive index of air is 1.005.The refractive index of GaAs depends on the frequency. The expression used in this model defines a linearzed frequency dependency between the refractive index values corresponding to the free space wavelengths 1.0332 µm and 1.2339 µm

IV.RESULTS

The z component of the electric field showing how the wave propagates along the path defined by the pillars in figure 2.

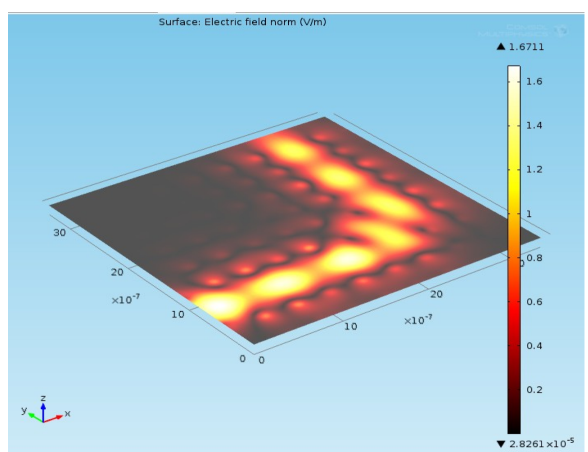

Figure 2: Distribution of electric fields z component (EZ) for 1µm

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If the angular frequency of the incoming wave is less than the cutoff frequency of the waveguide, the wave does not propagate through the outlined guide geometry. In Figure 3 the wavelength has been increased by a factor of 1.17.

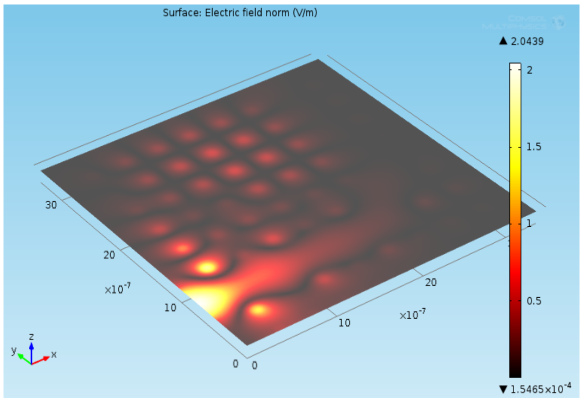

Figure 3: Distribution of electric fields z component (EZ) for 1.2µm

Hence a free space wavelength of 1 µm, is within the bandgap. The wave propagates all the way through the geometry, losing only a little of its energy. The y component of the magnetic field showing how the wave propagates along the path defined by the pillars in figure 6.

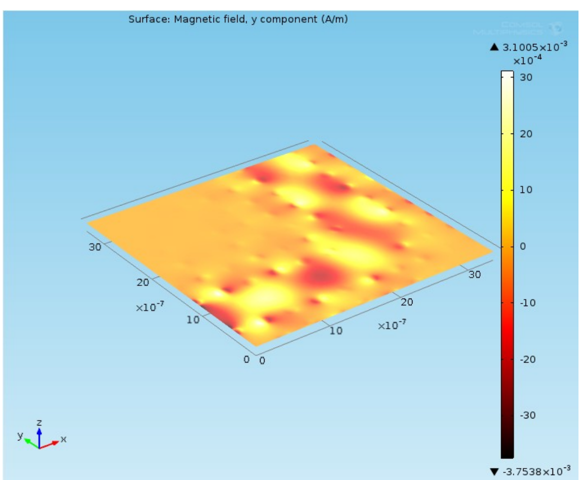

Figure 6: Distribution of magnetic fields y component (EZ) for 1µm

It shows that the wave does not propagate through the pillars. So while seeing this TE modes are comparatively achieves the better wave propagation.

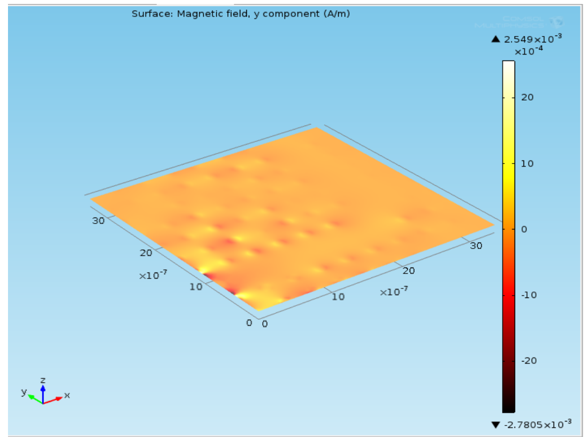

Figure 5: Distribution of electric fields y component (EZ) for 1.2µm

Depending upon the wave propagation through the crystal the energy band occurs for both the frequency in TE and TM modes. In that one will exponentially decline along the plot line.

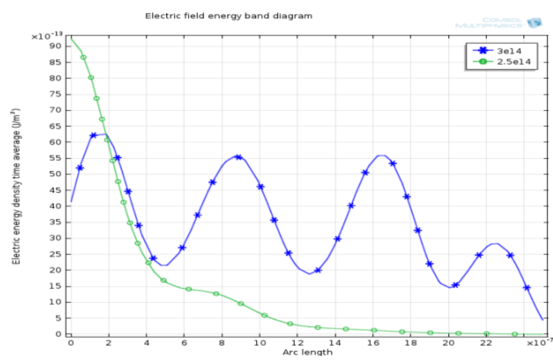

Figure 6: Energy band diagram for Electric field

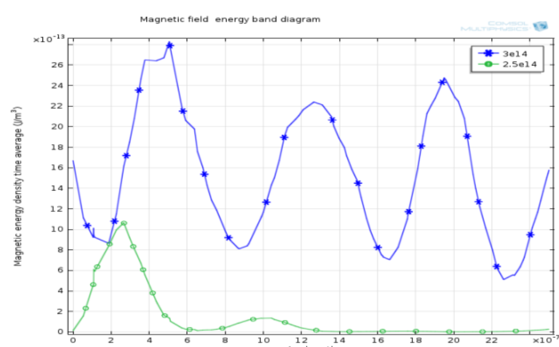

Figure 7: Energy band diagram for Magnetic field

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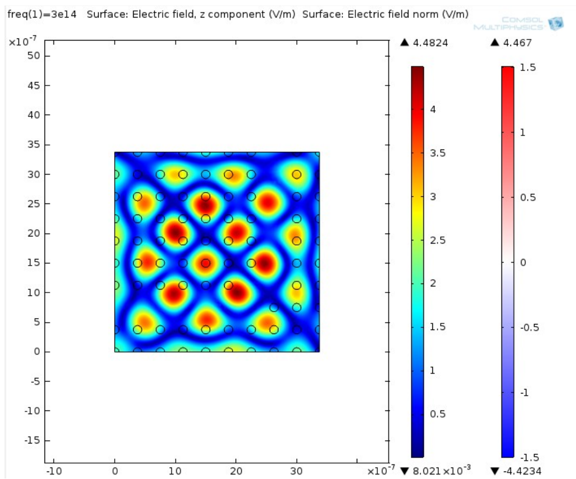

Figure:8 Self-collimated beam for 1μm wavelength

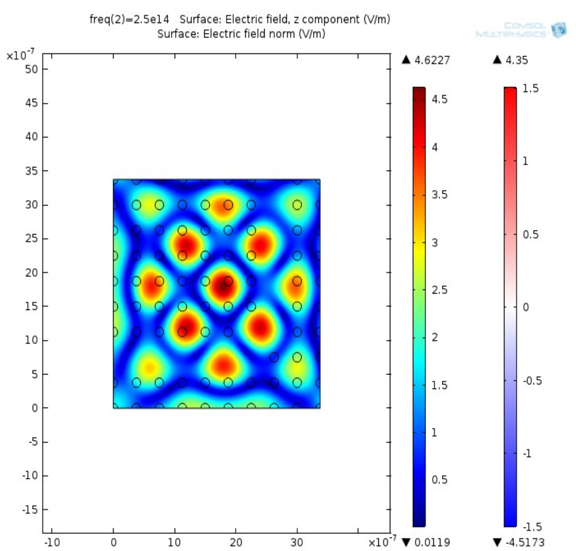

Figure: 9 Self-collimated beam for 1.2μm wavelength

Within the frequency range of self-collimation, the sum of the transmitted power reaches near 100% over the entire self-collimation bandwidth. Hence Self-collimated beams in photonic crystals are evaluated for applicability in an on-chip interconnect system.

V.CONCLUSION

In this paper we have studied and designed, a structure based on pillar type photonic crystal using comsol multiphysics simulation , we have shown that the distribution of TE waves and TM waves propagating through the crystal. So the field pattern shows the 100% transmission efficiency for 1μm wavelength. Also, we observed the self-collimation phenomenon. Pillar-based photonic crystal waveguides can successfully be integrated in photonic integrated circuits. Plane, line or point defects can be introduced into photonic crystals and used for making waveguides, microcavities or perfect dielectric mirrors by localization of light.

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