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Feasibility Study on Self-Collimated Light-Focusing Device Using 2-D Photonic Crystal with a Parallelogram Lattice

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1. Introduction

Recently, the superprism phenomena [1] and self-collimating phenomena [2] in photonic crystals (PCs) have received attention. Many studies from the viewpoint of equal-frequency contours behavior in dispersion surface have been reported for the PCs with air holes arranged on triangular, square or rectangular lattices [3]-[5], but little has been reported on parallelogram lattice.

We studied the light-focusing device using the 2-D PCs with various lattice structures. For square lattice in which equal-frequency contours have $\pi/2$ rotational symmetry, a preferable result was not obtained. So, we address on the parallelogram lattice and study the feasibility of the light-focusing device for the optical-chip.

2. Device structure

Figure 1 shows the parallelogram lattice structure. Side lengths of the parallelogram are a=500nm and 578.3nm, respectively, and the smaller angle is assumed to be 81.6°. The radius of the air holes is 160nm. The equal-frequency contours for the first band of 2-D PC with the parallelogram lattice formed in silicon medium are shown in Fig.2 for the TE wave. Contours near f=0.17 c/a (f: frequency, c: light speed in vacuum) have shape that resembles a parallelogram in appearance. We also found that the collimation vectors don't have $\pi/2$ rotational symmetry, and wide-angle-collimation and narrow-angle-collimation lights exist depending on this $\pi/2$ asymmetry. The light-focusing device is composed by using this wide-angle-collimation light.

Figure 3 shows the PC structure of self-collimated light-focusing device. Large arrows indicate the direction of the wide-angle-collimation light propagation, and have the angle of 18° for junction plane. The light injected vertically from input interface is collimated and is collected with angle of 18°.

3. Simulation model and results

The structure of light-focusing device for FDTD simulation is shown in Fig.4. Silicon PC of 300nm in thickness and 10μm in width is put on SiO_2 substrate. The y-component of electric field is excited, and. the propagation characteristics of TE wave are examined. Figure 5 shows the simulated electric (E_y) field distribution in the horizontal (yz) plane of the light-focusing device. It is seen that the injected light is collimated and collected. Energy transmission coefficient obtained from the energy flows through the input and output observation planes is shown in Fig.6. The input and output observation planes shown in Fig.5 have 7.2μm and 2μm widths, respectively. It is found that the optimum value exists in the PC length because transmission coefficient has peak value 0.55 at 8 μm in PC length. The arrangement of the air holes in the vicinity of the interface to which two crystals are connected largely influences. The air holes should not be periodically arranged near junction plane. Since strong standing wave is seen on the injection side, impedance matching is also important. The coefficient has increased up to 0.59 when the quarter wavelength impedance matching layer is put on the injection interface.

These results indicates that proposed light focusing device is possible to work.

4. Summary

The feasibility of the light-focusing device using 2-D PC with parallelogram lattice was studied. It has been shown that the equal-frequency contours for the parallelogram lattice have not $\pi/2$ rotational symmetry, and proposed light focusing device is possible to work.

Acknowledgment

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References

[1] H. Kosaka, T. Kawashima, A.Tomita, M. Notomi, T. Tamamura, T. Sato, and S. Kawakami, *Physical Review B*, **58**, (1998)R10096.
[2] H. Kosaka, T. Kawashima, A.Tomita, M. Notomi, T. Tamamura, T. Sato, and S. Kawakami, *Appl. Phys. Lett.*

74(1999)1212.
[3] X. Yu, *Appl. Phys. Lett*. **83**(2003)3251.
[4] A.I.Cabuz, E.Centeno, and D. Cassagne, *Appl. Phys. Lett*. **84** (2004)2031.
[5] T. Matsumoto and T. Baba, *J. Lightwave Tech*. **22**, (2004)917.

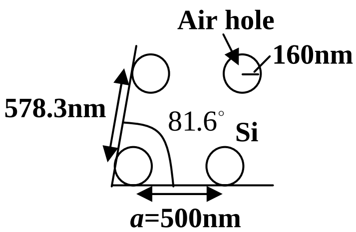

Fig. 1 Parallelogram lattice structure.

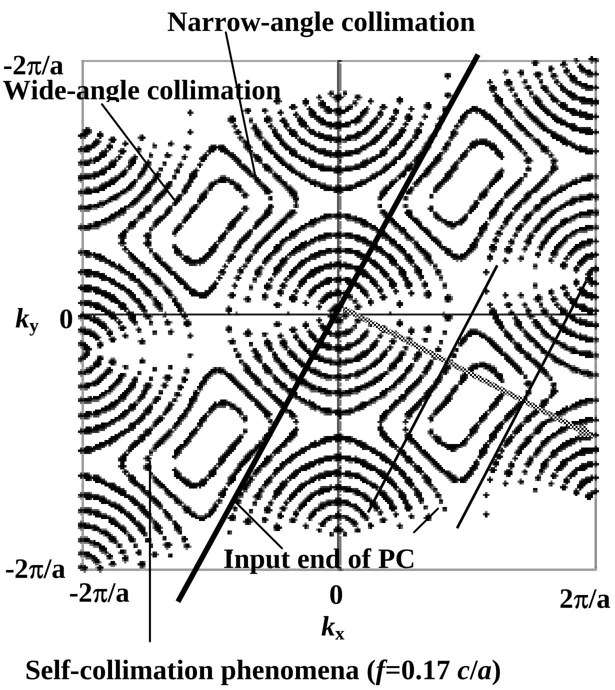

Fig. 2 The equal-frequency contours of parallelogram lattice for the TE wave. Self-collimation phenomena occur near f=0.17c/a. This collimation vectors don't have $\pi/2$ symmetry.

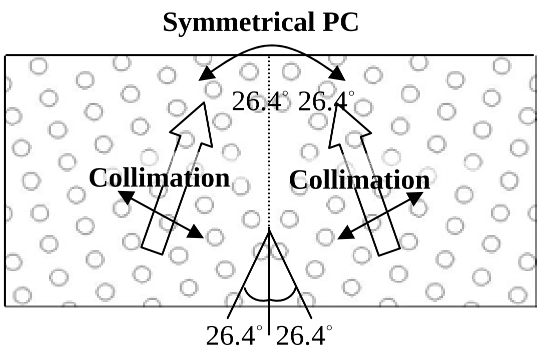

Fig. 3 Structure of self-collimated light-focusing device.

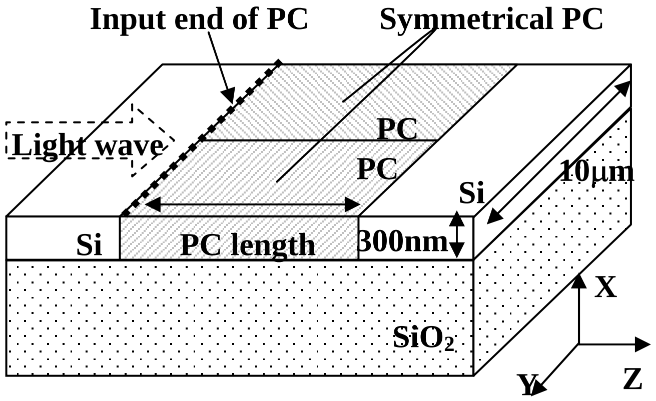

Fig. 4 the light-focusing device structure for FDTD simulation.

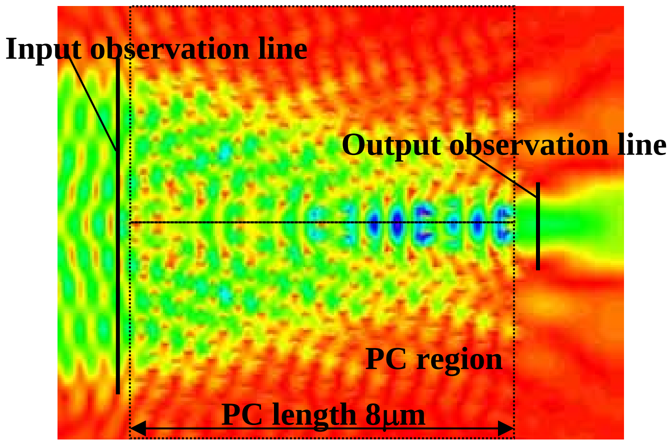

Fig. 5 Electric field (Ey) of light-focusing device by FDTD simulation.

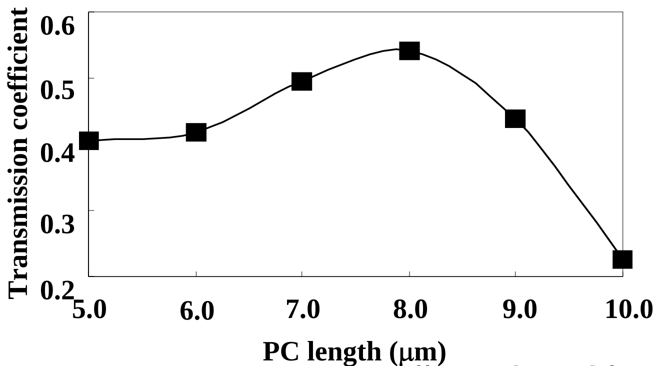

Fig. 6 Energy transmission coefficient obtained from the energy flows through the input and output observation planes.