An all Optical Photonic Crystal Based FSK Demodulator Suitable for Optical Communications

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Abstract

Optical frequency shift keying demodulator is an optical structure that can generate logic 0 and 1 codes based on the frequency of the input signal. In this paper we proposed and designed a new structure for realizing frequency shift keying demodulator based on photonic crystals. The propose structure was designed using resonant cavities. The simulation results show that by setting the frequency of the input signal at 191 THz and 192.3 THz the proposed structure can generate log 0 and 1 bits. The rise time of the proposed structure is about 2 ps.

Keywords: Optical Communications, Photonic crystal, FSK demodulator, Resonant cavity.

1. Introduction

In digital communications the data and information produced by digital devices are in digital form. However the signals used for transferring these data are continues analog waves. The technique that can be used for transferring digital data using analog signals is called modulation. Frequency shift keying (FSK) is one type of modulations in which the binary and digital codes are created using two different frequencies for the carrier signal. A typical FSK demodulator is a device which can produce logic 0 and 1 codes based on the frequency of the input signal.

Considering the current demands for high speed, high bit rate and high band width communication networks, the conventional communication technologies are not able to cope with this ever increasing demands. Therefore optical communications are going to dominate communication industry [1]. In optical communication, the optical waves and photons are used as the carrier signal. It is obvious that we can gain full advantage of optical communication benefits only if the total network works in optical domain without using any non-optical phenomena. To reach such a goal we should have all optical devices that are required in optical communications.

Recently it has been widely proven that photonic crystals (PhCs) have great potentials to be used in the future generation of optical communication industry [2–7]. Existence of photonic band gaps (PBGs) in their band structure diagram helps them at controlling the propagation of optical waves and photons [8–10]. The growth rate of PhC-based structures is such high that in less than two decades almost any kind of optical circuits that can be used in optical communication have been designed based on these periodic structures, such that very various methods have been proposed for designing optical filters [11–18], demultiplexers [19–28], logic gates [29–35], adders [36–43], decoders [44–48], encoders [49–54], comparators [55–57], subtractors

[58–60] and multipelxers [61]. Each of these devices can be used in some sections of optical communication networks like optical transmission and optical processing.

The only PhC-based demodulator that has been proposed previously is an optical phase shift keying demodulator [62]. In this work the proposed structure is capable of producing logic 1 and 0 bits based on the initial phase of the carrier signal. The proposed structure works based on constructive and destructive interference of optical beams. Optical analog to digital converters (OADCs) are other class of optical devices that have similar functionalities with optical demodulators. Mehdizadeh et al [63–65] proposed different designs for realizing OADCs using nonlinear cavities and ring resonators. Also Tavousi et al [66, 67] presented other structures for creating OADCs.

In this paper we are going to design and propose an all optical FSK demodulator. For designing the proposed structure we will use resonant cavities. The proposed structure will be designed using linear materials and there is no need to use nonlinear Kerr effects and high amount of optical powers.

2. PhC-Based Resonant Cavity

As mentioned the proposed structure for optical FSK demodulator will be designed using resonant cavities. Therefore first of all we design an optical cavity. The resonant cavity was created inside a 2D square lattice PhC composed of Silicon rods with the radius of 207 nm. The lattice constant of the PhC is 690 nm. For creating the suitable cavity we remove 3 rods in vertical direction, then located two defect rods with reduced radius at the corners of the cavity like figure 1. The radius of these defect rods is R=85 nm. In order to investigate the optical properties of the proposed resonant cavity, we used the proposed cavity inside an optical filter like figure 2. As shown the resonant cavity was located between an input and an output waveguide.

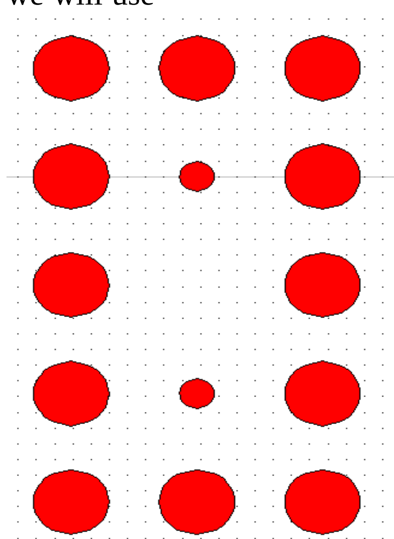


Fig.1. The resonant cavity.

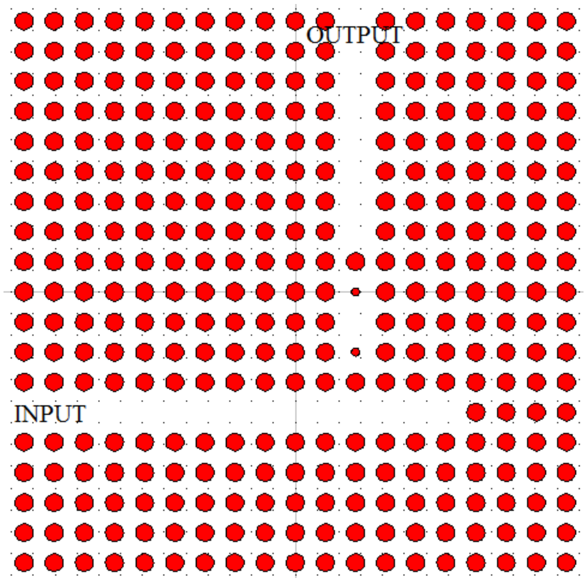


Fig.2. The optical filter.

The output spectrum of the proposed cavity is shown in figure 3, which shows the proposed cavity has a resonant mode at 1552 nm. The transmission efficiency and band width of the resonant mode are 95% and 3 nm respectively. I order to investigate the effect of defect rods radius on the optical behavior of the cavity the output spectra of the cavity for different values of R are calculated and presented in figure 4. As shown the by increasing the radius of defect rods the resonant mode shifts toward higher wavelengths.

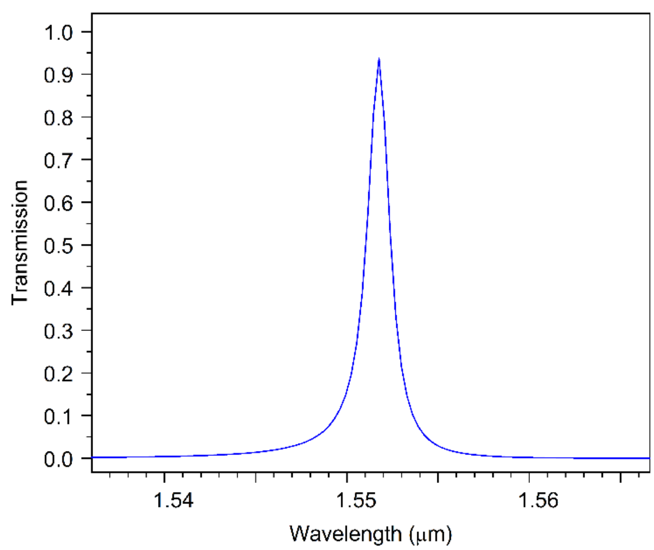


Fig.3. The output spectrum of the filter.

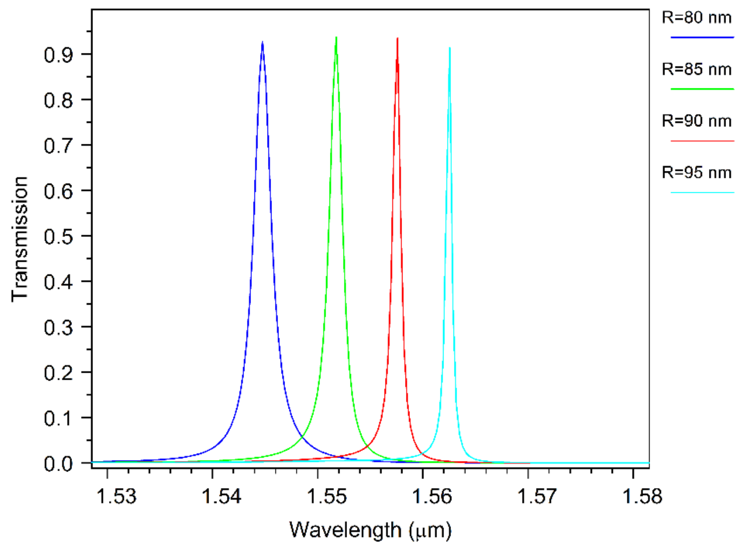


Fig.4. Output spectra of the filter for different values of R.

Also for investigating the effect of defect rods refractive index on the optical behavior of the cavity, the output spectra of the cavity for different values of the refractive index are calculated and presented in figure 5. As shown the by increasing the refractive index of defect rods the resonant mode shifts toward higher wavelengths.

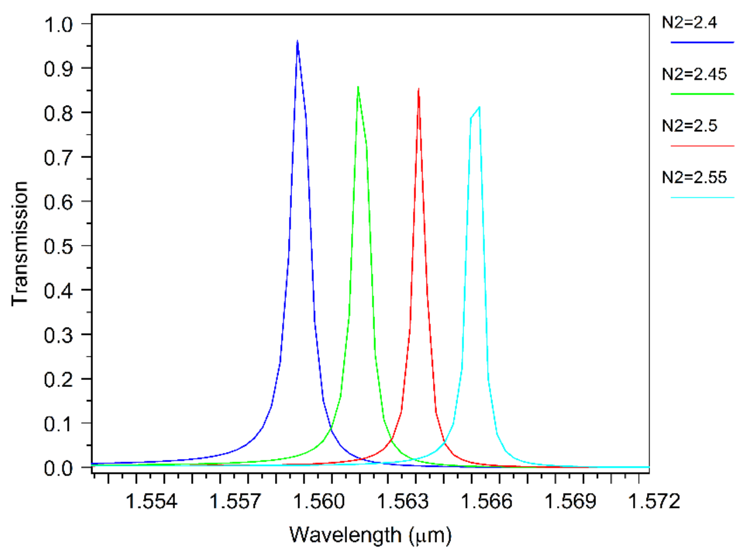


Fig.5. The output spectra of the filter for different values of N.

3. Optical FSK demodulator

In this section we are going to present the design procedure and simulation results for the proposed FSK demodulator. The fundamental PhC structure used for designing the proposed structure is a 2D square lattice array of Silicon rods with 38 columns and 20 rows. For a two level FSK demodulator one output port is required, whose ON or OFF states can be used for generating the logic 1 and 0 bits. But for this structure we use an extra port for amount of back reflection of input signals toward the input port. Therefore two resonant cavities are required for designing the proposed structure. These cavities should have different resonant modes. By using the results presented in section 2, we know that by choosing different values for the radius or refractive index of defect rods it is possible to obtain two different resonant cavities with different resonant modes. Also we know that choosing different radius is simpler than using different refractive indices. Therefore we chose two different values for the radius of defect rods. The radius of defect rods for the C1 and C2 cavities are 80 and 90 nm respectively. The final structure is shown in figure 6. The O port is for the output port of the optical demodulator and the Idle port is for preventing the back reflection toward input port.

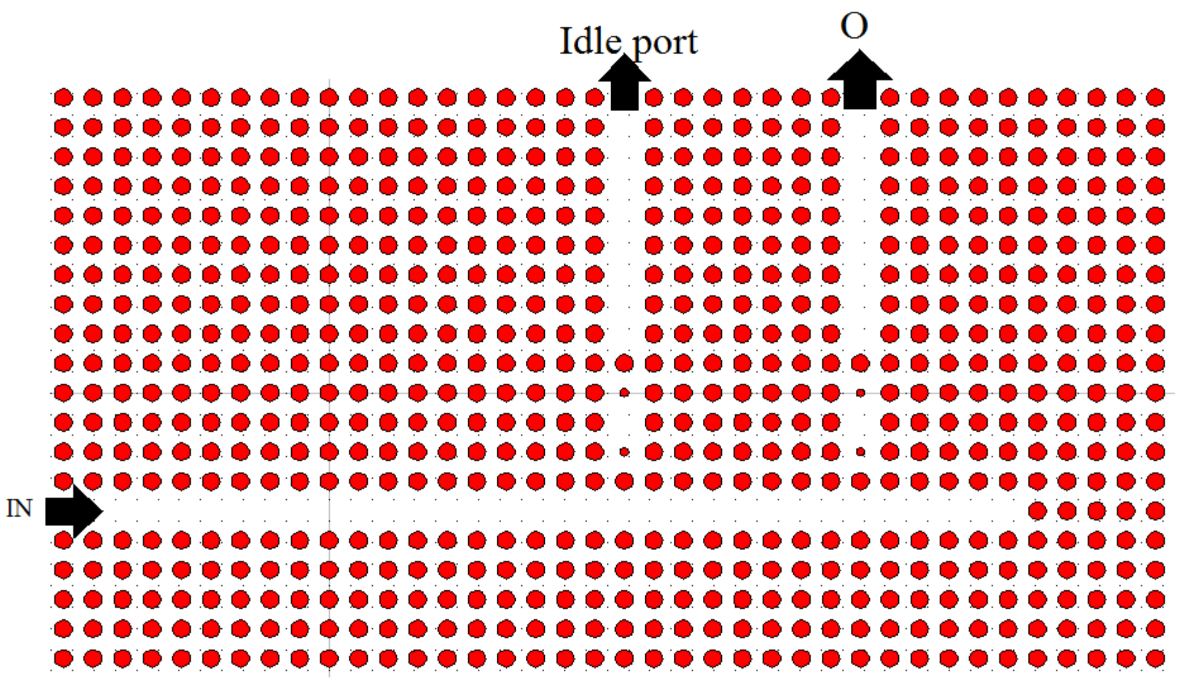


Fig.6. The optical FSK demodulator.

The output spectra of the proposed structure is shown in figure 7. As shown the proposed structure has two resonant modes. The resonant mode of the main output port is at 1560 nm which is equal to 192.3 THz. Also the resonant mode of the Idle port is at 1570 nm which is equal to 191 THz. It means if we launch optical waves with frequency of 192.3 THz they will exit from O and if we launch optical waves with frequency of 191 THz they will exit from the Idle port as shown in figure 8. In other words if we set the frequency of input signal on 191 THz, the O port will be OFF and the proposed structure generates logic 0 at the output port. Due to existence of the Idle port these optical waves exit the structure from this port and won't be back reflected toward the input port. If we set the frequency of the input signal at 192.3 THz, the O port will be ON and the proposed structure generates logic 1 at the output port. Time response diagram of the proposed structure is shown in figure 9, which shows that the amount of normalized intensity and the rise time for the generated logic 1 are 90% and 2 ps respectively.

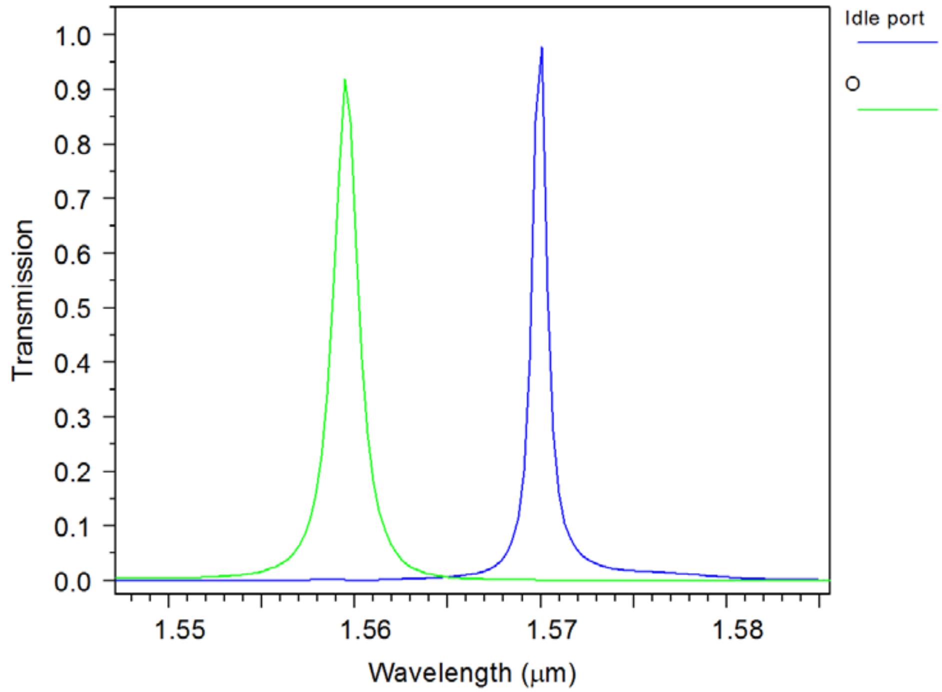
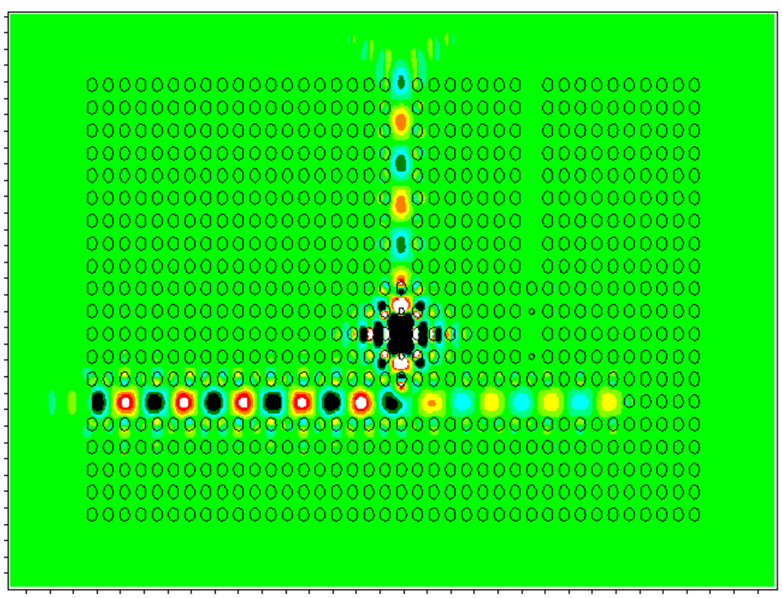
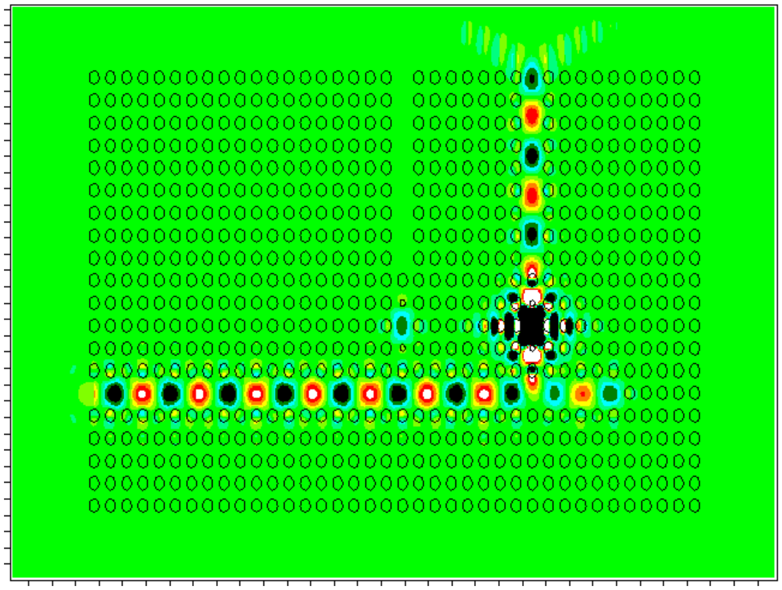


Fig.7. The output spectra of the proposed structure.



(a)



(b)

Fig. 8. The optical behavior of the proposed structure.

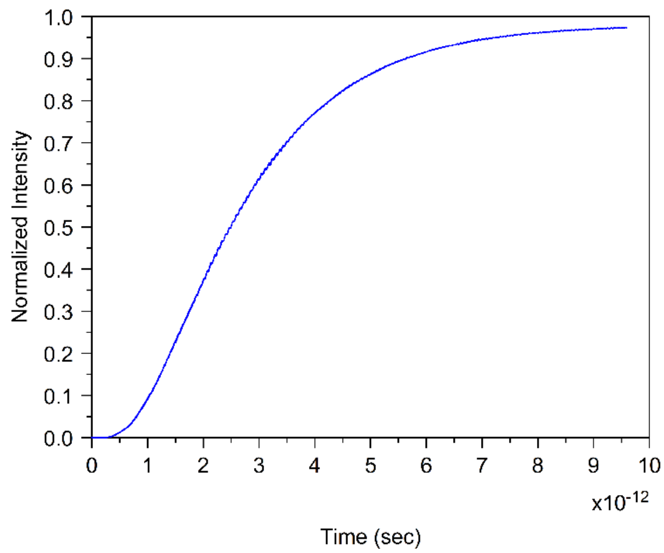


Fig.9. Time response diagram of the proposed structure.

Conclusion

An optical resonant cavity was created inside a 2DPhC. It has been shown that the resonant mode of the cavity is sensitive upon the variation of defect size and refractive index of defect rods. So it is possible to design a 2-channel structure by using two resonant cavities with different defect sizes. Then the proposed structure for optical FSK demodulator was designed. The simulation results show that by setting the frequency of the input signal at 191 THz and 192.3 THz the proposed structure can generate log 0 and 1 bits. The rise time of the proposed structure is about 2 ps.

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