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طراحی بهینه دی مالتی پلکسر سه کاناله نوری مبتنی بر کریستال های فوتونی

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چکیده – برای بهبود عملیات دی‌مالتی پلکسینگ در سیستم های مخابرات نوری یک ساختار خیلی فشرده با استفاده از حفره های رزونانسی در ساختار کریستال های فوتونی پیشنهاد شده است. هدف این طراحی، بهبود فاصله کانالی وکاهش آن تا *2nm* **می باشد. دی مالتی پلکسر موردنظر، فضایی برابر با** $16.5\mu m \times 6.5\mu m$ **اشغال می کند، این مقدار به خوبی نشان می دهد که این ساختار بسیار کوچک می‌باشد و به آسانی می تواند مجتمع شده و در مدارات مجتمع نوری با تکنولوژی نانوفوتونی به کار روند. خروجی طول موج های ساختار طراحی شده، می‌تواند برای کاربرد-های مخابراتی حدودا** *1550 nm* **به کار برده شود.**

کلید واژه- حفره‌ی رزونانسی، کریستال فوتونی، مدارات مجتمع نوری، نقص

Optimum Design of a Three Channel Demultiplexer Based on Photonic Crystal

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Abstract- We propose an ultra-compact structure to realize demultiplexing operation for Wavelengh Division Multiplexing (WDM) communication systems using resonant cavity in Photonic Crystal (PC) structure. This design improves the channel spacing which is reduced up to 2nm. The proposed demultiplexer has an area equal to ($16.5\ \mu m \times 6.5\ \mu m$) and thus it is verified that this structure is very small and can be integrated easily into optical integrated circuits with nanophotonic technologies. The output wavelengths of designed structure can be tuned for communication applications, around 1550 nm.

Keywords: Resonant cavity,Photonic crystal, Integrated optics, Defect

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1 Introduction

Photonic crysta (PCs) are very suitable candidates for realization of future passive and active optical devices[1]. Structures based on PCs enable researchers to design small-scale devices.

On the other hand, these structures offer the potential to be integrated on a single chip. Optical circulators [2], optical filters [3], optical switches [4,5] and power splitters [6] are some reported examples of photonic crystal based devices in research laboratories. An important application of PCs is the realization of devices for use in Wavelength Division Multiplexing (WDM) and Dense WDM (DWDM) systems. To the best of our knowledge photonic crystal is among the best alternative for design compact optical integrated circuits. For realization of demultiplexer operation according to DWDM standard, resonant cavity is one of the best choices that can be used in PC based structures. High quality factor resonant cavities are capable to filter the desired wavelengths with bandwidth suitable to DWDM. An in-plane-type channel-drop filtering device based on point defect cavity has been investigated in a two-dimensional photonic crystal slab [7]. But maximum value of the drop spectrum intensity in such structure was low 0.1 (a.u.). This is a very weak signal to be detected at destination in demultiplexing operation, thus, it could not be suitable for demultiplexing operation. In another case [8], a two channel wavelength division demultiplexer with 5.8 nm channel spacing and average quality factor of about 1000 has been studied. In another work, a ultra compact photonic crystal wavelength division demultiplexer using resonant cavities in a modified Y-Branch structure with 3.5 nm channel spacing and a quality factor Q = 1450 has been proposed [9]. Bouamami and et al could reach 107.25 μ m WDM that is suitable for integration into optical integrated circuits. In the following lines we present our design of demultiplexer.

2 Method and Analysis

For scrutiny and study electromagnetic waves behavior in periodic structures such as PCs, numerical solutions are used. Popular methods for numerical solutions commonly used for frequency domain consist of the plane wave expansion (PWE) [10] and multiple scattering theories [11].

Also nowadays, there is a popular method, proposed for the first time by Yee in 1966 Finite Difference Time Domain (FDTD) [12]. We try to consider several main parameters such as bandwidth, crosstalk, channel spacing, quality factor, output efficiency and size for designing favorable demultiplexer. Essential parameters are the low channel spacing and narrow bandwidth. The final goal is that the ultimate structure be simple without any complexity in the viewpoint of design and fabrication.

Fig. 1 shows the initial photonic crystal structure ($16.5\,\mu m \times 6.5\,\mu m$) consisting of air holes arranged by a triangular lattice, with lattice constant (a = 0.380 μm), radius (r= 0.130 μm), with refractive index n=3.181(InP), in air (n=1). In this structure, these parameters make it possible to show in the next paragraphs a design of a three-channel wavelength demultiplexer in the optical region (1.3–1.55 μ m). Before performing any work on the design of demultiplexer based on 2D photonic crystal the band structure and range of the type crystal bandgaps are calculated and extracted to determine whether the desired structure for our working wavelength is suitable or not.

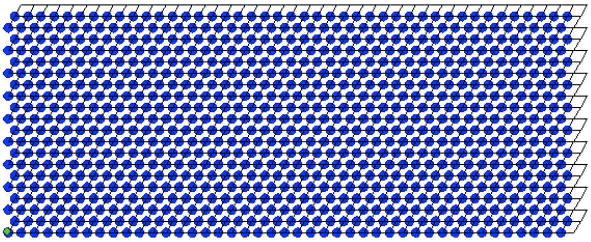


Figure 1: The initial photonic crystal structure.

To calculate the photonic bandgaps currently the best solution is to use numerical methods. One of the numerical methods is plane wave expansion (PWE), Usually special frequency alternating structure in the frequency domain with numerical solutions of Maxwell's equations to calculate. with drawing a two-dimensional diagram of the special frequency According to and Crystal photonic bandgaps obtained.

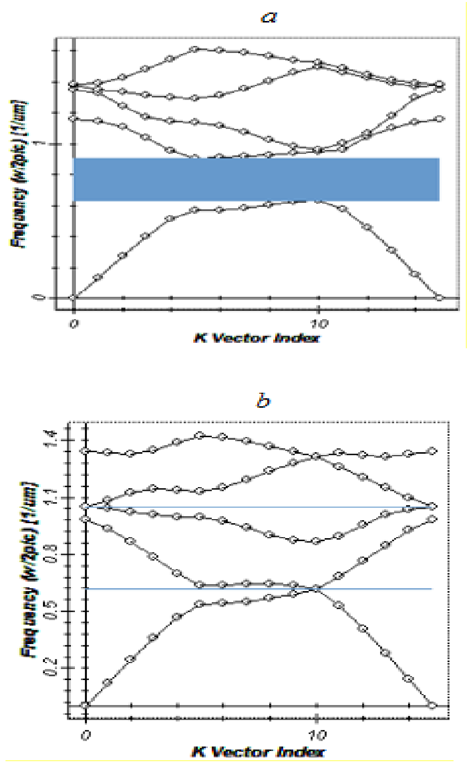


Figure 2: Dispersion curve for PC with R = 130 nm and a = 380 nm excited by light with (a) TE polarization and (b)TM polarization.

As shown in Fig. 2, this structure has a Photonic Band Gap for transverse-electric (TE) modes which extends from 1.58995 to 1.09510 μm, and for transverse-magnetic (TM) modes (1.6191-1.619986 μm and 0.954590-0.954827 μm) as shown in Fig. 2. A Photonic Band Gap (PBG) appears only for TE polarization and is displayed in the dark area. PBG is between 0.254 and 0.347 ca and 1095 1589 nm that is in the range of optical communication systems. In all our simulations we use the TE mode.

3 Simulation and Results

First of all, according to Figure 3, a resonant cavity structure that is able to select the desired wavelength with a bandwidth of demultiplexer are recommended. Some important parameters, such as Rc and Rd, demultiplexer operations are directly affected.

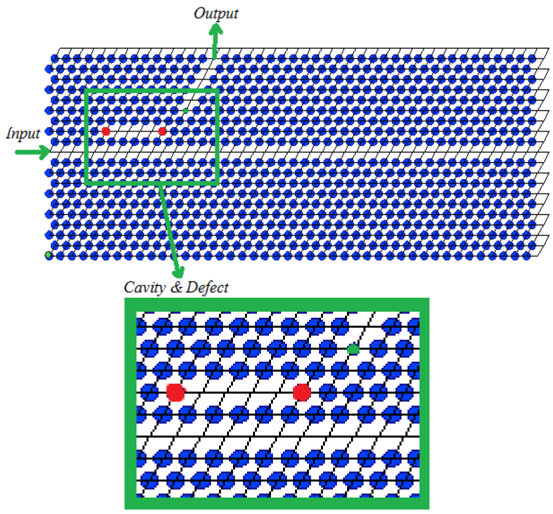
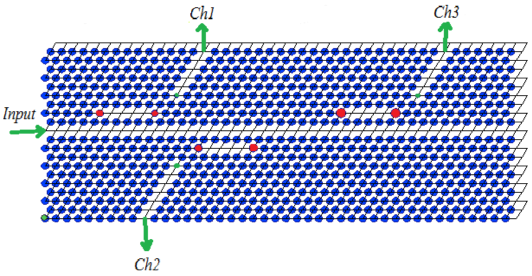
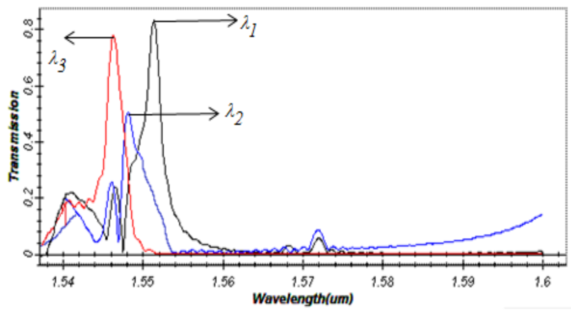


Figure 3: the resonant cavity with its defects.

The basic L4 Resonant Cavity (RC) region is achieved by omitting 4 holes. Resonant wavelengths can be accommodated in it and the regions to the left and right of RC play the role of mirrors using periodic dielectric structures, so that the system altogether behaves as a Fabry-Perot. Thus,this effective length can be increased or decreased byadjusting the number of missing holes and it can control constructive or destructive interferences at different wavelengths. For our goal, L4 cavity is suitable. Thus, by this choice the range of wavelengths would become suitable for Communication systems. The second important parameter is Rc, radius of corner defects. By changing them, due to changes in effective length of resonant cavity region, wavelengths channels adjacent to selected central wavelength in previous part are allowed to vary slowly and shift within some upper and lower bounds. In other words, it is the preferred second major parameter to apply small changes in selected wavelengths. As for the radius Rd of the hole in the output waveguide, it is used as a single filter that reduces the output spectral bandwidth and increases its amplitude. Our tests show that the best value is 53 nm. As seen in Fig. 5, the mentioned structure, when simulated with the different radius defects (Rci, i = 1, 2, 3) equal to 120 nm, 145 nm, 170 nm can select wavelengths 1550.9 nm, 1548.9 nm and 1546.6 nm respectively and the radius of defects in primary output is 53 nm in all of them. The output channel wavelength spacing is 2 nm.



Figuer5: Schematic design of seven channel demultiplexer based on photonic crystal waveguide.



Figuer 6: Representation of the demultiplexer output channels at $\lambda 1$, $\lambda 2$ and $\lambda 3$ wavelengths.

Table1: Simulation results of Dense wavelength division demultiplexer.

Channel	*λ0 (nm)*	*bandwidth*	*Transmission*
1	1550.9	۰.۹	83%
2	1548.9	0.۸	50%
3	1546.6	0.۷	78%

4 Conclusion

In this work we proposed a three-channel demultiplexer using resonant cavity in photonic crystal. The simplicity of the proposed structure is a good factor in comparison to other complex structures. According to the obtained FDTD simulation results, we reached the typical aims of optical communication demultiplexer systems with a PC based structure that has a small size and can be fabricated easily. The average values bandwidth of our structure is 0.۸ with exact 2nm channel spacing and thus it is verify that this structure is suitable for Communication systems applications.

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