Design and Simulation 4-Channel Demultiplexer Based on Photonic Crystals Ring Resonators

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ABSTRACT
In this paper, a new design of demultiplexer based on two-dimensional photonic crystal ring resonator is proposed. The structure is made of a hexagonal lattice of silicon rods with the refractive index 3.46 in coefficient of air with refractive index 1. The transmission efficiency and Quality factor for our proposed demultiplexer, respectively, are more than 65% and 1600. The normalized transmission spectra of the photonic crystal ring resonator are taken using Two-dimensional (2D) Finite Difference Time Domain (FDTD) method. The photonic band gap is calculated by Plane Wave Expansion (PWE) method.

KEYWORDS: Demultiplexer, Photonic crystal, Quality factor, Ring resonator

1. INTRODUCTION
Photonic crystals are new structures, that in recent years have attracted much attention due to their optical properties and potential that these reasons in the circuit design of optical and telecommunication networks have many applications. Photonic crystals are artificial structures which consist of periodic arrays of dielectric materials [1-3]. Photonic crystals can light waves in the micrometer range that is very small, incarcerate or conduct [2,4]. The most important feature of these structures is the photonic band gap. The photonic band gap to a region of the photonic crystal band structure is called that in this area, no wavelength is not allowed to release into the crystal [5-7]. By using the defects effects in photonic crystal structures, periodicity and photonic band gap have been broken, and the light is entered to a region of photonic band gap and this could lead to the design of optical devices based photonic crystals such as optical demultiplexers [8] and optical filters [9], and etc.

Ring resonators photonic crystal due to the coefficient of the high quality and the nature of their single mode ring and flexibility, have a choice of high spectral resolution that provides optical design types
of electronic devices [10]. In communication systems for optimal utilization of transmission channel capacity multiplex operation, and demultiplex signals occur. Demultiplexers are useful and essential elements of photonic integrated circuits which separate wavelengths multiplexed signals. In this paper, we designed a demultiplexer four-channel by using four ring resonators two-dimensional photonic crystal with the new structure. Also for simulation of electromagnetic wave propagation in time domain is used finite difference method in 2D time-domain (2D-FDTD) and to calculate the photonic band gap the plane wave expansion method (PWE) is used.

2. STRUCTURE DESIGN
There are several methods for the design of optical demultiplexers, according to the properties of ring resonators, the ring resonators can be a good option for the design of optical demultiplexers. From the main and important features of optical demultiplexers are for optical telecommunications systems, polarization-independent, crosstalk, high-quality spatial resolution and compression, allowing integration. Photonic crystals are with two topologies that first of them, contains a dielectric layer which air holes are introduced to periodically periodic, and second consists of dielectric rods, embedded on bed of air. In this paper, we designed the structure in Figure 1, based on 2D photonic crystals, of the silicon rods with refractive index 3.46, in the field of air with refractive index 1, is located. The number of rods in the x and z directions are respectively, 34 and 31. Lattice constant of the entire structure (a) is equal to 583 nm, and the radius of each of the rods is equal to 115 nm.

![Figure 1](image-url)  
**Figure 1.** Shows our proposed demultiplexer.

This structure consists of two photonic band gap in TM mode and one photonic band gap in TE band. Normalized frequency of the first photonic band gap of above corresponds to TE mode is equal to 0.87631 ≥ a/λ ≥ 0.82264, which corresponds to a wavelength range from 0.665 to 0.708 micrometer. The second photonic band gap that is related to the TM mode, the normalized frequency is 0.59349 ≥ a/λ ≥ 0.56915 and the wavelength range is from 0.982 micrometer to 1.024 micrometer and the last photonic band gap that is related to the TM mode, the normalized frequency is 0.45056 ≥ a/λ ≥ 0.27753 and the wavelength range is from 1.293 micrometer to 2.1 micrometer. **Figure 2** shows the band structure of the photonic crystal that is in TM polarization mode. Our structure consists of several parts which includes a waveguide that is in the middle of the
structure, and the structure in approximation has divided into two halves. Our structure also includes 4 rings that have a new structure. There are also four smaller waveguides that are located above each ring. Each ring be in the middle of the intermediate waveguide and a small waveguide.

![Figure 2](image)

**Figure 2.** Shows the band structure

We construct a new ring resonator as shown in Figure 3, including 6 rods of the scatter that the radius of each ring is different that have been shifted as much as 25% of its original location and scatters radius of the right ring above the intermediate waveguide is equal to 56.69 nm and scatters radius of the left ring above the intermediate waveguide is equal to 55.15 nm and scatters radius of the right ring down the intermediate waveguide is equal to 56.37 nm and scatters radius of the left ring down the intermediate waveguide is equal to 56.09 nm. There are 2 rows of ring inner rods which rods that are blue, as much as 25% are shifted of its original location. Different in scatter rods of each ring causes different wavelengths.

![Figure 3](image)

**Figure 3.** Ring structure used in demultiplexer

### 3. SIMULATION RESULTS

Gaussian stimulation signal to the input port (A), that is the intermediate waveguide, is applied. The signal output by the time monitors, that is located in the output port (B, C, D, E), is to be recorded. Figure 4 shows the normalized transmission spectrum of 4-channel demultiplexer that is based on photonic crystal ring resonator. As shown in Figure 4 it can be seen for output port B, the transmission efficiency is equal to 67.93% and the quality coefficient is equal to 1868.27. For output port E, the transmission efficiency is equal to 83.23% and the quality coefficient is equal to 1918.6. For output port C, the transmission efficiency is equal to 93.53% and the quality coefficient is equal to 2023.48 and for output port D, the transmission efficiency is equal to 88.02% and the quality coefficient is equal to 1668.78.
Audition value port of D to port C is calculated equals to -16.49 dB and total audition value of port C to port D equals to -26.85 dB and total audition value port B to port E equal to -32.38 dB. This value for the other ports is equal to zero.

4. CONCLUSIONS

In this paper, we design an optical demultiplexer based on photonic crystal ring resonator. For output port C the transmission efficiency is equal to 93.53% and the quality coefficient is equal to 2023.48. For 4 channel we have, the transmission efficiency and the quality factor of this demultiplexer, more than 65% and 1600 respectively. This approach represents a novel technique for creating high-Q demultiplexer that furthermore opens the possibility of the photonic integrated circuits.

REFERENCES