TELKOMNIKA, Vol. 11, No. 4, April 2013, pp. 1721~1724
ISSN: 2302-4046

Wavelength Demultiplexer using Heterostructure Ring Resonators in Triangular Photonic Crystals

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Abstract

In this paper a new type of wavelength demultiplexer using ring resonators in 2D triangular photonic crystal is presented. The designed demultiplexer contents two regions which each own a resonator. Two dielectric constants are used in this demultiplexer. These structures which are called hetero have the capability to be used in wavelength division multiplexing (WDM) systems. The average transferred power for the two output channels is about 93%. The crosstalk between output channels was more than -18.5dB, also the overall size of the structure was about 144µm2 which is so appropriate for fabrication and integration.

***Keywords**: photonic crystal, ring resonator, wavelength*

1. Introduction

Dielectrics play a very important role in leading the light inside the optical waveguides. There is a special class of dielectrics, named photonic crystals, in which the optical waves are only allowed to pass in specific frequencies. The photonic crystals technology is among newest innovations which is rapidly developing the technology of optical systems. These structures have the capability of controlling the dispersion of optical waves and also can be integrated in optical circuits [1-3]. Moreover, due to the defects modes in band gaps, photonic crystals share the interesting characteristics [3]. By creating a local defects on the structure of a 2D photonic crystal, may lead to resonating conditions beside the defect [4].

The photonic crystals circuits contains configuration such as demultiplexers and filters which is use static configuration likes waveguides and resonators for needed operations. For integrating photonic crystals in high modules and very little size they can be cross-passed over each other. Also the ring resonators which are coupled with waveguides can be experimented with crystals combinations or insulator silicon.

For among the most important functions of photonic crystals, designing configurations such as switches [5], filters [6] and power splitters [7] can be noted. Demultiplexers are useful and essential elements in photonic integrated circuits which separate wavelength of multiplex signal. So far several demultiplexers have been introduced such as resonant cavities, ring resonators and defect waveguides. In the present paper demultiplexer configuration using the ring resonators are introduced in which, two resonators with different dielectric constant are used.

2. Designing Single Channel Filter using Ring Resonators in Photonic Crystals

The taken geometry for the structure of photonic crystal in this paper, is a triangular structure is made of silicon rods in air background with radius r=0.2a in which a is lattice constant. As it is shown in Figure 1, by omitting some of the rods, the structure is reshaped into a circle. For increasing the output efficiency, we input the internal rods of the ring in a circle with radius of 2a.

For using this ring resonator in demultiplexer structure, as it is shown in Figure 2, two input and output waveguides are put beside the ring. Input and two output channels are indicated with A, B and C respectively. When a Gaussian pulse is entered in the TE polarization through channel A, in the resonating wavelength, the electromagnetic energy is totally omitted

Received January 2, 2013; Revised February 10, 2013; Accepted February 20, 2013

from the entered waveguide and is transferred to the channel ‘C’. By using finite difference time domain (FDTD) method in two dimensions and using PML as absorbing boundary conditions the normalized transmission of this structure obtained and shown in Figure 3. Electric field pattern of this structure for two wavelengths is shown in Figure 4. As it is shown in Figure 4, this configuration will be able to transfer the wavelength of 1553*nm* from the input waveguide to the channel ‘C’ waveguide, fully.

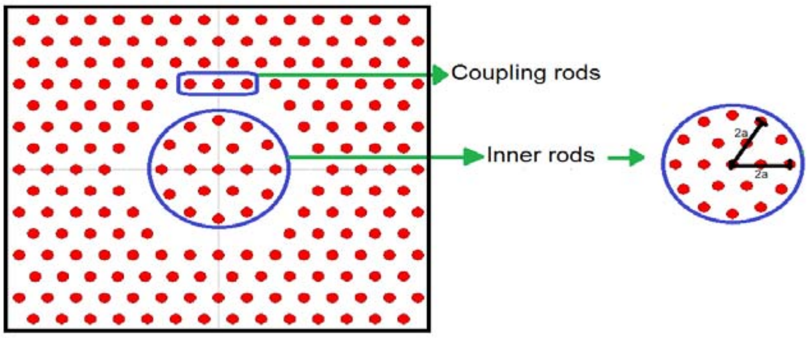


Figure 1. Schematic of Proposed Ring Resonator

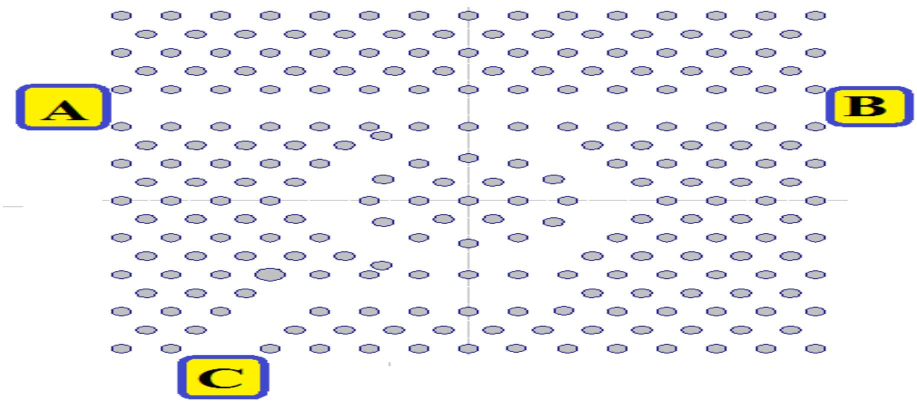


Figure 2. Proposed Demultiplexer with One Output Channel.

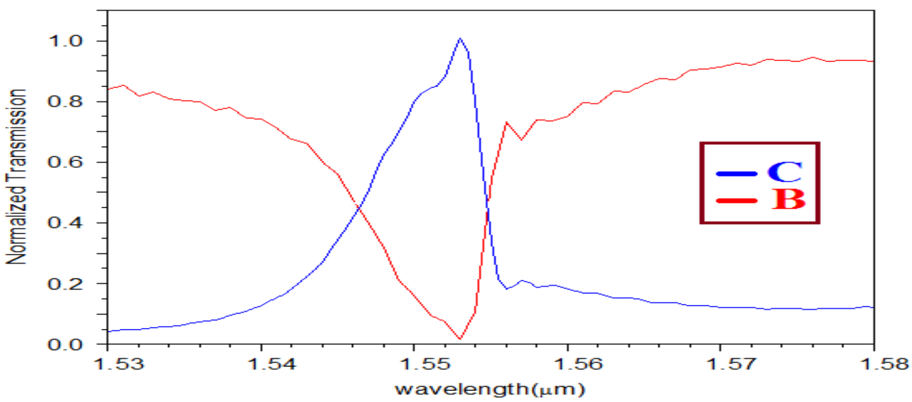
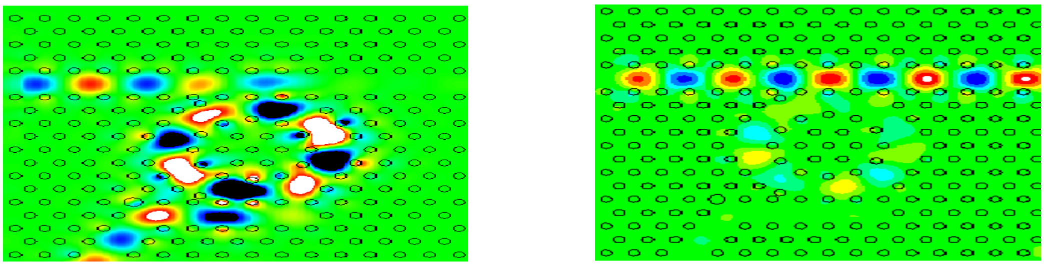


Figure 3. Normalized Transmission of the Structure shown in Figure 2.



(a) (b)

Figure 4. Electric Field Pattern of Figure 2 for Wavelength of (a) 1553*nm* (b) 1530*nm*.

3. Designing Demultiplexer using Ring Resonators

In this paper, a wavelength demultiplexer with three output channels was designed. This is a hybrid structure which is made of two infrastructures. The final design is shown in the Figure 5. The optical characteristic has both infrastructures and has overcome over the limits of refractive index. It means that if the structure of photonic crystal be made of two regions with different refractive indexes, the new structure is called hetero. To reach the inconsistently between the two regions of photonic crystals which have different refractive indexes, these regions should coincide to the band gaps. In this paper a design is introduced in which two refractive indexes n=3.1 and n=3.4 are used. Firstly a theoretical analysis from the photonic crystal with heterostructure is introduced. When the photonic crystals with different refractive indexes are put side-by-side, it is possible the because of the inconsistently between their band gaps, structural discontinuity may occur in their structure [8].

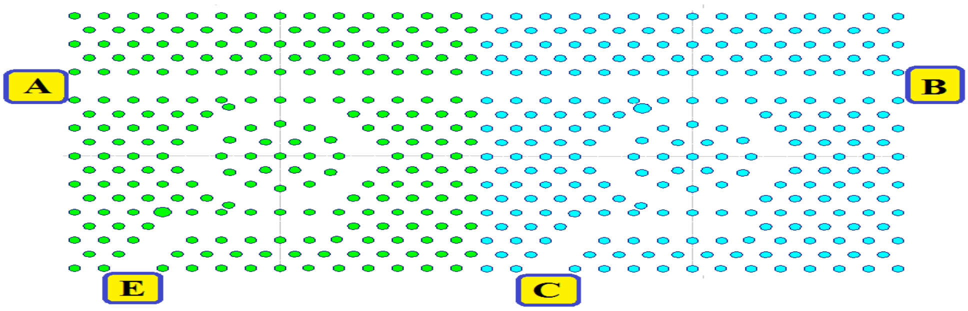
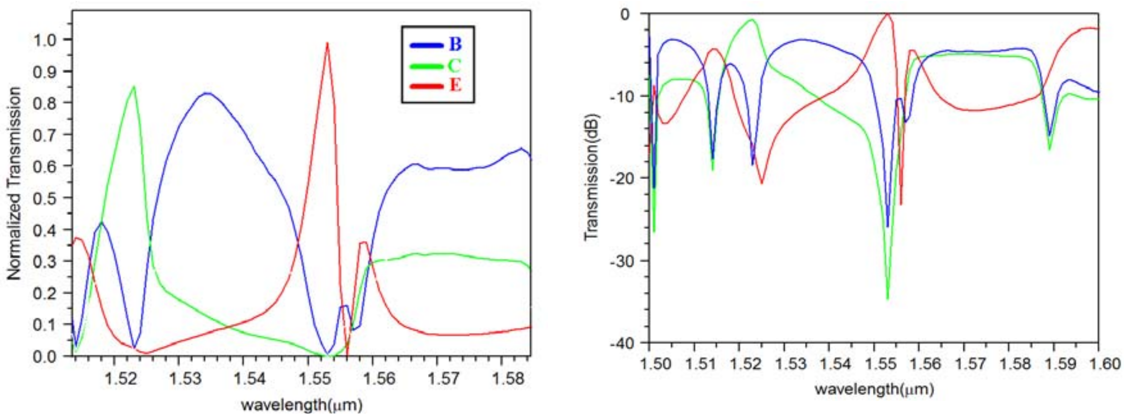


Figure 5. Proposed Demultipexer with Two Regions with Different Dielectric Constant of *n*=3.1 (Right ring) and *n*=3.4 (Left ring).

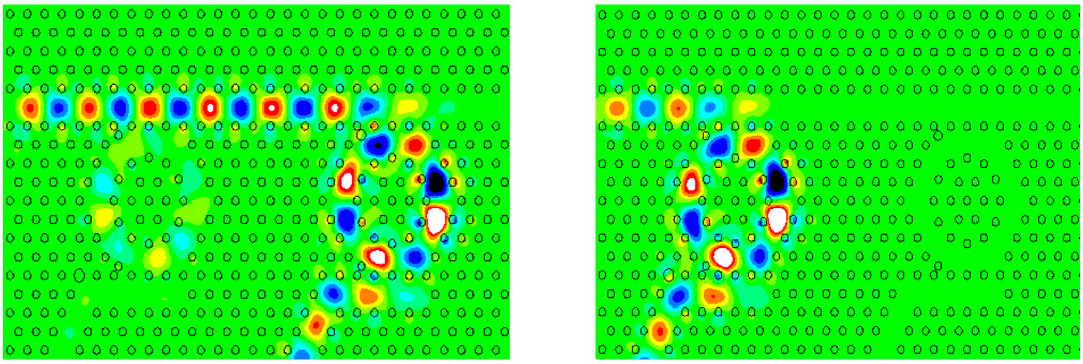


a) b)

Figure 6. Normalized Output Power Characteristic of Figure 5 for (a) Linear and (b) Decibel Scale

For the two refractive indexes used in this paper, the shared region of the two band gaps exactly contains the wavelengths of the third communication window. The final structure which is shown in Figure 5 includes two ring resonators which each have a unique coefficient.

The transferred characteristic of the final design is presented in Figure 6. As it is shown, this structure is able to transfer the wavelengths of 1553 and 1523*nm* with 78% and 99% efficiency to the channel ‘C’ and ‘E’. Finally, the electric field patterns for the final design of demultiplexer for wavelength of 1523 and 1553*nm* in the third communication window are shown in Figure 7.



a) b)

Figure 7. Electric Field Patterns for Final Demultiplexer for Wavelength of (a) 1523*nm* (b) 1553*nm*.

4. Conclusion

In this paper, a new type of wavelength demultipexer using ring resonators in triangular photonic crystal presented. This configuration is consists two regions with different dielectric constant. In this structure, the average transferred power of 93% for the three channels was obtained. Crosstalk between output channels reached higher than -18.5*dB*, which is very appropriate for fabrication and densely integration.

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