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Investigation of 2D-photonic crystal resonant cavity based WDM demultiplexer

V. Kannaiyan [a,c,*], R. Savarimuthu [a,c], S.K. Dhamodharan [a,b]

[a] Department of Electronics and Communication Engineering, India
[b] National Institute of Technology, Tiruchirappalli, Tamil Nadu, India
[c] Mount Zion College of Engineering and Technology, Pudukkottai, Tamil Nadu, India

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ABSTRACT

In this attempt, Two Dimensional Photonic Crystal (2DPC) Quasi Square Ring Resonator (QSRR) based four channel demultiplexer is proposed and designed for Wavelength Division Multiplexing systems. The performance parameters of the demultiplexer such as transmission efficiency, passband width, line spacing, Q factor and crosstalk are investigated. The proposed demultiplexer is composed of bus waveguide, drop waveguide and QSRR. In the proposed demultiplexer, the output ports are arranged separately in odd and even number, where an odd number of ports are located on the right side and even number of ports are located on the left side of the bus waveguide that are used to reduce the channel interference or crosstalk. Further, the refractive index of rods around the center rod is increased linearly one to another in order to improve the signal quality. The resonant wavelengths of the proposed demultiplexer are of 1521.1 nm, 1522.0 nm, 1523.2 nm and 1524.3 nm, respectively. The footprint of the device is of 180.96 μm^2. Then, a four channel point to point network is designed and the proposed four channel demultiplexer is implemented by replacing a conventional demultiplexer. Finally, functional parameters of the network, namely, BER, receiver sensitivity and Q factor are estimated by varying the link distance. This attempt could create new dimensions of research in the domain of photonic networks.

1. Introduction

Device miniaturization is one of the pioneering research areas in the optical community wherein Photonic Crystal (PC) technology supports extensively for miniaturization of the devices from 10 to 100 times. PC is composed of periodic dielectric material [1] which is classified into three types, namely, One Dimensional (1DPC), Two Dimensional (2DPC) and Three Dimensional (3DPC) models. These are differentiated by its structure such as periodic dielectric in a single direction for 1DPC, periodic dielectric in two directions and homogenous in third directions for 2DPC and periodic along three directions for 3DPC. In 2DPC, Plane Wave Expansion (PWE) computes complete Photonic Band Gap (PBG) [1,2] and its merits are easy fabrication, high aspect ratio, require lesser time and memory to simulate the device than 3DPC. Hence, 2DPC mostly considered for designing optical devices. The PBG in PC is an essential part to design a device which selects the operating wavelength of the device. The band gap of PC has similar behavior of electronic band gap in semiconductor devices. It control and manipulate the light beam in PC. The values of the structural parameters (lattice constant (a), radius of the rod (r) and refractive index (n)) are selected through gap map. Gap map [3] provides the information about the variation of TE/TM PBG for different structural parameters. From the PBG, the values are selected.

Typically, the 2DPC based optical devices are realized through square lattice and triangular lattice. The square lattice is structured periodically by arranging dielectric rods in air medium. Alternatively, the triangular lattice is developed by drilling periodic array of air holes in a dielectric medium. In triangular lattice, it is very difficult to make the air hole dimensions in uniform order which results propagation loss over square lattice. Further, The PC based devices are designed by introducing defects in the 2DPC structure. The defects are three types. They are point defects, line defects and surface defects. The point defect and line defect are employed in the structure which results light propagation inside the device. Point defects are employed to realize resonant cavity and linear or bus waveguide is generated by line defect. Both line defect and point defect are combined to design ring resonator. The resonant cavity and ring resonator are playing a major role to tune the resonant wavelength of the device. The defects are caused by changing the dimension of structural parameters and removing a single rod or many which results the defects inside the structure.

* Corresponding author.
E-mail addresses: venkatachalamece@gmail.com (V. Kannaiyan), mail2robinson@gmail.com (R. Savarimuthu).

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The reported devices using 2DPCs such as filter [4–6], power splitters [7], polarization splitter [8], switches [9], waveguides and couplers [10] are made through the resonant cavity [11,12] and ring resonator [13–22]. In the literature, the point defect based resonant cavity [11,19], point and line defect based ring resonator are used in many shapes like circular, square [4], quasi square [13–18], rectangular, and elliptical [19] etc. Either resonant cavity or ring resonator is incorporated in square lattice or triangular lattice for designing 2DPC based devices. However, square lattice easy to make periodic arrangement of uniform dimensions of the rod. The triangular lattice has a very difficult task to make uniform dimension air holes which causes to generate radiation losses in the device [23]. Hence, the proposed device is considered to design in the square lattice. In this device, the refractive index is an important parameter to choose the channel wavelength and analyze the performance of Q factor and transmission efficiency. Then the proposed device is incorporated in WDM optical point to point network for analysing the performance, such as Bit Error Rate (BER), Receiver Sensitivity and Q factor.

The paper is continued as follows. The Section 2 enumerates structural design of demultiplexer. Section 3 describes device simulation and the results and Section 4 incorporates 2DPC demultiplexer and analyses the performance of four channel demultiplexer in a WDM system. Finally, Section 5 concludes the paper.

2. Design of 2DPC four channel demultiplexer

Fig. 1 represents the PBG structure of proposed demultiplexer. The structural parameters that are used in the structure are lattice constant (a), radius (r) and refractive index (n) of rods and its values are 580 nm, 120 nm and 3.2, respectively. The Plane Wave Expansion (PWE) method [24] gives PBG for the 2DPC structure before introducing defects and obtained two PBGs as shown in Fig. 1.

Typically, both TE and TM PBG may occur, however one of the band gap is an active role to develop devices based on the operating wavelength. The blue colour represents TE modes and red colour represents TM modes. The frequency range of wide TE band gap

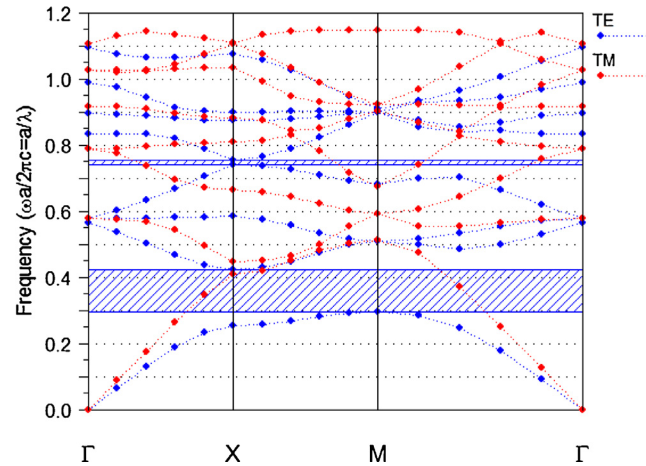

Fig. 1. Photonic Band gap structure of the proposed planar structure before introducing defects.

varies from 0.29651(a/λ) to 0.4186(a/λ) and narrow band gap from 0.74228(a/λ) to 0.75323 (a/λ). The wide PBG wavelength range 1385 nm to 1956 nm which is applicable for designing demultiplexer for WDM applications.

The structural design of proposed four channel demultiplexer is shown in Fig. 2. It has four Quasi Square Ring Resonators (QSRRs), L bend waveguide and bus waveguide. The bus waveguide separates an odd and even pair of QSRRs. Each QSRR consists of inner core which has five rods with the radius of 150 nm. The L shaped dropping waveguide is positioned at the side of QSRR and a small sized channel selector rod is located at the corner of each L bend dropping waveguide.

The sectional view of the single channel dropping section is shown Fig. 3. It has five important parts. They are described as follows.

i Quasi Square Ring Resonator (QSRR): A single line square shaped rods are removed and inserted a rod at the corner (both line and

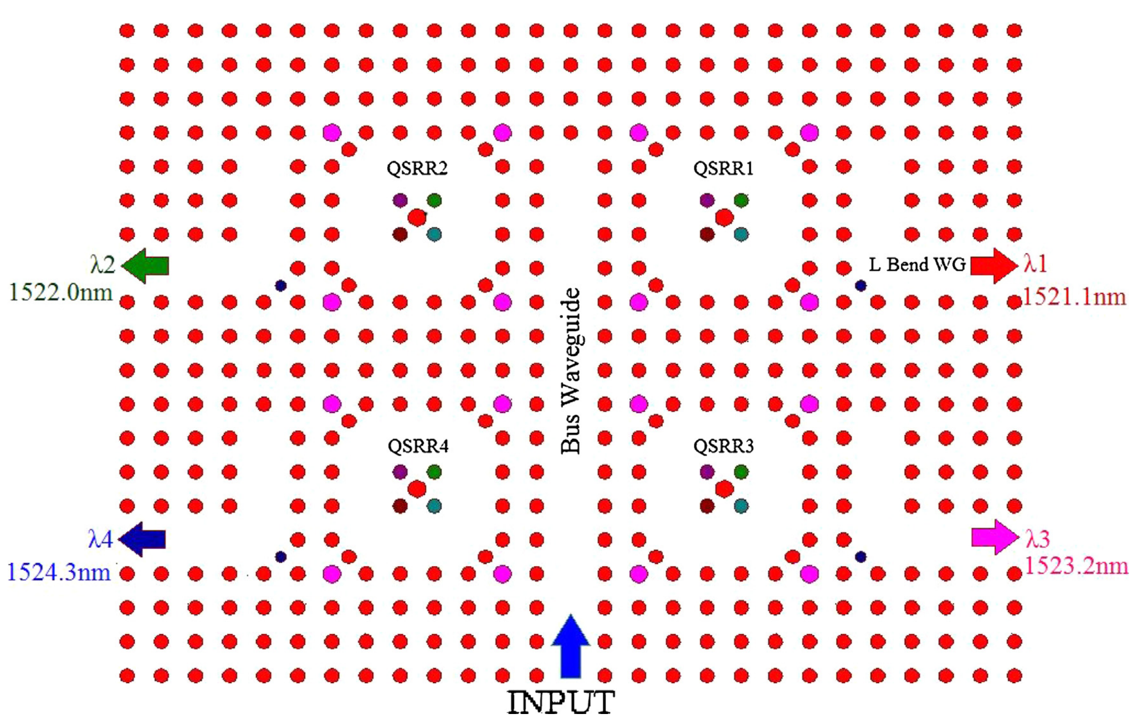

Fig. 2. Schematic representation of proposed QSRR four channel demultiplexer.