Optik 124 (2013) 824–827

Contents lists available at SciVerse ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

New design of channel drop filters based on photonic crystal ring resonators

Ahmed Taalbi, Ghaouti Bassou, Mahmoud Youcef Mahmoud*

Laboratory of Microanalysis, Microscopy and Molecular Spectroscopy, Faculty of Science, Djillali Liabes, University of Sidi Bel Abbes, Algeria

ARTICLE INFO

Article history:
Received 22 September 2011
Accepted 25 January 2012

Keywords:
Photonic crystals
Photonic crystals ring resonators
Photonic integrated circuits
Optical devices

ABSTRACT

In this paper, a new design of channel drop filters (CDFs) based on photonic crystals ring resonators (PCRRs) is presented. The filter characteristics for single-ring and dual-ring configurations based on two-dimensional (2D) triangular lattice photonic crystal (PC) silicon rods have been investigated by using the two-dimensional (2D) finite-difference time-domain (FDTD) method. Backward dropping efficiency of 96% and forward dropping efficiency up to 98% can be achieved in third communication window. Moreover, we investigate the dependence of resonant frequency on dielectric constant of whole rods of the structure as well as radius of the coupling rods. This device can be used as an optical channel drop filter (OCDF) in future communication applications.

© 2012 Elsevier GmbH. All rights reserved.

1. Introduction

The optical channel drop filters (OCDFs) are essential components of photonic integrated circuits (PICs) and wavelength division multiplex (WDM) optics communication systems. Various CDFs exist, such as fiber Bragg gratings, Fabry–Perot filters, and arrayed waveguide gratings. Resonant CDFs, which involve waveguide–cavity interaction, are other attractive applicants for this intention [1–3]. Significant progress has been made on CDF based devices in the areas of compactness, high spectral selectivity, wide spectral tunability, fast switching, and low-power switching [4,5]. Fan et al. [1] reported channel drop filters based on square-lattice 2D PCs. The resonators are consisted of one or two point defects inside the 2D PCs. The size and the refractive index of scatters are varied to match the desired resonance condition. The quality factor of forward and backward drop filters in their results is approximately 1000 and 6000, respectively.

Photonic crystals (PCs), on the other hand, are expected to be a promising platform for the next generation of photonic integrated circuits (PICs) [6,7]. PC ring resonators (PCRRs), PC tunneling resonators, PC directional couplers, and so on are expected to realize functional channel add-drop filtering or nonlinear signal processing and hence have attracted much research interest.

The first report of a photonic-crystal ring resonator (PCRR) was in a hexagonal waveguide ring laser cavity [8], where flexible mode design and efficient coupling were discussed. Later, the spectral characteristics of the waveguide-coupled rectangular ring resonators in photonic crystals were investigated by Dinesh Kumar et al. [9], where a large single quasi-rectangular ring was introduced as the frequency selective dropping elements. Qiang et al. [10] studied add-drop filters based on square-lattice PCs, thus the resonator comprises a square trace defect in 2D PCs. The quality factor of single square ring filter is enhanced from 160 to over 1000 by increasing the coupling sections between waveguide and ring. They also proposed a dual square ring filter in order to achieve forward dropping. Recently Monifi et al. [11] presented a three output-ports channel drop filter based on the ring structure introduced by Qiang et al. [10]. By manipulating the refractive index and radius of some scatters in PCs, they achieved a high transmission, three wavelengths channel drop filter in double-ring configuration. The estimated quality factor based on the reported data is about 100. PCs based ring resonators provide very well optical confinement due to ultra low bending loss. In addition, Bai et al. [12] reported a new 45° PCRR based on square lattice silicon rods. They obtained a quality factor of more than 830 and dropped efficiency of 90% at 1550 nm. It is helpful to overcome the challenge aforementioned by reducing the radius of ring to achieve a resonator with high-Q, high wavelength selectivity, and ultra small footprint size [13].

In this paper, we propose a new design of OCDFs based on PCRRs. The performance of the device is calculated by the two-dimensional (2D) finite-difference time-domain (FDTD) technique in triangular lattice photonic crystal (PC) silicon rods. Backward dropping efficiency of 96% and forward dropping efficiency up to 98% can be achieved in third communication window. This new device provides a possibility of channel drop filter and can be used in future communication applications.

2. Numerical results and analysis

In this paper, we consider a semi-infinite triangular lattice PCs composed of silicon (Si) rods embedded in air substrate. The

* Corresponding author. Tel.: +213 6 62 67 29 63.
E-mail address: mahmoudhamoud@yahoo.com (M. Youcef Mahmoud).

0030-4026/$ – see front matter © 2012 Elsevier GmbH. All rights reserved.
doi:10.1016/j.ijleo.2012.01.045

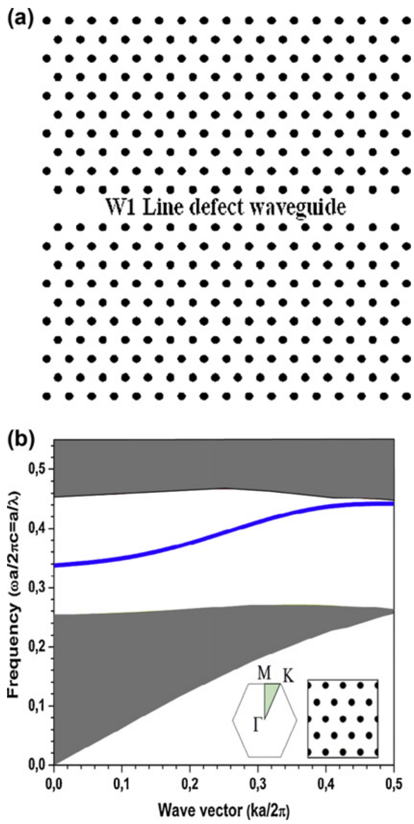

Fig. 1. (a) Single line-defect (W1) photonic crystal waveguide. (b) Dispersion plot for TM polarization and the corresponding guided mode shown as a blue line in the photonic band gap region. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

refractive index of the rods is 3.464 ($\varepsilon_r = 12$) and the radius to lattice constant ratio is 0.2. As shown in Fig. 1(a), the W1 line defect waveguide in the PCs is realized by removing a row of rods along the ΓK direction in a triangular lattice PC that have a fundamental band gap for TM mode (electric field is perpendicular to x–y plane). Fig. 1(b) shows the photonic band gap and the dispersion curve of the W1 line-defect PC waveguide for the TM polarization through the free MIT Photonics-Bands (MPB) package [14]. The waveguide supports a single-mode frequency (normalized) ranging from 0.337 a/λ to 0.442 a/λ below the light-line, where λ is the wavelength of light in free space. To be used in optical communication systems (1550 nm), the lattice constant, a, i.e. the distance between the two adjacent rods, is set as 616.28 nm. Thus the W1 PC waveguide is broadband, with guided single-mode spans from 1394 to 1828 nm.

The schematic diagram of optical CDF based PCRR is shown in Fig. 2(a). The structure consists of two waveguides in horizontal ΓK direction and single PCRR sandwiched between them. The top waveguide is called as bus waveguide whereas the bottom waveguide is know as dropping waveguide. The input port on the left side of the top (bus) waveguide is marked as A, whereas the opposite side of the top waveguide, i.e. port B, is called as the forward transmission terminal. The ports C and D of the bottom (drop) waveguide are the drop terminals and denoted as forward dropping and backward dropping respectively. Four additional extra scattering rods with blue color are introduced to achieve high channel drop efficiency. These extra scattering rods have similar refractive indexes as all other dielectric rods in PC structure and their diameters $r_S = 1.08r$ for better performance.

The transmission characteristics of the CDF are calculated using the free open 2D FDTD method, with perfectly matched layers (PMLs) absorbing boundary conditions [15]. In addition, a practical device requires a 3D analysis, which is typically computational time and memory consuming, however, our 2D approach offer us a guidelines of the expected 3D behaviour.

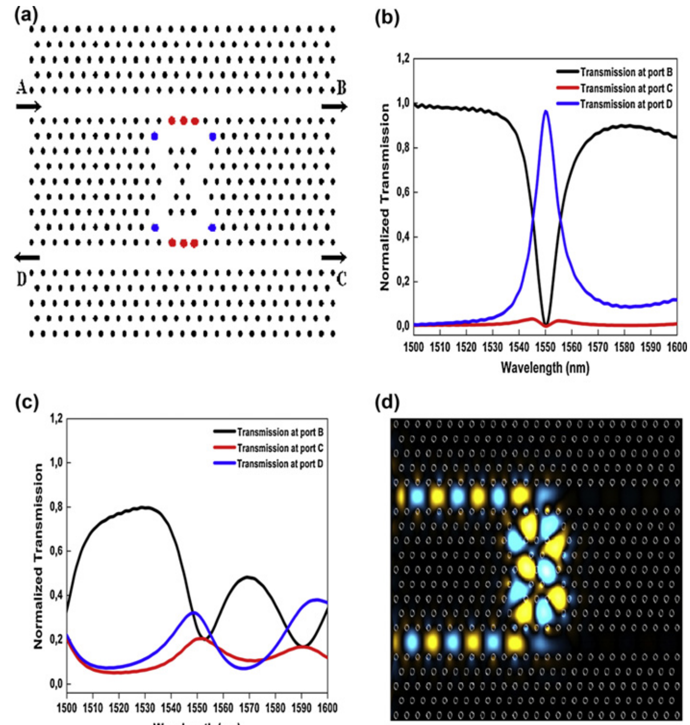

Fig. 2. (a) Schematic diagram of single-ring PCRR based CDF. (b) Normalized transmission spectra at ports B–D for PCRRs with scatterers. (c) Normalized transmission spectra at ports B–D for PCRRs without scatterers. (d) The electric field pattern at resonance ($\lambda = 1550$ nm).

As the light is launched at the port A in Fig. 2(a), three time monitors for the transmission light-waves energy is set at the ports B, C and D, respectively. The normalized power transmission spectra of ports B–D are obtained by conducting Fast Fourier Transform (FFT) of the fields that are calculated by 2D FDTD method.

The normalized transmission spectra of the single-ring CDF with and without extra scattering rods are displayed in Fig. 2(b) and (c), where the power transmission at ports B, C and D are denoted as black, red and blue lines, respectively. It is clear that the presence of the extra scattering rods improves the spectral selectivity and enhances the drop efficiency. Backward dropping efficiency of 96% can be achieved at the resonant frequency ($\lambda = 1550$ nm). The power in the bus waveguide is transferred to the drop one through the resonant ring. The propagating waveguide mode nearly rotates in the clockwise direction as a travelling wave mode in the ring resonator, which results in backward dropping.

As shown in Fig. 2(d), the steady field pattern is obtained by launching a continuous-wave (CW) at the maximum transfer efficiency (resonant frequency) at port A.

According to the results shown above, we can investigate parameters which affect the filter characteristics. Fig. 3 shows the transmission spectra at port D for different dielectric constant of whole rods, $\varepsilon_r = 11.6964$, $\varepsilon_r = 11.8336$, $\varepsilon_r = 12$, $\varepsilon_r = 12.1104$ and $\varepsilon_r = 12.25$ respectively. It is obvious that by increasing the dielectric constant of the rods, a red shift in resonant wavelength occurs. On the other words, the resonant peak shifts to a longer wavelength region without significant change in the backward dropping efficiencies values. The obtained output wavelengths are 1545.3 nm, 1546.8 nm, 1550 nm, 1551.5 nm and 1554.6 nm respectively.

In similar way, the dielectric constant of the extra scattering rods as well as the coupling rods can be changed. However, this

Download English Version:

https://daneshyari.com/en/article/849534

Download Persian Version:

https://daneshyari.com/article/849534

Daneshyari.com