Int. J. Electron. Commun. (AEÜ) 65 (2011) 281–287

Contents lists available at ScienceDirect

International Journal of Electronics and Communications (AEÜ)

journal homepage: www.elsevier.de/aeue

Improving the performance of all-optical switching based on nonlinear photonic Crystal microring resonators

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ARTICLE INFO

Article history:
Received 7 November 2009
Accepted 7 March 2010

Keywords:
All-optical switch
Nonlinear photonic crystal
FDTD
Microring resonator

ABSTRACT

Photonic crystal microring resonators are suitable devices for all-optical integrated circuits. Small size of the structure without radiation loss and topology of structure make these microrings more flexible in design. The light intensity can also be localized inside them, which is appropriate for nonlinear state. This localization and slow group velocity of light in photonic crystals lead to enhancement of nonlinearity within nonlinear photonic crystal microring resonators. So they can be used as active devices in all-optical integrated circuits which are under wide range of researches recently. In this paper, the nonlinear photonic crystal microring resonator is introduced and three different structures for all-optical switching based on them are proposed and their performances are simulated. Also the three structures are compared and the optimal structure is demonstrated. Required power for switching of optimal structure is 0.5655 W.

1. Introduction

All-optical switches have attracted many researchers, due to their important applications in optical communication and all-optical signal processing systems [1]. In the fast all-optical switches, properties of the structure should be changed by the input signal or by the pump signal. According to the low nonlinear coefficient of materials, appropriate structures are required to enhance the nonlinearity and hence to decrease the switching power and also dimensions [2]. Using nonlinear materials in dielectric microring resonators (MRRs) leads to design and fabrication of some devices of integrated optics such as all-optical switches, delay lines, and add-drop filters [3].

Since the wave can be localized in the MRRs, the nonlinear effect can be achieved by lower optical intensity. Hence nonlinear properties of these structures have an important role in all-optical integrated circuits [4].

Structures with high quality factor can enhance the nonlinearity. To have a high quality factor in a dielectric MRR, the ring should be small. The small size of a dielectric MRR leads to high radiation loss. This problem makes small dielectric MRRs inapplicable for optical integrated circuits [5].

Photonic crystals have recently been considered for fabrication of all-optical integrated circuits. The guiding mechanism of photonic crystals is a new approach for controlling the light. Low group velocity in photonic crystal waveguides increases the nonlinear effect which leads to decrease the dimension and required power in comparison with other optical devices such as optoelectronic devices [6]. Photonic crystal microring resonators (PC-MRR), in addition to their low group velocity, have the benefits of the dielectric MRRs. Therefore, these properties result in an enhancement of nonlinearity. Also PC-MRRs can be very small without radiation loss.

In this paper, nonlinear performances of PC-MRRs are simulated and their switching abilities are demonstrated. The resonant frequency and the quality factor of a PC-MRR are derived. The parameters of a PC-MRR are designed.

Three different structures for all-optical switching are proposed and their performances are compared. Finally the structure is optimized. The finite difference – time domain method has been applied for the simulation of the performance of the proposed switches, the code of which was written in Visual C++ and MATLAB.

2. Characterizing the photonic crystal microring resonators

When a MRR is situated between two parallel optical waveguides, as depicted in Fig. 1, the energy from the input waveguide will penetrate to the MRR due to the evanescent fields of the waveguide; hence the MRR's modes will be excited.

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doi:10.1016/j.aeue.2010.03.013

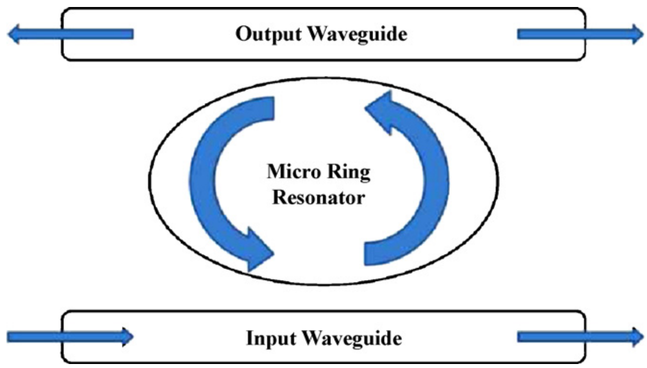

Fig. 1. Schematic of a microring resonator situated between two parallel optical waveguides.

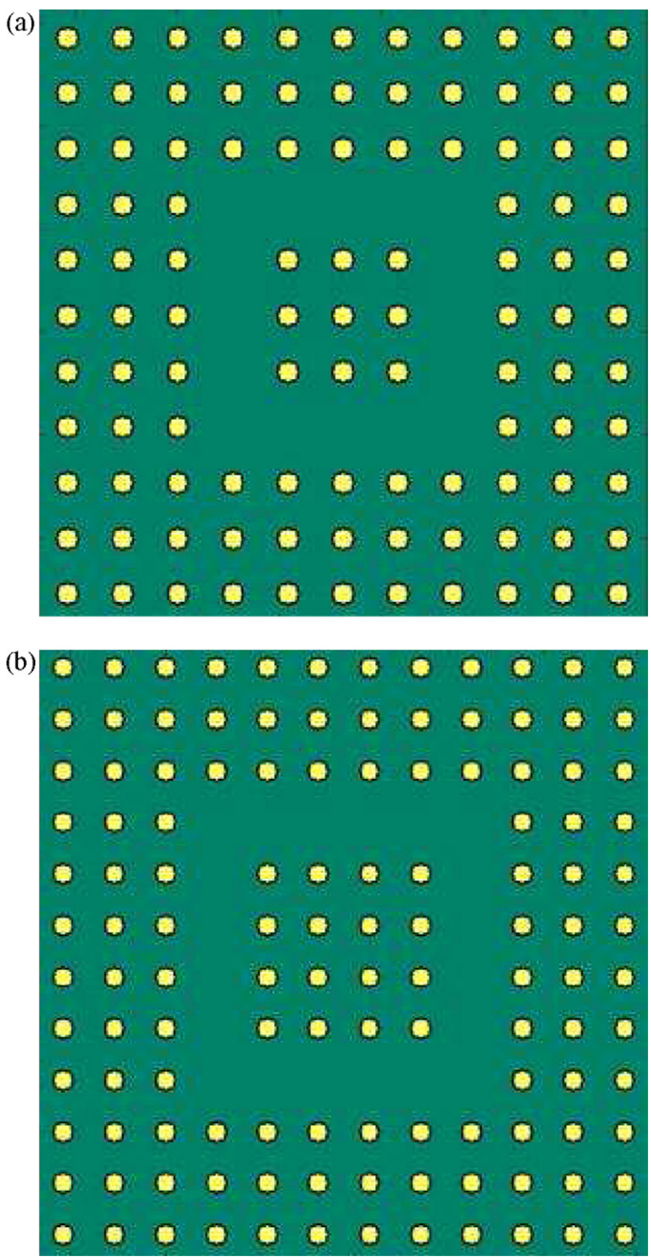

Fig. 2. (a) 5×5 and (b) 6×6 PC-MRR structures.

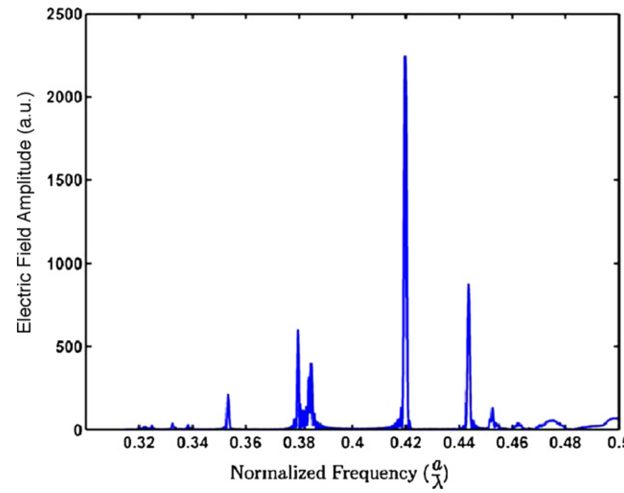

Fig. 3. Electric field amplitude versus normalized frequency.

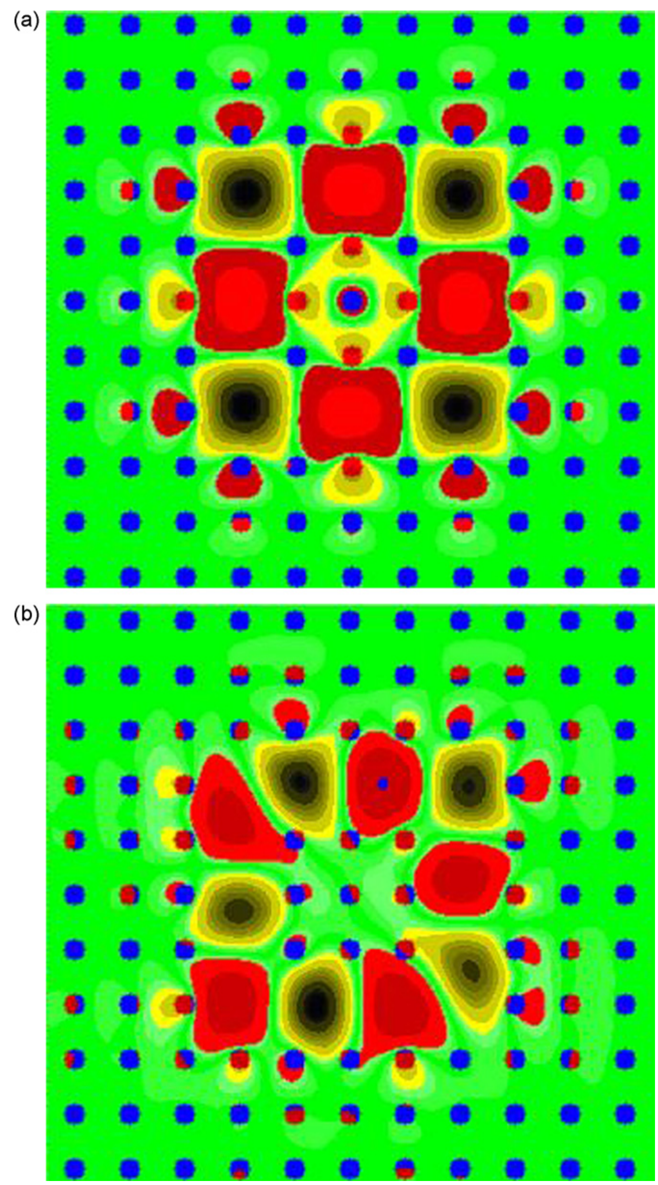

Fig. 4. Mode types in a photonic crystal microring resonator, (a) fr = 0.3795 × c/a and (b) fr = 0.4197 × c/a.