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Numerical Simulation of All-Optical NAND Logic Gate Based on 2-D Photonic Crystal using FDTD method

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1 Introduction

The demands for all-optical signal processing techniques in telecommunication systems are rapidly increasing, and now is accepted that digital electronics is not able to meet these requirements in the future [1]. Ultrafast all-optical logic gates based on Nonlinear Photonic Crystal (NPhC) are the key components in the all-optical signal processing systems and future optical networks [2]. In this work, a novel scheme for implementation of all-optical NAND logic gate based on two dimension (2-D) Photonic Crystal (PhC) ring resonator has been proposed, designed and simulated by a cascade of two all-optical switches. The new all-optical switch is composed of a nonlinear Photonic Crystal Ring Resonator (PCRR) and T-type waveguide. The Plane Wave Expansion (PWE) method is used to calculate the Photonic Band Gap of the PhC structure. Numerical simulation has been performed through 2-D Finite Difference Time Domain (FDTD) method, which is used to simulate electromagnetic wave propagation in any kind of materials in the time domain.

2 Materials and Methods

In this work, the 19×19 square lattice nonlinear 2-D PhC is used for designing the structure. The lattice constant, denoted by $'a'$, is 0.5943 μm, which is a distance between the two consecutive rods. The structure of gate NAND fabricated is implemented on the operational wavelength of the input ports is 1700 nm using finite difference on an air wafer of only 24 μm x 12 μm. Typically, the FDTD method is used to calculate

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the spectrum of the power transmission and field distribution that is based on numerical solutions of Maxwell's equations, which can be discretized in space and time by so call Yee-cell techniques. The 2-D transverse electric mode FDTD used in this work is

$$\frac{\partial H_x}{\partial t} = \frac{1}{\mu}\left(- \frac{\partial E_z}{\partial y}\right) \tag{1}$$

$$\frac{\partial H_y}{\partial t} = \frac{1}{\mu}\left(\frac{\partial E_z}{\partial x}\right) \tag{2}$$

$$\frac{\partial H_z}{\partial t} = \frac{1}{\varepsilon}\left(\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y}\right) \tag{3}$$

The Gaussian beam is initiated in the grid, travels through, reflects from, refracts in and resonates inside the photonic crystal. Where $\varepsilon(r)$, $\mu(r)$, $\sigma(r)$ are permittivity, permeability and conductivity of the material and all are in the function of position. In simulation, structure is surrounded by Perfectly Matched Layer (PML) from all the sides.

3 Conclusions

The simulation results using 2-D FDTD method show that the proposed PhC all-optical NAND logic gate presented here is a potential candidature for ultrafast optical digital circuits and highly advantageous with high transmitting power and simple design.

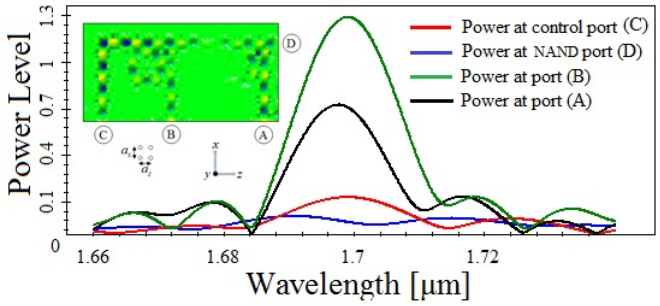

Figure 1: The electric field distribution and the power transmission [w/m] of the all-optical NAND logic gate when is applied input power at port B and port A.

References

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