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A REVIEW ON SYSTEM ON CHIP OPTICAL LOGIC GATES

Survey paper of Optical Logic Gates

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Abstract- *Optical computers are attractive for future broad band optical communication system which needed flexible optical processing devices. Optical logic gates are key element of these devices. Photonics technology till yet have been reviewed for optical logic gates in this paper. We present a study and comparison of structures like nonlinear, multibranch, ring; y-shaped waveguide and methods like beam propagation and finite difference time domain adapted by various researchers. By analyzing these comparisons we conclude that using finite difference time domain method and coupling structure we can reduce the size of optical logic gates*.

Keywords - Photonics technology, optical logic gates, finite difference time domain, coupling effect

I. INTRODUCTION

In semiconductor electronic device majority chip area is covered by electrical interconnection so these devices suffer from the limitations like time delay, speed, area and high heat generation [1,2]. These limitations can be overcome by photonics devices. Optical computers are important for future broadband optical communication system since they can overcome these limitations [3]. All optical signal processing devices are basics to build optical computers. Optical logic gates are key elements of signal processing devices and communication system.

Recently, different methods have been demonstrated for optical logic gates such as two-mode nonlinear waveguide [4], multi branch waveguide structure with localized optical nonlinearity [5], quantum dots [6], multimode interference in SiGe/Si [7]. There are many limitations of these methods such as big size, simultaneous output, difficult to perform chip scale integration.

In order to overcome these limitations silicon photonics is receiving much interest, which provides well-developed Si processing technology as well as Si substrate. It is cheaper than the compound semiconductor (GaAs or InP) substrates to fabricate wide range of optical devices(light emitters, photo detectors, optical switches, optical passive components, and nonlinear optic devices, logic gates) [8-11], small size and lower excess loss[1,2]. Using coupling effect on SOI waveguide small size and individual output design of basic logic gates can be obtain[1,2]

The purpose of this article is to compare different structures and methods had been used for optical logic gates. Section 2 gives different types of design structures. Section 3 describes methods of wave propagation. Results and Conclusions has been mentioned in section 4 and section 5 respectively.

II. DESIGN STRUCTURES

Performance and size of optical logic gets change with design structure of optical logic gates. Here, we describe some design structures like linear, non linear, Y-shaped coupling.

A. SiGe/Si Multimode interference coupler[7]

All optical logical gates OR, NOT, NAND and NOR has been demonstrated in these paper based on multi mode interference (MMI) principle on material SiGe/Si using beam propagation method. Size of this structure is 6500μm×38.4μm.

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B. multibranch waveguide structure[5]

They used localized optical nonlinearity on multi branch waveguide structure with size of 40μm×6000μm. In these paper AND and OR logic gates had been demonstrated by simply setting non linear media in the selected output guide.

C. cascaded two optical switches[12]

These paper proposed NOR gate design T-type cascaded switches with compact size of 18μm×11μm using finite difference time domain method.

D. Add-drop micro ring resonator[13]

Optical logic gates NAND, NOR, AND, OR has been demonstrated using add-drop micro ring resonator with size of 200μm×220μm, 400μm×120μm, 120μm×220μm, 320μm×140μm respectively. These paper conclude that a wavelength fluctuation 0.3 times greater than the resonant wavelength width will degrade the operation of the system and stronger coupling increase the wavelength tolerance

E. quantum dot semiconductor optical amplifier(QD-SOA)[14]

In these paper NAND, NOR, OR and NOT logic gates has been demonstrated by QD-SOA incorporated in a mach-zehnder interferometer (MZI) that exploits QD-SOA as nonlinear elements.

F. Two- mode nonlinear waveguide[4]

These paper used beam propagation method (BPM) simulations shows that proposed material is insensitive to relative phase difference between the incident beam on the input ports so they used phase shifter to demonstrate AND and NOT logic gates on two-mode nonlinear waveguide**.**

G. Ring cavity and Y-shaped line defect coupler[3, 15]

These paper gives two compact design for AND and OR gate size of 21.6μm×26.4μm using combination of ring cavity and y-shaped line defect coupler on photonic crystal. These gates have been analyzed using finite difference time domain method.

Other paper have been also demonstrated AND gate by modifying little in these structure and using same wave propagation method with the size of 30μm×18μm.

III. WAVE PROPAGATION METHODS

There are many computation methods for electromagnetic(EM) waves like finite difference time domain method(FDTD), multiresolution time domain(MRTD), Finite element method (FEM), Finite integration technique (FIT), Pseudospectral time domain (PSTD), Pseudo-spectral spatial domain (PSSD), EigenMode Expansion (EME), beam propagation method(BPM). But finite difference time domain (FDTD) and beam propagation method (BPM) mostly used techniques.

A. Beam propagation method

The beam wave propagation method (BPM) is technique which estimates simulation of the propagation of light (EM waves) in slowly varying optical waveguide. The BPM relies on approximate differential equations. This method involves only a first order derivative in the waveguide axis. There are spatial domain and spectral domain methods are available for the numerical solution. Spectral domain methods have benefit of stability even in presence of nonlinearity. Whereas spatial domain methods can possibly turn out to be numerically unstable.

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Table No.1 Comparisons of design and technique used for logic gate along with size

Reference paper No.	Structure	Method used	Proposed gate	Size
[3]	Two-mode linear waveguide	Beam propagation method	AND, XOR	100µm×1400µm
[4]	Multi branch waveguide		AND, OR	40µm×6000µm
[5]	SiGe/Si multimode interference		OR, NOT, NAND, NOR	6500µm×38.4µm
[6]	Y- branch waveguide and ring cavity	Finite difference time domain method	AND, OR	21.6µm×26.4µm
[7]	Y- shaped		AND	17µm×17µm
[8]	Cascaded optical switches		NOR	18µm×11µm
[9]	Add-drop micro ring resonator		NAND, NOR, AND , OR	NAND-200µm×220µm NOR-400µm×120µm AND-120µm×220µm OR-320µm×140µm
[10]	Semiconductor-dot optical amplifiers		NOT, NOR, OR, NAND	Not mentioned
[11]	Ring and line defect coupler		AND	30µm×18µm

B. Finite difference time domain method

Finite difference time domain method is a numerical technique which approximates simulation of the propagation of light. as it is time domain method FDTD solution can cover a broad frequency range with a single solution run and treat non linear properties in natural way. The FDTD method belongs in the general class of grid-based differential numerical modeling finite difference methods. The time dependent Maxwell equations approximates to the space and time partial derivatives.

IV. RESULT

Various structure design and techniques adopted are investigated and their results are summarized in Table Evaluation of structure design and method used made on the bases of size of the design. It shows that beam propagation method is not convenient for small size design structure. Finite difference time domain method gives best result for size design structure.

V. CONCLUSION

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This paper describes the relativity of size, method and design adopted. By analyzing this papers conclude that using finite difference time domain method compact size design can be demonstrated. Many logic gates had been demonstrated uses coupling effect in structure design. In future work this article useful for compact design of optical logic gates.

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