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All optical fan out able half adder circuit based on nonlinear directional coupler

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ABSTRACT

Since all optical computation and arithmetic can be achieved by complex and complicated all optical systems, the characteristic of cascading is an essential issue indesigned schemes of all optical simple gates or circuits. Hence, the aim of this paper is designing the fan out able half adder circuit by using optical nonlinear directional couplers. There are two $GaAs/SiO_2$ based half adder which one of them has only carry fan out and second scheme has the ability of driving next stages for both carry and sum outputs. These approaches are simple, compact and power efficient which has the potential to be used for all optical on chip computations. BER and quality factor have been investigated which show satisfactory performance of the proposed all optical half adder.

1. Introduction

Very large scale integrated (VLSI) technology which is used widely in communications and computations rapidly approaches to its fundamental limits such as dielectric breakdown, hot carriers, and short channel effects which causes to a disruptive new regime for digital chip designers known as dark silicon [1,2]. In recent years, the pace of seeking the next-generation communication and computation technologies has led to the developments of all-optical digital processing.Because of inherent features of light beam like high bandwidth, low-loss transmission and parallel processing without short circuits or electromagnetic interference, all optical devices especially integrated on silicon chips are becoming a major trend inrecent researches [3].

All optical signal processing by eliminating the e-o-e conversions induces performing the logical functions in high speed. Moreover, emerging optical interconnections in nano dimensions provides more integrity with low power consumption. Accordingly, many researches propose various schemes for implementing of all-optical devices by photonic elements which are CMOS compatible.

Recently, many researches propose various schemes for implementing of all optical devices such as semiconductor optical amplifier (SOA) [4], Mach-Zehnder interferometer (MZI) [5], periodically poled lithium niobate (PPLN) [6], Micro ring resonators [7,8], and quantum-dot semiconductor [9]. In addition, by utilizing some optical phenomena like cross polariza-

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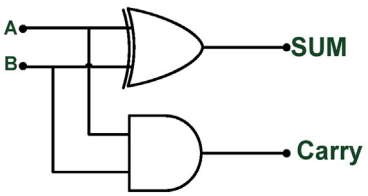

A	B	Carry	Sum
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

Fig. 1. Schematic diagram and truth table of half adder.

tion modulation (XPM) [10], cross gain modulation (XGM) [11] and four wave mixing (FWM) [12] optical logic gates can be obtained.

Generally, these optical elements are used to propose optical logic gates which are key building units for the development of modern photonic networks and systems [13], however, these schemes face some essential problems. These proposed logic gates not only use more than one wavelength such as clock wave, but also require additional electrical current resources to stimulate optical elements. Another significant issue which has effect on the capability of the mentioned techniques is cascading of optical gates, in the sense that most of the proposed logical gates can only drive one input from the next logic stage, hence, designing the complex systems is more difficult and sometimes is impossible.

Therefore, in this paper, a simple but efficient scheme for all optical half adder circuits is presented. Half adder circuit is one of the combinational circuit which has the key role in the digital arithmetic.

In the proposed scheme, by use of nonlinear materials, the requirement of electrical currents is completely eliminated, and the capability of cascading is provided to achieve complex systems optically.

The reminder of this paper is organized as follows: In continue, the operation principle of a half adder circuit, coupled mode theory and optical switching are described in Section 2. The details of the proposed all optical half adder circuits along with simulation results are given in Section 3, and finally, Section 3 concludes the paper.

2. Operation principle

2.1. Half adder function

All optical half adder is the essential primary component of any arithmetic logic systems which performs addition of two binary digits, and generates two binary outputs which are called ‘sum’ and ‘carry’. In the electrical domain, half adder is implemented by XOR/AND logic gates that both inputs (A,B) are applied into the gates simultaneously. Afterwards, ‘sum’ output exits from XOR gate while AND gate produces ‘carry’ output. The block diagram and the truth table of half adder are illustrated in Fig. 1.

Although some efforts implement half adder circuit by constructing optical AND/XOR gate distinctly and connecting them together [14–16], in this paper, the operation of half adder is implemented by optical waveguides and based on nonlinear directional coupler theory. For getting better insight into the proposed structure firstly the theoretical background is presented.

2.2. Coupled mode theory

In the linear mode, when two waveguides are phase matched ($\Delta\beta = 0$), fully coupling is achieved from one waveguide to another.

From coupled-mode theory, the field amplitude in each waveguide can be derived from the coupled-mode equations [17]:

$$\frac{da_1}{dz} = -jk_{21}e^{j\Delta\beta z}a_2(z) \tag{1}$$

$$\frac{da_2}{dz} = -jk_{12}e^{-j\Delta\beta z}a_1(z) \tag{2}$$