

Research Article

SOA Based All-Optical N-Bit-Binary Data Multiplier Design

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Abstract

Optics has already established its strong potential role in digital information processing, networking, image processing because of its high degree of inherent parallelism. In order to allow the transmission of data streams at high speed or beyond over long distances, all-optical signal regeneration techniques capable of handling ultra-short pulsed signals at very high rates will be needed in future transmission networks. In this Paper, the author proposes a method of developing frequency encoded two single bit multiplier unit and subsequently extending the scheme for developing multi-bit (n-bits) multiplier unit. The Semiconductor Optical Amplifier (SOA) has already taken a significant role in the field of ultrafast all-optical signal processing. The basic building block of multiplier circuit is all optical AND logic gate and half adder circuit which are developed using SOA.

Keywords: Lithography; Optical Data Storage; Physical Optics; Subwavelength Structures

Introduction

Recently, there is an increasing interest among researchers in the replacement of electrons with photons due to several advantages such as low crosstalk, high speed and bandwidth, parallel signal processing etc. Hence optical switching and interconnections will be the best alternative for the coming generation. The important aspects of all-optical computing are the possibility to integrate a large number of devices in a small chip and the possibility to cascade a large number of devices. Till now so many all data encoding techniques have been reported to design multiplier circuit such as polarization encoding, phase encoding, intensity encoding etc., [1,2]. But it is very difficult to maintain the specific state of polarization of the polarization encoded data, phase of the phase encoded data, and threshold intensities of the intensity encoded data in long haul communication system, and therefore,

all these proposed schemes lead to bit error problems [3]. In this article, the authors propose a new method of implementing two-bit-binary multiplication operation using frequency encoded data. The advantage of frequency encoded data is that, frequency is the fundamental character of a signal and it does not alter in reflection, refraction, absorption [4] etc., during transmission and therefore communication is almost bit error free [4].

Theory

Semiconductor Optical Amplifier

The increasing data traffic and the advantages of fiber optics for data transmission are the basic reasons behind the interest in the development of optical components, especially those capable to process the signals in the optical domain without the need of cumbersome opto-electro-optical conversions. Such a component, with central interest in fiber communications is the Semiconductor Optical Amplifier (SOA) and it is shown in (Figure 1).

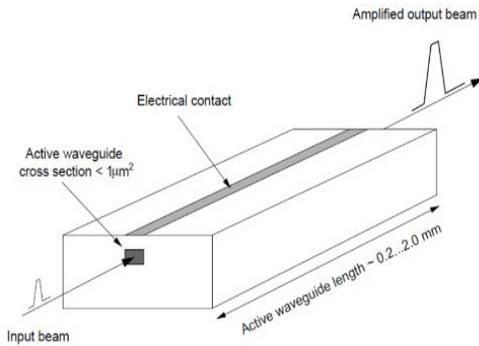


Figure 1: Structure of Semiconductor Optical Amplifier.

The reason behind the growing interest in SOAs is their ability to amplify and process optical signals in a wide range of bit rates at modest bias power requirements and in a tiny volume [5]. (Figure 1) depicts the basic structure of a SOA. The incoming optical beam is coupled into the active waveguide of the SOA. The free carrier population in the active region is inverted by electrical pumping providing optical gain. Thus, the optical beam is amplified during the propagation along the active waveguide and emerges from the opposite facet of the chip. SOAs are compact, electrically pumped and have a large optical bandwidth. Moreover, the semiconductor technology offers a wide flexibility in the choice of the gain peak wavelength by just appropriately choosing the material composition of the active layer. Another key advantage is that these devices can be integrated with other active or passive optical components to generate more complex functionalities. Finally, they are potentially cheap, according to the mature technology and economics of scale. The SOA is of two types: Fabry-Perot amplifier shown in (Figure 2) and travelling wave amplifier shown in (Figure 3).

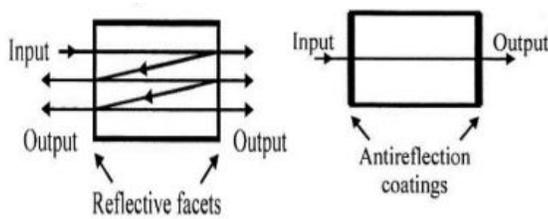


Figure 2: Fabry-Perot and Travelling Wave Amplifier.

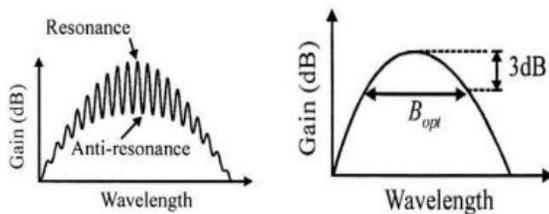


Figure 3: Gain Vs Wavelength of Fabry-Perot And Travelling Wave Amplifier.

In Fabry-Perot amplifier the light entering active region is reflected several times from cleaved face and is amplified as it leaves the cavity. The travelling wave amplifier is an active medium without reflective facets. So that the input signal is amplified by a single passage through active region.

Optical Multiplier

For the past several years, scientists have been trying to use the advantages in optics in data and signal processing because of its high speed, bandwidth, response time, and low noise etc. over electronics. All-optical combinational & sequential logic circuits and many other such devices are already developed. The prime motive in optical computation is to achieve the super-fast computation which is totally controlled by all-optical techniques. The multiplier is a basic requirement in a data processing [5]. It multiplies the $N \times M$ bit. Here, the binary logic state '1' and state '0' are encoded by the optical beams of frequency 'v2' and 'v1', respectively. Let two two-bit binary numbers are $A = (A1A0)$ and $B = (B1B0)$. Their multiplication gives the result $Y = 'S3S2S1S0'$. The optical multiplier is designed by using all optical AND and Optical HALF Adder.

Optical and Gate

The all-optical AND gate is one of the fundamental logic gates because it is able to perform the bit-level functions such as address recognition, packet-header modification, and data-integrity verification. The optical and gate consists of add drop mux, SOA and WDM. The channels of WDM are varied to perform AND operation [6].

Optical XOR Gate

The all-optical XOR gate is a key technology to implement primary systems for binary address and header recognition, binary addition and counting, decision and comparison, encoding and encryption, and pattern matching.

Optical Half Adder

The optical half adder adds two input bits and generates a carry and sum, which are the two outputs of a half adder shown in (Figure 4).

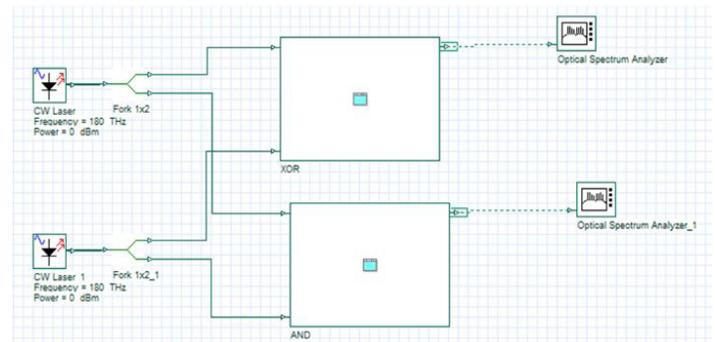


Figure 4: Optical HALF Adder.

Sum = A XOR B; Carry = A and B; *0-190 THz, 1-180 THz.

The input variables of a half adder are called the augend and addend bits. The output variables are the sum and carry and its corresponding truth table is shown in (Table 1).

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

Table 1: Truth table of Optical HALF Adder.

Two Bit Binary Multiplier

The all optical circuit for implementing the frequency encoded multiplication operation is shown in (Figure 5).

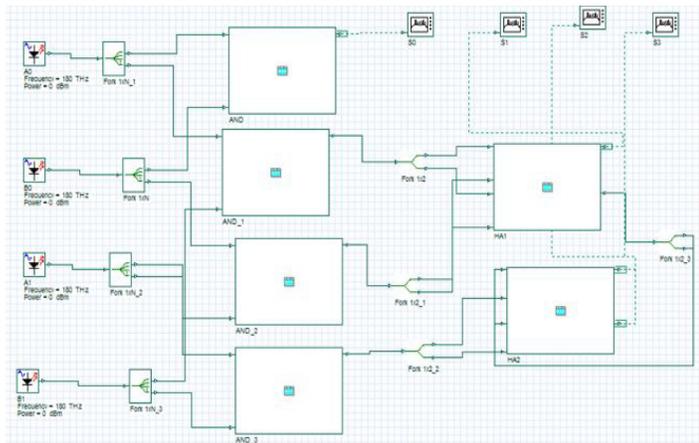


Table 2: Truth Table of Multiplier.

And its corresponding output is shown in (Figure 6).

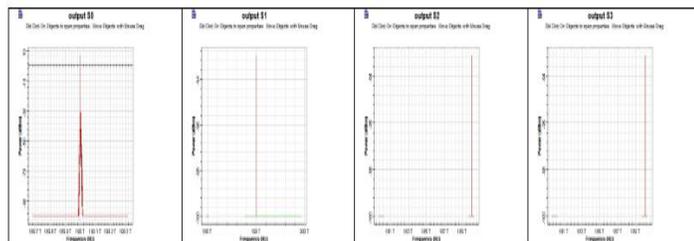


Figure 6: Optical Two-Bit Binary Multiplier.

Results

A Binary Multiplier is a digital circuit used in digital electronics to multiply two binary numbers and provide the result as output. The method used to multiply two binary numbers is similar for multiplying decimal numbers which is based on calculating partial product, shifting them and adding them together. Similar approach is used to multiply two binary numbers. Long multipli-

cand is multiplied by 0 or 1 which is much easier than decimal multiplication as product by 0 or 1 is 0 or same number respectively. The two numbers A1A0 and B1B0 are multiplied together to produce a 4-bit output S3S2S1S0. The optical two-bit binary multiplier is shown in (Figure 6).

Conclusion

The whole process is all an optical one, and the operational speed depends on the switching time of the SOA. The proposed optical binary data multiplier is designed using the all optical AND gate and all optical half adder and it is successfully simulated using Opti system. The results thus obtained satisfy the truth table. Realization of the all optical logic gates will provide not only increased speed and capacity of telecommunication systems, but also various functionalities including optical packet switching, add/drop, decision making, bit extraction, regenerating, and basic or complex optical computing. Since all the conversion techniques are based on frequency encoding/decoding technique, it is free from bit error problems which exist in conventional encoding/decoding techniques.

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