Performance Evolution of Full Adder Using Mach-Zehnder Interferometer and Polarization Effect on WDM Channels

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Abstract—In this paper, two types of techniques are discussed for transmitting the data from transmitter to receiver. Firstly, by using Semiconductor optical amplifier (SOA)-based Mach-Zehnder interferometer (MZI) and Optical tree architecture (OTA) and both play an important role in optical interconnecting networks. Secondly, by using wave division multiplexing techniques and in this optical communication data can be transmitting into the fiber by different techniques. In the proposed architecture the data is send by wave division multiplexing techniques from transmitting end and the effect of polarization seen on channel.

Keywords— MZI, SOA, CW, OTA, WDM, Full Adder.

I. INTRODUCTION

The demand for faster optical communication networks has been on the rise in recent years. To accommodate this demand, the new generation of optical communication networks is moving towards terabit per second data rates. Such data rates can be achieved if the data remain in the optical domain eliminating the need to convert the optical signals to electronic signals and back to optical signals [2]. Therefore, to successfully be able to achieve higher data rates, advanced optical networks will require all optical ultra-fast signals processing such as wavelength conversion, optical logic and arithmetic processing, add–drop function, etc. Various architectures, algorithms, logical and arithmetic operations have been proposed in the field of optical/optoelectronic computing and parallel processing in the last three decades. In almost all the above cases, a single port (cross port) is used to take the output signal. But the signal that exits from the other port (bar port) remains unused. In this communication tried to utilize the output of both the ports of the device. That is, light coming out from the cross port and bar port is taken into account. The light signal that exits through the bar port and also from the cross port of an SOA-based MZI switch is used to design an optical tree-net architecture. In digital optical computing, optical interconnecting systems are the primitives that constitute various optical algorithms and architectures. Optical tree architecture (OTA) also takes an important role in this regard [3][4]. In this communication proposed a new and alternative scheme, which exploits the advantages of both SOA-MZI and OTA, for implementation of all-optical parallel logic and arithmetic operations (half adder, full-adder and full-subtractor) of binary data.

II. PROBLEM FORMULATION

Base on the previous research in this field following research carried out:-

1. The previous research is limited to no. of input bits and to improve in this field means to do work in increasing no. of bits.
2. Intensity loss as well as other losses plays significant role and in previous work these are more and to
improve efficiency or to reduce losses up to some extent.

3. To make case study for Polarization effects and there relation with different parameters such as length, BER etc.

III. IMPLEMENTATION OF FULL ADDER USING MZI

To implement Full adder using MZI, OTA for triple-in-binary logic taken another four MZI-based optical switches s4, s5, s6 and s7 as shown in Fig.2. In this architecture the continuous wave laser source are falls on switch s1. For full adder three control signals is needed. Control signal A is given to the switch s1, control signal B is given to the switch s2 and s3 and control signal C is given to the switch s4, s5, s6, and s7. When the control signal is present then the light emerges upper channel and falls on the next channel and when the control signal is absent then light emerges from the lower channel followed by the next switch. A full adder is implemented using SOA based MZI switch, so on the reference of this describe the SOA based MZI switch. An MZI switch is a very powerful technique to realize ultra fast switching. In this switch a SOA is inserted in each arm of an MZI. The pulsed signal at the wavelength λ1 is split at the first coupler such that more power passes through one arm. At the same time, the CW signal at the wavelength λ2 is split equally by this coupler and propagates simultaneously in the two arms. In the absence of the λ1 beam, the CW beam exits from the cross port (lower port in the figure). However, when both means are present simultaneously, all one bits are directed towards the bar port (upper port in the figure) because of the refractive-index change induced by λ1 beam. The physical mechanism behind the behavior is cross-phase modulation (XPM).

Gain saturation induced by λ1 beam reduces carrier density inside one SOA, which in turn increases the refractive index only in the arm through which λ1 passes. As a result, an additional π phase shift can be introduced on the CW beam because of the XPM, and the CW wave is directed towards the bar port during each one bit. Optical filters are placed in front of the output ports for blocking the original signal λ1. The MZ scheme is preferable over cross gain saturation as it does not reverse the bit pattern and results in a higher on-off contrast simply because nothing exits from the bar port during 0 bit.

A. COMPONENTS DESCRIPTIONS

1) ANALOG SINE GENERATOR: This model creates an analog electrical signal representing a sine wave. It may be used to create a single sine wave, or a frequency comb of sine waves. In general, the output signal of this block can be described by the following equation:

$$S_0(t) = V_{pp} \sum_{n=1}^{N} \sin((2\pi f_n t) + \phi_n) + V_0$$

where $S_0$ is the output signal value (whether it be in units of volts or amps depends on the setting of the signal Type parameter). $V_{pp}$ is the peak to peak value of each sine wave in the frequency comb. $N$ is the total number of frequencies summed together in the frequency comb. $f_n$ is the frequency of each of the individual sine waves present in the frequency comb. $t$ is the time. $\phi_n$ is the phase offset for the nth element in the frequency comb. $V_0$ is the offset value, which is added to the total signal after all sine waves in the frequency comb have been summed together.

2) DIRECT MODULATED LASER: This block models a semiconductor laser directly modulated with an electrical signal. It computes the electrical current injected into the laser's optical cavity and solves the laser rate equations for the optical output. The behavior of the model can be partitioned into three blocks, as shown in Fig.3. The driving source consists of the electrical signal input into the model. The parasitic consist of a bond inductance and shunting capacitance. Finally, the laser cavity is modelled via a simplified current-voltage relationship and the laser rate equations.
3) **OPTICAL COUPLER (2x2):** This model represents an optical coupler. It takes an optical input signal on each port, and uses one of two ways to couple the optical signals together. If the mode is set to parameterized, it uses the following complex matrix to couple the signals, where $A$ represents the complex optical field amplitude:

$$
\begin{bmatrix}
A_{01} \\
A_{02}
\end{bmatrix} = \begin{bmatrix}
\sqrt{1 - \alpha} & j\sqrt{\alpha} \\
j\sqrt{\alpha} & \sqrt{1 - \alpha}
\end{bmatrix} \begin{bmatrix}
A_{i1} \\
A_{i2}
\end{bmatrix}
$$

If the mode is set to Custom, the following complex matrix is used to couple the signals:

$$
\begin{bmatrix}
A_{01} \\
A_{02}
\end{bmatrix} = \begin{bmatrix}
C_{11} & C_{12} \\
C_{21} & C_{22}
\end{bmatrix} \begin{bmatrix}
A_{i1} \\
A_{i2}
\end{bmatrix}
$$

There is also a loss factor that may be applied to both input signals.

4) **SEMICONDUCTOR OPTICAL AMPLIFIER (SOA):** This module simulates a Semiconductor Optical Amplifier (SOA). The SOA is a highly nonlinear device. It can be used not only for signal amplification but also for other optical signal processing applications, such as wavelength converting, switching and optical time domain de-multiplexing [1]. The SOA is modelled as a travelling wave amplifier. It takes into consideration the time dependence of the gain caused by the saturation effect and the time-dependent phase change due to the gain-index coupling. Fig. 4 shows a typical SOA geometry.

5) **OPTICAL FILTER:** This model represents one of the following types of optical filters: Fabry Perot, Gaussian, Raised Cosine, Lorentzian, Trapezoidal, Ideal, Custom1, Custom2, and Custom3. Each filter type except for the custom types may also be inverted. A wavelength signal whose filtered peak power does not exceed the user specified drop threshold will not be passed by the filter. The Trapezoidal filter type uses a Trapezoidal filter response to filter the optical signal amplitude. The user specifies the bandwidth in the wavelength domain, and the order of the filter.

**IV. POLARIZATION EFFECT ON WDM CHANNEL**

Polarization is a property of waves that describes the orientation of their oscillations. This will primarily cover the polarization of electromagnetic waves such as light although other types of wave also exhibit polarization. The introduction of wavelength converters into the cross-connects in WDM transport networks may allow improved blocking performance [7] and simpler network management. So-called optically transparent wavelength converters are modulation-format independent; and can perform multichannel wavelength conversion, in which a single wavelength converter simultaneously shifts the wavelengths of a comb of independently modulated wavelength-division multiplexing (WDM) channels. Large WDM cross connects based on multichannel wavelength converters may use fewer components and be more gracefully scalable than those based on single-channel wavelength converters [8]. An ideal multichannel wavelength converter is polarization insensitive; widely and arbitrarily tunable; and compact, because large arrays of wavelength converters may be required.

In wavelength division system there are number of channels launched into a single fiber span. Channel spacing is 50 GHz and they are generated in groups by odd and even channels by two PRBS generator. Initially all channels have the same polarization state. All even channels before being multiplexed with odd channels are passed through the Polarization Shifter, which rotates the polarization state by different angle. Fig. 5 shows the block diagram of WDM system. After multiplexing the signal is launched into a fiber, and then is de-multiplexed and sent to 8 receivers. At the receiver end measure the BER and Q-factor for given polarization state difference between adjacent channels.
A. COMPONENTS DESCRIPTION

1) **PRBS PATTERN GENERATOR**: This model generates a binary sequence of several different types. A single model instance may be used to provide multiple pattern outputs, optionally offset from each other, to drive different channels of a WDM or parallel optical bus simulation. Or, each channel may have its own model instance configured to provide a different pattern than the other model instances. The different pattern types are described according to their name in the user parameter list:
   - PRBS produces a maximal length pseudo-random binary sequence.
   - Alternating produces a series of bits alternating between 0 and 1.
   - Single produces a single 1 bit in the centre of a series of 0 bits.
   - One produces a series of 1 bits.
   - Zero produces a series of 0 bits.

2) **ELECTRICAL SIGNAL GENERATOR**: This model converts an input binary signal into an output electrical signal. The output signal may be specified as either voltage or current. The user parameters are used to configure the electrical signal output. Four different electrical drive types are modelled such as ON OFF, ON off Exponential, ON OFF Ramp, and Raised Cosine.

3) **CW LASER**: This model produces the optical signal output of one or more CW lasers. It is most commonly used in conjunction with the external modulator model to encode a binary signal upon the CW source. In this, the CW source is characterized completely by its power, wavelength, line width, relative intensity noise (RIN) and phase. These are controlled directly through the The parameters peak Power, wavelength, line width, RIN and phase. laser can also be assigned a random phase by setting random Phase=YES. There are two options for the temporal representation of the laser output selected by the parameter signal type.

4) **ELECTRO ABSORPTION MODULATOR**: This model represents an electro absorption modulator. It allows the user to specify the extinction ratio of the output optical signal and it scales the input modulating voltage signal as required to obtain the specified extinction ratio at the output. In addition, the user may specify whether or not the output optical signal should be modulated as the inverse of the input electrical signal. This model has two input ports and one output port. The first input port accepts an optical signal that is modulated to produce the output optical signal, and the second input port accepts an electrical signal that is used to modulate the input optical signal to produce the output in the optical signal.

5) **COMPOUND OPTICAL RECEIVER**: This models an optical receiver and all its standard parts. The OptSim photo receiver model is composed of several individual building blocks: the photo detector, the preamplifier, and the post amplifier/filter complex.

V. EXPERIMENTS AND RESULTS

A. FOR IMPLEMENTATION OF FULL ADDER USING MZI

Experiment done for all possible input combination and we have shown output waveform for some cases as below:

Case 1: When \( A = B = C = 0 \)
Case 2: When $A = B = 0, C = 1$

Case 3: When $A = B = C = 1$

B. **FOR POLARIZATION EFFECT ON WDM CHANNEL**

Case 1: Polarization State for Fiber Length of 75 km for Odd Channel

Case 2: Polarization State for Fiber Length of 80 km for Even Channel
Case 3: Combined Effect of polarization at different Length and angle of polarization for Odd Channel

Case 4: Combined Effect of polarization at different Length and angle of polarization for Even Channel

VI. CONCLUSIONS

From the experiments performed we can conclude that Full adder can be implemented successfully for any higher number of input digits by proper incorporation of MZI based optical switches, vertical and horizontal extension of the tree and by suitable branch selection. And also during the study of the polarization effect, it is demonstrated that various combinations of different polarization angles can be simulated efficiently and accurately to calculate BER and Q-factor. During this simulation, it is observed that at 90 degree polarization angle, minimum BER and maximum Q-factor can be achieved. The effect of polarization is studied at different fiber lengths, as the length of fiber increases the BER also increases but Q-factor decreases. This result holds that the polarization angle is independent of the length of fiber, i.e. for any length of fiber the effect of polarization is minimum at 90 degree. Using this, the receiver model can be improved using realistic filter shapes and to account for noise re-polarization during transmission.

REFERENCES