

# Optical Fiber Communication System Performance Using MZI Switching

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**Abstract-** First a simple all-optical logic device, called Mach Zehnder Interferometer is composed by using a Semiconductor Optical Amplifier (SOA) and an optical coupler. This device is used for generating the logical functions (AND, XOR) and a multiplexer and an Encoder is obtained using this device in Optical Tree Architecture. The simulation of Encoder and Multiplexer is done at a rate of 10 Gbit/s and both are simulated for different input logical combinations. Simulations indicate that the device is suitable to operate at much higher bit rate and also for different logical entities. Many lower-speed data streams can be multiplexed into one high-speed stream by means of Optical time division multiplexing (OTDM), such that each input channel transmits its data in an assigned time slot. The assignment is performed by a fast multiplexer switch (mux). The routing of different data streams at the end of the TDM link is performed by a demultiplexer switch (demux) and this demultiplexer is employed using MZI switch as it consists a semiconductor optical amplifier (SOA) and a optical coupler. In this chapter four channel OTDM is simulated at 40 Gbit/s and further it is investigated the impact of the signal power, pulse width and control signal power on BER. The Mach-Zehnder Interferometer switch (used with unequal interferometric arm lengths in the switch network) cycles between the cross state, where most of the light appears in the waveguide on the same side as the input, and the bar state, where most the light moves to the waveguide on the other side. In the proposed communication system (Fig. 1) where wavelength 1.3  $\mu\text{m}$  is being used for transmission and 1.5  $\mu\text{m}$ , for reception on the same fibre, the circuit remains in a bar state for 1.3 but in a cross at 1.5 so that most of the received light can be sent to the receiver, and not to the transmitter, without compromising the insertion loss between the transmitter and the fibre [1]. The ideal behaviour of the couplers in the switch (the 3dB point) could be changed to 1.3 or 1.5 to minimize the insertion loss of the transmitter or receiver, at the expense of the other, which is achieved by obtaining waveguide narrowing distance of 5.4683  $\mu\text{m}$  in the couplers.

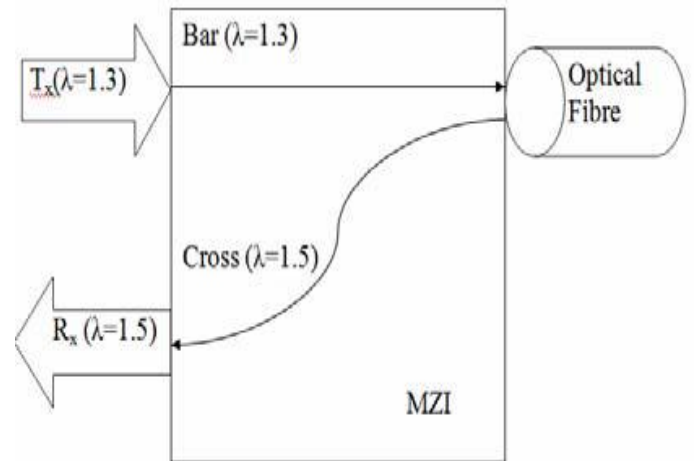
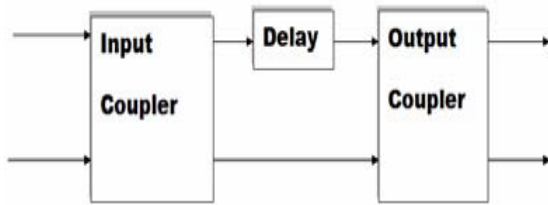
## I. INTRODUCTION

Optical communication technology has developed rapidly to achieve larger transmission capacity and longer transmission distance. For that such data

rates can be achieved if the data remain in the optical domain eliminating the need to convert the optical signals. Therefore, to successfully be able to achieve higher data rates, advanced optical networks will require all optical ultra fast signal 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. Nonlinear optical loop mirror (NOLM) provides a major support to optical switching based all optical logic and algebraic processing where the switching mechanism is based on fiber Kerr nonlinearities.

## II. MACH ZEHNDER INTERFEROMETER

The Mach-Zehnder Interferometer is a device used to determine the phase shift caused by a small sample which is placed in the path of one of two collimated beams from a coherent two light source. A Mach-Zehnder Interferometer is created from two couplers connected by arms of unequal optical length. The Mach-Zehnder Interferometer has two input ports and two output ports. The light is split in the two arms of the input coupler of the interferometer, and they are later recombined in the output coupler of the interferometer. The optical length of the two arms is unequal, making the phase corresponding to delay in Fig.1.1 to be a function of wavelength. The relative phase of the light in the two input ports of the output coupler is therefore a function of wavelength. As the phase of the delay ( $d$ ) is increased, the MZI cycles between the cross state, where most of the light appears in the waveguide on the same side as the input, and the bar state, where most the light moves to the waveguide on the other side.



### III. ELECTRO-OPTIC MZI SWITCHES

So as to have the modified banyan network rearrangeable in any case of blocking we can incorporate electro-optic MZI switches. In electro-optic switches, the switching function is achieved by changes in physical properties of materials caused by the application of an electrical voltage. The observed phenomenon typically include changes in the index of refraction of materials and are collectively referred to as electro-optic effects [3]. The material used is Lithium-Niobate [LiNbO<sub>3</sub>] which has a large electro-optic coefficient allowing very fast transition times with moderate switching voltages. An electrical voltage changes the refractive index of the substrate which in turn manipulates the light through the appropriate waveguide path to the desired port in the proposed switch structure (Fig. 5). The waveguide of the proposed electro-optic MZI switch clearly showing the electrode regions (courtesy optiBPM module of Optiwave software) So applying the electric voltage we can change the

### IV. SEMICONDUCTOR OPTICAL AMPLIFIER

Semiconductor optical amplifiers are amplifiers which use a semiconductor to provide the gain medium. Recent designs include anti-reflective coatings and tilted waveguide and window regions which can reduce end face reflection to less than 0.001%. Since this creates a loss of power from the cavity which is greater than the gain it prevents the amplifier from acting as a laser. Such amplifiers are often used in telecommunication systems in the form of fiber-pigtailed components, operating at signal wavelengths between 0.85 μm and 1.6 μm

switching characteristic of the switches. If the voltage is kept at zero the default switch will remain in the bar state. When the appropriate switching voltage (assumed to be 6.75V approx), the switch goes on into the cross state.

#### SPECIFICATIONS FOR ELECTRODE REGION AND SWITCHING

**VOLTAGES** The phenomenon of changing characteristics of the switch

can be of high importance in the modification of banyan network [4]. The modified banyan network can be made

rearrangeable so as to accommodate switching fluctuations as per the demand of the network. The switching voltage of all the individual electro-optic MZI single units can be well controlled by control signals as per the instantaneous connectivity of the input and output ports in the network. The changing of the electrical switching voltages can be easily detected in the network and the connectivity gets rearranged.

and generating gains of up to 30 Db. The semiconductor optical amplifier is of small size and electrically pumped. It can be potentially less expensive than the EDFA and can be integrated with semiconductor lasers, modulators, etc. However, the performance is still not 5 comparable with the EDFA. The SOA has higher noise, lower gain, and moderate polarization dependence and high nonlinearity with fast transient time. This originates from the short nanosecond or less upper state lifetime, so that the gain reacts rapidly to changes of pump or signal power and the changes of gain also because phase changes which can distort the signals. This nonlinearity presents the

most severe problem for optical communication applications. However it provides the possibility for gain in different wavelength regions from the EDFA.

waveguides are designed such, that the light can be transferred from one waveguide to the other by coupling. The switching is obtained by properly adjusting the effective refractive index of one of the waveguides. For switching only a small refractive index change is needed.

For a good transfer of the light, an accurate coupling length is required. Since this length is attenuation of an optical signal, by turning the gain on and off. This property can be employed for a simple but effective way of switching by splitting an optical signal with a 3 dB splitter, after which this signal is attenuated in one arm and amplified in the other arm. Since the splitter losses and additional losses (e.g. fiber-chip coupling loss) can be compensated by the SOA, this type of switch can have low loss or even gain and, in addition, excellent on-off ratios leading to low crosstalk levels.

The most important disadvantage of a SOA switch is its high additional noise level in the —on—state caused by spontaneous emission generated in the SOA.

#### V. OPTSIM

Optsim is an advanced optical communication system simulation package designed for professional engineering and cutting-edge research of WDM, DWDM, TDM, CATV, optical LAN, parallel optical bus, and other emerging optical systems in telecom, datacom, and other applications. It can be used to design optical communication systems and simulate them to determine their performance considering various component parameters

highlighted that, when integrated on chip, this type of all-optical flip-flop opens new prospects for implementing all-optical fast memories and timing regeneration circuits. Jingsheng Yang et al. presented a function-lock strategy for all-optical logic gate (AOLG) utilizing the cross-polarization modulation (CPM) effect in a semiconductor optical amplifier (SOA). By monitoring the power of logic light, the strategy realized controllable methods to capture OR and NOR functions and switch between them. The strategy had been successfully applied in experiment with 10-Gb/s not-return-to-zero (NRZ) signals, which had a high

#### DC Switch:

In a directional coupler switch two adjacent wavelength dependent and strongly influenced by fabrication deviations

usually polarization and (etch depth, waveguide spacing), a good switch performance is hard to obtain.

#### SOA based MZI Switch:

A semiconductor optical amplifier can both be used for amplification and

success-rate above 95% and ensures the high extinction ratio of result light above 11.4 dB. Every step in the strategy had definite numeric evaluation, which provides the potential of automatic implementation.

#### VI. HORIZONTAL AND VERTICAL EXPANSION

However, with a banyan topology, only a unique path can be found from each network input to each network output,

which degrades the network to a blocking one. A general approach to building banyan-based non-blocking optical switching networks is to jointly perform horizontal expansion and vertical stacking [5] in which a regular banyan network is first horizontally expanded by adding some extra stages to the back of the network, and then multiple copies of the

horizontally expanded banyan network are vertically stacked. When two optical signals traverse through a single switch at the same time, a small portion of optical power in one waveguide will be coupled into the other unintended waveguide. This undesirable coupling is called the first-order crosstalk. This first-order crosstalk will propagate downstream

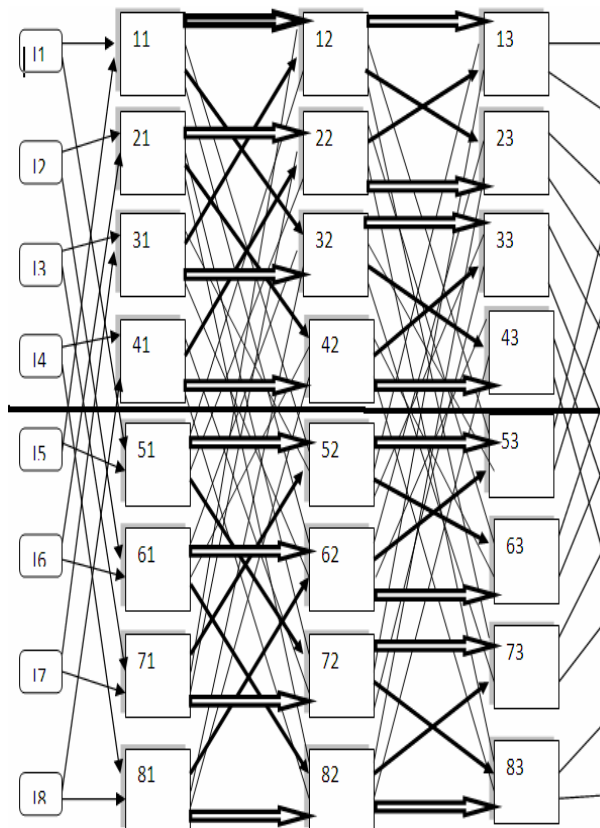
stage by stage, leading to a higher order crosstalk in each downstream stage with a decreasing magnitude. Due to the stringent bit-error rate requirement of fiber optics, crosstalk

elimination has become an important issue for improving the signal-to-noise ratio of the optical flow transmission [6]. A

cost-effective solution to the crosstalk problem is to guarantee that only one signal passes through a single switch at a time, thus eliminating the first-order crosstalk.

So, opting for the simultaneous horizontal as well as vertical expansion of the modified banyan

network must be towards the perfection that no common individual switch is expected to be part of the link for two different sets of input and output ports. But the expansion comes with a high hardware cost or a large network depth to guarantee the nonblocking property. Blocking behavior analysis of a network is an effective approach to the study of network performance and to finding a desirable trade-off between hardware costs and blocking probability. The horizontal expansion of two extra stages (Fig. 6) leads to the path of attaining non-blocking feature for the modified banyan network. The vertical extension for the network can be determined with the simulation of the network to get the minimum number of vertical planes needed to attain the complete non-blocking status for the modified network. The upper and lower bound set for the blocking probability for such a modified network with simultaneous horizontal and vertical expansion is feasible [5] and the minimum number of vertical planes stacked together is also set low. So the realization of the modified architecture of the network gets facilitated.



VII. WORKING OF MULTIPLEXER

As we already discussed the MZI switch for all-optical logic so here the working of the optical tree using MZI based optical switches. There is a constant source of CW beam of which may be a laser source. The light signal that comes from CWLS can be taken as the incoming signal. The incoming light signal is incident on switch s1 first. Now we can obtain the light in different desired branches or sub branches by proper placing of control signals. Control signals are also light signals.

**Case 1: When A= '0' and B= '0' :**

The CW light beam that comes from constant CWLS is incident on switch s1 first. As here  $A = \_0'$ , the control signal A is absent, that means only incoming light signal is present at s1. As per the switching principle discussed above, the light emerges through the lower channel and falls on switch s3 at C. Here the control signal B is absent. As signal B is absent so light finally comes out through lower channel of s3 and reaches output 1. In this case, no light is present at other outputs ports, so output port1 is one state and others are in zero state.

**Case 2: When A = '0' and B = '1' :**

Light from the CW light source is incident on s1. As  $A = \_0'$ , the light beam emerges through the lower channel and falls on s3. At s3 the control signal B is present. In the presence of the control signal emerges through the upper channel of s3 and finally reaches to the output port 2. In this case light is only present in output port 2. Hence output port shows one state while others shows zero state.

**Case 3: When A = '1' and B = '0'**

The light from CWLS is incident on switch s1 first. As here  $A = \_1'$ , the control signal A is present. Because of that, the light emerges through the upper channel of s1 and falls on s2 at O. As  $B = \_0'$ , no control signal is present at B, that means the light comes out from the lower channel of s2 to reach output port 3. So output port 3 is in one state and others are in zero state.

**Case 4: When A = '1' and B = '1':** The light from CWLS is incident on switch s1 first. As here  $A = \_1'$ , the input control signal A is present. Because of that, the light emerges through the upper channel of s1 and falls on s2

VIII. CONCLUSION

In this thesis the scheme generating optical logic is implemented by MZ Interferometer as discussed in chapter 2 can be used for different purposes. This scheme can easily and successfully be extended

and implemented 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. Again the whole operation is parallel in nature, i.e. the results of different operations between the data are obtained at a time. Here we can implement the multiple instruction multiple data type operation nicely. Arithmetic operations can be conducted here between any two large-shaped data. The proposed one bit digital comparison scheme also successfully exploits non-linear material based tree structures for its operation. It is important to note that the above discussions are based on a simple model. In this simulation some walk parameter has to be considered such that dispersion, polarization properties of the fiber, predetermined values of the intensities/wavelength of laser light for control and incoming signals, introduction of the filter, intensity losses due to the beam splitters/fiber couplers etc. As in this thesis the wavelength of the continuous wave of laser beam is 1550  $\mu\text{m}$  and pulsed signal of wavelength of 1650  $\mu\text{m}$  can be used as incoming and control signals, respectively. Intensity losses due to the couplers and splitters in the interconnecting stage may not create much trouble in producing the desired optical bits at the output as the whole system is a digital one and the output depends on the presence and absence of the light.

#### IX. FUTURE ASPECTS

All-optical logic is recent research in the field of optical computing as this scheme also provides the idea of optical memory if we design an optical flip-flop which stores data as an optical pulse. As FTTH has many advantages over the all transmission techniques so, Providers could use ATM, SONET, Ethernet or Analog modulated RF carriers as their data link layer technology. Since all users served by the same splitter – combiner on a curbside PON (and by the same Remote Node in an Active Star architecture) have to be served by the same data-link layer technology. FTTH infrastructure that is technologically and competitively neutral; where voice, video and data service providers can choose and deploy the technology of their choice to support the services they plan to offer. FTTH also provides additional services over it just like UWB (Ultra wide band), WCDMA, Radio over fiber, so many other services as network will use FTTH network as the interface for access network.

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