Design of All-Optical Toggle Flip-Flop Using Bi-Directional Optical Fiber

Gemkutti Kanagaselvi M J[1], V.Anusooya[2]

PG Scholar[1], Assistant Professor[2], V V College of Engineering, Tirunelveli, Tamil nadu, India.

gemgracethiva@gmail.com , anusooya@vvcoe.org

***Abstract* - Optical technologies represent the main bet for the future communication system. So it is necessary to convert all the digital components in to optical. In the field of sequential circuits, flip flops are used, because designing with flip flop is more convenient. All-optical flip flop have been widely investigated mainly because they can be exploited in all-optical packet switches. Optical flip flop results in high transition speed and switching energy, low power consumption and less complexity. Recent developments in optical signal processing and in photonic switching have made possible to reach bit rates in the order of gigabits per second per wavelength and terabits per second per fiber.**

In this project, All-optical Toggle flip flop using Bidirectional optical fiber is demonstrated at an operating bit rate (speed) of 10Gbps. The non linear phenomenon, cross phase modulation is achieved in Bidirectional optical fiber and also this component simulates the bidirectional propagation of arbitrary configuration of optical signals in a single-mode fiber. However the proposed technology has potential for multi Giga bits per second operation.

***Keywords* – Optical flip flop, communication system, optical signal processing, bidirectional optical fiber.**

I. INTRODUCTION

In Optical Communication, light is used to transfer the message. So it will be more speed than the digital communication. All optical processing of light signals is a key step towards the development of future fiber optic telecommunication system. Research in this field is in its very early stages even if some interesting techniques have been already theoretically addressed and experimentally demonstrated. All-optical packet switching seems to be the most promising way to take advantage of fiber bandwidth to increase routers forwarding capacity, being able to achieve very high data rate operations.

The exponential growth of internet traffic has been the major driving force for the increasing demand for transmission bandwidth [10]. To increase the efficiency of the network and to allow high data bit rates is desirable that switching and routing can be carried out in the physical layer, avoiding optical-to-electrical and electrical-to-optical converters. All-optical devices provide data format transparency, and may provide lower power consumption and higher-speed processing, compared to their electronic counter parts [13]. Recent developments in optical signal processing and in photonic switching have made it possible to reach bit rates in the order of gigabits per second per wavelength and terabits per second per fiber. AOFF can be used to perform many optical signal processing functions in future optical packet switching networks. Examples of such applications are: as storage of the header information of a packet, as basic building blocks of optical shift registers and optical counters, in threshold functions and self-routing, in optical contention resolution schemes, as regenerative memory elements, among others.

In the last few years, considerable research has been done using AOFFs as basic building blocks of several photonic schemes. The flip-flop state is determined by the laser that is currently lasing. It uses steady state characteristics to obtain the rate equation [6]. The flip-flop model was based on a laser model which assumed a constant carrier density along the laser length. The speed of the system will be dependent on the intrinsic modulation bandwidth of the individual lasers. The T-FF circuit with a single output was successfully operated and finite direct current (dc) supply current margins were obtained at temperatures from 27 to 34k [5]. Correct logic operations at low frequencies of the test circuit including T-FF with a single output was confirmed at temperatures from 27to34K. The narrowest dc supply current margins were wider than ±7 % at 34 K except for the dc supply current of the SFQ-dc converter. The narrowest dc supply current margin of the T-FF circuit could be ±10 % even at 40 K.

All-optical flip-flops are one of the key components because they can act as temporary memory elements [4]. Using pulses with repetition rates of 2 GHz and energies below 200 fJ, we obtain switch-on times of 75 ps and almost immediate switch-off of the DFB laser diode. However, most of these designs are relatively complex or require a difficult active passive integration. The switching behavior of the synchronous S-R flip-flop which is based on a hybrid-integrated S-R latch and two additional Mach-Zehnder interferometer structures has 18 dB extinction ratio with switching times less than 450 ps [7]. Fast and low energy all optical flip-flop devices based on asymmetric active-multimode interferometer showed high speed all-optical flip-flop operation with 25ps long pulses [3].

The TFF architecture requires the minimum number of active components and just a single toggling signal as input [8]. This layout holds the credentials for reaching multi Gb/s operational speeds when using integrated short-length feedback-loop implementations by exploiting the high index contrast silicon-on-insulator (SOI) technology. The state of the art for all-optical flip-flop based on semiconductor technologies: best result will be highlighted in terms of transition speed, switching energy, complexity and power consumption [2]. Research in the field of semiconductor technologies is in its very early stages even if some techniques have been already addressed.

II. DEVICE CONCEPT AND EXPERIMENTS

A. Device Description

Bidirectional optical fiber simulates the bidirectional propagation of arbitrary configuration of optical signals in a single-mode fiber. Dispersive and nonlinear self phase modulation (SPM), cross phase modulation (XPM), stimulated Raman (SRS) and Brillouin (SBS) scattering effects - are taken into account [14]. Cross-phase modulation (XPM) is a nonlinear optical effect where one wavelength of light can affect the phase of another wavelength of light through the optical Kerr effect. Self-phase modulation (SPM) is a nonlinear optical effect of light-matter interaction. An ultra short pulse of light, when travelling in a medium, will induce a varying refractive index of the medium due to the optical Kerr effect.

Stimulated Raman scattering is a nonlinear-optical effect. Raman interaction for an arbitrary configuration of sampled and parameterized signals is also considered. Brillouin scattering arises from the interaction of light with acoustic waves that are always present in any material. The component provides most of the functionality of the total field approach fiber model (except for the simulation of the Raman effect in birefringent fibers). The four-wave mixing effect between multiple sampled signals is not considered.

B. Experiment

In the Simulation setup of all-optical Toggle flip-flop using Bi-Directional optical fiber, Toggle signal is generated by passing the output of a CW laser through a Mach-Zehnder Modulator which will control the amplitude of an optical wave and it is driven by the bit sequence generator and pulse generator.

Purpose of bit sequence generator is to produce a prescribed sequence of outputs. NRZ pulse generator is used to generate binary code in which ones are represented by one significant condition, usually a positive voltage, while zeros are represented by some other significant condition, usually a negative voltage, with no other neutral or rest condition. Output from the MZM is splitted through a 50:50 power splitter. The split signals are then injected into two arms. A time delay line is present in one arm to equalize the length of the two paths.

EDFA is used in each arm which is used to boost the intensity of the optical signals, Polarization Controller (PC) is used in each arm which is used to allow one to modify the polarization state of light and used to separate signal. Now the output from the two PC are fed as input to the Bi-Directional Optical Fiber which produces the output as set and reset signals. Design method of All-Optical Toggle Flip-Flop was shown as block diagram in Figure1.

The 10Gbps Toggle signal is generated by selecting a proper NRZ sequence on the pattern generator for generating the binary code with 2GHz clock frequency. The following 8-bit sequence is used as a test example: 10101010 as shown in Figure 2. Thus producing Toggle trigger pulses.

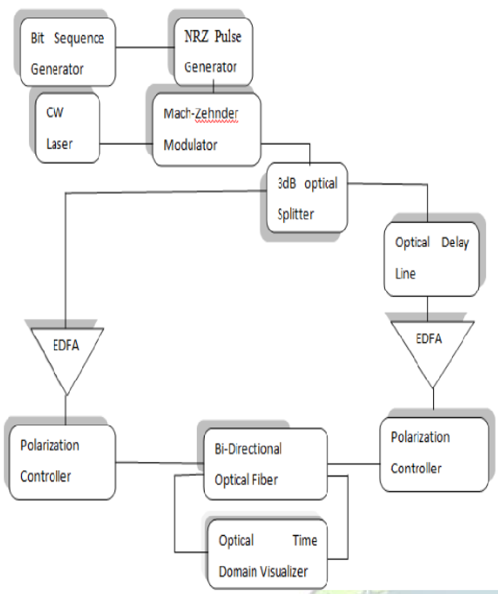

Fig. 1. Design of All-Optical Toggle Flip-Flop

The output is obtained with the amplitude 10a.u and with the rise and fall time are 0.05 bits. The output occurs between amplitude and time. This input signal is given as input to the MZM. Now the output is produced with the controlled amplitude of an optical wave as shown in Figure3 which is the optical signal. The output obtained from the MZM is considered as the optical signal with the extinction ratio 16dB and it has the power of 3mW.

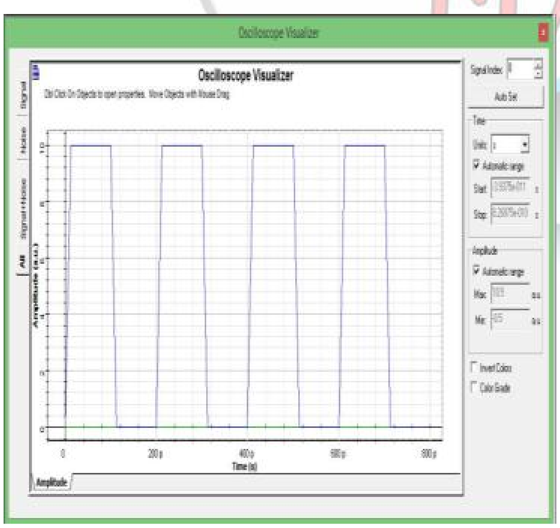

Fig. 2. Output from NRZ pulse generator

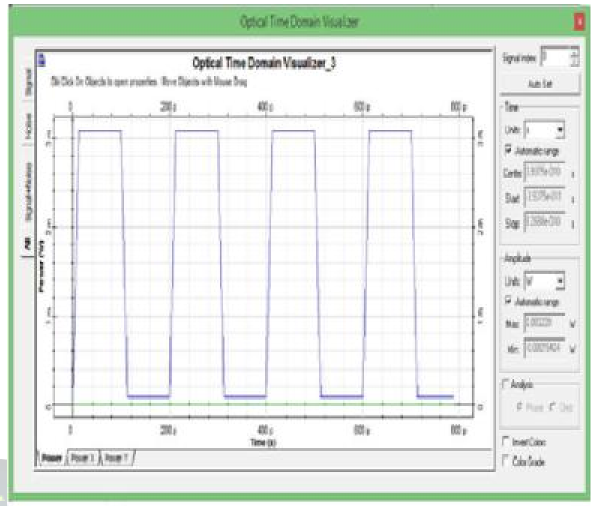

Fig. 3. Output from MZM

Then the power is splitted using the splitter and passes through the EDFA which modifies the signal that is, it boost the intensity of optical signals. Thus producing the modified output signal with 100mW. It has the forward pump power as 20 dBm and forwarding pump wavelength is 980 nm.

This modified signal passes through the Polarization Controller to avoid the random state of polarization and to modify the polarization state. The input and output waveforms of the PC are obtained as shown in Figure 4. The signal which goes into the PC has azimuth, ellipticity as -0.00534 and -0.00169 degree.

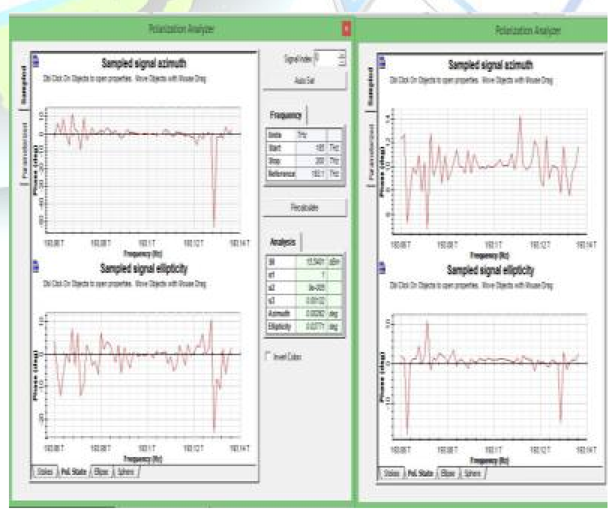

Fig. 4. Output from Polarization Controller

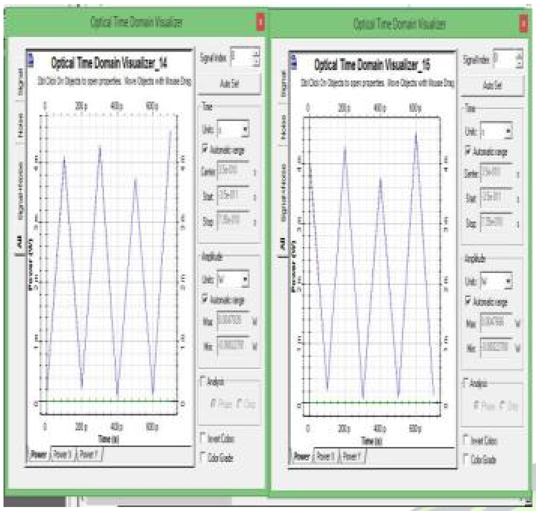

Fig. 5. Set and Reset waveforms from Bidirectional Optical Fiber

These signals are given to the Bi-Directional Optical Fiber which simulates the bidirectional propagation of arbitrary configuration of optical signals. From this component both the set and reset signals of a given continuous toggle signal are obtained as shown in figure 5.

C. Characteristic Table of T Flip-Flop

The analysis of the T flip-flop is illustrated as a characteristic table which is shown in table I. It specifies T as the input and Q as the output and Q' is the inversion of the output Q. Here T is the toggle signal, Q and Q' are the set and reset pulses of the given input signal.

TABLE I

CHARACTERISTIC TABLE OF T FLIP-FLOP

Toggle Signal **T**	**Set Signal** **Q**	**Reset Signal** **Q'**
1	0	1
0	1	0
1	0	1
0	1	0
1	0	1
0	1	0
1	0	1
0	1	0

When the given input is high, the output gets toggles but when the input is low, it holds the previous input as flip-flop output. Consider example:10101010 when '1' is given as the output, it get toggles and produces the output as '0'. When '0' is given as the input, it produces the output as '1' that is, the previous state input is produced as the output.

III. CONCLUSION

Thus the all-optical toggle flip flop using bidirectional optical fiber is designed and simulated using optisystem7 software. The higher bit rate of 10 Gbps is achieved. The set and reset pulses of continuous toggle input signal is obtained by a nonlinear phenomenon, cross phase modulation, which is obtained in the bidirectional optical fiber. However the proposed technology has potential for multi giga bits per second operation.

REFERENCES

[1] Amin Abbasi, *et al* (2012), 'Ultra compact and fast All Optical Flip Flop design in photonic crystal platform', Photonics Group, Research Institute for Applied Physics, University of Tabriz, Tabriz, Iran.

[2] Antonella Bogoni, *et al*, 'All-optical flip-flops based on semiconductor technologies', Consorzio Nazionale Interuniversitario per le Telecomunicazioni (CNIT) Pisa, Italy.

[3] Jae Hun Kim, *et al* (2004) 'All-Optical Logic Gates using Semiconductor Optical Amplifier based devices and their Applications', Journal of the Korean Physical Society, Vol. 45, No. 5, pp. 1158-1161.

[4] Jiang, *et al* (2011), 'All-optical flip-flop operation based on asymmetric Active Multimode interferometer bi-stable Laser Diodes', Vol. 19, No. 26, pp. 119-124.

[5] Koen Huybrechts, *et al* (2008), 'Fast all-optical flip-flop based on a single Distributed Feedback laser diode', Vol. 16, No. 15, pp. 11405-11410.

[6] Koji Tsubone, *et al* (2006), 'Operation of HTS Toggle-Flip-Flop Circuit With Improved layout design', IEEE transactions on applied superconductivity Vol. 16, No.4.

[7] Martin Hill, *et al* (2001), 'All-Optical Flip-Flop Based on Coupled Laser Diodes', IEEE journal of quantum electronics, vol. 37, No. 3.

[8] Maziotis, *et al* (2010), 'All-optical synchronous S-R flip-flop based on active Interferometric Devices' Vol. 21, No. 15, pp. 164-170.

[9] Paraskevas Bakopoulos, *et al* (2012), 'All-Optical T-Flip-Flop Using a Single SOA-MZI based latching element', IEEE photonics technology letters, Vol. 24, No. 9.

[10] Reis, *et al* (2011), 'All-optical clocked D flip-flop memory using a hybrid Integrated S-R latch', vol. 23, No. 12, pp. 262-270.

[11] Teixeira, *et al*, 'Evolution of All-Optical Flip-Flops and Their Applications in Optical communication networks', Institute de Telecomunicações – Pólo de Aveiro, Portugal.

[12] Villafranca, *et al* (2010), 'Multiple-bit All-Optical logic based on cross gain modulation in Semiconductor optical Amplifier', IEEE, ICTON, Vol. 30, No.6.

[13] Zaitsu, *et al* (2011), 'Optically clocked flip-flop operation based on coupled DBR laser diode' Opto-Electronics and Communications Conference (OECC), Vol. 4, No. 8, pp. 291-292.

[14] Muthukumaran, N & Ravi, R, 'Simulation Based VLSI Implementation of Fast Efficient Lossless Image Compression System using Simplified Adjusted Binary Code & Golumb Rice Code', World Academy of Science, Engineering and Technology, Volume. 8, No. 9, pp.1603-1606, 2014