iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** XI **Month of publication:** November 2017

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

All-optical Switching Network Design using Terahertz Optical Asymmetric Demultiplexer

Ashis Kumar Mandal[1], Goutam Kumar Maity[2], Nabin Baran Manik[3]
[1]*Department of Physics, Jadavpur University, Kolkata-32, India*
[2,3]*Department of Physics,Pingla Thana Mahavidyalaya, Maligram,Paschim Medinipur, West Bengal, India*

Abstract: In recent past the ultra high speed all-optical switches, like 2×2 Terahertz Optical Asymmetric Demultiplexer (TOAD),based on semiconductor optical amplifier (SOA) especially in interferometric configuration are very pronouncing due to their high repetition rate, low power consumption, fast switching time, easily integrated, noise and jitter tolerance. And this2×2 TOAD operationally versatile all-optical switch has brought the revolution in all-optical information processing systems. To achieve this goal, the switching network of this type of all-optical switches is explored in this paper.This switching network is designed by all-optical 2×2 TOAD, based interferometric switch to have four switching actions. And the application of proposed switching network i.e., a logic unit is also designed to get 16-logical operations. Numerical simulation confirmed the circuit's feasibility and performance in terms of the choice of the critical parameters.
Keywords—Terahertz Optical Asymmetric Demultiplexer; Optical Cross-bar Switch; Switching Network; Logic Unit

I. INTRODUCTION

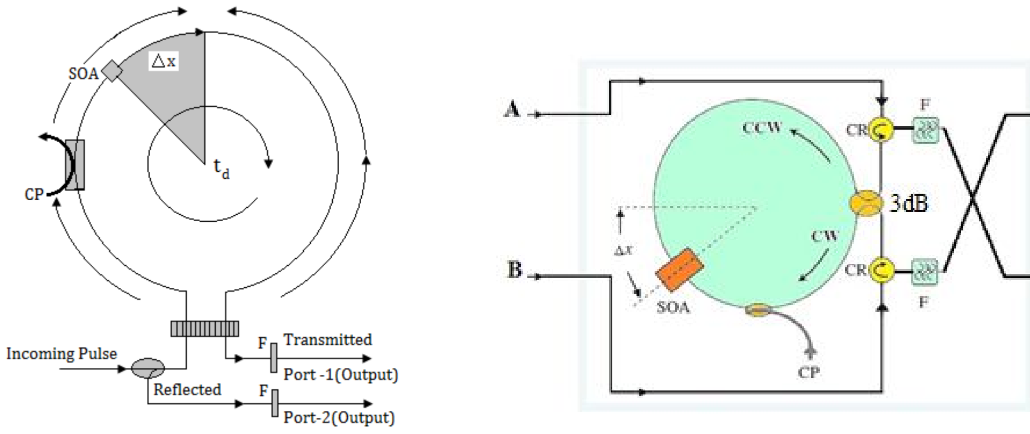
For optical cross connect (OXC), it is necessary a number of optical switches of optical networks with wavelength division multiplexing (DWDM) [1]. In a square array structure, a cross-bar switch (XBS) is used and is made of 2 × 2 basic switching cells with the practical choice of our optical networks because of its comfortable sensed and no-blocking nature. Also, it is easy to implement and simple routing control [2-4].Now semiconductor optical amplifier (SOA) based interferometric all-optical switches are very good due to their fast switching time, high repetition rate, etc. in all-optical information processing systems [5-7]. In this field the Terahertz Optical Asymmetric Demultiplexer (TOAD) effectively contributes fast switching time and a reasonable noise figure with easy integration. It can operate with high speed switching rates and commercial available in chip level [7, 8]. The monolithically integrated the TOAD based switch isvery much robust and steady against external fluctuations than a Mach–Zehnder interferometer. Since, the interference occurs in same optical path between the co-propagating and counter-propagating beams[10].In this work, TOAD can be used to design more complex circuits of enhanced combinatorial and sequential functionality particularly regarding the critical issues of versatility, reconfigure ability, cascade ability, etc. For these advantages, the switching network of all-optical cross-bar switch based on TOAD has been designed and reported in this paper. The superiority of the proposed scheme is also verified by simulation results.

This paper is progressed in such way that in Section-2 describes briefly all-Optical 2×2 TOAD based Cross-bar Switch. All-optical circuit of TOAD based proposed switching network is discussed in Section-3 and application of proposed switching network i.e., a logic unit is reported in Section-4. Corresponding simulation (by in Optiwave.OptiSystem.v7.0 and Mathcad-7.0) results confirm the properties proposed switching network and are also attached in Section-5 of this paper. The paper concludes with a discussion of future scope in Section 6.

II. ALL-OPTICAL 2X2 TOAD BASED CROSS-BAR SWITCH

A. Operating principle

It has been proved that all-optical TOAD is an outstanding semiconductor optical amplifier (SOA) based optical switch having demultiplexing data capability about 50 Gbits/s [11]. It has two input port, one is data signal and other is a control pulse (CP) of different wavelength and two output ports, which are output port-1 and output port-2. When control signal is absent, the data signal of TOAD exits through only output port-2 as shown in Fig. 1(a). But, when control signal is present, the data will exit only from the output port-1 due to SOA is offset from the loop's midpoint of TOAD by a distance Δx as shown in Fig. 1(a) [12].To design 2×2 optical cross-bar switching component it is necessary to change something of this circuit. This cross-bar switch has two inputs (A, B) and two outputs (P, Q) as shown in Fig. 1(b). 'A' and 'B' are the incoming pulses (IP) of different wavelength than CP, which is injected to the loop through 3-dB coupler. The IP is divided into two equal parts inside TOAD, one clockwise pulse (CW) and other counter clock wise pulse (CCW). The outputs are coming out through optical circulator (CR) and band pass filter (it blocks the CP and passes the IP) as shown in Fig. 1(b).



(a) (b)

Fig: 1(a) TOAD based optical switch, (b) All-optical TOAD based 2×2 optical cross-bar switching component. CW: clockwise pulse, CCW: counter clockwise pulse, CP: Control pulse, CR: optical circulator, F: band pass filter which blocks the CP, 3 dB: (ideally 50:50) 2×2 3dB coupler, SOA: Semiconductor optical amplifier

The output transfer function for transmitted (T) and reflected (R) port can be expressed as [6-10, 13]:

$$T(t) = 1/4\{G_{cw}(t) + G_{ccw}(t) - 2\sqrt{G_{cw}(t)\,G_{ccw}(t)}.\cos(\Delta\varphi) \quad (1)$$

$$R(t) = 1/4\{G_{cw}(t) + G_{ccw}(t) + 2\sqrt{G_{cw}(t)\,G_{ccw}(t)}.\cos(\Delta\varphi) \quad (2)$$

The phase difference between cw and ccw pulse is defined by $\Delta\varphi = (\varphi_{cw} - \varphi_{ccw})$. The symbols $G_{cw}(t), G_{ccw}(t)$ indicate the respective power gains and $\Delta\varphi = -(\alpha/2).\ln(G_{cw}/G_{ccw})$, where α is line-width enhancement factor.

When a control pulse is present, it changes refractive index of SOA due to saturation. So that, CW and CCW data signals will experience a differential gain of saturation, i.e. $G_{ccw} \neq G_{cw}$ and $R(t) \approx 0$. Data will exit from output port-1. When a control pulse is absent, the incoming signal experiences same unsaturated state of SOA with gain G_0, i.e. $G_{ccw} \approx G_{cw}$, $\Delta\varphi \approx 0$ and $T(t) \approx 0$. Data will exit from output port-2 [14, 15].

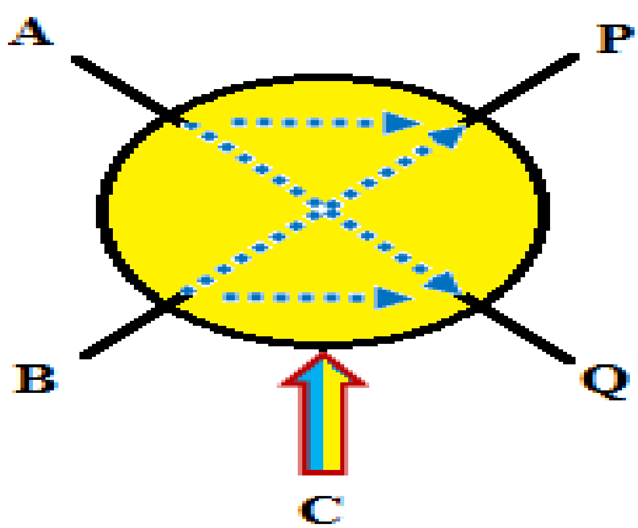


Fig. 2.Schematic diagram of all-optical TOAD based 2×2 optical cross-bar switch

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

TABLE I
TRUTH TABLE OF CROSS-BAR SWITCH

A	B	CP	P		Q		Remarks
0	0	0	0	B	0	A	Cross-state (×)
0	1	0	1		0		
1	0	0	0		1		
1	1	0	1		1		
0	0	1	0	A	0	B	Bar-state (=)
0	1	1	0		1		
1	0	1	1		0		
1	1	1	1		1		

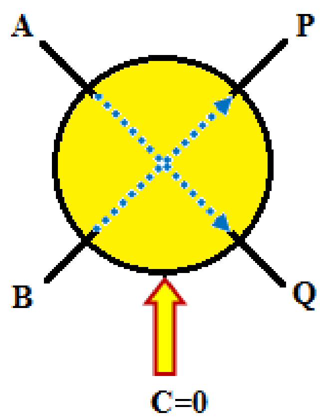


Fig. 3.Schematic diagram of all-optical TOAD based 2×2 optical cross-bar switch when CP=0, i.e. Cross-state operation

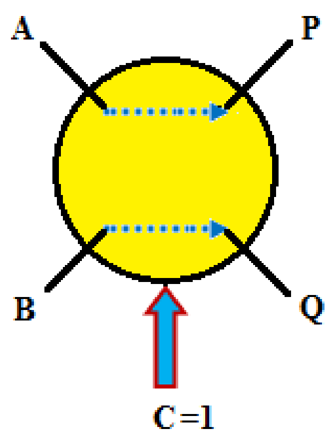


Fig. 4.Schematic diagram of all-optical TOAD based 2×2 optical cross-bar switch when CP=1, i.e. Bar-state operation

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

The schematic diagram of this 2×2 optical cross-bar switching element is shown in Fig. 2. The truth table of this switching element is shown in Table I. From this table we can say that, if CP input is ‘C’ then,

$$P=AC+B\overline{C}$$

$$Q=BC+A\overline{C} \qquad (3)$$

Hence, if C = 0 then P = B and Q = A, i.e. it act as ‘cross-state’ (shown in Fig. 3.). And if C = 1 then P = A and Q = B, i.e. it act as ‘bar-state’ (shown in Fig. 4.) [16, 17].

III.PROPOSED SWITCHING NETWORK

The all-optical proposed switching network is designed by four cross-bar switches as shown in Fig. 5. There are four separate switching actions. Therefore it is needed two control inputs. Let the two control inputs are C_1 and C_2.

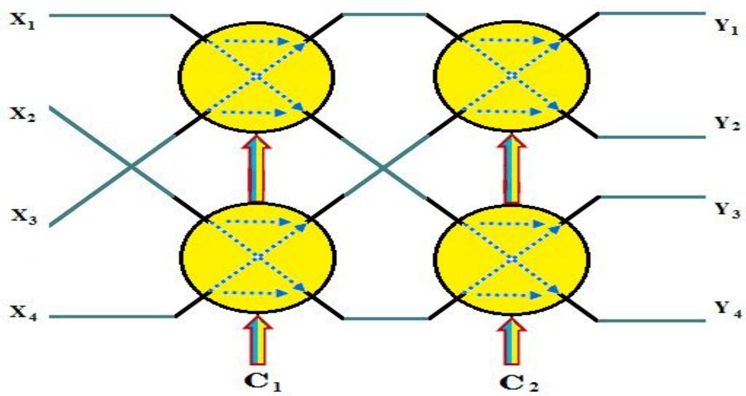


Fig. 5.Design of proposed switching network, Inputs: X_1, X_2, X_3 and X_4, Outputs: Y_1, Y_2, Y_3 and Y_4 and Control inputs: C_1 and C_2

For the four switching actions it is assumed the following:

$C_1 C_2$ = 00 for the 1st switching actions (as shown in Fig. 6),
$C_1 C_2$ = 01 for the 2nd switching actions (as shown in Fig. 7),
$C_1 C_2$ = 10 for the 3rd switching actions (as shown in Fig. 8),
$C_1 C_2$ = 11 for the 4th switching actions (as shown in Fig. 9).

Here X_1, X_2, X_3 and X_4 are inputs and Y_1, Y_2, Y_3 and Y_4 are outputs of the switching network. The following four equations for the above four switching actions are given below.

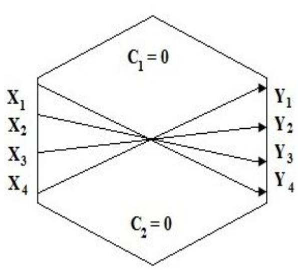
$$Y_1 = \overline{C}_2\overline{C}_1X_4 + \overline{C}_2C_1X_2 + C_2\overline{C}_1X_3 + C_2C_1X_1$$

$$Y_2 = \overline{C}_2\overline{C}_1X_3 + \overline{C}_2C_1X_1 + C_2\overline{C}_1X_4 + C_2C_1X_2$$

$$Y_3 = \overline{C}_2\overline{C}_1X_2 + \overline{C}_2C_1X_4 + C_2\overline{C}_1X_1 + C_2C_1X_3$$

$$Y_4 = \overline{C}_2\overline{C}_1X_1 + \overline{C}_2C_1X_3 + C_2\overline{C}_1X_2 + C_2C_1X_4 \qquad (4)$$

The above equations can be realized using the proposed design which is shown in fig. 5.



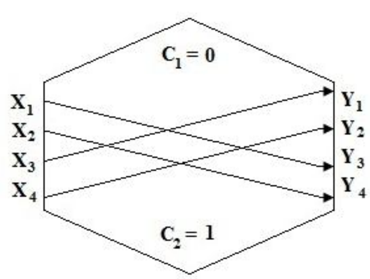


Fig. 6. 1stswitching actionFig.7. 2nd switching action

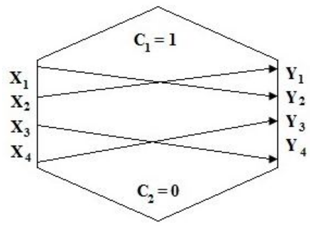


Fig. 8. 3rdswitching action

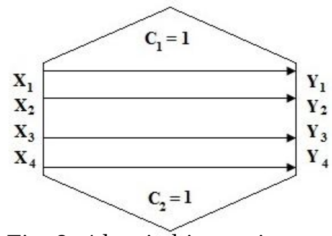


Fig. 9. 4thswitching action

IV. APPLICATION OF PROPOSED SWITCHING NETWORK: LOGIC UNIT

All-optical reconfigurable logic unit using cross-bar network is designed in this section, which is shown in Fig. 10. Here a constant pulsed light source (CPLS) is connected to one input of switch-1. The control input of switch-1 is 'A'. The outputs of the switch-1 are A and $\bar{A}$ respectively. They are connected to the inputs of switch-2 and switch-3 accordingly as shown inFig. 10. Also 'B' is the control input of switch-2 and switch-3. Hence $A\bar{B}$, AB, $\bar{A}B$ and $\bar{A}\bar{B}$ are fed to the input of switch-4, 5 and 6 of 4 × 4 cross-bar systems as shown in Fig. 10. The switches (2×2) unmarked by 'number' are cross connected, i.e. control inputs of such switches are all '0'. The control inputs of switch-7, 8, 9 and 10 are 'C_4', 'C_3', 'C_2' and 'C_1' respectively. It can be varied according to our demand. For example, if $C_4 = 0$ then switch-7 is in 'cross-state' and $A\bar{B}$ is directed to the output. Hence 16-logical operations can be found if we vary the inputs 'C_4', 'C_3', 'C_2' and 'C_1', which is shown in Table 2.

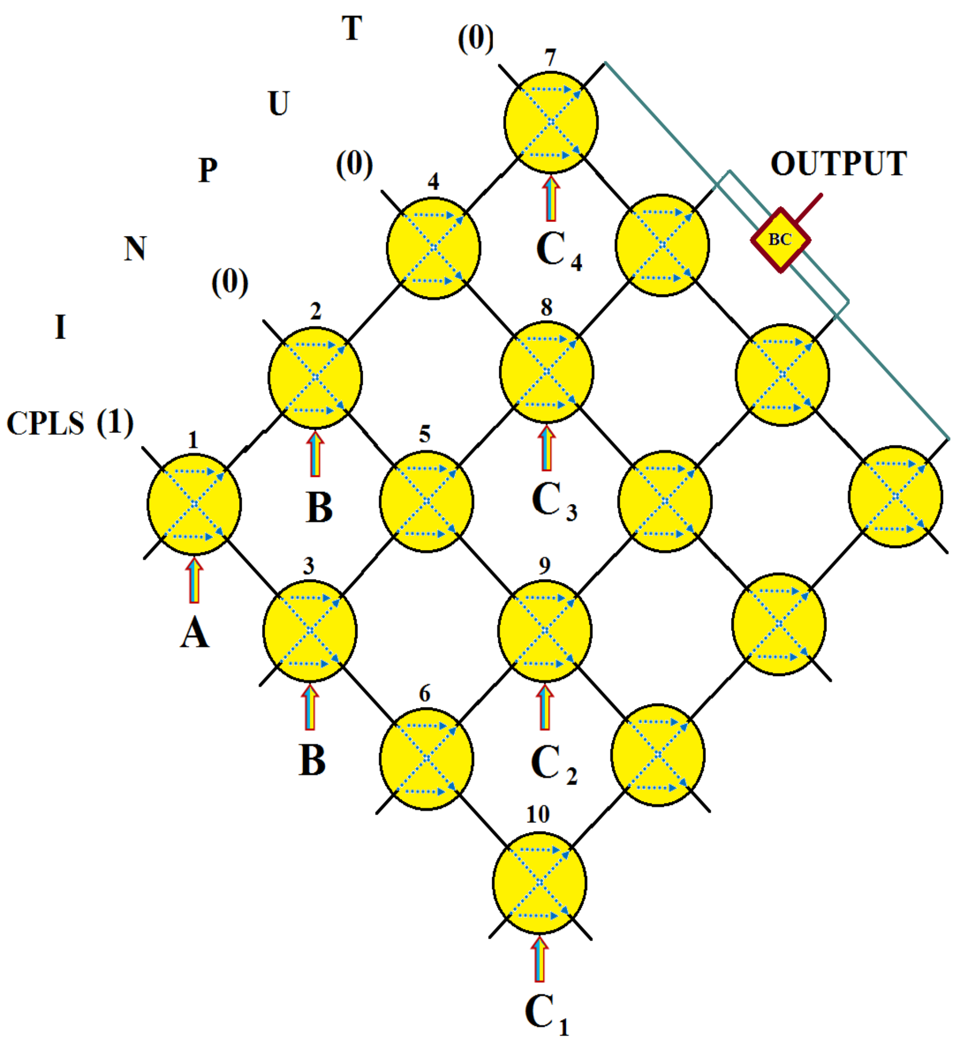


Fig. 10. All-optical logic unit using cross-bar network system. BC: beam combiner, CPLS: constant pulsed light source

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

TABLE III
16-BOOLEAN LOGICAL OPERATION

Function	C_1	C_2	C_3	C_4	Output
F_1	0	0	0	0	$A \oplus B$
F_2	0	0	0	1	$\bar{A}B$
F_3	0	0	1	0	$A\bar{B}$
F_4	0	0	1	1	0
F_5	0	1	0	0	A+B
F_6	0	1	0	1	B
F_7	0	1	1	0	A
F_8	0	1	1	1	AB
F_9	1	0	0	0	$\bar{A}+\bar{B}$
F_{10}	1	0	0	1	$\bar{A}$
F_{11}	1	0	1	0	$\bar{B}$
F_{12}	1	0	1	1	$\bar{A}\bar{B}$
F_{13}	1	1	0	0	1
F_{14}	1	1	0	1	$\bar{A}+B$
F_{15}	1	1	1	0	$A+\bar{B}$
F_{16}	1	1	1	1	A ʘ B

V. SIMULATION AND RESULT

The simulation by computer (in Optiwave.OptiSystem.v7.0) has been done using the parameter [18, 19] of SOA, which is shown in Table 3. The timing instant for the occurrence of bit pattern of outputs P and Q with the corresponding input A, B and CP are at 50, 150, 250, 350, 450, 550, 650 and 750 ps. Fig. 14 and 15show the outputs P= 01010011 (when, CP=0, P=B and when, CP=1, P=A) and Q=00110101 (when, CP=0, Q=A and when, CP=1, Q=B) with the corresponding input A = '0 0 1 1 0 0 1 1', B = '0 1 0 1 0 1 0 1' and CP = '0 0 0 0 1 1 1 1' (shown in Fig. 12, 13 and 11 respectively). This section presents the simulation results that verify the all-optical proposed switching network. Fig. 11, 12, 13, 14 and 15 are the simulation result of cross-bar switch whereas, Fig. 16, 17, 18, 19, 20 and 21 are for the proposed switching network. Here the binary logical states {0, 1} are represented by absence of light and presence of light, respectively. This computer simulation has been done using suitable parameter of SOA. Like above Fig. 18, 19, 20 and 21 show the outputs Y_1=11011101 (when C_1=0 and C_2=0), Y_2=11101110 (when C_1=0 and C_2=1), Y_3=01110111 (when C_1=1 and C_2=0) and Y_4=10111011 (when C_1=1 and C_2=1) with the corresponding input X_1= X_3= X_4=11111111 andX_2=00000000 as shown in Fig. 16 and 17 respectively.

Normalized output transfer function (T (t)) from Eq. (1) is plotted with time (in ps) in Fig. 22 (when CP is ON) for different set of G_0. From this graph it is observed that the normalized transfer function is shifted toward the right for higher values of G_0. We select the output contrast ratio (C.R.) as the optimization criteria. This indicates the opening of the eye diagram and defines the output contrast ratio *(C.R.)* as the minimum peak power when the pulse of the payload is high (1) say (P^1_{Min}) and to the maximum when the pulse is low (0) say (P^0_{Max}) [20].

$$C.R.\ (dB) = 10 \log (P^1_{Min} / P^0_{Max}) \quad (5)$$

By Eq. (5) we can calculate the output C.R. (dB) for reversible logic gates is found 18.027 dB.

Fig-23 shows give the variation of *C.R.* with control pulse energy (E_{cp}) with eccentricity of the loop (T) is kept constant. It shows that maximum C.R. is obtained at 95.5fJ control pulse energy.

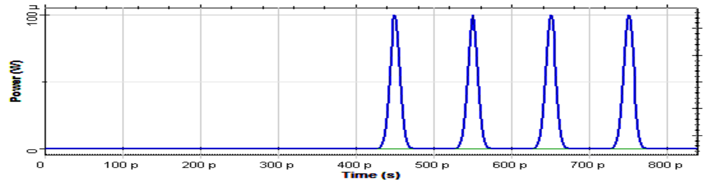


Fig. 11. Input: CP (00001111)

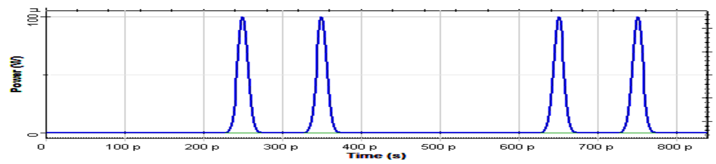


Fig. 12. Input: A (00110011)

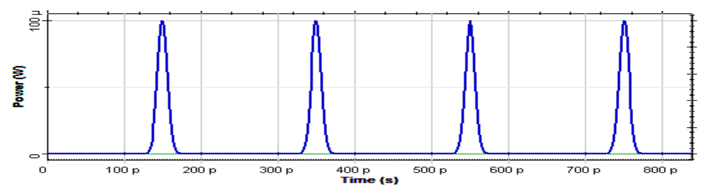


Fig. 13. Input: B (01010101)

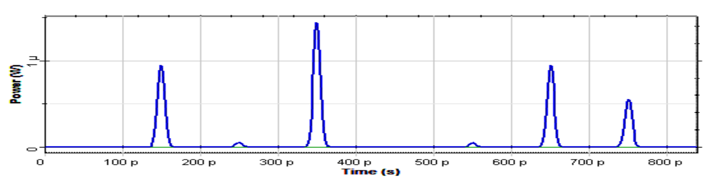


Fig. 14. Output: P (01010011), when, CP=0, P=B and when, CP=1, P=A

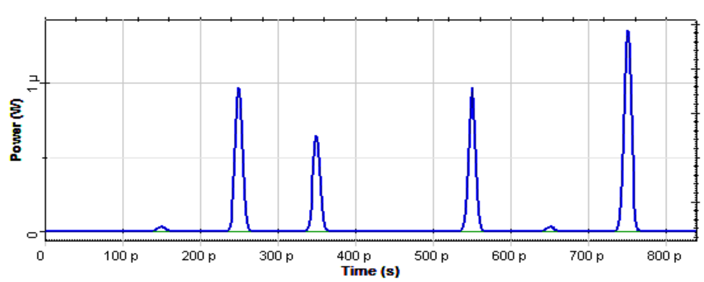


Fig. 15. Output: Q (00110101), when, CP=0, Q=A and when, CP=1, Q=B

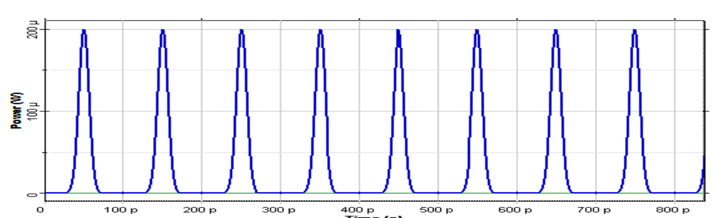


Fig. 16. Input: X_1= X_3= X_4=11111111

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

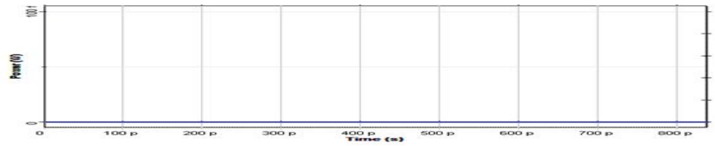


Fig. 17. Input: X_2=00000000

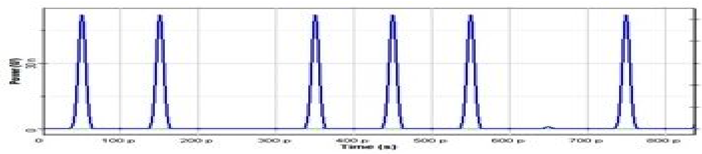


Fig. 18. Output: Y_1=11011101, when C_1=0 and C_2=0

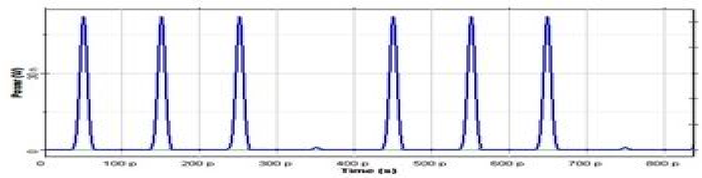


Fig. 19. Output: Y_2=11101110, when C_1=0 and C_2=1

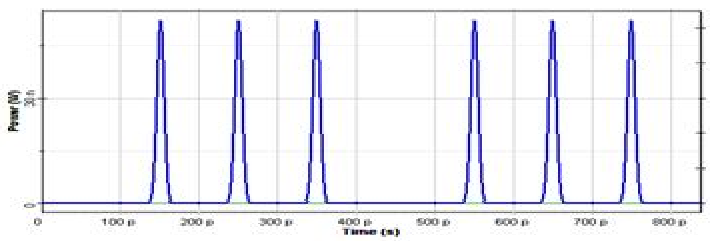


Fig. 20. Output:Y_3=01110111, when C_1=1 and C_2=0

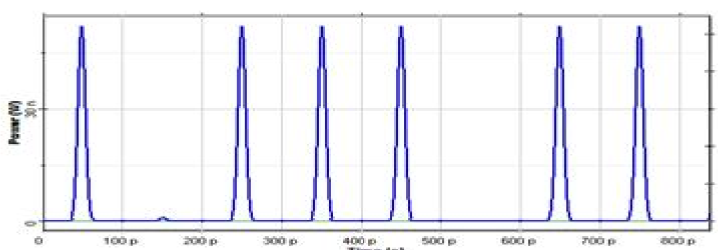


Fig. 21. Output: Y_4=10111011, when C_1=1 and C_2=1

Table 3. Used Parameters for simulation

Parameters	Symbol	Value
Injection current of SOA	I	300 mA
Confinement factor	Γ	0.49
Differential gain	a_N	3.3×10^{-20} m^2
Line-width enhancement factor of SOA	α	7
Carrier density at transparency	N_{tr}	1.0×10^{24} m^{-3}
Width of the active region of SOA	w	1.4 μm

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

Depth of the active region of SOA	d	300 nm
Internal loss of the wave guide	α_D	2500 m^{-1}
Wave length of light	λ_0	1550 nm
Gain recovery time	τ_e	100 ps
Control pulse energy	E_c	500fJ
Full width at half maximum of control pulse	σ	2 ps
Incoming pulse energy	E_{in}	0.01 mW

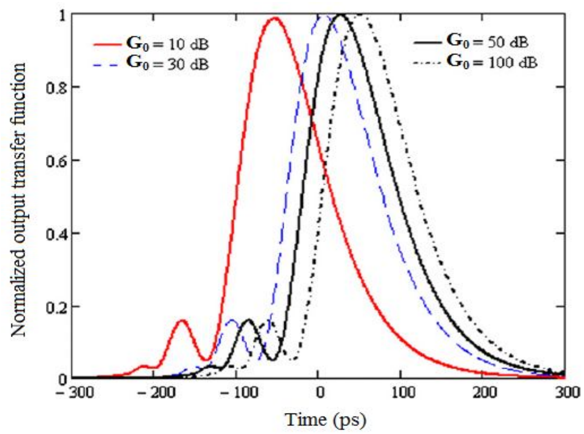


Fig. 22. Normalized output transfer function variation with time (ps)

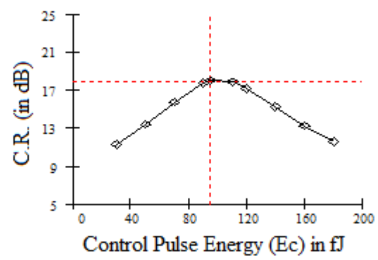


Fig. 23. The variation of contrast ratio (C.R.) with control pulse energy (E_c)

VI. CONCLUSION

In this paper, we proposed TOAD based cross-bar switch and switching network design scheme in all-optical domain. The understanding of this design is predicting due to its issues of versatility, re-configurability and compactness. The theoretical form presented in this paper and the results obtained numerically are useful to future all-optical logic computing system.. In order to experimentally achieve the result from the proposed design, some design issues have to be considered like, intensity losses due to beam splitters/fiber couplers, walk-off problem due to dispersion, optical circulator, etc. The walk-off between control and incoming signal may not be a great problem due to the small size of TOAD. The polarization controller may use at the fiber to maintain the state of polarization at different paths. To neglect the effect of amplified spontaneous emission (ASE) we use the small length of the SOA and also, to avoid two photon absorption (TPA) and ultrafast nonlinear refection (UNR) we apply the energy of the narrow control pulse of very lower than 1 pJ. The low intensity loss because of beam splitters or couplers, optical circulators and in interconnecting stages may not produce such trouble of getting the desired output optical bits. In future, the proposed schemes are also expected to be logical for other 2×2 optical switches and thus might be productive for optical computing devices.The future work canalso be concentrate for the realization of various network architecture and reconfigurable logic unit.

REFERENCES

[1] S. Okamoto, A. Watanabe, K-I. Sato, Optical path cross-connect node architectures for photonic transport network, J. Lightw. Technol. 14 (6) 1410–1422, 1996.

[2] T. Chikama, H. Onaka, S. Kuroyanagi, Photonic networking using optical add drop multiplexer and optical cross-connects, FUJITSU Sci. Tech. J. 35 (1) 46–55, 1999.

[3] H. Obara, Extended class of reduced crossbar switches, IEEE, International Conf. on advanced Tech. for Communication, 129–132, 2009.

[4] L. Gao, J. Sun, X. Sun, T. Li, W. Gao, .Y. Yan, D. Zhang, Simulation and optimization of a polymer 2×2 multimode interference Mach-Zehnder interferometer electro optic switch with push pull electrodes, Opt. Laser Tech. 42 (1) 85–92, 2010.

[5] J.P. Sokoloff, P.R. Prucnal, I. Glesk, M. Kane, A terahertz optical asymmetric demultiplexer (TOAD), IEEE Photon. Technol. Lett. 5 (7) 787–790, 1993.

[6] T. Houbavlis, K.E. Zoiros, Numerical simulation of semiconductor optical amplifier assisted Sagnac gate and investigation of its switching characteristics, Opt. Eng. 43 (7) 1622–1627, 2004.

[7] K.E. Zoiros, J. Vardakas, T. Houbavlis, M. Moyssidis, Investigation of SOAassisted Sagnac re-circulating shift register switching characteristics, Optik 116 527–541, 2005.

[8] M. Melo, J. L. S. Lima, R. S. de Oliveira and A. S. B. Sombra, “Photonic time-division multiplexing (OTDM) using ultrashort picosecond pulses in a terahertz optical asymmetric demultiplexer (TOAD),” Opt. Commun., 205(4-6), 299-312, 2002.

[9] T. Houbavlis, K. E. Zoiros, SOA-assisted Sagnac switch and investigation of its roadmap from 10 to 40 GHz, Optical and Quantum Electronics 35, 1175–1203, 2003.

[10] K.E. Zoiros, R. Chasioti, C.S. Koukourlis, T. Houbavlis, On the output characteristics of a semiconductor optical amplifier driven by an ultrafast optical time division multiplexing pulse train, Optik 118 (3) 134–146, 2007.

[11] J.P. Sokoloff, I. Glesk, P.R. Prucnal, R.K. Boncek, Performance of a 50 Gbit/s optical time domain multiplexed system using a terahertz optical asymmetric demultiplexer, IEEE Photon. Technol. Lett. 6 (1) 98–100, 1994.

[12] A.J. Poustie, K.J. Blow, Demonstration of an all-optical Fredkin gate, Opt. Commun. 174, 317–320, 2000.

[13] T. Chattopadhyay, All-optical symmetric ternary logic gate, Opt. Laser Technol. 42, 1014–1021, 2010.

[14] G.A. Bogert, E.J. Murphy, R.T. Ku, Low crosstalk 4×4 TiLiNbO3 optical switch with permanently attached polarization maintaining fiber array, J. Lightw. Technol. LT-4 (10) 1542–1545, 1986.

[15] T.S. El-Bawab, Optical Switching, Springer Science + Business Media Inc., USA, Chapters 9 and 10, 2006.

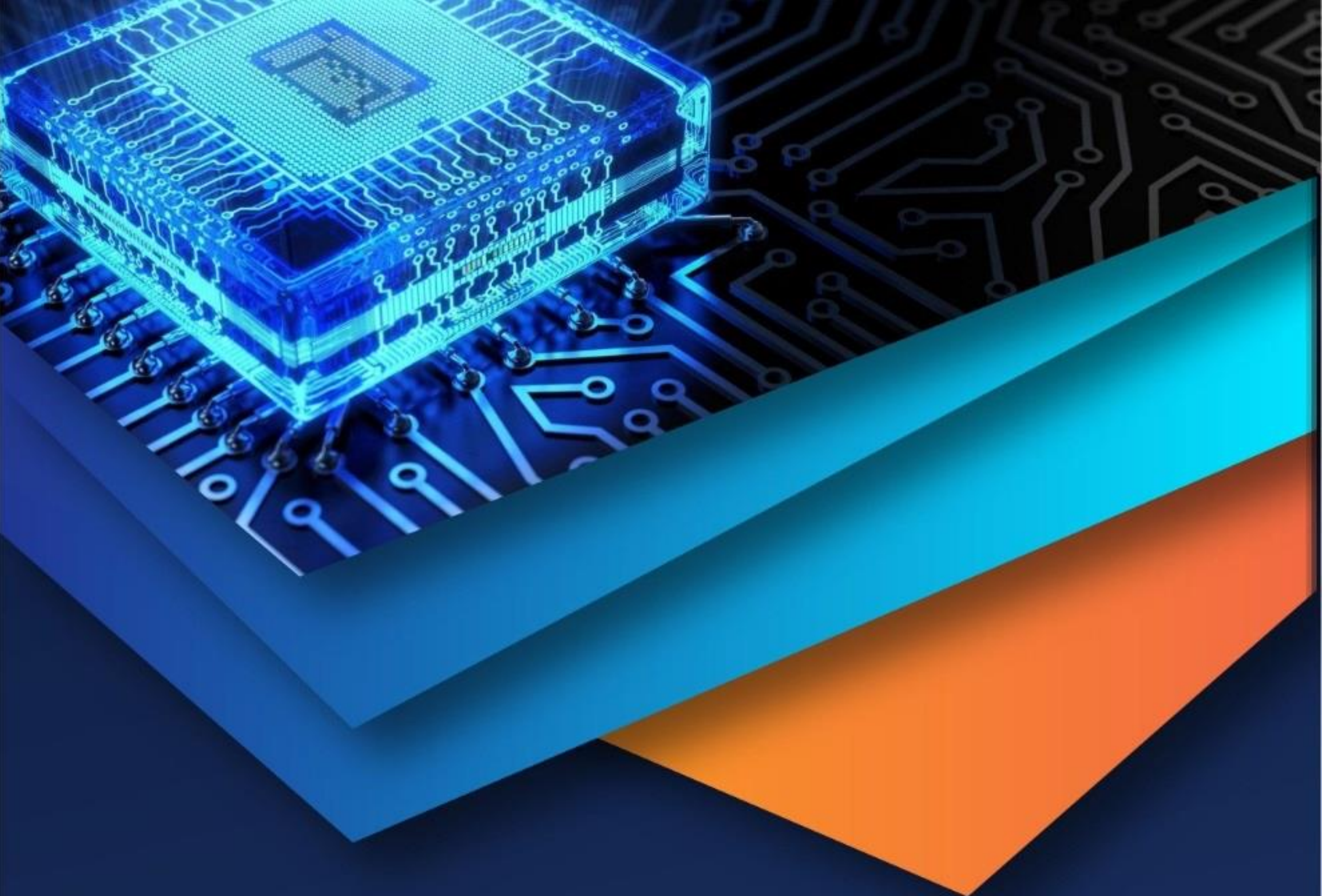
[16] J. Dong, X. Zhang, D. Huang, A proposal for two-input arbitrary Boolean logic gates using single semiconductor optical amplifier by picosecond pulse injection, Opt. Exp. 17 (10) 7725–7730, 2009.

[17] G. Goertzel, An algorithm for the evalution of finite trigonometric series, Amer. Math. Monthly, 6534-35, 1958.

[18] T. Chattopadhyay, All-optical cross-bar network architecture using TOAD based Interferometric switch and designing of reconfigurable logic unit, Optical Fiber Technology 17 558–567, 2011.

[19] A.K. Mandal, G.K. Maity, All Optical Reversible NOR Gates using TOAD, International Journal of Computer Applications, 973-93-80883-42-5 (ISSN: 0975 – 8887), 18-23, 2014.

[20] Y. J.Jung, S. Lee, N. Park, All-optical 4-bit gray code to binary coded decimal converter, Integrated Optoelectronic Devices, International Society for Optics and Photonics, 68900S-68900S-10, 2008.



10.22214/IJRASET

INDEX COPERNICUS 45.98

ISRA JIF IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY