International Journal of Advanced Computer Research (ISSN (print): 2249-7277 ISSN (online): 2277-7970)
Volume-4 Number-2 Issue-15 June-2014

The All Optical New Universal Gate Using TOAD

Goutam Kumar Maity[1], Ashis Kumar Mandal[2], Supriti Samanta[3]

Abstract

Since the seventies of the past century the reversible logic has originated as an unconventional form of computing. It is new relatively in the area of extensive applications in quantum computing, low power CMOS, DNA computing, digital signal processing (DSP), nanotechnology, communication, optical computing, computer graphics, bio information, etc .Here we present and configure a new TAND gate in all-optical domain and also in this paper we have explained their principle of operations and used a theoretical model to fulfil this task, finally supporting through numerical simulations. In the field of ultra-fast all-optical signal processing Terahertz Optical Asymmetric Demultiplexer (TOAD), semiconductor optical amplifier (SOA)-based, has an important function. The different logical (composing of Boolean function) operations can be executed by designed circuits with TAND gate in the domain of universal logic-based information processing.

Keywords

Reversible logic gates, Terahertz Optical Asymmetric Demultiplexer (TOAD), TAND gate.

1. Introduction

In our traditional computer's logic blocks, irreversible, lose the information during their operation, i.e. once logic block generates the output bits, the input bits are lost. Due to this fact the information once lost cannot be recovered in any way. The classical logic gates have multiple input but single output. So, combinational logic circuits, which are made by those logic gates, dissipate heat for losing of every bit of information. R. Landauer showed that with high technology circuits and systems built by irreversible hardware, results in energy dissipation because of information loss with the amount KTln2 joule of energy for one bit of information, where 'k' is the Boltzmann constant and 'T' is the temperature in Kelvin at which the system is operating [1]. And C. H. Bennett interpreted that this amount of energy dissipation would not occur in circuit if this computation of circuit is carried out in reversible logic circuits system [2]. The reversible gates have inputs and outputs which are one–to-one correspondence, i.e. n-input and n-output logic device with one-to-one mapping. That is why, the inputs of such gates can be determined from its outputs. The reversible gates are formed by all-optical switching-the switching of one beam of light by another-is an essential operation for transparent fiber optic network and information processing [3-8].The reversible logic circuits give us the computation with arbitrary small energy dissipation and without information loss [9-10].

Fan-out, an important constrain, is not allowed on the design of reversible logic circuit using logic gate. And also, a reversible circuit should be designed taking minimum number of reversible gates, garbage outputs and constant inputs [11-12]. Garbage is defined as the number of outputs added to make an n-input k-output Boolean function ((n, k) function) reversible [13].

This paper is prepared as follows: In Section 2, principle and operation of TOAD-based optical switch is explained [14-18]. All-optical circuit realization for TOAD switch-based New TAND Gate is reported in Section 3 and universal application of this gate is informed in Section 4. Section 5 covers simulation (by Matlab-7.0) based treatment. In the end, conclusions are kept in Section 6 with the scope of future works.

2. Operational principle of TOAD: optical switch

TOAD based gate has taken an important role in optical communication and information processing [19-24]. Sokoloff et al. [19] demonstrated a TOAD capable of demultiplexing data at 50 Gb/s. The TOAD consists of a loop mirror with an additional intra loop 2×2 (ideally 50:50) coupler. The loop contains a control pulse (CP) and a nonlinear element

Manuscript received May 5, 2014.
Goutam Kumar Maity, Electronics & Communication Engineering , MCKV Institute of Engineering , Howrah , India.
Ashis Kumar Mandal, Physics, Chakur Haris Seminary High School, Howrah, India.
Supriti Samanta, Physics, Chaipat Girls' High School, Daspur, West Bengal, India.

(NLE) that is offset from the loop's midpoint by a distance Δx as shown in Fig. 1.

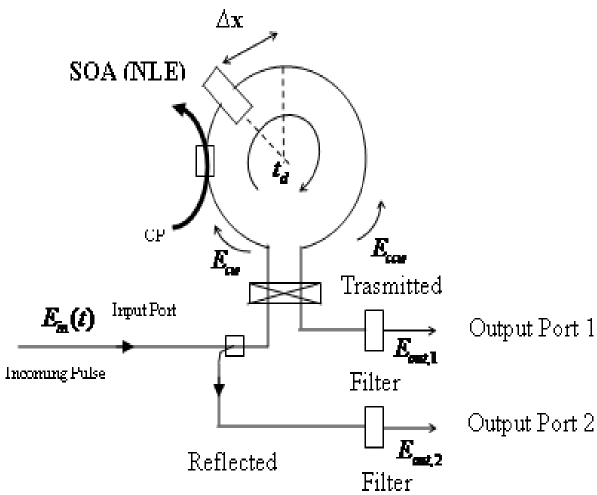


Fig. 1: TOAD-based optical switch

A signal with field $E_{in}(t)$ at angular frequency ω is split in coupler. It travels in clockwise (cw) and counter clockwise (ccw) direction through the loop. The electrical field at port-1 and port-2, can be expressed as follows.

$$\underline{E}_{out,1}(t)=\underline{E}_{in}(t-t_d)\cdot e^{-j\omega t_d}\cdot\left[d^2\cdot\underline{g}_{cw}(t-t_d)-k^2\cdot\underline{g}_{ccw}(t-t_d)\right] \quad (1)$$

$$\underline{E}_{out,2}(t)=jdk\underline{E}_{in}(t-t_d)\cdot e^{-j\omega t_d}\cdot\left[\underline{g}_{cw}(t-t_d)+\underline{g}_{ccw}(t-t_d)\right] \quad (2)$$

Where t_d is pulse round trip time within the loop as shown in the Fig- 1. Coupling ratios *k* and *d* indicate the cross and through coupling, respectively. The cw signal be amplified by the complex field gain. $\underline{g}_{cw}(t)$, while ccw by $\underline{g}_{ccw}(t)$. The output power at port-1 can be expressed as,

$$P_{out,1}(t)=\frac{P_{in}(t-t_d)}{4}\cdot\left\{G_{cw}(t)+G_{ccw}(t)-2\sqrt{G_{cw}(t)\cdot G_{ccw}(t)}\cdot\cos(\Delta\varphi)\right\} \quad (3)$$
$$=\frac{P_{in}(t-t_d)}{4}\cdot SW(t)$$

where, $SW(t)$ is the transfer function. 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.

Power gain is related with the field gain as $G=g^2$ and $\Delta\varphi=-\frac{\alpha}{2}\cdot\ln\left(\frac{G_{cw}}{G_{ccw}}\right)$.

Now we will calculate the power at port-2

$$P_{out,2}(t)=\frac{1}{2}\underline{E}_{out,2}(t)\cdot\underline{E}^*_{out,2}(t)$$
$$=d^2k^2\cdot P_{in}(t-t_d)\cdot g_{cw}^{\ 2}(t-t_d)$$
$$\cdot\left\{1+\frac{g_{ccw}^{\ 2}(t-t_d)}{g_{cw}^{\ 2}(t-t_d)}+2\cdot\frac{g_{ccw}(t-t_d)}{g_{cw}(t-t_d)}\cdot\cos\left[\varphi_{cw}(t-t_d)-\varphi_{ccw}(t-t_d)\right]\right\}$$
$$=d^2k^2\cdot P_{in}(t-t_d)\cdot G_{cw}\cdot\left\{1+\frac{G_{ccw}}{G_{cw}}+2\cdot\sqrt{\frac{G_{ccw}}{G_{cw}}}\cdot\cos[\Delta\varphi]\right\}$$
$$=d^2k^2\cdot P_{in}(t-t_d)\cdot\left\{G_{cw}+G_{ccw}+2\cdot\sqrt{G_{ccw}\cdot G_{cw}}\cdot\cos[\Delta\varphi]\right\} \quad (4)$$

For ideal 50:50 coupler, $d^2=k^2=1/2$. In the absence of a control signal, data signal (incoming signal) enters the fiber loop, pass through the SOA at different times as they counter-propagate around the loop, and experience the same unsaturated amplifier gain G_0, recombine at the input coupler i.e. $G_{ccw}=G_{cw}$. This leads to $\Delta\varphi=0$. So expression for $P_{out,1}(t)=0$ and $P_{out,2}(t)=G_0\cdot P_{in}$. It shows that data is reflected back toward the source. When a control pulse is injected into the loop, it saturates the SOA and changes its index of refraction. As a result, the two counter-propagated data signals will experience a differential gain saturation profiles i.e. $G_{ccw}\neq G_{cw}$. Therefore, when they recombine at the input coupler, the data will exit from the output port-1. For this case, the mathematical forms of two output powers can be expressed as, $P_{out,1}(t)=\frac{P_{in}(t-t_d)}{4}\cdot SW(t)$ and $P_{out,2}(t)\approx 0$.

Result of numerical simulation with Matlab7.0 has been shown in Fig. 2. In this simulation line-width enhancement factor of SOA (α) was taken 9.5 and the ratio G_{ccw}/G_{cw} was taken 0.52.

A polarization or wavelength filter may be used at the output to reject the control and pass the input pulse. Now it is clear that in the absence of control signal, the incoming pulse exits through input port of TOAD and reaches the output port-2 as shown in Fig. 2. In this case no light is present in the output port-1. But in the presence of control signal, the incoming signal exits through output port of TOAD and reaches the output port-1 as shown in Fig. 1. In this case no light is present in the output port-2.

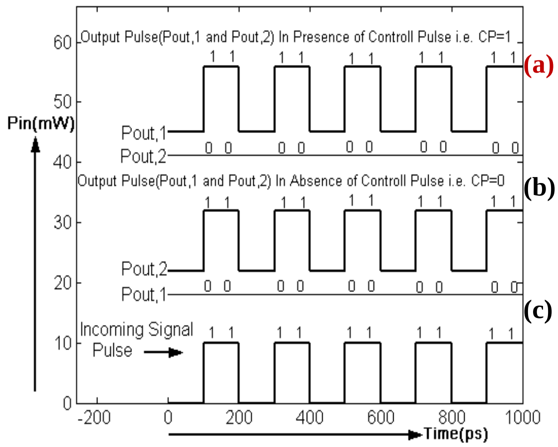


Fig. 2: Simulation result: (a) output pulse (Pout,1 and Pout,2) in presence of control pulse i.e. CP=1 (b) output pulse (Pout,1 and Pout,2) in absence of control pulse i.e. CP=0 (c) incoming signal pulse

In the absence of incoming signal, Port-1 and Port-2 receive no light signal as the filter blocks the control signal. Schematic block diagram is shown in Fig. 2(a) and truth table of the operation is given in Table-1.

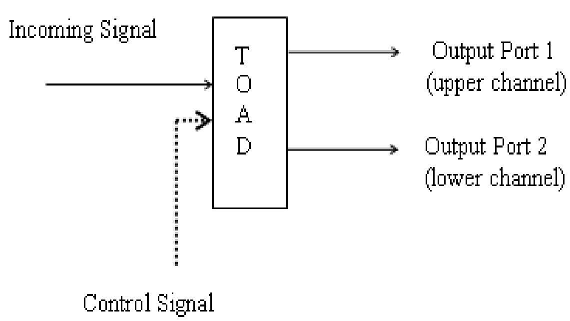


Fig. 2(a): Schematic diagram of TOAD-based optical switch:

Table 1: Truth table of TOAD based optical switch as shown in Fig. 3

Incoming Signal	Control Signal	Output Port-1	Output Port-2
0	0	0	0
0	1	0	0
1	0	0	1
1	1	1	0

3. TOAD-based new gate: TAND gate

TAND gate is also a (2*2) conservative universal gate. It has two inputs (A, B) and two outputs (P, Q) satisfy the relation as follows:

$$\left.\begin{aligned} P &= A \\ Q &= A\overline{B} \end{aligned}\right\} \qquad (6)$$

Table 2: Truth table of TAND gate

Inputs		Outputs	
A	B	P	Q
0	0	0	0
0	1	0	0
1	0	1	1
1	1	1	0

3.1. Principle and design

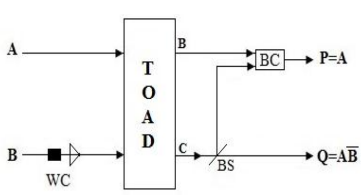
Schematic diagram is given in Fig. 3(b). The TOAD-based circuit for all-optical universal TAND gate is given in Fig. 3(a). Here input ‘A’ is connected with TOAD as incoming signal. The control signal of the corresponding gate comes from the input ‘B’. The output ‘P’ is taken by combining the light through a beam combiner (BC) from the bar port (B) and from the cross port (C) of TOAD by splitting it by BS .The output ‘Q’ is taken from the cross port (C) of TOAD. The operational principle of this gate is discussed below in details.

(1) When A=B=0, i.e. input A and B do not receive any light, the final output P and Q receives no light from the TOAD. So P=Q=0, which satisfy the first row of the truth table 4.

(2) When A = 0 and B = 1, only the control signal is present at TOAD. No incoming signal is present at TOAD. According to the working principle of TOAD described in the Section 2, all the ports do not receive any light. So the final output is P=0 and Q=0, which satisfy the second row of the truth table 4.

(3) When A=1 and B=0, then only the incoming signal is present at TOAD and no control signal is present at TOAD. According to the working principle of TOAD described in the Section 2, only the cross port(C) of TOAD receives light. Other port does not receive light. So P=1 and Q=1, which satisfy the third row of the truth table 4.

(4) When A=1 and B=1, then bar port(B) of TOAD receives light (as both incoming and control signal of TOAD receive light) and cross port does not receive light. So P=1 and Q=0, which satisfy the fourth row of the truth table 4.



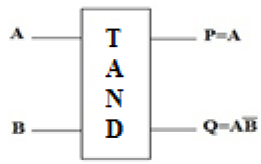
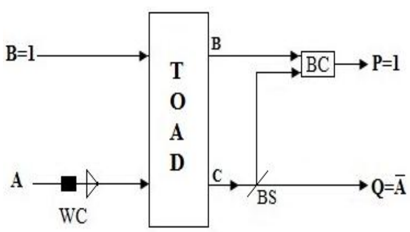


Fig.3(a) Fig. 3(b)

BC Beam Combiner, BS: Beam Splitter, EDFA: Erbium Doped Fiber Amplifier, WC: Wavelength Converter

4. TAND gate can be used to perform as universal logic gate. Proposed arrangements to perform various gate operations are as follow

4.1. NOT operation:



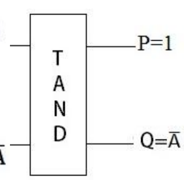


Fig. 4(a) Fig. 4(b)

BC Beam Combiner, BS: Beam Splitter, EDFA: Erbium Doped Fiber Amplifier, WC: Wavelength Converter

Schematic diagram is given in Fig. 4(b). The TOAD-based circuit for NOT gate by all-optical TAND gate is given in Fig. 4(a). Here input 'B'(=1) is connected with TOAD as incoming signal. The control signal of the corresponding gate comes from the input 'A'. The output 'P' is taken by combining the light through a beam combiner (BC) from the bar port (B) and from the cross port (C) of TOAD by splitting it by BS.The output 'Q' is taken from the cross port (C) of TOAD. The operational principle of this gate is discussed below in details.

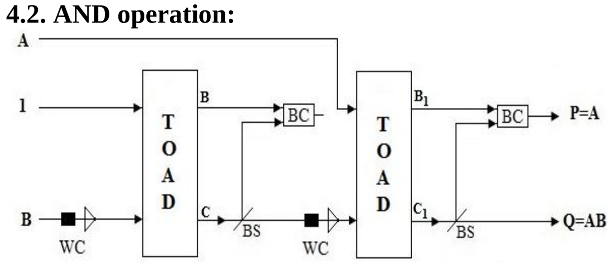
Table 3: Truth of NOT gate

A	Q
0	1
1	0

(1) When B=1 and A=0, then only the incoming signal is present at TOAD and no control signal is present at TOAD. According to the working principle of TOAD described in the Section 2, only the cross port of TOAD(C) receives light. Other port does not receive light. So P=1 and Q=1, which satisfy the first row of the truth table 3.

(2) When A=1 and B=1, then bar port of TOAD (B) receives light (as both incoming and control signal of TOAD receive light) and cross port does not receive light. So P=1 and Q=0, which satisfy the second row of the truth table 3.

4.2. AND operation:



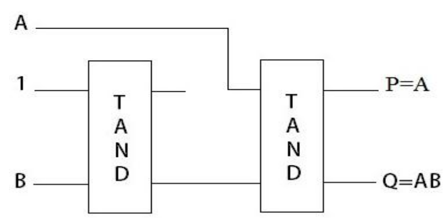


Fig. 5(a) Fig. 5(b)

BC Beam Combiner, BS: Beam Splitter, EDFA: Erbium Doped Fiber Amplifier, WC: Wavelength Converter

Schematic diagram is given in Fig. 5(b). The TOAD-based circuit for AND gate by all-optical TAND gate is given in Fig. 5(a). Here input 'A' is connected with TOAD-based TAND gate as incoming signal. The control signal of another gate (TAND gate based NOT gate) comes from the input 'B' and the output (C)of this gate is connected as a control signal of other gate. The final output 'Q' is taken from the cross port (C1) of TOAD. The operational principle of this gate is discussed below in details.

Table 4: Truth table of AND gate

A	B	P	Q
0	0	0	0
0	1	0	0
1	0	1	0
1	1	1	1

(1) When A=B=0, i.e. input A and B do not receive any light, the final output P and Q receives no light from the TOAD. So P=Q=0, which satisfy the first row of the truth table 4.
(2) When A = 0 and B = 1, then only the control signal is present at TOAD. No incoming signal is present at TOAD. According to the working principle of TOAD described in the Section 2. So the final output is P=0 and Q=0, which satisfy the second row of the truth table 4.
(3) When A=1 and B=0, then only the incoming signal is present at TOAD and no control signal is present at TOAD. According to the working principle of TOAD described in the Section 2, P=1 and Q=0, which satisfy the third row of the truth table 4.
(4) When A=1 and B=1, then both incoming and control signal of TOAD receive light and according to the working principle of TOAD described in the Section 2 and TAND gate, P=1 and Q=1, which satisfy the fourth row of the truth table 4.

4.3. OR operation:

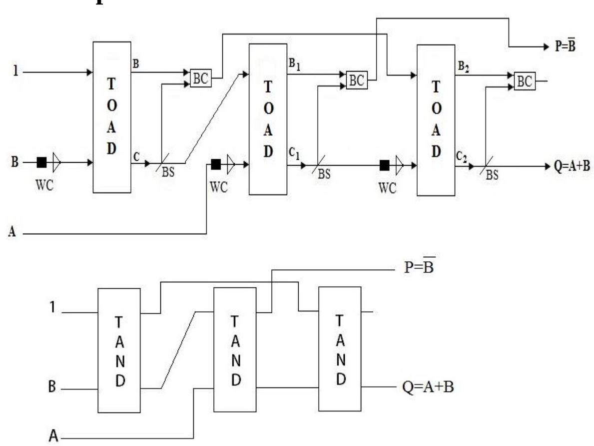


Fig. 6(a) Fig. 6(b)
BC: Beam Combiner, BS: Beam Splitter, EDFA: Erbium Doped Fiber Amplifier, WC: Wavelength Converter

Schematic diagram is given in Fig. 6(b). The TOAD-based circuit for OR gate by all-optical TAND gate is given in Fig. 6(a). Here input 'A' is connected with TOAD-based TAND gate as control signal. The control signal of the TAND based NOT gate comes from the input 'B' and its cross port (C) is connected as an input signal of above TAND gate. And cross port (C1) of this gate is connected as a control signal of another TAND based NOT gate. The output 'P' is taken form bar port (B1) and output 'Q' is taken form cross port (C2). The operational principle of this gate is discussed below in details.

Table 5: Truth table of OR gate

A	B	P	Q
0	0	1	0
0	1	0	1
1	0	1	1
1	1	0	1

(1) When A=B=0, i.e. input A and B do not receive any light, the final output P and Q accordingly is P=1 andQ=0, which satisfy the first row of the truth table 5.
(2) When A = 0 and B = 1, then only the control signal is present at TOAD-based TAND gate. No incoming signal is present at TAND based NOT gate. According to the working principle of TOAD and TAND gate described in the Section 2 Section 3, all the final output is P=0 and Q=1, which satisfy the second row of the truth table 5.
(3) When A=1 and B=0, then only the incoming signal is present at TOAD-based TAND gate and no control signal is present at TAND based NOT gate. According to the working principle of TOAD and TAND gate described in the Section 2 Section 3, the cross port (C2) receives light. Other port also receives light. So P=1 and Q=1, which satisfy the third row of the truth table 5.
(4) When A=1 and B=1, then as both control signal of corresponding gates receive light and cross port (C2) receive light. So P=0 and Q=1, which satisfy the fourth row of the truth table 5.

4.4. NAND operation:

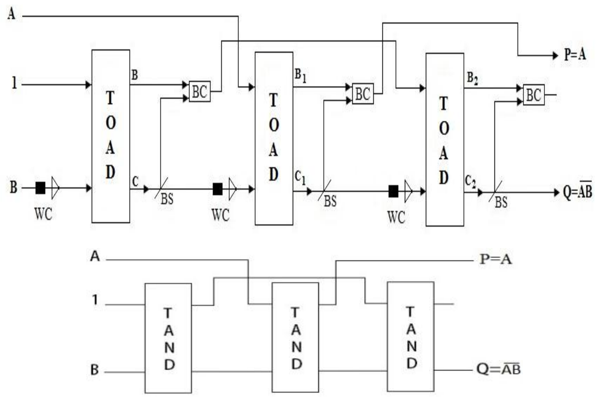


Fig. 7(a) Fig. 7(b)

BC Beam Combiner, / BS: Beam Splitter, ▷ EDFA: Erbium Doped Fiber Amplifier, ■ WC: Wavelength Converter

Schematic diagram is given in Fig. 7(b). The TOAD-based circuit for NAND gate by all-optical TAND gate is given in Fig. 7(a). Here input 'A' is connected with TOAD -based TAND gate as incoming signal. The control signal of the TAND based NOT gate comes from the input 'B'. The output of this gate, cross port (C), is connected to the control port of above gate. The out of this TOAD -based TAND gate, cross port (C1), is connected to another TAND based NOT gate and its output, cross port (C2), is taken as final output 'Q'. 'P' is taken from bar port (B1) of TOAD -based TAND gate. The operational principle of this gate is discussed below in details.

Table 6: Truth table of NAND gate

A	B	P	Q
0	0	0	1
0	1	0	1
1	0	1	1
1	1	1	0

(1) When A=B=0, i.e. input A and B do not receive any light, the final output P receives no light and Q receives light from the TOAD. So P=0 and Q=1, which satisfy the first row of the truth table 6.

(2) When A = 0 and B = 1, then only the control signal is present at TAND based NOT gate. No incoming signal is present at TOAD -based TAND gate. According to the working principle of TOAD and TOAD -based TAND gate described in the Section 2 and Section 3, the final outputs are P=0 and Q=1, which satisfy the second row of the truth table 6.

(3) When A=1 and B=0, then only the incoming signal is present at TOAD -base TAND gate and no control signal is present at TAND based NOT gate. According to the working principle of TOAD and TOAD -based TAND gate described in the Section 2 and Section 3, the final outputs are P=1 and Q=1, which satisfy the third row of the truth table 6.

(4) When A=1 and B=1, According to the working principle of TOAD and TOAD -based TAND gate described in the Section 2 and Section 3, the final outputs are P=1 and Q=0, which satisfy the fourth row of the truth table 6.

4.5. NOR operation:

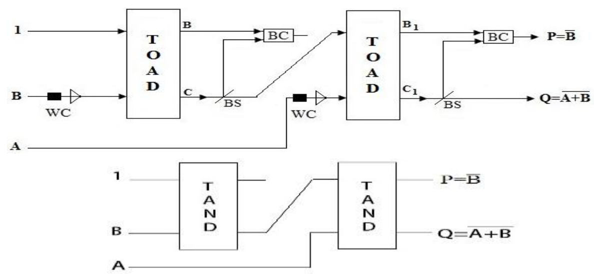


Fig. 8(a) Fig. 8(b)

BC : Beam Combiner, / BS: Beam Splitter, ▷ EDFA: Erbium Doped Fiber Amplifier, ■ WC: Wavelength Converter

Schematic diagram is given in Fig. 8 (b). The TOAD -based circuit for NOR gate by all-optical TAND gate is given in Fig. 8 (a). Here input 'A' is connected with TOAD -based TANT gate as control signal. The control signal of TAND based NOT gate comes from the input 'B'. The output of this gate, cross port (C), is connected to the incoming signal of above gate, TOAD -based TAND gate. The output 'Q' and 'P' are taken from the cross port (C1) and bar port (B1) of this TOAD -based TAND gate. The operational principle of this gate is discussed below in details.

Table 7: Truth table of NOR gate

A	B	P	Q
0	0	1	1
0	1	0	0
1	0	1	0
1	1	0	0

(1) When A=B=0, i.e. input A and B do not receive any light, the final output P and Q receives light from the TOAD -based TAND gate. So P=Q=1, which satisfy the first row of the truth table 7.

(2) When A = 0 and B = 1, then only the control signal is present at TAND based NOT gate. No control signal is present at TOAD -based TAND gate. According to the working principle of TOAD and TOAD -based TAND gate described in the Section 2 and Section 3, the final outputs are P=0 and Q=0, which satisfy the second row of the truth table 7.
(3) When A=1 and B=0, then only the control signal is present at TOAD -based TAND gate and no control signal is present at TAND based NOT gate. According to the working principle of TOAD and TOAD -based TAND gate described in the Section 2 and Section 3, the final outputs are P=1 and Q=0, which satisfy the third row of the truth table 7.
(4) When A=1 and B=1, then both control signals of TOAD -based TAND gate and TAND based NOT gate receive light. So P=0 and Q=0, which satisfy the fourth row of the truth table 7.

a. X NOR operation:

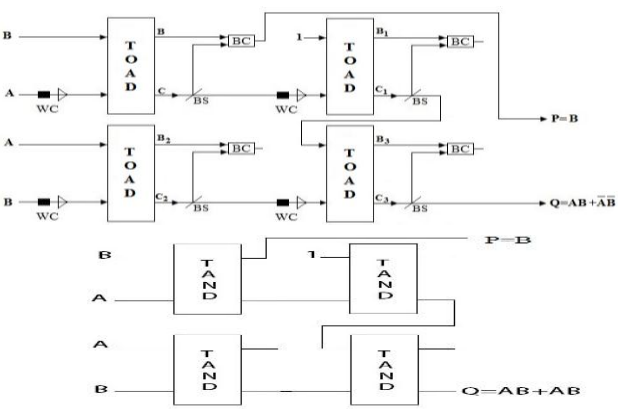


Fig. 9(a) Fig. 9(b)
BCeam Combiner, BS: Beam Splitter, EDFA: Erbium Doped Fiber Amplifier, WC: Wavelength Converter

Schematic diagram is given in Fig. 9(b). The TOAD -based circuit for X-NOR gate by all-optical TAND gate is given in Fig. 9(a). Here input 'A' and 'B' are connected with two TOAD -based TAND gates as incoming and also control signal at the same time. The outputs of the cross port (C, C2) are connected to the control port of TAND based NOT gate and TOAD -based TAND gate respectively. The output from cross port (C1) is connected to the input port of TOAD -based TAND gate which gives final output 'Q' through cross port C3. And output 'P' is taken from bar port (B). The operational principle of this gate is discussed below in details.

Table-8: Truth table of X-NOR gate

A	B	P	Q
0	0	0	1
0	1	1	0
1	0	0	0
1	1	1	1

(1) When A=B=0, i.e. input A and B do not receive any light, the final output P receives no light and Q receives light from the corresponding gate. So P=0 and Q=1, which satisfy the first row of the truth table 8.
(2) When A = 0 and B = 1, according to the working principle of TOAD and TOAD -based TAND gate described in the Section 2 and Section 3, the final outputs are P=1 and Q=0, which satisfy the second row of the truth table 8.
(3) When A=1 and B=0, according to the working principle of TOAD and TOAD -based TAND gate described in the Section 2 and Section 3, the final outputs are P=0 and Q=0, which satisfy the third row of the truth table 8.
(4) When A=1 and B=1, the final outputs are P=1 and Q=1, which satisfy the fourth row of the truth table 8.

4.7. X OR operation:

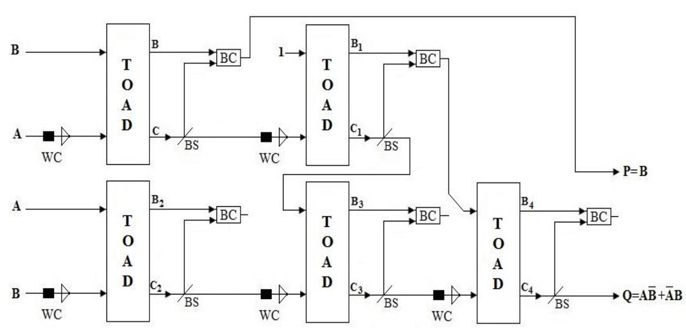


Fig. 10(a)

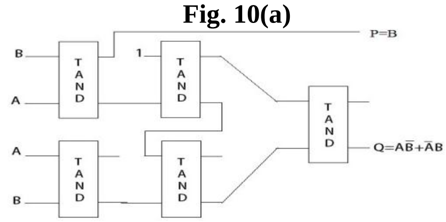


Fig. 10(b)
BC Beam Combiner, BS: Beam Splitter, EDFA: Erbium Doped Fiber Amplifier, WC: Wavelength Converter

Schematic diagram is given in Fig. 10(b). The TOAD -based circuit for X-OR gate by all-optical TAND gate is given in Fig. 10(a). First, a circuit is done like X-NOR gate operation. Then outputs from cross port (C3) and bar port (B1) are connected to a TOAD -based TAND gate as control signal and incoming signal respectively. The final outputs 'Q' and 'P' are taken from cross port (C4) and bar port (B). The operational principle of this gate is discussed below in details.

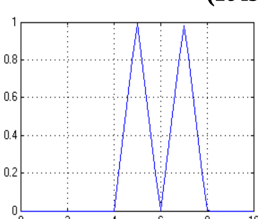
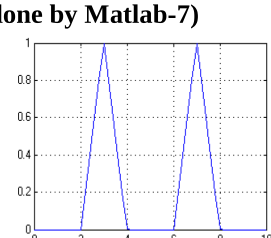
Table 9: Truth table of X-OR gate

A	B	P	Q
0	0	0	0
0	1	1	1
1	0	0	1
1	1	1	0

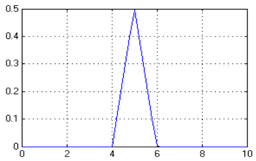
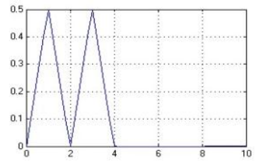
(1) When A=B=0, i.e. input A and B do not receive any light, the final output P and Q receives no light from the used TOAD -based TAND gate. So P=Q=0, which satisfy the first row of the truth table 9.
(2) When A = 0 and B = 1, according to the working principle of TOAD and TOAD -based TAND gate described in the Section 2 and Section 3, the final outputs are P=1 and Q=1, which satisfy the second row of the truth table 9.
(3) When A=1 and B=0, according to the same working principle of the used gate, the final outputs are P=0 and Q=1, which satisfy the third row of the truth table 9.
(4) When A=1 and B=1, the both incoming and control signal of TOAD -based TAND gate receive light and cross port does not receive light. And then similar working principle we get the final outputs are P=1 and Q=0, which satisfy the fourth row of the truth table 9.

5. Simulation results of above designed gates:

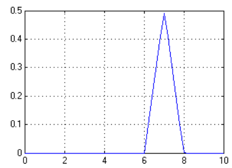
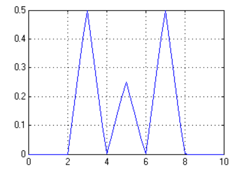
(It is done by Matlab-7)

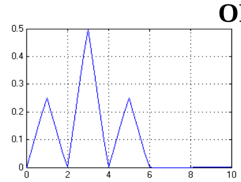
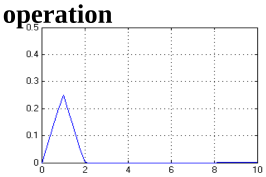
11(a)InputA **11(b) InputB**

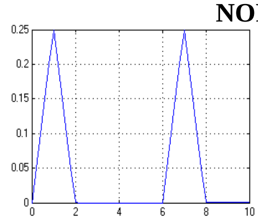
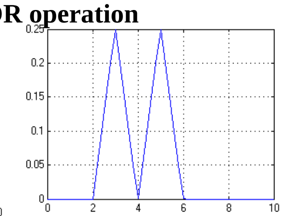
11(c) Output (cross port C) of TAND gate,11(d) Output ofNOT operation

11(e) Output of AND operation,11(f) Output of OR operation

11(g) Output of NAND operation,11(h) Output of NOR operation

11(i) Output of X-NOR operation, 11(j) Output of X-OR operation

The vertical axis in Fig. 11(a) to 11(j) indicates power in dB, while horizontal axis represents time scale in ps. The timing instant for the occurrence of bit pattern is at 1,3,5,7 ps. Upper first two (Fig. 11a and Fig. 11b) set waveforms indicate the input bit sequences, **0011** and **0101** for the input variables A and B respectively.

Let us test the reversible operation from the simulation results with chosen arbitrary time at 5 ps for the fig.11a, 11b and 11c of TAND gate. The output signal P=1, Q=1. Using these specific outputs we get from equation-6, A=1, B=0. Similarly, from different output bit patterns gives the different input bit combinations which satisfies the reversibility condition.

6. Conclusion and Future Work

In this paper, the all-optical scheme of universal TAND gate is proposed and explained. Simulation result verifies the functionality of those designed gates. This is important that the above explanations are based on simple model. It is executed experimentally also with taking predetermined values of wavelength (1552nm and 1534nm can be used for input and control signal) and intensity of laser, intensity loss by beam splitters, fiber and couplers, etc. The design of all-optical universal TAND gate by TOAD is theoretically addressed and demonstrated. The theoretical models developed and the results obtained numerically are useful to future all-optical reversible logic computing system. Different logic operations in reversible system can easily be performed with these gates. It is worth noting that the synthesis of reversible logic is different from irreversible logic synthesis. The major constraints in reversible logic are to minimize the number of reversible gates used and garbage outputs produced. The output, which is not used for further computations, is known as garbage output. Future work would concentrate realization of various Boolean expression and arithmetic operations using TAND gate.

References

[1] R.Landauer, Irreversibility and heat generation in the computational process. IBM Journal of Research and Development (1961), 5:183–91.
[2] CH. Bennett, Logical reversibility of computation. IBM Journal of Research and Development (1973), 17:525–32.
[3] J.Hardy and J.Shamir, Optics inspired logic architecture, Optics Express, 15(1), (2007), 150-165.
[4] S.Dolev, T. Haist and M. Oltean, Optical Supercomputing: First International Workshop, Vienna, Austria, (Springer) P. 33-45 (2008).
[5] F. T. S. Yu, S. Jutamulia, S. Yin, Introduction to information optics. Academic Press, San Diego (2001).
[6] G. P. Agrwal Applications of nonlinear fibre optics (Academic press, India [an imprint of Elsevier, San Diego, USA,]) (2001).
[7] M. A. Karim, A. A. S. Awal, Optical Computing: an introduction (Wiley, New York) (1992).
[8] A.I. Zavalin, J. Shamir, C. S. Vikram, H. J. Caulfield, Achieving Stabilization in interferometric Logic Operations, Appl. Opt. 45, (2006), 360-365.
[9] R. W.Keyes and R Landauer, "Minimal energy dissipation in logic", IBM J. Research and Development, pp. 152-157, March 1970.
[10] C. H. Bennett, "Notes on the history of reversible computation", IBM J. Research and Development, vol. 32, pp. 16-23, January 1988.
[11] T. Toffoli.," Reversible Computing," Tech memo MIT/LCS/TM-151, MIT Lab for Computer Science 1980.
[12] E. Fredkin and T. Toffoli, "Conservative logic," *Int'l J. Theoretical Physics, Vol. 21*, pp.219–253, 1982.
[13] D. Maslov and G. W. Dueck, "Garbage in reversible desing of multiple output functions", In 6th International Symposium on Representations and Methodology of Future Computing Technologies, pp. 162-170, March 2003.
[14] DP. Vasudavan, PK. Lala, J. Di, JP. Parkerson, Reversible-logic design with online testability. IEEE Transactions on Instrumentation and Measurement (2006), 55(2):406–14.
[15] M. Mohammadi, M.Eshghi, M.Haghparast, Bahroloom A. Design and optimization of reversible BCD adder/subtractor circuit for quantum and nanotechnology based system. World Applied Sciences Journal (2008), 4(6):787–92.
[16] M.Haghparasat, K.A. Navi, novel reversible BCD adder for nanotechnology based systems. American Journal of Applied Sciences (2008), 5(3):282–8.
[17] J. Shamir, HJ.Caulfield, W.Micelli, RJ. Seymour, Optical computing and Fredkin gates. Applied Optics (1986), 25(10):1604–7.
[18] N. A. Whitaker, Jr., M. C. Gabriel, H. Avramopoulos, A. Huang, All-optical, all-fiber circulating shift register with an inverter, Opt. Lett. (1991), 16(24).
[19] J. P. Sokoloff, P. R. Prucnal, I. Glesk, M. Kane, A terahertz optical asymmetric demultiplexer (TOAD), IEEE Photon. Techno. Lett. 5 (7), (1993), 787-789.
[20] J. P. Sokoloff, I. Glesk, P. R. Prucnal, R. K. Boneck, Performance of a 50 Gbit/s Optical Time Domain Multiplexed System Using a Terahertz Optical Asymmetric Demultiplexer, IEEE Photon. Techno. Lett.6 (1), (1994), 98-100.
[21] Z.Y. Shen and L. L. Wu, Reconfigurable optical logic unit with a terahertz optical asymmetric demultiplexer and electro-optic switches, Appl. Opt. 47(21), (2008), 3737-3742.
[22] Y. J.Jung, S. Lee, N. Park, All-optical 4-bit gray code to binary coded decimal converter, Optical Components and Materials, Proceedings of the SPIE, Volume 6890, (2008), 68900S.
[23] B.C. Wang, V. Baby, W. Tong, L. Xu, M. Friedman, R.J. Runser, I. Glesk, P. R. Pruncnal, A novel fast optical switch based on two

cascaded Terahertz Asymmetric Demultiplexers(TOAD), Optics Express 10(1), (2002), 15-23.

[24] Y.K.Huang, I.Glesk, R.Shankar, P.R.Prucnal, Simultaneous all-optical 3R regeneration scheme with improved scalability using TOAD, Optics Express, 14(22), (2006), 10339-10344.

Goutam Kumar Maity had started his carrier with Lectureship at PanskuraBanamali College, after completing his post graduation in Eletronics from Jadavpur University, Kolkata, West Bengal, India in 2000. He left Lectureship in 2005 & switched to reputed privateengineering colleges since last ten years. He did M.Tech. from West Bengal University of Technology& Ph.D from Bengal Engineering and Science University, Shibpur, Howrah,West Bengal, India in Information Technology & Optical Communications respectively. He has teaching and research experience of more than 14 years. Presently he is workingas Associate Professor in ECE Department at MCKV Institute of Engineering, Liluah, Howrah, West Bengal, India. His interests include embedded systems, optical information processing in communication Systems and optical cryptography.

Ashis Kumar Mandal was born in Howrah, West Bengal on 15th March, 1980. He received BSc (Hons. In Physics) degree from Calcutta University & MSc (in Pure Physics) degree from Madurai Kamaraj University. He is presently working as an Assistant Teacher in Chakur Haris Seminary High School. With nearly 8 years of teaching experience he passed CSIR-UGC NET-2012 (LS, Rank-70) in India. He is interested in Digital Electronics, optical information processing in communication system & organic solar cell.

Supriti Samanta was born in Purba-Medinipur, West Bengal on 28th July, 1978. She received BSc (Hons. in Physics) degree & MSc (Physics) degree from Vidyasagar University in 1999 & 2001 respectively. She is presently working as an Assitt. Teacher in Chaipat Girls' High School.. Her interests include Digital Electronics, Embedded systems and optical communication Systems.