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An innovative scheme for representation of signed numbers employing ternary logic and method of development of semiconductor optical amplifiers based wavelength encoded optical ternary half adder

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Abstract: *In binary logic, two different logical states are used to represent signed as well as unsigned numbers. In case of signed numbers one bit, usually the Most Significant Bit is solely devoted to represent the sign and thereby losing large amount of information storage capacity of a channel. In this communication, the authors use ternary logic comprising of 1, 0 and $\bar{1}$ to represent the number without any dedicated sign bit, so that the information storage capacity will increase to a large extent. Again it is also established that tri-state or ternary logic operations have the basic advantages of higher capacity and superior quality over its binary counterpart. In optics, multiple-valued logic can very easily be accommodated utilizing intensity, polarization, phase and also the wavelength of the wave as well. The wavelength dependent encoding/decoding techniques have established its superiority over the other optical data encoding techniques. In this communication the authors also propose a new scheme of implementing a wavelength encoded half adder with tri-state logic in the all optical domain using the wavelength conversion by the nonlinear polarization rotation in semiconductor optical amplifiers. Also the optical add/drop multiplexer employing the special filtering property of the SOA is utilized for the designing of the tri-state logic based half adder circuits.*
***Keywords**: Nonlinear polarization rotation, Multiple-valued logic, Optical half adder, Ternary numbers, Semiconductor optical amplifier, Add/drop multiplexing.*

I. Introduction

The all optical realization of different arithmetic and logical system is the fundamental to develop future high performance telecommunication networks, where all the node functionalities such as add-drop multiplexing, packet synchronization, clock recovery, address recognition, signal regeneration and many more should be carried out in the all optical domain in order to resolve the electronic bottleneck toward broadband and flexible networks. Binary logic is accepted by far the best for representing numbers and used widely in almost all types of existing electronic computers and communication systems. But binary number (framed by only two digits 0 and 1) is proved to be insufficient in respect to the ever increasing demand of the coming generation. Multiple-valued logic (MVL) can be viewed as an alternative approach to solve many problems in transmission, storage and processing of large amount of information in digital signal processing. The key building blocks for many all-optical digital processors are half adder. In a packet switched network to ensure that a packet is correctly forwarded through the network, routers are used for performing a lots of processing functions on each packet's header. Optical half adder and full adders can be used to implement optical checksum calculation and binary counter type of routing functions to ensure data integrity. Photonics have already established its strong and potential role for realization of many all optical digital systems including all optical logic gates, half adder, full adder, encoder/decoder, multiplexer/demultiplexer and many more in the recent past [1]. The prime advantages of photonic processing over the conventional electronic processing is the high speed, very large capacity of parallel processing, less power consumption, less wiring density, very small possibility of EMI, much higher throughput and finally has the capacity to realize multi-nary (beyond binary) logical systems [1-4]. Most of the system works mainly on the Boolean logic, in which two different logical levels are used to represent the information of any kind. But the conventional binary system have already shown it's limitations, that restricts the operating speed as well as the efficiency of parallel processing with a wide range of information and thereby reducing the maximum achievable throughputs. To overcome this sort of limitations of the Boolean system, multi-valued logical (MVL) system such as tri-state or the ternary logic system, quaternary system etc. have also been proposed [5–8]. In such systems, logical levels are in excess of two always, e. g., if it is three then it is the ternary logic system; if it is four then the system is of quaternary one and so on. Over the last decades, several all optical systems of half adder and half subtractor are proposed, simulated and demonstrated as well [9-17]. The optical nonlinear material based switching used in the earlier proposal, requires very precise control of the intensity and the directions of the different beams involved in the system. Since generation of X-OR for SUM output requires dual rail logic, most of these proposals involve interferometric configurations which need very precise control and stabilization schemes for proper operation of the systems. Again the FWM based earlier proposals suffer from the disadvantage of using tunable filters, requirement of high injection current and also the FWM has poor conversion efficiency. Beside all of these drawbacks the earlier proposals [5-17] have common intensity loss dependent problems. Since most of the proposals utilize intensity encoding mechanisms to represent the optical information, i. e., the presence of photon has been taken as logic ‘1’ and absence of the same as logic ‘0’ in the binary logic domain. In order to avoid those problems very recently a number of proposals for all optical systems of logic gates and different binary logic systems employing the completely new frequency/wavelength dependent encoding/decoding scheme has been reported [7, 18-22]. The prime beauty of the scheme is that as frequency or the wavelength is the fundamental property of the wave so it remains unaltered irrespective of the absorption, reflection, transmission during its propagation through different systems as well as communicating media. That’s why we have chosen this encoding mechanism for developing the ternary logic based half adder. Another advantage of using this encoding is that any multi-nary logic can easily be accommodated within this. Finally it should be worth mentioning that very little number of proposals include the tri-state or ternary logic. In this communication, the authors proposed a completely new scheme of developing ternary logic based half adders using the advantageous wavelength encoding mechanism.

The semiconductor optical amplifier (SOA), utilized as an active nonlinear optical medium, has demonstrated its feasibilities in all optical functional applications including optical switching, wavelength conversion, pulse generation and optical logic gate based on the nonlinear effects namely, cross gain modulation (XGM), cross phase modulation (XPM), four wave mixing (FWM) and cross polarization modulation (XPolM) within SOA [23-24]. These SOA based nonlinear effects are very much promising due to SOA’s high gain in the optical frequency region, strong change of refractive index and potential for photonic integration [4, 23-24].

Reflective semiconductor optical amplifiers (RSOA) utilize a highly reflective (HR) coating on one facet and an antireflective (AR) coating on the other facet to provide a stable versatile gain medium. RSOA offer low noise figure and high optical gain at low drive current [25]. Very recently, the use of polarization switches based on nonlinear polarization rotation in semiconductor optical amplifier in optical signal processing applications is receiving considerable importance by many researchers all over the world [26-30]. The section 1 is of introductory type in which literature survey along with relevance of our work is highlighted. In section 2 introduction to symmetry ternary logic system is given also the representation scheme for signed decimal number is discussed. In section 3 rule of ternary addition and excitation table of wavelength encoded optical ternary half adder is given. Optical switching using SOA are briefly discussed in section 4. Section 5 is dedicated to implementation of optical ternary half adder. Discussions about various aspects of the experiment are given in section 6. Section 7 is of concluding one.

II. The ternary number system and its advantages in signal processing:

The ternary number system is a positional number system having ‘radix’ or ‘base’ of decimal 3 and it may be formulated using symmetric ($\bar{1}$ = -1, 0 and 1) as well as asymmetric numerals (0, 1 and 2 or 0, -1 and -2). In our proposed scheme of arithmetic half adder we have proposed all optical system capable of handling the ternary numbers having symmetric numerals $\bar{1}$, 0 and 1. This is due to some inherent and important advantages of the symmetric ternary numbers relative to the other ternary as well as binary numbers. The ternary number system has attracted interest from the very beginning of the development of digital machines in view of the arithmetic properties of the symmetric number system. In the symmetric ternary number system any decimal integer number (N) can be represented as follows

$$\mathbf{N_{10} = (d_{n-1}3^{n-1} + d_{n-2}3^{n-2} + \ldots\ldots\ d_i3^i + \ldots\ldots\ d_23^2 + d_13^1 + d_03^0)} \qquad \textbf{(1)}$$

Where N_{10} is the decimal number whose ternary equivalent is represented by

$$\mathbf{d_{n-1}\ d_{n-2} \ldots\ldots\ d_i \ldots\ldots\ d_2d_1d_0,}$$

d_i = $\bar{1}$/0/1 are the numerals used to formulate the ternary number system and decimal number 3 is the ‘base’ or ‘radix’ of the number system. By employing the equation (1) it is possible to convert any symmetric ternary number into its decimal equivalent.

2.1 Representation of Signed Numbers using Ternary Logic:

In Boolean logic also known as binary logic system, the signed numbers can be represented using an additional bit apart from the magnitude representing bits, known as the ‘Sign bit’ positioned at the left most or the most significant location of the number. Usually logic ‘0’ is used to indicate positive numbers and logic ‘1’ is used to represent the negative numbers. Technically it will indicate reduced information carrying capacity of the system. In our proposed scheme, the sign bit is not at all required to represent the signed numbers. In binary single bit signed number representation is not possible as one bit is reserved to represent the sign and at least another one is definitely desired to indicate the magnitude or the value of the number. But in our system single bit representation is very much possible, in which $\bar{1}$ represent -1, 0 represent 0 and 1 indicates +1, all of which are signed integers. In binary, using two bits we can represent the following signed numbers in three different schemes in comparison with the ternary representation as shown in the Table 1

Table 1: Representation of Signed Nos using minimum number of bits in different Schemes

Information	Representation using different Schemes			
Signed Decimal Number	Sign Magnitude	1's Complement	2's Complement	Ternary
-2	-	-	10	
-1	11	10	11	$\bar{1}$
0	10	11	00	0
	00	00		
+1	01	01	01	1

Using two bits in our scheme it is possible to represent all integers between +4 (11) and -4 ($\bar{1}\bar{1}$) including 0 making a total of 9 representations in comparison with only 4 representations using the conventional and most advantageous 2's complement scheme employing binary logic. In a similar manner, using 3 bits it is possible to represent all signed integers between +13 (111) and -13 ($\bar{1}\bar{1}\bar{1}$) including 0 making a total of 27 representations in comparison with only 8 representations of the 2's complement scheme. So it is said that using the proposed scheme it is very much possible to achieve three and half fold increase in the capacity of a particular channel. Technically we can expect much higher throughput from a particular channel using our proposed scheme of representation using ternary numbers.

Table 2: Representation of Signed decimal using Ternary logic Scheme

1-Bit Representation		2-Bit Representation	
Decimal Value	Ternary	Decimal Value	Ternary
-1	$\bar{1}$	-4	$\bar{1}\bar{1}$
		-3	$\bar{1}0$
		-2	$\bar{1}1$
0	0	-1	$0\bar{1}$
		0	00
		+1	01
+1	1	+2	$1\bar{1}$
		+3	10
		+4	11

One of the greatest advantages of the complement schemes is the sign bit extension capability, which is not at all possible in the sign magnitude scheme of representation. But as in our scheme, the sign bit has no importance so sign bit extension becomes meaningless. In case of a particular number of bits representation (e.g., 4-bit, 8-bit, 16-bit, 32-bit, 64-bit representation etc.) the required no. of zeros can be appended on the left in all representations (for both +ve and –ve numbers), viz., 8-bit representation for +13 and -13 in our proposed scheme turns out to be 00000111 and 00000$\bar{1}\bar{1}\bar{1}$, respectively. In Table 2 the representation of signed numbers using ternary logic for 1 and 2 bit representations are shown exclusively.

III. Implementation of Optical Ternary Half Adder (OTHA)

To implement the ternary logic based half adder the authors have taken the three different wavelengths λ_0, λ_1 and λ_2 to represent the three states of the tri-state logic system $\bar{1}$, 0 and 1 following the wavelength encoding mechanism. The rules for arithmetic addition with ternary numbers should run as follows:

a) $\bar{1} + \bar{1} = \bar{1}\,1$ b) $\bar{1} + 0 = 0\,\bar{1}$ c) $\bar{1} + 1 = 00$

d) $0 + \bar{1} = 0\,\bar{1}$ e) $0 + 0 = 00$ f) $0 + 1 = 01$

g) $1 + \bar{1} = 0\,0$ h) $1 + 0 = 01$ i) $1 + 1 = 1\bar{1}$

It is to be noted that in the symmetric ternary number system, $\bar{1}1$ represents the decimal value of -2, $1\bar{1}$ represents the decimal value of +2, $0\bar{1}$ represents -1, 01 represents +1 and so on. The results follow from the general conversion principle of number conversion from the ternary one to decimal equivalent as depicted in equation (1). The conventional excitation table of the half adder with ternary logic following the rules of arithmetic addition of the symmetric ternary numbers is given in Table 3, where A and B represent two single bit ternary numbers and the corresponding outputs of the half adder are SUM and CARRY respectively.

Table 3: Excitation table of OTHA

EXCITATION TABLE FOR SUM

B \ A	$\bar{1}$	0	1
$\bar{1}$	1	$\bar{1}$	0
0	$\bar{1}$	0	1
1	0	1	$\bar{1}$

EXCITATION TABLE FOR CARRY

B \ A	$\bar{1}$	0	1
$\bar{1}$	$\bar{1}$	0	0
0	0	0	0
1	0	0	1

However, the excitation table of the proposed all optical wavelength encoded half adder in the ternary logic domain is given in the Table 4, where the three different numerals of the symmetric ternary numbers are encoded by the three different wavelengths λ_0, λ_1 and λ_2 respectively to represent $\bar{1}$, 0 and 1 states of the tri-state logic. It should be mentioned here that in our proposed scheme it can easily be possible to use the same unit for half addition of any ternary numbers (other than symmetric one) as well. To achieve the same it is required to encode the information in a proper way so that it would follow the ternary number addition rules.

Table 4: Excitation table of the wavelength encoded OTHA.

TERNARY INPUTS		Final Output of the half Adder (Y=A + B)	
A	B	CARRY	SUM
$\lambda_0(\bar{1})$	$\lambda_0(\bar{1})$	$\lambda_0(\bar{1})$	$\lambda_2(1)$
$\lambda_0(\bar{1})$	$\lambda_1(0)$	$\lambda_1(0)$	$\lambda_0(\bar{1})$
$\lambda_0(\bar{1})$	$\lambda_2(1)$	$\lambda_1(0)$	$\lambda_1(0)$
$\lambda_1(0)$	$\lambda_0(\bar{1})$	$\lambda_1(0)$	$\lambda_0(\bar{1})$
$\lambda_1(0)$	$\lambda_1(0)$	$\lambda_1(0)$	$\lambda_1(0)$
$\lambda_1(0)$	$\lambda_2(1)$	$\lambda_1(0)$	$\lambda_2(1)$
$\lambda_2(1)$	$\lambda_0(\bar{1})$	$\lambda_1(0)$	$\lambda_1(0)$
$\lambda_2(1)$	$\lambda_1(0)$	$\lambda_1(0)$	$\lambda_2(1)$
$\lambda_2(1)$	$\lambda_2(1)$	$\lambda_2(1)$	$\lambda_0(\bar{1})$

4.1 Working principles of the proposed OTHA system:

Operation of the wavelength encoded OTHA is based mainly on the following two principles involving nonlinear SOA:

(a) Principle of wavelength routing by optical add/drop multiplexer and

(b) Principle of wavelength conversion using nonlinear polarization rotation of the state of polarization (SOP) of the linearly polarized probe (LPP) input within nonlinear SOA.

4.2 Principle of wavelength routing by optical Add/Drop multiplexing:

The data signals of several wavelengths may be routed to different paths using optical 'ADM' [6, 21-23, 30-31]. The function of a wavelength ADM is to separate a particular channel without interference in adjacent channel, which can be achieved by using an integrated SOA with a tunable filter as shown in the Figure-1.

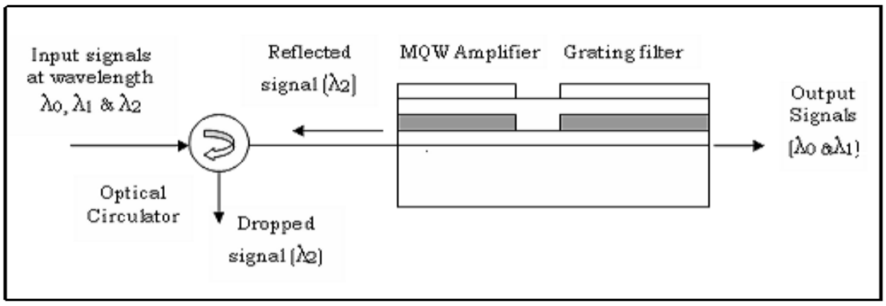

Figure-1: principle of wavelength routing using SOA

The main advantage of using optical ADM is that the reflected signal (i. e., the filtered out signal) is amplified by the MQW section of the SOA. The remaining signals can easily pass through the system without much loss for further processing.

4.3 Principle of wavelength conversion using nonlinear polarization rotation of the state of polarization (SOP) in semiconductor optical amplifier:

One of the important properties of SOA is the non- linear polarization rotation of the probe beam due to optically induced nonlinear refractive index in a bulk SOA caused by highly intense pump beams [24-29, 32] as shown in the figure 2.

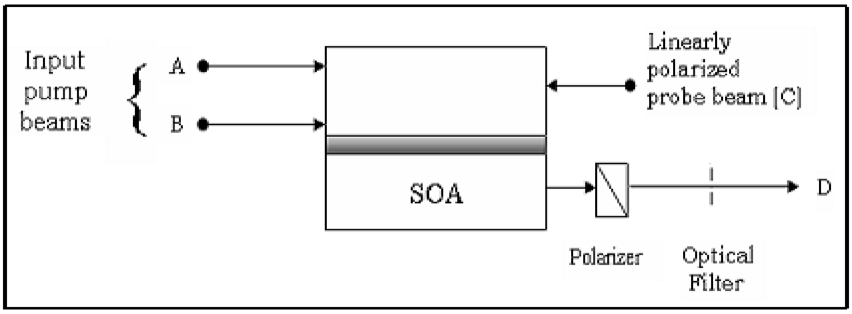

Figure-2: State of polarization rotation of probe beam by SOA

During the interaction of the intense pump beams (A & B) with probe beam (C) within the nonlinear SOA, the polarization dependent gain saturation character give rise to different refractive index change for TE and TM component of the probe beam, and hence they propagate with different velocities. At the output end of the SOA when they recombine, the SOP of the probe will be rotated through certain angle depending on the phase difference introduced between the two modes. An optical polarizer at the output end can detect the nonlinear polarization rotation and convert the phase difference into intensity difference [25, 32]. By suitably adjusting the bias current of the SOA and the power level of the pump beams it can very easily be possible to convert the output to any wavelength. This can be achieved by using an optical BPF (to reject undesired signals) and a polarizing Nichol at the output port as shown in the Figure 2.

5.1 The scheme of the experiment of the OTHA: The scheme of the experiment for the optical ternary logic based half adder is shown in the Figure 3. The two ternary input beams 'A' and 'B' are separately allowed to pass through two successive optical ADMs AD0 and AD1 in series which are tuned for reflecting optical signals of wavelengths λ_0 and λ_1, respectively [30]. The reflected wave from each ADM is dropped down by means of optical circulators. The dropped beams act as the input pump beams for the array of eleven nonlinear SOA namely, 'S_1', 'S_2', 'S_3', 'S_4', 'S_5', 'S_6', 'S_7', 'S_8', 'S_9', 'S_{10}' and 'S_{11}' respectively. These nonlinear SOAs are used to produce the desired outputs of the OTHA by employing the wavelength conversion property of the said SOA depending upon the specific input data conditions among 'A' and 'B'. The tuning of ADM can be made feasible by controlling the bias current of the SOA, constituting the ADM properly. The reflected signals from 'AD0' and 'AD1' are divided into three equal intensity parts with the help of optical beam couplers as and when required and injected as the pump beam for specific semiconductor optical amplifiers as shown in Figure 3. Input pump beams of wavelength λ_2 will pass through 'AD0' and 'AD1' and the final beams of wavelength λ_2 are split up into three equal intensity parts in the same manner as above and injected as pump beam for specific SOAs. Linearly polarized beam of wavelength λ_0 is applied as probe beam for 'S_1', 'S_6' , 'S_7', and

'S_8' respectively where as that of wavelength λ_1 is serving as the probe for 'S_3', 'S_4' and 'S_5'and finally signal of wavelength λ_2 is injected as probe beam for 'S_2', 'S_9', 'S_{10}' and 'S_{11}'. Output of all the SOAs having the same output wavelengths ($\lambda_0 / \lambda_1 / \lambda_2$) are combined together and then passed successively through polarizing Nichol and optical band pass filter (OBPF) having pass wavelength equal to the corresponding probe input wavelength.

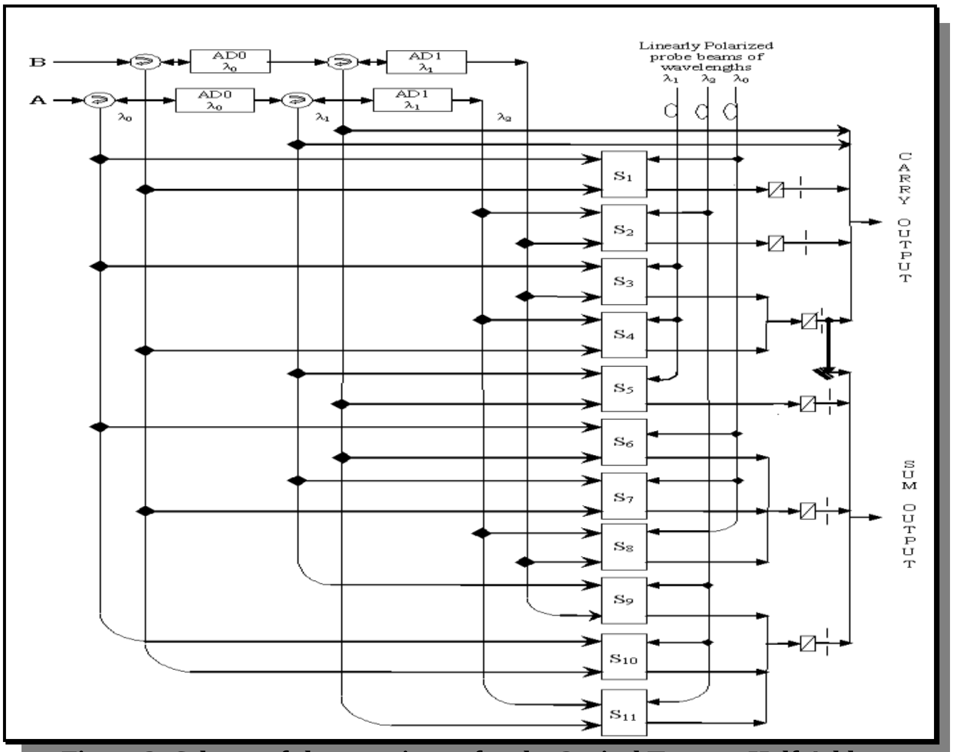

Figure 3: Scheme of the experiment for the Optical Ternary Half Adder

The polarization controllers are used in proper places in order to maintain the orientation of the linearly polarized probe beams at specific position. By careful observation of the excitation Table 4 of OTHA, it is clear that final CARRY output is of wavelength λ_1 if either one or both the inputs (A & B) are of wavelength λ_1. That's why the reflected waves of wavelength λ_1 from both AD1's are directly coupled to the CARRY output of the system. The output beams from the OBPFs are properly combined together to get the final CARRY and SUM output of the OTHA.

5.2 The operation of the OTHA:

The excitation table of the wavelength encoded OTHA is given in Table 4. Let us explain the function of our proposed optical scheme of the ternary half adder with reference to the Figure 3 for all possible combinations of the two ternary inputs A and B.

First of all let us consider that both the input signals 'A' and 'B' are of wavelength λ_0, i.e. both are at '$\bar{1}$' states: In this case, both the input signals of wavelength λ_0 will be reflected from 'AD0s' and will drop down by optical circulators for both the ternary inputs A and B respectively. Now the four equal intensity parts corresponding to 'A' input will reach the nonlinear SOA 'S_1', 'S_3', 'S_6' and 'S_{10}' and the splitting parts of 'B' input signal will reach 'S_1', 'S_4' ,'S_7' and 'S_{10}' respectively. Under these circumstances 'S_{10}' and 'S_1' will get both the pump beams simultaneously whereas 'S_3', 'S_4', 'S_6' and 'S_7' will get one pump beam each at a time. All other remaining SOAs will not get any pump beam at this situation. As both the input pump beams are present at the inputs of 'S_{10}' and 'S_1', therefore, both the pump beams significantly rotate the state of polarization of input probe beams of wavelengths of λ_2 and λ_0 respectively and the optical polarizer at the output ends can easily detect the nonlinear polarization rotation in terms of intensity difference [27]. As a result the outputs of 'S_{10}' and 'S_1' will give the filtered beam of wavelength λ_2 and λ_0 respectively as the output after passing through OBPF. All other SOAs will no longer remain active for this particular input combination. Now the output of 'S_{10}' is directed towards the SUM output of the OTHA and that of 'S_1' will be available as the

CARRY output of the OTHA. In this way, the 1st row of the excitation table of the wavelength encoded OTHA is verified. In a similar manner as explained above it is possible to verify all other combinations of the optical ternary inputs A and B to produce the desired outputs of the OTHA.

Table 5: Extended excitation table for SUM output of the OTHA

TERNARY INPUTS		SOAs receiving pump from A	SOAs receiving pump from B	SOA receiving pump from both A and B	Wavelength of LPP Beam	FINAL SUM OUTPUT	Remarks
A	B						
λ_0	λ_0	S_1, S_3, S_6, S_{10}	S_1, S_4, S_7, S_{10}	S_{10}	λ_2	$\lambda_2(1)$	$\bar{1}+\bar{1}=\bar{1}1$
λ_0	λ_1	S_1, S_3, S_6, S_{10}	S_5, S_6, S_{11}	S_6	λ_0	$\lambda_0(\bar{1})$	$\bar{1}+0=0\bar{1}$
λ_0	λ_2	S_1, S_3, S_6, S_{10}	S_2, S_3, S_8, S_9	S_3	λ_1	$\lambda_1(0)$	$\bar{1}+1=00$
λ_1	λ_0	S_5, S_7, S_9	S_1, S_4, S_7, S_{10}	S_7	λ_0	$\lambda_0(\bar{1})$	$0+\bar{1}=0\bar{1}$
λ_1	λ_1	S_5, S_7, S_9	S_5, S_6, S_{11}	S_5	λ_1	$\lambda_1(0)$	$0+0=00$
λ_1	λ_2	S_5, S_7, S_9	S_2, S_3, S_8, S_9	S_9	λ_2	$\lambda_2(1)$	$0+1=01$
λ_2	λ_0	S_2, S_4, S_8, S_{11}	S_1, S_4, S_7, S_{10}	S_4	λ_1	$\lambda_1(0)$	$1+\bar{1}=00$
λ_2	λ_1	S_2, S_4, S_8, S_{11}	S_5, S_6, S_{11}	S_{11}	λ_2	$\lambda_2(1)$	$1+0=01$
λ_2	λ_2	S_2, S_4, S_8, S_{11}	S_2, S_3, S_8, S_9	S_8	λ_0	$\lambda_0(\bar{1})$	$1+1=1\bar{1}$

The extended version of the excitation tables for SUM as well as CARRY output of the proposed OTHA are given in the adjoining Tables 5 and 6, respectively for complete illustration of our proposed system of OTHA. In the design of CARRY output only four SOA - S_1, S_2, S_3, and S_4 are used to form the wavelength conversion segment of the same. The other outputs will be obtained directly from the dropped signal from the OADM having reflecting wavelength λ_1 as indicated in the extended excitation table of the CARRY output of the OTHA.

Table 6: Extended excitation table for CARRY output of the OTHA

TERNARY INPUTS		SOAs receiving pump from A	SOAs receiving pump from B	SOA receiving pump from both A and B	Wavelength of LPP Beam	FINAL CARRY OUTPUT	Remarks
A	B						
λ_0	λ_0	S_1, S_3, S_6, S_{10}	S_1, S_4, S_7, S_{10}	S_1	λ_0	$\lambda_0(\bar{1})$	$\bar{1}+\bar{1}=\bar{1}1$
λ_0	λ_1	S_1, S_3, S_6, S_{10}	S_5, S_6, S_{11}	-	-	$\lambda_1(0)$	$\bar{1}+0=0\bar{1}$
λ_0	λ_2	S_1, S_3, S_6, S_{10}	S_2, S_3, S_8, S_9	S_3	λ_1	$\lambda_1(0)$	$\bar{1}+1=00$
λ_1	λ_0	S_5, S_7, S_9	S_1, S_4, S_7, S_{10}	-	-	$\lambda_1(0)$	$0+\bar{1}=0\bar{1}$
λ_1	λ_1	S_5, S_7, S_9	S_5, S_6, S_{11}	-	-	$\lambda_1(0)$	$0+0=00$
λ_1	λ_2	S_5, S_7, S_9	S_2, S_3, S_8, S_9	-	-	$\lambda_1(0)$	$0+1=01$
λ_2	λ_0	S_2, S_4, S_8, S_{11}	S_1, S_4, S_7, S_{10}	S_4	λ_1	$\lambda_1(0)$	$1+\bar{1}=00$
λ_2	λ_1	S_2, S_4, S_8, S_{11}	S_5, S_6, S_{11}	-	-	$\lambda_1(0)$	$1+0=01$
λ_2	λ_2	S_2, S_4, S_8, S_{11}	S_2, S_3, S_8, S_9	S_2	λ_2	$\lambda_2(1)$	$1+1=1\bar{1}$

IV. Discussions:

Semiconductor optical amplifiers are to be biased with a current of 200mA and the ambient temperature may be kept at 20^0C to get faithful operation of the proposed all optical system of ternary half adder [27]. One may use the laser beams of wavelengths λ_0 = 1546.8nm, λ_1 = 1552.2nm and λ_2 = 1556.6nm corresponding to $\bar{1}$, 0 and 1, respectively and they are modulated at a bit rate of 2.488 Gb/s via a Lithium Niobate Mach-Zehnder modulator [27] to obtain a standard result. The minimum separation between two consecutive encoded wavelengths is of the order of '5nm' which is sufficient for encoding/decoding purposes.

Here the wavelengths lie in C-band (1536nm -1570nm). The reason behind selecting such wavelength is that the prescribed SOA shows polarization sensitivity less than 1.0 dB and gain ripple of less than 0.5 dB around 1500nm [24]. This is due to the fact that within C band the performance of the system will be independent of the wavelength of the signals used. The counter propagating configuration in the nonlinear polarization rotation based SOA switch allows operating on signals at the same wavelength [27]. It is also required to maintain the power level of the pump beams for SOAs between 2 dB and 4dB to obtain faithful rotation of the SOP of the LPP beam [32]. The power level of the probe beams for nonlinear polarization rotation within the SOA should be maintained between -7dB to -4dB with a bias current of 200mA [24]. It is very much required to control the power level of the pump and the probe beams precisely in order to achieve a faithful operation from the proposed scheme. Instead of 2.488Gbits/s, the system may extend operation with higher bit rates (40Gb/s or more) with improved extinction ratio if multiple quantum well (MQWs) SOA with rapid gain recovery time [33] and the large differential refractive index [34] is used as a nonlinear medium.

V. Conclusion:

In summary, here we have presented an innovative scheme of representing signed number and presented the method of implementation of an optical half adder by using the tristate logic. The whole operation is all-optical and also the proposed system can be implemented by only SOA, one can expect a THz operation speed from such a system. The most important advantage of wavelength encoding/decoding mechanism over many other techniques is that use of wavelength encoded optical ternary logic information ($\bar{1}$, 0, and 1) in a signal remains unaltered in reflection, refraction, transmission and absorption over long distance communication channels. To maintain the state of polarization of probe beams polarization controller is to be used. Since the output beam may be of wavelength $\lambda_0/\lambda_1/\lambda_2$, six polarizer and six optical band pass filters (optical BW < 1nm) are sufficient to get noise free output. Reduction of the number of optical filters and reduction of the number of polarizer at the output end reduce the hardware complexity as well as cost of the system to a large extent. Again very fast switching action of the SOA enhances the speed of operation and the ternary logical system increases the throughput of the system to a great extent. Moreover, the intensity levels of the input and output data signals may not be very crucial in our system compared to the systems reported earlier. This is due to our encoding technique in which the different ternary logics are encoded by the different wavelengths of the signal rather than the intensity labels. The logic operation being wavelength encoded equally intense input beams (A & B) will give equal intensity pump beam (for all possible combination of input wavelengths) for the active SOA at any time independent of input wavelengths. As a result output beam will be obtained with highest possible extinction ratio which is expected to be in the range of 11.3dB and 11.6dB for all possible combination of input beam wavelengths.

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