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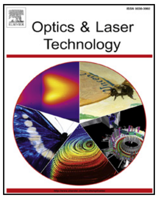

Full length article

All optical frequency encoded quaternary memory unit using symmetric configuration of MZI-SOA

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HIGHLIGHTS

- This is an all optical scheme for optical data storage unit associated with purely frequency encoding technique.
- It is implemented with all optical symmetric MZI-SOA switches.
- Data can be stored randomly without any mixing with the previously stored data in the system.
- This scheme can perform in GHz range and can be extended for higher bit memory storage too.

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ABSTRACT

Optical memory is an essential optical element for optical communication and computing system. Here the authors propose an optical scheme for developing a quaternary memory unit associated with wavelength encoding technique and based on Mach Zhender Interferometer based semiconductor optical amplifier (MZI-SOA) optical switches in symmetric configuration mode. Here the symmetry is introduced by injecting same biasing current to two SOAs of a MZI-SOA optical switch.

1. Introduction

Optics is playing an efficient role since decades with its high speed data carrying capacity. Optical computing and optical communication system is developed for faster communication since decades and it is still developing to achieve higher speed rate [1,2]. For this purpose many optical elements are developed to construct the optical communication network and optical computation system. Optical memory unit is such an essential optical element which is required to store and retrieve the optical data with very high speed response (in THz range). Sometimes optical memory is also required to store more than one command to execute multitasks in computational program. Many optical memories are successfully developed during last few decades [3–10]. Optical switch like Semiconductor Optical Amplifier (SOA) has been widely used to develop many optical elements due to its high frequency conversion efficiency as well as its very high speed operation (GHz range) [11–17]. SOA can be used in Mach-Zhender Interferometer in asymmetric and symmetric configuration for optical switching operation and many optical switches have been developed using the both configurations [11,18–25]. Some all optical memory cells with all optical switches are incorporated with photonic crystal of high speed response have been developed earlier [25–30]. Optical memory unit using optical switches based on MZI-SOA has been proposed earlier [31]. In that case the current data to be stored into the memory has a chance to mix up with the previously stored data as the previous data cannot be removed completely from the memory system when a new data is introduced i.e. the interference between the present and previous data is observed. A frequency encoded optical memory unit using polarization optical switch (PSW) and MZI-SOA has also been proposed earlier [32]. This scheme is polarization dependent as because the PSW switch is used and to operate the switching action of PSW it requires a polarization controller unit. And it is troublesome to maintain the specific polarization of the light throughout the entire operation of the scheme. So, a polarization independent system is always preferable than that of a dependent one. In the earlier scheme there is a limitation for consecutive and random data storage in the memory unit. The scheme is working fine to store a single bit data at a time but when one enters a new data for storage after the previous one (i.e. consecutively), the system does not work properly. Interference or mixing between the previously stored data and the newly entered data takes place as there

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is no arrangement to remove the previously stored data when the new data is introduced to the system for storage. Even the initial condition for the scheme is different for different data input, so one has to change the initial condition for the scheme each time for a new data entry. This is the limitation of the earlier proposed memory units [31,32]. An all optical wavelength encoded 1-bit optical memory unit using asymmetric configuration of MZI-SOA switch has been proposed by the authors where the chance of interference between stored previous and present data is completely removed [33]. In this scheme the symmetric MZI-SOA switch is introduced using same biasing current to the two SOAs. Here in this paper the authors propose an all optical scheme to develop a quaternary memory unit associated with frequency encoding technique. In this present scheme one can store any data among the four data bits randomly and consecutively one after another without any chance of mixing of new data with the old one. The previously stored data is completely removed as soon as a new data is given at the input. And also there is no need to change the initial condition for each time of data entry what solves the major problem seen in the earlier case. This proposed scheme is an extended work of the previously proposed single bit memory unit. And also this proposed work is done using the symmetric configuration of MZI-SOA switch and reflecting semiconductor optical amplifier (RSOA) [12,34–39]. This proposed scheme of operation is free from interference of data previously stored in the memory unit. Optical switching action of MZI-SOA switch in both counter and co-propagation schemes is used here and it is clearly discussed on the later sections.

2. The function of RSOA as wavelength converter

To increase the channel capacity and to enhance the better data management the use of wave division multiplexing (WDM) in all optical network is highly significant. The important element of all optical WDM network is an all optical wavelength converter. Several wavelength conversion techniques to achieve all optical wavelength conversion mechanisms have already been proposed [35-39]. Here in this present scheme the authors have used RSOA as an optical wavelength converter to develop the all optical memory unit and the operation of RSOA is briefly discussed here.

The principle of wavelength conversion using RSOA is achieved by exploiting its Cross Gain Modulation (XGM) nonlinear character. The gain of SOA depends on the carrier density of the active region of SOA. So, by changing the carrier density of the amplifier the gain can be varied and this gain variation can affect the input signal entered into the SOA. The carrier density can be changed by a strong optical signal with high intensity. So it is possible for a strong optical signal (called as pump signal) of one wavelength (say λ_2) to affect the gain of a weak continuous wave (CW) optical signal (called as probe beam) of another wavelength (say λ_1), when both are injected at the same time inside the SOA. Let the pump signal which is intensity modulated and the intensity is high enough to compress the gain of SOA significantly, is inserted along with a CW probe signal. Then the presence (high) and absence (low) of pump signal in accordance to the intensity modulation, it affects the gain dynamics of the amplifier through carrier depletion and this gain behaviour is imposed over the weak probe beam. The CW probe beam is not amplified (i.e. low) due to the gain saturation during the presence (high) of pump signal whereas the CW probe beam is amplified (i.e. high) in absence (low) of pump beam because of unsaturated gain during that duration. Therefore the probe will be modulated depending upon the pump signal due to the temporal variation of its gain (i.e. with the nature of the pump beam). Transposing the information imposed in the pump signal to the probe beam is achieved by modulation which is shown in Fig. 1(a). The information imposed in the probe beam is a replica of the information of the pump signal. This mechanism is referred as the cross gain modulation (XGM) [36,37]. This XGM technique is utilized in the RSOA to obtain the wavelength conversion.

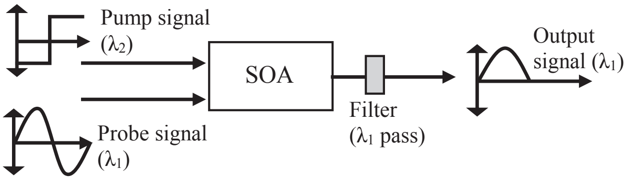

Fig. 1a. Cross Gain Modulation (XGM).

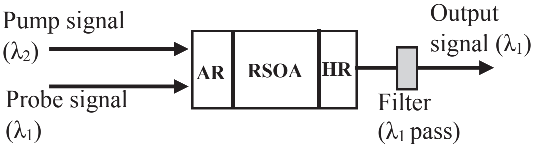

Fig. 1b. Operation of RSOA in co-propagating mode.

The basic diagram of RSOA is shown in Fig. 1(b) in co-propagation mode. The surface of the input facet of RSOA is made anti-reflecting (AR) by coating which provides no reflection for the probe beam λ_1 but allow transmission for both probe signal (λ_1) and pump signal (λ_2). The surface of the output facet of RSOA is made highly reflecting (HR) which provides very good reflection for pump signal λ_2 and good transmission for probe signal λ_1 and a filter (λ_1 pass filter) is used at the output to block the λ_2 if some fraction of λ_2 may transmits at the output end. Here to transmit the probe signal at the output of the RSOA by satisfaction of gain suppression character of it, the pump power of λ_2 wavelength is chosen properly (i.e. with minimum pump power). Under such condition the probe is amplified and transferred at the output directly. This is shown in Fig. 1(c). This operation i.e. the amplification of a wavelength encoded light signal can also be realized by the use of a simple SOA, with the choice of wavelengths in its high gain region.

So, when both the pump and probe signal are injected to the input of RSOA, the output will be modulated probe signal of wavelength λ_1 by XGM inside the RSOA. And this modulated signal can be used as the pump signal in later stage.

Here in this scheme the authors used RSOA as a wavelength converter to convert CW probe signal to get intensity modulated probe signal which has been treated as the pump signal for later stage operation.

It is seen from the Fig. 2 that when both the controlled electrical signal and probe beam λ_1 are present at the input side then the signal probe beam λ_1 is obtained at the output of SOA with a greater power. And when the probe beam λ_1 is absent and only no output is received. This switching action of SOA or of an RSOA can be used in the memory unit.

3. The principle of operation of MZI-SOA switch

Semiconductor optical amplifiers (SOA) are successfully utilized for de-multiplexing (time division) a high speed optical signal and also for wavelength conversion by the use of Mach Zhender interferometer (MZI) based system. The basic diagram of a MZI-SOA switch is shown on Figs. 3a-3c

In this configuration two SOAs (SOA1 & SOA2) are taken into the

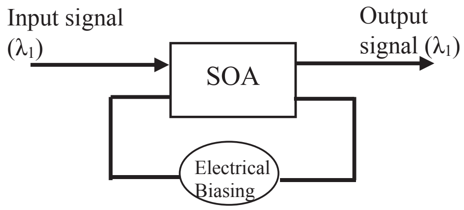

Fig. 1c. Operation of an electrically biased SOA.

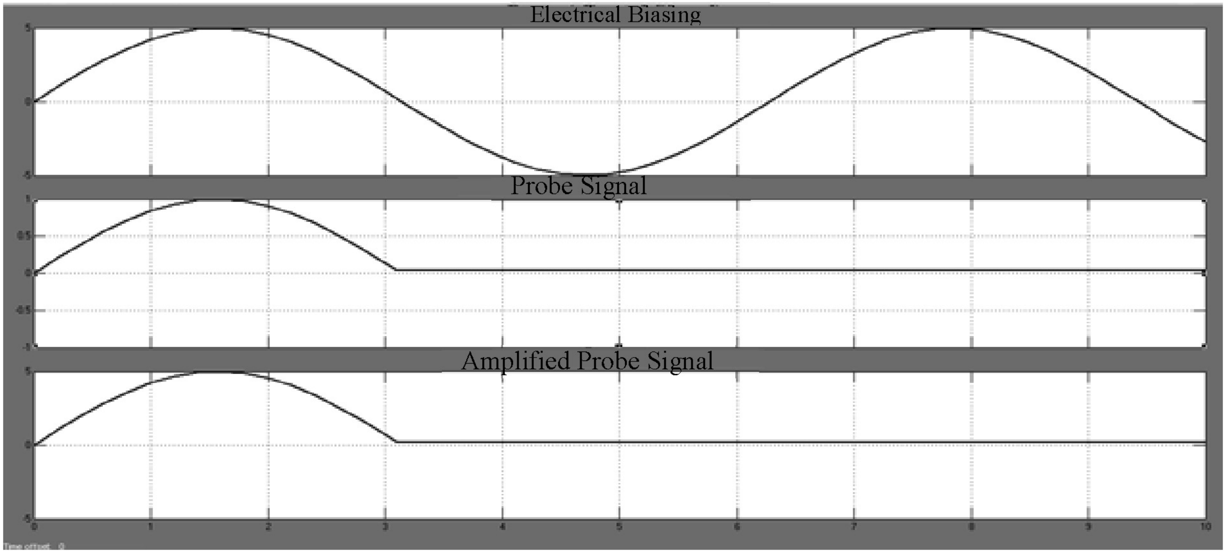

Fig. 2. Switching action of electrically biased SOA in absence/presence of probe beam.

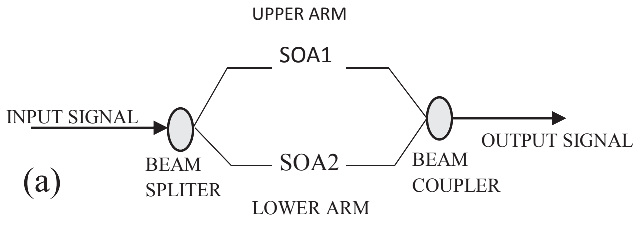

Fig. 3a. Basic diagram of a MZI-SOA switch.

two wings of the interferometer. An input optical signal beam being splited into two equal parts and travel through the two SOAs, and after emerging from the SOAs they interfere either constructively or destructively depending upon their relative phase difference of the two beams. The phase difference depends upon the biasing current of the SOAs and also on the optical power of the external control beam. When this relative phase difference between two split beams is π (both are in out of phase) then they interfere destructively, so no output is obtained. And when the relative phase between them 0 (both are in same phase), output is observed. MZI-SOA switch can be realized in two main configurations – (i) symmetric and (ii) symmetric configurations. The proposed work is done exploiting the symmetric configuration of the MZI-SOA.

4. Symmetric MZI-SOA configuration

In this case the two SOAs are taken identical in the two arms of the MZI-SOA switch and the biasing currents are same for two SOAs. The input signal splits into two equal parts by a 50:50 beam splitter and they travel through two SOAs in two arms of the MZI-SOA switch. When there is no control beam, the configuration of the switch is such that it gives a 0 phase difference (in phase) between two split beams after travelling through two SOAs. So the split beams make constructive interference and output will be obtained.

When a control beam (high intensity) is injected at any one of two SOAs along with the signal beam, then one of the two split beams will experience a π phase change when it travels through the SOA in which the control beam is injected due to the cross phase modulation. It results a π phase difference between two split beams. So the split beams make destructive interference and no output will be obtained.

Symmetric MZI-SOA in co-propagation and counter propagation scheme is shown in Figs. 3(a) and 3(b). For co-propagation scheme a filter is required to block the small fractional part of the control beam which may appear at the output. But in counter propagation scheme no filter is required.

Let a probe signal of wavelength λ_1 is given as the input of the MZI-SOA and a control signal of wavelength λ_2 is taken having high intensity. When only the probe beam is applied, control beam is absent then one get the signal of wavelength λ_1 at the output of the MZI-SOA switch. When along with the probe beam, the control signal of wavelength λ_2 is applied to the one of the SOAs of the MZI-SOA switch then no output will be obtained at the output of the MZI-SOA switch.

The simulation result of the switching action of the MZI-SOA in presence/absence of the pump beam is shown in Fig. 4.

It is clear from the Fig. 4 that when the pump pulse is present (i.e. 1) along with the probe beam then no output is obtained. As soon as the pump pulse is withdrawn (i.e. 0) and only the probe beam is present

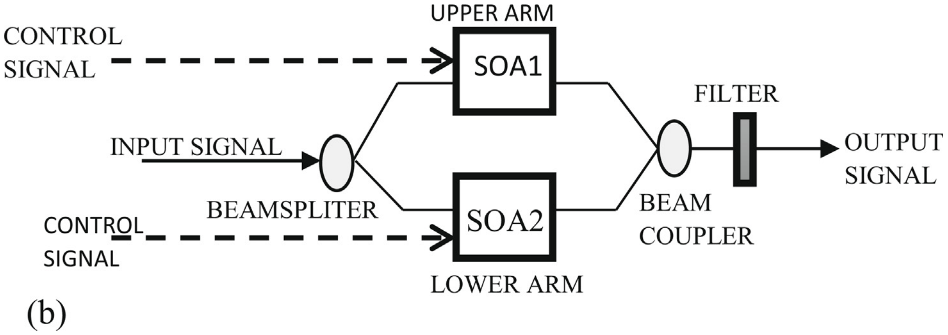

Fig. 3b. Symmetric MZI-SOA in co-propagation scheme.

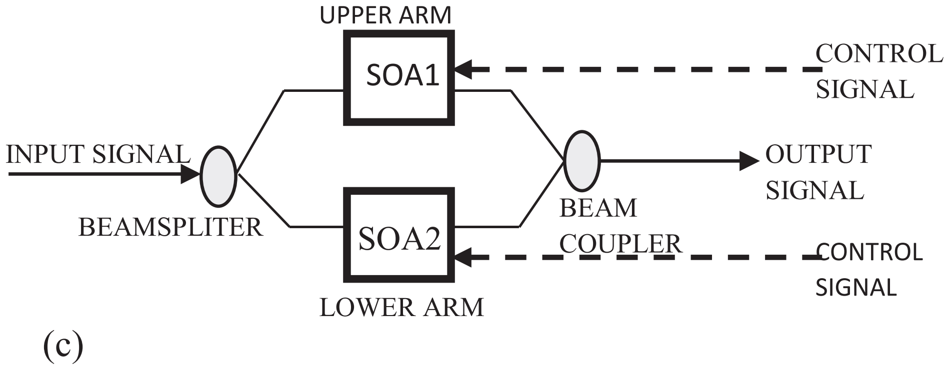

Fig. 3c. Symmetric MZI-SOA in counter propagation scheme.

then the output (the probe beam) is obtained.

5. Bit storage unit with MZI-SOA switch

A single bit memory unit using symmetric MZI-SOA switch consists of two symmetric MZI-SOA switches and two mirrors (M_1& M_2) placed in some specific places in the optical circuit for performing a particular operation. The schematic diagram of a memory block is shown in Fig. 5.

(i) When an input signal of wavelength λ_1 is given at the input of MZI-SOA1, it splits into two equal parts by a 3 dB beam splitter and travel through two SOAs. During travel through the SOAs the two split beams experience same unsaturated gain in two SOAs and a same amount of phase change occurs in the split beams. This results no phase difference between two split beams (i.e. phase difference 0). So after emerging out from SOAs, two split beams does make constructive interference and finally an output of wavelength λ_1 is observed.

(ii) The output beam splits into two parts by a beam splitter, one part is taken at the final output and the other part is given at the input of MZI-SOA2. MZI-SOA2 gives the same operation as of MZI-SOA1, so a beam of wavelength λ_1 is obtained at output of MZI-SOA2 which is coupled with the primary input line. And it repeats the same operation as (i) & (ii) respectively.

Now when the main input is withdrawn, MZI-SOA1 will get an input from the output of MZI-SOA2, so the rotation of light beam of wavelength λ_1 will continue through the MZI-SOA1 & MZI-SOA2. And hence λ_1 will be displayed at the final output in the absence of primary input. So it acts like a memory unit.

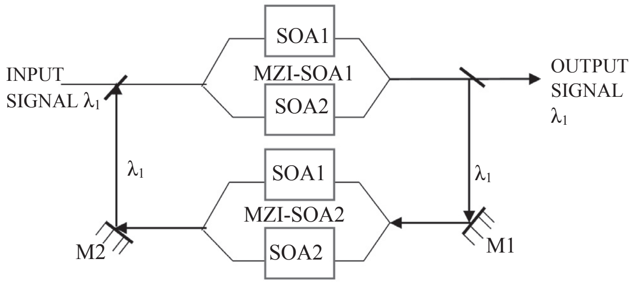

Fig. 5. Schematic diagram for BIT storage unit.

6. Single bit memory unit using symmetric configurations of MZI-SOA

A single bit memory unit consists of two memory blocks (BLOCK1 & BLOCK2) which are constructed by four symmetric MZI-SOA switches (MZI-SOA1, 2, 3, and 4) and a RSOA. A schematic diagram of the memory unit is shown in Fig. 6. The input signal of this memory unit is frequency encoded where the number ‘1′ is encoded with wavelength λ_1 and number ‘0’ is encoded with wavelength λ_2. Another signal of wavelength λ_3 is taken as the pump beam of RSOA. Here the BLOCK1

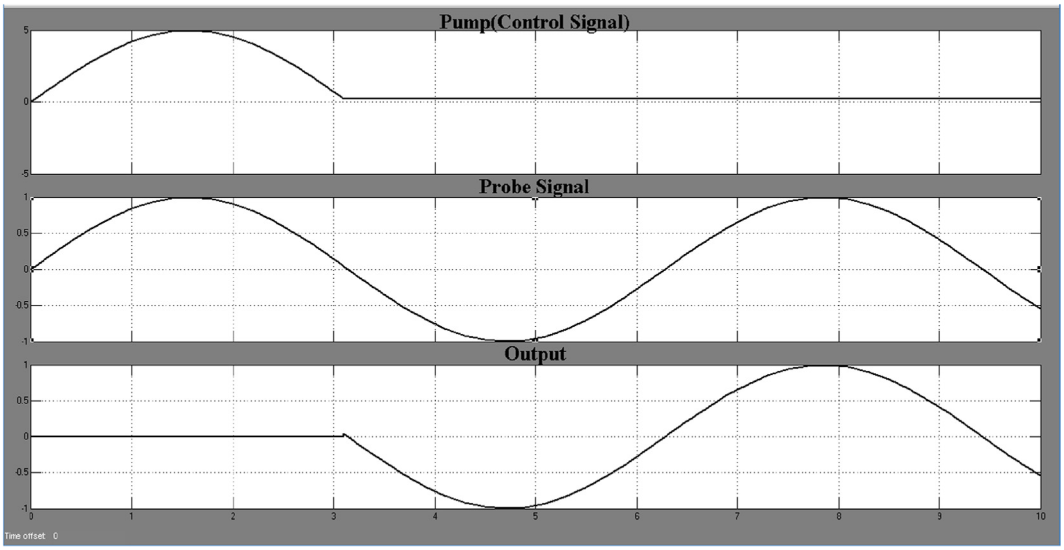

Fig. 4. Result of switching action of MZI-SOA in absence/presence of control/pump pulse at the output of the MZI-SOA switch.

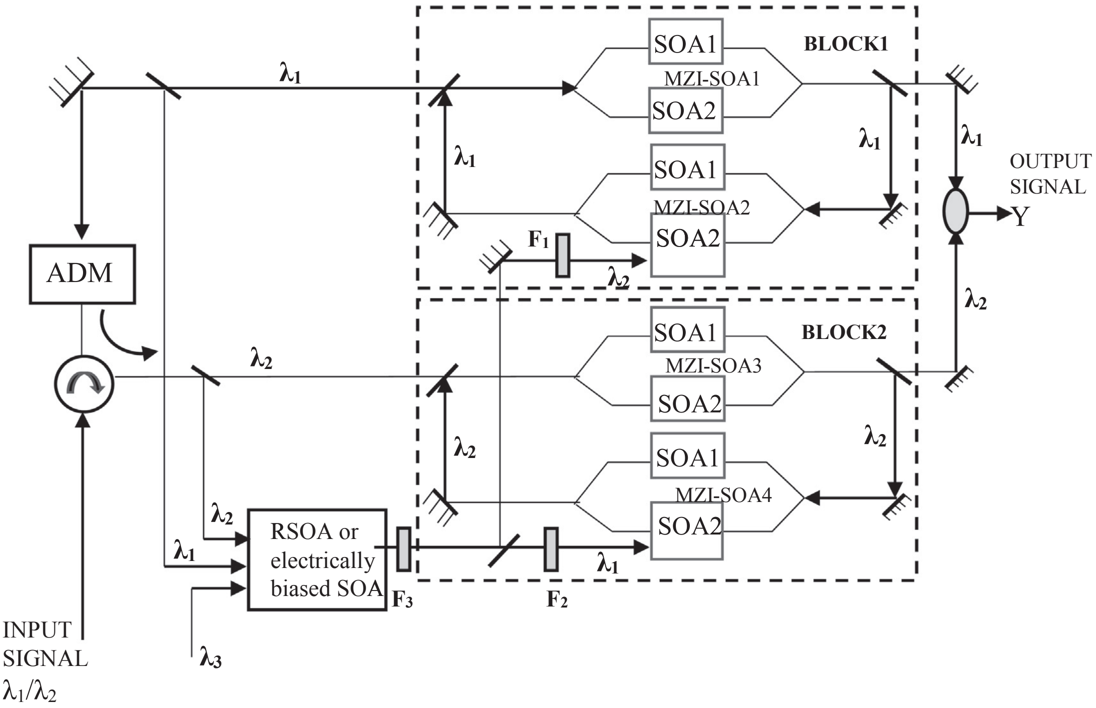

Fig. 6. Schematic diagram for single bit memory.

always (in absence of control beam at MZI-SOA2) gives the output of wavelength λ_1 i.e. 1 and the BLOCK2 always (in absence of control beam at MZI-SOA4) gives the output of wavelength λ_2 i.e. 0. The add drop multiplexer (ADM) is used to reflect the signal of wavelength λ_2 to a particular route and it pass the signal of wavelength λ_1 as shown in Fig. 6. Filters F_1, F_2, F_3 are used to block the wavelength λ_1, λ_2, λ_3 respectively.

A part of input signal of wavelength λ_1, after getting amplified by RSOA, is injected at the input of SOA2 of MZI-SOA4 in BLOCK2 and also a part of input signal of wavelength λ_2, after getting amplified by RSOA, is injected at the input SOA2 of MZI-SOA2 in BLOCK1. In this way the two blocks are interconnected. Outputs of two blocks are coupled together to get a final output Y. Here the RSOA is used to amplify the power of the signal of wavelength λ_1 & λ_2, so that they can be used as a control (pump) beam where as required in this present scheme of operation. The whole operation is explained below.

At first let input signal λ_1 (i.e.1) is given, and then it passes through the ADM and splits into two parts. One part goes to the input of the RSOA and after getting amplified through RSOA it is used as the control beam of MZI-SOA4. The other part goes to the BLOCK1 and BLOCK1 gives the output signal of wavelength λ_1 and it continues even when the input signal is withdrawn. And hence the final output is λ_1 (i.e.1) and it will continuously display 1 until a new signal is given to the input.

Now the input signal is given of wavelength λ_2 (i.e.0) and it is reflected back by the ADM and circulated by the circulator and splits into two parts. One part goes to the input of the RSOA and after getting amplified through RSOA it is used as the control beam of MZI-SOA2 in which the signal of wavelength λ_1 is already present at the input of the switch due to the first input λ_1. The signal λ_2 acts as the control signal of the switch MZI-SOA2 and in presence of control signal MZI-SOA2 gives no output in symmetric configuration as discussed earlier. At that instant BLOCK1 stops and gives no output. So λ_1 will not be displayed anymore at the final output.

At the same time the other part of λ_2 goes to BLOCK2. And as λ_1 is not present at the input so no control beam is present at MZI-SOA4. So the BLOCK2 will give the output of wavelength λ_2 even when the input is withdrawn. And hence the final output is λ_2 (i.e.0) and it will continuously display 0 until the new input is given to the input end.

Again the input signal of wavelength λ_1 is given, a part of it acts as the control beam of switch MZI-SOA4 and the other part goes to the BLOCK1. And now MZI-SOA4 gives no output in presence of control beam. At this instant BLOCK2 stops and gives no output. So 0 will not be present at the final output. At the same time BLOCK1 will gives output of wavelength λ_1 as there is no control beam present at MZI-SOA2 because there is no λ_2 at the main input. So the final output again displays number 1 even withdrawal of input signal. And the single bit memory unit will work in this way continuously.

The result of the above operation can be shown in a Tabular form which is given below in Table 1.

7. Single bit quarternery memory operation with symmetric configuration of mzi-soa:

The single bit memory unit can be extended to an quarternery memory unit by adding two more memory block and a single RSOA with that and the details proceedure and operation is discussed below. The schematic diagram of the quarternery latch is shown Fig. 7. Here the wavelength λ_1, λ_2, λ_3, λ_4 are taken corresponding to four different states (1st bit state, 2nd bit state, 3rd bit state, 4th bit state) of quarternery logic respectively.

When a signal beam splited into two equal parts and travel through two SOAs, they experience same unsaturated gain within SOA1 & SOA2 (as both are equally biased and are identical). So when there is only the signal beam, and no control beam, there is no phase difference between two splited beams after passing the SOAs of the two arms of the MZI-

Table 1
Frequency encoded truth table of the Boolean memory unit.

SL NO.	Input signal of wavelength $\lambda_1(1)/\lambda_2(0)$	Final output
1	λ_1 (1)	λ_1 (1)
2	λ_1 WITHDRAWN	λ_1 (1)
3	λ_2 (0)	λ_2 (0)
4	λ_2 WITHDRAWN	λ_2 (0)
5	λ_1 (1)	λ_1 (1)

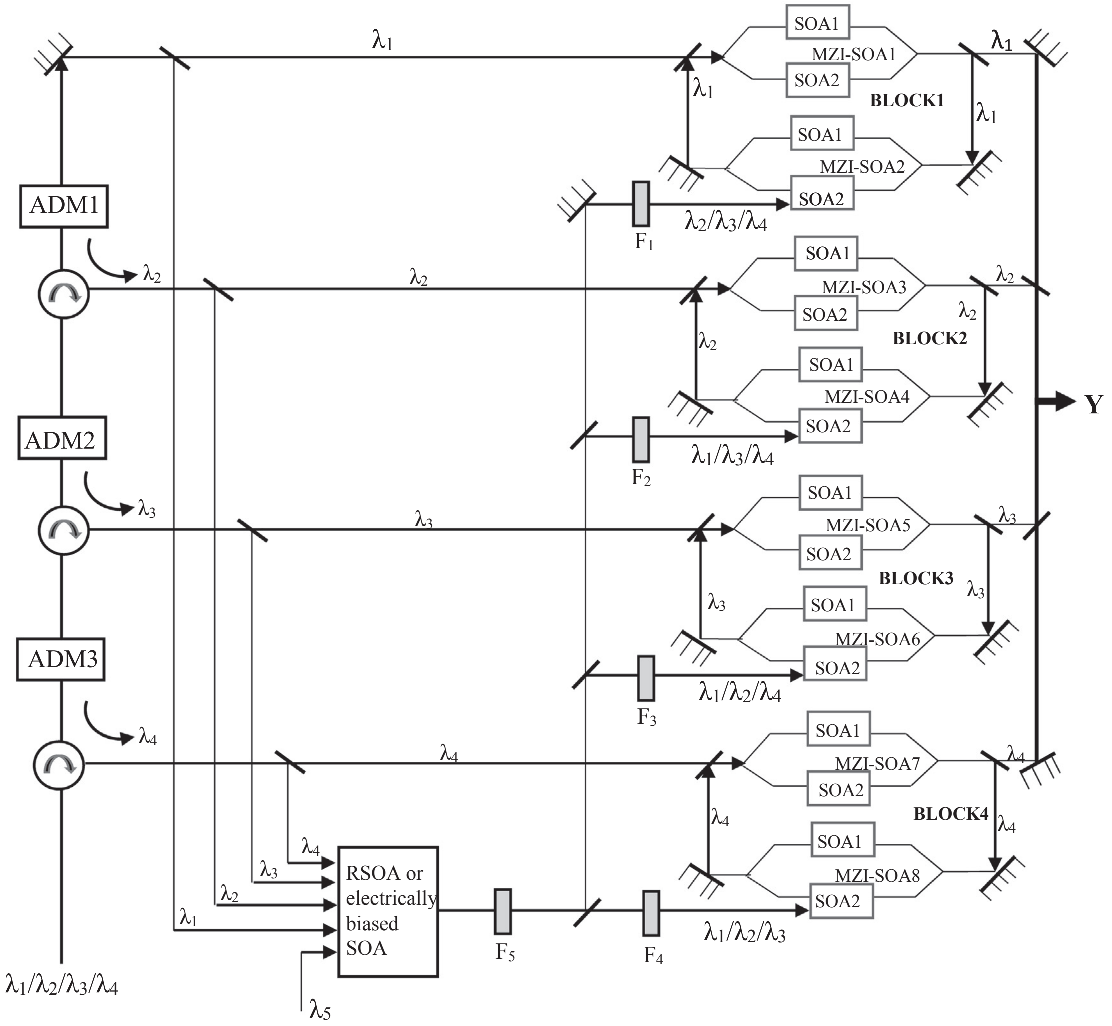

Fig. 7. Schematic diagram for Quarternery memory unit.

SOA switch. So they make constructive interference when they are coupled at the output end of the MZI-SOA switch. So output is obtained.

But when the control signal is present along with the signal beam to the any one of two SOAs of the MZI-SOA switch, a π phase difference is introduced between two splited beams. So they make destructive interference when they meet at the output end of the switch, and hence there is no output.

Here a part of each signal beam (λ_1/ λ_2/ λ_3/ λ_4) is connected to the input line of the RSOA and a signal of wavelength λ_5 having high intensity is used as the pump beam of the RSOA. RSOA is used to amplify the power of the signal beams (λ_1/ λ_2/ λ_3/ λ_4) so that they can be used as control beam to control the switching action of the MZI-SOA and the output of the RSOA is given to the inputs of SOA2s of MZI-SOA2,4,6,8 switches as shown in Fig. 6. Filters F_1,F_2,F_3,F_4 & F_5 are used to block the signal λ_1/ λ_2/ λ_3/ λ_4 & λ_5 respectively.

For example let λ_1 is present at the input of the RSOA along with the pump signal λ_5, then one get λ_1 with high power at the output of the RSOA and this output can be used as the control beam of MZI-SOA3,5,7 but not of MZI-SOA1 as it is blocked by filter F1.

At the input of the RSOA switch only one of the four signal beams (λ_1/λ_2/λ_3/λ_4) will be present at a time.

The configurations required for a specific operation of each MZI-SOA switch is discussed below.

MZI-SOA1: In this switch only the signal beam of wavelength λ_1 is given as the input, no control beam is applied. So whenever the input signal is present at the input of the switch MZI-SOA1 one get the output of wavelength λ_1.

MZI-SOA2: In this switch when only the signal beam λ_1 is present, then at the output the two split beams will make interference constructively. As no phase difference is introduced during traveling through the two SOAs because of the symmetric biasing current configuration. So some optical output of wavelength λ_1 will be obtained.

But when the control beam of wavelength λ_2/λ_3/λ_4 is given to the SOA2 at the lower arm of the MZI-SOA2, causes an introduction of π phase change between the two split beams of the signal beam λ_1 passing through the two arms of the MZI-SOA2 switch. So the two split beams interfere destructively when they meet. And then no output will be received at the output.

MZI-SOA3,5,7 switches operate in the same principle as that of MZI-SOA1 and MZI-SOA2,4,6 operate in the same way like MZI-SOA2.

The operations of the MZI-SOA switches in presence and absence of control beam in this present scheme of operation is shown in a tabular form in Table 2.

For example let first the signal beam of wavelength λ_2 (2nd bit state) is given in the input to store it, then by the joint action of circulator and ADM2 it is routed to the BLOCK2 and a part of it goes to the input of RSOA. BLOCK2 gives the output of wavelength λ_2 as there is no control beam present. And at the same time other 3 blocks (1,3,4) remain off as the control beam of wavelength λ_2, coming from the output of RSOA, is present at other 3 blocks. So the final output is λ_2 (i.e. 2nd bit state) and it will be continuously displayed even in withdrawal of the given input until a new data is given to the input.

Table 2
Wavelength encoded truth table of quaternary single bit logic unit (Here '×' is used to mean absence of light i.e. no signal.

Switch No.	Main Input Signal (data to be stored)	Control Signal	Phase difference between two splited beams	Output Signal
MZI-SOA 1	λ_1	×	0	λ_1
MZI-SOA 2	λ_1	×	0	λ_1
	λ_1	λ_2	π	×
	λ_1	λ_3	π	×
	λ_1	λ_4	π	×
MZI-SOA 3	λ_2	×	0	λ_2
MZI-SOA 4	λ_2	×	0	λ_2
	λ_2	λ_1	π	×
	λ_2	λ_3	π	×
	λ_2	λ_4	π	×
MZI-SOA 5	λ_3	×	0	λ_3
MZI-SOA 6	λ_3	×	0	λ_3
	λ_3	λ_1	π	×
	λ_3	λ_2	π	×
	λ_3	λ_4	π	×
MZI-SOA 7	λ_4	×	0	λ_4
MZI-SOA 8	λ_4	×	0	λ_4
	λ_4	λ_1	π	×
	λ_4	λ_2	π	×
	λ_4	λ_3	π	×

Now the signal of wavelength λ_4 (4th bit state) is given to the input to store it, then by the joint action of circulator and ADM3 it is routed to the BLOCK4 and a part of it goes to the input of RSOA. As soon as the new signal is given, BLOCK2 will be stopped by the control beam of wavelength λ_4 coming from the RSOA output. So the previously store data '2nd bit state' will be disappeared from final output. At the same time BLOCK4 will gives the output of wavelength λ_4 as there is no control beam present. So the final output will be λ_4 (i.e. 4th state bit) even in withdrawal of the input signal until a new signal is given to the input.

In this way one can store data randomly with this present scheme without any impression of the previous stored data. So there is no chance of interference between the newly stored data and the previously stored data. A simulation of the whole scheme has been done which is discussed in later section.

8. Simulated experiment of the quaternary memory unit

Simulation experiment of the whole model starts with the simulation of individual Blocks such as SOA, RSOA, MZI-SOA, ADM & CIRCULATOR, and COUPLER etc. Then using these blocks and following the All-optical scheme shown in Fig. 7 the authors have designed the whole process. Here five signals are taken for the operation naming Lambda1 (λ_1), Lambda2 (λ_2), Lambda3 (λ_3), Lambda4 (λ_4) and Lambda5 (λ_5). Lambda1 (λ_1), Lambda2 (λ_2), Lambda3 (λ_3) and Lambda4 (λ_4) are respectively represents the four different states (1st bit state, 2nd bit state, 3rd bit state, 4th bit state) of quaternary logic which have to store in the memory unit. Lambda5 (λ_5) is used as the input pump signal at the input of the RSOA. The whole scheme in Fig. 8 is done on Matlab Simulink platform to mimic the operation of the propose scheme and to verify its working. The Inputs and Outputs to store the 1st bit state (λ_1) and then the 2nd bit state (λ_2) in the memory unit are shown in the Fig. 9 & Fig. 10.

The upper four parts of the Fig. 9 show the input configuration corresponding to four input signals Lambda1 (λ_1), Lambda2 (λ_2), Lambda3 (λ_3) and Lambda4 (λ_4). And the lowest part shows the final memory output for the stored data in the memory. At the time of storing data into the memory unit only one signal is given in the input of the memory unit out of four signals which have to be store. Here the example is taken for storing 1st frequency encoded bit state λ_1 (Fig. 9) then the 2nd bit state λ_2. For this in the input lambda1 (λ_1) is given and withdrawn later. And from the Fig. 9 it is clear that when lambda1 (λ_1) is given in the input the final output of the memory unit is lambda1 (λ_1) and even in withdrawal the input the final output remain the same i.e. λ_1 until new wavelength is given to the input for storing the next. And hence the 1st bit state (λ_1) is kept in the memory.

Later as soon as the Lambda2 (λ_2) is given to the input to store the 2nd bit state (λ_2), it is shown in Fig. 10 clearly that the final output in the memory unit is Lambda2 (λ_2) and there is no impression of the previously stored data λ_1. And the final output remain the same λ_2 even in withdrawn of the input Lambda2 (λ_2). And hence the 2nd bit state is stored.

Thus the result is verified with the proposed memory unit scheme and in the following way the rest of the operations can also be verified.

9. Physical realization of the proposed system

For physical realization of the proposed system one can easily use a tuneable diode laser system in C band (1530 nm to 1565 nm). For example the diode laser source of wavelength 1529 nm to 1562 nm can be used for this purpose. Similarly MZI-SOA and RSOA systems are available in market which use lower laser power for probe and pump beams. The switching time of the system is in GHz range.

The losses in the different sections of this scheme are important to mention. They are from beam splitters, beam couplers, mirrors, filters, SOAs itself, ADMs etc, but this can be managed by proper amplification of SOAs and RSOAs controlling the electrical biasing powers of them. Again proper selection of the optical components are necessary for minimization of other loss factors.

The stability factor is also an important issue. The scheme may be unstable if the biasing electrical power fluctuates. So to set a reliable and stable operation of the scheme a dedicated electrical power source having constant flow of electrical current is highly essential. For an example to run a SOA or RSOA or MZI-SOA the electrical biasing current range is 180 mA to 250 mA. A standard tunable diode laser source of wavelength range 1529 nm to 1562 nm, gives + 6dBm to + 9dBm power of the output laser. Again a standard SOA needs 250 mA electrical biasing current for its dynamic operation where the probe beam requires a power 2.6mW and the pump beam requires a power 4.8mW. As the whole paper describes the operation of a prototype Quaternary memory unit in all optical domain so it appears voluminous scheme, but the implementation of the whole scheme can be realized in Photonic Band Gap (Pbg) system where SOAs/RSOAs can be combined with Pbg towards the development of a reduced and integrated optical scheme. In such nano-photonic device the use of circulator, beam splitter, optical filters etc. can be restricted.

The cost of this proposed scheme is another issue for practical realization of the scheme. The major cost lies in the tunable laser diode source. Then the cost of RSOAs, ADMs and MZI-SOAs are also significant. This cost may be minimized if the parallel uses of the optical devices (ADMs, RSOA, and MZI-SOA) are done followed by a hardware research. All the optical devices are currently available in the market.

10. A comparative discussion between the symmetric and asymmetric configuration based systems:

(a) In the present scheme the symmetric configuration of MZI-SOA switch is used rather than asymmetric configuration in the previous one. It is comparatively easier to configure a symmetric MZI-SOA than its asymmetric counterpart and also the response time of symmetric configuration is less (i.e. faster switching speed) than the asymmetric one.

As because to make the asymmetric configuration one has to control one or more factors of the used SOAs to maintain asymmetric behaviour. This is done by the factors injecting biasing current or optical power of the injected control signal or beam splitter ration at the input of the MZI-SOA switch. Where as in case of symmetric configuration

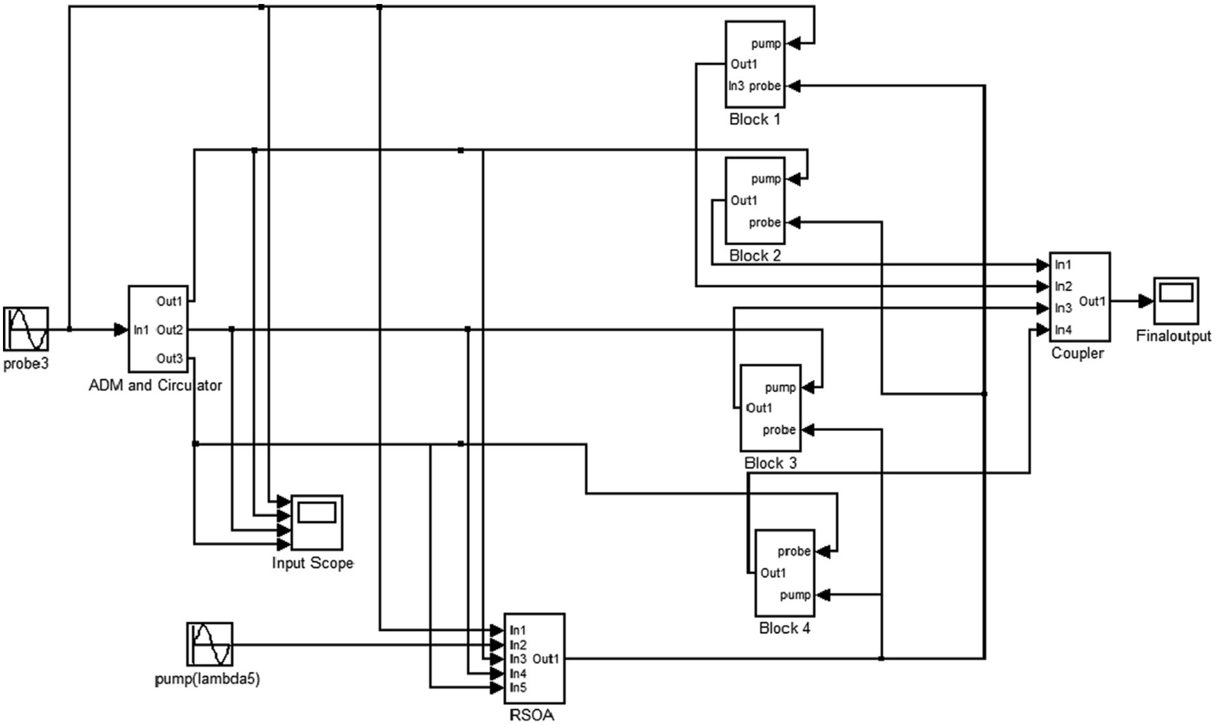

Fig. 8. Simulink (MATLAB) model of the memory unit.

one has to control only one factor and i.e. the optical power of the control signal applied to the MZI-SOA switches for the specific operations. Hence the speed of operation is faster than that of the system based on asymmetric configuration.

(b) The second important point is that the proposed system is a quaternary bit storage system, so it can store the desired one bit from one of the four frequency encoded bits. Where as in the earlier reported case only one out of two bits is stored.

(c) In the present scheme used by the asymmetric configuration of MZI-SOA, one RSOA is used to amplify the power of the signals of wavelengths λ_1 and λ_2, so that they can be used as a pump (control) beams as required in the scheme.

In the previous design RSOA has not been used, so there may be a chance that the power of wavelengths λ_1 and λ_2 may fall below the limit then it may not be possible to use λ_1 or λ_2 as pump beam, and this can affect the switching operation of the whole system.

In the present system of quaternary memory unit a single RSOA is used to increase the power of signals $\lambda_1/\lambda_2/\lambda_3/\lambda_4$ sufficiently, so it will be suitable to use them as pump beam.

11. Conclusion

It is seen from the above analysis that one bit binary, trinary and quaternary memory unit can be successfully implemented by the symmetric configuration of MZI-SOA, implemented by wavelength encoding technique. For quaternary bit memory unit four different

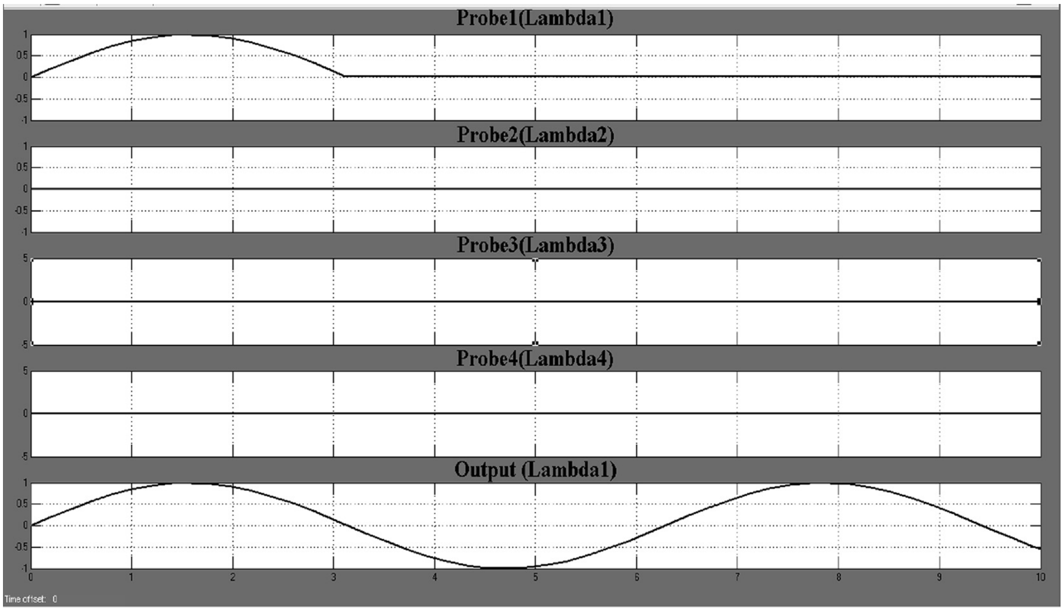

Fig. 9. Inputs and outputs configuration during storing the 1st bit state (λ_1) in the memory unit.

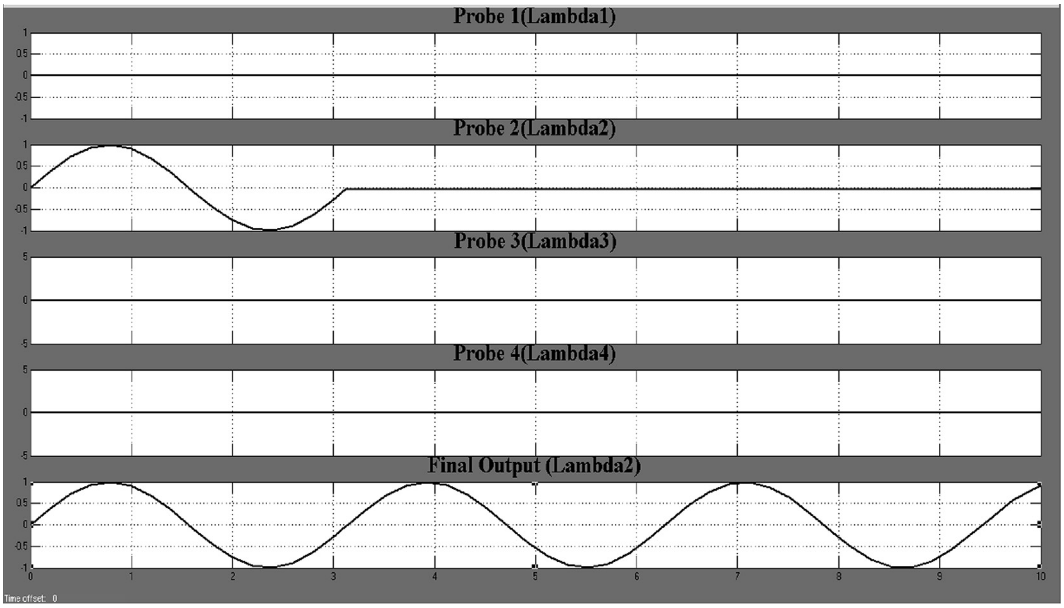

Fig. 10. Inputs and outputs configuration during storing the 2nd bit state (λ_2) in the memory unit.

wavelengths represent four different bit values. The main advantage of this memory unit is that when the system is used for storing one bit (one wavelength) the impression of the last bit (last wavelength) is totally removed. From this point of view this type of memory operation is free from the interference of previous bit (light). As soon as one new bit is applied the old bit vanishes from the output.

As the system is polarization dependent in case of RSOA based system so this is not taken into the account, but for a polarization independent system (when we are using electrically biased SOA) the question will come and the component like coupler, beam splitter, mirror etc. are polarization independent.

Again this method of memory operation can be used successfully for the storage of penternary, octernary or even decimal digits. The speed of operation is also fast and it is in GHz range, as SOA can show its switching function near about pico-second response time. For further improvement of the proposed scheme one can take the first attempt for realization of cost minimization. This may be possible by proper design for reduction of the no. of SOAs as well as using the SOAs for parallel operations. Again the scheme can be imported to a system of decimal bit storage unit or multi-valued storage unit by the necessary modification.

Declaration of Competing Interest

None.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.optlastec.2020.106386.

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