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Implementation of an All-Optical Time-Domain Multiplexing and Demultiplexing Scheme Exploiting Material Nonlinearity and Polarization Encoded Light Signal

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ABSTRACT

A new method of all-optical time domain multiplexing and demultiplexing scheme is proposed. This type of switching is developed by the proper use of optical nonlinear material and also polarization encoding technique. The state of polarization of light ensures the field intensity level same in whole operation. Again the real time speed of operation can be experienced here for achieving very high rate of data processing.The scheme may be extend to some wide application in all optical parallel computation and information processing.

Keywords: Non-linear medium; all optical switch; Multiplexture and Demultiplexture; Polarization encoding technique.

1. Introduction

The limitations of electronics are removed if light is introduced as the information carrying signal in high speed communication and data processing systems. Here one can expect very high operational speed, far above Tera hertz level [1,3,6]. In the implementation of many all-optical processing techniques, nonlinear materials (NLMs) can provide major support to optical switching based circuits [4,7,8]. To implement the logic operation with nonlinear material as a switching element, the intensity level of the signal is considered to indicate the logic states. So it is required to fix a specific intensity level of the light signal in favour of each bit. But in long distance communication the intensity of the optical signal may be changed due to various reasons. Then the logic operation fails to work properly in the detecting side. This difficulty may be avoided if the principle of polarization based encoding-decoding technique is adopted as the polarization state of a light signal is not changed [2,5,9-11]. In this paper a new scheme of implementing all-optical time-domain Multiplexing and Demultiplexing based on polarization encoded light signal and material non linearity is proposed.

2. Principle of time division multiplexing and demultiplexing

Time division Multiplexing is a process of selecting a particular input out of several inputs at a particular time and of sending it through the proper output channel. Let us explain it in details. In figure 1, X_0, X_1, X_2 and X_3 are four inputs. A and B are control or triggering channels and Y is the output channel. By a proper combination of control bits A and B [there are four possible combinations of A and B which are (0, 0), (0,1), (1,0) and (1,1)]we can select a specific input data (X_0 or X_1 or X_2 or X_3) and this input data can sent to the output Y.

Demultiplexing is the reverse process of multiplexing. Here we have one input and several output terminals. A time division demultiplexer is shown in figure 2 where one input Y is connected to the four outputs X_0, X_1, X_2 and X_3 by suitable circuit and two control channels A and B. By a proper combination of A and B we can connect the input to a specific output (X_0 or X_1 or X_2 or X_3). The above multiplexer is a 4×1 time domain multiplexer and the above demultiplexer is a 1×4 time domain demultiplexer.

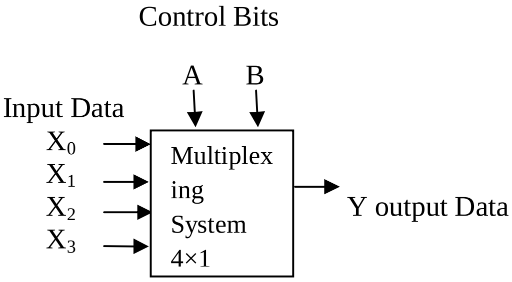

Figure 1: Multiplexing Operation

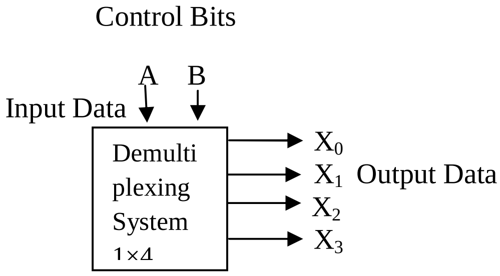

Figure 2: Demultiplexing Operation

3. Principle of switching operation by nonlinear material and half wave plate

The refractive index for some types of nonlinear materials can be written as

$$n_{NL} = n_0 + n_2 I \tag{1}$$

where n_0 is a constant term, n_2 is coefficient of the nonlinear correction term, and I is the intensity of the input light. It is seen that the refractive index of the material changes with the variation of intensity of the input light beam. Thus output beam direction will also be change (shown in Fig 3). If X,Y,Z are three input laser sources with equal prefixed intensities (I) the presence of any one input, one may receive output at S end. When two input beams are present output follows OD direction because of higher refractive index due to higher intensity level (2I) of the light through the nonlinear materials. Similarly when three input beams are present, output follows OT direction. Hence the combination of LM and NLM may act as a directional switch.

A half wave plate (Here Hi, i=1,2…) is usually made of thin sheets of split mica or of quartz crystal cut parallel to its optic axis. This plate introduces a phase difference of π if the wavelength of the light remains constant. Thus when a light polarized perpendicular to the plane of paper passes through a half wave plate, it becomes polarized in the plane of paper and vice versa at the outlet. So a half wave plate can act as a NOT gate.

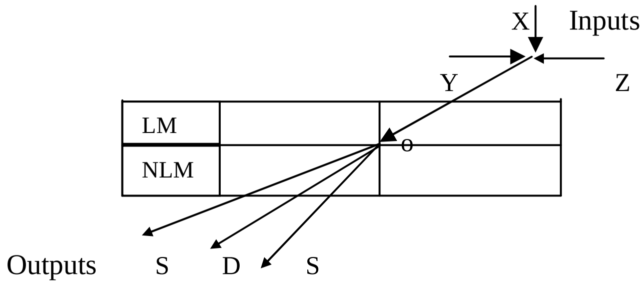

Figure 3: Optical isotropic nonlinear material as a switch.

A half wave plate (Here Hi, i=1,2…) is usually made of thin sheets of split mica or of quartz crystal cut parallel to its optic axis. This plate introduces a phase difference of π if the wavelength of the light remains constant. Thus when a light polarized perpendicular to the plane of paper passes through a half wave plate, it becomes polarized in the plane of paper and vice versa at the outlet. So a half wave plate can act as a NOT gate.

4. All-optical time domain Multiplexing (TDM) scheme

We now propose all-optical time domain multiplexing scheme with the combination of polarizers, linear and non-linear material blocks. The scheme is shown in the figure 4. Table 1 is its truth table. The polarizers P_1, P_2, P_3, P_4, P_6, P_8, P_9 and P_{12} allow only '↕' polarized light to pass through it and polarizers P_5, P_7, P_{10}, P_{11} allow '·' polarized light beam. Here '↕' polarized light is denoted by bit value 1 (one) and '·' polarized light is denoted by bit value 0 (zero). X_0, X_1, X_2, X_3 are four inputs of bit value 1 (one) which are supposed to be connected to the output channel Y. A and B are the control bits of the multiplexing system. By changing the control bits A and B we can transmit any input data to the output.

The scheme is divided by four units. The output of each unit is '↕' polarized (one) when one and only one input ('↕' polarized) is passed through the linear and non linear block, i.e. if one input light of intensity (I) is presented at the interface between LM and NLM then output light follow the S channel, then we get light output 1. On the other hand (2I or 3I intensity of light beams) output light follows the path D or T channel which is omitted here.

Case 1: When A=B=0, polarizers P_1, P_2 of unit 1 block the light beams, only the input light X_0 passes through the polarizer P_3. This light is made incident on the linear nonlinear material (LM-NLM). It is then refracted along the S channel. As a result data bit X_0 is transmitted to the output giving $Y=X_0$. On the other hand in case of unit 2, unit 3 and unit 4, both the '·' polarized light and '↕' polarized light are passed through the polarizers. These beams are combined with intensity 2I (in case of unit 2 and unit 3) and 3I (in case of unit 4).These combined light beams are now made incident on the (LM-NLM)

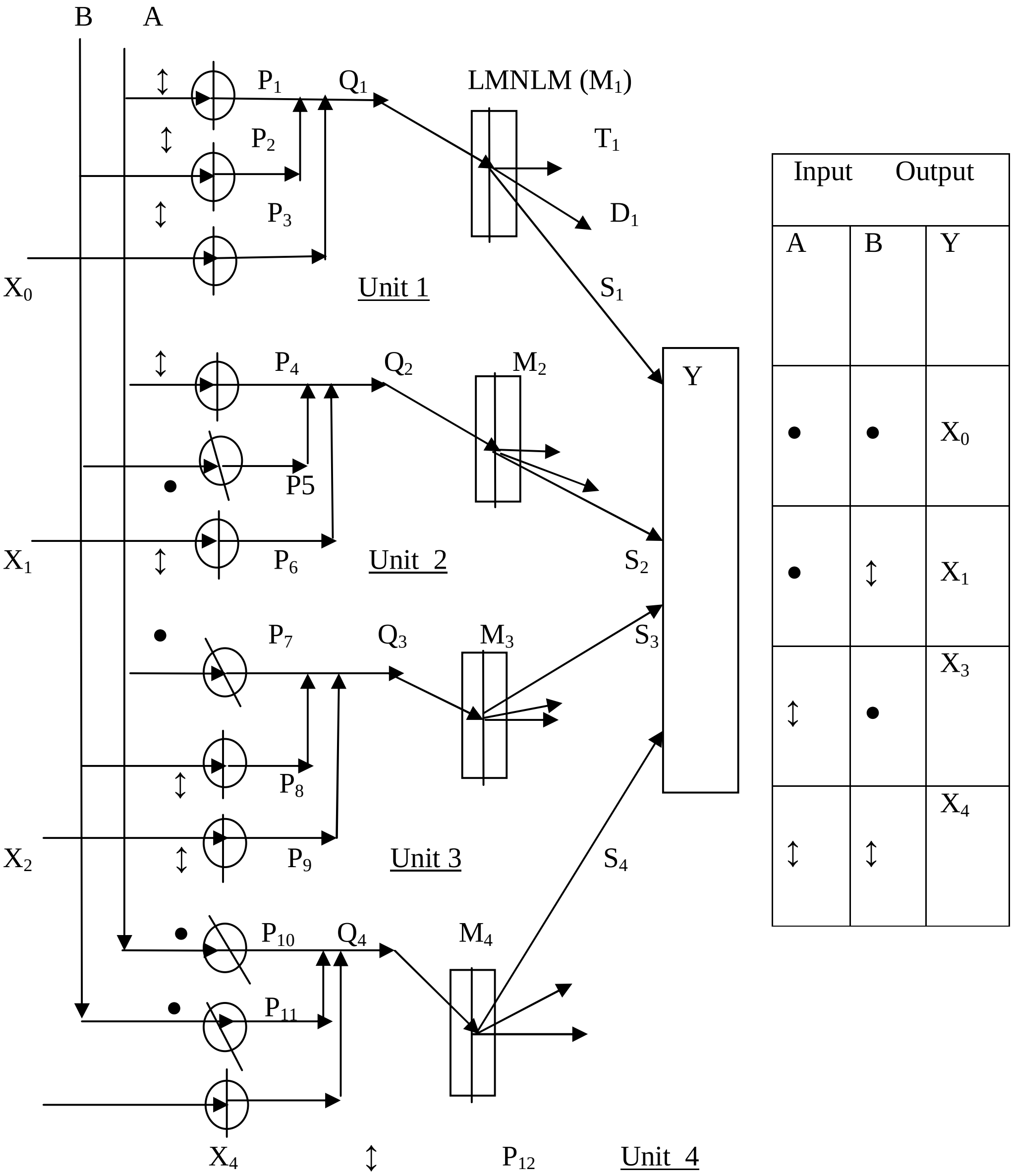

Figure 4: An all-optical 4-line to1-line Multiplexer. P_1,P_2,…are polarizers. M_1, M_2,…are the combination of linear and nonlinear materials. A and B are data selectors, X_0,…X_3 are four inputs, Y is the output boundary and refracted along the channels D and T which are omitted. So the inputs X_1, X_2 and X_3 are not passed.

Case 2: If the control bits are changed to A=0, B=1, both the polarizers P_4 and P_5 of unit 2 block the light beam and only P_6 allows to pass light beam having '↕' polarization coming from input X_1. Thus at Q_2 '↕' polarized light is obtained with intensity I. This light beam incident at the LM-NLM boundary, so this beam is refracted to the S channel causing light at the output (i.e. $Y=X_1$). Similarly form other units we get no light.

Case 3: When A=1, B=0, polarizers P_7 and P_8 of unit 3 block the light and P_9 passes light having '↕' polarization coming from input X_2, which gives at $Y=X_2$.

Case 4: If the control bits are changed to A=B=1, similar case is arrived in unit 4. Thus the output Y gives light of '↕' polarization (logic 1).

5. All-optical time domain demultiplexing scheme

Here a 1 to 4 line demultiplexer is proposed using suitable accommodation of polarizers, half wave plate (H) and optical non linear materials. The proposed scheme is shown in figure 5. By changing the control bits A, B the input data Ycan be routed to the output X_n, where n is the decimal number represented by the binary string A, B.

Case 1: If A=B=0, polarizers P_1 and P_2 of unit 1 block the light and P_3 passes light having '↕' polarization coming from input Y. This light beam of intensity I incident at the LM-NLM boundary, so this beam is refracted to the S channel. Therefore Y is transmitted to the output X_0. In case of unit 2 polarizers P_5 and P_6 pass the light beams and P_4 blocks the light beam. A s a result the combined light beam of intensity 2I ('↕' polarized light and '·' polarized light) refracted to the D channel from LM-NLM boundary (M_2)and only '·' polarized light passes through P_{14}. Thus we get no light at X_1. The operation is similar to the unit 3 and unit 4 in figure 5. That is $X_1=X_2=X_3=0$ ('·' polarized light).

Case 2: When A=0, B=1. Polarizer P_4 and P_5 of unit 2 block the light and P_6 allows to pass light having '↕' polarization coming from input Y. As this light beam has the intensity I, it is refracted to the S channel. Thus we get at $X_1=1$. The operation is similar to the unit 1, 3 and 4 which is discussed above. Thus $X_0=X_2=X_3=0$ ('·' polarized light).

Case 3: Similarly X_2 =1and $X_0=X_1=X_3=0$ when A=1, B=0.

Case 4: If A=B=1, polarizers P_1 and P_2 and P_3 of unit 1 pass the respective light beams. Therefore at Q_1 gets light of '↕' polarization having intensity 3I (for the combination of two data selector and one input beams). So the beam is refracted to the channel T. The light beam after traveling through the have wave plate becomes '·' polarized. Thus at the output D_0 we get light having '·' polarization. In case of unit 2, P_4 and P_6 pass the light beams. We get both '·' and '↕'polarized light at Q_2. The combined light beam follow the D channel and only the '·' polarized light is presented at the output of X_1. Unit 3 gives the

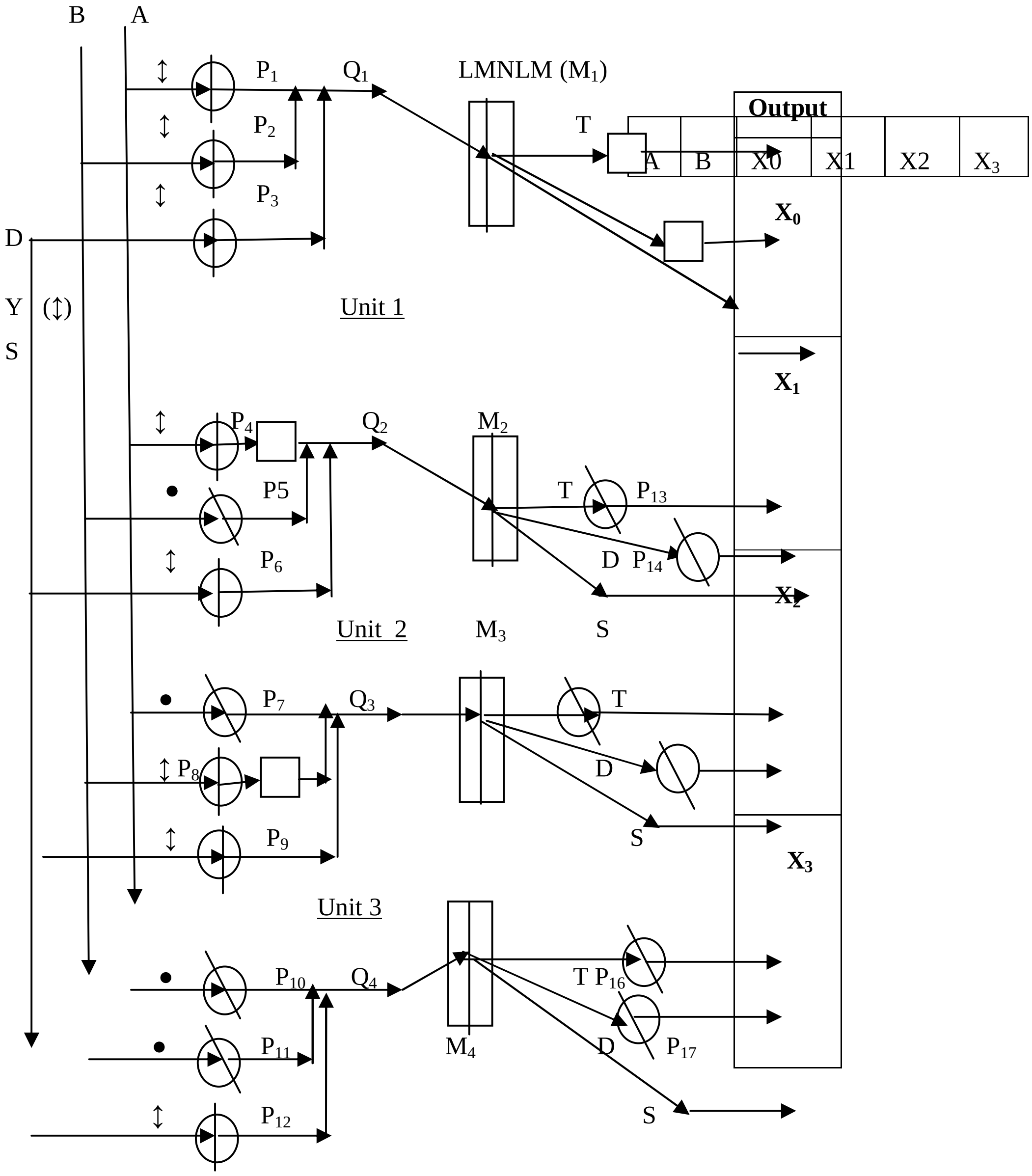

Figure: 5. An all-optical 1-line to 4-line Demultiplexer. $P_{1,}P_2$,…are polarizers. M_1, $M_{2,}$…are the combination of linear and nonlinear materials. Half wave plates, A and B are data selectors, Y input data,X_0,…X_3 are. four outputs. Same result of unit 2 as stated above. In case of unit 4, polarizer P_{10} and P_{11} block the light beams and only P_{12} passes the '↕' polarized light of intensity I, which follows the S channel. Hence the output of X_3 gives '↕' polarized light. i.e X_3=1. The table below shows the truth table of Fig. 5.

•	•	Y	0	0	0
•	↕	0	Y	0	0
↕	•	0	0	Y	0
↕	↕	0	0	0	Y

6. Conclusion

The above schemes of multiplexing and demultiplexing are an all- optic one, so the real time speed of operation can be achieved from the scheme. Again the system accommodates the polarization encoding techniques which has much advantageous sides over intensity encoding. Hence each logic state carries the same amount of light whether the logic state indicates 0 or 1.Therefore at the time of transmission the average power of a byte remains constant and it does not change on the number of 'zeroes' and 'ones' present in it.

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