

# Implementation of tristate logic based all optical flip-flop with nonlinear material

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The advantages of multivalued logic in optical parallel computation need no introduction. There are lots of proposals, already reported, where tristate, quarternary state logic operations can be performed with optics. Here we report a new approach to implement tristate logic based all optical flip-flop using optical nonlinear material. The concept and the principle of operation of this type of flip-flop are different from that of the conventional binary one.

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In way of multivalued logic based optical system implementations of tristate and quarternary logic systems are already established. In Boolean logic based implementations, the states of information are established by presence (1) and absence (0) of the signal. To accommodate more states of information in inference drawing mechanisms, the usefulness of dibit representations and the substitutions of the dibit by ternary numbers 1, 0,  $\bar{1}$  with the optical implementations of the tristate logic gates are also proposed by so many scientists/researchers around the world<sup>[1-5]</sup>. These three states of information are depicted by 1 (assertion, in dibit representation 01),  $\bar{1}$  (negation, in dibit representation 10) and 0 (non-occurring state of the information or contradiction, in dibit representation non-occurring state is assigned by 11 and contradiction by 00). Here the authors propose an all-optical scheme of tristate logic based flip-flop using optical nonlinear material (OPNLM).

OPNLM has already been reported for its usefulness in switching operations<sup>[6-8]</sup>. Figure 1 describes the functions of nonlinear materials (NLM). Here 1 and 2 are two input read beams, preferably laser, incident from the two opposite sides on the OPNLM. Let an other input beam, called as a probe beam, partially reflected from a beam splitter (BS) is incident on the OPNLM at the same point where beams 1 and 2 are incident. This incident beam will be reflected back from that point following the same path to give the output beam. It is interesting to note that this output will not emerge, if either beam 1 or beam 2 is absent or both the beams are absent. This

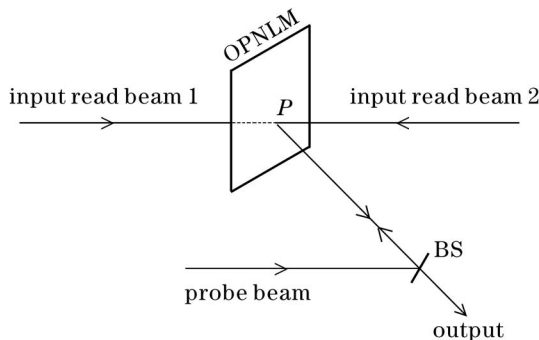


Fig. 1. Function of an OPNLM.

optical switch will become operative only if its two input beams are coherent in nature and then only the real time gratings in the optical material are formed. The example of such NLM is an optical phase conjugated device having at least cubic type of nonlinearity. This is basically a technique of four waves coupling which develops a real time grating hologram when two input coherent read beams appear. The output probe beam will be reflected only till the grating presents. To organize the whole switching operation we need to support the phase-matching condition among the read and probe beams.

In tristate logic, both of conventional and some non-conventional gates are seen to be operated with their different concepts. Conventional logic gates are OR, AND, EX-OR, INVERTER, etc.; and non-conventional gates are truth detector, false detector, etc.. In Fig. 2 the truth tables of these gates are given<sup>[5]</sup>.

The use of two OPNLMs can easily implement the all-optical single bit flip-flop. This scheme is shown in Fig. 3. This type of optical flip-flop uses the tristate values 1 and  $\bar{1}$  by designating two orthogonal states of polarized lights, and 0 is designated by complete absence of light. Let vertical polarized light ( $\downarrow$ ) be designated by 1 and horizontal polarized light ( $\cdot$ ) by  $\bar{1}$ . Here a system of two OPNLMs with a constant unpolarized input light source (used as probe beam which contains both vertical and horizontal polarizations), divided into two with a BS, is used and the output (Q) of the first OPNLM (i.e., OPNLM1) is fed to the input ( $\bar{A}$ ) of the second OPNLM (i.e., OPNLM2) through BS and

$\bar{1}$	$\bar{1}$	0	1	$\bar{1}$	$\bar{1}$	0	1	$\bar{1}$	$\bar{1}$	0	1
$\bar{1}$	1	1	1	$\bar{1}$	1	0	0	$\bar{1}$	1	1	0
0	1	0	1	0	0	0	0	0	1	0	1
1	0	1	1	1	0	0	1	1	0	1	1
OR				AND				EX-OR			
input	output	input	output	input	output	input	output	input	output	input	output
$\bar{1}$	1	1	1	1	0	1	0	1	0	1	0
1	$\bar{1}$	0	1	0	1	0	$\bar{1}$	0	$\bar{1}$	0	$\bar{1}$
0	0	$\bar{1}$	0	$\bar{1}$	0	$\bar{1}$	$\bar{1}$	$\bar{1}$	$\bar{1}$	$\bar{1}$	$\bar{1}$
INVERTER		truth detector		false detector		false detector		false detector		false detector	

Fig. 2. Truth tables of tristate OR, AND, EX-OR, INVERTER, truth detector, and false detector.

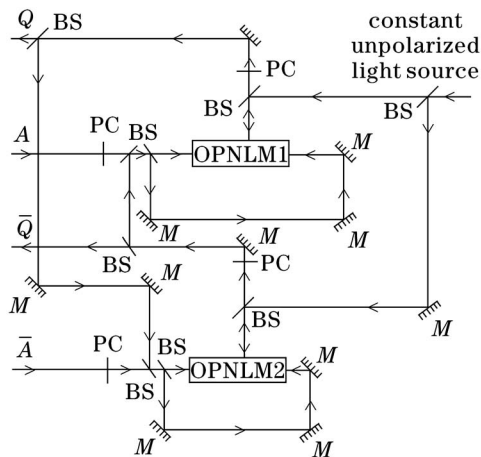


Fig. 3. Tristate logic based single bit all optical flip-flop with OPNLM.

mirror ( $M$ ). In the same way the output ( $\bar{Q}$ ) of the second OPNLM is connected to the input ( $A$ ) of the first OPNLM. PC is polarization converter (preferably a quarter wave plate which acts as an inverter) converting vertical polarized light ( $\downarrow$ ) into horizontal polarized light ( $\cdot$ ) or horizontal into vertical polarized light. Now the operation will be clear if we cite an example. Let us consider  $A = 1$  and  $\bar{A} = \bar{1}$ , which indicates that  $A$  gets the vertical polarized light ( $\downarrow$ ) as input and  $\bar{A}$  gets the horizontal polarized light ( $\cdot$ ) as input. Then following the switching mechanism of OPNLM, we will get vertical polarized light reflected from the OPNLM1, which is rotated through  $\pi/2$  angle by the respective PC to give a horizontal polarized light at the  $Q$  output. Similarly, because of horizontal polarized light at  $\bar{A}$ , we can expect vertical polarized light at the output  $\bar{Q}$  after the switching operation of the OPNLM2. So, when  $A = 1$  and  $\bar{A} = \bar{1}$ ,  $Q$  becomes  $\bar{1}$  and  $\bar{Q}$  becomes 1. Now as  $Q$  is connected with  $\bar{A}$  input and  $\bar{Q}$  with  $A$  input, so if any one of  $A$  or  $\bar{A}$  is withdrawn (i.e.,  $A$  or  $\bar{A}$  becomes 0),  $Q$  and  $\bar{Q}$  retain their values. In the same fashion, if both  $A$  and  $\bar{A}$  are withdrawn, then also  $Q$  and  $\bar{Q}$  retain their same values, as in this case the output light powers and input light powers are managed from the constant unpolarized light source. This is the example of tristate flip-flop or memory operation. Similar case of memory operation will happen if  $A$  takes horizontal polarized light and  $\bar{A}$  takes vertical polarized light as inputs, i.e.,  $A = \bar{1}$  and  $\bar{A} = 1$ . The important point is that when  $A$  is withdrawn,  $Q$  and  $\bar{Q}$  remain unchanged (or locked), because  $\bar{A}$  works as supply there. In the same way the locking result will be obtained by withdrawing  $\bar{A}$  keeping  $A$  intact (here  $A$  works as supply). The process continues if both  $A$  and  $\bar{A}$  are withdrawn. The truth table of this flip-flop is given in Fig. 4. Thus we can see that when  $A$  and  $\bar{A}$  are given then outputs  $Q$  and  $\bar{Q}$  are obtained as followed by the truth table, but if any of  $A$  or  $\bar{A}$  is

No.	inputs		outputs		
	$A$	$\bar{A}$	$Q$	$\bar{Q}$	
1	1	$\bar{1}$	$\bar{1}$	1	unchanged
2	0	$\bar{1}$	$\bar{1}$	1	
3	1	0	$\bar{1}$	1	
4	0	0	$\bar{1}$	1	
1	$\bar{1}$	1	1	$\bar{1}$	unchanged
2	0	1	1	$\bar{1}$	
3	$\bar{1}$	0	1	$\bar{1}$	
4	0	0	1	$\bar{1}$	

Fig. 4. Truth table of the all optical flip-flop with tristate logic.

withdrawn or both  $A$  and  $\bar{A}$  are withdrawn, the outputs  $Q$  and  $\bar{Q}$  retain its previous values. These outputs are locked till the new values of  $A$  and  $\bar{A}$  come. It is important to mention that in this memory operation as guided by the truth table, we should start from the state of serial number 1 in the truth table (Fig. 4). Then we will see that the outputs  $Q$  and  $\bar{Q}$  remain unchanged at the stages of serial numbers 2, 3, and 4 in the truth table.

In this scheme we can expect a real time performance, as the propagation delays by the OPNLMs are practically negligible. Other optical combinational logic operations in tristate scheme can also be developed in this way of implementation. It is also important to mention that the tristate nature of any 1, 0, or  $\bar{1}$  signal is the same in both input and output. The main advantage of tristate logic is the inclusion of contradiction or non-occurrence state along with assertion and negation states, which is essential in inference drawing resolutions. This advantage is fully exploited in the very high-speed optical memory cell. The practical realization of such type of flip-flop is easy.

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