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Polymer based frequency encoded all optical tri state logic gates

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All optical logic gates in frequency encoding format is proposed using polymer as nonlinear material. Ternary logic truth and false selector are proposed based on Total Reflection Switch (TRS). Polymer used is 4BCMU and an efficient nonlinear material for such applications.

Keywords: All optical logic, frequency encoding, TRS, 4BCMU polymer, tri state.

Introduction

Frequency-encoding is popular among the researchers and many designs of logic gates and circuits have been given in last decade[1–3]. Besides the other advantages, frequency encoding for the representation of logic states is very useful for tri state or tri-nary logic. Ternary or tri state logic is capable of handling more data in comparison to the binary logic. In binary system there is only two logical states whereas in tri-nary system a third state is used to represent information more effectively. In frequency encoding, signals of different frequency are used to represent different states of information not by intensity or polarization states. In this communication the '1' state or truth is represented by a signal of frequency ν_1, the '2' state (or false) is represented by ν_2 , and the third state ('0') or ambiguity state is represented by absence of any signal.

TRS is very attractive for the implementation of all optical logic gates[1–3]. But most of these TRS based logic proposals use nonlinear material in liquid form and need liquid to gas transitions for the routing of optical signal. These are very difficult to handle. In this communication, TRS is designed using polymers that is in solid state and require no liquid to solid transitions.

Working principle of the switch

Non linear property induced by the controlling light (shining perpendicular to the plane and into the paper) and alternation of the propagation path of the probe beams in a **1×2** total internal reflectional switch shown in the Fig. 1 is the basic mechanism of switching and routing. Two nonlinear prism of linear refractive index n_l (1.56) and a nonlinear material (NLM) indicated as a small circle at the centre constitute the switch. The nonlinear material has negative second order refractive index parameter, and when control signal is present, its refractive index become lower to have a total internal reflection of the probe signal. Therefore, the probe signal transmit along the path 1. In absence of control signal, no refractive index change of NLM, and is also equal to that of prism material and no change of path of probe. Probe signal follows undeviated path 2 as shown in the Fig. 1.

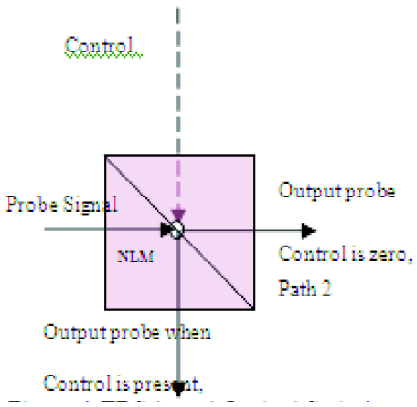

Fig. 1. TRS based optical switch.

Results of operation and discussion

In tri state, the logical states '1' '2' are called truth and false respectively. The state '0' is called ambiguity state as it may contain truth and false both. Table 1 depicts the operation of tri state truth selector and false selector. It is worthy to mention that the ambiguity state contains both truth and false.

Table 1. Truth table of ternary logic

Input A	Output of truth selector	Output of false selector
'0'	'1(ν_1)'	'2(ν_2)'
'1(ν_1)'	'1(ν_1)'	'0'
'2(ν_2)'	'0'	'2(ν_2)'

Fig. 2 shows the design of tri state truth selector. The probe is a signal of frequency ν_1, which represents truth when logically encoded. In Fig. 2, F is a ν_2 pass filter, A is the input and path-II is taken as output of the truth selector. Let us explain the operation of truth selector.

When A = 0, i.e. no light shines on the nonlinear material (NLM) and its refractive index does not change. Therefore, signal of frequency ν_1 straight pass to the path-II and gives the truth ν_1 (first entry of truth table).

When A = ν_1 (truth), the filter F blocks the signal, and in this case also no light shines on the NLM and the probe comes out giving truth again through path-II.

Now when A = ν_2 (false), it passes through the filter F and shines on the NLM and decreases refractive index. Now there will be total internal refraction of the probe beam. Therefore, the probe light passes out of the path-I, and no light (0) in path-II (output). This results in '0' output logically.

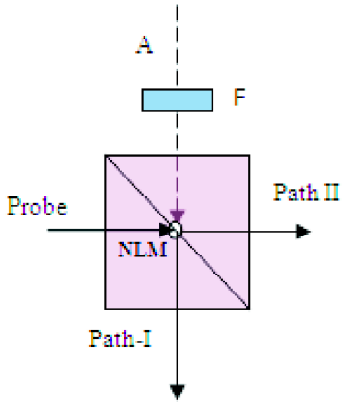

Fig. 2. Tri state truth selector.

Fig. 3 shows the design of tri state false selector. The probe is a signal of frequency ν_2, which represents truth when logically encoded. In Fig. 3, F is a ν_1 pass filter, A is the input and path-II is taken as output of the truth selector. Let us explain the operation of truth selector.

When A = 0, i.e. no light shines on the nonlinear material (NLM) and its refractive index does not change. Therefore, signal of frequency ν_2 straight pass to the path-II and gives the false ν_2 (first entry of truth table).

Now when A = ν_1 (truth), it passes through the filter F and shines on the NLM and decreases refractive index. Now there will be total internal refraction of the probe beam. Therefore, the probe light passes out of the path-I, and no light (0) in path-II (output). This results in '0' output logically.

When A = ν_2 (false), the filter F blocks the signal, and in this case also no light shines on the NLM and the probe comes out giving false again through path-II.

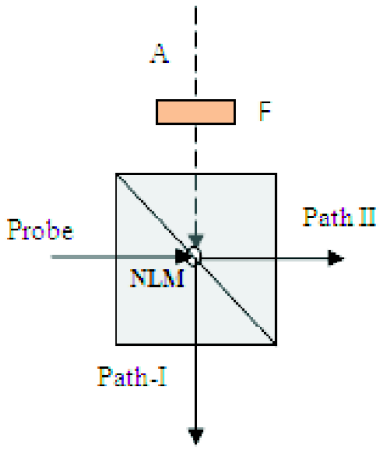

Fig. 3. Tri state false selector.

For the proper operation of the logic gates proposed, in this communication polymer based nonlinear material 4BCMU is used to avoid liquid to gas transition as required in other related works[1–3]. Quartz (with refractive index 1.56) is the prism material. Value of linear refractive index of this polymer is 1.56 is equal to that of quartz. Therefore, when control light is absent, probe signal will pass without any al-

ternation of the propagating path. The value of negative Kerr effect coefficients of this polymer is $n_2 = -1.5\times10^{-17}$ m^2/W^4. A total internal reflection for an incidence angle of 45° requires intensity of the control light to be 3.05×10^{16} W/m^2. Such intensity is available in laser pulse.

Conclusions

A novel design of polymer based tri state truth selector and false selector are designed and operation is explained in frequency encoding. Tri state logic devices boost all optical information processing as far as the speed is concerned. Moreover, data handling capacity is also boosted. The use of polymer demands possibility of integration of these devices in future[5].

References

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