Development on astable multivibrators using the combination of linear and non-linear materials as switching elements based on all optial method

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In this communication we propose a method to implement an all-optical astable multivibrator using the non-linear material based switches and logic gates. The scheme can operate in real time. The delay time can achieve ps(pico-second). The pulse duration can be made very low and may cross the THz easily by selecting proper material and laser source.

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The roles of switches are essential and obvious in any information processing mechanism. Different all-optical switches are already developed by scientists. Also the all-optical logic gates are developed using the combination of linear and non-linear optical materials. Several memory devices, such as all optical clocked R-S flipflop, J-K flip flop etc., are developed using this switching mechanism of non-linear material. Here, the authors propose a new proposal to develop an astable multivibrator using NOT (Inversion) logic gate, which are all optical in nature. It is widely established that super fast computation can deal with photon easily[1-3]. In this connection different all-optical logic devices are already developed around the world by the last few decades[4-6].

Inherent parallelisms of an optical signal over its electronic counterpart can be exploited in several ways. Non-linear optical devices come in the frontline of such ways of optical information processing. Many high-speed operations have been implemented by the use of optical non-linear material[7-9]. We know that many isotropic non-linear materials (such as pure silica glass, CS2 etc.) follow the refractive index relation as

$$n = n_0 + n_2 I \ ,$$

where n is the refractive index (r.i) of a non-linear material, n_2 is the non-linear correction term, n_0 is a constant linear r. i term and I is the intensity of light passing through the material.

This helps us to understand the basic switching operation using nonlinear material with an optical signal. In Fig.1 we have shown an optical switch. Here X and Y are the two inputs each with a prefixed intensity I, M is the mirror used to change the path, and B.S is the beam splitter or combiner. When both of the inputs are present, the refracted output will pass through O_1 channel and when any one of them is present, the output will be obtained through O_2 channel. This happens according to the above nonlinear equation and Snells' law. Now we discuss the basic operation of logic NOT gate using the combination of linear and non-linear materials and above switching mechanism.

The schematic diagram of NOT logic gate can be understood also by Fig.1. Here X is the input channel and CLS represents the constant light source Y, which both have a specified intensity I_1. The output channels are O_1 and O_2. When the input channel X does not have any light signal i.e. at the logic state 0, then light goes through channel O_2;and when X is in a logic state 1, i.e. it has light with a specified intensity, then light follows the channel O_1. To get the output of a NOT logic gate, the observer should be at the position of channel O_2. Several all optical logic and arithmetic devices have been proposed which are based on this type of switching[6,9]. An optical J-K Flip-flop which is nothing but a bi-stable multivibrator has been also proposed on this concept of switching[10].

The concerned circuit diagram of an electronic astable multivibrator is shown in Fig.2. Here the two transistors T_1 and T_2 act as switches. When one of them is in cut-off region, the other will be in saturation and vice-versa depending upon the charging and discharging time of the capacitor C_1 and C_2 and the resistors R_1, R_2, R_3 and R_4. The output V_{out} will generate square wave.

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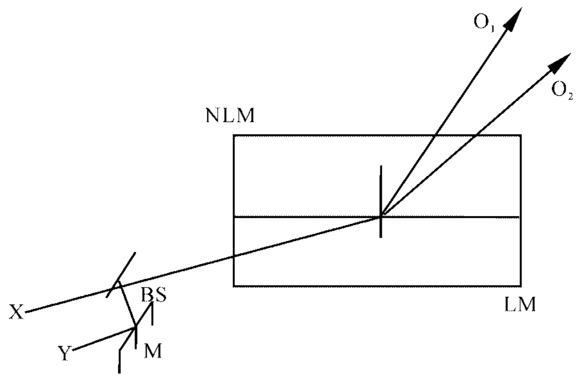

Fig.1 The switching operation using the combination of linear and non-linear material. It is also the schematic diagram for NOT Gate. M means mirrors, BS means Beam splitters.

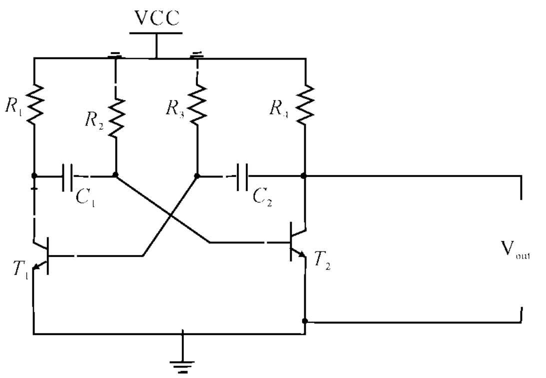

Fig.2 Electronic circuit for astable multivibrator.

Fig.3 shows the all-optical astable multivibrator using NOT logic gate as it is proposed at the beginning of this communication. Here G_1 and G_2 are two NOT gates. R_1 and R_2 are the two blocks of high refractive index material. All the connections are made with optical fibre to get high degree of accuracy and low loss during the process.

Here A is the input channel of G_1 and O_2' is the final output. The final output O_2' feedback to the input through the block R_2. Each Gate is provided with the CLSs.

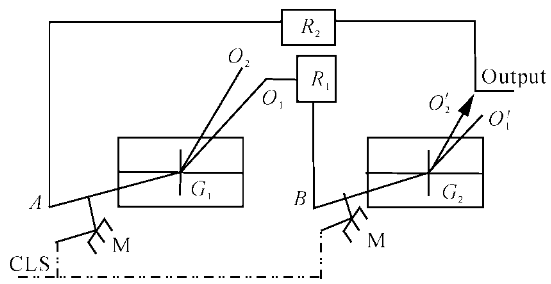

Fig.3 All optical representation of astable multivibrator.

To understand the operation,we suppose that the input A initially has no light signal i.e. it is in the logic state 0, then light passes through the gate G_1, and goes through the channel O_1. Now this is connected with R1, which introduce some fixed delay (according to its refractive index) before reaching the input B of gate 2. Since both the input B and CLS are present, the light will go through channel O_2' from which the output of astable multivibrator is taken. That means, depending upon the delay time (t_1) at R_1, the main output stays at the level 0 for t_1 time, and as soon as the time crosses t_1, automatically it becomes at the logic state 1 as the light comes from R_1 to B. Now as O_2' connects with A through the block R_2 , the logic state at O_2' continues to be 1 depending on delay time t_2 offered by R_2. When the signal reaches A after crossing the delay at R_2 , i.e. both the input of G_1 is present then the signal follows the output path O_2 hence no light will go to the input B and the light will be obtained at the channel O_1'. Thus the main output O_2' will be changed to the logic state 0. So the process will continue to generate the train of light pulse at the output O_2' as shown in Fig.4. Here, t_1 and t_2 are the off time and on time of the pulse train.

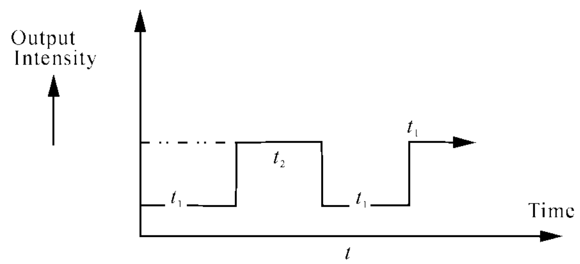

Fig.4 Expected output of the proposed astable multivibrator.

The scheme stated above is all-optical in nature, hence, the real time operation is possible. Here the delay times of R_1 and R_2 can be made in pico second range if we choose a block of crown glass with refractive index 1.52, length 1 cm and light with wavelength 5.89×10^{-5} cm. For this delay, the pulse train output of 50×10^{-12} second on time and the same off time is obtained. The delay time can be chosen suitably as required.

The pulse duration of the system can be made very low and may cross the THz limit easily if proper material and laser source are selected. As it is all optical one, therefore inherent parallelism of optics is fully exploited.

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