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Implementation of all-Optical Solitonic Remote Controlled NOR Logic Operation using Evanescent Optical Wave Coupling Technique

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ABSTRACT

Optical evanescent wave coupling techniques are massively used in photonics technology especially in optical communication field due to some inherent character. In this communication, we propose to realize all-optical solitonic remote controlled NOR logic operation at any point of interest by using this techniques. For this directional couplers and electro-optic effect of optical wave guides are used actively. As optical soliton pulse is used here as the carrier of information, therefore, this technique is very much effective for secure, high speed and very very long distance repeaters free operation.

Keywords: Directional Coupler, Electro-Optic Effect. Couple Mode Equation

I. INTRODUCTION

Evanescent wave is a near field wave showing exponential falling-off with distance from the edge. Evanescent wave coupling is a term mostly used in optics. In this coupling evanescent waves are conveyed from one medium to another. When two wave guides are sited in such that the evanescent field waves of one wave guide is insignificant at the other wave guide then the interaction between the two wave guides becomes very slight and as a consequence the energy in each wave guide propagates freely even in being there of other waveguides. But if the separation between the two wave guides becomes so small that the evanescent waves of the two wave guides overlap to a considerable range, then there is an exchange of energy between the two wave guides. In this situation, the evanescent field associated with the propagating modes in the two wave guides interact and lead to a periodic exchange of energy between the two wave guides. Such type of wave guides where coupling between two wave guides occurs is termed as directional coupler. [1,2,3]. The strength of interaction between two wave guides in a directional coupler depends upon the wave guides parameters, the separation between the wave guides and the wave length of operation. There is complete transfer of energy from one to other wave guide will occur if the propagation constant of the modes in the two wave guides are identical and otherwise there is an incomplete transfer of energy. This type of energy exchange can be used in building an optical modulator or optical switch. Optical directional couplers are used in signal routing, in time division multiplexing etc. [4,5,6]

In this communication, we propose to adopt a remote controlled NOR logic operation at any distance in an optical fiber using optical soliton pulse. The evanescent wave coupling techniques in the couple wave guide is actively used here. Electro-optic effect of an optical fiber media is used here to transfer the energy from one wave guide to other. The propose NOR logic operation is thus achieve in the out let of a wave guide by introducing the electro-optic effect in the wave guide coupler in the coupling region. Optical soliton pulse is introduced at the input face instead of ordinary optical pulse due to some very important character of soliton pulse as stated in conclusion part. [5,7].

II. METHODS AND MATERIAL

Energy exchange in a directional coupler:

Due to evanescent wave coupling, optical energy will be in the wave guide which is in couple with an another wave guide where an optical pulse is incident. We may write the couple mode equations for a directional coupler coupled over a length L [as shown in fig. 1]

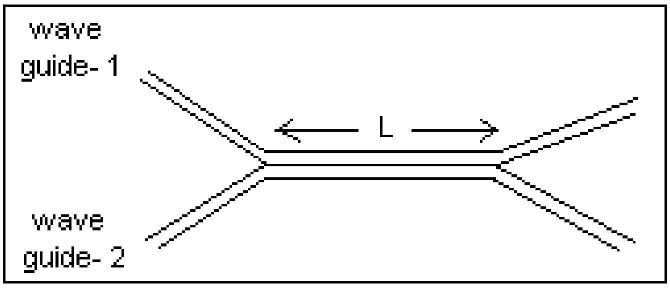

Figure 1 : An optical directional coupler where two wave guides are at close

$$\frac{d\xi_1(z)}{dz} = -iK_1\xi_1(z) - i\alpha_{12}\xi_2(z) \text{ ----- (1)}$$

And, $$\frac{d\xi_2(z)}{dz} = -iK_2\xi_1(z) - i\alpha_{21}\xi_2(z) \text{ --- (2)}$$

Where, $\xi_2(z)$ represent the amplitude of the evanescent wave in the wave guide 2 due to optical pulse of amplitude $\xi_1(z)$ incident on wave guide 1. α_{12}, α_{21} are the strength of interaction between two modes refer as coupling constant. K_1 , K_2 are the propagation constants of the mode in the wave guide 1 and wave guide 2 respectively. The block diagram of a directional coupler is as shown in figure (1). The general solution of equations 1 and 2 shows that symmetric and anti symmetric modes of propagation will be appear in the coupled wave guide .

As the optical power in a wave guide is proportional to the square of the pulse inside it, therefore, the power of the evanescent wave in wave guide 2 is proportional to $|\xi_2(z)|^2$ where,

$$|\xi_2(z)|^2 = \frac{\alpha^2}{\Phi^2} Sin^2\Phi z \text{ ------- (3)}$$

Similarly, power in wave guide 1 will be as,

$$|\xi_1(z)|^2 = 1 - \frac{\alpha^2}{\Phi^2} Sin^2\Phi z \text{ ------------ (4)}$$

Where, $\alpha = \sqrt{\alpha_{12}.\alpha_{21}}$, $\Phi = \sqrt{\left[\frac{1}{4}(\Delta K)^2 + \alpha_{12}\alpha_{21}\right]}$ and ΔK = ($K_1 - K_2$)

Equations (3) and (4) shows that there is a periodic exchange of energy between two adjacent wave guides in a coupler with a period equal to $\Pi\left[\alpha^2 + \frac{(\Delta K)^2}{4}\right]^{-\frac{1}{2}}$

The minimum length of inter action of two wave guides in a coupler for which maximum energy will be transferred from one to another wave guide is termed as coupling length (z_c) of the directional coupler which is given as

$$z_c = \frac{\Pi}{2}\left[\alpha^2 + \frac{(\Delta K)^2}{4}\right]^{-\frac{1}{2}} \text{ -------------------------- (5)}$$

Now, if some how we introduce the difference of propagation constant (ΔK) between two wave guides for a mode in addition of its own propagation constant such that the coupling length becomes half of its previous value then almost total energy incident on one wave guide will be come out through the same wave guide. Here, we introduce the extra difference of propagation constant by using the electro-optic effect of wave guide material. To achieve this oppositely directed electric fields are applied to the two wave guide, such that the effective index of one wave guide increases where as that of the other decreases. The extra difference in propagation constant between two wave guide to achieve the exact above situation is as

$$\Delta K' = 2\sqrt{\left[3\alpha^2 + (\Delta K)^2\right]} - \Delta K \text{ --------- (6)}$$

Again the extra change in propagation constant in the wave guide is determined as given by

$$\Delta K' = \frac{2\pi}{\lambda_0} n_e^3 r_m \frac{V}{d} \text{ -------------- (7)}$$

Here r_m represent the material constant.

III. RESULTS AND DISCUSSION

Implementation of NOR logic:

The schematic diagram of the proposed logic implementation as shown in figure (2). Here two directional coupler is used in cascade.

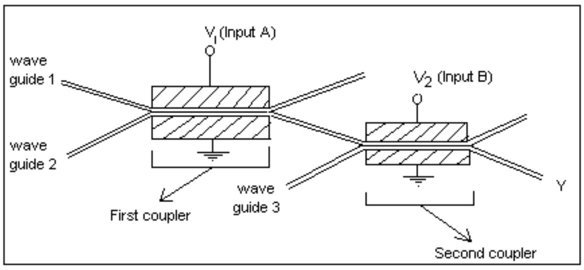

Figure 2 : Schematic diagram of the proposed NOR logic operation.

The first coupler is formed in between wave guide 1 and wave guide 2 , where as the second coupler is formed in between the outlet of wave guide 2 from first coupler and an another similar wave guide 3. Oppositely directed electric field having a prefixed value are applied in both the couplers in coupling region, such that the condition as stated in equation (6) have been satisfied in case of each couplers. Here, optical soliton pulse is fed into the input face of the wave guide 1 only and no pulse is fed on wave guide 2.

The external voltages applied to the wave guide are considered as input of the proposed logic. The voltage applied to the first coupler is considered as input A and that for coupler 2 is considered as input B. The input state is considered as state one (1) or zero (0) only when the external voltage is applied or not respectively. The optical signal emerges from wave guide 3 is considered as out put of the proposed NOR logic.

Case 1: When A=0, B=0, there is no external electric field is applied in both the couplers. In this case a portion of optical soliton pulse will be transferred to wave guide 2 through the coupling region of the first coupler. After this a portion of the transferred energy will be then transferred to wave guide 3 through the coupling region of the second coupler. Therefore, some optical intensity will be obtained in the out put side (Y) of the wave guide 3 and this out put state is considered as state one (1).

Case 2: When A=0, B=1, i.e. the external electric field is applied only in the coupling region of second coupler but not in the first coupler. In this situation a portion of light intensity will be transferred in wave guide 2 from wave guide 1 through first coupler. As a prefixed voltage is applied in the coupling region of the second coupler, therefore, almost all the light intensity will be remain in second wave guide and a very very little amount of energy will be transferred in wave guide 3 through the second coupler. Therefore, almost zero optical intensity will be obtained at Y which may be considered as state zero (0).

Case3: When A=1, B=0, then external field is applied only in the first coupler, not in the second coupler. Here, almost total light will be remain in the wave guide 1 and a very very little amount of light will be transferred to wave guide 2 through first coupler. Therefore, a very very insignificant amount of optical intensity will be obtained Y in this case which is considered as state zero (0).

Case 4: When A=1, B=1, then external field is applied in both the couplers. Like the previous manner almost no light will be obtained at Y and the corresponding state may be considered as state zero (0).

The output optical intensity at Y for different combination of inputs A, B are therefore follow the truth table of NOR logic operation.

IV. CONCLUSION

The evanescent wave coupling between wave guides and electro-optic effect of a wave guide are used here actively to achieve the proposed remote controlled logic. The main advantage of the proposed technique is that the proposed logic operations may be achieved at any distance from the input end of the wave guide. To achieve the required values of $\Delta K'$, we use the electro-optic effect due to some advantages of this method over other techniques already reported. These are i) a small voltage is required to obtain the required $\Delta K'$, ii) the voltage required to obtain the required values of $\Delta K'$ can be reduced either by increasing the length or by reducing the electrode gap iii) the energy exchange between the wave guide of the coupler may be tuned very precisely by controlling the electric signal applied to the modulator. As the intensity of the optical pulse introduced into the optical fiber is high valued therefore it is better to correct the coupling length according to the non-linearity of the wave guide. For proper realization of the logic operation all wave guide should be identical in character.

It is very much important to report that as soliton pulse is used as the main carrier of the information, therefore, this technique is suitable for more secure, extreme high speed, repeaters free long distance communication system.

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