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All-Optical Solitonic Half-Subtractor Realization Using biased Electr-Optic Modulator : An Analytical Approach

Puspendu Kuila*
Department of Physics, Midnapore College (Autonomous), Midnapore, West Bengal, India

ABSTRACT

To achieve high-speed performance we think of the introduction of optics instead of electronics for information processing and computing. Optical soliton pulse is spontaneously accepted for communication purpose especially in very high speed remote controlled repeaters free operation due to its some inborn characters of the soliton pulse. Here we propose an analytical method to implement an all-optical soliton based binary half subtractor. For this purpose, externally triggered (longitudinally) electro-optic-modulators and character of Kerr type non-linear optical fiber are extensively used. This operation is very much suitable for ultra-high speed remote controlled very long distance digital communication system.

Keywords : Electro-Optic Modulator, Phase Modulation, Non-Linear Optical Fiber, Soliton Pulse

I. INTRODUCTION

Optical soliton pulse (OSP), an exceptional nature of optical pulse that can travel through a fiber without any distortion due to dispersion or any other effect. When an optical pulse having a precise power profile travels through an optical fiber, at which the dispersion effect and non-linear effect perfectly balanced each other than a stable wave packet is formed. These special types of pulse is characterized as optical soliton pulse (OSP) which does not broaden in time domain or in frequency domain when it travels through the non-linear optical fiber medium. Though optical soliton have been planned in many fields but the most encouraging and also challenging applications are in the field of optical communication. [1,2,3].

Previously we described the method of formation of OSP inside the fiber media by using EOM with phase modulation and amplitude modulation modes (both in longitudinal and transverse mode).[4,5]. Furthermore we recommend the exploitation of OSP in the field of remote controlled logic world where all the signals are controlled from a very long distant point.[6,7].

For these purpose, the electro-optic behavior of the electro-optic crystal and the non-linear character of the fiber material are exploited vigorously. Here we propose the realization of soliton based half-subtractor operation by using longitudinally excited EOM in phase modulation scheme. Such type of action may be used in distortion free long distance communication system with super high speed.

II. METHODS AND MATERIAL

Triggered EOM in Phase modulation mode:

Consider an optical gaussion pulse (OGP) incident on a longitudinally biased EOM in phase modulation scheme (PMS) as shown in fig. (1). If the modulator is biased by an external sinusoidal electric field then a phase modulated optical gaussion pulse (PMOGP) is obtained at the output side of the modulator. This PMOGP may be written as [5],

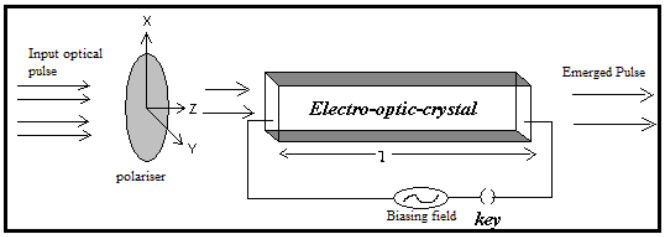

Figure 1 : Externally triggered EOM in Phase modulation scheme.

$$E = E_0 \exp\left(-\frac{t^2}{T^2}\right) Cos\left[\omega t - n_0 K_0 l + \eta Sin(\omega_{tri} t)\right] \text{ -- (1)}$$

Where $\eta = \frac{\omega}{2C} n_0^{\,3} \delta_m V_0$ ----- (2)

Here, η is defined as the phase modulation index, δ_m represent the co-efficient describing the EOC in this configuration, V_0 & ω_{tri} are the peak value & angular frequency of the applied triggered field respectively, T is the time width of the input OGP incident on the polarizer , l is the length of the crystal.

Soliton pulse formation:

The modulated pulse, emerged from modulator travels through the fiber media, then the electric polarization inside the non-linear optical fiber media will be as [5],

$$P = R_1 Cos\left(\omega t - \frac{\omega n_o l}{C}\right) + R_2 Cos\left(\omega t - \frac{3\omega n_o l}{C}\right) \quad \text{--(3)}$$

Where, $R_1 = B_1 J_0(\eta)$, $R_2 = B_2 J_S(\eta')$, $\eta' = 3\eta$,

$B_1 = \varepsilon_0 \chi^{(1)} E_0 \exp\left(-\frac{t^2}{T^2}\right) + \frac{3}{4}\varepsilon_0 \chi^{(3)} E_0^{\,3} \exp\left(-\frac{3t^2}{T^2}\right)$ and

$B_2 = \frac{1}{4}\varepsilon_0 \chi^{(3)} E_0^{\,3} \exp\left(-\frac{3t^2}{T^2}\right)$.

Equation (3) shows that the electric polarization inside the wave guide media contains two terms of amplitudes R_1 and R_2 and there is also a phase difference between the two components which also depends upon the length (l) of the EOM. When $l = ml_0$ where m=1,2,3…… and $l_0 = \frac{\pi C}{\omega n_0}$, then the amplitude of the electric polarization will be maximum i.e. amplitude = $(R_1 + R_2)$. Again, equation (3) shows that, the amplitude and the intensity of the pulse inside the OF media may be controlled very perfectly by governing the amplitude or circular frequency or both of the applied external field. Thus it is not at all difficult to obtain a particular power profile inside the fiber media to form an OSP inside the fiber by simply monitoring the triggering field. Once the soliton pulse is formed inside the fiber, then it travels throughout the fiber media without any variation of its shape and character.

Superposition of two phase modulated pulse inside optical fiber:

When two phase modulated optical pulse, emerged from two EOM of different lengths, travel through non-linear optical fiber media then they first interact with the nonlinearity of the medium and the amplitude (A) of the resultant electric polarization inside the media becomes as [6]

$$A = \left[A_1^{\,2} + A_2^{\,2} + 2A_1 A_2 Cos\left\{\frac{\omega n_0}{C}(l_1 + l_2)\right\}\right] \quad \text{----(4)}$$

Where, $A_1 = 2B_1 J_0(\eta) Cos\left\{\frac{\omega n_0}{2C}(l_2 - l_1)\right\}$ and

$A_2 = 2B_2 J_S(\eta') Cos\left\{\frac{3\omega n_0}{2C}(l_2 - l_1)\right\}$

This shows that if the lengths of the two EOM are same ($l_1 = xl_0$ & $l_2 = xl_0$) then a appreciable value of optical pulse will be available at the outlet of the corresponding optical fiber and if then lengths of the two EOM are $l_1 = xl_0$ & $l_2 = (x+1)l_0$ then zero intense output from the fiber even high input optical pulse present at the inlet. These optical behavior are used here.

III. RESULTS AND DISCUSSION

Realization of proposed soliton based half-subtractor operation:

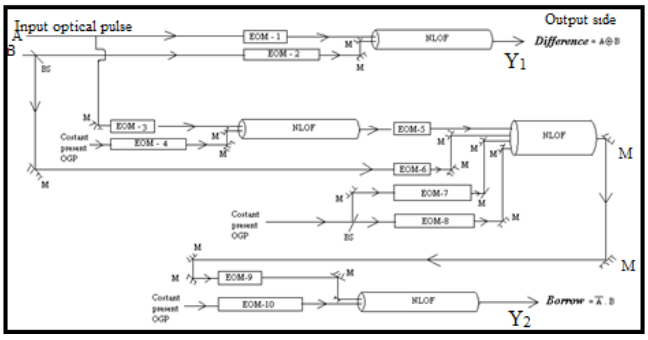

Figure 2. Schematic diagram for implementation of proposed all-optical soliton based half-subtractor operation.

The proposed operation is as shown in fig. (2). Here, A and B input signals (incident on different EOMs), considered as the input data whose solitonic forms are obtained at the output side of the fiber and represented by Y_1 and Y_2. Different Y_i are considered as state one when the corresponding amplitude of the output soliton pulse is considerably high and considered as zero when the output soliton pulse is absent or a very low valued

pulse is obtained at the output side. Here beam splitters (BS) are used to split the optical beams and highly polished mirror (M) ae used to reflect the optical pulse. The output pulses as emerged from the modulators are incident on the fiber where they interact with the non-linearity of the fiber material. Here all the modulators are biased by same type of sinusoidal electric field. All EOMs are longitudinally biased and fixed in phase modulation mode. The amplitude and frequency of the field applied externally to the modulators are fixed in such a way that soliton pulse is designed inside the fiber media. Different solitonic output for the different combination of the inputs are shown in tabular form in table: 1. Thus the proposed diagram represent the half – subtractor operation.

Table 1: Different combination of input optical pulse corresponding different output.

Input (A)	Input (B)	Output intensity (at Y_1)	Output intensity (at Y_2)	Difference (Y_1)	Borrow (Y_2)
0	0	Zero value	Zero value	0	0
0	1	High value	High value	1	1
1	0	High value	Zero value	1	0
1	1	Zero value	Zero value	0	0

IV. CONCLUSION

For such operation the lengths of all the EOMs should be set very accurately and the external field are selected perfectly so that soliton pulse is formed inside the fiber media. Therefore, appropriate lengths of the modulators may be accommodated. Here we use the modulators in phase modulation mode and all the modulators are triggered by longitudinal electric fields. But amplitude modulation scheme and transverse triggering technique may also be adopted for this purpose. The main advantage of this scheme is that the proposed technique is all-optical one and because of using soliton based optical message, a very long distance communication (multiplexed data communication) is possible to achieve, which is effectively suitable for remote controlled operation also. It is to be mentioned that, the polarization state and the coherent nature of the input optical pulses should be retained accurately. Here we use OGP as the input pulses instead of ordinary optical pulses as it takes a very important role to transfer the system to the soliton based one. For accurate functioning of the system, all the modulators should be biased by same type external field having perfectly equal character.

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