

SOLITON TRAPPED IN 2X2 DIRECTIONAL FIBER COUPLER

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ABSTRACT

The study of soliton trapped in 2X2 directional fiber coupler is reported. By introducing an optical signal with high intensity into two cores of directional fiber coupler will create the soliton pulse in that coupling region. Soliton can carry the data in an extended distance without distortion with high-speed, so that it is promising an ideal communication system in a long distance. In its propagation, the loss was still appears. It is caused by the trapping of soliton pulses at the coupling region so that the collision take placed. The collision of two coupled solitons was determined from the Non-linear Schrodinger Equation (NLSE) based on the Coupling Mode Theory (CMT). The distance of collision can be reduced by decreasing the separation of the two soliton pulses. Another way can be done by choosing a value of medium misalignment saturation H . for the value of $H=0.1$, it can be seen clearly that length of pulse propagating more broaden. The relationship between the amplitude and width of a soliton is also investigated. It is found that increasing the width, the amplitude also increases. However, the knowledge of collision between two trapped solitons is important and promises a good application for the optical switching.

Keywords: *Non-linear Schrodinger Equation; Coupled Mode Theory; Directional Fiber Coupler; Soliton Pulses;*

I. INTRODUCTION

The study of light propagation in fiber optics has been developed until advance case. Now, light signal can propagate carrying data to a long distance

with low loss. Study of light has also developed especially in directional coupler. Fiber coupler is device that consists of two or more fiber fused in parallel arrangement. This case is almost same with propagation of light in two

parallel fibers. Their energy exchange is determined by coupled mode theory. When light with low intensity is launched in to two core fibers, the fiber behave as linear case. But, if the intensity of light is high, there are nonlinearities present in that fibers. In this case, the refractive index is changes due to Kerr effect [1].

The Nonlinear fiber is an optical device to use as ultrafast all optical processing, sampling and optical calculating [2]. The nonlinearity may act as solitonay pulse propagation. The soliton can carry communication data with high speed. The propagation of soliton in two parallel fiber still has loss interm of long distance. The loss is caused by interaction of these two soliton. When the two soliton pulses with equal amplitudes are close enough to each other, they undergo periodic merging and separation, which can upset the data transmission [3]. To avoid this case, the study of soliton collision becomes important.

Long time ago, the soliton propagation in parallel two core fiber is studied by solving coupling linear

Schrodinger equation. But, it is no longer, because the shortest pulse that can be switched can be limited by the intermodal dispersion in fiber [4].

$$u_0 = \left[\begin{array}{l} \left\{ \eta_{10} \operatorname{sech} \left(\frac{\tau - T_1}{\tau_{10}} \right) \exp [i(-P_1 \tau) + \theta_1] + \Delta u_1 \right\} \exp i \left(\frac{P_1^2 x}{2} + \frac{x}{2\tau_{10}^2} \right) \\ \left\{ \eta_{20} \operatorname{sech} \left(\frac{\tau - T_2}{\tau_{20}} \right) \exp [i(-P_2 \tau) + \theta_2] + \Delta u_2 \right\} \exp i \left(\frac{P_2^2 x}{2} + \frac{x}{2\tau_{20}^2} \right) \end{array} \right] \quad (2)$$

So far, the coupled mode theory has been determined from nonlinear Schrodinger equation to calculate the energy exchange between two light signal propagating in two or more fibers.

II. NON-LINEARSCHRODINGER'S EQUATION OF SOLITON PULSE

The propagation of solitary pulse in two parallel core fiber is described by the coupled mode nonlinear Schrodinger equation. If the field function is $u(x, \tau)$, the transmission equation for each fiber can be written as follow.

$$i \frac{\partial u_1}{\partial x} + P \frac{\partial^2 u_1}{\partial \tau^2} + A |u_1|^2 u_1 - H |u_2|^4 u_2 = 0 \quad (1a)$$

$$i \frac{\partial u_2}{\partial x} + P \frac{\partial^2 u_2}{\partial \tau^2} + A |u_2|^2 u_2 - H |u_1|^4 u_1 = 0 \quad (1b)$$

Where A is non-linear coefficient of optical fiber, $P > 0$ is dispersion coefficient, and H is description medium misalignment saturation factor. In this Equation (1), the high order effects are neglected. The solution of this Equation (1) can be written as Equation (2) in a form of transfer matrix.

Where Δu_i is the deformed field input in two cores of fiber, and assumed it is equal to zero. η_{i0} is the input amplitudes. To solve coupled mode non-linear equation (1), the furrier transformation and its inverse is needed [5].

$$u(\tau, x+h) = F^{-1} \left\{ \exp\left(-i\omega^2 \frac{h}{2}\right) F \left\{ \exp\left[i\left(A|u|^2 - H|u|^4\right)h\right] u(x, \tau) \right\} \right\} \quad (3)$$

III. RESULTS AND DISCUSSION

Taking the fundamental soliton equation as following equation.

$$u(\tau, 0) = \text{sech}(\tau+3) + \text{sech}(\tau-3) \quad (4)$$

It can be plotted as shown by Figure 1. In this case the width is taken $(-10t, 10t)$.

The relationship between the amplitude and the width of soliton is given by following equation,

$$t_0^2 \eta_{i0}^2 = \frac{|\beta|}{\gamma} \quad (5)$$

and that intensity $|u(x, \tau)|^2$ in two soliton is periodic in z direction with the period of

$$L = \frac{\pi t_0^2}{2|\beta|} \quad (6)$$

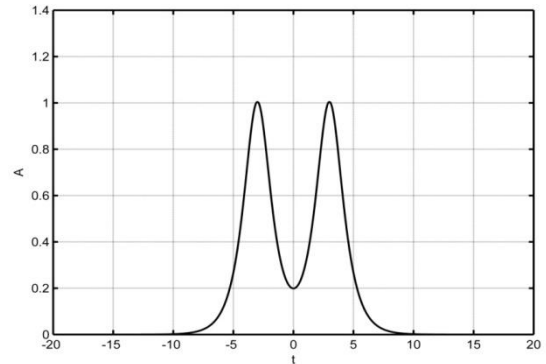


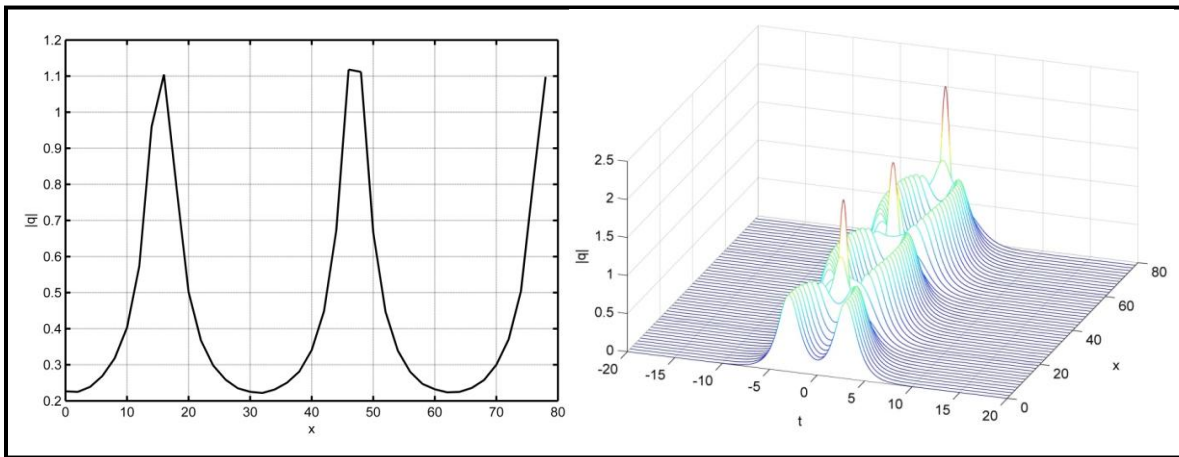
Figure 1 Two soliton pulses

Figure 1 shows the fundamental of soliton pulse at the coupling region with depicted as in term of light intensity versus width. Since the boundary is the coupled waveguide, the propagation of these two pulses is described by the matrix equation given by Equation 2.

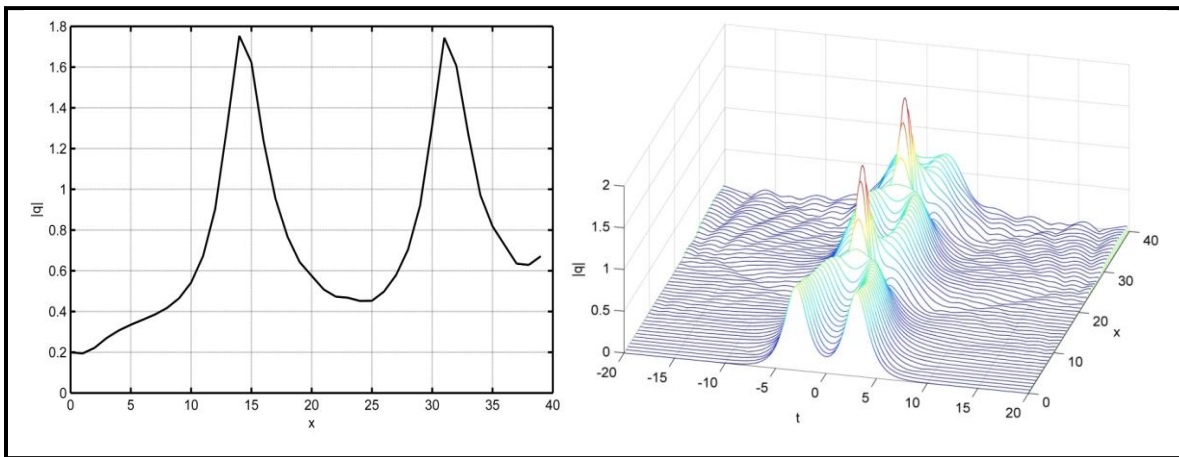
Since the soliton pulses are propagating along the coupling region, z , the pulses' interaction is described by the collision. It can be seen that it is trapped and the possibility of the collision can be controlled.

Plotting 3-Dimension of the two soliton propagating in two core fibers as function of time and distance can be seen in Figure 2. Figure 2 shows the collision of two pulse solitons in two core fiber for

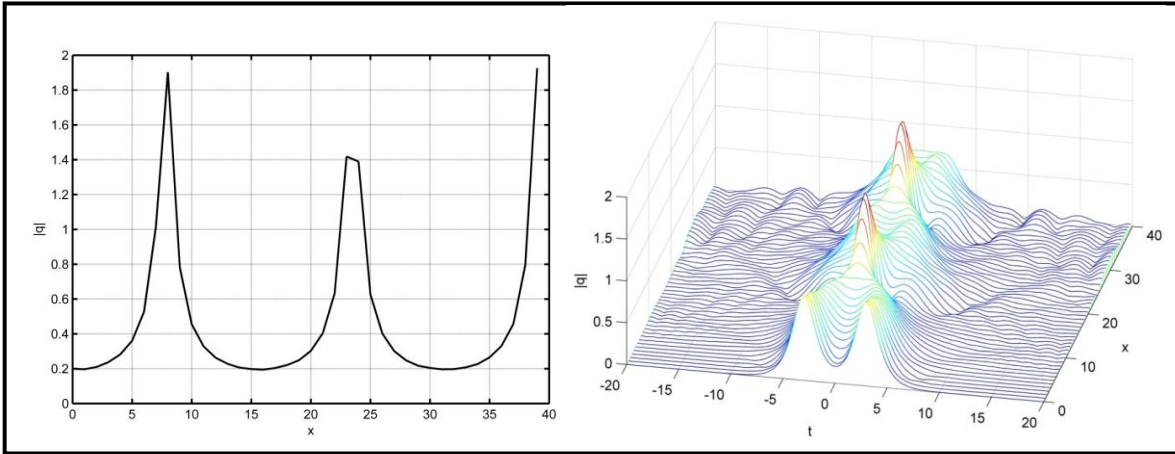
various value of H (0, 0.1, and 0.2.). If H is set equal zero, it is obviously to the Kerr medium, because the interaction presents the periodic meeting and parting the characteristic. The cyclical length is approximated 30, and each pulse doesn't have the change in the entire propagation process after the collision. If $H > 0$, first let $H = 0.1$, the Equation 1 becomes under the medium refractive index misalignment saturated condition.



(a)



(b)



(c)

Figure 2 Soliton trapped in two core coupled fiber, 2a) collision of two solution pulse with $H=0$, 2b) collision of two solution pulse with $H=0.1$, 2c) collision of two solution pulse with $H=0.2$,

Then, if $H=0.2$, Equation 1 still becomes under the medium refractive index misalignment saturated condition. But, cyclical length reduces obviously, approximately is 17. If Figure 2a is compared with Figure 2b, when the medium misalignment saturation factor is changed, $H=0.1$ to $H=0.2$, the length of pulse propagation becomes more broaden. Moreover, set $H=0.3$, the pulse propagation changes with small value. In these all case, it can be seen that $H=2$ gives the long of pulse propagating more broaden compared to the others value of H .

The relationship between the amplitude and width of a soliton given by Equation 5 is shown in Figure 3.

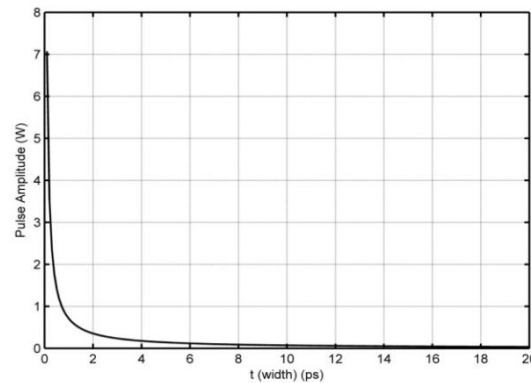


Figure 3 Pulse Amplitude of two Soliton pulses change by width, t

Figure 3 shows that increasing the width of soliton pulse, the amplitude becomes sharply decrease. So, to transmit the soliton, the high amplitude is better. It is caused periodic of soliton collision. The more two soliton makes collision, the more loss in that nonlinear optical fiber.

IV. CONCLUSION

Transmission of soliton in two core parallel fiber is high speed to carry communication data. Optical loss caused

by the collision can be reduced by adjusting the separation of two fiber's cores due while trapped at the coupling region. It has been found that by increasing the value of medium misalignment saturation H , makes the long of pulse propagation more broaden.

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