Effect of Interaction Caused by Relative Phase, Amplitude and Spacing on Neighboring Soliton Pulses

Anita Antwiwaa , Shanthi Prince, *Member, IAENG*

***Abstract*— Optical solitons are essentially stable pulses that travel without changing their shape; they do not disperse and can resist perturbation in the physical medium. In order to achieve stability, there should be a balance between the group velocity dispersion (GVD) which causes pulse broadening and the self phase modulation (SPM) which causes spectrum broadening. After balancing the GVD and SPM, there is a need to take into consideration the relative phase, relative amplitude and the spacing between neighboring soliton pulses.**

In this work, the effect of varying the relative phase, spacing and amplitude between neighboring soliton pulses are studied and discussed.

The simulation results show that care must be taken when choosing the amplitude, phase and spacing in order to avoid interaction as interaction affects the efficiency of soliton propagation.

Keywords- Soliton, Phase, amplitude, spacing and interaction.

I. INTRODUCTION

Soliton has the ability to transmit a huge data within the shortest possible time without distortion or change in shape. Optical solitons are essentially stable pulses that travel without changing their shape; they do not disperse and can resist perturbation in the physical medium. When the optical intensity is higher, the refractive index increases with increasing light intensity, since the phase of light beam depends on the refractive index of the medium. The beam itself changes the refractive index of the medium thereby changing its phase and this effect is called self-phase modulation (SPM).

SPM causes spectrum broadening. Group velocity dispersion is the phenomenon whereby the group velocity of light in a medium depends on the optical frequency or wavelength.

This work was supported by All Nations University Koforidua, Ghana. The authors wish to express their sincere gratitude for their support.

Anita Antwiwaa is a postgraduate student with the Electronics and Communication Engineering Department in SRM University, Kattankulathur 603203, India.(Phone:91-9677186668) email:anitaantwiwaa@yahoo.com

Shanthi Prince an IAENG member, is with the Department of Electronics and Communication Engineering, SRM University, Kattankulathur 603203, INDIA. (Phone: 91-9444962179); fax: 91(44)27452343; email:shanthi.p@ktr.srmuniv.ac.in

It causes short pulses of light to spread with time as a result of different frequency components of pulse travelling with different velocities. In order to achieve stability, there should be a balance between the group velocity dispersion (GVD) which causes pulse broadening and the self phase modulation (SPM) which causes spectrum broadening[1,2]. After balancing the GVD and SPM, there is a need to take into consideration the relative phase, relative amplitude and the spacing between neighboring soliton pulses.

In this work, various simulation experiments have been performed using Matlab to investigate the interaction between two neighboring solitons of equal amplitude and unequal amplitude by varying the phase between them. Also the interactions between neighboring solitons by varying the spacing and amplitude have been investigated.

II. MATHEMATICAL MODEL

The equation governing soliton which is the Non-linear Schrodinger equation (NLSE) for an optical pulse with the field envelope u(z,t) propagating in the optical fiber with the absence of loss and higher order dispersion is given in [3,4,5] as

$$\frac{du}{dz} = \frac{-j}{2}\beta^2 \frac{d^2u}{dt^2} + |u|^2 u \qquad (1)$$

where β^2 is the second order dispersion parameter. By solving the equation numerically with the input amplitude consisting of a soliton pair [1] we can find the effect of interaction on solitons. The solution is given as

$$u(0,t) = sech(\tau - q_0) + rsech[r(\tau + q_0)]exp(i\theta) \qquad (2)$$

$$u(0,t) = sech(\tau - q_0) + \text{sech}(\tau) + rsech[r(\tau + q_0)]exp(i\theta) \qquad (3)$$

Equation 2 and 3 represent the propagation of two and three soliton pulses through a fiber respectively, where r is the relative amplitude; θ is the relative phase and $2q_0$ is the initial separation between neighboring solitons.

In order to achieve stability, soliton width T_0 can be related to the bit rate as

ISBN: 978-988-19252-1-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

$$B = \frac{1}{T_B} = \frac{1}{2q_0 T_0} \qquad (4)$$

where T_B is the duration of the bit slot.

$$2q_0 = \frac{T_B}{T_0} \qquad (5)$$

Equation 5 is the separation between neighboring solitons. Soliton spacing should be equal to or more than the pulse width.

III. SIMULATION RESULTS

The effect of varying the phase, amplitude and spacing between neighboring solitons has been studied with Matlab using equation 2 and 3 and the results are given below.

A. Varying the phase of solitons with equal amplitude and a constant spacing between them

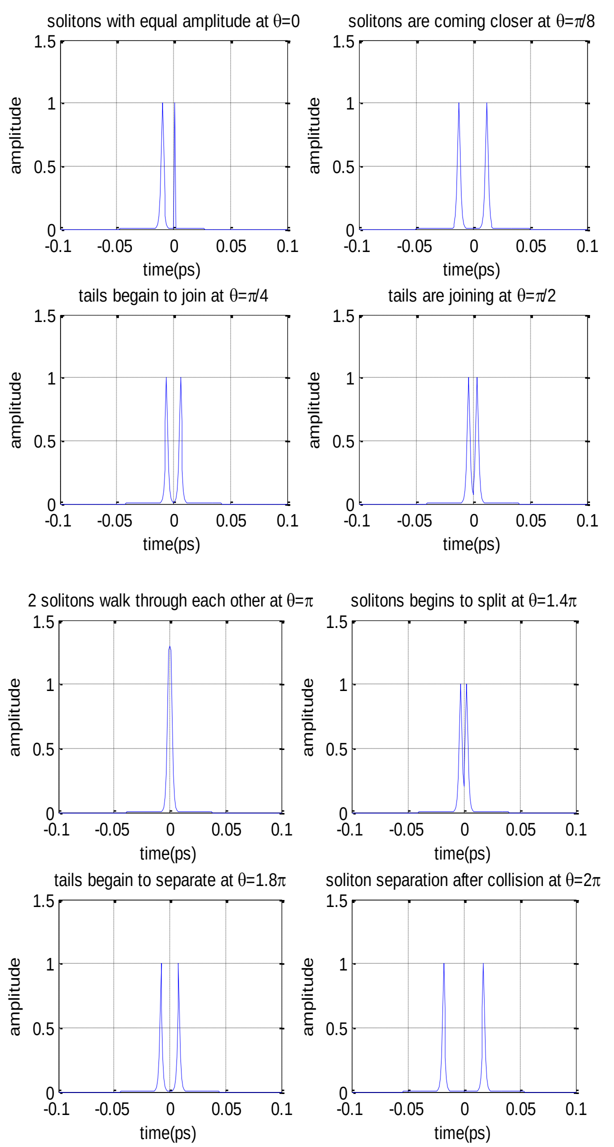

Fig 1: Pulse evolution of two solitons of equal amplitude and spacing with phase varying from θ=0 to 2π

Figure 1 shows the pulse evolution of various soliton propagation conditions as θ varies from 0 to 2π keeping amplitude and pulse separation constant at r=1 and $q_{0=}$ 3.5 respectively. Solitons interaction depends strongly on the phase θ. The two solitons interact with each other at θ=π/2. They form a giant pulse with amplitude higher than the amplitude of the individual pulses at θ=π. They then walk through each other and separate after the interaction as if there was no interaction at all. This shows that soliton pulses are stable even in the midst of interaction, they are not affected.

B. Varying the phase of solitons with unequal amplitude and a constant spacing

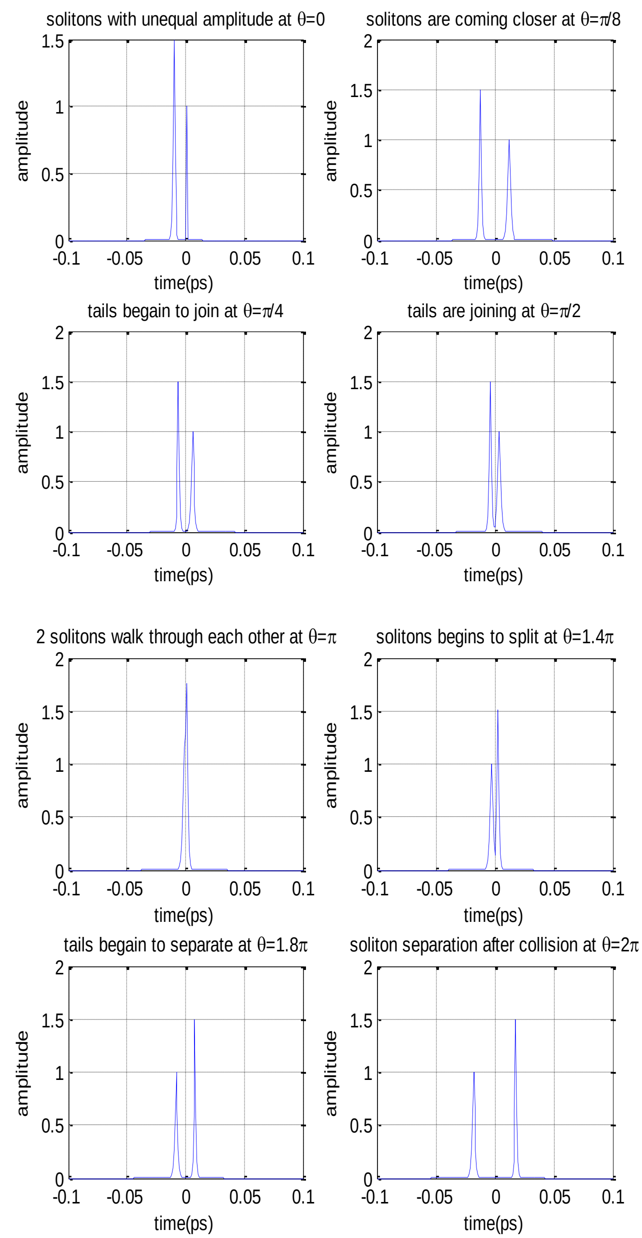

Fig 2: Pulse evolution of two solitons of unequal amplitude and constant spacing with phase varying from θ=0 to 2π

.

Fig 2 shows the propagation of soliton pulses of unequal amplitude and changing phase. The amplitude is kept at r=1.5 and phase is varied from θ=0 to 2π. At θ=π/8, the two soliton pulses are getting closer to each other. Tails of the two pulses begin to join at θ=π/4. The two solitons join together to form a giant pulse with amplitude higher than the amplitude of the individual pulses. After the interaction at θ=1.8π, it can be seen that the two pulses have walked through each without any change in pulse shape.

From the simulation results, it can be seen that in order to avoid interaction, the phase should be kept at θ=0 or θ=2π.

C. Varying the soliton amplitude keeping θ and q_0 constant

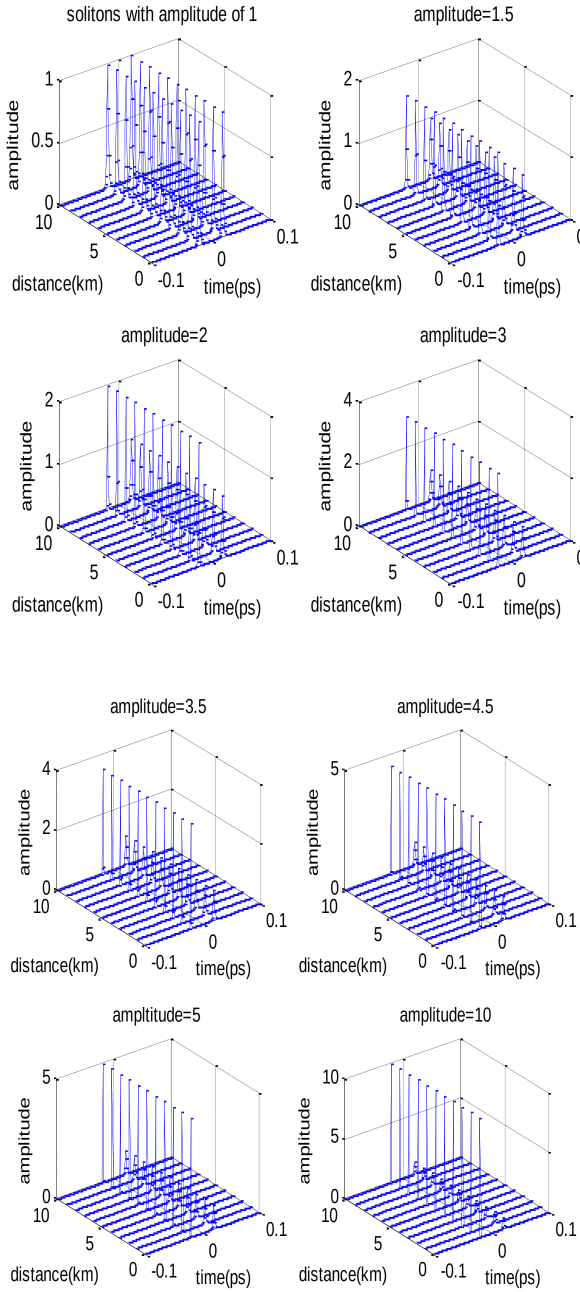

Fig 3: Propagation of varying amplitude soliton pulses with fixed phase (θ=0) and pulse spacing

Fig 3 shows the solitons propagation pair for different values of amplitude at constant phase and spacing of θ=0 and $q_{0=}$3.5 respectively. When amplitude r=1, there is no interaction so efficient transmission along fiber is possible. As amplitude increases to r=2, it can be seen that the amplitude of one of the soliton pulses has maintained its amplitude while the other pulse has reduced by 50%. As amplitude increases to r=10, it can be seen that one of the pulse is diminishing while the other pulse maintains its amplitude.

The simulation results show that as amplitude increases, amplitude of the second pulse keeps on decreasing which gradually causes loss of pulse initial amplitude and shape; therefore increase in amplitude increases the rate of interaction thereby reducing the efficiency of soliton transmission. The choice of amplitude should be taken into consideration when transmitting soliton pulses. Lower amplitude should be chosen because the higher the amplitude the greater the interaction.

D. Varying the separation between neighboring equal amplitude solitons with phase of θ=0 between them.

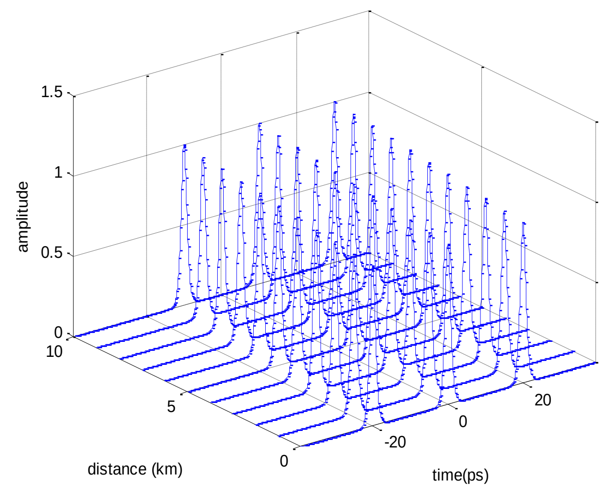

Fig 4: Three soliton pulses with a separation of 20ps

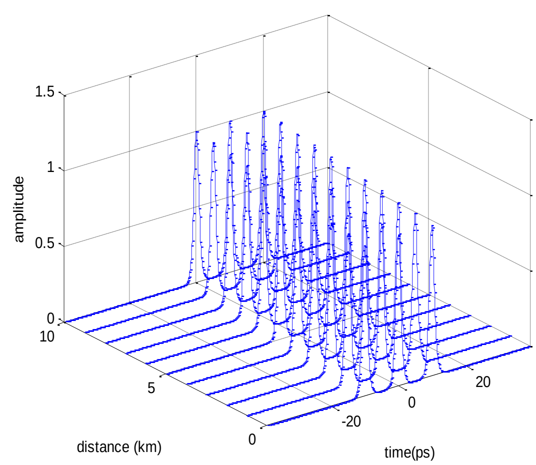

Fig 5: Three soliton pulses with separation of 10ps

ISBN: 978-988-19252-1-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

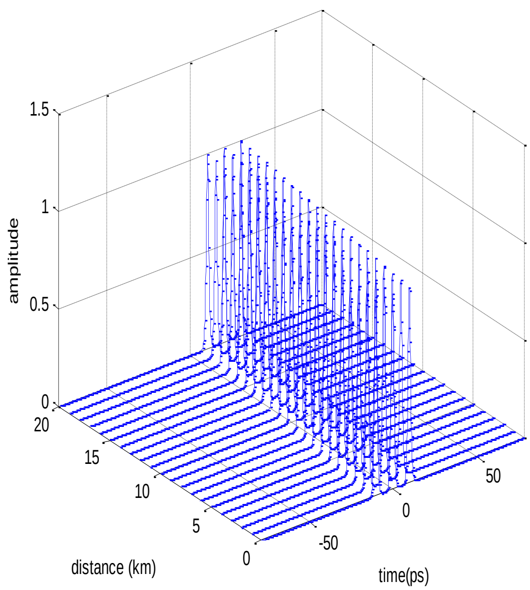

Fig 6: Three soliton pulses with spacing of 1ps

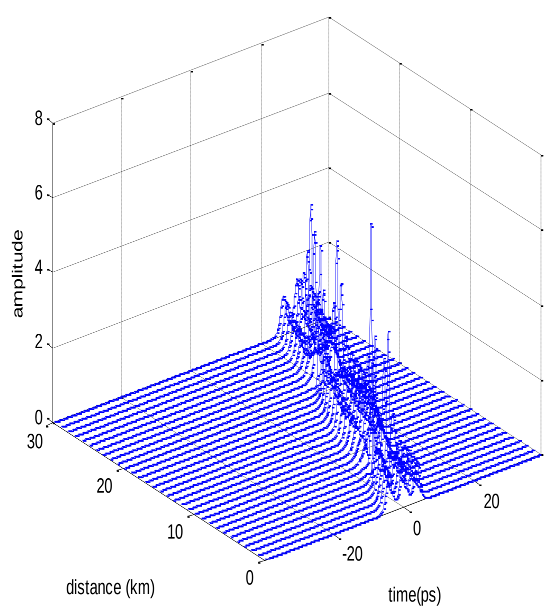

Fig 7: Three soliton pulses with spacing of 0.5ps

Fig 4 to 7 represent the results obtained from varying q_0 and keeping θ=0 and r=1 from equation 3. Comparing fig 4 and fig 5 it can be seen that as the spacing reduces from 20ps to 10ps, the soliton pulses begin to draw closer. Comparing fig 5 and fig 6, it was observed that as the spacing reduces from 10ps to 1ps; the spacing between them becomes very small. As the spacing reduces to 0.5ps as shown in fig 7 solitons undergo periodic collision. The pulses interact to form a pulse with higher amplitude, separate again and travel.

The simulation result shows that when soliton pulses are kept very tight, perturbations will occur, therefore the closer the pulse the greater the interaction. In order to avoid interaction, the spacing between two neighboring soliton should be equal to or more than the width of the pulse.

IV. CONCLUSION

In this work, the effect of varying the phase, amplitude and spacing between soliton pulses are analyzed. The study shows that the phase between two soliton pulses has an effect on the pulse transmission, therefore care should be taken when choosing the phase. The study also reveals that the choice of amplitude causes interaction therefore lower amplitude should be selected in order to avoid interaction, also the choice of spacing between soliton pulses plays an important role in transmission. The wider the spacing the lesser the interaction. In order to avoid interaction, the phase, the choice of amplitude and spacing should be taken into consideration since interaction reduces the efficiency of soliton transmission.

REFERENCES

[1] A. Hasegawa, Y. Kodama, *Solitons in Optical Communications*, in Clarendon Press, Oxford (1995).
[2] H. Li, D. N. Wang, Journal of Modern Optics 54, 807 (2007).
[3] G.P. Agrawal, *Fiber-optic Communication Systems*, John Wiley and Sons, NY, 1997.
[4] C. R. Menyuk, G. M. Carter, W. L. Kath and R. M. Mu, 'Dispersion managed solitons and chirped return to zero: what is the difference?', in I. P. Kaminow and T. Li (Eds), *Optical Fiber Telecommunications IVB*, Academic Press, pp. 305–328, 2002.
[5] Optical solitons theory and experiments edited J.R.Taylor.

ISBN: 978-988-19252-1-3
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)