The Aspect of the Radiation Superposed on the Soliton Pulse Propagated in Single Mode Optical Fiber

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Abstract

The first part of the research involves, investigate the aspect of the radiation superposed on the one bright soliton pulse propagated in ideal single mode optical fiber. According to the numerical study, the radiation has no affect on the one of birght soliton, leaving the one soliton bright pulse preserve its shape (hyperbolic secant shape) propagates along the communication system .

For this reason bright solitons could be useful as information carriers in optical fibers communications system for achieving high bit rates.

The second part of the research involves, study absorption effect on the performances of the radiation superposed on the one bright or black soliton pulse propagated in natural single mode optical fiber. The study shows the aspect of the one bright soliton pulse lost its shape along the path of the link designed.

But the affect of the absorption on the black soliton superposed on the radiation pulse was big that lead to stop the black soliton pulse propagates directly after the first stage of the communication system.

Introduction

In recent years lasers producing high intensity short-duration optical pulses have become readily available .It is now possible, with such lasers to probe the interesting, and potentially useful, nonlinear effects in fibers. The exploitation of these effects in optical devices is already taking place for example in pulse compressors [1,2] and the consequences for future long distance high bit rate communication systems are the subject of much study._Solitons could be used to increase transmission speed up to 40 Gb/s and possibly beyond but the most important benefit of soliton is extending the transmission distance of optical communication [3]. Solitons generate in optical fibers system only when the nonlinearity of the refractive index (Kerr effect) of optical fiber material makes it possible to balance the linear pulse broadening that results from the group velocity dispersion (GVD), also named the second order dispersion(β_2).

Hasegewa and Tappert first suggested in 1973 that optical solitons could exist in optical fiber transmission [4] . A soliton is a type of light pulse, could be

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Useful as information carriers in optical fibers communications system and can maintains its shape even when transmitted over long distance in ideal optical fiber . After few kilometers transmission of soliton pulses is severely affected by interaction between soliton pulses and loss. These induce a large number of theoretical researches including the performers of soliton pulses due to these effects and how to solve these problems **[5,6]**. With computer simulation, Mollenauer study soliton propagation in long fibers with periodically compensated loss by Raman gain **[6]**. Raman amplifiers require a relatively high power, which is difficult to obtain from semiconductor lasers. From 1989 a different approach to loss compensation uses typically erbium doped fiber amplifiers (EDFA) to restore the soliton energy **[7,8]** due to high gain, low noise figure and small cross talk **[9,10]**. Now day experimental soliton systems have achieved over 28Mm **[11]**.

The performances of radiation superposed on soliton pulses in lossless and loss optical fiber by using one of the efficient numerical method called Split Step Fourier Method (SSFM) present in this work.

Theory

The wave equation governing the propagation of optical signals in single mode fibers is called the nonlinear Schrodinger (NLS) equation. For anomalous dispersion (β_2<0) regime and ideal (no absorption) optical fiber, the standard normalized NLS equation with periodic boundary condition is given by

$$iu_\tau + \frac{1}{2}u_{zz} + |u^2|u = 0 \quad \ldots\ldots\ldots\ldots(1)$$

The second term is originated from the GVD and the third term is due to the Kerr effect.

where u is the complex amplitude of the pulse, z is the distance along direction of propagation , τ is the time.

$$u_\tau = \frac{\partial u}{\partial \tau}, \quad u_{zz} = \frac{\partial^2 u}{\partial z^2}$$

The boundary condition is given by:

$$u(-L/2,\tau) = u(L/2,\tau) \text{ and}$$

$$u_z(-L/2,\tau) = u_z(L/2,\tau) \quad \ldots\ldots\ldots\ldots(2)$$

Numerically equation 1 is solved by using Split Step Fourier Method (SSFM) described by Al-Dabagh[12]. The initial condition for radiation superposed on bright soliton pulse is written as

$$u(z,0) = (1+\cos 3z)\sec h(z) \quad \ldots\ldots.(3)$$

To study the absorption effect by adding the absorbing function γ results, the modified NLS equation 1 [13].

$$iu_\tau + \frac{1}{2}u_{zz}|u^2|u = -i\gamma(z)u \quad \ldots\ldots\ldots(4)$$

while the absorption function is written as[14]

$$\gamma(z) =$$

$$\gamma_0(\sec h^2[\alpha(z-L/2)] + \sec h^2[\alpha(z+L/2)])$$

$$\ldots\ldots\ldots\ldots\ldots(5)$$

the absorption function γ(z) introduce losses in the neighborhood of the periodic boundaries at z=-L/2 and z=L/2 through the choice of $\gamma(z)$; γ_0 is the absorption factor at z=0, while $1/\alpha$ represent the pulse width of the absorption walls. For normal dispersion (> β_2 0) regime and non ideal (absorption) optical fiber, the standard normalized NLS equation with periodic boundary condition is given by

$$iu_\tau - \frac{1}{2}u_{zz}|u^2|u = -i\gamma(z)u \quad \ldots\ldots.(6)$$

The initial condition for the radiation superposed on black soliton is given by

$$u(z,0) = (1+\cos 3z)\tanh(z) \quad \ldots\ldots\ldots(7)$$

Results and conclusion

Using Matlab program to represent equation (1). The investigation of the Performa's of radiation superposed on one bright soliton pulse in ideal single mode optical fiber are plotted in figure (1). Results out from figure (1a) show that initially one bright soliton pulse (a secant hyperbolic shape) superposed on the radiation is incident in lossless single mode optical fiber, then the one soliton propagate undisturbed without changing its shape along the fiber as shown in figure (1b). For this reason bright solitons could be useful as information carriers in optical fibers communications system for achieving high bit rates. The absorption function $\gamma(z)$ is plotted against the distance z is shown in figure (2). This function introduces losses in the neighborhood of the periodic boundaries at z=-L/2 and z=L/2.

Using the same approach to represent equation 5 .The parameters used L=10 $\gamma_0 = 20, \alpha = 0.5, 1.0, 1.5$. These parameters are chosen such that the scattering from the absorption wall"$\sec h^2[\alpha(z \pm L/2)]$"is small. Resolution $\Delta z = 0.1, \Delta\tau = 0.001$. Figure (3) shows that the amplitude of the one bright soliton pulse reduce gradually and the pulsewidth increase then the pulse split into two pulses. It means since the radiation cannot escape from the communication system owing to the spatial periodically and eventually destroy the one bright soliton along the natural optical fiber and the affect of $\alpha = 0.5, 1.0, 1.5$ is very small on the pulse amplitude. As a consequence the information carried by the bright soliton will be lost at the end of the path of the link designed. Our results show a good agreement with the numerical results of ref.14 for the radiation superposed on bright soliton as shown in figure(4).

Performa's of the one dark soliton in the presence of loss is plotted in figure (5).Results show that the dark soliton pulse stopped propagate directly at the first stage of the communication system since dark solitons generated due to balance between nonlinearity of the refractive index (Kerr effect) of optical fiber material and the normal dispersion(i.e> β_2 0),which has more effect to increase the pulsewidth than the anomalous dispersion. That means black soliton cannot be use as carrier information in natural optical fiber loss since black soliton pulse is severely affected by absorption.

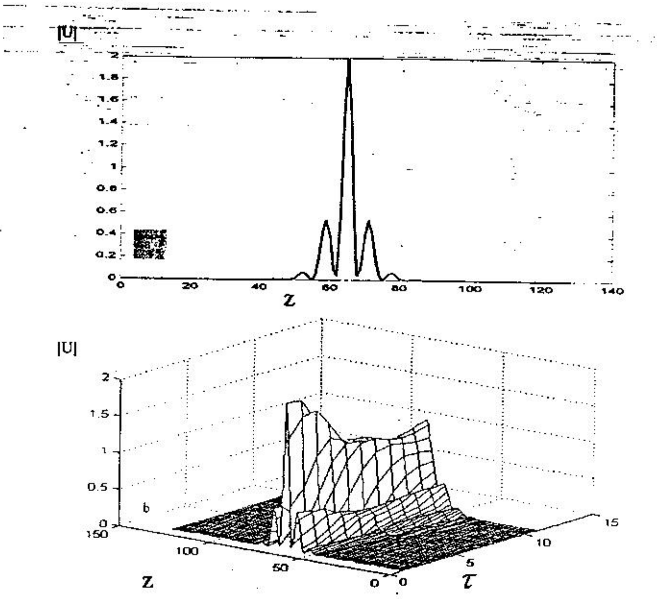

Fig.(1):Evolution of One Bright Soliton with Radiation Propagate in Ideal Optical Fiber at (a) $\tau = 0$,(b)$\tau = 12$.

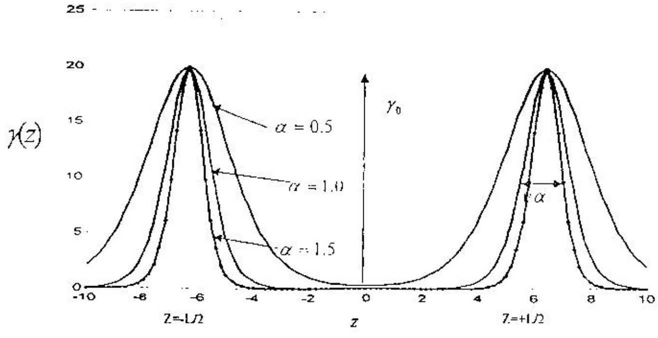

Fig.(2):The Absorption Function Against Distance z for Different Value of α .

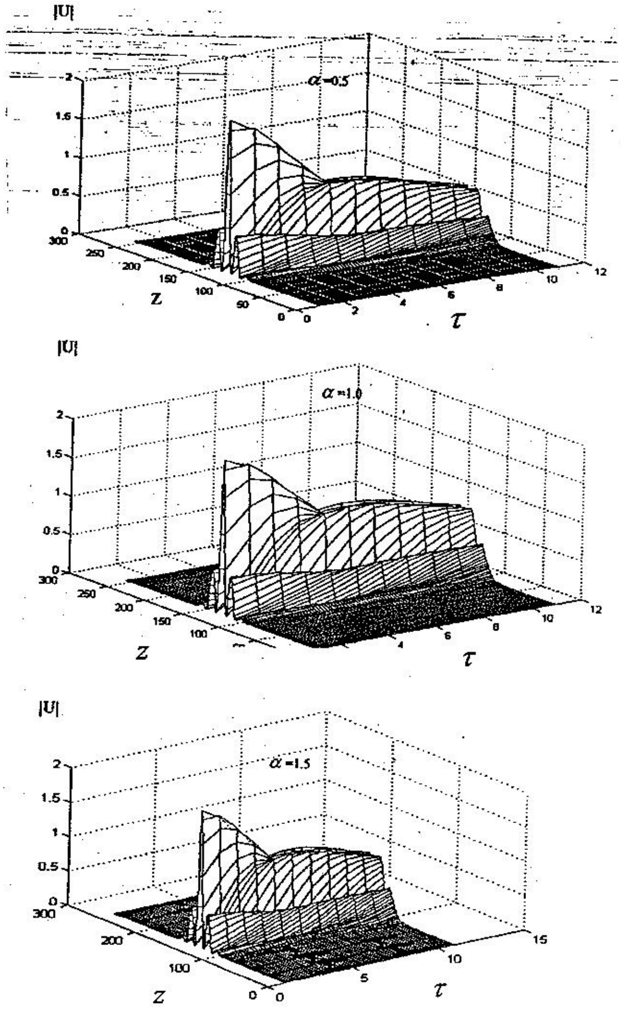

Fig.(3):The Time Development of One Bright Soliton with Radiation at $\alpha = 0.5, 1, 1.5$ in the Presence's of Absorption

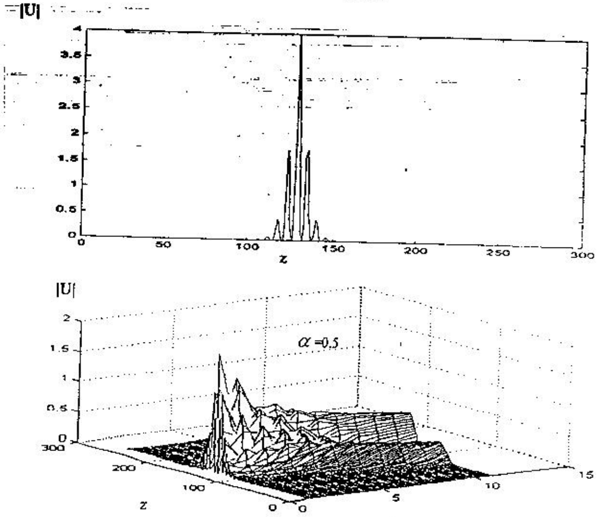

Fig (4): The Time Development of One Bright Soliton with Radiation at $\alpha = 0.5$ in the Presence's of Absorption [14]

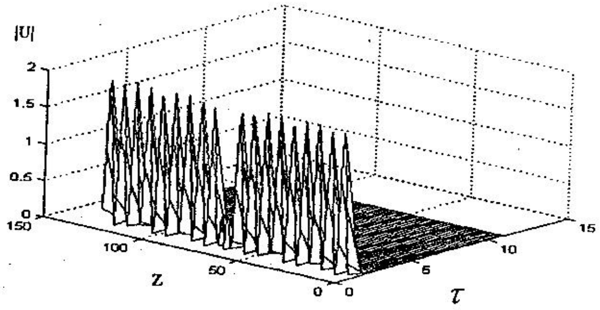

Fig.(5):Evolution of One Black Soliton with Radiation Propagate in Natural Optical Fiber

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هيئة الأشعة المتراكبة مع بنضة السوليتون المنتشرة في ليف أحادي النمط

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الخلاصة

يتضمن الجزء الأول من البحث تفحص هيئة الأشعة المتراكبة مع نبضة السوليتون المضية داخل ليف بصري مثالي أحادي النمط.أظهرت نتائج الدراسة العددية أن الأشعة ليس لها تأثير على نبضة السوليتون المضية حيث تنتشر نبضة السوليتون المضية محافظة على شكلها (secant hyperbolic) داخل منظومة الاتصالات.لهذا السبب ممكن استخدم السوليتونات المضيئة كحاملات للمعلومات في منظومة الاتصالات البصرية لاجل الحصول على معدلات إرسال عالية.

أما الجزء الثاني من البحث فتضمن دراسة تأثير عامل الامتصاص على هيئة نبضة السوليتون المضيئة أو السوداء المتراكبة على الأشعة المنتشرة داخل ليف بصري طبيعي أحادي النمط.تبين من الدراسة ان نبضة السوليتون المضيئة تفقد شكلها على طول المسار المصمم .أما تأثير الامتصاص كان كبيرا على نبضة السوليتون السوداء المتراكبة على الأشعة والذي أدى إلى توقف انتشار نبضة السوليتون السوداء مباشرة في المرحلة الأولى لمنظومة الاتصالات.