Global Advanced Research Journal of Physical and Applied Sciences Vol. 3 (3) pp. 031-034, August, 2014
Available online http://www.garj.org/garjpas/index.htm

Review

Investigation of soliton propagation in the optical fibers considering fiber loss and gain coefficient

Mohammad Bagher Askari[1], Fatemeh Ahmadi[2]

[1]Department. of Physics Azad University, North branch, Tehran, Iran
[2]Faculty of Physics, Shahid Rajaee Teacher Training University, Tehran, Iran

Accepted 26 August, 2014

In this paper, the nonlinear Schrödinger equation is solved (Equation core optical fiber data transmission) with regard to fiber loss and gain and it will show that using intermittent reinforcement amplifiers and soliton pulse can be input from a broad concentration. We also show the two properties of non-normal dispersion and nonlinear effects under certain conditions that they can neutralize each other's effect (Both of which are factors that are destructive to them and are a limiting factor for optical telecommunications) and can make a balance between these two properties with the lowest error rate of data transfer.

Keywords: Nonlinear Schrödinger equation, the abnormal dispersion, nonlinear effects, soliton waves

INTRODUCTION

soliton is the only stable pulse shape at the fiber and its characteristics are dispersion and nonlinear and this feature cause the pulse width of 1 ps 50 and power (mw 10 ~ 1).But the waves are always facing problems as follow: they are the only one solution whenever they completely separated from other solitons, and the other one is, time sliding can cause an error more than the pulse distortion. Sources of time sliding are noise amplifier or the interaction between solitons and soliton-soliton interaction of adjacent or other channels. Best time is to eliminate slippage to zero with decreasing average dispersion compensator that these dispersion decreasing fibers are done using two ways:

1-Well-designed waveguide

2-Connect a fiber with different dispersion to each other which is called dispersion-managed fiber (Agrawal, 2002).

*Corresponding author Email: mb_askari@yahoo.com

Broad the band

In this paper we will show that the two properties of non-normal dispersion and nonlinear effects under certain conditions they can neutralize each other's effect (Both of which are factors that are destructive to them and are a limiting factor for optical telecommunications) and can have a balance between these two properties with the lowest error rate of data transfer. The balance is between the two properties of non-normal dispersion and nonlinear factors cause the soliton (Boyd, 2003).

We propose to solve this equation, in order to solve the Nonlinear Schrödinger equation and after normalization, the equations taking into account the non-linearity, including abnormal dispersion coefficient with respect to fiber loss.

1 - The basic equation for the data transmission, fiber dispersion and group consideration of nonlinear effects and Tapert and Hasgava that the first time it was collected in 1973 (Optical Solitons in Fibers by Hasegawa and Akira). In Nonlinear Schrödinger equation, the

coefficients of this equation depends on the geometry of the fiber and optical Wave structure

$$\frac{\partial q}{\partial Z}=\frac{i}{2}\frac{\partial^2 q}{\partial T^2}+i|q|^2 q \quad (1)$$

Where q is the normalized range and it is equal to:

$$q=\sqrt{\frac{\omega_0 g\bar{n}_2 z_0}{2c}}\,\bar{E} \quad (2)$$

3 - The evolution of the wave packet group velocity dispersion

In the absence of non-linear element of Nonlinear Schrödinger equation is:

$$\frac{\partial q}{\partial Z}=\frac{i}{2}\frac{\partial^2 q}{\partial T^2} \quad (3)$$

Answer the above equation using the Fourier transform is:

$$q(Z,T)\frac{1}{2\pi}\int_{-\infty}^{+\infty}\bar{q}(Z,\Omega)e^{-i\Omega T}d\Omega \quad (4)$$

As it can be seen, the response of equation (3) is a function EXP, with negative exponent. It means by frequency is changed by the elimination of the nonlinear term and using dispersion term.

Nonlinear characteristics of wave due to the Non-linear feature

This time remove the fiber dispersion term and solve the nonlinear Schrödinger equation using the term including non-linear feature.

Equation (1) is as follows:

$$\frac{\partial q}{\partial Z}=i|q|^2 q \quad (5)$$

The answer is as follows:

$$qq_0(0,T)exp\left[i\int_0^z |q|^2 dZ'\right] \quad (6)$$

This result suggests that the q-phase is changed during diffusion. We see that the nonlinear effect is caused the change of frequency. And this change is the EXP Function with positive exponential.

As was observed, Nonlinear Schrödinger equation is contained two terms. One of them shows nonlinear effects, and the other one shows the effects of non-normal dispersion. We observed by removing any of the sentences and answer the equation, one time the answer is EXP function and the other time the EXP, obtained with positive exponential

It can be concluded that both non-linearity and dispersion, are caused errors in data transmission, however, balance between these two factors can minimize data loss and transmission errors and the Response to such an equation is a soliton.

1 - Nonlinear Schrödinger equation solitons response using boundary conditions (disorder techniques)

Nonlinear Schrödinger equation in (9) is expressed by the following conditions have been focused response for | q | is fixed to Z

1 - $|q|^2$ is limited to ρ_s and ρ_D.

2- At $|q|^2=\rho_s$, $|q|^2$ is extremum.it means $|q|^2=\rho_s$; $\frac{\partial |q|^2}{\partial T}=0$;

$$\frac{\partial^2 |q|}{\partial T^2}\neq 0$$

3 - ρD is the asymptotic value of $|q|^2$.until $T\rightarrow\infty$ it means $|q|^2=\rho_D$;.. $\frac{\partial^n |q|}{\partial T^n}=0$ For n=1, 2, 3…

We are currently seeking an answer to the equation (1) satisfies the above conditions. Firstly, we introduce two variables that represent the values of the real and imaginary q, ρ and σ, respectively

$$q(T,Z)=\sqrt{\rho(T,Z)}e^{i\sigma(T,Z)} \quad (7)$$

By inserting them in equation 1, we have:

$$\frac{\partial \rho}{\partial z}\frac{\partial}{\partial T}\left(\rho\frac{\partial\sigma}{\partial T}\right)0 \quad (8)$$

$$\frac{1}{8}\frac{d}{d\rho}\left[4\rho^2\frac{1}{\rho}\left(\frac{\partial\sigma}{\partial T}\right)^2\right]\frac{\partial\sigma}{\partial Z}\frac{1}{2}\left(\frac{\partial\sigma}{\partial T}\right)^2 \quad (9)$$

Static condition for | q | 2 (= ρ) will result ∂ ρ / ∂ z = 0. Then (8) we have:

$$\rho\frac{\partial\sigma}{\partial T}=c(Z) \quad (10)$$

We show that the only possibility for the integration constant c (Z), Z is a constant independent of the proof; we note that the left side of (9) is only a function of T, then:

$$\frac{\partial\sigma}{\partial Z}+\frac{1}{2}\left(\frac{\partial\sigma}{\partial T}\right)^2=f(T) \quad (11)$$

Differentiation with respect to Z and T are:

$$\frac{\partial^3\sigma}{\partial Z^2\partial T}-\frac{1}{\rho^3}\frac{d\rho}{dT}\frac{dc^2}{dZ}=0 \quad (12)$$

From (11) we have:

$$\frac{\partial^3\sigma}{\partial Z^2\partial T}=\frac{1}{\rho}\frac{d^2c}{dz^2} \quad (13)$$

Then

$$\frac{1}{\rho}\frac{dc^2}{dZ^2}-\frac{1}{\rho^3}\frac{d\rho}{dT}\frac{dc^2}{dZ}=0 \quad (14)$$

Or

$$\frac{\frac{dc^2}{dZ^2}}{\frac{dc^2}{dZ}}=\frac{1}{\rho^2}\frac{d\rho}{dT}=const \quad (15)$$

Because we cannot respond to ρ-2 (dρ / dT) = const is accepted, the only option that remains c (Z) = const will be. Thus:

$$\rho\frac{\partial\sigma}{\partial T}=c_1(const) \quad (16)$$

Or

$$\sigma=\int\frac{c_1}{\rho}dT+A(Z) \quad (17)$$

As proved ∂ σ / ∂ T is only a function of T, we conclude that ∂ σ / ∂ Z is also a function of T .dA / dZ is equal to a constant as (Ω) we get:

$$\sigma=\int\frac{c_1}{\rho}dT+\Omega(Z) \quad (18)$$

If the expression in (13) we used to get the following ordinary differential equation:

$$\left(\frac{d\rho}{dT}\right)^2=-4\rho^3+8\Omega\rho^2c_2\rho 4c_1^2 \quad (19)$$

We are looking for the answer for this equation with regard to the boundary conditions. For condition 1, dρ / dT for only two values of ρ_D and ρ_s should be zero. In addition to the double root ρ_D should also be indicative of

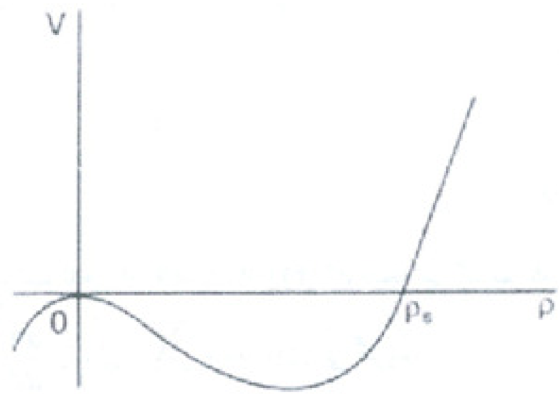

Figure 1 Non-linear effective potential

an asymptotic ρ. When these conditions are provided, $-4C_1^2 \geq 0$or $c_1 = 0$, and hence is $c_2 = 0$., In this case equation (19) becomes as follows:

$$(\frac{d\rho}{dT})^2 - 4\rho^3 8\Omega\rho^2 4\rho^2(\rho - \rho_s) \quad (20)$$

That

$$\rho_s = \rho_0 = 2\Omega \quad (21)$$

equation (20) can be written in the form of Hamilton:

$$\frac{1}{2}\left(\frac{d\rho}{dT}\right)^2 VE_0 \quad (22)$$

Where $V=2\rho^2(\rho-\rho_s)$ and is $E_0= 0$. Potential of the form (1) is shown. Notice that if a particle trapped in a potential fall, the oscillation frequency will be infinite. This means that if the initial velocity of zero, and $\rho = \rho_0$ starts after an infinite time to reach $\rho = 0$ This mode of response corresponded to the soliton. Simply from (20) we get the integral:

$$\rho_0 sech^2(\sqrt{\rho_0}T) \quad (23)$$

That $\rho_0 = \rho_s = 2\Omega$ و $\Omega > 0$

$$\sigma\Omega Z \frac{\rho_0}{2} \quad (24)$$

Nonlinear Schrödinger equation can be shown that (1) the Galilean transformation is constant, i.e., it can be shown that a function such as q '(T, Z) is fulfilled.

$$q'(T,Z)exp\left[-i\left(kT + \frac{1}{2}k^2 Z\right)\right] q(T + kZ, T) \quad (25)$$

With an additional independent variable and constant k and σ (phase position) T_0(Time situation), the answer is a single wave packet:

$$q(T,Z) = \eta sech\eta(T + kZ - T_0)exp\left[-ikT + \frac{i}{2}(\eta^2 - k^2)Z - i\sigma\right] \quad (26)$$

That $\sqrt{\rho_0}$ have been replaced by η: Response to a single wave (26) is shown with four parameters. η represents amplitude and pulse width of a single wave, k represents the pulse velocity (the velocity, the group velocity is velocity deviation), T0 time position and σ is the phase denotes. (Zakharov and Shabat 1972) to solve the nonlinear Schrodinger equation, considered inverse dispersion problem and it stated that answer to this the equation can be combined in a single wave response (26) and as a continuous wave. Accordingly, (26) a soliton is a nonlinear Schrödinger equation. For this reason, a single wave response expressed in (26) is called the envelope soliton. The form of a light wave optical solitons in Figure (2) is shown in (Optical Solitons In Fibers By Hasegawa and Akira).

When abnormal dispersion wavelength region, ie, with $k'' < 0$ applied, Soliton wave packet exist .In contrast, in the normal dispersion region $k'' > 0$, ie, the absence of non-continuous wave optical light appears as a soliton (Hasegawa and Tappert 1973). Therefore, k" with a positive response range is called dark soliton.

2 - Solving the nonlinear Schrödinger equation by applying fiber loss.

However, by reducing the fiber, the soliton properties may be changed. Now we solve the equations of nonlinear fiber Schrödinger in the fiber loss and show that to transmit data over long distances using soliton waves, there is a need to the series of amplifiers or repeaters. Nonlinear Schrödinger equation with the fiber loss is as follow and the fiber loss added to the right of (1) by adding -iγq element:

$$i\frac{\partial q}{\partial Z} - \frac{1}{2}\frac{\partial^2 q}{\partial T^2}\frac{\omega_0 n_2}{2c}|q|^2 qi\Gamma q \quad (27)$$

Which is $\Gamma = \gamma z_0$

That the answer of equation (27) using the impaired technique is as follow:

$$q(T,Z) = \eta(Z)\,\mathrm{sech}[\eta(Z)T]\exp[\eta(Z)T]\exp[i\sigma(Z)] + \mathcal{O}(\Gamma) \quad (28)$$

Soliton amplitude will be equal to:

$$\eta(Z)q_0\exp(-2\Gamma Z) \quad (29)$$

And its energy:

$$\int_{-\infty}^{+\infty}\eta^2 sech^2\eta T\, dT = \eta \quad (30)$$

According to the obtained relations can be seen that the soliton amplitude reduce in terms of the exponential $\exp(-2\Gamma Z)$and its width $\exp(-2\Gamma Z)$increases and therefore the multiplying range in the soliton width is fixed. Soliton energy is naturally decreases proportional to$\exp(-2\Gamma□)$. Soliton amplitude decreases at a double rate and the rate of loss is linearly due to a nonlinear soliton pulse. This result indicates that no distortion for a

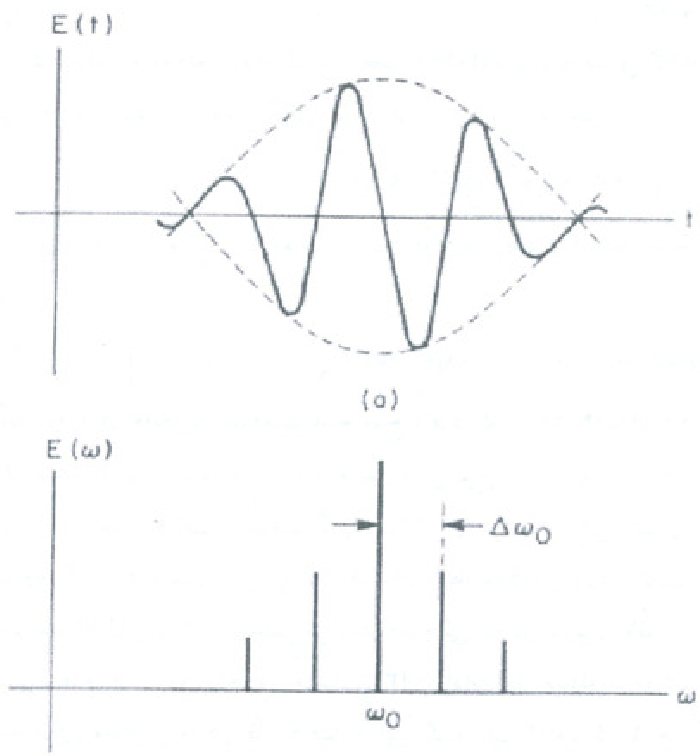

Figure 2 is an optical soliton

soliton in a long line, we need to strengthen. In order to post solitons in a fiber, the loss will be prevented by intermittent amplification.

Nonlinear Schrödinger equation in this case is modified as follows

$$\frac{\partial q}{\partial Z} = \frac{i}{2} d(Z) \frac{\partial^2 q}{\partial T^2} + i|q|^2 q + [G(Z) - \Gamma]q \qquad (31)$$

Which in this strengthen the fiber and fiber loss in dispersion distance z0, are, G (Z) and Γ respectively.

RESULTS AND CONCLUSION

Intrinsic stability of solitons makes it possible to long-distance transmission without using repeaters and could potentially double transmission capacity. Optical solitons in fibers profound an example of how technology transfer is an absolute mathematical concept. Discussing about all optical data transmission systems, setting the standard for optical soliton transmission system is very sophisticated. Today, one of the most important issues in optical communication systems is to achieve a very compact optical pulse. One of the fundamental problems in optical systems, the pulse shape and flatten along the propagation path. Soliton pulses have the capacity, by creating a dynamic balance between nonlinearity and dispersion effects in fiber cross low dissipation and relatively long paths without deformation. Soliton pulses are a special type of optical pulse which is obtained from nonlinear Schrödinger equations. Although pulses are able to maintain their shape at long distances in low-loss fibers, but factors such as fiber losses, nonlinear effects of and high-order dispersion especially in femtosecond soliton pulses are caused their deformation. At this time, the use of Iterator or amplifier comes to help us and transfer data with minimal casualties or disruption spread.

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