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SIMULATION OF SOLITON PULSE PROFILES IN SINGLE MODE OPTICAL FIBERS WITH CUBIC NONLINEAR SCHRODINGER EQUATION (CNLSE)

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ABSTRACT
A theoretical approach is important for an understanding of the nonlinear effects in optical media. It is important for practicability and system design to study optical soliton propagation in optical nonlinear media. In this research work, ansatz method of solving differential equation was used to derive the solution of unperturbed and perturbed cubic nonlinear Schrödinger equation (CNLSE). The perturbation terms consist of Third-Order dispersion term and self-steppening. The result of analytical study was used for the simulation using surfer simulation software and the data was generated using Microsoft office excel. The governing equation is the cubic nonlinear Schrödinger equation, (CNLSE), in the presence of perturbation terms. The input pulse and the nonlinear coefficient parameter at the wavelength of $\lambda = 1.55\ \mu\mathrm{m}$ with pulse duration of $T_s = 30\ \mathrm{Ps}$ for group velocity dispersion $\beta_2 = -20\ \mathrm{Ps}^2/\mathrm{km}$, nonlinear parameters $\gamma = 1.0\ W^{-1}kg^{-1}$ third-order dispersion TOD $\beta_3 = 0.01\ \mathrm{Ps}^3/\mathrm{km}$, input power $P_0 = 1.2$ mW. The method of ansatz was used. The ansatz was formulated and dimensionally verified. The CNLSE was divided into two, the perturbation term and the unperturbation term. The simulation shows that the unperturbed CNLSE become so large that the pulse cannot form a soliton and becomes broader than the input pulse, the effect of two perturbation terms such as TOD and Self steppening are responsible for improving the quality of the compressed pulse. From the simulations, it shows that the velocity of pulse profiles propagation increase by the influence of b_1, the amplitude increases and the power loses decreases.

Key words: Soliton, Pertubation, Pulse, Ansatz, Nonliner, Dispersion

1.0 Introduction
Today we are on the verge of another industrial revolution, the information revolution. The present-day earth is becoming more digitized and light is playing an indispensable role in keeping the communication lines open. Because of the internet, information flows across the continents as easily as it flows across an office. The ever-increasing internet traffic will soon exceed today's performance limit of Terabits per second per fiber. The rapid increase in network traffic demands reliability, more transmission capacity, good performance, rapid transmission with less transmission loss. The above traits are easily achievable with fibers. To offer high-bandwidth services ranging from home-based PCs to large business and research organizations, telecommunication companies worldwide are using light waves that travel within optical fibers as the dominant transmission system. Other examples include: database queries and updated shopping, video-on-demand, remote education, video conferencing, and web-based courses. A large number of research is in progress on optical computers [1].

After the invention of the laser in 1960, people attempted to use it for communication purposes because of its coherent radiation. Researchers struggled to find a suitable medium for communications for more than five years. Fortunately, in 1966, the fiber medium emerged as the best choice to transmit optical signals. The fiber is selected as a medium, because it has a peculiar property of confining an electromagnetic field in the plane perpendicular to the axis of the fiber core. The physical principle behind such devices is the principle of total internal reflection, which was first demonstrated by John Tyndall in 1870. The first optical fibers were made from glass. The fibers are capable of guiding the light similarly as electrons are guided in copper cables. Though the number of bits sent per second increased, fiber loss was a serious problem. In traditional electrical communications, the message is sent to distant places through copper cables, after superposing them over a carrier wave. The process of superposition is called modulation. During modulation, the amplitude, the frequency or the phase of the carrier changes in accordance with the message and these modulations are respectively called Amplitude Modulation (AM), Frequency Modulation (FM) and Phase Modulation (PM). The carrier here is one among the known electromagnetic spectrum. At the receiving end, the message is extracted from the carrier by a demodulation process.

The medium of transmission was later extended to atmosphere in which the carrier is either radio waves or microwaves. The satellite communication system operates in the microwave region. With the merits of fibers like low cost, easy installation, signal security, life more than 25 years, accommodation of more channels, low transmission loss, no electromagnetic interference, abundant availability of raw material. The decade-old battle between the fiber medium and the satellite systems for international communications to the fiber system being the clear economic and technological winner. This is because the satellite communication system is costly, life is limited to only five to ten years, handling the system requires more technical and professional people and it has lower channel handling capacity. With the astonishing development of lasers, various telecommunication companies across the world have started using light as the ascendant transmission system. In fiber systems, the transmission of signals is through dielectric media called waveguides. The medium is of hair thin glass fibers that guide the light signals over long distances. As the carrier here is light, this type of communication is called Optical Fibre Communication [2].

In both wired and wireless communications the amount of information transmitted can be increased by increasing the range of the frequency of the carrier called bandwidth. Optical Frequency carrie (OFC) system is an excellent communication system compared to the other media such as copper or atmosphere. They offer low-loss transmission over a wide range of frequencies of about 50 THz. This range is several times more than the bandwidth available in copper cables or any other transmission medium. Because of this property, this system allows signals to be transmitted over very long distances at higher speeds before they need to be amplified. Unlike the electrical communications, in optical systems, the transmission of information in an optical format, which is carried out not by AM, FM or PM of the carrier but by varying the intensity of the optical power. The information to be sent is converted into bits (zero or one) using an Analog-to-Digital Converter (ADC) [3].

This fiber loss can still be limited by using periodic amplifiers. The dispersion loss can be reduced by a dispersion compensation scheme, which requires the wavelength to be at 1330 nm for almost zeroing dispersion. A major accomplishment in the development of OFC was the invention of Erbium Doped fiber Amplifiers (EDFA) in 1987 [4].

The word *soliton* refers to special kinds of wave packets that can propagate undistorted over long distances. Solitons have been discovered in many branches of physics. In the context of optical fibers, not only are solitons of fundamental interest but they have also found practical applications in the field of fiber-optic communications [5].

Such waves were later called solitary waves. However, their properties were not understood completely until the inverse scattering method was developed. The term *soliton* was coined in1965 to reflect the particle like nature of those solitary waves that remained intact even after mutual collisions. Since then, solitons have been discovered and studied in many branches of physics including optics. In the context of optical fibers, the use of solitons for optical communications was first suggested in 1973 [6].

The Cubic Nonlinear Schrodinger equation (CNLSE) is a nonlinear partial differential equation that does not generally lend itself to analytic solutions except for some specific cases in which the inverse scattering method can be employed. A numerical approach is therefore often necessary for an understanding of the nonlinear effects in optical fibers. A large number of numerical methods can be used for this purpose. These can be classified into two broad categories known as: The finite-difference methods; split-step Fourier method and the Pseudospectral methods. The one method that has been used extensively to solve the pulse-propagation problem in nonlinear dispersive media is the split-step Fourier method. In this research the method of Ansatz was used to determine the effect of perturbed and unperturbed CNLSE because the method is straight forward and fast in determine the pulse profile in an optical fiber in single mode pulse propagation. The relative speed of this method compared with most finite-difference schemes can be attributed in part to the use of the ansatz method. This research also determine the influence and effect of each perturbation terms in single-mode optical fiber with CNLSE.

The purpose of this work is to analyse and simulate the soliton pulse profiles in single mode optical fiber with cubic nonlinear Schrodinger equation (CNLSE).

The specific objectives are:

1. To determine the effect of third order dispersion (TOD) term on solitary wave pulses in optical fiber
2. To examine influence of self stepenning on soliton pulse propagation
3. To determine nonlinear effects without the perturbation terms in the wave profiles
4. To determine effects of nonlinear perturbation terms in the wave profiles

2.0 MATERIALS AND METHODS

Materials

The materials used in this research are computer softwares: Surfer and Microsoft office excel.

2.1 Method of Ansatz

In physics and mathematics, an ansatz is a placement of a tool at a work piece. It can also be regarded as an educated guess or an additional assumption made to help solve a problem, and which may later be verified to be part of the solution by its results [7].

An ansatz is the establishment of the starting equations, the theorems, or the values describing a mathematical or physical problem or solution. It typically provides an initial estimate or framework to the solution of a physical or mathematical problem, and can also take into consideration of the boundary conditions (in fact, an ansatz is sometimes thought of as a "trial answer" and an important technique in solving differential equations). An ansatz which can be used to constitute nothing more than an assumption, has been established. The equations are solved more precisely for the general function of interest, which then constitutes a confirmation of the assumption. In essence, an ansatz makes assumptions about the form of the solution to a problem so as to make the solution easier to find [8].

An ansatz method can be employed to solve CNLSE. CNLSE is a homogeneous linear differential equation to take an exponential form or a power form in the case of a differential equation. More generally, one can guess a particular solution of a system of equations and test such an ansatz by directly substituting the solution into the system of equations. In many cases, the assumed form of the solution is general enough that it can represent arbitrary functions, in such a way that the set of solutions found this way is a full set of all the solutions.

2.2 Solution of Unpartubed Cubic Nonlinear Schrodinger Equation

The solution of unperturbed CNLSE was used to determine nonlinear effects without the perturbation terms in the wave profiles

The normalized CNLSE without perturbation terms is [8]

$$i\hbar \frac{\partial U}{\partial \xi} - \alpha U - \frac{\partial^2 U}{\partial \tau^2} + c|U|^2 U = 0 \tag{1}$$

where

$$U(\xi,\tau) = \frac{A(\xi,\tau)}{A_0} \equiv \frac{\tau_0}{N}\left(\frac{\alpha_2}{\beta_2}\right)^{\frac{1}{2}} A(\xi,\tau) \tag{2}$$

$$\delta = \pm 1 \quad \text{(for anomalous (+), for normal (-))} \tag{3}$$

$$\alpha_2 = \frac{\varpi^2}{2kc^2}\frac{1}{A_{eff}}\frac{3}{4}\chi^{(3)} \equiv \frac{\varpi n_2}{cA_{eff}} \tag{4}$$

$$\alpha_0 = a_0 L_D = \frac{L_D \varpi^2 c}{2\omega} = \frac{L_D \lambda \varpi^2}{4\pi} \tag{5}$$

$$b_1 = \frac{\beta_3}{6|\beta_2|\tau_0} \tag{6}$$

$$b_2 = \frac{\lambda}{2\pi c \tau_0} \tag{7}$$

$$a_0 = \frac{\varpi^2}{2k} \tag{8}$$

ϖ^2 is a constant of separation, that represent the mode of propagation equation from the pulse propagation equation.

For the fundamental solution N = 1; thus, the ansatz is

$$U(\xi,\tau) = U_0 \exp[i(\gamma\xi - \gamma_0 - \omega\tau)] \times \operatorname{sec}h\left(\frac{\tau - \tau_0 - \beta\xi}{T}\right) \tag{9}$$

Next is to use equation (9) in equation (1), as follows:

$$i\hbar \frac{\partial U}{\partial \xi} = i\hbar U_0 \exp(iy)\operatorname{sec}h(x)\left(\frac{-\beta}{T}\tanh(x) + i\gamma\right) \tag{10}$$

Where $y = \gamma\xi - \gamma_0 - \omega\tau$ and (11)

$$x = \frac{\tau - \tau_0 - \beta\xi}{T} \tag{12}$$

$$-\alpha U = -\alpha U_0 \exp(iy)\sec h(x) \tag{13}$$

$$-\frac{\partial^2 U}{\partial \tau^2} = \exp(iy)\left[\left(\omega^2 \delta U_0 - \frac{\delta U_0 \beta^2}{T^2}\right)\sec h(x) - \frac{2i\omega\delta\beta U_0}{T}\sec h(x)\tanh(x)\right] \tag{14}$$

$$c|U|^2 U = cU_0^3 \exp(iy) sch^3 x \tag{15}$$

Next is to use equation (10), (13), (14) and (15) in (1) thus

$$i\hbar U_0 \exp(iy)\sec h(x)\left(\frac{-\beta}{T}\tanh(x) + i\gamma\right) - \alpha U_0 \exp(iy)\sec h(x)$$
$$+\exp(iy)\left[\left(\omega^2 \delta U_0 - \frac{\delta U_0 \beta^2}{T^2}\right)\sec h(x) - \frac{2i\omega\delta\beta U_0}{T}\sec h(x)\tanh(x)\right] \tag{16}$$
$$+cU_0^3 \exp(iy) sch^3 x = 0$$

Hence equation (16) will yield

$$\frac{-\beta}{T}\left(\hbar + 2\omega\delta\right)\sec h(x)\tanh(x) + \left(cU_0^2 + \omega^2\delta - \hbar\gamma - \frac{\delta\beta^2}{T^2}\right)\sec h(x) \tag{17}$$
$$-cU_0^2 \tanh^2 x = 0$$

Using quadratic equation in (17), one get

$$\hbar + 2\omega\delta \equiv 0 \tag{18}$$

$$U_0^2 + \omega^2\delta - \hbar\gamma - \alpha - \frac{\delta\beta^2}{T^2} \equiv 0 \tag{19}$$

$$U_0^2 \exp(iy) sch^2 x \equiv 0 \tag{20}$$

For equation (18) may be considered to be a constraint, Thus

$\delta = -1$ for anomalous dispersion

$\hbar$ = 1

$\therefore$ equation (18) one get

$$\omega = \frac{1}{2} \tag{21}$$

Also, $U_0 = 1, c = 1, \gamma = \frac{1}{2}$, and $\alpha = 0$, are to be used in Equation (19).

That is with $\omega = \frac{1}{2}$, we get

$$\beta = i \text{ and } T = \sqrt{2} \tag{22}$$

But $i = \cos\left(\frac{\pi}{2}\right) + i\sin\left(\frac{\pi}{2}\right) = i$

There is a phase of $\frac{\pi}{2}$ or 90^0

$$\beta = |i| = 1 \tag{23}$$

And if is the ansatz, $\gamma_0 = 0, \tau_0 = 0,$ then

$$U(\xi, \tau) = \exp\left[i\left(\frac{1}{2}\xi - \frac{1}{2}\tau\right)\right] \times \sec h\left(\frac{\tau - \xi}{\sqrt{2}}\right) \tag{24}$$

To use equation (24) for simulation, recall that

$$|U(\xi,\tau)|^2 = \left|\exp\left[i\left(\frac{1}{2}\xi - \frac{1}{2}\tau\right)\right]\right|^2 \sec h^2\left(\frac{\tau-\xi}{\sqrt{2}}\right)$$

$$|U(\xi,\tau)|^2 = \sec h^2\left(\frac{\tau-\xi}{\sqrt{2}}\right) \tag{25}$$

$$U(\xi,\tau) = \sec h\left(\frac{\tau-\xi}{\sqrt{2}}\right) \tag{26}$$

Equation (26) was utilized to determine nonlinear effects without the perturbation terms in the wave profiles for the fundamental soliton or solitary wave.

2.3 Solution of TOD as the first perturbation term

The solution of third order dispersion (TOD) was used to determine the effect of third order dispersion (TOD) term on solitary wave pulses in optical fiber

The normalized CNLSE with first perturbation terms is [5]

$$i\hbar\frac{\partial U}{\partial \xi} - \alpha U - \frac{\partial^2 U}{\partial \tau^2} + c|U|^2 U - ib_1\frac{\partial^3 U}{\partial \tau^3} = 0 \tag{27}$$

The fifth term of equation (27) can be evaluated as

$$-ib_1\frac{\partial^3 U}{\partial \tau^3} = \left(-b_1\omega^3 U_0^2 + \frac{b_1\omega U_0^2\beta^2}{T^2} + \frac{2\omega U_0^2\beta^2 b_1}{T^3}\right)\sec h(x) + \left(\frac{i\omega^2 b_1 U_0^2\beta}{T} - \frac{ib_1 U_0^2\beta^3}{T^3}\right)\sec h(x)\tanh(x) \tag{28}$$

$$\begin{aligned} & i\hbar U_0\exp(iy)\sec h(x)\left(\frac{-\beta}{T}\tanh(x) + i\gamma\right) - \alpha U_0\exp(iy)\sec h(x) \\ & + \exp(iy)\left[\left(\omega^2\delta U_0 - \frac{\delta U_0\beta^2}{T^2}\right)\sec h(x) - \frac{2i\omega\delta\beta U_0}{T}\sec h(x)\tanh(x)\right] \\ & + cU_0^3\exp(iy)sch^3 x + \left(-b_1\omega^3 U_0^2 + \frac{b_1\omega U_0^2\beta^2}{T^2} + \frac{2\omega U_0^2\beta^2 b_1}{T^3}\right)\sec h(x) \\ & + \left(\frac{i\omega^2 b_1 U_0^2\beta}{T} - \frac{ib_1 U_0^2\beta^3}{T^3}\right)\sec h(x)\tanh(x) = 0 \end{aligned} \tag{29}$$

Hence equation (29) yield

$$\begin{aligned} & \frac{i\beta}{T}\left(\hbar + 2\omega\delta - \frac{b_1 U_0\beta^2}{T^2} + b_1\omega^2\right)\sec h(x)\tanh(x) \\ & + \left(cU_0^2 + \omega^2\delta + b_1\omega^2 U_0 - \hbar\gamma - \alpha\frac{-\delta\beta^2}{T^2} - \frac{b_1\omega U_0\beta^2}{T^2} - \frac{-2\omega U_0\beta^2 b_1}{T^3}\right)\sec h(x) \\ & - cU_0^2\tanh^2(x) = 0 \end{aligned} \tag{30}$$

By comparing the coefficients of *sech (x) tanch (x)* and *sech (x)* in equation (30) one gets

$$\hbar + 2\omega\delta - \frac{b_1 U_0 \beta^2}{T^2} + b_1\omega^2 \equiv 0 \tag{31}$$

$$cU_0^2 + \omega^2\delta + b_1\omega^2 U_0 - \hbar\gamma - \alpha\frac{-\delta\beta^2}{T^2} - \frac{b_1\omega U_0\beta^2}{T^2} - \frac{-2\omega U_0\beta^2 b_1}{T^3} \equiv 0 \tag{32}$$

$$-cU_0^2 \tanh^2(x) \equiv 0 \tag{33}$$

For equation (31) may be considered to be a constraint, Thus
$\delta = -1$ for anomalous dispersion
$\hbar$ = 1
When we solve equation (31) using quadratic equation, one get

$$\omega = \frac{1}{2} \tag{34}$$

Also, $U_0 = 1, c = 1, \gamma = \frac{1}{2}$, and $\alpha = 0$, are to be used in Equation (32).

That is with $\omega = \frac{1}{2}$, one gets

$$T = 4b_1 \tag{35}$$

And if is the ansatz, $\gamma_0 = 0, \tau_0 = 0,$ then

$$U(\xi,\tau) = \sec h\left(\frac{\tau - \xi}{4b_1}\right) \tag{36}$$

Equation (36) was used for the simulation of first perturbation term in figure 1.0

2.4 Solution with Second Perturbation term of CNLSE

The solution of second perturbation term was used to examine the influence of self stepenning on soliton pulse propagation.

The normalized CNLSE with second perturbation terms is

$$i\hbar\frac{\partial U}{\partial \xi} - \alpha U - \frac{\partial^2 U}{\partial \tau^2} + c|U|^2 U - ib_2\frac{\partial}{\partial \tau}\left(|U|^2 U\right) = 0 \tag{37}$$

The fifth term of equation (3.36) can be evaluated as

$$-ib_2\frac{\partial}{\partial \tau}\left(|U|^2 U\right) = U_0^3\left[\sec h^3(x)\left(\frac{3i\beta b_2}{T}\tanh(x) + \gamma b_2\right)\right]\exp(iy) \tag{38}$$

Next is to use equation (3.10), (3.13), (3.14) and (3.38) in (3.37). Thus

$$\begin{aligned} &i\hbar U_0 \exp(iy)\sec h(x)\left(\frac{-\beta}{T}\tanh(x) + i\gamma\right) - \alpha U_0 \exp(iy)\sec h(x) \\ &+\exp(iy)\left[\left(\omega^2\delta U_0 - \frac{\delta U_0\beta^2}{T^2}\right)\sec h(x) - \frac{2i\omega\delta\beta U_0}{T}\sec h(x)\tanh(x)\right] \\ &+cU_0^3\exp(iy)sch^3 x + U_0^3\left[\sec h^3(x)\left(\frac{3i\beta b_2}{T}\tanh(x) + \gamma b_2\right)\right]\exp(iy) = 0 \end{aligned} \tag{39}$$

Hence equation (3.39) yields

$$\frac{i\beta}{T}\left(\hbar + 2\omega\delta - 3b_2U_0^2\right)\sec h(x)\tanh(x)$$
$$+\left(-\hbar\gamma - \alpha + \omega^2\delta - \frac{\delta\beta^2}{T} + cU_0^2 - \gamma b_2U_0^2\right)\sec h(x) \quad (40)$$
$$+\left(\gamma b - c\right)U_0^2\tanh^2(x) + \frac{3ib_2\beta}{T}U_0^2\tanh^3(x) = 0$$

From equation (40) one gets

$$\hbar + 2\omega\delta - 3b_2U_0^2 \equiv 0 \quad (41)$$

$$-\hbar\gamma - \alpha + \omega^2\delta - \frac{\delta\beta^2}{T} + cU_0^2 - \gamma b_2U_0^2 \equiv 0 \quad (42)$$

$$\left(\gamma b - c\right)U_0^2\tanh^2(x) \equiv 0 \quad (43)$$

$$\frac{3ib_2\beta}{T}U_0^2\tanh^3(x) \equiv 0 \quad (44)$$

For equation (41) may be considered to be a constraint, Thus

$\delta = -1$ for anomalous dispersion

$\hbar$ = 1

When we solve equation (41) using quadratic equation equation, one get

$$\omega = \frac{1-3b_2}{2} \quad (45)$$

Also, $U_0 = 1, c = 1, \gamma = \frac{1}{2}$, and $\alpha = 0$, are to be used in Equation (42).

That is with $\omega = \frac{1-3b_2}{2}$, one gets

$$T = \frac{4}{4b_2 - 1} \quad (46)$$

And if is the ansatz, $\gamma_0 = 0, \tau_0 = 0,$ then

$$U(\xi,\tau) = \sec h\left(\frac{4(\tau-\xi)}{4b_2 - 1}\right) \quad (47)$$

Equation (47) was used for the simulation of second perturbation term in figure 1.2

Table 1.0: Parameters used for Data Generation and Simulation

S/N	Parameter Name	Values	S.I Units
1	Non-linear parameter γ	1.0	$W^{-1}g^{-1}$
2	Dispersion of the second order β_2	-20.0×10^{-12}	s^2/m
3	Pulse width τ_0	$30 X 10^{-12}$	s
4	Third order Dispersion β_3	1×10^{-10}	s^3/m
5	Frequency ω	209.53	rad/s
6	Wavelength λ	1.55×10^{-6}	m
7	Self Stepenning b_2	0.16	
9.	Input Power P_0	1.2×10^{-3}	W
10	Dispersion Length L_D	4.5×10^{-2}	m
11	Nonlinear Length L_{NL}	833.3	m

Source: [5].

3.0 RESULT AND DISCUSSION

3.1 Introduction

The main aim of the study was to simulate perturbed and unperturbed CNLSE in an optical fiber profile using ansatz method. The result and discussion of the findings are presented as.

3.2 The Result and Discussion of unperturbed CNLSE

The result of the solution of unperturbed CNLSE was used to determine nonlinear effects without the perturbation terms in the wave profiles was simulated using equation (26) as shown in Fig. 1.

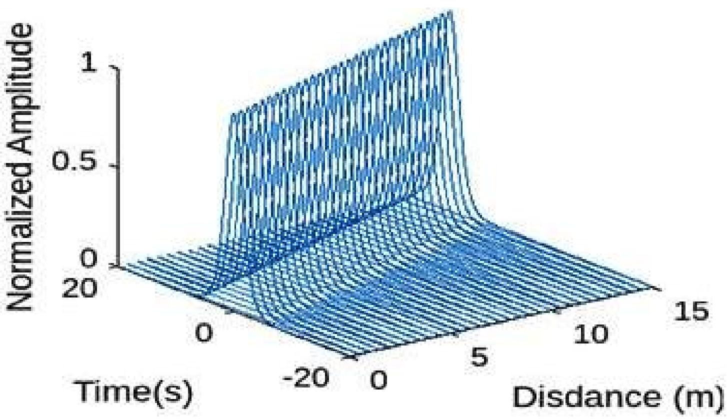

Figure. 1. Profile of the unperturbed CNLSE with dimensionless pulse width of $T = \sqrt{2}$ input power of P_0 = 1.2 mW, shows that the maximum normalized amplitude $U_0 = 1$and the corresponding power P = 1.2 mW which shows no effect on the pulse propagation

Figure. 1. shows the simulation of pulse propagation of input pulse corresponds to the case of single eigenvalue. This is referred to as the fundamental soliton because its shape does not change on propagation which agreed with the result of [6].

The input pulse was simulated using equation (26) where the distance is initially set to be zero to correspond at any point in time in a given pulse width. Fig. 4.1 is the simulation from the analytical result which is governed by equation (1.0), which is the solution to unperturbed CNLSE given by equation (26)

3.3 The Result and Discussion of first perturbation term of CNLSE

The result of the solution of first perturbation term of CNLSE was used to determine the effect of third order dispersion (TOD) term on solitary wave pulses in optical fiber was simulated using equation (36) as shown in Figure. 2

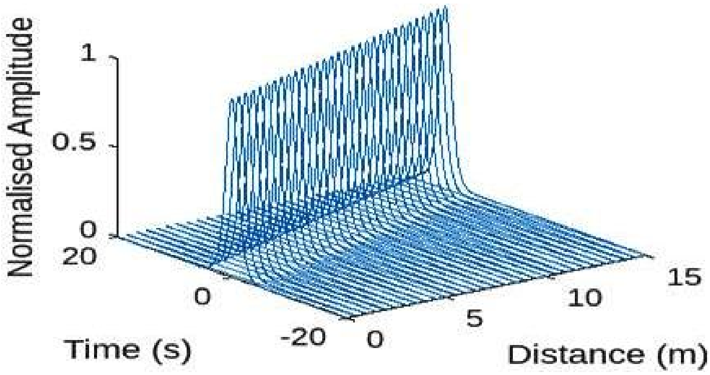

Fig. 2. Profile of first perturbation term of CNLSE pulse propagation using equation $T = 4b_1$ with dimensionless pulse width of $T = 0.64$, input pulse power P_0 = 1.2 mW, The maximum normalized amplitude is $U_0 = 1$.

Figure 3 shows the pulse propagation simulation of first perturbation term equation (27). The data was generated using equation (35). The result shows that the optical pulse propagated relatively far from the zero dispersion wavelength of an optical fibre, the TOD effect on soliton is small and can be treated as pertubatively. The simulation propagated at a maximum normalized amplitude 1 of which is approximately equal to the intensity of the fundamental input pulse and the velocity of pulse propagation is the same as that of the unperturbed equation. Finally, the frequency and amplitude are not affected. The pulse profile shown in figure 1.1 was partially similar with that of [5] because the input pulse of $T = 0.64$, input pulse power P_0 = 1.2 mW, The maximum normalized amplitude is $U_0 = 1$.

3.4 The Result and Discussion of Second Perturbation Term of CNLSE

The result of the solution of second perturbation term of CNLSE was used to examine influence of self stepenning on soliton pulse propagation using equation (47) as shown in Figure. 3

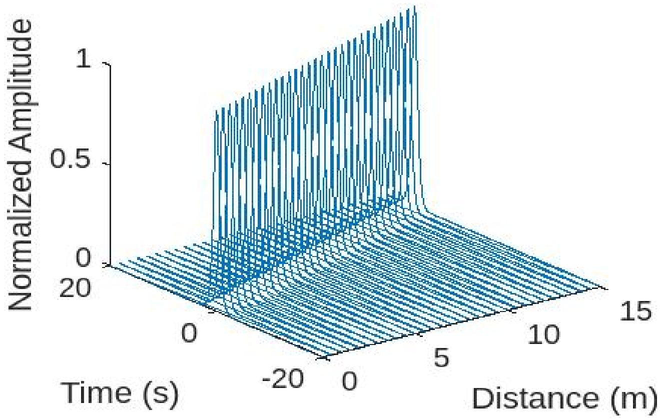

Figure 3: Profile of second perturbation term of CNLSE with dimensionless pulse width of $T = 0.03$, input power P_0 = 1.2 mW and Self Stepenning = *0.16*. The maximum normalized amplitude $U_0 = 1$ was obtained from the simulation in Fig. 3

The simulation presented in Figure 1.2 is the pulse profile solution of equation (47), which is the solution of the second perturbation term given by equation (37). The result shows that the pulse created an optical shock on the trailing edge of the pulse in the absence of GVD effect and TOD because of higher intensity dependence of the GVD that result in the peak of the pulse moving slower than the unperturbed CNLSE. The result also shows that the maximum normalized intensity is 1 which corresponded with input pulse of $T = 0.03$, input power P_0 = 1.2 mW and Self Stepenning = *0.16*. The maximum normalized amplitude $U_0 = 1$. The self stepenning was actually the one responsible for improving the pulse profile as it correspond with the result of [6].

4.0 Conclusion

This research investigated the numerical pulse simulation of CNLSE by using a mathematical method called the method of ansatz of solving differential equation. The solution of perturbed and unperturbed CNLSE and the result of analytical and numerical study of CNLSE soliton pulse propagation have been investigated and simulated using surfer simulation software and the data used for the simulation was generated using Microsoft office excel. The simulation the pulse profiles shows that the unperturbed CNLSE become so large that the pulse cannot form a soliton and becomes broader than the input pulse, the effect of perturbation terms such as TOD, Self steppening are responsible for improving the quality of compressed pulse.

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