ISSN:0971-1260
Vol-22- Issue-12-November-2019

Pulse Propagation And Its Dynamics Under Dissipative And Nonlinear Effects

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Introduction

For the last five decades, the development in optical fiber technology has revolutionised the way of communication. These days, large amount of data can be transferred over large distances with very little loss at much higher speed with the help of optical fibers. Traditionally, optical fibers were made from silicon but nowadays, optical fibers made up of fluoroaluminate, fluorozirconate and chalcogenide glasses. These fiber materials are observed to exhibit higher order nonlinear effects when they interact with light of higher intensity. These light-matter interaction often results in realization of nonlinear effects in the fiber [1]. These effects can have beneficial or detrimental effects on the pulse propagation through fiber. Generally, the propagation of pulse in optical fiber is governed by nonlinear Schrodinger equation (NLSE). [2]. But, with the introduction of femto-second pulses in the optical fiber communication, the higher order dispersive as well as non-linear effects are observed.

Model

Such system demonstrating the propagation of pulse in the presence of dispersive and nonlinear effects can be described by complex Ginzburg Landau equation (CGLE) [2, 3] as follow:

$$i\frac{\partial E}{\partial z}+\frac{1}{2}\frac{\partial^2 E}{\partial t^2}+|E|^2E+\gamma|E|^4E=\frac{i}{2}g_0E+\frac{id}{2}\frac{\partial^2 E}{\partial t^2}-\frac{i}{2}\alpha E-iK|E|^2E-i\nu|E|^4E$$

(1)

where, E is the amplitude of the pulse, normalized propagation distance by z and retarded time by t. The progress of the pulse with propagation is given by first term of eqn. (1). Group velocity dispersion (GVD) of the fiber is given by the second term. The cubic and quintic nonlinearities are represented by the third and fourth terms respectively. γ denotes normalized quintic nonlinearity

ISSN:0971-1260
Vol-22-Issue-12-November-2019

coefficient. g_0 and d represents the gain saturation and gain dispersion coefficients respectively. In third term denotes the loss present in the system and α stands for wave guide loss coefficient. The fourth and fifth terms are due to the Two Photon Absorption (TPA) and Three Photon Absorption (3PA) respectively. K symbolizes the TPA coefficient, while ν denotes 3PA coefficient.

We have taken the ansartz of following form for study:

$$E(z,t) = A(z)\sec h\left(\frac{t}{W(z)}\right)\exp\left(i\phi(z)\right)$$

Where, the complex amplitude, temporal pulse width and phase are represented by $A(z), W(z)$ and $\phi(z)$ respectively. The eqn. (1) can be solved using variational methods.

PULSE DYNAMICS UNDER DISSIPATIVE EFFECTS

The effect of multiphoton absorption on pulse propagation has been observed to be detrimental. as shown in Fig 1. TPA and 3PA individually have detrimental effect on the pulse propagation as depicted in Fig 1(a) and 1(b) respectively.

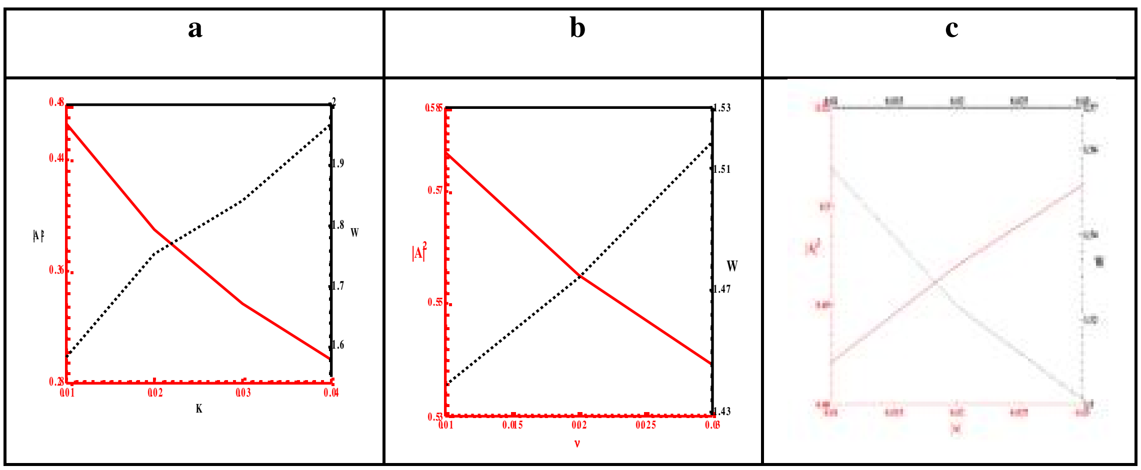

Figure 1. Decay of normalized pulse intensity and broadening of pulse width with increasing values of (a) TPA coefficient. ν= 0, γ= -0.1 and d=0.05, (b) 3PA coefficient. K= 0, γ= -0.1 and d=0.05. (c) Growth of normalized pulse intensity and pulse width condensation with increasing 3PE coefficient$|\nu|$. K= 0, γ = -0.1 and d=0.05.

The TPA and 3PA combined effect might be more detrimental but three photon emission (3PE) has been observed to have beneficial effect on the pulse propagation. Fig2 demonstrates the negative effects of TPA, 3PA separately and mutually. With rise in gain dispersion and quintic nonlinearity the intensity of pulse decreases and broadening has also

ISSN:0971-1260
Vol-22- Issue-12-November-2019

been observed. Careful assessment of fig. 2(a) and fig. 2(b) tells us that the pulse deterioration takes place at slower pace under the effect of 3PA.

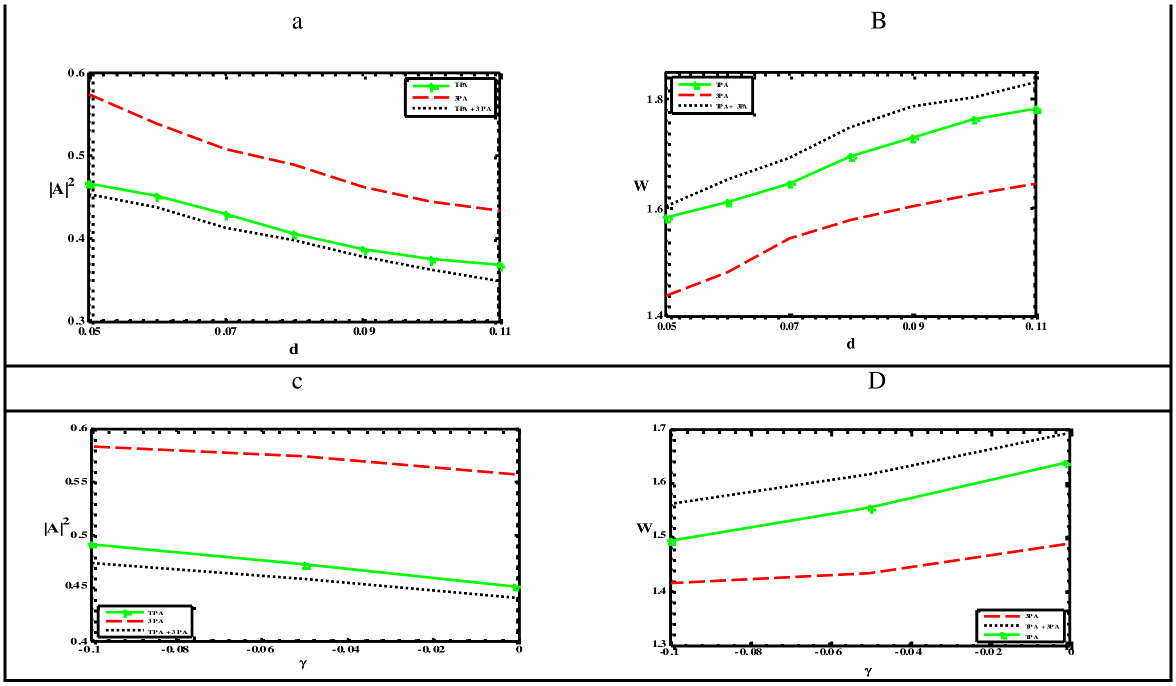

Figure 2. Variation of normalized (a) pulse intensity and (b) width with gain dispersion 'd' in presence of TPA, 3PA and both TPA and 3PA . For TPA, K= 0.01, γ= -0.1, ν= 0. For 3PA, K= 0, γ= -0.1, ν= 0.01. For both TPA and 3PA, K= 0.01, γ= -0.1, ν= 0.01. Variation of normalized (c) pulse intensity and (d) width with quintic nonlinearity 'γ' in presence of TPA, 3PA and both TPA and 3PA . For TPA, K= 0.01, d=0.05, ν= 0. For 3PA, K= 0, d=0.05, ν= 0.01. For both TPA and 3PA, K= 0.01, d=0.05, ν= 0.01.

As the system is dissipative in nature, the loss due to dispersion and multiphoton absorption can be compensated by providing proper gain to the system. With the introduction of gain in the system, the solitonic pulse propagation can be realised. Here, we not only realized the generation of solitonic pulse but we also studied the interaction of two solitons as shown in figure 3. Instead of periodic union and splitting they unites and exhibit breather like propagation. However at greater initial separation radiation increases and the composite soliton started destabilizing. The low intensity and hence small value of nonlinearity is responsible for the instability at larger separation. Up to an initial separation of 13 the two low amplitude solitons shows robust breathers.

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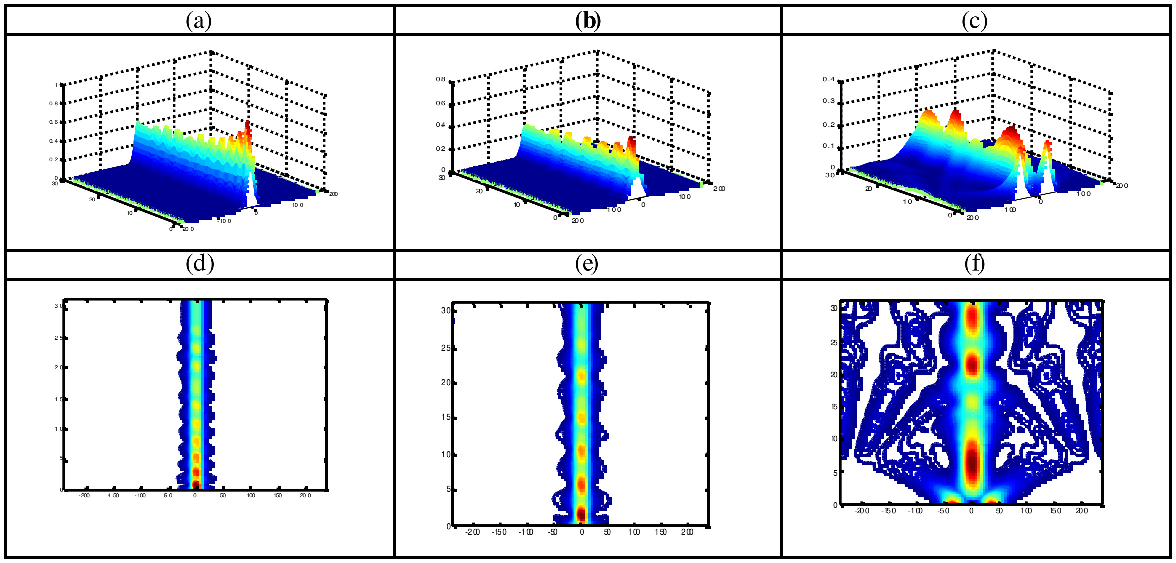

Fig3*. Interaction between two low amplitude DS for different initial pulse separation. (a) $T_g=0$, (b) $T_g=13$ and (c) $T_g=36$. The corresponding contour plots are (d), (e) and (f) respectively. Other parameters are $\gamma = -0.1$, $d=0.032\times D$, $K=0.01$ and $\nu = -0.01$. Net gain $(g_0 - \alpha)$ ranges from* 0.570×10^{-6} *to* 1.152×10^{-6}.

CONCLUSION

Propagation of pulse in the presence of dissipative and nonlinear effect has been studied. Multiphoton absorption has been observed to have significant effect on the pulse dynamics propagating through optical fiber. The decay of the pulse can be controlled by injecting proper gain into the system. Solitonic pulse generated shows robustness even on interacting with each other. Results can be helpful to study system dynamics and generation of all optical devices.

ISSN:0971-1260
Vol-22- Issue-12-November-2019

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