بیستمین کنفرانس اپتیک و فوتونیک ایران
و ششمین کنفرانس مهندسی و فناوری فوتونیک ایران
۸ تا ۱۰ بهمن ماه۱۳۹۲ - دانشگاه صنعتی شیراز

فشردگی پالس سالیتونهای تاریک مرتبه دو

الهام یوسفی[۱]، محسن حاتمی[۲]، رویا عطارزاده[۳] و مریم دهقانی[۴]

۱دانشگاه یزد، دانشکده فیزیک، گروه اتمی و مولکولی

۲ دانشگاه صنعتی شیراز، دانشکده فیزیک

۳دانشگاه آزاد اسلامی، واحد بهبهان، باشگاه پژوهشگران جوان، بهبهان، ایران

۴ دانشگاه پیام نور شیراز، گروه فیزیک

چکیده – در این مقاله با در نظر گرفتن ضریب پاشندگی و دوره تناوب، فشردگی سالیتونهای نوری مرتبه دو در فیبرهای نوری غیرخطی بررسی شده است. در شبیه سازیهای عددی خود از سالیتونهای نوری تاریک به دلیل پایداری بیشتر آنها در مقابل نویز نسبت به سالیتونهای نوری روشن استفاده شده است.

کلید واژه- سالیتونهای روشن، سالیتونهای تاریک، فیبر نوری غیرخطی، فشردگی پالس.

The Pulse Compression of Second-Order Dark Solitons

Elham Yousefi[1], Mohsen Hatami[2], Roya Attarzadeh[3], and Maryam Dehghani[4]

1Atomic and Molecular Group, Faculty of Physics, Yazd University, Yazd, Iran

2 Physics Department, School of Science, Shiraz University of Technology, Shiraz, Iran

3 Young Researchers Club, Behbahan Branch, Islamic Azad University, Behbahan, Iran

4 Department of Physics, Science and Research Branch, Payame Noor University, Shiraz, Iran

Abstract- In this paper with considering dispersion coefficient and period normal length, pulse compression 2-order solitons in nonlinear fiber optics is investigated. In our numerical simulation we have used optical dark solitons because of its more stability in presence of noise as compared optical bright solitons.

Keywords: Bright Solitons, Dark Solitons, Nonlinear Fiber Optics, Pulse Compression.

The Pulse Compression of Second- Order Dark Solitons

E. Yousefi **M. Hatami**
elham1252002@yahoo.com
mhatami@yazduni.ac.ir

R. Attarzadeh **M. Dehghani**
roya_Attar2009@yahoo.com
maryamdehghani98@yahoo.com

1 Introduction

An important application of nonlinear fiber optics consists of compressing optical pulses. Pulses shorter than $5\,fs$ have been produced by using dispersive and nonlinear effects occurring in optical fibers [1]. Pulse compressors based of nonlinear fiber optics can be classified two broad categories: grating fiber and soliton- effect compressors. A soliton- effect pulse compressor consists of only a piece of fiber whose wavelength is suitably chosen. Pulse compression takes place as a result of interplay between group velocity dispersion (GVD) and self-phase modulation (SPM). This method has been used since 1983[2,3].

Because dark solitons are more stable in the presence of noise and spread more slowly in the presence of loss as compared with bright solitons in optical communication systems[4-6]. In the recent work, by using soliton effects, make a new method to compress dark solitons in fiber. This method has significant advantages compared with other pulse compression methods because of its low cost and simplicity. We consider dark solitons with N=2 and investigate dark soliton pulse compression.

2 Second- Order Optical Dark soliton

Nonlinear Schrödinger Equation (NLSE) manages pulse propagation as follow [4]:

$$i\frac{\partial u}{\partial \xi} - \frac{\beta_2}{2}\frac{\partial^2 u}{\partial \tau^2} + \gamma |u|^2 u = 0 \qquad (1)$$

where, u is the normal slowly varying amplitude of the pulse envelope, ξ is the normal distance, τ is the normal time, β_2 is the second-order dispersion coefficient which is a positive number for dark soliton, and γ is the Kerr coefficient. The soliton order is defined by:

$$N = \sqrt{L_D / L_{NL}} \qquad (2)$$

where L_D is the dispersion length and L_{NL} is the nonlinear length of the soliton propagation. In this paper, specifically, we consider the fiber is a lossless media and the order of soliton is $N = 2$.

As known, dark soliton is the valley pulse in the uniform background. We want to simulate dark soliton pulse propagation in two cascaded fibers with Crank- Nicholson method.

At the first, we lunch the pulse with the form of $N\tanh(x)$ as an input pulse into the first fiber. Figure 1 shows output pulse of dark soliton with $N = 2$. In 2-order dark soliton, actually, the dispersion length is 2 orders higher than the nonlinear length. For investigate the compression in these kind of solitons we need some parameters like period normal length where after that, the pulse is repeated and reconstructed its first shape. The other important parameter that can be effective in pulse is dispersion coefficient. However, decreasing and increasing in dispersion coefficient make a considerable changes in pulse compression and its periodic time. One of important characteristic of the 2-order optical dark soliton in nonlinear fiber optics is the production of gray solitons in two sides of the central dark soliton in time domain. Even after one period of the fiber, these dark solitons are remaining. In Figure *2*, the input and output dark soliton with the $\beta_2 = -0.2$ in the fiber. As shown clearly in Figure 2, during through the length of fibers, the output pulse is narrower and most intense and also, the output pulse has two gray soliton is produced.

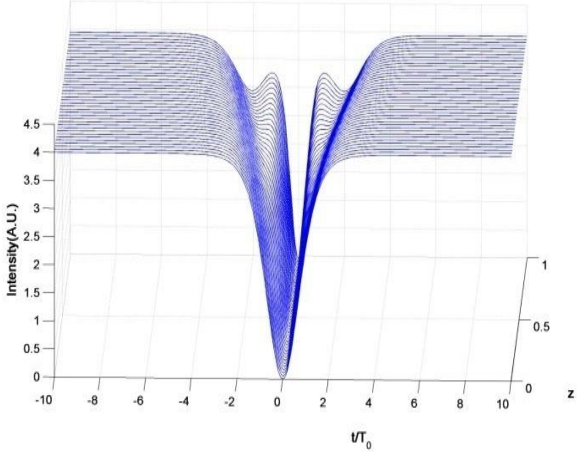


Figure 1: Output pulse of dark solitons with $N = 2$

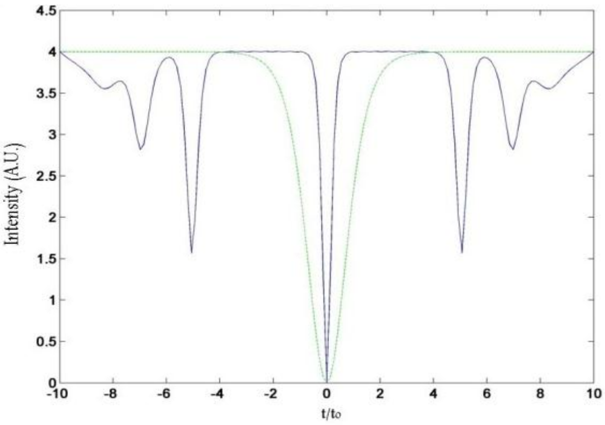


Figure 2: Dark soliton propagation in optical fiber; the green line is the input pulse and the blue line is the output pulse.

2.1 Second -Order Dark Soliton Period

In the Figure 3, the pulse evolution in different length is shown.

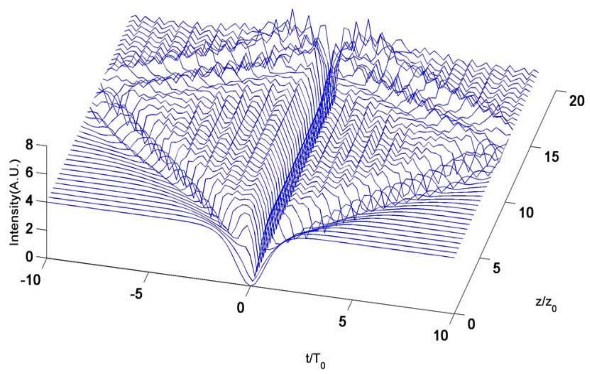
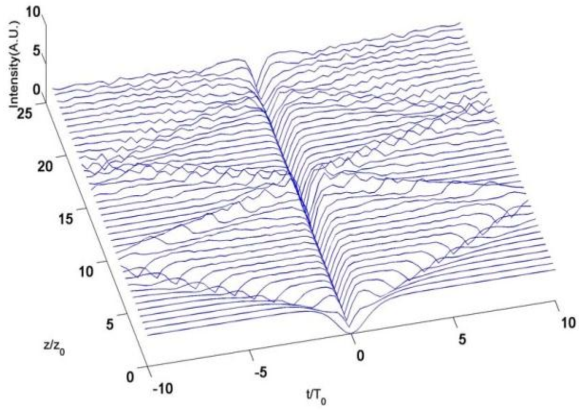
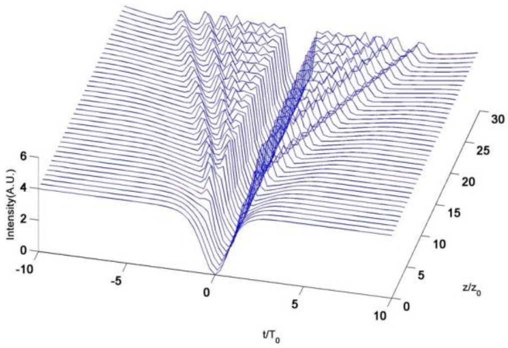


Figure 3: Simulation of 2-order dark soliton propagation in nonlinear fiber with $\beta_2 = -0.2$ and $z / z_0 = 17$.

As shown in Figure 3, dark soliton like the bright soliton, evolution to its first shape and repeated after characteristic length with little different in shape. There is considerable notice that if the dispersion coefficient is increased, the periodic length is decreased and the soliton pulse is constructed in lower distances. In Figures 4, two dark solitons with different dispersion coefficient are compared. If the dispersion coefficient increases, the total normal length decrease and the pulse in lower distance repeated.



(a)



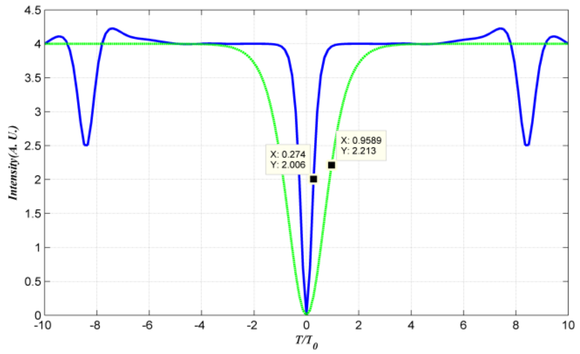
(b)

Figure 4: Dark soliton propagation in nonlinear optical fiber with: (a) $z / z_0 = 25$ and $\beta_2 = -0.4$, (b) $z / z_0 = 30$ and $\beta_2 = -0.01$.

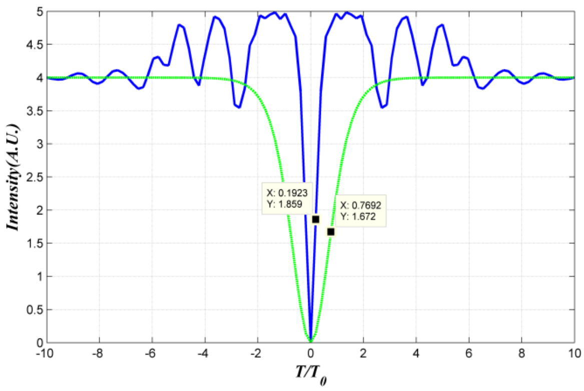
2.2 The Compression of Second-Order Dark Optical Soliton In Nonlinear optical Fiber

In 2-order dark soliton, if we decrease the value of second order dispersion coefficient, the pulse compression is increased but this pulse compression has a low limit where lower that the compression of pulse is not change. In this section considering two various values for β and simulated numerically dark soliton propagation. In Figure 5, we take $\beta_2 = -0.4$ and we have shown dark solitons propagation in $z/z_0 = 6 and 12$. As shown, in both $z/z_0 = 6 and 12$ pulse is compressed in time zero. In Figure 5(a) the rate of value of input soliton pulse compression to value of output soliton pulse compression is approximately 3.5 and in Figure 5(b) this ratio is nearly 4. Also in $z/z_0 = 6$ pulse is compressed but its intensity is the same with input pulse intensity.

In Figure 6, we take $\beta_2 = -0.7$ and we have shown dark solitons propagation in $z/z_0 = 6 and 12$. In Figure 6(a) the rate of value of input soliton pulse compression to value ofoutput soliton pulse compression is approximately 2 and in Figure 6(b) this ratio is nearly 2.5.

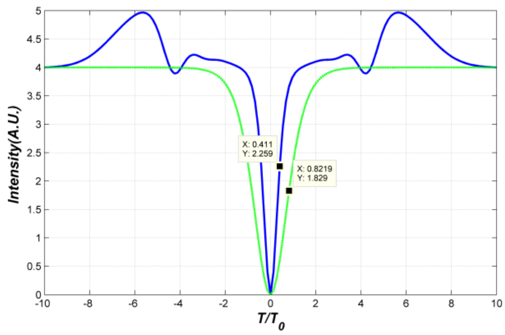


(a)



(b)

Figure 5: Pulse shapes and its compression with $\beta_2 = -0.4$ (a) $z/z_0 = 6$, (b) $z/z_0 = 12$.



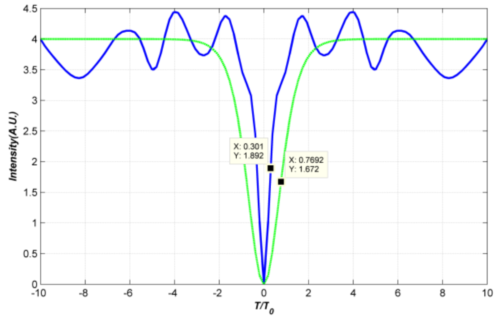


Figure 6: Pulse shapes and its compression with $\beta_2 = -0.7$ (a) $z/z_0 = 6$, (b) $z/z_0 = 12$.

3 Conclusion

In this paper pulse compression for second-order of dark solitons in nonlinear fiber optics is investigated. In 2-order dark soliton, if we decrease the value of second order dispersion coefficient, the pulse compression is increased. Also the larger the dispersion coefficient of 2-order dark soliton is the more compression of central soliton.

References

[1] G. P. Agrawal, *Applications of Nonlinear Fiber Optics*, Academic Press, pp.12-85, 2011.

[2] V. C. Kuriakose and K. Porsezian, *Elementsof Optical Solitons: An Overview*; RESONANCE, July 2010.

[3] Q. Li , J. N. Kutz and P. K. A. Wai,“ cascaded higher order soliton for non-adiabatic pulse compression” *J. Opt. Soc. Am. B.* Vol. 27, No. 11, pp. 2180-2189, 2010.

[4] G. P. Agrawal, *Nonlinear Fiber Optics*, Academic Press, pp. 125-140, 2005.

[5] Zakeri A, Hatami, "Design of an ultra-fast all-optical dark soliton switch in a nonlinear directional coupler (NLDC) made of chalcogenide glasses" *J. Phys. D: Appl. Phys.* M40, pp. 1010-1016, 2007.

[6] M. Hatami, R. Attarzadeh, A. Gharaati, "Design of an all- optical dark soliton switch in a three- core nonlinear directional coupler (TNLDC) made of chalcogenide glasses". *JNOPM*, 21 pp. 1250038(1-6) , 2012.