ATLANTIS PRESS

Advances in Engineering Research, volume 184

2nd International Conference on Sustainable Energy, Environment and Information Engineering (SEEIE 2019)

The Research on Propagation of Ultrashort Pulse in Normal Group-velocity Dispersion Fiber

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***Abstract*—In this paper, we investigate the properties of ultrashort pulse propagation in normal group-velocity dispersion (GVD) fiber based on nonlinear Schrodinger equation. A numerical model is established and is programmed and calculated by the split-step Fourier transforms. Nonlinear pulse evolution transmitted in normal dispersion fiber with gain is stimulated through computer. Some useful conclusions are obtained.**

Keywords—ultrashort pulse; normal group-velocity dispersion fiber;nonlinear Schrodinger equation; split-step Fourier transforms

I. INTRODUCTION

Ultrashort laser pulses, which have a lot of remarkable advantages, such as high repetition rate, wide spectrum, high peak power and so on, can be applied extensively in the civil, communication, mechanical, energy, military and other fields[1-6].

However, the very high peak power is often required in practical research and application of ultrashort pulses. If the pulse is direct output from laser, the performance of saturated absorber of laser is highly demanded. One disadvantage of laser amplification that cannot be ignored is lasers are expensive, especially in the high power amplification process, the saturated absorber of the laser is very easy to be destruction, which increases the cost of laser amplification.

The optical fiber amplifier technology is a good method to solve the problem because it has many advantages. The optical fiber structure has good strength and toughness and is not easily damaged by physical damage. The cladding structure of the optical fibers protects the stability of the optical fibers. Pulse propagates in the normal group-velocity dispersion (GVD) fibers and is not easily affected by external factors, thus ensuring the stability of the system.

The normal dispersion fiber, which is stable and the loss threshold is relatively large, is suitable for high power transmission and amplification. Therefore, it is necessary and practical to study the optical fiber amplification technology of ultrashort pulses. The paper is structured as follows: starting from the theoretical model in section II, the theoretical model is introduced. In section III, the ultrashort pulse propagation and amplification are investigated and discussed. A brief conclusion is given in section IV.

II. THEORETICAL MODEL

The simulation is based on nonlinear Schrodinger equation (NLSE):[3-6]

$$i\frac{\partial\psi(Z,T)}{\partial Z} = \frac{\beta_2}{2}\frac{\partial^2\psi(Z,T)}{\partial T^2} - \gamma\left|\psi(Z,T)\right|^2\psi(Z,T) + i\frac{g_0}{2}\psi(Z,T) \qquad (1)$$

For an amplification with a constant longitudianal gain g_0, it has been demonstrated that the NLSE admits of an parabolic asymptotic solution as follows.[4-6]

$$\psi(Z,T) = \sqrt{P(Z)}\left\{1-\left[\frac{T}{\tau(Z)}\right]^2\right\}^{1/2}\exp[i\varphi(Z,T) \quad , \quad |T| \le \tau(Z),\ \ Z\to\infty \qquad (2)$$

where, $P(Z) = \frac{E_0^{2/3}}{4}[\frac{2g_0^{\ 2}}{\gamma\beta_2(1+g_0Z)}]^{1/3}$,

$\tau(Z) = 3E_0^{1/3}[\frac{\gamma\beta_2(1+g_0Z)}{2g_0^{\ 2}}]^{1/3}$,

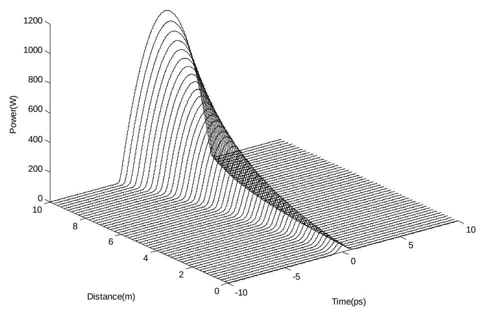
and $\varphi(Z,T) = -\frac{g_0}{6\beta_2}T^2 + \gamma\int_0^z P(Z^{'})dZ^{'}$.

where, $\psi(Z,T)$ is the pulse envelope in a co-moving frame; chirp is $\delta\omega(t) = -\frac{\partial\phi}{\partial t}$, β_2 is normal GVD, g_0 is gain coefficient, nonlinearity coefficient γ, ω_0 is mid frequency and T_0 is pulse width.

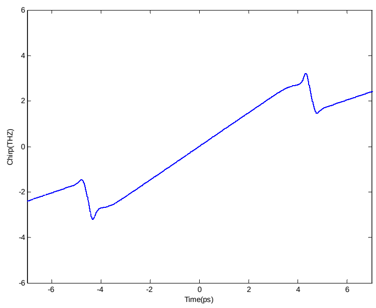
III. SIMULATION ANALYSIS

We solve the GNLS equation by split-step Fourier method, for the input field a Gaussian pulse with g_0 = 0.5 m^{-1}, β_2 = 4.6 × 10^{-2} ps^2/m, γ = 2.5 × 10^{-3} $W^{-1}m^{-1}$, λ_0=1550nm,

T_0=0.5ps, E_0=40pj. Evolution of the parabolic pulses is simulated numerically as follows.



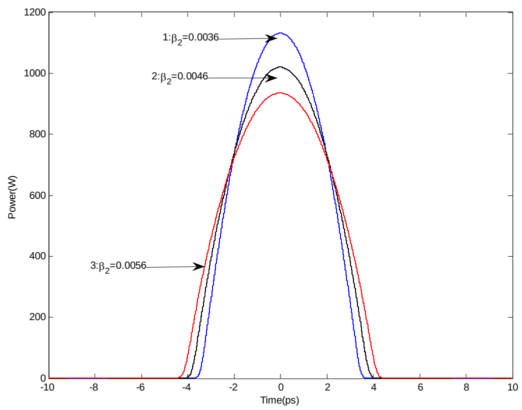
(a) waveform



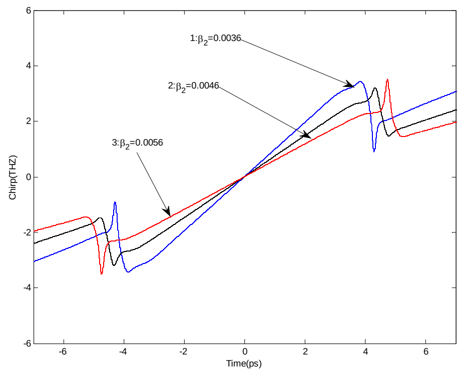
(b) chirp

FIGURE I. THE EVOLUTION OF PARABOLIC PULSE (A) WAVEFORM AND (B) CHIRP

From Figure I, we can find that the parabolic pulse is generated and transmitted. In order to analyze the influence of different dispersion effect in detail, we discuss them respectively.



(a) waveform



(b) chirp

FIGURE II. THE EVOLUTION OF PARABOLIC PULSE WITH β_2 (A) WAVEFORM AND (B) CHIRP

From the Figure II, with the increase of β_2, we can see a considerable pulse broadening is observed, and the chirp become greater linearity which can be used in higher output power.

IV. CONCLUSION

In summary, the evolution of ultrashort pulse is investigated which propagates in normal group-velocity dispersion (GVD) fiber and is simulated by nonlinear Schrodinger equation. The parabolic pulse and linear chirp would improve the output power greatly. The results is significant for the developmental research of high power pulse technology.

ACKNOWLEDGEMENT

This research was financially supported by the Foundation for Distinguished Young Talents in Higher Education of Guangdong, China, (No. 2016KQNCX195), the Guangdong provincial College Students' innovation and entrepreneurship training program(No. 201813714013), and College Students' innovation and entrepreneurship training program of Guangzhou College of Technology and Business (No. xj201913714079).

REFERENCES

[1] Toshihiko Hirooka and Masataka Nakazawa, Parabolic Pulse Generation by Use of a Dispersion-decreasing Fiber with Normal Group-velocity Dispersion, Opt. Lett, 2004, 29(5): 498-500.

[2] F.O.Ilday, J.R.Buckley, W.G.Clark and F.W.Wise, Self-similar Evolution of Parabolic Pulse in a Laser, Phys. Rev. Lett, 2004, 92(21): 213902(1-4).

[3] C.K.Nielsen, B.Ortac, T.Schreiber, and J.Limpert, Self-starting Self-similar All-polarization Maintaining Yb-doped Fiber Laser, Opt. Lett, 2005, 13(23): 9346-9351.

[4] Feng Jie，Du Guoping, Zhu Ruixing, Huang Lei，Progress of Ultra-Short Self-Similar Pulse Optical Fiber Lasers[J] ， Laser&Optoelectronics Progress(2011)，48 , 081409 : 1-15.

[5] Shi J K, Chai L, Zhao X W, et al. Amplifier similariton oscillator using 10m photonic crystal fiber[J]. Acta Phys. Sin., 2015, 18(64):184210.1-6

[6] Li Chao,Zhao Lei, Huang Zhihua,Lin Honghuan,Tian Xiaocheng,Deng Ying,Huang Xiaojun,Zhu Qihua,Theory Study on Self-similar Pulse in Mode-Locked Fiber Laser[J],Chin. Journal of Lasers 2013,40(6), 0602017:1-6.

[7] Li Chao,Zhao Lei, Huang Zhihua,Lin Honghuan,Tian Xiaocheng,Deng Ying,Huang Xiaojun,Zhu Qihua,Theory Study on Self-similar Pulse in Mode-Locked Fiber Laser[J].Chin. Journal of Lasers 2013,40(6), 0602017:1-6 (in Chinese).

[8] Ozeki.Y, Takushima.Y, Aiso.K, et al. Generation of 10 GHz similariton pulse trains from 1,2 km-long erbium-doped fibre amplifier for application to multi-wavelength pulse sources[J]. Electron. Lett., 2004,40(18):1103-1104.

[9] Nie B, Pestov D, Wise F W, et al. Generation of 42-fs and 10-nJ pulses from a fiber laser with self-similar evolution in the gain segment[J]. Opt.Express,2011, 19(13):12074-12080.

[10] Lefrancois S, Liu C H, Stock M L，et al. High-energy similariton fiber laser using chirally coupled core fiber[J].Opt.Lett.,2013, 38(1):43-5.

[11] G.P. Agrawal. Nonlinear Fiber Optics (Academic, San Diego, Calif, 1995)