Optics & Laser Technology 43 (2011) 1321–1324

Contents lists available at ScienceDirect

Optics & Laser Technology

journal homepage: www.elsevier.com/locate/optlastec

Pulse compression in dispersion-decreasing-like fibers

Hongjun Zheng [a,b,*], Shanliang Liu [b], Xin Li [b], Chongqing Wu [a]

[a] School of Science, Beijing Jiaotong University, No. 3 Shang Yuan Cun, Hai Dian District Beijing, Beijing 100044, P.R. China
[b] Institute of Optical Communication, Liaocheng University, Culture Road 34, Liaocheng Shandong 252059, P.R. China

ARTICLE INFO

Article history:
Received 1 January 2011
Received in revised form
22 March 2011
Accepted 29 March 2011
Available online 15 April 2011

Keywords:
Pulse compression
Nonlinear propagation
Temporal waveform

ABSTRACT

Pulse compression characteristics in dispersion-decreasing-like fibers (DDLF) are firstly investigated by employing the second-harmonic generation frequency-resolved optical gating (SHG-FROG) technique, are compared with the numerical results that are obtained using the split-step Fourier method. It is found that the experimental data are consistent with the numerical results. The results show that the pulse compression method is effective. The pulse can be effectively compressed and its spectrum can be broadened in the DDLF. That the pulse compression effect is enhanced with the increase of the input power is in correspondence with the spectrum broadening.

1. Introduction

Pulse compression, which is an important nonlinear effect, has been attracting more and more attention in the applications of optical transmission and high-energy field in recent years [1–14]. There are several methods of pulse compression such as by employing fiber-grating compression [1–3] and using high-order soliton compression in standard single-mode fiber (SSMF) [4,5], dispersion-shift fiber (DSF) [1–6], dispersion-decreasing fiber (DDF) [7–10], photonic-crystal fiber (PCF) [10–12], comblike dispersion profiled fiber (CDPF) [13,14] and step like dispersion profiled fiber (SDPF) [15]. However, previous research on pulse compression is normally performed using the autocorrelation technology so that the temporal waveform and other characteristics of the pulses cannot be exactly determined [4–15]. It shows that deep study in the correlative field need use of new methods. The method of second-harmonic generation frequency-resolved optical gating (SHG-FROG) can exactly measure temporal waveform and other parameters of the optical pulse [16–19]. In order to perform deep investigation in this field, we investigate pulse compression characteristics in dispersion-decreasing-like fibers (DDLF) by employing the SHG-FROG technique. The proposed DDLF is made up of a segment of SSMF with high dispersion, a segment of DSF with middle dispersion and a segment of dispersion-flatted fiber (DFF) with low dispersion. We firstly measure temporal waveform and phase of the input pulse using the SHG-FROG technique. Then, we obtain the expression and other parameters of the input pulse from the experimental data for numerical investigation. Finally, we compare the experimental data of pulse compression with the numerical results which are obtained using the split-step Fourier method (SSFM).

2. Characteristics of input optical pulse

Fig. 1 shows the experimental setup. Optical wave at wavelength of 1551.9 nm is generated from a DFB laser, is inputted into a 40 GHz modulator after passing through a polarization controller, is modulated by 21.6 GHz clock pulse which is generated from Agilent 43 Gbit/s parallel bit error ratio tester (ParBERT) system 81250. The modulated optical pulse is amplified by an erbium-doped fiber amplifier (EDFA), is compressed in the DDLF, is measured using the SHG-FROG technique and an optical spectrum analyzer AQ6319.

We measure temporal waveform and other parameters of the modulated optical pulse, and import the experimental data into MATLAB program to obtain the expression of the experimental pulse and other parameters use of curve fitting. Fig. 2 shows temporal waveform and phase curve of the pulse for $Ip=3$A (the two pumped currents of the EDFA are all 3A). The solid dots show the experimental data, which are well fitted by

$$U(0,T)=\cos\left(\frac{T}{T_0}\right)\exp\left(-\frac{iCT^2}{2T_0^2}\right), \tag{1}$$

where $U(0,T)$ is incident field of the input optical pulse, T is the time, $T_0=\Delta T/1.5708=23.22/1.5708$ ps is the half-width at the $\cos^2(1)-$intensity point, ΔT is the full width at half maximum of the pulse, $C=-1.5$ is linear frequency chirp parameter. Fig. 3

* Corresponding author. Tel.: +86 635 8231235; fax: +86 635 8238167.
E-mail addresses: hjzheng@yahoo.com, zhj@lcu.edu.cn (H. Zheng), cqwu@bjtu.edu.cn (C. Wu).

0030-3992/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.optlastec.2011.03.032

shows the optical spectrum of the input pulse. Solid curve is the experimental spectrum, dotted curve is the Fourier transformation of Eq. (1) obtained by use of numerical method. The experimental spectrum is basically symmetrical about central wavelength, its spectral width (−3 dB) is 0.12 nm. It shows that the optical spectrum and temporal waveform of the input pulse are regular. The experimental spectrum is consistent with the numerical one. The spectral width is almost unchanged with the increase of the input power.

3. Temporal characteristics of pulse compression

We input the optical pulse into various DDLFs for pulse compression. It is found from the experimental and numerical results that one can obtain a good characteristics in the DDLF when the total value of second-order dispersion parameter of the DFF is about one-third as much as that of the DSF and the parameter value of the DSF is about one-third as much as that of the SSMF. In our experiment, the mode field diameter of the SSMF is 9 μm, the dispersion parameter is 14.81 ps/(nm km) at 1550 nm, the dispersion slope is 0.085 ps/(nm^2 km), the fiber loss is 0.183 dB/km, the length is 2.17 km. The mode field diameter of the DSF is 9.5 μm, the dispersion parameter is 6.02 ps/(nm km) at 1565 nm, the dispersion slope is 0.077 ps/(nm^2 km), the fiber loss is 0.199 dB/km, the length is 2.162 km. The mode field diameter of the DFF is 7.27 μm, the dispersion parameter is 0.177 ps/(nm km) at 1550 nm, the fiber loss is 0.226 dB/km, the length is 12.7 km. The totle second-order dispersion parameters of the SSMF, DSF and DFF at 1551.9 nm are −41.45, −14.26 and −3.81 ps^2, respectively. The theoretical model can be modified by [1]

$$i\frac{\partial U}{\partial \xi}+\frac{1}{2}d(\xi)\frac{\partial^2 U}{\partial \tau^2}+|U|^2U=-0.5i\alpha_s L_D U, \tag{2}$$

where U is the normalized incident field, ξ is the normalized propagation distance, $d(\xi)=\beta_2(\xi)/\beta_2(0)$ is normalized dispersion of the DDLF, $\tau=T/T_0$ is the normalized time, α_s is the fiber loss coefficient (average) at signal wavelength, L_D is a dispersion length. Pulse compression characteristics are numerically investigated by use of SSFM according to Eq. (2). The input pulse is Eq. (1) which is obtained from the experimental data using the SHG-FROG technique.

Fig. 4 shows that temporal width of the chirped pulse varies with the normalized propagation distance (17.032 km) using the SSFM. Solid curve is the numerical result, solid dot is experimental datum of the output pulse for $Ip=3$ A. It is found that the input pulse with initial negative chirp is gradually compressed with the propagation distance in the DDLF except an initial broadening at the beginning. The numerical width 2.72 ps of the output pulse is consistent with the experimental width 2.42 ps, is much less than the initial width 23.22 ps. Temporal waveform of 2.42 ps output pulse is shown in Fig. 5. The solid dots show the experimental data of temporal waveform, solid curve shows numerical one. It can be obtained that experimental waveform of output pulse is basically consistent with the numerical one, and has little pedestals. The temporal width 2.42 ps of output pulse is about one-tenth as wide as the initial width, is about one-fourth as wide as the experimental width 9.26 ps for $Ip=1.5$ A. It shows that the chirped pulse can be effectively compressed in the DDLF, and the ratio of pulse compression is increased with the increase of the input power. It is predicted that temporal compression of the pulse is in correspondence with the spectrum broadening [1]. Fig. 6 shows the experimental spectrum of output pulse for

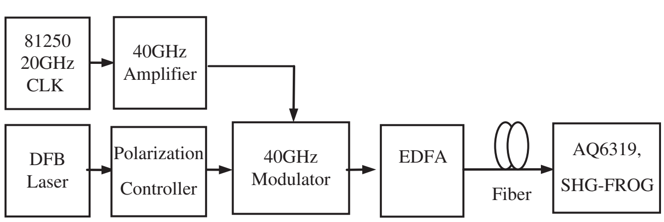

Fig. 1. Experimental setup.

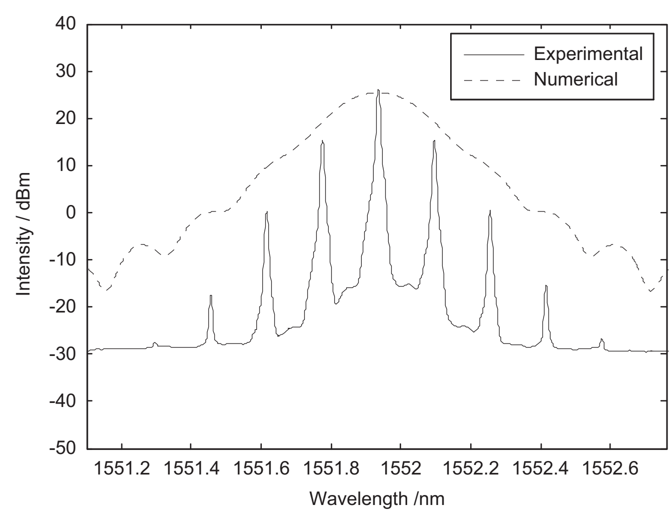

Fig. 3. Optical spectrum of the input pulse. Solid curve is the experimental spectrum, and dotted curve is the Fourier transformation of Eq. (1).

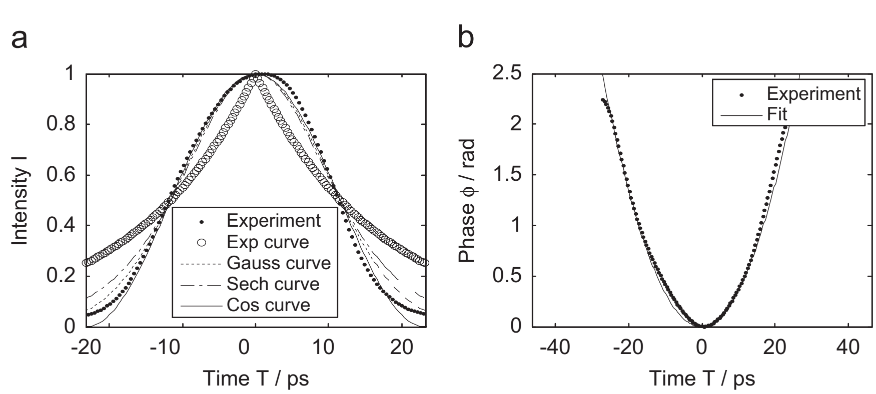

Fig. 2. Temporal waveform (a) and phase curve (b) of the input optical pulse. The solid dots show the experimental data. Circles shows the double-side exponential curve, dotted curve shows a Gaussian one, dot-dashed curve shows hyperbolic secant curve, solid curve shows cosine curve in (a) and solid curve is the phase curve of Eq. (1) in Fig. 2(b).