120-nm, 10-GHz supercontinuum generation in a dispersion-shifted fiber pumped by a three-stage compressed gain-switched DFB laser

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The supercontinuum (SC) generation in conventional dispersion-shifted fiber (DSF) at the repetition rate of 10 GHz with a three-stage compressed gain-switched distributed feedback (DFB) laser as pump source was demonstrated. A novel SC pulse source with a bandwidth up to 120 nm was obtained. At the same time, the stable, narrow pulses with pulsewidth of 9.2 ps and time-bandwidth product of 0.46 were filtered out across the whole SC bandwidth.

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Wavelength-division multiplexing (WDM) and optical time-division multiplexing (OTDM) are two different kinds of technologies for constructing large capacity (> 1 Tb/s) optical communication networks in the future. Now, there is a tendency of combining WDM with OTDM for expanding the transmission capacity over Tb/s. Fiber-based supercontinuum (SC) ultrashort pulse source can simultaneously produce narrow optical pulses in wide spectral range, so it will play an important role in future WDM/OTDM networks[1−3]. Besides using as transmission source in optical communication, SC pulse source has been in great demand for a wide variety of applications, such as wavelength conversion[4] all-optical switching,[5] optical coherence tomography,[6] optical metrology[7] and so on.

The properties of the SC depend considerably on the type of fiber used for the nonlinear spectrum expansion as well as ultra-short pump pulses. To date, most fiber-based SC generations with bandwidth greater than 100 nm have used special fibers as nonlinear media, such as dispersion decreasing fiber[8] (DDF), dispersion flattened fiber[9](DFF), dispersion-flattened dispersion decreasing fiber[10] (DFDF), photonic crystal fiber[11] (PCF) and other special fibers. In this paper, we report on a SC pulse source with a bandwidth of 120 nm generated in conventional dispersion-shifted fiber (DSF) pumped by a three-stage compressed gain-switched DFB laser with repetition rate of 10 GHz.

Figure 1 shows the experimental setup, which is divided into two parts. In the first part, pulses from a 10-GHz gain-switched DFB laser with central wavelength of 1552.6 nm are compressed by a novel three-stage optical pulse compressor, which includes chirp compensation in dispersion compensating fiber (DCF_1), compressing in anomalous dispersion fiber followed normal dispersion fiber and in comb-like dispersion profile fiber (CDPF), in order to reduce the pulse width and increase the peak power. In the second part, the compressed pulse has been amplified by a high power Er^{3+}-doped fiber amplifier ($EDFA_3$) before it is injected into the DSF to generate SC spectrum. The amplifier introduces amplified spontaneous emission (ASE) noise, so a bandpass filter ($OBPF_1$) is used to remove it. The length, the zero-dispersion wavelength, and the dispersion slope of DSF used for SC generation are 4.2 km, 1543 nm, and 0.0676 ps/nm^2/km, respectively. An optical bandpass filter ($OBPF_2$) centered at 1525 nm with 0.4-nm bandwidth is used to filter out ultrashort pulses across the SC spectrum. The waveform of the output pulse is observed by a sampled oscilloscope. Moreover, an autocorrelator is also needed to measure the precise pulse width. The spectrum either before or after $OBPF_2$ is measured by an optical spectrum analyzer (OSA) with resolution of 0.05 nm.

The initial width of the pulse produced by the 10-GHz gain-switched DFB laser was 28 ps. Figure 2 shows its waveform and spectrum. The bandwidth, time-bandwidth product are 0.56 nm and 1.96, respectively. Subsequently, the output pulse is compressed using a novel three-stage optical pulse compressor. At first, a segment of DCF with β_2 of 36 ps^2/km is used to compensate the negative chirp of the output pulse of the gain-switched DFB laser. The fiber length is 1.8 km. The second stage compressor is composed of normal dispersion fiber and anomalous dispersion fiber. $EDFA_2$ amplifies input power strong enough for the anomalous dispersion fiber. In the experiment the length of the normal dispersion is 1.09 km with the same parameter of the above DCF_1. The length of the anomalous dispersion fiber is 1.96 km, with β_2 is -20 ps^2/km. The third stage compressing is CDPF made of DSF (β_2 is -1.2 ps^2/km) and the anomalous dispersion fiber (β_2 is -17 ps^2/km) welding alternatively. The welding procedure must be well done to minimize the welding loss. The length of CDPF is 7.323 km with the loss of 8 dB.

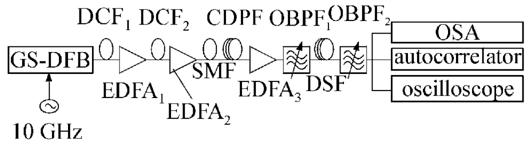

Fig. 1. Experimental setup for SC generation and measurement.

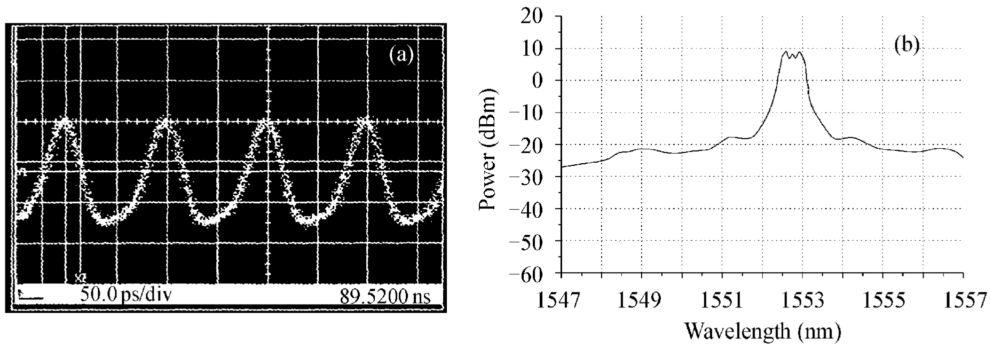

Fig. 2. (a) Waveform and (b) spectrum of pulse from gain-switched DFB laser.

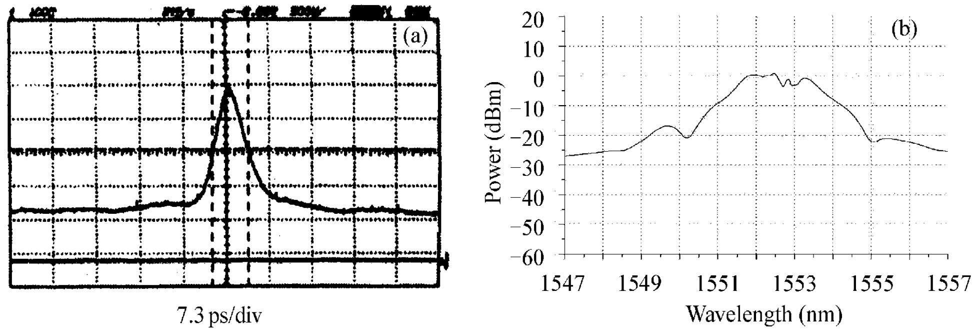

Fig. 3. (a) Autocorrelation trace and (b) spectrum of the output of the compressor of the comb-like dispersion profile fiber.

The autocorrelation trace of the compressed pulse with width of 3 ps is shown in Fig. 3(a). The corresponding spectrum with width of 1.9 nm is shown in Fig. 3(b).

The compressed pulse with width of $\sim$ 3 ps is actual pumping pulse, which was amplified by the $EDFA_3$ and launched into the DSF in which the SC was generated. During this experiment, there exists an obvious threshold pump power in SC generation. As the pump power is exceeded the threshold, SC bandwidth increases dramatically. Figure 4 shows SC spectra measured when peak pump powers are 1, 2, 3, 4, and 5 W. As the peak power of the input pulse increases, a broader spectrum is obtained. When the peak power of 5 W launched into the DSF, the −20 dB bandwidth is 120 nm, as shown in Fig. 4. A small peak around 1552.6 nm observed in the spectrum is residual pump light from the laser. The generated SC pulses remained very stable and changes in the input polarization state of the pump pulse did not essentially affect SC generation.

The SC pulse characteristics of pulse width and spectral width were measured by filtering the SC output with a 0.4-nm optical bandpass filter centered at 1525 nm. Figures 5(a), (b), and (c) show the spectrum, actual waveform, and autocorrelation trace of the pulse carved

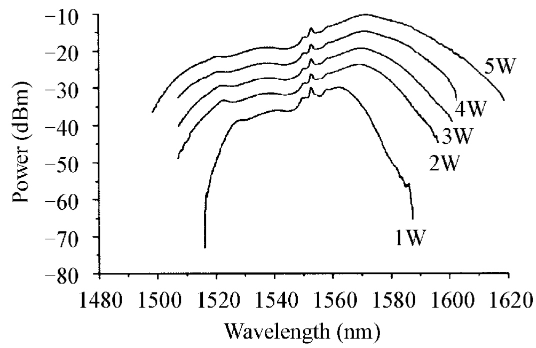

Fig. 4. SC spectra measured when input peak powers are 1, 2, 3, 4, and 5 W.

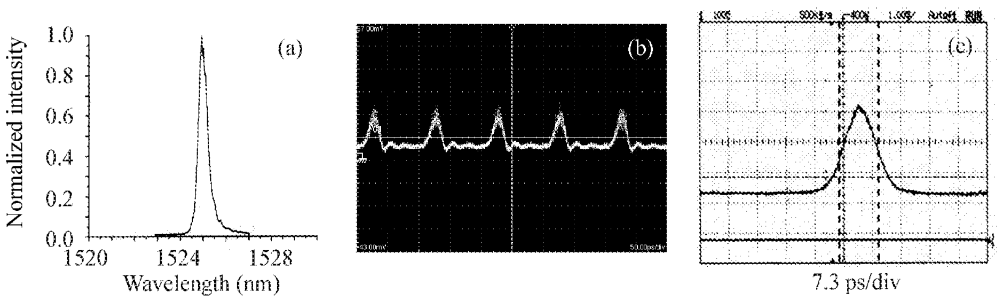

Fig. 5. (a) Spectrum, (b) waveform and (c) autocorrelation trace of SC pulse filtered at 1525 nm when the peak power is 5 W.

from SC at 1525 nm when the input peak power is 5 W. Both the autocorrelation trace and the spectrum are smoothing, which means the SC source is quite stable. The pulsewidth is 9.2 ps and the time-bandwidth product is 0.46, indicating that the pulse contains a little frequency chirp.

In summary, an ultrashort pulse source with SC up to 120 nm at a repetition rate of 10 GHz has been demonstrated with a three-stage compressed gain-switched DFB laser as pump source and its some basic characteristics are studied experimentally. At the same time, the stable, narrow pulses with mean pulsewidth of 9.2 ps and time-bandwidth product of 0.46 are filtered from the whole SC bandwidth.

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