Wide Broadband Supercontinuum Generated in Conventional Dispersion-shifted Fiber*

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Abstract The whole evolution of supercontinuum (SC) is observed experimentally and explained theoretically. Widely broadened SC spectra are generated from 1311 nm to 1780 nm in 2.5 km conventional dispersion-shifted fiber with 55 mW average pump power. Over more than 196 nm spectrum region on the long wavelength side with ±1 dB uniformity is obtained. More than 92 and 46 channels with flattop are sliced from the SC by an F-P filter. By using only 100 m the same type of fiber, we obtained 453.3 nm, 20 dB bandwidth covers S-, C-, and L-band seamlessly.

Keywords Supercontinuum; Dispersion-shifted fiber; Stimulated Raman Scattering
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0 Introduction

Recently, numerous investigations on supercontinuum (SC) generation in optical fiber with pump pulses from nanosecond to femtosecond durations were published[1~5]. Since SC is a multiple wavelength source with large and uniform bandwidth, accurate wavelength spacing, high coherence and high-power spectral density, it has been widely used in optical waveform sampling, group-velocity dispersion measurement, optical coherence tomography etc as well as optical communication. Multiple wavelength pulse sources with more than 100 nm spectral bandwidth generated in long fibers (> 1 km) have been demonstrated by different groups. For example, it has been reported that an SC bandwidth more than 280 nm was observed by using 1km-long dispersion-flattened and decreasing fiber (DFDF) when the peak power of the launched pulse was only 12 W[6]. In 2000, O. Boyraz obtained 250 nm 20 dB bandwidth SC in only 4 m HNL-DSF[7]. The generation of SC spectrum reaching wavelength of 2.1 μm was firstly observed by using 200 m polarization maintaining HNL-DSF[8]. In 2003, M. Seefeldt obtained a spectral range from 700 to 1600 nm in a dispersion-adapted air-silica microstructured fiber pumped by a passively mode-locked Nd: YVO_4 laser[9].

However, those special type fibers they used are difficult to fabricate and fairly expensive. In this paper, we present broadband flat SC in 2.5 km conventional dispersion-shifted fiber (DSF). On the right side of zero dispersion wavelength λ_0, more than 260.5 nm 20 dB bandwidth is obtained, in which more than 196 nm spectrum region has ±1 dB uniformity. On the opposite side, 185.5 nm 15 dB bandwidth is also generated. 453 nm 20 dB bandwidth SC is also obtained by using only 100 m the same kind of DSF.

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1 Experimental setup

The experimental set-up for generating the SC is shown in Fig. 1. The pump laser is a passively mode-locked erbium-doped fiber laser, which is pumped by a 100 mW 980 nm LD. With a repetition rate of 13.9 MHz and pulse width of 1.5 ps, its wavelength is centered at 1562 nm. Since the pulse width of pump source is fairly short, we amplify it directly with erbium-doped fiber amplifier (EDFA) without any compression. We launch the output of EDFA into conventional DSF with $\lambda_0 = 1543$ nm and dispersion slope $= 0.0651$ ps/nm^2. km for SC formation. The output result is sent into Ando AQ-6315A optical spectrum analyzer (OSA), HP 500 MHz 54615B oscillator and FR-103MN autocorrelator for diagnostics. We investigate the SC generation in two different lengths DSF, denoted DSF1 and DSF2. The lengths of DSF1 and DSF2 are 2.5 km and 100 m respectively.

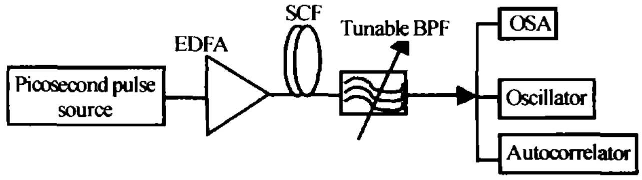

Fig. 1 Experiment setup of SC generation

2 Results

Fig. 2 shows the SC observed in DSF1 as the average pump power increases from 1mW to 40mW. It can be seen at first that the spectrum is significantly broadened due to self-phase modulation (SPM). The obvious asymmetry caused by three-order dispersion

(TOD), cross-phase modulation (XPM) and optical parametric generation (OPG) is shown with increased pump power. If the pump power is further increased, the spectrum quickly broadens towards long wavelength due stimulated Raman scattering (SRS). Fig. 3 (a) shows the SC is broadened from about 1311 nm to 1780 nm with 55 mW average pump power. Data for wavelengths greater than 1780 nm cannot be obtained due to spectral limitation of the OSA. The SC has a 20 dB bandwidth of more than 260.5 nm on the right side of λ_0 and a 15 dB bandwidth of 185.5 nm on the opposite side. The flat region on the short wavelength side from 1325 nm to 1453 nm has uniformity of ±2.5 dB. While on the opposite side, a flatter region from 1584 nm to 1780 nm with uniformity of ±1 dB can be clearly seen from Fig. 3 (b).

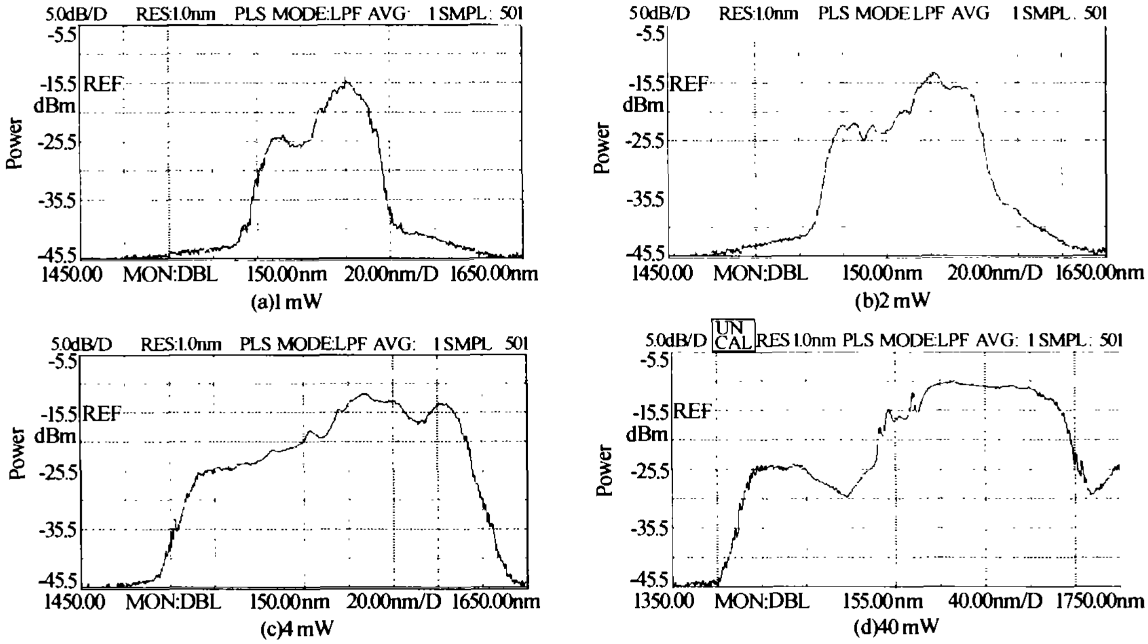

Fig. 2 SC spectrum generated at different pump power

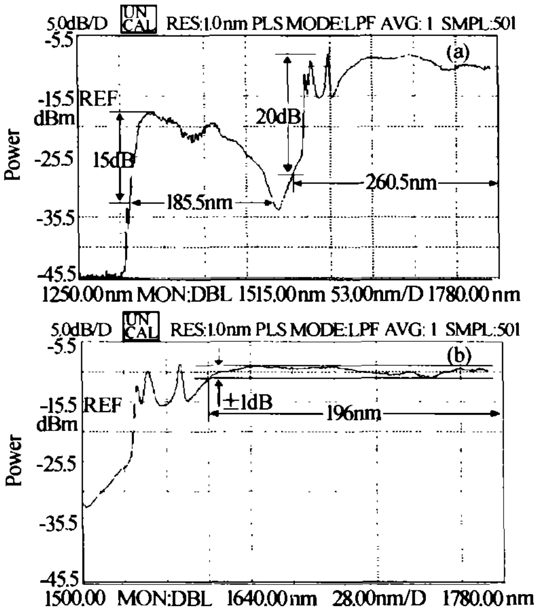

Fig. 3 SC spectrum generated at 55 mW (a) and its detail on L-band (b)

An F-P filter with 0.2 nm line width and 2.52 free spectrum region (FSR) is used to get multiple channels output as shown in Fig. 4. The output spectrum exhibits that more than 92 and 46 channels with flattened on each side of λ_0 are generated. While on the edge of SC, this F-P filter failed to carve spectrum due to its coated thin-film limitation.

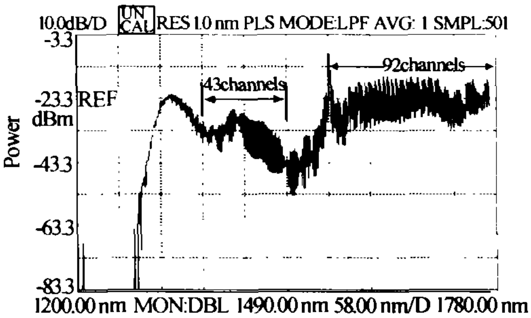

Fig. 4 Slices in the spectrum obtained by F-P filter

The deep dip in Fig. 2-3 is decreased by replacing DSF1 with DSF2. Fig. 5 shows the generated supercontinuum in DSF2 at 55 mW average pump power. The 20 dB bandwidth of optical spectrum is broadened to more than 453.3 nm seamlessly over S-, C- and L- band. A 195.4 nm wide spectral region between 1335.2 nm to 1530.6 nm has ±2 dB uniformity.

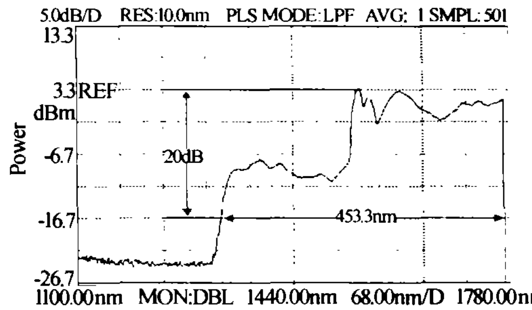

Fig. 5 SC spectrum generated at 55 mW average pump power

Meanwhile, a 246.5 nm wide spectral region between 1533.5 nm to 1780 nm has ±2.5 dB uniformity is also obtained. It can be seen that the power spectrum density is greatly increased in this case due to the shortening of fiber length. While on the other hand, its output flatness is not as good as that of DSF2, which means that further work should be done on optimizing fiber length.

3 Conclusion

In conclusion, ultra-broadband supercontinuum is generated in 2.5 km and 100 m DSF respectively. It has been demonstrated that there exist an optimized fiber length in supercontinuum generating. Now further work is under way.

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利用普通色散位移光纤得到的超宽带超连续谱

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摘 要 对实验中观察到的超连续谱（SC）演变过程进行了理论分析．在泵浦光平均功率 55 mW 时，利用普通色散位移光纤得到 SC 谱从 1311 nm 到 1780 nm 的展宽．其中泵浦波长右侧 196 nm 范围内的光谱不平坦度 < ±1 dB．利用 F-P 进行谱切片，在泵浦波长右侧和左侧分别得到 92 个和 46 个顶部平坦的信道．将色散位移光纤长度缩短到 100 m 时，还得到了 SC 谱 20 dB 带宽 453.3 nm 的实验结果，实现了无缝覆盖 S 带、C 带、和 L 带．

关键词 超连续；色散位移光纤；受激喇曼散射

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