Multiwavelength CW source with precise 25-GHz channel spacing based on longitudinal mode-carving of supercontinuum

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We experimentally demonstrate a novel multiwavelength continuous wave (CW) optical source with precise 25-GHz spacing based on the longitudinal mode-carving of a supercontinuum (SC) spectrum. The CW light was modulated with a 10-Gb/s non-return zero (NRZ) format. The experimental results show that the multiwavelength CW optical source is promising for dense wavelength division multiplexing (DWDM) systems.

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Wavelength division multiplexing (WDM) system with very dense channel spacing of 25-GHz-or-less is an attractive option for providing large capacity in optical transmission systems[1]. As the number of the WDM channels increases, reducing the cost of light sources and maintaining the frequencies of the large number of light sources become important issues. Using one laser diode (LD) for each channel requires complicated procedures for monitoring and controlling the wavelength of each LD by controlling either temperature or injection current.

The supercontinuum (SC) generation is a phenomenon in which an intense seed optical pulse is broadened in spectrum over a continuous range in a SC fiber, while maintaining their coherent characteristics[2]. The broadened spectrum has many modes whose frequency spacing is equal to the repetition of the seed pulse[3]. One mode can be extracted when fed into an optical filter. Then each light is modulated individually by an external modulator and transmitted. One advantage of using longitudinal modes of the SC spectrum is the fixed channel spacing with accuracy equivalent to that of a microwave oscillator (-Hz)[4]. This means that the entire wavelength channels can be fixed to ITU-T grid frequencies by adjusting just one wavelength. In this letter, we present a SC lightwave source that emits a 25 GHz spacing optical multicarrier on the ITU grid.

Figure 1 shows the experimental setup of SC generation. An actively modelocked fiber laser (AML-EDFL) made by ourselves is used as the pump optical pulse, which generated 10-ps chirp-free Gauss pulse at 1554 nm. The short term stability of the AML-EDFL was achieved by the nonlinear polarization rotation (NPR) technology[5]. The long term instability was removed by the feedback to control fiber cavity length[6]. So our AML-EDFL can operate stably for more than eight hours. The pulse train was amplified to an average optical power of 50 mW before launching into the comb-like dispersion profiled fiber (CDPF) for pulse compression[7]. The compressed 2.1 ps pedestal-free pulse train was amplified to an average optical power of 20 dBm by EDFA2 before injected into a 1-km high nonlinear fiber (HNLF), which has a zero dispersion wavelength of 1555.5 nm and three order dispersion of 0.018 ps/nm^2/km. The output spectrum shown in Fig. 2 was broadened owing to self-phase modulation (SPM), cross-phase modulation (XPM), and four-wave mixing (FWM). The 20-dB bandwidth measured from the peak is 132 nm. On the Stokes' side, we obtained ±0.5-dB flatness of 50 nm. So in the flat region, we can get 250 channel optical frequency chain with 25-GHz channel spacing.

The experimental setup for multiwavelength CW generation by longitudinal mode-carving is shown in Fig. 3

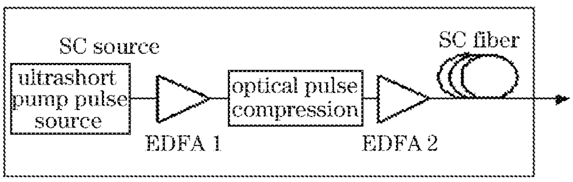

Fig. 1. Experimental setup for SC generation.

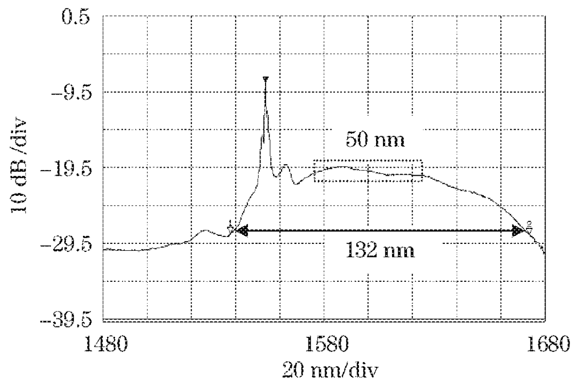

Fig. 2. SC spectrum generated with HNLF, with 20-dB bandwidth of 132 nm and ±0.5-dB flatness of 50 nm.

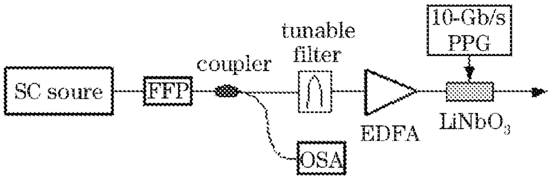

Fig. 3. Experimental setup for CW generation by longitudinal mode-carving.

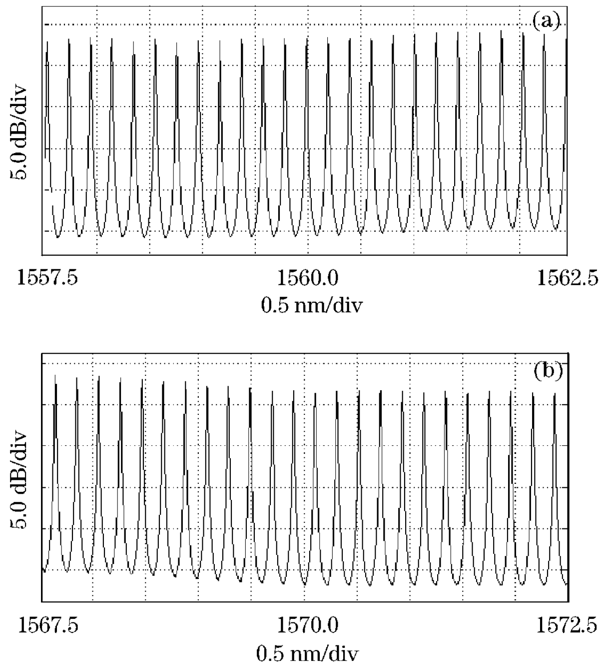

Fig. 4. Generated optical frequency chain spectra. (a) Spectrum around 1560 nm and (b) around 1570 nm.

with the SC source shown in Fig. 1. Each single longitudinal mode of the SC spectrum was demultiplxed with a 25-GHz FSR fiber Fabry-Perot (FFP) tunable filter with fineness over 40. The optical frequency chain spectra around 1560 and 1570 nm are shown in Figs. 4(a) and (b), respectively.

By using the fiber Bragg grating (FBG) as the tunable bandpass filter, we can carve out each individual mode to generate CW signal. Each extracted light was modulated in a $LiNbO_3$ modulator at 10 Gb/s. Figure 5 shows the eye diagram at wavelength of 1555.8 nm, which indicates good eye opening. We can see that there is much noise in the eye diagram. This is because the extracted signal is so small that the amplified spontaneous emission (ASE) noise is added when amplified. In our experiments, we can only extract one CW light by the tunable filter. But if the 25 GHz spaced arrayed waveguide grating (AWG) is used instead of the tunable filter, we can get multiwavelength CW source. The optical frequency chain can align the ITU-T grid with a constant spacing of 25 GHz as precise as the repetition rate of the pump optical pulse.

In this paper, we have generated an optical frequency chain with 25-GHz channel spacing from a single SC source. The channel spacing is strictly determined by the microwave frequency of the pump modelocked laser and the absolute frequency stabilities are satisfactory for the narrow channel spacing. The CW light was modulated with a 10-Gb/s non-return zero (NRZ) format, which shows good eye opening. These results show that longitudinal mode carving of the SC spectrum is promising for creating a multiwavelength optical source for DWDM systems. The generated optical frequency can also be applied to optical frequency standards and frequency stabilization of DWDM channels.

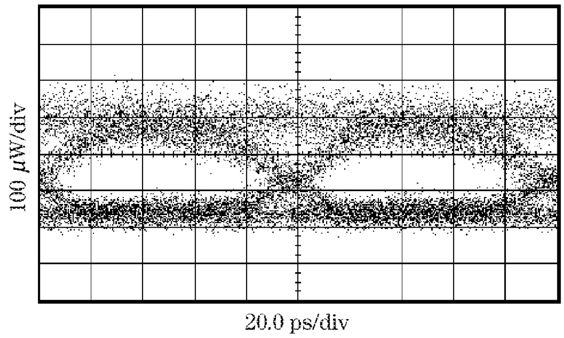

Fig. 5. Measured eye diagram at 10 Gb/s.

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