Wavelength-tunable light sources based on a self-seeding RSOA

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In this letter, two kinds of continuous wavelength-tunable light sources are achieved and investigated experimentally using a self-seeding reflective semiconductor optical amplifier (RSOA). Over 40 single mode wavelengths with 100 GHz spacing are generated by setting the parameters of the wavelength selective switch. The peak power of each wavelength reaches over 0.2 dBm with the signal-to-noise ratio (SNR) $>$ 35 dB. The proposed schemes are appropriate for multi-wavelength-tunable light sources; the maximum number of wavelengths generated can reach to 4.

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Wavelength-tunable light sources[1−4] have gained considerable interest because of the large demand in optical fiber communication and fiber sensor systems. Self-seeding schemes have been studied and reported as the main technique to achieve wavelength tunable light sources. Self-seeding schemes are grouped into three categories: the self-seeding erbium-doped fiber ring laser, which has a high output power; the self-seeding Fabry–Perot laser diode (FP-LD) ring, which has advantages of low cost and high rate modulation[5−8]; the self-seeding reflective semiconductor optical amplifier (RSOA), which has good performance in some aspects, such as wider wavelength tuning range, easy tuning step, large-scale production, and higher output peak power[9].

In this letter, two continuous wavelength-tunable schemes based on RSOA and wavelength selective switch (WSS) have been proposed. The self-seeding RSOA can output a single International Telecommunication Union (ITU) standard wavelength spacing from 1 529.28 to 1 563.6 nm. The control signals are sent to the WSS by a computer, which determine the wavelengths of the light source output. Changing from one wavelength to another took no more than 850 ms. Optical signal-to-noise ratio (SNR) reached over 35 dB or even over 65 dB. The relative intensity noise (RIN) of the proposed schemes was about −115 dB/Hz.

The proposed schemes were compared in the experiment. Although the devices in the two schemes are the same, the differences between their performances are obvious.

The proposed light sources are also multi-wavelength-tunable light sources. Multi-mode wavelengths with similar amplitude can be obtained. This study, to our knowledge, generated multi-wavelengths using a self-seeding RSOA for the first time. The frequencies of the generated wavelengths can be selected. The maximum number of wavelengths generated simultaneously reached 4.

Figure 1 illustrates the experimental schemes of the proposed continuous wavelength-tunable light sources. These light sources consist of a RSOA that generates an optical signal. The RSOA worked from 1 530 to 1 580 nm. The bias current of the RSOA was set at 0.21 A. In scheme I, the signal was separated by a 50:50 optical coupler. About half of the output light power was recorded by an optical spectrum analyzer (OSA) with 0.1-nm resolution, whereas the other half was filtered by a WSS, which worked from 1 529.28 to 1 563.6 nm with approximately 100 GHz wavelength spacing and ±20 GHz for clear active channel band. The SNR of the WSS reached over 65 dB, and the switching time reached 850 ms. Given that RSOA is a polarization sensitive device, a polarization controller (PC) was applied to ensure that the RSOA was locked at the best working state. The wavelength filtered by WSS was injected back to the RSOA for self-seeding via a circulator. The self-seeding single mode wavelength was enhanced in the loop. In scheme II, the output light was filtered by the WSS before it was separated by the coupler, which was the main difference from scheme I.

Any single wavelength from 1 529.28 to 1 563.6 nm can be obtained using the proposed schemes. The output peak power and SNR of these wavelengths were measured

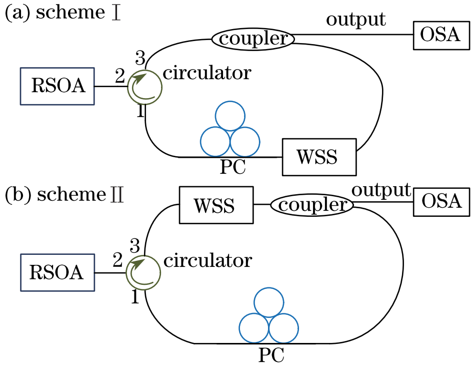

Fig. 1. Experimental schemes of continuous wavelength-tunable light source utilizing a self-seeding RSOA.

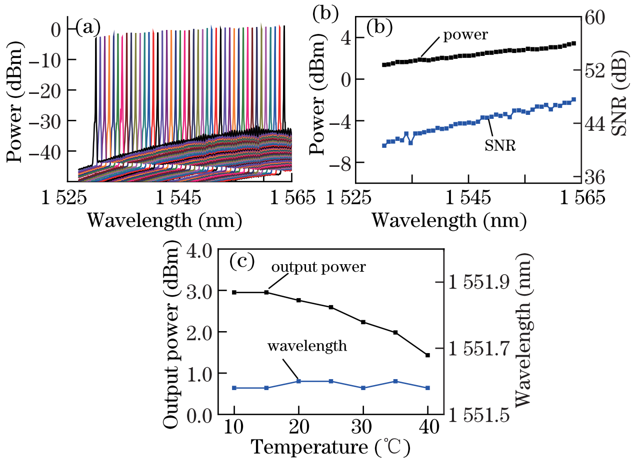

Fig. 2. (a) Output spectra of scheme I in the tuning range from 1 529.28 to 1 563.6 nm; (b) output peak power and SNR versus different wavelengths of scheme I; (c) output peak power and peak wavelengths versus different temperatures of scheme I. The wavelength center is near 1 551.8 nm. The bias current of RSOA is about 0.21 A.

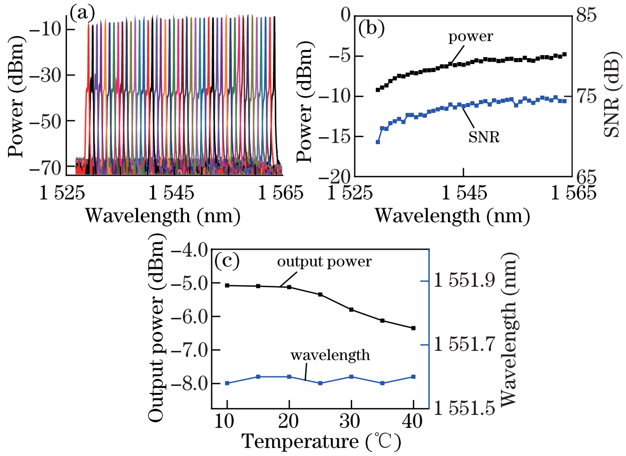

Fig. 3. (a) Output spectra of scheme II in the tuning range of 1 529.28 to 1 563.6 nm; (b) output peak power and SNR versus different wavelengths of scheme II; (c) output peak power and peak wavelengths versus different temperatures of scheme II. The wavelength center is near 1 551.8 nm. The bias current of RSOA is about 0.21 A.

in the experiment. Figures 2(a) and (b) and Figs. 3(a) and (b) show the significant difference in the performance of scheme I and scheme II. The output amplifier spectrum of the RSOA was not flat, resulting in the interconnected relationship between output peak power of both schemes and wavelengths. However, the floating scope of the amplitude was different. Given that the output of scheme I was before WSS and the bias current of the RSOA was fixed, the output peak power did not change obviously according to the changing wavelength. Meanwhile, the SNR depended on the amplitude of self-seeding wavelength in the self-seeding schemes. The lower peak power of the output led to lower SNR. The SNR of scheme I varied from 38 to 48 dB, the RIN reached −118.1 dB/Hz, and ΔSNR reached 10 dB. In scheme II, the light wavelength generated by the RSOA was flitted by the WSS before being recorded by OSA. Therefore, the SNR was mainly influenced by the WSS's SNR. The SNR of scheme II was 30 dB higher than that of scheme I and the RIN was −1.6 dB/Hz lower than scheme I. However, the output light wavelength was filtered once more than scheme I, which led to about 10 dB lower peak power than scheme I. The peak optical power of scheme II had fluctuations of about 5 dB.

Different schemes should be used in different situations according to their different performances. In remote areas, scheme I had the advantage in output peak power. However, in built-up areas, more users shared the fiber; thus, reducing the interface between different users is important. Scheme II had the advantage of low SNR, which may reduce the user's interface.

System stability test was performed to study the effects of temperature on the proposed schemes. The RSOA was placed into a temperature control box to simulate the practical application. The wavelength near 1 551.6 nm, which is near the C-band center wavelength, was selected. Thus, the selected wavelength had a certain representation. When the temperature varied from 10 to 40 °C, the wavelength shift was less than 0.4 nm (Figs. 2(c) and 3(c)). Given that the RSOA is a travelling wave amplifier, it is not sensitive to the wavelengths. According to the architecture, the output wavelength is mainly affected by WSS, which works as a filter. Temperature changes also cause changes in the frequency response of RSOA. The frequency response of WSS and RSOA allows the wavelength drift according to change in temperature.

The WSS had over 40 channels, and the attenuation of each channel was set independently. By proper computer operation, several wavelengths can be selected to pass the WSS at the same time. Figures 4 and 5 show selected seeding wavelengths: 1 547.3, 1 549.78, 1 551.38, and 1 552.84 nm. These wavelengths were injected back

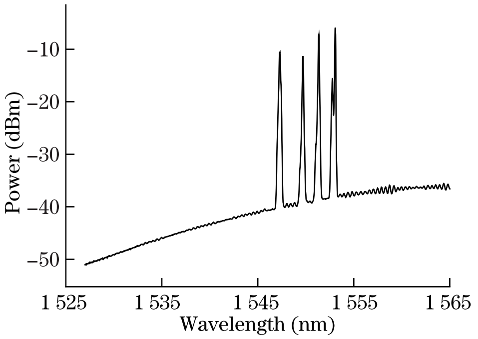

Fig. 4. Output spectra of scheme I. Multi-wavelength tunable light source utilizing a self-seeding RSOA.

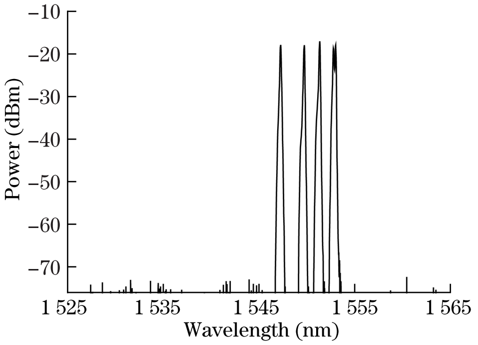

Fig. 5. Output spectra of scheme II. Multi-wavelength tunable light source utilizing a self-seeding RSOA.

to the RSOA to generate multi-wavelengths. The principle is similar to the self-seeding single-wavelength; however, multi-wavelength-tunable light sources depend more on the WSS attenuation. A small change in the WSS attenuation will be amplified by the self-seeding RSOA because RSOA exists in the scheme loop. The change in the amplitude of one wavelength may influence other wavelengths. The RINs of schemes I and II were –115.8 and –112.3 dB/Hz, respectively. If the parameter is set appropriately, multi-wavelengths of the same amplitude are obtained.

This study applies the WSS in self-seeding wavelength-tunable light sources. Over 40 ITU-T standard single mode wavelengths ranging from 1 529.28 to 1 563.6 nm were generated and obtained, with a switching time of less than 850 ms.

Two schemes were compared in this letter, and a small difference exists between them. When their output light spectra were compared, their difference in performance was significant. The output peak power of scheme I was 10 dB, which was higher than that of scheme II. However, the SNR of scheme II was 30 dB higher than that of scheme I. Scheme I is a good light source for the long-reach wavelength-division-multiplexed passive optical network (WDM-PON) and the time and wavelength division multiplexing-WDM-PON with a small number of users that provides a high output peak power. On the contrary, scheme II is more suitable for the concentrated area PON. High SNR may limit multiple users' interference to a low degree.

The proposed schemes are appropriate for the multi-wavelength-tunable light sources. The schemes can output multi-wavelengths with the same amplitude by setting proper parameters. Therefore, these schemes are promising light sources for WDM-PON because of their advantages of easy management and fast wavelength conversion.

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