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Using Saganc Loop of Optical-Injected Semiconductor Laser Scheme for Stable and Continuous CW Wavelength-Tuning[1]

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Abstract—We propose and experimentally investigate a stable and continuous wavelength-tuning laser structure by using self-injected Fabry–Perot laser diode (FP-LD) with Saganc loop scheme. In this proposed laser scheme, the lasing wavelength can be tuned in the range of 1526.20 to 1549.75 nm with tuning-step of 1.30 nm in single-longitudinal-mode (SLM) output. Here, the maximum and minimum output powers are −7.4 and −17.0 dBm, and their corresponding side-mode suppression ratios are 52.0 and 52.8 dB/0.05 nm, respectively. Moreover, to achieve the continuous wavelength tuning, we can also adjust the temperature of FP-LD for wavelength shifting.

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1. INTRODUCTION

Nowadays, optical fiber communication is operated around the wavelength region of 1530 to 1560 nm (C-band) generally. Actually, optical fiber amplifier at this wavelength region is dominated by using erbium-doped fiber amplifiers (EDFAs). However, the ever-increasing demand for data bandwidth has resulted in saturation of the C-band in wavelength division multiplexed (WDM) systems [1, 2]. The limited gain bandwidth of erbium demands that new amplifier components are developed to allow transmission at other ranges of the optical spectrum, providing greater capacity for WDM systems, such as using tunable Raman pump source to cover the 1470 to 1560 nm region [3, 4], employing erbium fiber for S-band from 1470 to 1520 nm [5–8] or L-band of 1560 to 1620 nm windows [9, 10]. Using these optical fiber amplifiers, the tunable continuous wave (CW) fiber lasers were also proposed in various operating wavelength ranges [3–10]. To obtain tunable CW laser source, the erbium-doped fiber amplifier (EDFA), Raman amplifier (RA) or semiconductor optical amplifier (SOA) based ring laser structures [11–14], are attractive applications in optical communication, optical testing, fiber sensor, and spectroscopy [15–17]. However, these fiber lasers are relatively costly since fiber amplifiers inside the gain cavities are required. Furthermore, using nonlinear effect and passive filter also can achieve single wavelength-tuning and multi-wavelength output in C-band or broadly bandwidth operation [18–26].

In this paper, a stable and continuous wavelength-tuning laser structure by using self-injected Fabry–Perot laser diode (FP-LD) with Saganc loop scheme has been proposed and experimentally investigated. In this proposed laser scheme, the lasing wavelength can be tuned in the range of 1526.20 to 1549.75 nm with tuning-step of 1.30 nm in single-longitudinal-mode (SLM) output. Here, the maximum and minimum output powers are −7.4 and −17.0 dBm, and their corresponding side-mode suppression ratios are 52.0 and 52.8 dB/0.05 nm, respectively. In addition, to obtain the continuous wavelength-tuning in effectively amplification range, we can adjust the temperature of FP-LD for wavelength shifting in the laser scheme.

2. EXPERIMENT AND DISCUSSIONS

Figure 1 shows the experimental setup of the proposed stable SLM wavelength-tuning semiconductor laser structure. The proposed laser was consisted of a FP-LD, a tunable bandpass filter (TBF), a polariza-

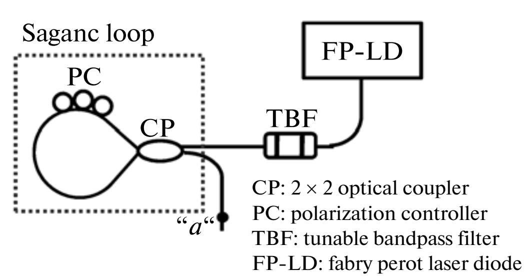

Fig. 1. Experimental setup of proposed wavelength-tuning laser configuration.

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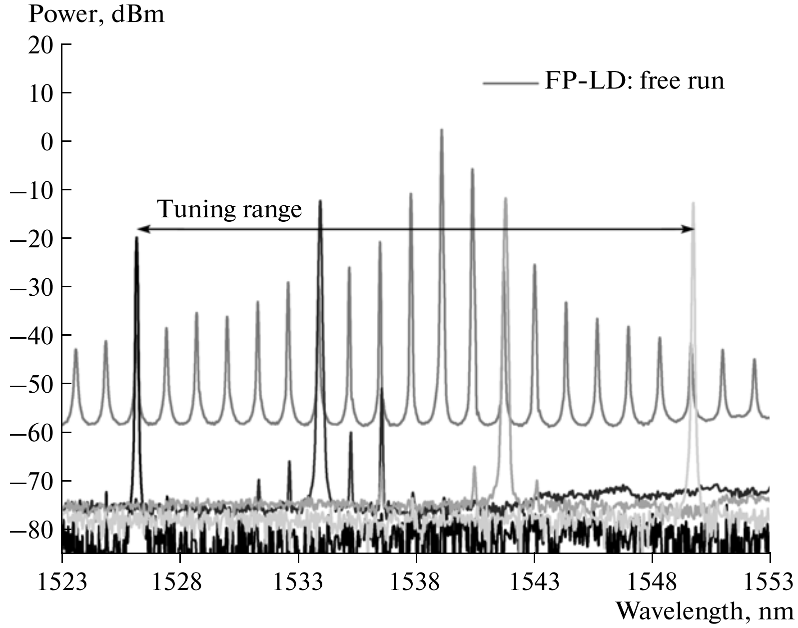

Fig. 2. Output spectrum of FP-LD in free-run status (gray line) and output spectra of the proposed laser configuration in the wavelength-tuning range of 1526.20 to 1549.75 nm with tuning-step of 1.30 nm.

tion controller (PC), and a 2 × 2 and 50 : 50 optical coupler (CP). The 2 × 2 CP and PC was structured to Saganc loop mirror, as illustrated in Fig. 1. Here, the mode-spacing and threshold current of multi-longitudinal-mode (MLM) FP-LD used were 1.30 nm and 9.1 mA, respectively. And the wavelength tuning range and insertion loss of TBF were 30 nm (1530–1560 nm) and 6 dB. In this measurement, the output wavelength and output power of the proposed laser are measured by employing an optical spectrum analyzer (OSA) with a 0.05 nm resolution and a power meter (PM).

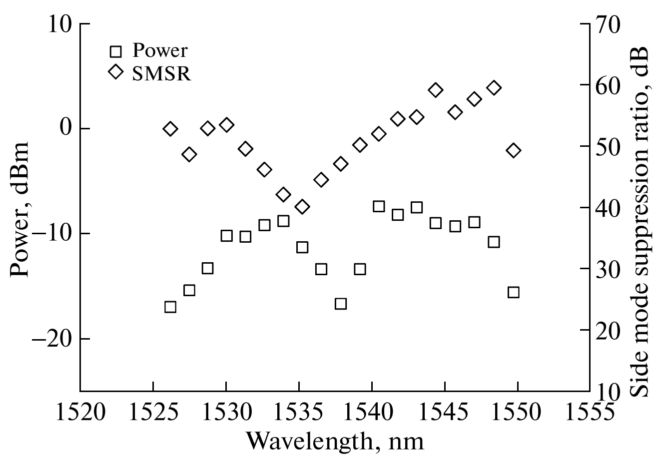

Fig. 3. Output curves of output powers and side-mode suppression ratios (SMSRs) of the laser scheme under different lasing wavelengths in the range of 1526.20 to 1549.75 nm.

In the experiment, the FP-LD was operated at 28 mA in the temperature of 25°C. Hence, Fig. 2 shows the output spectrum of FP-LD in free-run status, as illustrated in gray line. The output central wavelength of FP-LD was 1539.10 nm with 0.24 dBm peak power. In the proposed laser, the TBF was used to filter the corresponding output mode of MLM FP-LD. And the filtered output mode of FP-LD was reflected via the proposed Saganc loop mirror, as shown in Fig. 1. And then, the reflected mode would launch into FP-LD for self-injecting operation. Therefore, the each lasing wavelength can be tuned by adjusting the TBF via self-injection mechanism in the proposed laser structure. Besides, the PC of Saganc loop was employed in this measurement to maintain the polarization state and retrieve the maximum output power. Due to the optical-injected operation, the injected mode of FP-LD would obtain larger gain to suppress the side-modes to generate a single-frequency output. Therefore, the output spectra of the proposed laser configuration are also shown in Fig. 2 (observed at "*a*" point in Fig. 1) in the wavelength-tuning range of 1526.20 to 1549.75 nm with tuning-step of 1.30 nm in SLM output. And here, the lasing wavelength range of the proposed laser depended on the effectively gain amplification of FP-LD used.

Figure 3 presents the output curves of output powers and side-mode suppression ratios (SMSRs) of the laser scheme under different lasing wavelengths in the range of 1526.20 to 1549.75 nm. Here, the maximum and minimum output powers are observed at −7.4 and −17.0 dBm at the wavelength of 1540.50 and 1526.20 nm, and their corresponding SMSR are

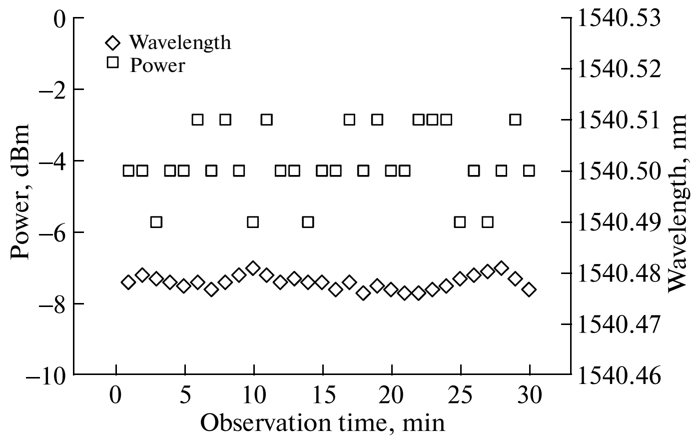

Fig. 4. Output stabilities of power and wavelength for the proposed wavelength tuning laser scheme over 20 min observing-time while a lasing wavelength is set at 1540.50 nm with −7.4 dBm output power initially.

52.0 and 52.8 dB/0.05 nm, respectively. As seen in Fig. 3, we can observe a power drop at 1537.90 nm with −16.7 dBm output power. And we also obtain a drop point of SMSR curve at 1535.25 nm. This is because the larger gain of FL-LD around 1537.90 nm (as seen in Fig. 2), the side-mode around 1535.25 nm could not be suppressed easily. Besides, the maximum and minimum SMSRs of 57.7 and 40.1 dB/0.05 nm are also measured at the wavelengths of 1547.05 and 1535.25 nm, respectively.

In this experiment, to realize and investigate the output stabilities of power and wavelength in the proposed wavelength-tuning laser, a short-term observation was performed. Here, a lasing wavelength was set at 1540.50 nm with −7.4 dBm output power initially for output stability measurements. After the observation time of 20 min, the maximum output power variation and wavelength fluctuation of the proposed laser can be measured within 0.7 dB and 0.02 nm respectively, as shown in Fig. 4. Furthermore, after one hour observation time, the measured output stabilities of power and wavelength are still maintained. According to the measured results, this proposed laser shows a good output performance.

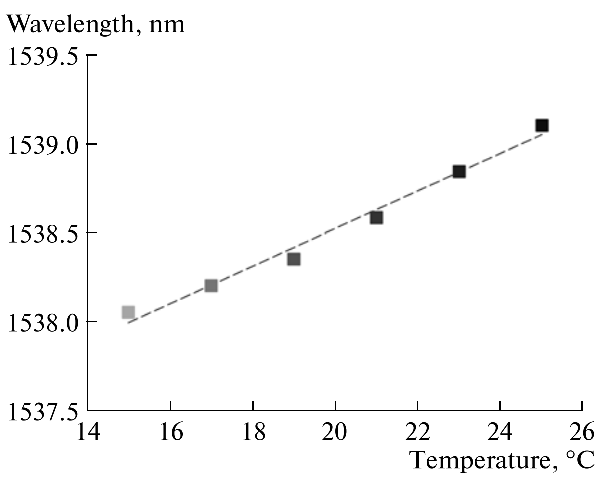

Fig. 5. Output central wavelength of original MLM FP-LD versus the different applied temperatures of 15 to 25°C, when the operating current of FP-LD is set at 28 mA.

In order to achieve a continuous wavelength tuning, we can control and adjust the different temperature of FP-LD used in the laser scheme for wavelength shifting. Thus, Fig. 5 shows the output central wavelength of original MLM FP-LD versus the different applied temperatures of 15 to 25°C, when the operating current of FP-LD is set at 28 mA. We can observe the maximum wavelength shifting of 1.1 nm while the temperature difference is 10°C. As a result, we can adjust the temperature of FP-LD for continuous wavelength-tuning.

3. CONCLUSIONS

In conclusion, we have experimentally investigate a stable and continuous wavelength-tuning laser structure by using self-injected FP-LD with Saganc loop scheme. In this proposed laser scheme, the lasing wavelength can be tuned in the range of 1526.20 to 1549.75 nm with tuning-step of 1.30 nm in SLM operation. Here, the maximum and minimum output powers are −7.4 and −17.0 dBm, and their corresponding side-mode suppression ratios are 52.0 and 52.8 dB/0.05 nm, respectively. In the experiment, to achieve the continuous wavelength tuning, we can adjust the temperature of FP-LD for wavelength shifting in the laser scheme. Furthermore, the output stabilities of power and wavelength for the SLM wavelength-tuning laser have been also executed and discussed.

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