

Cost-effective tunable fiber laser based on self-seeded Fabry-Perot laser diode using a Sagnac loop reflector

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We propose and demonstrate a simple configuration of wavelength-tunable fiber laser made up of a tunable band-pass filter, a Sagnac loop reflector, and a Fabry-Perot laser diode. Based on the self-seeded operation, the proposed fiber laser can obtain a single-longitudinal-mode output in the wavelength tuning range of 1544.69–1563.39 nm with tuning step of 1.34 nm. The performances of output power (> -9 dBm), optical side-mode suppression ratio (> 65.5 dB), and power and wavelength stabilities are well exhibited.

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Tunable frequency-stable and power-constant fiber lasers have attracted much interest in recent years because of their potential applications in wavelength-division-multiplexed (WDM) communications, optical code-division multiple-access (CDMA) technique, and optical sensor systems. Several erbium-doped fiber (EDF) ring lasers with the fiber Fabry-Perot (FFP) filters used for wavelength tuning have been reported^[1–3]. However, FFP alone is insufficient to stabilize both the lasing wavelength and the power of a fiber ring laser, and the EDF bandwidth limits the wavelength tuning range of fiber laser. Utilizing a self-seeded Fabry-Perot laser diode (FP-LD) is a potential candidate to compensate for these disadvantages. Past study employing a FP-LD and optical filter inside an external fiber cavity can obtain a stable and tunable single-longitudinal-mode (SLM) output^[4,5]. However, these fiber lasers are relatively costly because a fiber amplifier or an additional optical reflector inside the fiber cavities is required.

In this letter, we propose and experimentally demonstrate a simple configuration of a wavelength-tunable fiber ring laser based on a self-seeded FP-LD without fiber amplifiers inside the gain cavity. The wavelength-tunable SLM output is implemented via the optical injection and feedback scheme of the FP-LD using a Sagnac fiber loop reflector, which is composed of an optical coupler. Furthermore, in contrast with the conventional setup, our proposed configuration is low cost and easy to construct. Hence, the simple fiber laser has wider application prospects, such as a promising solution for a colorless optical network unit (ONU) in passive optical network (PON). The performances of the tuning range, wavelength, and power stabilities, side-mode suppression ratio (SMSR) are also studied.

The experimental setup for the proposed configuration of wavelength-tunable fiber laser is shown in Fig. 1. The simple fiber laser consists of a 2×2 and 90:10 optical coupler, a tunable band-pass filter (TBF), a polarization controller (PC), and a multi-longitudinal-mode (MLM) FP-LD with 1.34-nm mode spacing. The 2×2 and 90:10 optical coupler is constructed into a Sagnac

fiber loop reflector to provide feedback to the 1550-nm commercially available FP-LD. The 3-dB bandwidth and insertion loss of the TBF used are 0.4 nm and 3.5 dB, respectively. The TBF is capable of precisely changing its center wavelength according to a voltage signal. The PC is placed inside the gain cavity to control the polarization state of the feedback lightwave into the FP-LD properly, obtain maximum output power, and maintain wavelength stabilization. The injected lightwave at the state of the TE mode of FP-LD will result in the maximum injection locking efficiency^[6]. The FP-LD has MLM output with $\sim 45\%$ front-facet reflectivity. The FP-LD is biased at 30 mA and the temperature is at 25 °C.

The operating mechanism for the proposed self-seeded fiber laser is discussed as follows. When the lasing light from the MLM FP-LD initially passes through the PC, TBF, and optical coupler, the observed 90% output lasing wavelength power is only filtered by the TBF without self-seeding operation. Another 10% lasing wavelength power is turned back to the FP-LD by the Sagnac fiber loop reflector. Therefore, the feedback light is selected by the TBF and is transmitted through the following fiber path: FP-LD \rightarrow PC \rightarrow TBF \rightarrow Sagnac loop \rightarrow TBF \rightarrow PC \rightarrow FP-LD \rightarrow PC \rightarrow TBF \rightarrow Sagnac loop \rightarrow output. Here, the central wavelength of the TBF is tuned to align to the corresponding SLM of the FP-LD for single wavelength lasing. The side-modes of the FP-LD are suppressed and the optical output is amplified by a self-seeded operation.

The proposed wavelength-tunable fiber laser can obtain a stable single frequency output by using the Sagnac

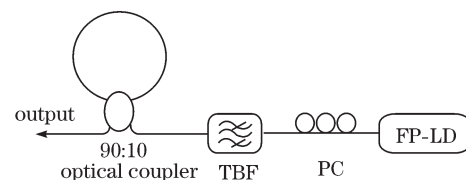


Fig. 1. Experimental setup for the proposed confirmation of wavelength-tunable fiber laser.

loop reflector to provide feedback function. Figure 2(a) shows the free run output spectrum of the MLM FP-LD without self-seeding when the bias current and temperature are 30 mA and 25 °C, respectively. When the self-seeded laser is adopted, the SLM wavelength output is obtained as shown in Fig. 2(b), while the TBF is set at 1555.3 nm. Therefore, Fig. 2(c) presents the complex output power spectra of the proposed laser module in the tuning range of 1544.69–1563.39 nm with a tuning step of ~ 1.34 nm. The SMSR is distributed from 65.5 to 71.4 dB.

Figure 3 shows the output power and SMSR versus the different lasing wavelengths with ~ 1.34 -nm tuning step. The maximum output power of -3.4 dBm is at the wavelength of 1546.0 nm. The minimum output power is -9.0 dBm at 1556.69 nm. The output power difference ΔP_{\max} is about 5.6 dB. When the lasing wavelength is 1556.69 nm, the SMSR can reach 71.4 dB. The minimum of SMSR is 65.5 dB at 1544.96-nm wavelength ($\Delta \text{SMSR}_{\max} = 5.9$ dB). The output power of the laser is determined by the gain profile of the FP-LD; hence, it is lower at both ends of the spectrum.

To investigate the output performances of power and wavelength stabilities, a short-term stability is measured. Initially, the lasing wavelength is 1554.08 nm and the observing time is over 30 min. In Fig. 4, wavelength variation and power fluctuation for the fiber laser are 0.05 nm and 1.37 dB, respectively. After two hours of ob-

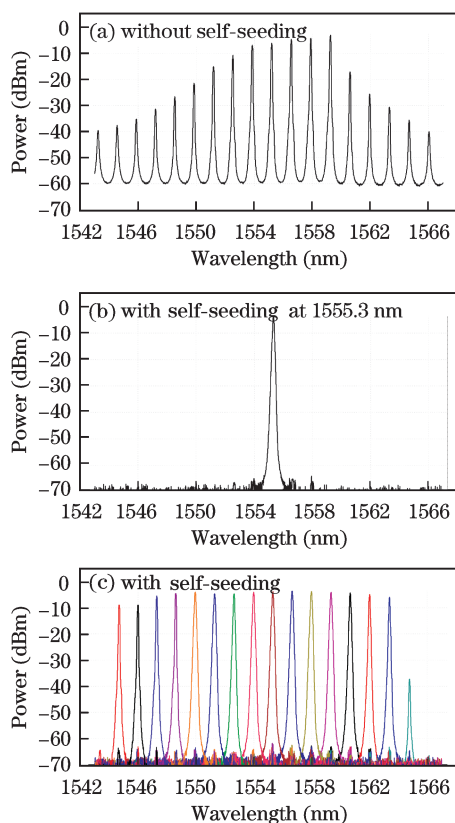


Fig. 2. (a) Original output spectrum of MLM FP-LD used operates at 30 mA in 25 °C; (b) when the proposed self-seeded laser is adopted, the SLM wavelength output is obtained while the TBF is set at 1555.3 nm; (c) complex output spectra of proposed laser in the wavelength range of 1544.69–1563.39 nm with a tuning step of 1.34 nm.

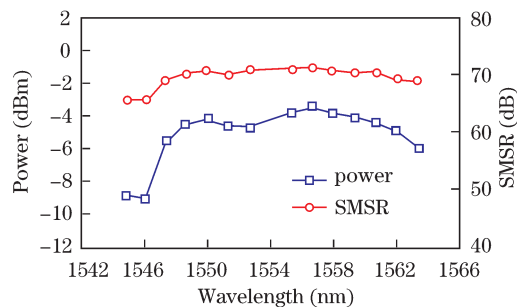


Fig. 3. Output power and SMSR spectra in the wavelength range of 1544.69–1563.39 nm with a tuning step of 1.34 nm.

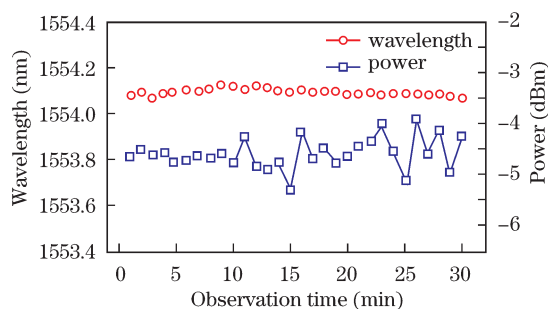


Fig. 4. Output variations of central wavelength and power at 1554.08 nm within 30 min.

servation, the stabilized output of the fiber laser is still maintained. As a result, the wavelength-tunable fiber laser has the advantage of simple scheme, low cost, better output efficiency, and wide wavelength tuning range.

In conclusion, we propose and investigate a novel and simple scheme to construct a wavelength-tunable fiber laser. By employing a TBF and a Sagnac loop reflector within an external fiber cavity of a FP-LD, the fiber laser can produce a SLM output because of the self-seeded operation. The proposed configuration of wavelength-tunable fiber laser has a good performance of output power (> -9 dBm) and optical SMSR (> 65.5 dB) in the wavelength tuning range of 1544.69–1563.39 nm with a tuning step of 1.34 nm. The output performances of power and wavelength stabilities are also investigated.

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