Generation of Wavelength-Tunable Optical Pulses Using a Linear-Cavity Fiber Laser Scheme With a Fabry–Pérot Laser Diode

Peng-Chun Peng, Jia-He Lin, and Sien Chi

***Abstract*—A wavelength-tunable mode-locked linear-cavity fiber laser was demonstrated using a Fabry–Pérot laser diode. By adding a tunable bandpass filter within the linear cavity, the wavelength-tunable fiber laser was easy to be tuned dynamically. This linear-cavity fiber laser output exhibited a good performance having the optical sidemode suppression ratio over 30 dB and the wavelength-tuning range up to 27 nm. Furthermore, this fiber laser generated pulses with pulsewidth between 53.2 and 80.4 ps at a repetition frequency of 908.39 MHz.**

***Index Terms*—Fabry–Pérot laser diode (FP-LD), fiber laser, mode-locked fiber laser, tunable laser.**

I. INTRODUCTION

THERE HAS been increased research interest in wavelength-tunable optical short pulse generation due to its application in wavelength-division multiplexing (WDM) and time-division multiplexing optical communication systems, high-speed optical switching, and optical fiber sensors. Actively mode-locked fiber ring lasers are attractive optical sources to realize such pulse sources. Generally, fiber ring lasers are actively mode-locked by several kinds of modulators such as Mach–Zehnder modulators and electroabsorption modulators. In recent years, fiber ring lasers for generating wavelength-tunable pulses by using a Fabry–Pérot (FP-LD) or a distributed feedback laser diode as both a modulator and a tunable filter were presented. The tuning range was up to 4.8 nm [1]–[3]. Furthermore, a modified scheme by using a high birefringence fiber loop mirror in the ring cavity as filter and an FP-LD as a modulator also has been proposed. The tuning range of this fiber laser was about 10 nm. The best sidemode suppression ratio (SMSR) was 29.2 dB and the pulsewidth was 60.4 ps [4]. In this letter, we demonstrate a novel and simple configuration of a wavelength-tunable mode-locked linear-cavity fiber laser by using an FP-LD. The linear-cavity fiber laser scheme is implemented via the fiber loop mirror and FP-LD as a cavity mirror. By adjusting the tunable bandpass filter (TF), the laser output can be tuned flexibly. In contrast with the conventional setup, our proposed scheme is easy to be constructed and has a wide tuning range. The performance of the linear-cavity fiber laser operated at the different wavelengths is reported.

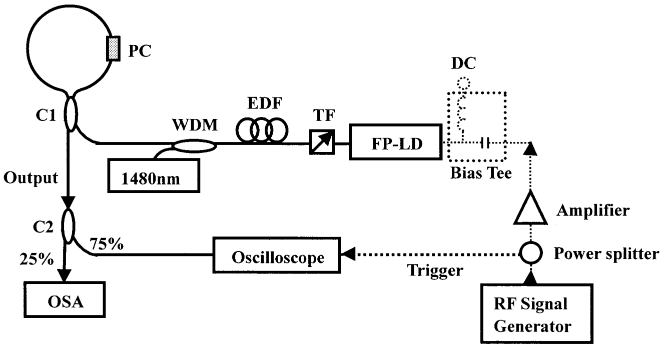

Fig. 1. Experimental setup of the wavelength-tunable mode-locked linear-cavity fiber laser. (C1: 2 × 2 coupler. C2: 1 × 2 coupler. WDM: 1480/1550-nm WDM coupler.

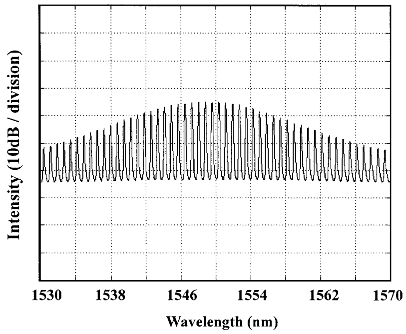

Fig. 2. Output spectrum of the gain-switched FP-LD.

II. EXPERIMENTAL SETUP

Fig. 1 shows the proposed configuration of the wavelength-tunable mode-locked fiber laser using an FP-LD. In our experiment, the fiber laser consisted of an erbium-doped fiber (EDF) amplifier, an FP-LD, a TF, and a fiber loop mirror with a polarization controller (PC) and a 2 × 2 optical coupler (C1) as a cavity mirror. The fiber loop mirror was used to construct an external linear-cavity for providing feedback to the FP-LD. The PC was arranged for the reflectivity of this fiber loop mirror. The coupling ratio of the 2 × 2 coupler (C1) for the fiber loop mirror was 30 : 70. The lasing light emerging from the 2 × 2 coupler arrived in an optical spectrum analyzer (OSA) and an oscilloscope with optical input port (86100A from Agilent Technologies).

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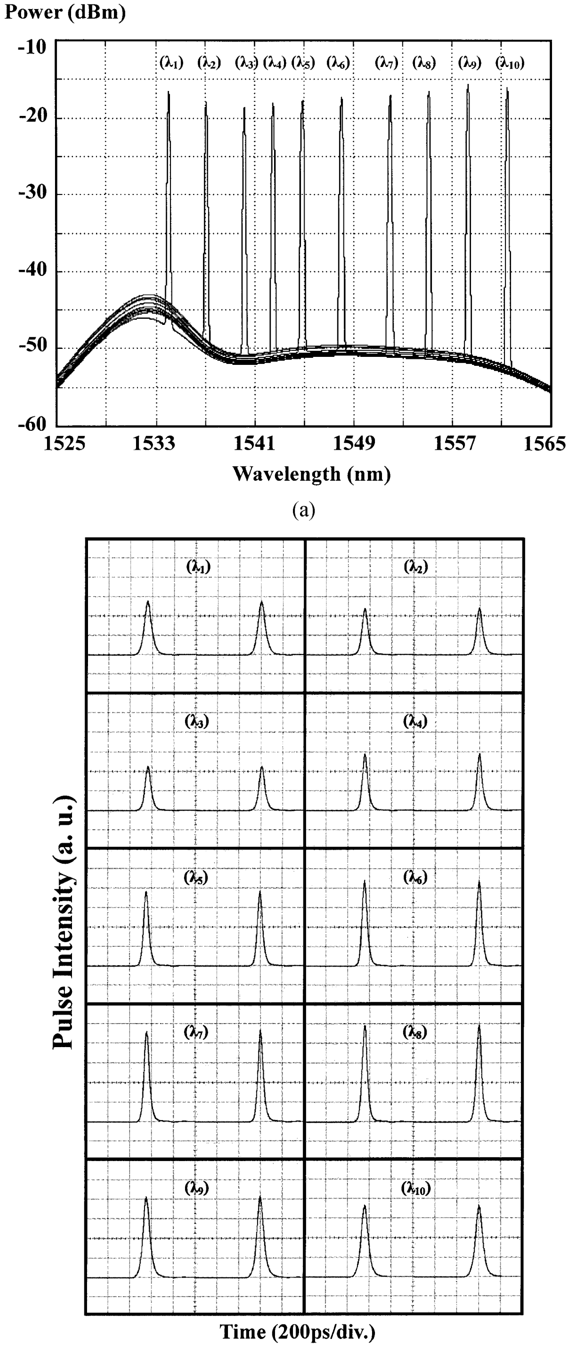

(b)

Fig. 3. Output spectra and pulse waveforms of the fiber laser when the central wavelength of the TF was at different FP-LD lasing modes. (a) Output spectra. (b) Pulse waveforms.

A 1480-nm laser diode with 70-mW output power pumped the 9-m EDF via a 1480/1550-nm WDM coupler (WDM). The operating range of the TF (TB4500 from JDS Uniphase Co.) was from 1530 to 1562 nm. The average 3-dB bandwidth of the TF was 0.4 nm. When the central wavelength was located at 1530, 1545, and 1560 nm, the insertion loss of TF was 5.51, 4.38, and 2.49 dB, respectively. A 1550-nm commercial FP-LD had a threshold current of 18 mA at 24°C and a mode spacing of 0.78 nm. The radio frequency sinusoidal signal was used to drive the FP-LD into gain-switching operation via a bias-tee circuit.

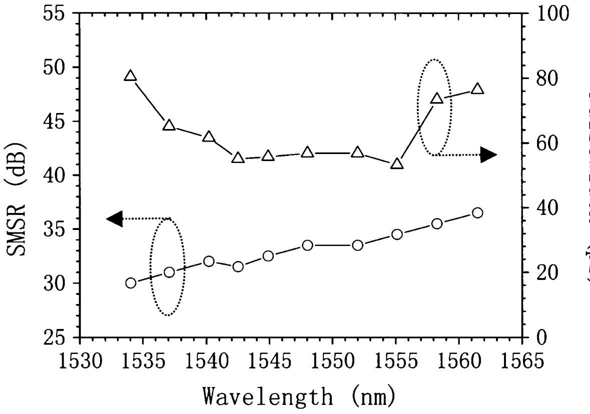

Fig. 4. SMSR and pulsewidth as a function of wavelengths.

III. RESULTS AND DISCUSSION

For simultaneous spectrum and waveform measurement, the output laser was split by a 1×2 coupler (C2) with coupling ratio 25 : 75 and measured by an OSA and an oscilloscope. The FP-LD was biased slightly below the threshold 6.6 mA and gain-switched at 908.39 MHz. Fig. 2 shows the output spectrum of the gain-switched FP-LD. The fundamental frequency of this linear cavity was 3.74 MHz. The TF was used within this cavity to select the lasing wavelength. When the central wavelength of the TF was close to one of the wavelengths of the FP-LD lasing modes, the output of the FP-LD was limited to this specific wavelength. Thus, the fiber laser only performed on single wavelength operation. Because of the FP-LD self-seeded mechanism in combination with the tunable filter function, the linear-cavity fiber laser can stably generate short-pulse and is easy to be tuned dynamically. Fig. 3 shows the output spectra and pulse waveforms when the central wavelength of the TF was located at different FP-LD lasing modes. The laser intensities and SMSR were not uniform due to cavity loss at different wavelengths and the gain profile of the FP-LD and EDF amplifier. The tuning range of this fiber laser was more than 27 nm (from 1534.04 to 1561.48 nm). The SMSR and the pulsewidth as a function of wavelengths are shown in Fig. 4. The shortest pulsewidth was 53.2 ps with SMSR 34.5 dB. The variation of pulsewidth was caused by the different wavelengths with different mode-locked frequencies. Under the fixed modulation frequency, the fiber laser cannot be improved for a wider tuning range in the mode-locked mechanism. Nevertheless, we can add a variable optical delay line in the linear-cavity to control the cavity length so that the tuning range and repetition frequency will not be limited by the mode-locked mechanism [5].

For the long-term stability, the pulse stability and characteristics can be improved by adding a PC in the linear cavity. This PC can be used to optimize the pulse characteristics because only one polarization direction of the feedback light results in the maximum efficiency of the FP-LD [4], [5].

IV. CONCLUSION

In this letter, we have demonstrated a novel and simple scheme to construct a wavelength-tunable mode-locked linear-cavity fiber laser. This wavelength-tunable output was implemented by using a self-seeded FP-LD incorporated with an external fiber cavity. The tuning range of this fiber laser was over 27 nm with SMSR up to 30 dB. The pulsewidth was between 53.2 and 80.4 ps at a repetition frequency of 908.39 MHz. We also discuss the variations of SMSRs and pulsewidths at different wavelengths.

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