Generation of Wavelength-Tunable Optical Pulses Using EDFA as External-Injection Light Source and Amplifier for Fabry–Pérot Laser Diode

Peng-Chun Peng, Wei-Ren Peng, Jia-He Lin, Wen-Piao Lin, and Sien Chi

***Abstract*—We propose and experimentally demonstrate a system for the generation of wavelength-tunable pulses using a gain-switched Fabry–Pérot laser diode (FPLD) and an erbium-doped fiber amplifier (EDFA). The EDFA is used as both an external-injection light source and an amplifier for the FPLD. The wavelength tuning is achieved by a tunable filter. The optical sidemode suppression ratio of this system is better than 32 dB over the wavelength-tunable range of 34.5 nm. Moreover, the repetition frequency is 2000 MHz, and the pulsewidth is between 49.3 and 65.3 ps. The whole system is simple and can be easily constructed.**

***Index Terms*—Erbium-doped fiber amplifier (EDFA), external injection, Fabry–Pérot laser diode (FPLD), optical pulse generation, wavelength-tunable.**

I. Introduction

WAVELENGTH-TUNABLE short pulses are very important for the optical communication systems and optical fiber sensing systems. A simple and economic way to produce optical short pulses is by using a gain-switched Fabry–Pérot laser diode (FPLD). In order to enable wavelength-tunable operation of the optical pulses, gain-switched FPLDs in external- injection schemes have been developed [1]–[6]. The external- injection scheme is generally injected by a continuous-wave (CW) tunable laser source. When the injected wavelength coincides with one of the wavelengths of the FPLD lasing modes, single wavelength optical pulses can be produced. Recently, due to the high cost of CW tunable laser source, a dc-driven FPLD together with the fiber Bragg grating has been used as an external-injection source. The sidemode suppression ratio (SMSR) in this system was about 20 dB [4]. Another FPLD together with a tunable filter (TF) and an erbium-doped fiber amplifier (EDFA) as an external-injection source was also presented. The SMSR is better than 30 dB over the wavelength- tunable range of 19 nm [5], [6].However, the wavelength-tunable range of these systems are limited by the overlap spectrum of two FPLDs.

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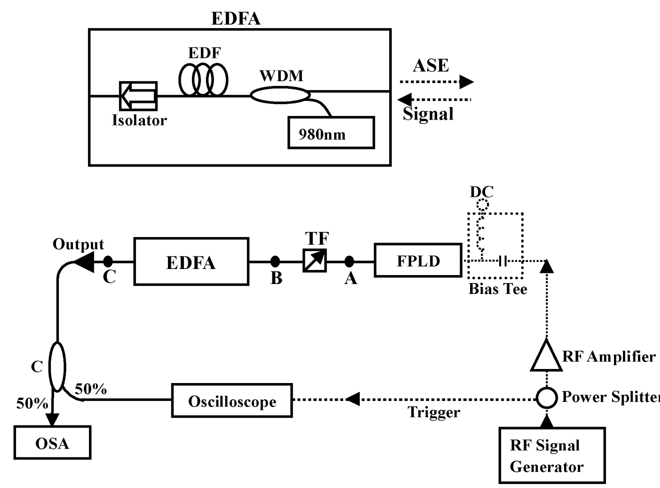

Fig. 1. Schematic diagram of the proposed system for the generation of wavelength-tunable optical pulses.

In this letter, we present a simple system to generate wavelength-tunable optical pulses by a gain-switched FPLD in an external-injection scheme. An EDFA in the system is used as both an external-injection source and an amplifier for the FPLD, and a TF is used as a wavelength selector. The lasing mode of the FPLD is locked by the backward amplified spontaneous emission (ASE) of the EDFA. The performance of system operated at the different wavelengths is reported. We also show the performance of the system without ASE injection.

II. Experiments and Results

Fig. 1 shows the schematic diagram of the proposed system for the generation of wavelength-tunable pulses using a gain-switched FPLD and an EDFA. The system consists of an FPLD, a commercial TF, and an EDFA. The EDFA consists of an isolator, a 980-nm laser diode, and an erbium-doped fiber (EDF). The isolation and insertion loss of the isolator are 48 and 1 dB, respectively. In our experiment, the 980-nm laser diode with 50-mW output power pumps the 14-m-long EDF via a 980/1550-nm wavelength-division-multiplexing coupler. The operating range of TF (TB4500 from JDS Uniphase Co.) is from 1527 to 1562 nm. The average 3-dB bandwidth of the TF is 0.4 nm. When the central wavelengths are 1530, 1545, and 1560 nm, the insertion losses of the TF are 5.51,

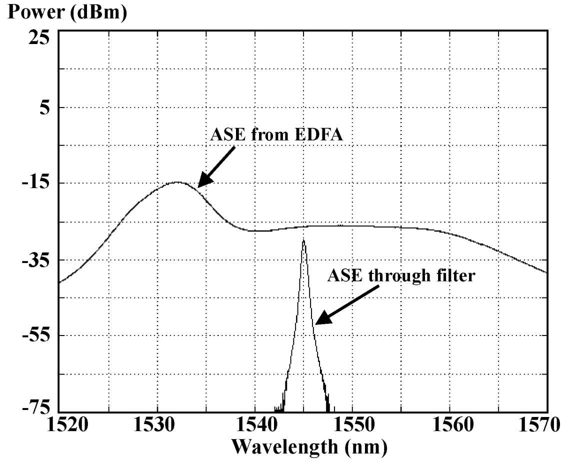

Fig. 2. Output spectra of the backward ASE and the ASE through the TF.

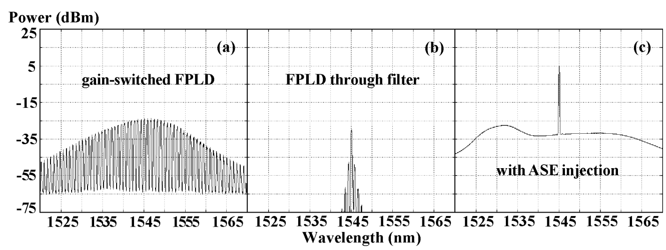

Fig. 3. Output spectra obtain at different points in Fig. 1, (a) at point "A," (b) at point "B," and (c) at point "C".

4.38, and 2.49 dB, respectively. When the central wavelength of the TF is close to one of the wavelengths of the FPLD lasing modes, the output of the FPLD is limited to this specific wavelength. Thus, the system has a single wavelength output. Fig. 2 shows the measured spectra of the backward ASE and the ASE through the TF. The spectrum of the ASE through the TF is measured at the point "A" in Fig. 1. The FPLD used is a commercial 1550-nm device (from Appointech, Inc.) with a threshold current of 18 mA at 25 °C and a mode spacing of 0.8 nm. The radio-frequency sinusoidal signal is used to drive the FPLD into gain-switching operation via a bias-tee circuit. The FPLD is biased at 15.8 mA and gain-switched at 2000 MHz. The spectrum of gain-switched FPLD is shown in Fig. 3(a). The spectrum of FPLD through the TF is shown in Fig. 3(b), and the SMSR is only 17.5 dB. Fig. 3(c) shows the measured spectrum at point "C" in Fig. 1. Because the EDFA is used as both an external-injection source and an amplifier for the FPLD, the SMSR and output peak power of the system are increased by 19 and 34.3 dB, respectively. Moreover, we add an additional isolator for the EDFA (see inset of Fig. 4) to reject the ASE injection. The output spectrum of system without ASE injection is shown in Fig. 4, and the SMSR is similar to the FPLD through the TF. Hence, the backward ASE injection can effectively increase the SMSR and suppress the other lasing modes of FPLD.

For simultaneous spectrum and waveform measurement, the laser output is split by a 1×2 coupler (C) with coupling ratio 50 : 50 and measured by an optical spectrum analyzer and a sampling oscilloscope with optical input port (86100A from Agilent Technologies). Fig. 5 shows the output spectra and pulse

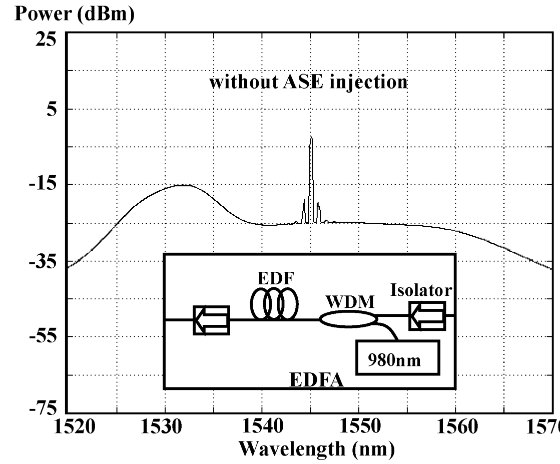

Fig. 4. Output spectrum of the system when the FPLD is without ASE injection.

waveforms of the system when the central wavelength of the TF is tuned to one of the wavelength of the FPLD lasing modes, and the background of output spectra reflects the ASE of the EDFA. The lasing wavelengths $\lambda 1$, $\lambda 2$, and $\lambda 3$ are 1527.13, 1545.05, and 1561.78 nm, and the pulsewidths are 49.4, 54.5, and 61.2 ps, respectively. The time-bandwidth products of the pulses are around 0.63, 0.76, and 0.60 at the lasing wavelengths 1527.13, 1545.05, and 1561.78 nm, respectively. The SMSR and intensities are not uniform due to different losses at different wavelengths and the gain profile of the FPLD and EDFA. The tuning range of this system is from 1527.13 to 1561.78 nm, and the average power of output pulses is between 7.81 and 5.6 dBm. The SMSR and the pulsewidth as a function of wavelengths are shown in Fig. 6. The pulsewidth is between 49.3 and 65.3 ps at a repetition frequency of 2000 MHz. The wavelength-tunable range in our system is limited by the TF because the gain profile of the FPLD and EDFA are over 34.5 nm [see Figs. 2 and 3(a)]. When the operating range of the TF is larger, a larger wavelength-tunable range is expected.

The SMSR in this system is related to the bandwidth of TF. The narrower bandwidth of TF may increase the SMSR. However, the thermal drift in the FPLD can induce the wavelength shift of FPLD. Using the narrower bandwidth of TF has lower tolerance of the wavelength shift. Therefore, the bandwidth of TF in this system needs to consider the SMSR, the thermal reliability, and the acceptable cost. Furthermore, the SMSR is also related to the ASE injection power. When the ASE injection power is increased, the SMSR increase simultaneously. Nevertheless, when the ASE power saturates, the SMSR will not increase. In our experiment, the ASE power is close to saturation when the 980-nm pump power is 50 mW, and the SMSR saturates around 36.5 dB at the wavelength 1545.05 nm. We also measure the level of timing jitter at the wavelength 1545.05 nm. When the pump power is 50 mW, the timing jitter is 1.64 ps. Moreover, the ASE injection power increases 0.96 dB at 1545.05 nm when the pump power increases from 50 to 65 mW. The timing jitter is 1.51 ps. The output pulses are stable at this level of pump power. In addition, we observe that the timing jitter decreases when the ASE injection power increases.

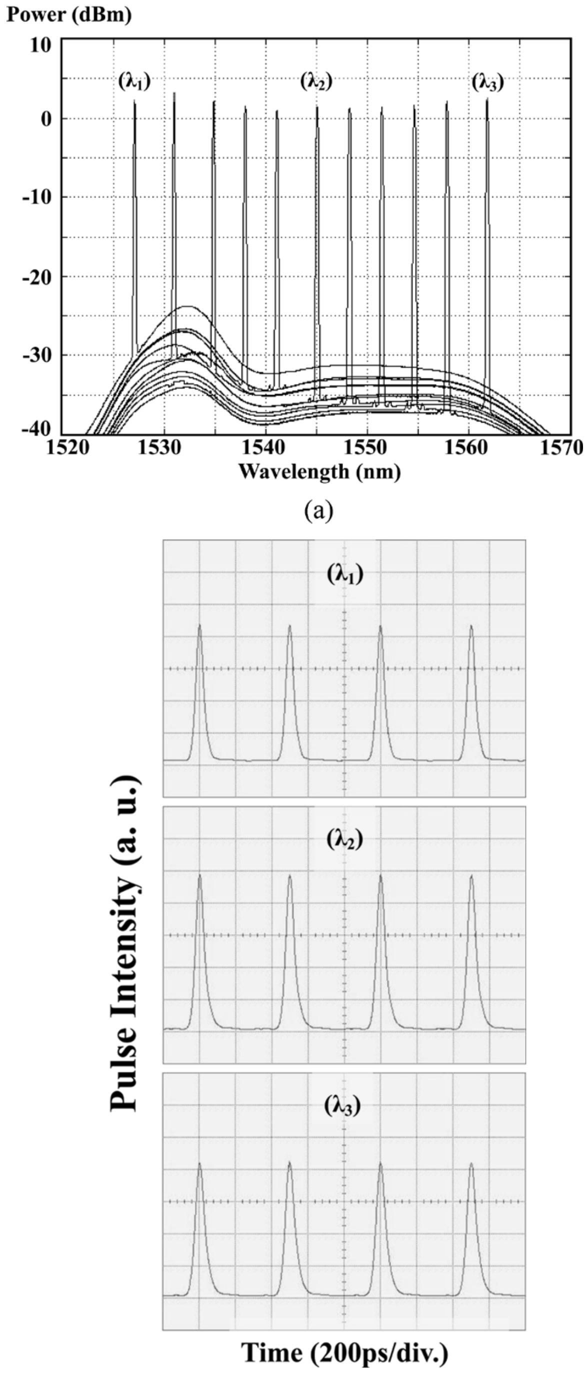

Fig. 5. (a) Output spectra and (b) pulse waveforms of the system when the central wavelength of the TF is tuned to one of the wavelength of the FPLD lasing modes.

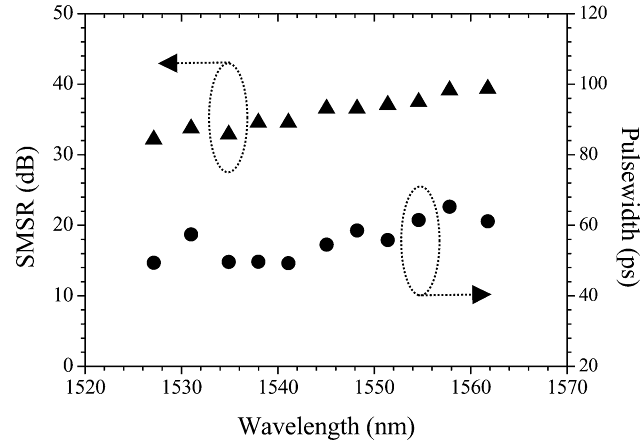

Fig. 6. SMSR and pulsewidth as a function of wavelengths.

III. Conclusion

We have demonstrated a system to generate wavelength-tunable optical pulses using an FPLD and an EDFA. The wavelength tuning is achieved by the TF, and the EDFA is used as both an external-injection source and an amplifier for the FPLD. The wavelength-tunable range of this system is over 34.5 nm with SMSR over 32 dB. The repetition frequency is 2000 MHz, and the pulsewidth is between 49.3 and 65.3 ps. The whole system is simple and can be easily constructed.

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