

Wavelength-tunable optical short pulse generation with constant repetition frequency and pulsewidth

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Abstract. A system to generate wavelength-tunable optical short pulses with a constant repetition frequency and pulse width by a gain-switched Fabry-Pérot laser diode (FPLD) in a self-injection scheme is demonstrated. A variable optical delay line is used to control the self-injection scheme to maintain a constant repetition frequency and pulse width at different wavelengths. The optical sidemode suppression ratio (SMSR) of this system is better than 33 dB over the wavelength-tunable range of 33 nm. © 2005 Society of Photo-Optical Instrumentation Engineers.

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1 Introduction

Wavelength-tunable short pulses are very important in many applications such as wavelength-division multiplexed (WDM), optical time-division multiplexed (OTDM), and hybrid WDM/OTDM optical communication systems and optical fiber sensors. A simple way to produce optical pulses is by a gain-switched Fabry-Pérot laser diode (FPLD). To enable wavelength-tunable operation of the optical pulses, an FPLD has been developed in self-injection schemes.¹⁻⁴ In this system, the selected wavelength output from a gain-switched FPLD is arranged to be fed back into the FPLD and results in a single-wavelength emission when the feedback pulse overlaps with the emission pulse in a timely manner. Due to the fact that repetition frequency is determined by the external cavity length of the gain-switched FPLD, this self-injection scheme makes it difficult to achieve a wide wavelength-tunable range and a constant repetition frequency and pulse width at different wavelengths.²⁻⁴ In this paper, we present a configuration to generate wavelength-tunable optical pulses by a gain-switched FPLD in a self-injection scheme. The operating wavelength is flexibly selected by a tunable optical filter, and its intensity is enhanced by an erbium-doped fiber (EDF) amplifier. Moreover, we add a variable optical delay line in our system to control the external cavity length so that the wavelength-tunable range and repetition frequency are not limited by a fixed external cavity length. Therefore, our system can maintain a constant repetition frequency and pulse width at different wavelengths. The performance of the system operated at the different wavelengths is reported.

2 Experiment and Results

Figure 1 shows the schematic diagram of the proposed gain-switched FPLD in a self-injection scheme. The system

consisted of an FPLD, a polarization controller (PC), a tunable optical filter (TF), an EDF amplifier, a variable optical delay line (VODL), and a fiber loop mirror as a cavity mirror. The FPLD used is a commercial 1550-nm InGaAsP device (from Appointech, Inc.) with a threshold current of 18 mA at 25°C and a mode spacing of 0.8 nm. Moreover, it does not have antireflection coating. The radio frequency (rf) sinusoidal signal is used to drive the FPLD into gain-switching operation via a bias-tee circuit. The polarization controller is used to optimize the output sidemode suppression ratio (SMSR) because only one polarization direction of the feedback light results in the maximum efficiency of the FPLD. The operating range of the tunable optical filter (TB4500 from JDS Uniphase Co.) is from 1528 to 1562 nm. The average 3-dB bandwidth of the tunable optical filter is 0.4 nm. When the central wavelength is located at 1530, 1545, and 1560 nm, the insertion loss of tunable optical filter is 5.51, 4.38, and 2.49 dB, respectively. In our experiment, a 980-nm laser diode with a 20-mW output

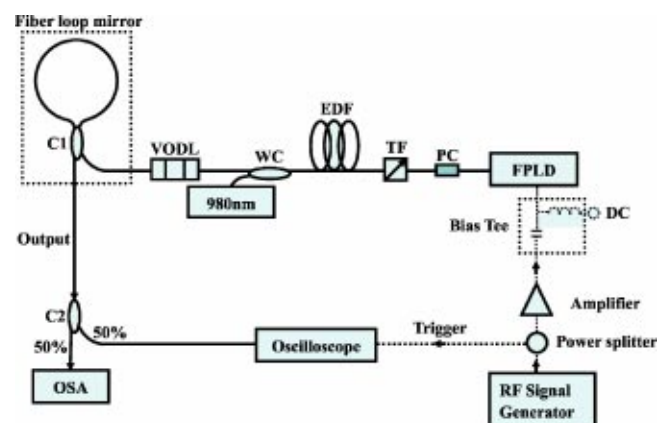


Fig. 1 Experimental setup for a gain-switched FPLD in a self-injection scheme.

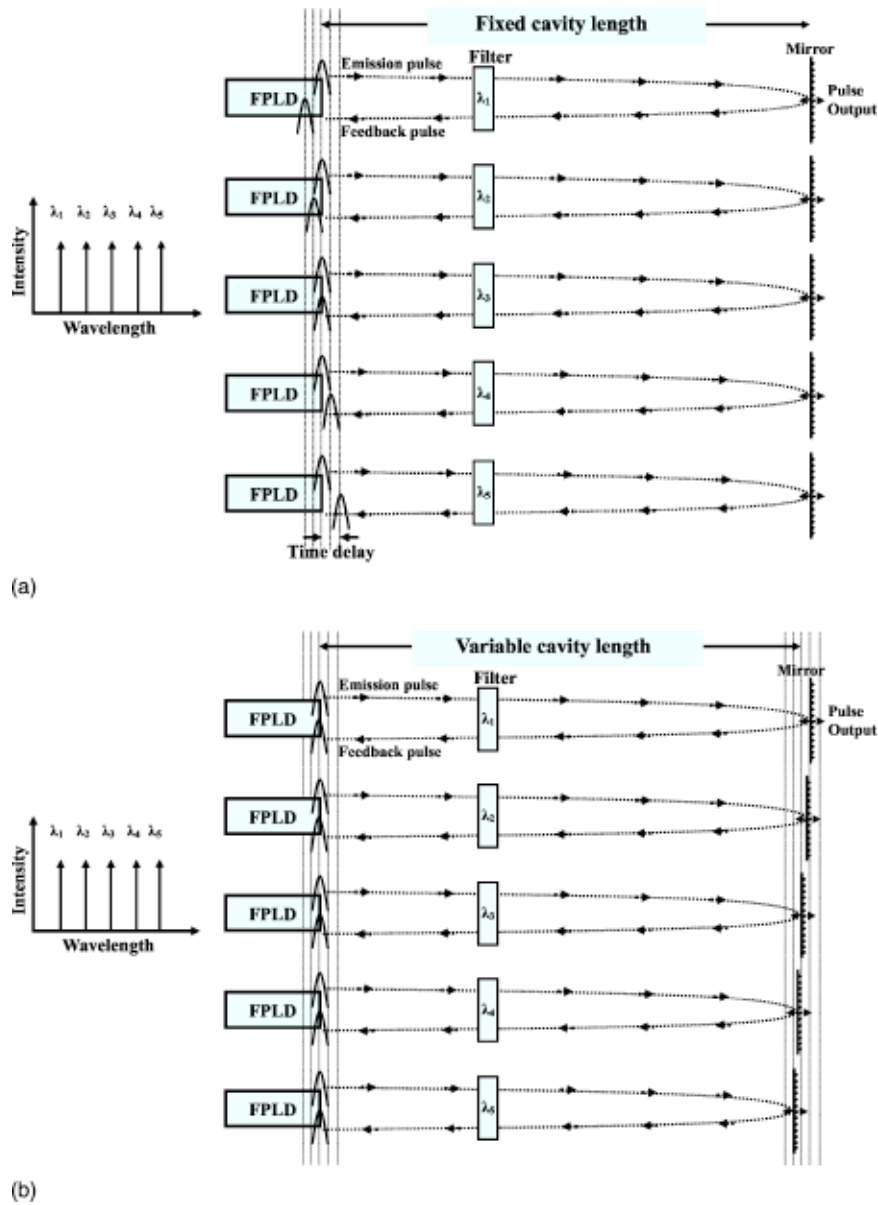


Fig. 2 Self-injection scheme (a) without VODL and (b) with VODL.

power pump the 14-m EDF via a 980/1550 nm WDM coupler (WC). The EDF amplifier is used to compensate for the loss of TF and VODL. The VODL is used to control the pulse propagation time from FPLD to FPLD. The fiber loop mirror is used to provide feedback to the FPLD. The coupling ratio of the 2×2 coupler (C1) for the fiber loop mirror is 30:70.

The operating principle of this self-injection scheme is as follows. The feedback light at the wavelength selected by the tunable optical filter travels along the following route: FPLD \rightarrow PC \rightarrow TF \rightarrow EDF amplifier \rightarrow VODL \rightarrow fiber loop mirror \rightarrow VODL \rightarrow EDF amplifier \rightarrow TF \rightarrow PC \rightarrow FPLD. Figures 2(a) and 2(b) show the self-injection scheme without VODL and with VODL, respectively, for comparison. Figure 2(a) shows the self-injection scheme without VODL when the central wavelength of the tunable optical filter is at different FPLD lasing modes.⁴ Because different wavelengths propagate in the cavity at different speeds, the feed-

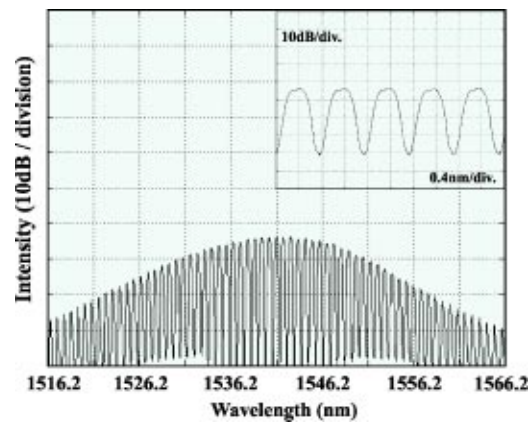
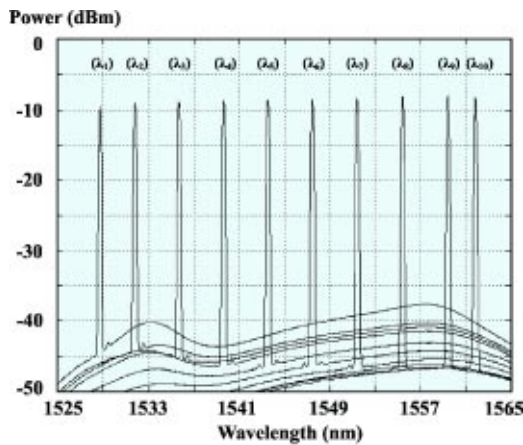
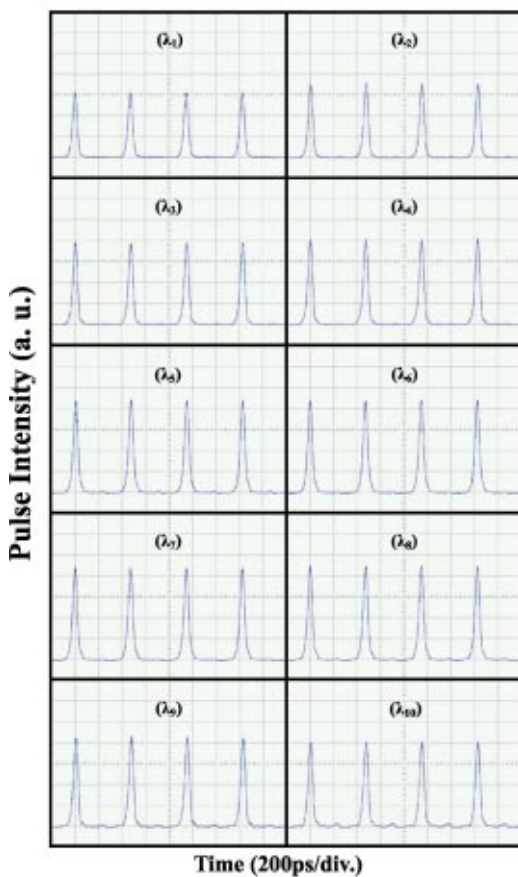


Fig. 3 Output spectrum of the gain-switched FPLD.



(a)



(b)

Fig. 4 (a) Output spectra and (b) pulse waveforms of the system when the central wavelength of the tunable optical filter is at different FPLD lasing modes.

back pulse is difficult to overlap with the emission pulse at different wavelengths. Therefore, the self-injection scheme without the VODL did not maintain a constant repetition frequency and pulsewidth at different wavelengths. Figure 2(b) shows the self-injection scheme with a VODL. The VODL can control the external cavity length and, hence, the self-injection scheme with the VODL can maintain a constant repetition frequency and pulse width at different

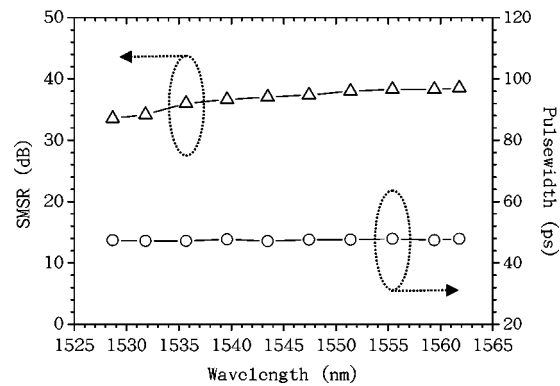


Fig. 5 SMSR and pulse width as a function of wavelengths.

wavelengths. Furthermore, this scheme has a wide wavelength-tunable range.

For simultaneous spectrum and waveform measurement, the output laser is split by a 1×2 coupler (C2) with coupling ratio 50:50 and measured by an optical spectrum analyzer (OSA) and a sampling oscilloscope with optical input port (86100A from Agilent Technologies). The FPLD is biased slightly below the threshold 2.6 mA and gain-switched at 2100 MHz. Figure 3 shows the output spectrum of the gain-switched FPLD. The enlarged spectrum of FPLD is shown in the inset of Fig. 3. The tunable optical filter is used to select the lasing wavelength. When the central wavelength of the tunable optical filter 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 performed only on single-wavelength operation. In our experiment, the optimum cavity length of system was selected so that the system can generate the best SMSR by adjusting the VODL. The cavity length is about 29.56 m, and the fundamental frequency is about 3.5 MHz. Figure 4 shows the output spectra and pulse waveforms when the central wavelength of the tunable optical filter is located at different FPLD lasing modes. The background of output spectra reflects the amplified spontaneous emission of the EDF amplifier. The SMSR and intensities are not uniform due to cavity loss at different wavelengths and the gain profile of the FPLD and EDF amplifier. Furthermore, different injection powers and wavelengths to the FPLD will generate different pulse widths. To maintain the pulse width, we must slightly adjust the VODL at different wavelengths. The tuning range of this system is more than 33 nm (from 1528.68 to 1561.8 nm). The SMSR and the pulse width as a function of wavelengths are shown in Fig. 5. The pulse width is around 47.5 ps at a repetition frequency of 2100 MHz. The wavelength-tunable range in our system is limited by the tunable optical filter because the gain profile of FPLD is over 33 nm (see Fig. 3). When the operating range of the tunable optical filter is large, a large wavelength-tunable range is expected.

3 Conclusion

We demonstrated a system to generate wavelength-tunable optical pulses with a constant repetition frequency and pulse width. The wavelength tunability is achieved by the tunable filter, and the EDF amplifier is employed to enhance the selected wavelength power to induce the self-

injection mechanism. To maintain a constant repetition frequency and pulse width at different wavelengths, the variable optical delay line is used to control the pulse propagation in the external cavity of the FPLD. The wavelength-tunable range of this system is over 33 nm with an SMSR over 33 dB. A constant repetition frequency of 2100 MHz and a constant pulse width of 47.5 ps are achieved.

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