Bistable wavelength switching in a two-section quantum-dot mode-locked diode laser

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Abstract: We investigate the wavelength-switching dynamics of a bistable two-section quantum-dot diode laser. The switching time between the two stable wavelengths is about 150 ps, which corresponds to two round trips in the laser.

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Wavelength switching is very important in applications such as optical switching and memory in optical communications and optical signal processing. Wavelength switching from two-section diode lasers with bistable lasing wavelengths is more attractive because of their compact size and simple structure as compared with other types of wavelength bistable lasers, such as fiber and external cavity lasers [1-3]. Studies of wavelength bistability and switching in two-section diode lasers started in the 1980s [4]. Since then, this area remained relatively unexplored until recently. In the last few years, the emergence of two-section–quantum-dot (QD) diode lasers has led to new and exciting results in the area of wavelength bistability with mode-locked pulse lasing [5,6]. Cataluna et al., reported wavelength bistability between the excited state mode and ground state mode with low power contrast ratio between these two modes. In wavelength switching applications, high contrast ratio is important to fully switch one wavelength to another one. Previously, we demonstrated wavelength bistability with a high contrast ratio in a QD laser. We showed that when one mode is lasing, the other mode is quenched. Here, we present fast switching in a bistable-wavelength two-section mode-locked QD diode laser. The two bistable wavelengths are 1170 nm and 1140 nm. The switching time between these two modes is about two round trips of the laser cavity, or 150 ps.

The two-section diode QD diode laser is a single mode ridge-waveguide laser and has the same configuration as our previous work [6]. The lengths of the gain and absorber sections are 2.8 mm and 0.3 mm, respectively.

Wavelength bistability, i.e., a hysteresis loop in the wavelengths, is observed when the reverse bias on the saturable absorber is swept between 0 V and -8 V with a fixed-gain section current of 100 mA. In this wavelength hysteresis loop, there are two branches throughout the saturable-absorber bias range of -6 to -1 V. The two stable branches are at 1140 and 1170 nm. These two-branches are in the ground states of the QD gain. From the optical spectra of the two bistable wavelengths, when the absorber bias is -4 V, the contrast ratio between these two modes is greater than 40 dB over the noise. The output of the laser is a picosecond pulse train, as characterized in reference [6]. One round-trip time of the cavity is 70 ps.

To demonstrate wavelength switching between the two bistable modes, we operate the saturable-absorber bias voltage in the middle of the hysteresis loop (-4V). When an ultrafast electrical pulse of the required polarity is applied on the absorber, the output wavelength can be switched.

To measure this switching time, we disperse the output of the laser with a grating and measure each wavelength mode independently with photodiodes. While high-speed electrical pulses are applied to the direct current (DC) biased (-4V) absorber, the optical power is monitored with a high-speed oscilloscope. The set pulse switches the wavelength from 1140 to 1170 nm. The leading edge of the set pulse is 200 ps from -4 to 0 V, with a pulse width of 1 ns and a repetition rate of 100 kHz. The reset pulse switches the wavelength from 1170 nm back to 1140 nm. The leading edge of the reset pulse is 600 ps from -4 to -8 V, with a pulse width of 10 ns.

The measured switching dynamics are presented in Fig. 1. We present the wavelength switching between 1170 and 1140 nm with the set and reset pulses at large time scales in Fig. 1(a). We also show a close-up of the ultrafast switching dynamics in Fig. 1(b).

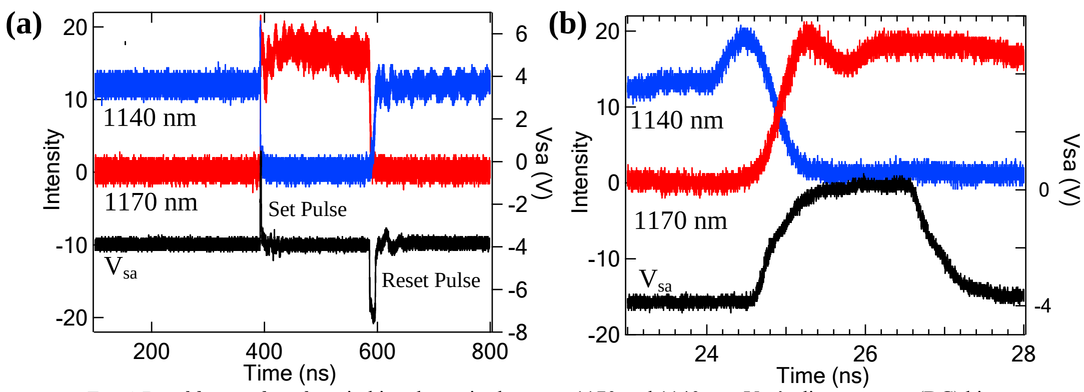

Fig. 1 Bistable wavelength-switching dynamics between 1170 and 1140 nm. Vsa's direct current (DC) bias is -4 V. The red line is the intensity of 1170 nm branch, the blue line is the intensity of 1140 nm branch, and the black line is the Vsa voltage. (a) Bistable wavelength switching between 1170 and 1140 nm with the set and reset pulses. (b) The fast dynamics of wavelength switching from 1140 to 1170 nm.

To characterize the ultrafast switching dynamics, we define the switching time as the measured time from 90% intensity of wavelength one to 90% intensity of wavelength two. In our case, the shortest measured time to switch from the 1140 nm branch to the 1170 nm branch is about 150 ps. The switching time actually occurs faster than the rise time of the set pulse, 200 ps, indicating that the jump in wavelength takes place over a narrow voltage range. The measured switching time is about two round trips of the laser cavity.

We have studied bistable wavelength switching in a two-section mode-locked QD laser. We observe hysteresis and bistability in the lasing wavelengths when the reverse bias voltage is varied on the saturable absorber. The measured switching time is about 150 ps, which corresponds to two round trips in the laser.

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