Experimental Demonstration of Subnano-Second Wavelength Switching in V-Coupled-Cavity Semiconductor Laser

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Abstract: The tuning characteristics based on both free carrier dispersion and thermal effect induced by the tuning current of a V-coupled-cavity laser are investigated. Sub-naosecond and tens of microseconds wavelength switching time between two neighboring channels are measured, respectively.
OCIS codes: (140.3600) Lasers, tunable; (250.6715) Switching

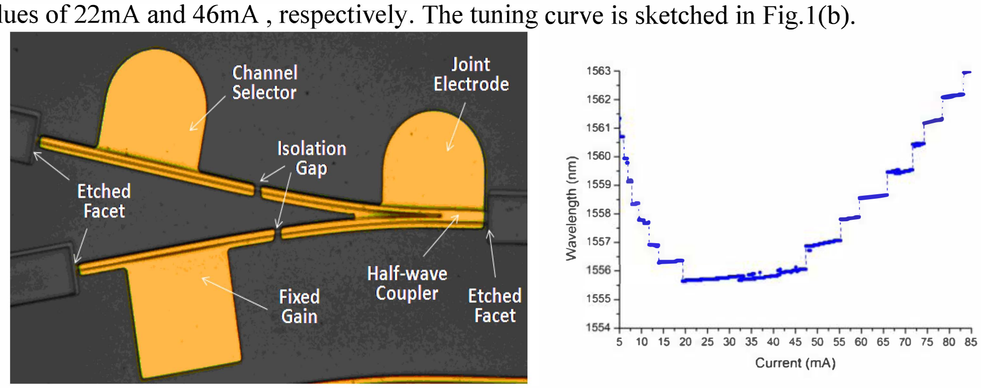
1. Introduction

Low-cost, reliable and wideband wavelength tunable semiconductor laser is a key enabling technology for optical networks. Compared with fixed wavelength DFB lasers, the tunable lasers can reduce the inventory cost in an optical network. They are also important components for reconfigurable optical add-drop multiplexing (ROADM). Besides, high speed wavelength switchable lasers can open the possibility for new intelligent system architectures such as wavelength based packet switching [1].

Wavelength switchable lasers can be realized by using two V-coupled cavities of slightly different lengths without complex non-uniform (or selective area) gratings and multiple epitaxial growths [2]. In this paper, we report the first experimental results of wavelength switching time in V-coupled-cavity semiconductor laser.

2. Steady state tuning characteristics

The V-coupled-cavity laser (VCCL) used in this study is a standard ridge waveguide laser with InGaAsP/InP multiple quantum wells (MQW). It comprises with two coupled Fabry-Perot (FP) cavities with different optical path length which are coupled by a reflective 2x2 half-wave coupler as shown in Figure 1(a). One is the fix gain cavity (the short one) and the other is the wavelength selector cavity (the long one). The principle and the detailed fabrication process of VCCL can be found in Ref. [3]. The emission wavelength was tuned by changing the current in the channel selector electrode from 5 to 85mA while the fixed gain electrode and the joint electrode were biased at fixed values of 22mA and 46mA , respectively. The tuning curve is sketched in Fig.1(b).



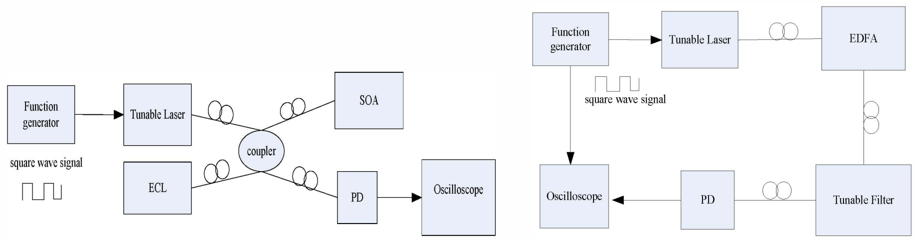
(a) (b)

Fig.1 (a) Optical microscope image of the V-coupled-cavity laser and (b) measured tuning curve

As shown in Fig. 1(b), when the current biased on the channel selector electrode increases within the range of 0-20mA, the wavelength decreases with the current injection due to the free carrier dispersion effect. Above 20mA to 47mA, the free carrier induced wavelength tuning is compensated by the thermal effect, the wavelength keeps almost constant. After the current increases above 47mA, the thermal effect starts to dominate the wavelength tuning. Since the refractive index increases with the temperature but decreases with the carrier density, the switching direction is opposite for thermal tuning and free carrier dispersion tuning schemes.

3. Dynamic wavelength switching

To investigate the dynamic characteristics, we use two different methods to measure the wavelength switching time for the above two different tuning schemes. Fig. 2 shows the measurement set-ups for the two methods. For both of the method, a square wave signal generated by a function generator drives the channel selector to make the wavelength switching between two channels. For operation in the fast free dispersion carrier tuning range, optical heterodyne technique is used to convert the wavelength signal to an intensity signal in time domain and displayed by a high speed sampling oscilloscope (Fig. 2(a)). On the other hand, for the thermal effect dominated slow switching, an optical filter is utilized to achieve the wavelength-intensity conversion and a real time oscilloscope to visualize the waveform (Fig.2(b)). The reason for the usage of optical filter is that the period of the signal used in thermal effect domain is very small (1kHz), and such a slow waveform cannot be measured by the sampling oscilloscope used in the experiment.



(a) (b)

Fig. 2 (a)Optical heterodyne method and (b) optical filter method for the switching time measurements

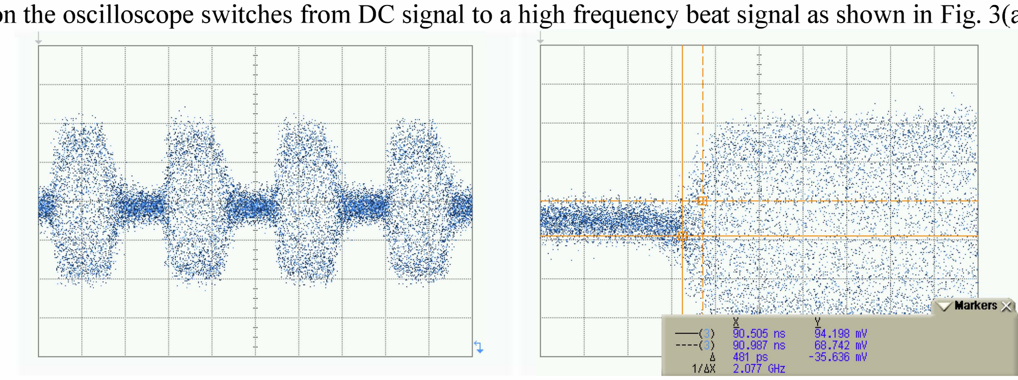
Table 1 shows four wavelengths and their corresponding current values from the static measurements. The switching between Channel A and Channel B is based on carrier injection effect while the thermal effect dominates the switching between Channel C and Channel D. The switching times are measured below.

Table. 1: Four wavelengths and their corresponding tuning current values

	Channel A	**Channel B**	**Channel C**	**Channel D**
Current	17mA	25mA	39mA	49mA
Wavelength	1556.33nm	1555.70nm	1555.88nm	1556.67nm

3.1 Free carrier dispersion switching time measurement by optical heterodyne method

The setup of the optical heterodyne is schematically illustrated in Figure 2(a). A square wave signal (frequency=155.5MHz, duty cycle=0.5, rise/fall time $T_0 = 30ps$) is used. The optical heterodyne technique [4] is employed to select out one of the two channels and thus convert the wavelength signal to an intensity waveform. After the optical emission from the two lasers is mixed through the coupler, the mixed light wave is observed in a optical spectrum analyzer (OSA) and detected by a 12.5GHz photodetector (PD). The external cavity laser (ECL) output wavelength is tuned near Channel B so that when the VCCL operate on Channel B, the frequency difference of the lasers is within the bandwidth of the PD. The heterodyne beat signal can then be detected by the PD and displayed by the oscilloscope. When the wavelength switches from Channel A to Channel B, the detected electrical signal on the oscilloscope switches from DC signal to a high frequency beat signal as shown in Fig. 3(a).



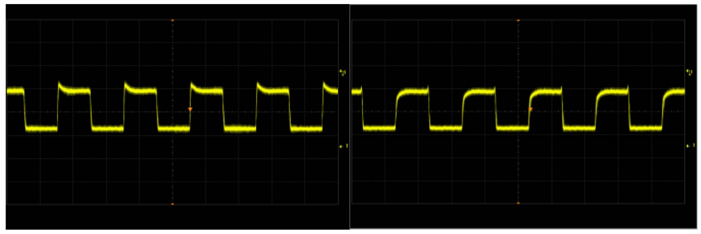
(a) (b)

(b) Fig. 3 Wavelength witching signal as viewed on the sampling oscilloscope with (a) 5 ns / div. and (b) 1ns/ div.

As shown in the expanded view of Fig.3 (b), the switching time between Channel A and Channel B is about $500ps$.

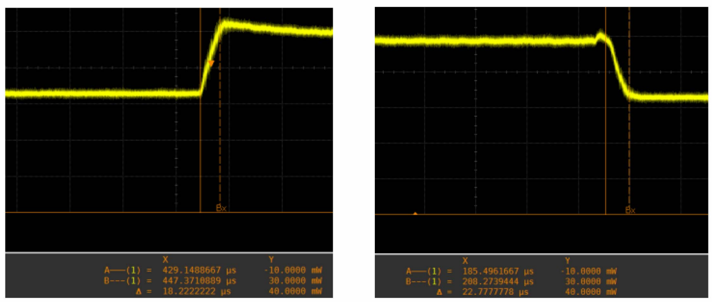
3.2 Thermal switching measurement by optical filter method

The setup of the measurement for the optical filter method is sketched in Fig. 2(b). The square wave signal (frequency=1kHz, duty cycle=0.5, rise/fall time $T_0 = 6\mu s$) make the wavelength switch between Channel C and Channel D. After amplification by an EDFA, the light is launched in to a tunable filter. Since the central wavelength of the tunable filter can be set on one channel to filter out the other channel and only the selected channel can be observed on the oscilloscope though the photodetector (PD), as shown in Fig. 4.



(a) (b)

Fig.4 (a) Channel D and (b) Channel C signals as viewed on the oscilloscope with 500μs / div



(a) (b)

Fig.5 (a) the rise time of Channel D signal and (b) the fall time of Channel C with 50μs/div

As shown in Fig. 5, the rise time of Channel D is 18μs and the fall time of Channel C is 22μs. Therefore, the switching time between Channel D and Channel C is about 20μs.

4. Conclusion

The switching times of thermal effect induced wavelength switching and the free carrier dispersion switching of V-coupled-cavity lasers have been experimentally measured. The free carrier dispersion switching time can be as low as 500ps while the thermal effect switching time is in the order of tens of microseconds. The switching characteristics of the V-coupled-cavity lasers are very important for optical network applications.

5. Acknowledgement

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6. References

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