Novel Thermal Drift Suppression Method in Channel Switching of Mode-hop-free Tunable Laser Array

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Abstract: A switching time of less than 40 μs has been achieved for a TDA-DFB laser array with a thermal drift suppression technique using the tuning regions of non-lasing lasers as heaters for temperature compensation.

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1. Introduction

Tunable wavelength lasers are expected to provide light sources for future photonic networks based on wavelength division multiplexing (WDM). In particular, high-speed wavelength switching in tunable wavelength lasers is a key function for a wavelength routing system. High-speed tuning can be obtained by current tuning, because the injection of current into a semiconductor provides a large and fast change in refractive index. The wavelength switching times of several tunable wavelength lasers that employ current injection have been reported including those of super structure grating (SSG) distributed Bragg reflector (DBR) lasers [1,2], sampled grating (SG) DBR lasers [3] and digital super-mode (DS) DBR lasers [4]. While carrier effects (plasma effect, band filling effect) appear within several nanoseconds, a slow effect, namely thermal drift, also appears when the operating wavelength is maintained for a relatively long time before and after switching.

On the other hand, tunable lasers whose wavelength can be changed reliably and easily are also needed for optical fiber communication systems. The lasing wavelengths of tunable twin guide (TTG) lasers [5] and short cavity DBR [6] or DFB [7] lasers can be tuned without mode hopping with a single tuning terminal. However, the maximum tunable wavelength range of mode-hop-free tunable wavelength lasers is usually less than 10 nm.

To achieve high-speed, wide-band and mode-hop-free tuning, we have been developing a tunable distributed amplification (TDA-) DFB laser array, in which multiple TDA-DFB LDs are monolithically integrated with a coupler and a semiconductor amplifier (SOA). A tuning range of 44 nm, which corresponds to 110 channels with a 50 GHz grid, has been reported for a 6 TDA-DFB laser array [8].

In this work, a thermal drift suppression technique for channel switching in the tunable laser array is proposed and demonstrated without any other additional structures. A sub-ms wavelength switching time is obtained for the first time with a TDA-DFB laser array with temperature compensation.

2. Device structure and measurement technique

Asymmetric TDA-DFB lasers have multiple units consisting of both an active region and a tuning region, and these regions are connected alternately and periodically, as shown in Fig. 1 (a). To expand the tuning range without mode hopping the unit lengths in sections before and after a λ/4 shift are different (L_1=60 μm, L_2=81 μm), but the ratios of the lengths of the active layers and tuning layers must be the same for both sections The TDA-DFB laser has two electrodes since the upper electrodes in each region are connected to each other. The structure is described

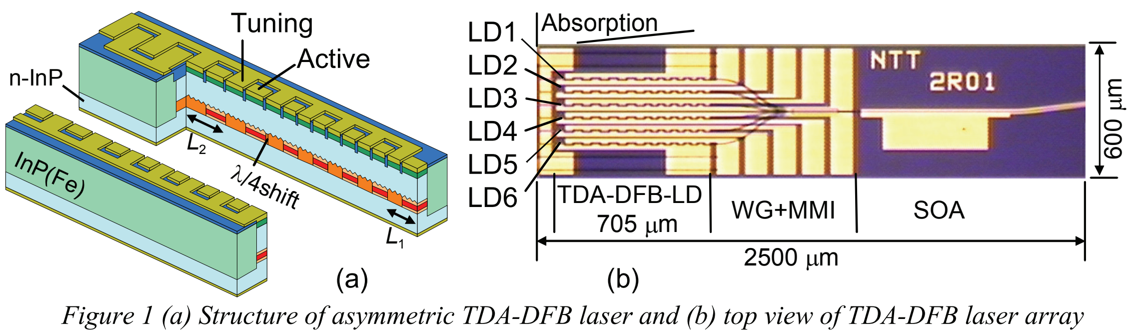

Figure 1 (a) Structure of asymmetric TDA-DFB laser and (b) top view of TDA-DFB laser array in detail in [8]. Figure 1(b) shows the top view of a TDA-DFB-LD array consisting of 6 LDs, a multi-mode interferometer (MMI) coupler and an SOA. These lasers are arranged in parallel at 60-µm intervals. The device is 2500 µm long and 600 µm wide.

To obtain time resolved spectra, we used the measurement setup shown in [2]. To clarify the suppression effect of thermal drift, the switching period should be lengthened to follow the temperature change in the device caused by current injection. Therefore, as shown in Fig. 2(a), the lasing wavelength was switched by changing the injection current with a period of 100 ms, where the time resolution was 40 µs. Figure 2(b) explains the thermal drift. As the tuning current increases, the lasing frequency increases rapidly (within several ns) due to the plasma effect. The injected current also induces a gradual increase in the chip temperature, which lowers the frequency.

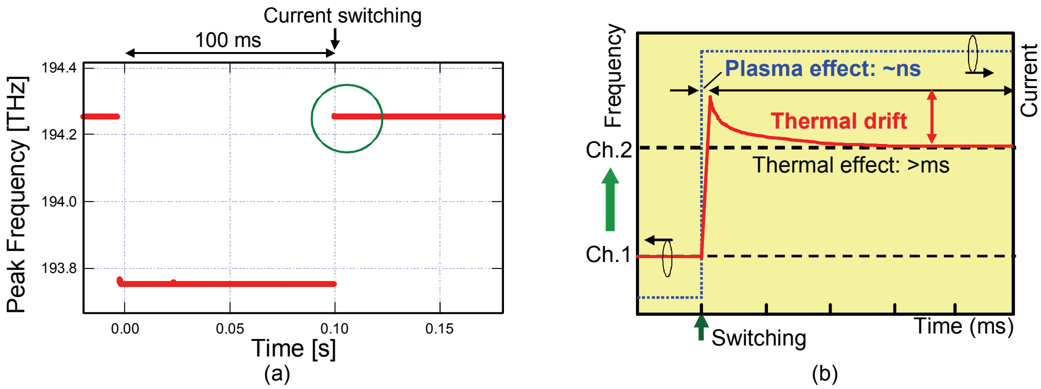

Figure 2 (a) Example of switching (193.75 to 194.25 THz) and (b) explanation of thermal drift

3. Thermal compensation in LD array

A temperature compensation method employing thermal drift compensators (TDCs) [2,9] that are monolithically integrated parallel to the laser mesa has been reported for suppressing thermal drift. With this technique, the total heat generated by the injected currents is kept constant for all the channels. We can apply this method to the TDA-DFB LD array without adding any other special mesa structure, since we use the tuning regions of an LD mesa that is not lasing in parallel to the operated LD mesa as a TDC. There are two cases of channel switching in the LD array. One is where both channels exist in the same LD. The other is where channels are switched between different LDs.

First, we measured the channel switching time in the same LD. Figure 3 shows time resolved spectra immediately after current switching. Since both channels can be operated in LD5, the tuning current changes from 1.56 to 52.3 mA while the active current is kept at 75 mA. The SOA current was 150 mA for all conditions. The tuning region in LD6 was used to compensate for the chip temperature, where the tuning current was changed from 52.3 to 1.56 mA to keep the total injection current constant. Figure 3(a) and (b) show the results of channel switching without and with compensation, respectively. Without compensation, the maximum frequency deviation from a static frequency, which means the frequency under continuous operation, is 7 GHz. The channel switching time with a frequency deviation of less than 1 GHz is around 3 ms. The compensated operation greatly suppressed the thermal drift. The channel switching time is estimated to be less than 0.2 ms.

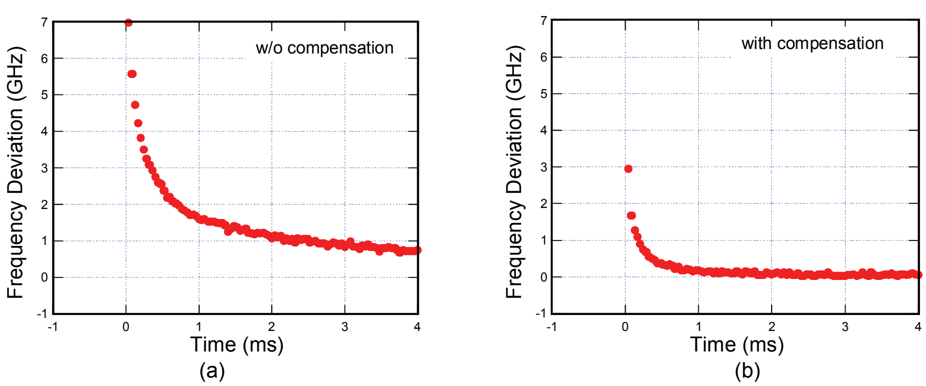

Figure 3 Time resolved spectra of channel switching (193.80 to 194.55 THz)
(a) without thermal compensation and (b) with thermal compensation

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Next, we measured the channel switching time between different LDs. Figure 4 shows the results of channel switching from 194.65 THz in LD6 to 194.25 THz in LD5. Figure 4(a) shows a result of simple switching without thermal compensation, whose current condition is shown in Table I(a). The frequency deviation and switching time were 6 GHz and around 1 ms, respectively. Figure 4(b) shows a thermal compensation result, where the tuning current for each laser was kept constant under both channels, as shown in Table I(b). Although the switching time was reduced to around 0.3 ms as a result of the thermal compensation by keeping the total injected current constant, a slight thermal drift remained because of the large current change in the active layers. Since the distance between each LD is too great for complete thermal compensation, the next LD should be heated adequately before its lasing. Therefore, we applied a local heating current to the tuning regions of LD5 before its operation, as shown in Table I(c). To compensate for the chip temperature, we used the tuning regions of LD3 so that the total injected current was kept constant. Finally, as shown in Fig. 4(c), we achieved a channel switching time of less than 40 μs, which was the time resolution limit for this measurement. This local heating technique is more effective in a TDA-DFB laser because of the periodic tuning regions in the cavity.

Table 1 Operating conditions for each channel

(a) no compensation

	LD6		LD5	
Frequency (THz)	194.65	194.25	194.65	194.25
Active current (mA)	75.0	0.0	0.0	75.0
Tuning current (mA)	0.97	0.0	0.0	16.92

(b) compensation

LD6		LD5	
194.65	194.25	194.65	194.25
75.0	0.0	0.0	75.0
0.99	0.99	16.93	16.93

(c) compensation & local heating

LD6		LD5		LD3	
194.65	194.25	194.65	194.25	194.65	194.25
75.0	0.0	0.0	75.0	0.0	0.0
1.14	1.14	65.00	17.47	27.47	75.00

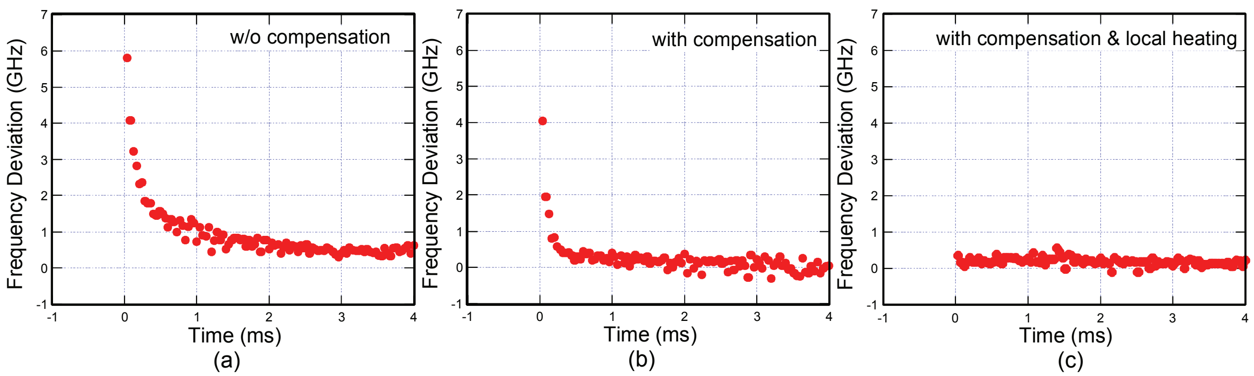

Figure 4 Time resolved spectra of channel switching between different LDs (194.65 to 194.25 THz) (a) without thermal compensation, (b) with thermal compensation and (c) with thermal compensation and local heating current

4. Summary

High-speed wavelength tuning in the TDA-DFB-LD array that can change the lasing wavelength without mode hop was demonstrated for the first time. A channel switching time of less than 0.3 ms were obtained with the thermal drift compensation technique using a tuning current of next LD in laser array. In addition, by means of local heating technique, switching time can be decreased to less than 40 μs. The novel thermal drift suppression method in the TDA-DFB laser array is very effective for systems that use high-speed wavelength switching.

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