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Communication

Distributed Feedback Laser in External Light Injection Scheme for Tunable Slow Light

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This investigation experimentally demonstrates a commercial distributed feedback (DFB) laser in an external light injection scheme for tunable slow light. The effect of the polarization of the probe signal on tunable optical delay is studied. Tunable optical delays of up to 30 ps for 10 GHz sinusoidal signals with optimal polarization are achieved. We also study the relationship between optical delay and input optical modulation index. [DOI: 10.1143/JJAP.47.4600]

KEYWORDS: distributed feedback laser, optical delay

Tunable slow-light devices (variable optical delay lines) are important components in optical communication and signal processing systems.[1–3] The variable optical delay lines using semiconductor-based devices are very attractive owing to their compactness and low power consumption. Recently, tunable optical delay using a quantum well Fabry–Perot (FP) laser has been reported.[4] The probe signal with about 14 ps tunable delay at 2 GHz has been demonstrated. Moreover, tunable optical delays using a vertical-cavity semiconductor optical amplifier have also been proposed.[5] A tunable time delay of about 100 ps at 1 GHz was presented. However, tunable optical delay using a commercial distributed feedback (DFB) laser has not yet been addressed. In addition, how the polarization of the probe laser affects time delay has not been studied while a FP or DFB laser is an edge emitting laser.

In this paper, we report the tunable optical delay in a commercial quantum well DFB laser. The relationship between probe signal polarization and time delay is studied for the first time. With optimal probe signal polarization, a 10 GHz sinusoidal modulation signal with tunable optical group delays of up to 30 ps is demonstrated. Moreover, the relationship between time delay and input optical modulation index (OMI) is also studied for the first time.

A commercial 1.55 μm InGaAsP/InP quantum well DFB laser is hermetically sealed by a standard TO-Can package with a built-in aspherical lens. The TO-Can packaged DFB laser and the single mode fiber are assembled by the laser welding technique. The threshold current is about 8 mA. Figure 1 shows the experimental setup for measuring the optical group delays in the DFB laser. A probe signal is generated by a tunable laser and modulated via an electro-optical modulator. The signal power is controlled by a variable optical attenuator at the output of the electro-optical modulator. An optical circulator is used to couple the probe signal into the DFB laser. Because the DFB laser is a polarization dependence device, the different polarizations of the probe signal for DFB laser injection will result in a corresponding effective optical injection power in the DFB laser cavity. Different effective powers of the probe signal in the laser cavity will induce different time delays.[5,6] In this study, the polarization of the probe signal is adjusted to reach the maximum time delay in the DFB laser, and the wavelength of the probe signal is tuned to the resonance of the DFB laser cavity.

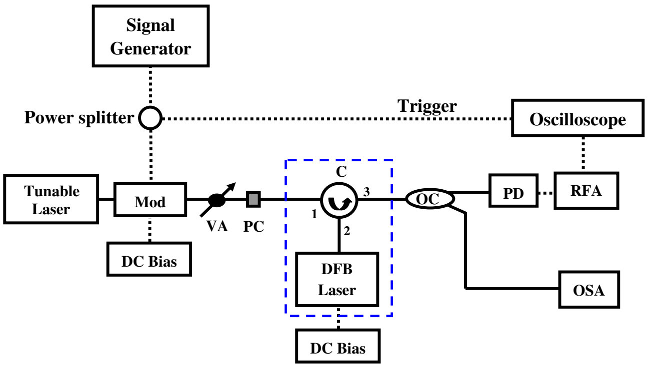

Fig. 1. (Color online) Experimental setup for measuring tunable optical delays in DFB laser (Mod: electro-optic modulator, VA: variable optical attenuator, C: optical circulator, OC: optical coupler, PC: polarization controller, RFA: RF amplifier, PD: photodetector, OSA: optical spectrum analyzer).

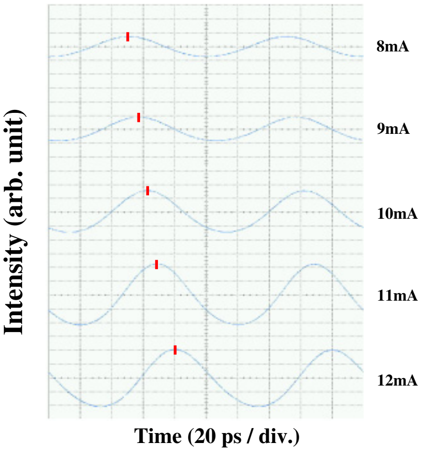

Fig. 2. (Color online) Measured time delays for 10 GHz probe signal at various bias currents of DFB laser.

The probe signal is tuned to the resonance of the DFB cavity, and the probe signal power is −7 dBm. The polarization of probe signal has a marked effect on the tunable time delay of the DFB laser. The probe signal polarization is adjusted to reach the maximum time delay at a bias current of 12 mA. Figure 2 shows the measured time delays for a 10 GHz sinusoidal probe signal. As the bias current of DFB laser increases from 8 to 12 mA, the RF gain increases and the time delay of the probe signal increases. A maximum group delay of 30 ps is observed. Figure 3 shows the curve

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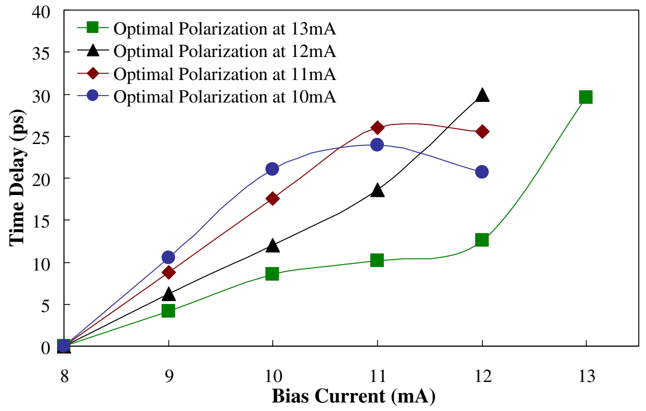
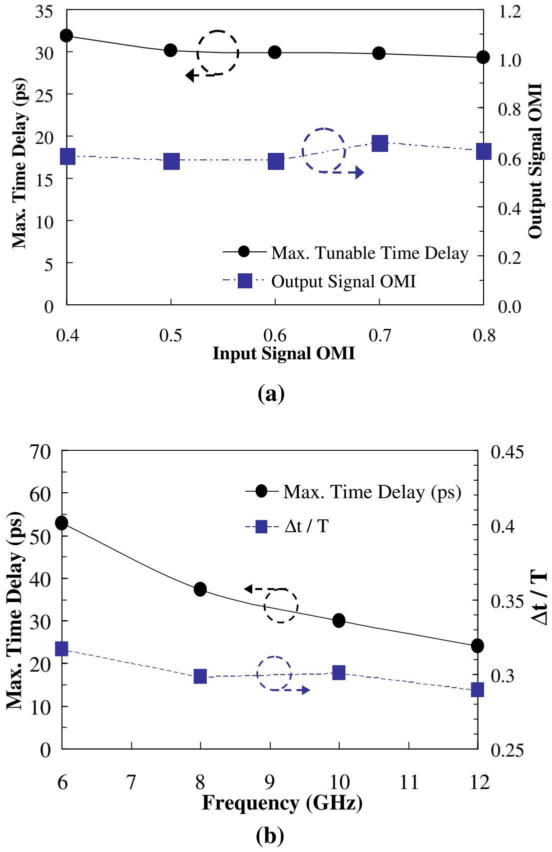


Fig. 3. (Color online) Measured time delays for 10 GHz probe signal at various bias currents of DFB laser at different optimal polarizations.

of tunable time delay when the optimal polarization is adjusted to reach the maximum time delay at different bias currents. When the bias current is more than 13 mA, the probe signal experiences distortion. Therefore, the optimal polarization condition for tunable time delays is obtained when the polarization of probe signal is adjusted to reach the maximum time delay at a bias current of 12 mA. A tunable time delay of up to 30 ps is achieved by varying the bias current from 8 to 12 mA.

The relationship between time delay and input probe signal OMI is also studied. Figure 4(a) shows the maximum tunable time delays with OMIs of the input probe signals varied from 0.4 to 0.8 under the optimal polarization condition at a bias current of 12 mA. The maximum time delays are about 30 ps even when the OMIs of the input probe signals vary from 0.4 to 0.8. The relationship between time delay and modulation frequency of probe signals are shown in Fig. 4(b). For 12 and 6 GHz, the time delays are 24 and 53 ps, respectively. The maximum time delay in the DFB laser increases as the modulation frequency decreases. It should be noted that the ratio of delay time (Δt) to probe signal period (T) is about 0.3 as the probe signal frequency is varied from 6 to 12 GHz.

We experimentally demonstrate tunable optical delay using a commercial 1.55 µm DFB laser at room temperature. The polarization of the probe signal plays an important role in optical group delay. Tunable optical group delays of up to 30 ps for 10 GHz sinusoidal signals under the optimal polarization condition are achieved by varying bias current. In contrast with the FP laser(4) or a vertical-cavity semiconductor optical amplifier,(5) the commercial DFB laser is a single-mode light source by direct electrical control. Moreover, a slow-light device using the DFB laser is possible for the polarization-mode dispersion compensation in the optical communication system.(7) In the polarization-mode dispersion compensator,(8) an optical delay is required to compensate for the polarization-mode dispersion. The slow light device has the potential to reduce the size and cost of the polarization-mode dispersion compensator in the optical communication system.



(a)

(b)

Fig. 4. (Color online) (a) Relationship between maximum time delays and input probe signal OMIs. (b) Relationship between maximum time delays and modulation frequencies of probe signals.

Acknowledgments

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