Suppression of Second Harmonic Distortion in DFB Lasers with Optical Injection Locking

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The performance of the sub-carrier-multiplexed (SCM) fiber optic systems with direct modulation is often limited by the nonlinear distortions of semiconductor lasers. The nonlinear distortion increases significantly as the carrier frequency approaches the relaxation oscillation frequency of the laser due to the coupling between photons and elections in the laser cavity [1-2]. Recently, it has been theoretically shown that the laser nonlinearity can be considerably reduced by optical injection locking [3]. In this paper, we report on the experimental observation of the reduction of the second harmonic distortion in directly modulated semiconductor lasers under strong injection locking.

The experimental setup is shown in Fig. 1. The master laser is a commercial external-cavity tunable laser diode (ECT-LD) at 1.55 μm. The laser linewidth is less than 200 kHz. The CW light from the ECT-LD is injected into the slave laser through an optical isolator. The slave laser is a 1.55 μm single-longitudinal mode distributed feedback (DFB) laser diode with a threshold current I_{th} of 23 mA. A polarization controller is employed to adjust the polarization of the injected light. The DFB laser is directly modulated by a microwave signal through a bias-T. The optical signal is detected and amplified by a 15-GHz lightwave converter (HP 11982A) with responsivitiy of 300 V/W for 50 Ω load. The output is connected to a microwave spectrum analyzer for measuring the second harmonic distortion (2HD), which is defined as the power ratio of the fundamental wave to the second harmonic wave.

Figure 2(a) shows the measured power spectrum of the laser without external optical injection. The laser is biased at 40 mA and modulated by a 3.4-GHz microwave signal with – 2 dBm power. The relaxation oscillation frequency of the laser under this bias condition is 4.1 GHz. The 2HD is measured to be –19 dBc. In contrast, Fig. 2(b) shows the corresponding power spectrum of the DFB laser under injection locking. The 2HD has been dramatically reduced to -40 dBc. The injection ratio and frequency detuning are –8 dBm and –15 GHz, respectively, which are located in the middle of the stable locking range. Figure 3 shows the measured second harmonic distortion with and without external optical injection versus the modulation frequency. The injection parameters are the same as those used in Fig. 2(b). With injection locking, the second harmonic distortion is suppressed by more than 15 dB from 2 to 4 GHz.

In conclusion, we have experimentally demonstrated that optical injection locking is very effective in suppressing the second harmonic distortion in directly modulated semiconductor lasers. More than 15 dB reduction in second harmonic distortion has been observed from 2 to 4 GHz. This technique is very useful for high performance sub-carrier multiplexed fiber optic systems with carrier frequencies of several GHz. This work is supported by ONR MURI on RF Photonics.

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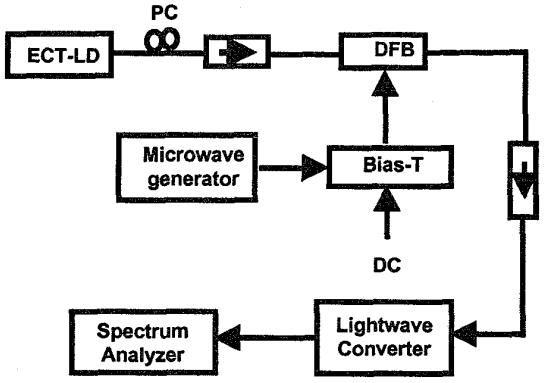

Fig.1 Experimental setup. PC: polarization Controller

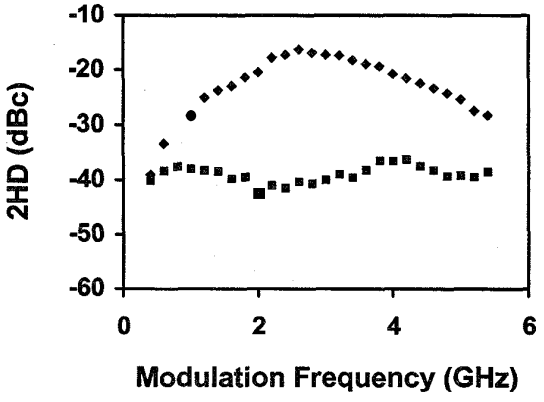

Fig. 3 Second harmonic distortion versus modulation frequency for free-running (♦♦♦) and injection locked (■ ■ ■) laser .

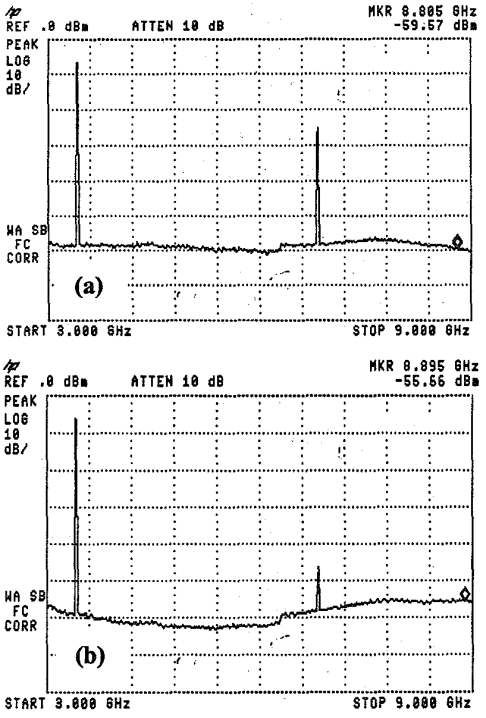

Fig. 2 Power Spectrum of DFB laser modulated at 3.4 GHz. (a) free-running, and (b) injection locked laser.