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Nonlinear Distortion Suppression in Fabry-Perot Semiconductor Lasers by Optical Injection Locking

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Abstract

The effects of optical injection locking on the injection locking bandwidth and third-order inter-modulation distortion (IMD3) suppression in a side-mode injection-locked Fabry-Perot laser diode (FP-LD) are experimentally investigated. It is shown that FP-LD injection locking bandwidth and reduction of IMD3 is varied at the different injection target mode of FP-LD. Injection locking bandwidth and reduction of IMD3 can be enhanced by choosing an appropriate injection target mode.

Key Words – optical injection locking , injection locking bandwidth , inter-modulation distortion

Session-Th1

1. Introduction

Subcarrier multiplexed (SCM) fiber optic systems with direct laser intensity modulation are recently attracting much attention for wireless local loop, cable television distributions and fiber radios. Direct modulation of semiconductor laser is a simple, low-cost approach for transmitting RF range subcarriers. In this approach, the nonlinear distortions of semiconductor lasers limit the performance of the SCM fiber optic systems. To overcome this problem, the injection locking technique of semiconductor laser has been investigated theoretically [1] and experimentally [2], and found very effective for suppressing the nonlinear distortions in gigahertz range due to the improved laser dynamics [3,4]. However, there has been no work reported on the nonlinear distortions of the injection-locked FP-LDs.

Injection locking characteristics of an intermodal injection-locked semiconductor laser were reported theoretically by J. M. Luo et al. [5] and experimentally by Y. Hong et al. [6]. They showed that at a fixed optical injection power, the relaxation oscillation frequency increases when light is injected into a shorter wavelength mode and a larger stable locking range is achieved by choosing an appropriate injection target mode. In this paper, we examine the injection locking bandwidth and make the first experimental demonstration of the IMD3 suppression at the different injection target modes of FP-LD.

2. Experiments

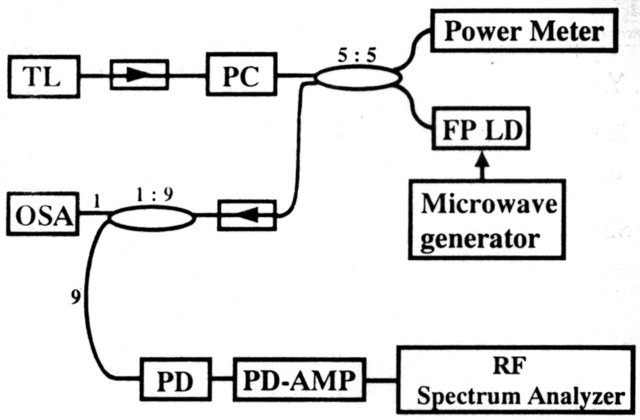

Fig. 1. Experimental setup
PC : Polization controller
TL : External cavity tunable laser
PD : Photodetector
OSA : Optical spectrum anaylzer
PD- AMP : Photodetector Amplifier

For the stable locking range and reduction of IMD3 at a different target mode of a FP-LD, the experimental setup is illustrated in Fig. 1. An external cavity tunable laser (TL) with a tuning range of 0.002nm is used as a master laser (ML) and a commercially available FP-LD (SAMSUNG, SFL24-B1-3) with mode spacing of ~0.84nm at a dc bias of 19.0mA is used as a slave laser (SL). Two optical isolators of >50 dB isolation are used to prevent light coupling from the SL to the ML and to protect the ML against backreflected light. The optical spectrum analyzer and RF spectrum analyzer were used to monitor the stable injection-locked state.

Fig. 2(a) shows optical spectrum of free-running FP-LD and definition of mode number of the FD- LD operating at dc bias 19.0mA. Mode number 0(wavelength=1550.52nm) is near the peak of all FP-LD lasing modes, positive mode number indicates shorter wavelength than mode 0 and negative mode number indicates longer wavelength than mode 0. Each mode is spaced by 3 mode difference from defined neighboring modes. Fig. 2(b) shows that under stable strong injection-locked state, mode +4 is dominant and other modes are sufficiently suppressed at a

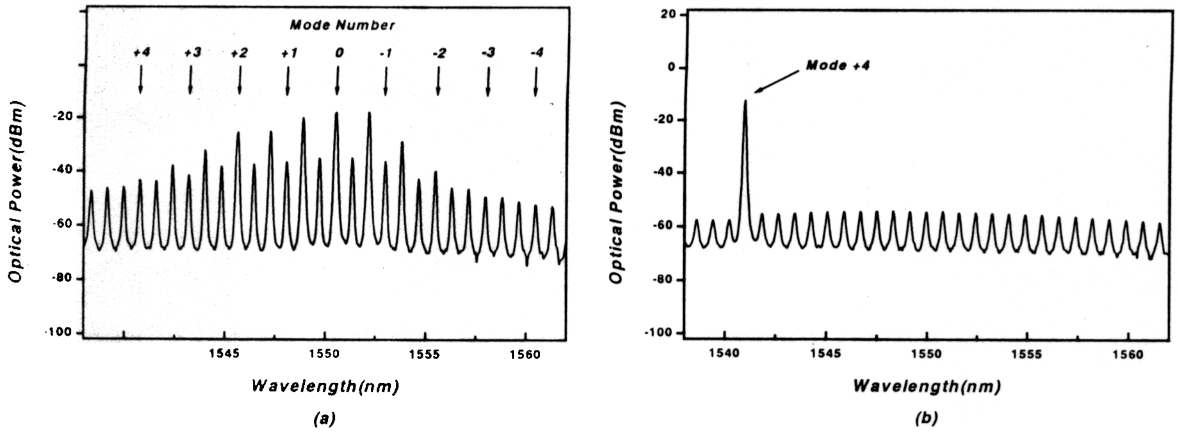

Fig. 2. Optical power spectra of FP-LD and definition of mode number.
(a) free running , (b) injection into +4 mode at a 5dBm ML output power

degree of mode suppression ratio (MSR) >40dB.

Stable locking ranges at different target modes are determined by observing optical power spectra of OSA and beat phenomena of RF spectrum analyzer. The measured stable locking bandwidth is shown Fig. 3. The frequency detuning is defined the difference of ML's frequency and SL's free running target mode frequency. As reported previously [5,6], the injection into short-wavelength target mode (positive mode number) increases the stable locking range and this characteristic is related to gain peak shifts towards longer wavelength and injection power ratio of ML to SL's injection target mode at free running [6].

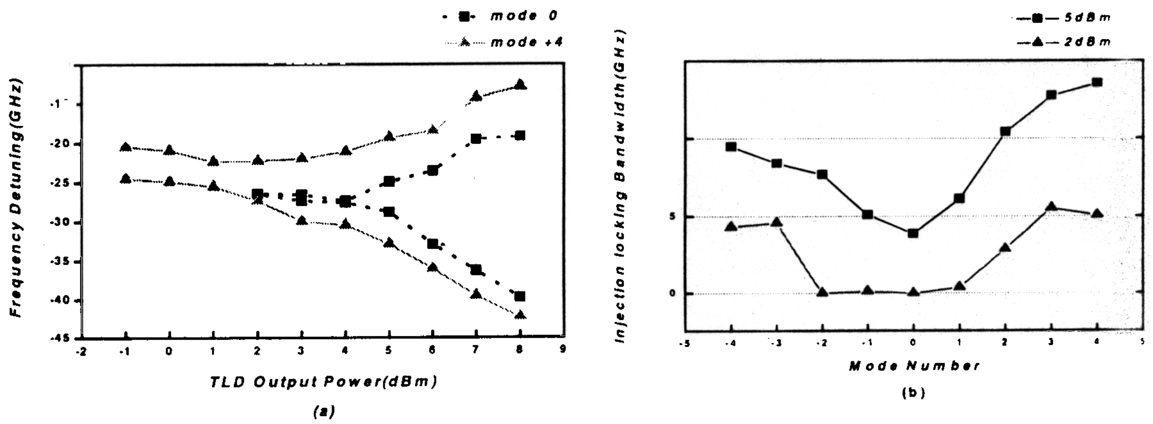

Fig. 3. Stable locking bandwidth. (a)frequency detuning versus ML out put power for injection target mode 0 and +4 respectively. For mode 0, below TL output power 2dBm, frequency detuning is not distinguishable. (b) stable injection locking bandwidth versus mode number measured at TL output power 2dBm and 5dBm respectively.

The characteristics of IMD3 for different injection target modes under modulating SL by two-tone RF signals (f_1=2.5GHz, f_2=2.6GHz) are investigated. For each of the selected injection target mode, ML frequency is chosen at the center of each stable locking range. Fig. 4 shows

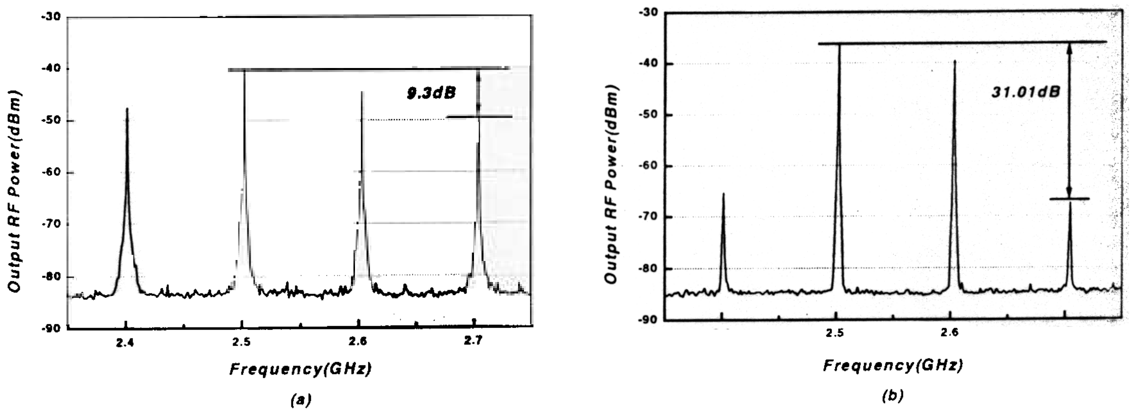

Fig. 4. Measured RF spectrum (a) free running , (b) mode +4 injection locking Two-tone RF power +4dBm, ML output power +5dBm

measured IMD3 for the case of free running and mode +4 injection locking. Fig. 4(b) shows significant suppression of IMD3 at the frequency of $2f_2$-f_1 (=2.7GHz) and $2f_1$-f_2 (=2.4GHz).

We only concern about the one IMD3, $2f_2$-f_1. Fig.5 shows the power of fundamental components and IMD3 of FP-LD output as a function of power of modulating two-tone RF signal where two-tone RF signal power are the same. By linear fitting, suprious-free dynamic

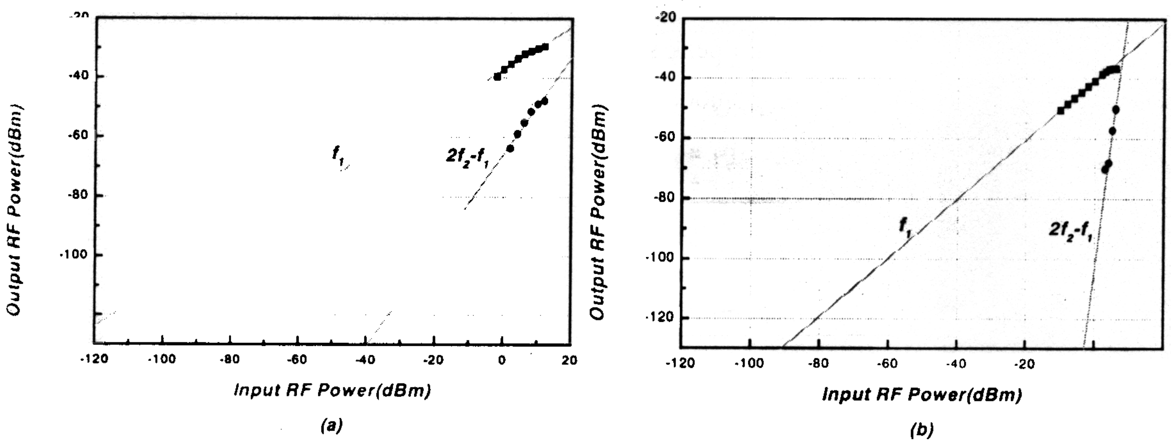

Fig. 5. Measured FP-LD output RF component and IMD3 versus modulating input RF power. (a) free running , (b) mode +4 injection locking

range(SFDR) is estimated. Compared with free running case, mode +4 injection locking case shows reduction of IMD3. Consequently, SFDR is significantly enhanced at the latter case. Using the same experimental procedure, powers at the fundamental component and IMD3 are measured for all modes defined in Fig. 2(a). Fig. 6 shows normalized SFDR to free running for all injection target modes. Injection locking into any side-mode reduces IMD3 compared to free

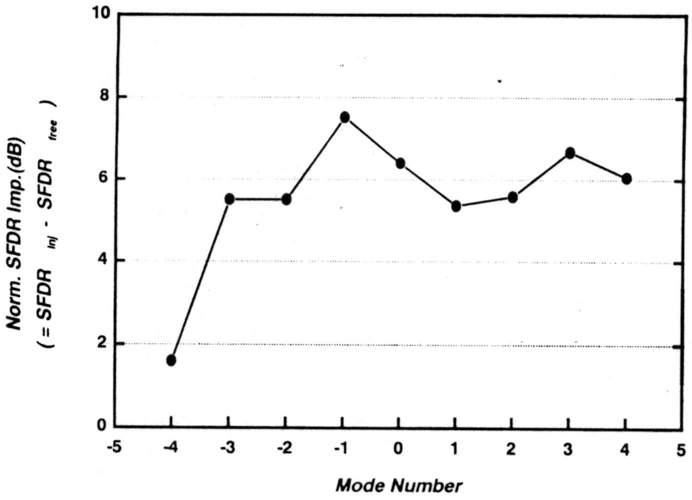

Fig. 6. Normalized SFDR improvement for all injection target modes. The noise floors is assumed -90dBm.

running and choosing an appropriate injection target mode, especially positive mode numbe significantly improves nonlinear suppression of FP-LD.

3. Conclusions

We have experimentally investigated the nonlinear distortion suppression of FP-LD by optical injection locking. We examined the intermodal injection locking characteristics of FP-LD for nine different target modes, and showed that at a fixed injection power, injection into shorter wavelength from a peak mode is useful to enlarge stable locking range. For the injection locked state into different injection target modes, experimental measurements of IMD3 reduction were also performed. We showed for the first time that IMD3 reductions are achievable at any target mode injection locking. Consequently, choosing an appropriate injection target mode can enlarge stable locking bandwidth and reduce IMD3 significantly.

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