Nonlinear Distortion Suppression in Directly Modulated DFB Lasers by Sidemode Optical Injection

J.-H. Seo, Y.-K. Seo, and W.-Y. Choi.

Dept. of Electrical and Electronic Eng., Yonsei University, Seoul, 120-749, Korea.

e-mail: wchoi@yonsei.ac.kr

Abstract: **We demonstrate a new method of suppressing nonlinear distortions in directly modulated DFB lasers. In our scheme, external laser light is injected into the sidemode of the DFB laser. We achieve significant reduction in nonlinear distortions and enhancement in the detuning range.**

I. INTRODUCTION

The optical analog transmission of RF-range electrical signals is attracting much interest for WLL (wireless local loop), CATV, and satellite system applications. In these applications, the direct modulation of semiconductor lasers can be used for transmitting signals multiplexed by RF-range subcarriers. Consequently, the LD nonlinearity becomes a key issue in the system performance because it can impose signal distortions by inter-channel interference, which limit the number of channels as well as transmission distance [1].

One method of overcoming the LD nonlinearity problem is using the optical injection locking technique, where light from an external laser (master laser, ML) is injected into the signal transmitting laser (slave laser, SL). Meng et *al*. has recently found that the laser nonlinearities can be significantly suppressed by the optical injection locking technique [2]. But, the optical injection locking occurs within the relatively narrow lasing frequency detuning range between the ML and SL, which is typically tens of GHz. This may limit the applicability of the injection locking technique. As a solution for this problem, we propose a new technique - sidemode optical injection in that ML light is injected into the DFB laser sidemode.

II. EXPERIMENTAL RESULT

Fig.1 shows experimental setup used for our investigation. The external cavity tunable light source is used as the ML for the simple control of the incident wavelength. For the SL, a commercially available fiber-pigtailed, unisolated DFB laser (Samsung SDL-24) is used. An optical circulator is used to prevent the unwanted light coupling from the SL to the ML.

Fig.2-(a) shows the SL optical spectra in the free running (no optical injection). When a significant amount of the ML light is injected into the sidemode marked as -1 mode, the fundamental mode is significantly suppressed and the sidemode becomes dominant as can be seen in Fig. 2-(b). This is due to the XGM effect [3]. Fig. 3 shows the dependence of the normalized fundamental mode suppression on the injected ML power and wavelength.

For generating subcarriers, the SL is directly modulated by two RF signals (f1 = 2.8GHz and f2 = 2.9GHz). The frequencies are the maximum nonlinear distortion occurrence points within our laser mount capacity. From this experimental setup, we measure second harmonic distortion (SHD), second order intermodulation distortion (IMD2), and third order intermodulation distortion (IMD3). SHD is defined as the ratio between powers at the second harmonic to the fundamental. IMD2 and IMD3 are defined as the ratio of the powers at f1+f2 and at 2f2-f1, respectively, to the fundamental frequency. For the sidemode injection, optical power from external cavity tunable light source is used as ML output power. The ML power is set at 8dBm and the wavelength at 1550.434nm.

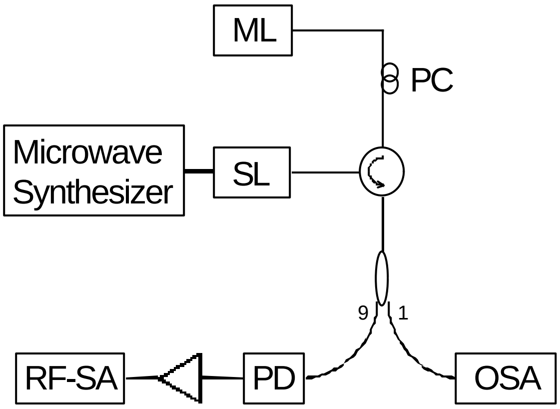

Fig. 1 Experimental setup. OSA optical spectrum analyzer, PC polarization controller, and RF-SA RF-spectrum analyzer.

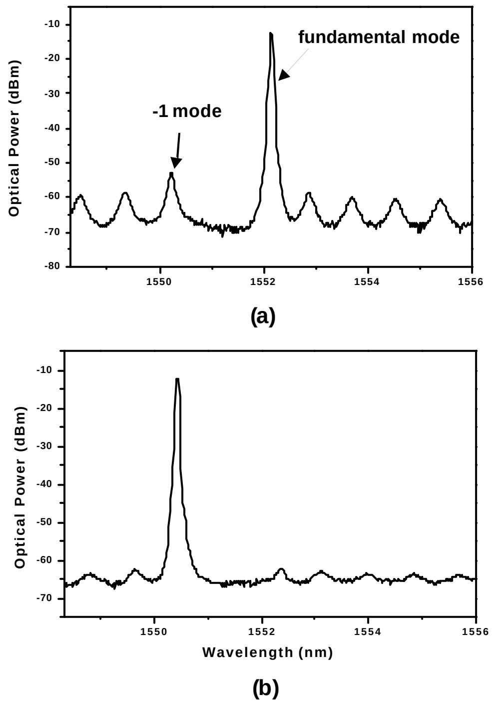

Fig. 2 SL optical spectra for the free-running (a) and sidemode optical injection (b). The incident light wavelength and power are 1550.434nm and 8dBm, respectively.

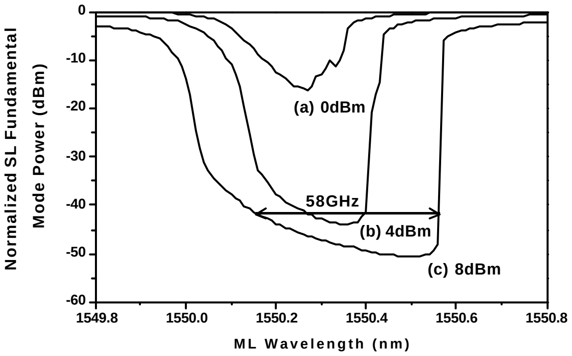

Fig. 3 Normalized peak power of SL fundamental mode under sidemode optical injection. The ML injection powers were 0 dBm (a), 4 dBm (b), and 8 dBm (c), respectively.

As shown in Fig. 4, SHD and IMD2 are noticeably suppressed (more than 10dB) for the sidemode injection case. Fig. 5(a) and (b) shows the RF spectra for free running and sidemode optical injection, respectively, where the applied RF power is 0dBm. The measured IMD3 were -34.54dBc for free running and -45.41dBc for the sidemode injection. IMD3 is reduced by 10dB by sidemode optical injection.

Fig. 6 shows the IMP3 power for the free running and sidemode optical injection state according to the input RF powers.

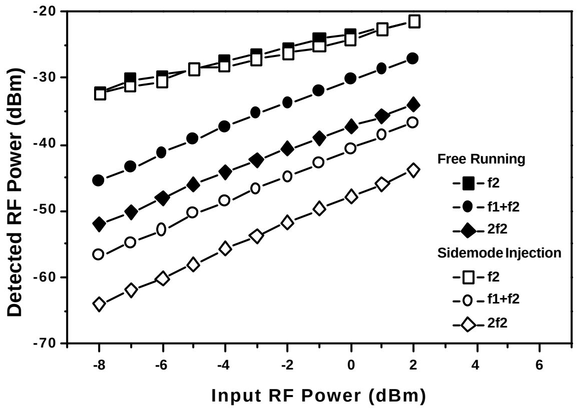

Fig. 4 The photo-detected second order intermodulation product power (IMP2: f1+f2) and second harmonic (2f2) power for the free running and sidemode injection.

From Fig. 6, we can estimate spurious-free dynamic range (SFDR) by linear-fitting. When the system noise floor is assumed -90dBm, SFDR for free running is about 53dB•MHz$^{2/3}$ and SFDR for sidemode optical injection is 59dB•MHz$^{2/3}$. 6dB dynamic range enhancement by sidemode optical injection is achieved.

Finally, we compare the ML detuning range for the stable operation for the sidemode injection and the fundamental mode injection. Under the identical conditions, we measured 27GHz for the fundamental-mode injection. By relating the detuning range by the sidemode suppression ratio as was done for Fig. 3, we estimate that the stable detuning range for the sidemode injection is larger than 58GHz. This increase in detuning range for the sidemode injection is believed to the enhanced ratio of the ML power to the SL power. It is well known that increasing the ML power increases the stable locking range for the fundamental mode injection [4]. We achieved the same effect without increasing ML power by injecting ML light into the sidemode.

IV. CONCLUSIONS

We have experimentally investigated the effects of sidemode optical injection on the nonlinear distortions of directly modulated DFB lasers. The SHD and IMD2 as well as the IMD3 are measured as functions of modulation RF powers with and without external sidemode optical injection. We found that under sidemode optical injection, the nonlinear distortions are suppressed by more than 10dB. In addition, the stable operating range of sidemode optical injection case is more than twice than in the case of fundamental-mode optical injection locking. Thus, we believe our method can provide improved performance with better stability in using optical injection technique for laser diode nonlinearity suppression.

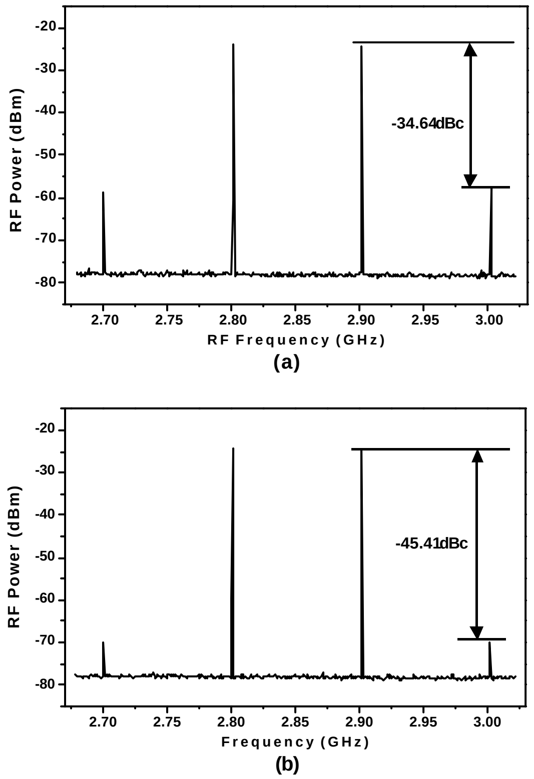

Fig. 5. RF-spectra for the free running (a) and sidemode injection (b).

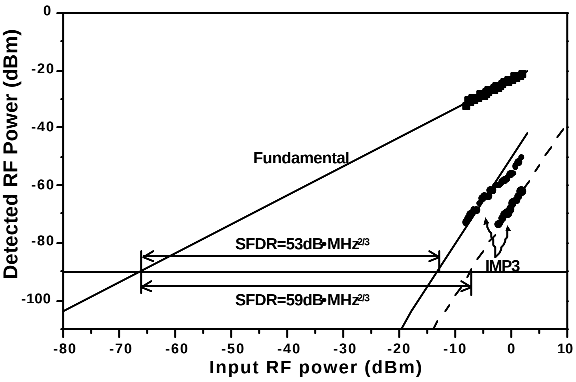

Fig. 6. SFDR of directly modulated DFB lasers for the free running (solid line) and sidemode injection (dashed line), respectively. The applied RF-frequencies were of 2.8GHz and 2.9GHz

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