Chapter 5

Suppression of relaxation oscillations and static power excursions in an optical gain-clamped EDFA using a control channel

5.1 Introduction

Erbium-doped fiber amplifiers (EDFA) have high optical gain and wide bandwidth which are useful in the wavelength division multiplexing (WDM) optical transmission. However, the gain variations causing degradation of system need to be constrained when the channels in WDM are in add/drop operations. The all-optical feedback loop has been demonstrated to stabilize the gain variations. But, this technique leads to the dynamic power oscillation and the static power excursion. Two improved techniques such as time-dependent feedback loop and dual-cavity optical automatic gain control are investigated to suppress these gain excursions [5.1],[5.2]. Recently, a combined optical feedback and electronic feedforward technique is developed as a feasible method to deal with these instabilities. With the combined gain control scheme, the optical feedback loops can be classified with the internal and external loops. The investigations with respect to the combined gain control using the internal or external loops have been reported respectively [5.3]-[5.5].

In this chapter, we propose a simple and novel conventional-band (C-band) gain-clamped EDFA using an internal optical feedback loop and an extra control channel. In comparison with the combined gain-control method, an extra control design instead of the pump-control design is used to compensate for input WDM channels in drop operation. The experimental results show that the amplitude and frequency of dynamic power excursions on the surviving channels are reduced compared to all-optical feedback loop technique alone. Furthermore, the suppression of the static power excursions is also confirmed.

5.2 Experiment

The schematic diagram of a gain-clamped EDFA we propose is shown in Fig. 5.1. The gain-clamping of this EDFA, which amplified spontaneous emission spectrum is shown in Fig. 5.2, is primarily achieved with the counterpropagating laser feedback. The EDFA consists of a 980 nm pump with 85 mW and a 10 m erbium doped fiber with a peak absorption 6.7 dB/m at 1530 nm. The optical filters with 1529 nm and 1546 nm are used respectively to form a laser feedback loop. Although the optical gain-clamping is a simple and efficient method to stabilize the gain in which WDM channels are added or dropped, the gain instability including dynamic power excursion owing to the relaxation oscillation in laser and static power excursion owing to spectral hole burning (SHB) are serious problems in optical transmission with an EDFA [5.7]. To further overcome these issues, a photodiode and an extra control channel are added in the front of the optical gain-clamped EDFA. With a tap coupler, the photodiode monitors the input signal power. Through a control circuit, the optical power of the control channel is inversely proportional to the monitored input signal power. Here, we apply a DFB laser at 1540.5 nm as the control channel. The saturating tone at 1554 nm with 1kHz modulation rate is used to simulate the 31 channels (-2 dBm) adding and dropping. Furthermore, in order to evaluate the feasibility of the proposed scheme, the transient responses of the surviving channels at 1531.9 nm and 1548.5 nm with -17 dBm input power are investigated respectively.

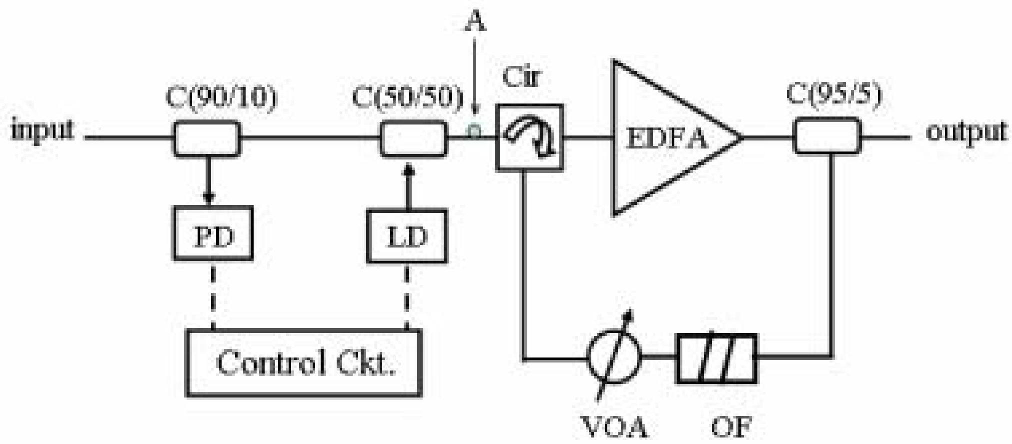

Fig. 5.1. Schematic diagram of the proposed gain-clamped EDFA. C: coupler. PD: photodiode. LD: laser diode. Cir: circulator. VOA: variable optical attenuator. OF: optical filter.

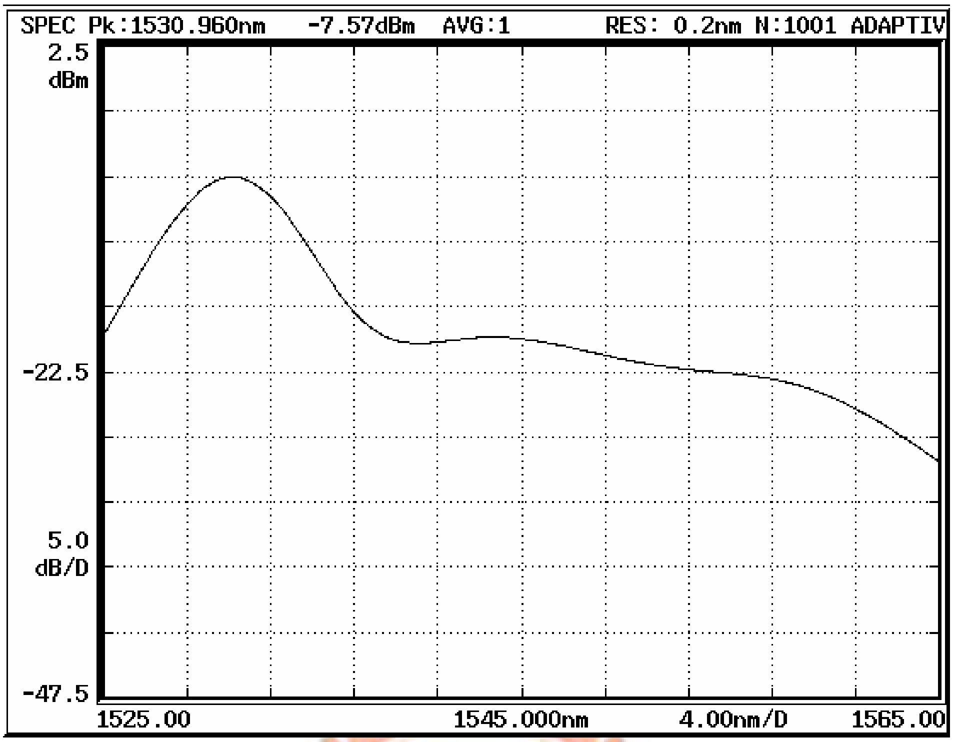

Fig. 5.2. Amplified spontaneous emission spectrum of EDFA in the Fig. 5.1. It is noted that a optical attenuator of 2.6dB is used in the front of optical spectrum analyzer.

5.3 Results and Discussion

The extra control channel, a scheme against fast transients by maintaining constant input power, has been demonstrated in the gain-flattened EDFA [5.6]. However, in general, the intrinsic gain spectrum of a C-band EDFA is not flat. To further promote the gain-clamping in the whole C-band, we use the hybrid gain control, a technique to apply an extra control channel in the front of an optical gain-clamped EDFA. In the meantime, the dynamic and static power excursions resulting from optical gain-clamping are also suppressed by this control channel. Consequently, the proposed method simultaneously possesses the advantages of a extra control channel scheme and an optical automatic gain-clamped scheme.

The input powers at position A with and without the control channel operation are shown in Fig. 5.3. As a result of the saturating tone adding/dropping, the great change in the input power is apparent for no control channel scheme. This change leads to the large gain variation of the surviving channel in EDFA. To mitigate the gain fluctuation, we compensate for the input power loss in virtue of an extra control channel. In this letter, as the saturating tone (i.e. 31 input channels) is switching on and off, the static input power variation decreases and is equal to 9 channels adding/dropping, and two input power spikes with about 25 μs duration exist in the addition and removal of the saturating tone. The reduction of switched channels number implies the decrease in both the frequency and amplitude of dynamic power excursion of the surviving channel [5.7]. The less static power excursion and shorter power spike can be obtained by improving the control circuit. Although this control channel design is not optimal, the following results show the obvious suppression of the dynamic power excursions and the static power excursions in an optical gain-clamped EDFA.

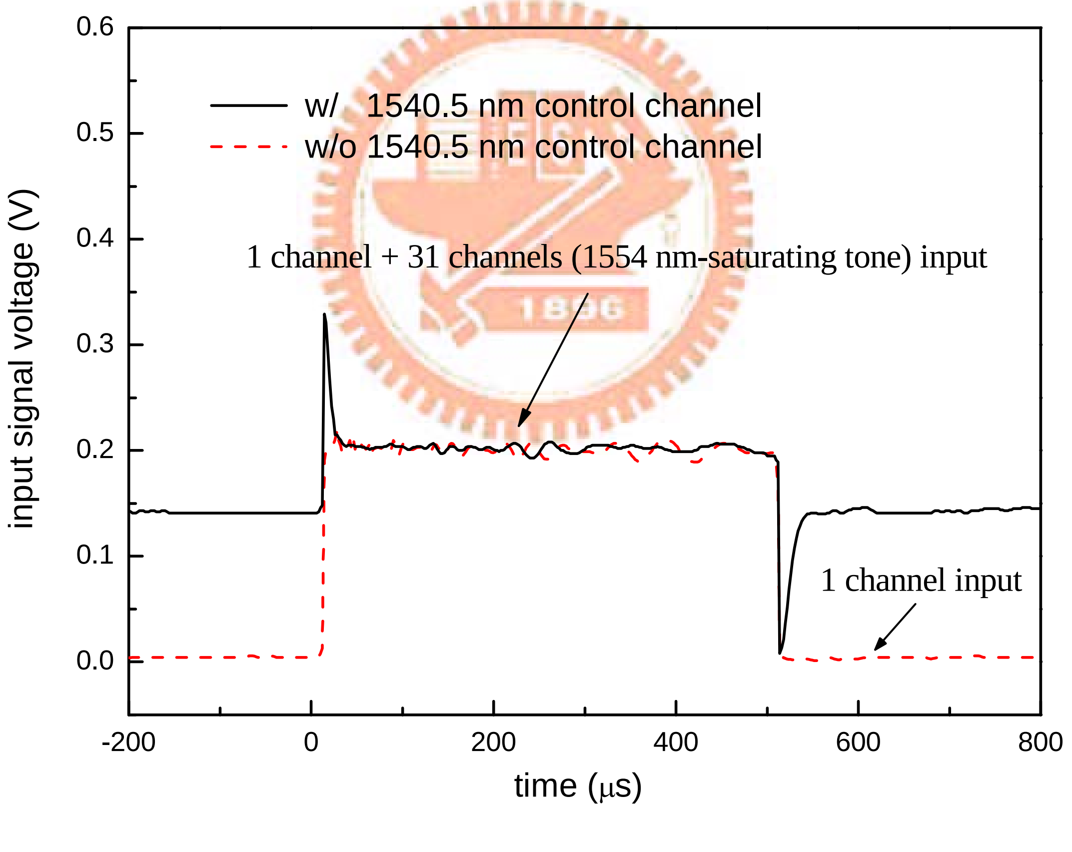

Fig. 5.3. Input signals with and without the extra control channel are measured at position A in the Fig. 5.1. The power excursions result from 31 channels (-2 dBm saturating tone at 1554 nm) modulation at 1kHz.

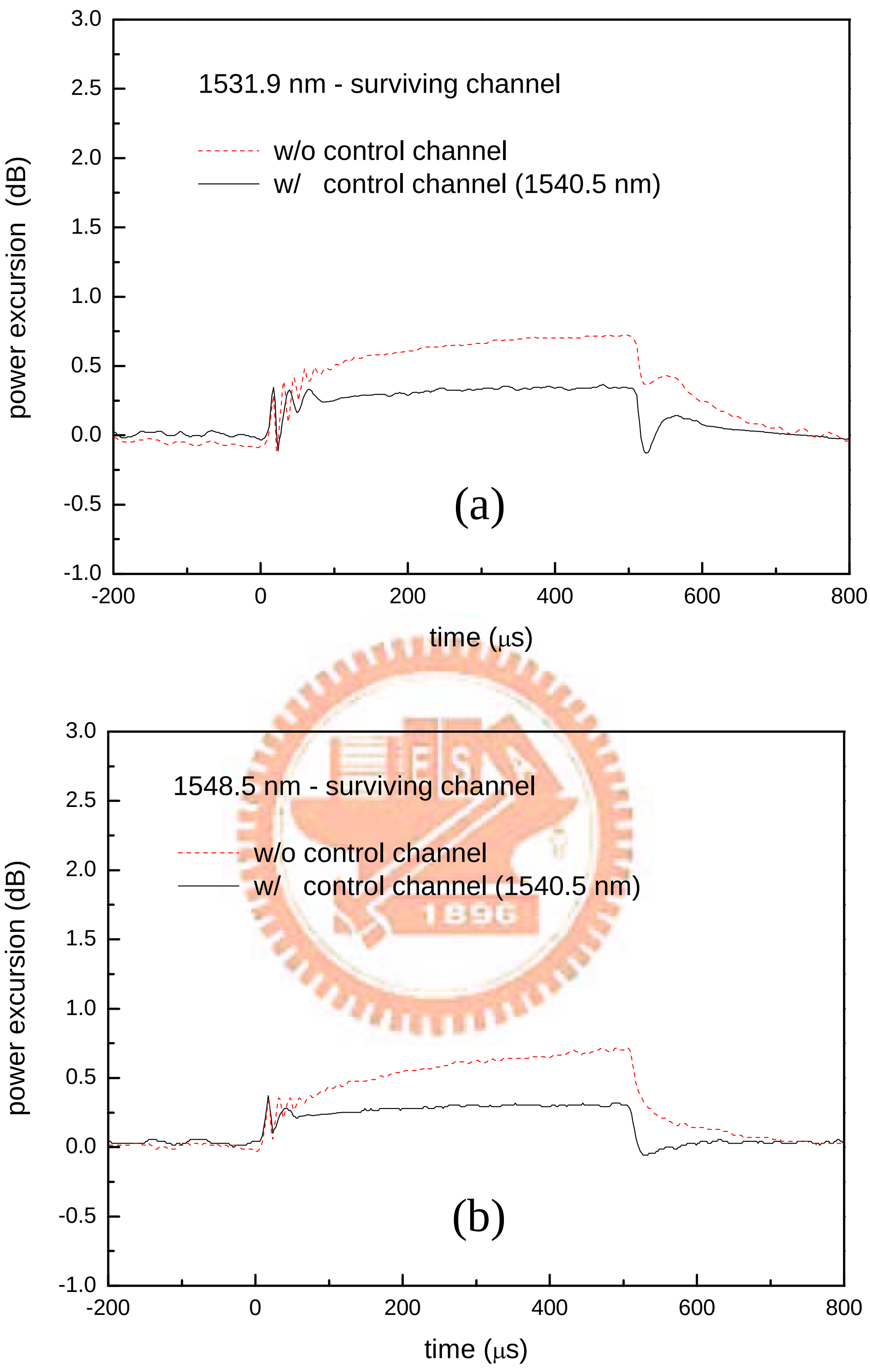

Fig. 5.4. Transient responses of (a) 1531.9 nm and (b) 1548.5 nm surviving channel output power to dropping/adding 31 of 32 channels when the optical feedback laser wavelength is 1529 nm.

Fig. 5.4 shows the transient responses of the 1531.9 nm and 1548.5 nm surviving channels with and without the control channel respectively as the optical feedback laser is set at the wavelength of 1529 nm. Now, the dominant power excursion is static component related to SHB rather than dynamic component because the lasing wavelength is not close to the spectal band occupied by signal wavelengths. However, the lasing wavelength that results in smaller dynamic power excursion exhibits higher oscillation frequency [5.7]. With the proposed gain control, the static power excursions corresponding to 1531.9 nm and 1548.5 nm surviving channels are suppressed from 0.77 dB and 0.7 dB to 0.35 dB and 0.3 dB respectively. Furthermore, it is shown that the frequency of relaxation oscillation decreases to 45.4 kHz from 71.4 kHz.

In order to further investigate the characteristics of dynamic power excursion with the control channel, the lasing wavelength is selected at 1546 nm by design because the power excursions result from both static component and dynamic component as the lasing wavelength appraoches the signal wavelengths. Fig. 5.5 shows the transient responses of the 1531.9 nm and 1548.5 nm surviving channels with and without the control channel respectively. As expected, the dynamic power excursion has higher amplitude but lower frequency in comparison with the case of the laser at 1529 nm. The experimental results indicate that the static power excursions corresponding to 1531.9 nm and 1548.5 nm surviving channels reduce to 0.28 dB and 0.18 dB from 0.41 dB and 0.34 dB respectively. Meanwhile, the amplitude and frequency of relaxation oscillation decrease. The frequencies of relaxation oscillations corresponding to 1531.9 nm and 1548.5 nm surviving channels decrease to 26.3 kHz and 25 kHz from 50 kHz and 45.5 kHz respectively.

5.4 Summary

We experimentally investigate the dynamic and static power excursions of the surviving channels in an optical gain-clamped EDFA using an extra control channel. Through a tap coupler, a photodiode and a control circuit, the optical power of the control channel is inversely proportional to the monitored input signal channels. Even though this scheme only compensates for the part of the switched input signal and frequency of the dynamic power excursion arising from the relaxation oscillation

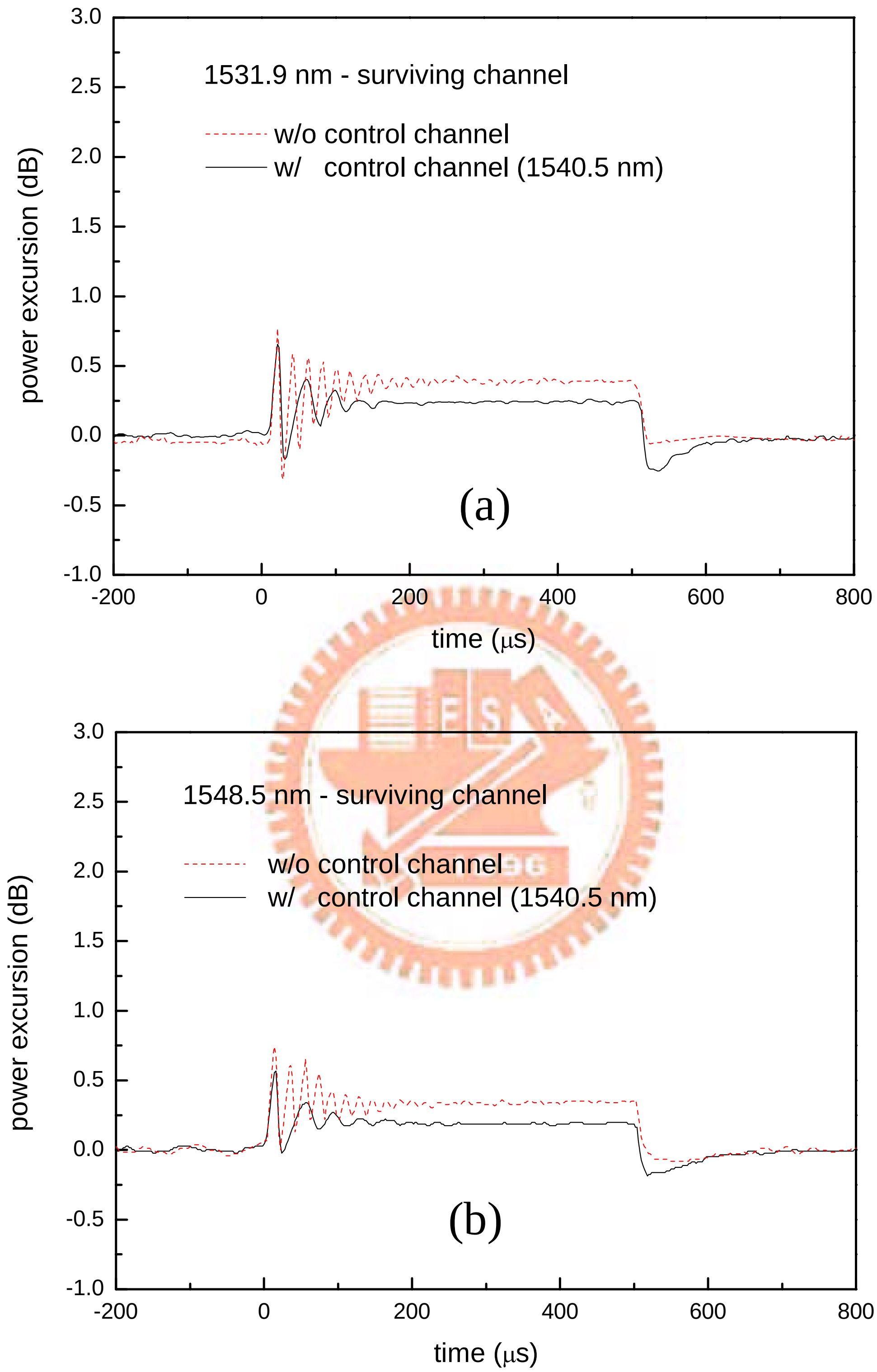

Fig. 5.5. Transient responses of (a) 1531.9 nm and (b) 1548.5 nm surviving channel output power to dropping/adding 31 of 32 channels when the optical feedback laser wavelength is 1546 nm.

channels, it can be seen that this design has contributed to the decrease of amplitude in laser, for the 31 adding and dropping of 32 channels with each -17dBm input power. Moreover, the mitigation of the static power excursions related to SHB is also confirmed in this experiment.

References

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