Regenerative Erbium-Doped Fiber Ring Amplifier with Unidirectional and Bi-directional Feedbacks

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Abstract: In this paper, the performance of unidirectional and bi-directional regenerative erbium-doped fiber amplifier (EDFA) is compared. The systems are operating above laser oscillation threshold. The experimental results show that the unidirectional regenerative EDFA has a better performance than the bi-directional.
Key words: Regenerative erbium doped fiber ring amplifier, laser oscillation threshold, gain-clamping, injection-locking

1. Introduction

Multi-channels optical network requires optical add-drop services. To overcome problems arising from power fluctuation when channels are added or dropped, gain-clamped amplifiers are used [1].

One of the systems that satisfied the gain-clamping effect is regenerative erbium-doped fiber amplifier (EDFA) as shown in Fig.1, when operating above laser oscillation threshold. The difference between this amplifier and the conventional gain-clamped amplifier is that there is no tunable bandpass filter in the cavity. This allows circulation of the injected in the cavity. It has been shown in Ref. [2] that regenerative amplifier is an extremely useful technique in CO_2 laser applications to achieve high power frequency-stabilized laser sources and it is an efficient power amplifier. Additionally, the regenerative amplifier provides high signal gain by small pump power [3].

In this paper, the performance of the regenerative EDFA when the system has a single oscillation (unidirectional) is compared with the system with two independent oscillations in opposite direction (bi-directional).

2. Experiment

A schematic diagram of a unidirectional regenerative EDFA is illustrated in Figure 1. The system consists of two wavelength division multiplexers: WDM 1 and WDM 2, three couplers: C_1 and C_2, with an output coupling ratio of 95%, and C_3 for monitoring the system from 1% port. Two optical isolators were placed at the input and output ends to avoid back-reflection, and another isolator, Isolator 1, was placed in the cavity to ensure a unidirectional oscillation of the laser. Without the Isolator 1, the amplifier becomes a bi-directional regenerative EDFA where the oscillating laser travels in both clockwise and counter-clockwise directions.

A 15 m long erbium-doped fiber (EDF) with a cut-off wavelength of 950 nm, a refractive index of 1.473 and an Er^{3+} concentration of +400 ppm was used as the active medium. Pump power was provided by a laser diode operating at 980 nm.

The unidirectional system has a lasing wavelength of 1558.1 nm, while the bi-directional system has two initial lasing wavelengths of 1556.1 nm and 1559.2 nm. Both systems were exemplified at the input signal wavelength of 1550 nm.

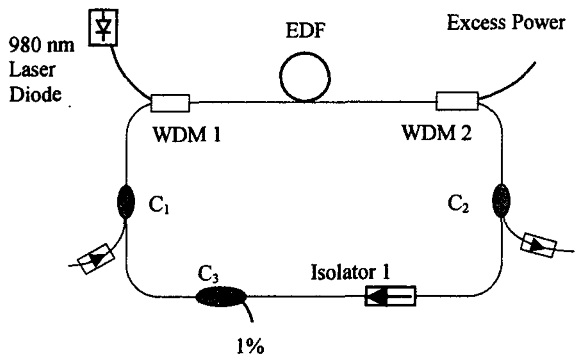

Figure 1. Experimental setup

3. Results and Discussion

The signal gain and noise figure as a function of pump power for unidirectional and bi-directional systems are shown in Figure 2. The unidirectional and bi-directional systems start to lase at the pump power of 29.4 mW and 28.4 mW, respectively. The bi-directional system lase at a lower pump power, thus, the gain is clamped at a lower inversion. As a result, the system has a lower signal gain and a higher noise figure.

The signal gain graph shows that there is still a small slope above the lasing threshold. In Reference [4], the authors attributed such a phenomenon to the spectral hole burning at the control laser wavelength. Therefore, the population of the sub-levels is not fully clamped.

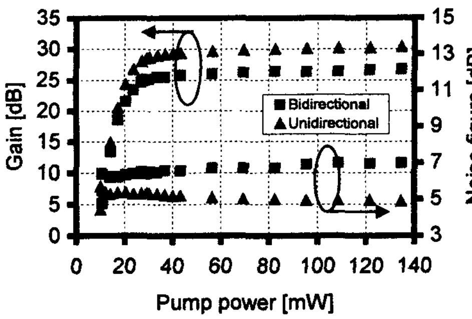

Figure 2. Signal gain and noise figure as a function of pump power. The input signal power is –30 dBm.

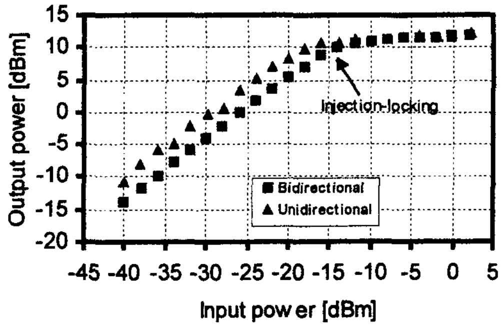

Figure 4. Output signal power as a function of input signal power for the signal wavelength of 1550 nm.

Figure 3 shows the performance at different input signal powers for the pump power of 58.7 mW. The saturation input power, which is referred to the -3 dB gain compression [5], is –17 dBm and –13.5 dBm for the unidirectional and the bi-directional system, respectively. The noise figure characteristic in Figure 3 shows a dip at the saturated regime. The dip effect appears from the suppression of backward ASE by the high input signal power [6].

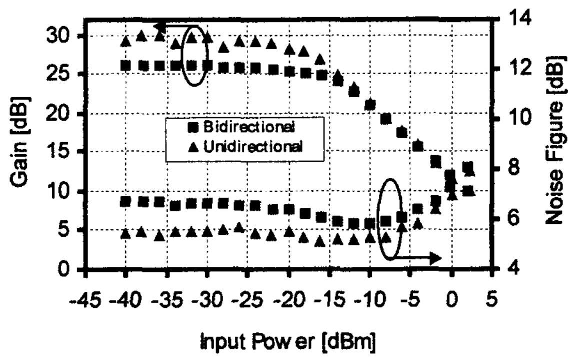

Figure 3. Signal gain and noise figure as a function of input signal power for the signal wavelength of 1550 nm.

Figure 4 shows the output signal power versus input signal power at the pump power of 58.7 mW. The plots differ from that of the conventional single-pass amplifier in which the slopes have a sudden change at the input signal power of ~-15 dBm. This point corresponds to the condition of injection locking where the oscillating laser in the cavity is locked to the injected signal [7]. After the input signal power of -15 dBm, the cavity is dominated by the input signal.

4. Conclusions

Signal gain and noise characteristics of the unidirectional and the bi-directional regenerative EDFA systems have been compared. Gain-clamping effect has been observed for both systems. Since the bi-directional system starts to lase at a lower inversion, a lower signal gain and a higher noise figure were achieved. At the high input signal levels, both systems were dominated by the input signal due to the occurrence of the injection-locking phenomenon.

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