Gain-Clamped L-Band EDFA Incorporating An Inline Fiber Bragg Grating

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Abstract: This paper present a gain-clamped L-band EDFA based on reflecting back a portion of backward amplified spontaneous emission into the erbium-doped fiber section, utilizing a fiber Bragg grating. By using FBG with R=66.1 and 99.9%, the gain is clamped at 15.1 and 14.3dB, respectively, with a variation of less than 0.2dB for an input signal power as high as -5 dBm. However, a small noise figure penalty is obtained, which is the consequence of the gain clamping effect.

1. Introduction

Long wavelength band (L-band) erbium-doped fiber amplifier (EDFA) has been developed rapidly following conventional 1550-nm band (C-band) EDFA as a component for wide-band wavelength division multiplexing (WDM) systems. The L-band EDFA associated with the C-band EDFA greatly expands the optical bandwidth in WDM transmission systems.1) When EDFAs are used in networks involving a multiplicity of WDM channels that are randomly turned on and off, their gain could suffer slow, undesirable fluctuation due to saturation effects. Therefore, gain clamping on EDFAs is required in the systems to maintain the optical gain experienced by the surviving channels as channel loading changes.

There have been many efforts to clamp a gain especially in C-band EDFA such as forming a feedback fiber loop.2) However, there is still a lack of research effort in L-band EDFA. This paper present a gain-clamped L-band EDFA based on reflecting back a portion of backward amplified spontaneous emission (ASE) into the erbium-doped fiber (EDF) section, utilizing a fiber Bragg grating (FBG). The effect of injection of backward ASE is demonstrated by experimentally comparing gain and noise figure for different reflectivity of FBG.

2. Experimental Set Up

The experimental set up is shown in Fig. 1. The EDF for L-band gain clamping is 50m long with a cutoff wavelength of 962nm, a numerical aperture of 0.24, and an absorption coefficient of 6.6dB/m at the 1531nm of absorption peak. The EDF is pumped at 980nm using a semiconductor diode laser with a maximum power at the doped fiber end of 92mW. A WDM coupler combines a pump and a L-band signal from a tunable laser source (TLS). Isolator is used to avoid spurious signal reflection disturbs TLS. A FBG is spliced to the input port of the forward-pumped L-band EDFA for optical feedback. It reflects a portion of the C-band backward ASE back into the system. The amplified signal is detected by an optical spectrum analyzer (OSA). The effect of injection of backward ASE is studied by comparing gain and noise figure for two FBGs with different reflectivity. The parameters of the FBGs are shown in Table 1.

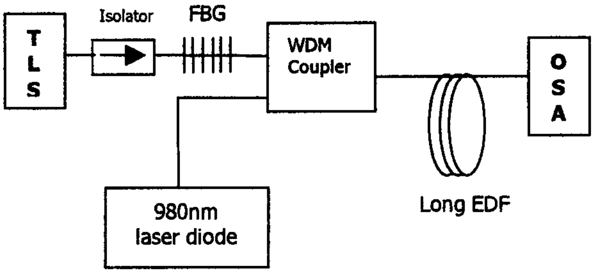

Fig. 1: Experimental set up.

Table 1: FBG Parameters

FBG	*Reflectivity*	*Center Wavelength*	*3-dB Bandwidth*
FBG 1	66.1%	1553.3nm	0.2nm
FBG 2	99.9%	1553.7nm	0.9nm

3. Result and Discussion

The dependence of gain and noise figure on pump power for the common EDFA (no grating) and gain clamped EDFAs under different grating reflectivities (R) of 66.1% and 99.9% are shown in Fig. 2. The signal wavelength and power are fixed at 1580nm and -30dBm, respectively. For gain-clamped EDFA, the configuration with FBG 1 shows a slightly higher clamped gain and lower noise figure compared to the FBG 2. However, both configurations show the constant gains compared to the configuration with no grating. The L-band mechanism is made possible by the intra-Stark level multiphonon transitions that transfer energy from the short wavelength to the longer wavelengths. Therefore, incorporation of a FBG in the C-band, causes saturation of this band since the reflected spectra now constitutes a high level signal. This saturation limits the population inversion which in-turn reduces the number of multiphonon transitions, thereby clamping the L-band gain. The reflectivity of the FBGs then determine the level of population inversion. A higher reflectivity simulates a larger signal which slightly degrades the amount of available inversion. This explains the differences in the clamping levels and noise figures of Fig. 3 between the FBG 1 and FBG 2 used.

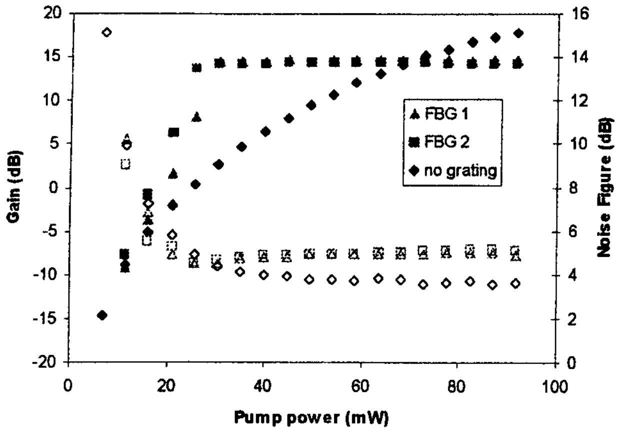

Fig. 2: Gain (shaded) and noise figure (clear) as a function of pump power

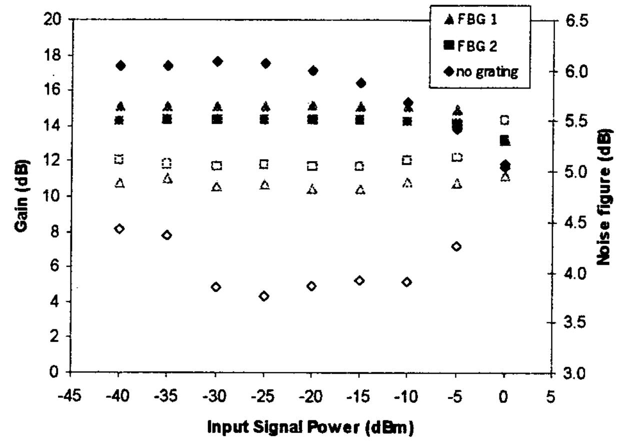

Fig. 3: Gain (shaded) and noise figure (clear) as a function input signal power

Fig. 3 shows the gain and noise figure characteristics at various input signal powers. The signal wavelength and pump power is fixed at 1580nm and 92mW, respectively. For the EDFA with no grating, the unsaturated gain obtained at about 17.5dB and degrades as the input signal power increases. On the other hand, gain of the EDFA with FBG 1 and FBG 2 are clamped at 15.1dB and 14.31dB, respectively, for all input signal powers from -40dBm to -5dBm. This clamping is due to the fixed average population inversion provided by the reflection of signal due to the FBG at input end of the amplifier. The maximum gain variation for the input signal power range is only 0.2dB. The gain clamping, however, is effective up to -5dBm of input signal power, above which the signal begins to saturate the amplifier gain. From this figure, it is clear that the introduction of grating decreases the small-signal gain and this gain depression increases with the reflectivity. However noise figures for the gain clamped EDFA are higher than that for the common EDFA by about 0.5 ~ 1dB. The noise figure degradation is due to the injected 1553nm signal that depletes the energy conversion from pump to signals at the input end and causes noise figure to be higher. Overall, the noise figure for GC-EDFA is measured to be less than 5.5dB.

4. Conclusion

A design of L-band gain clamped EDFA by injecting a portion of backward C-band ASE using a FBG is experimentally demonstrated. By using FBG with R=66.1 and 99.9%, the gain is clamped at 15.1 and 14.3dB, respectively, with a variation of less than 0.2dB for an input signal power as high as -5 dBm. However, a small noise figure penalty is obtained, which is the consequence of the gain clamping effect.

References

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