

# Gain optimization of a two-stage L-band Erbium-doped fiber amplifier in double-pass configuration

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In this contribution, a two stage L-band Erbium-doped fiber amplifier in double-pass configuration is presented. This amplifier provides gain as high as 44 dB with almost 45 nm flat bandwidth in L-band. Erbium-doped fiber of length 15 m is used in first stage and second stage utilizes 70 m Erbium-doped fiber. Pump powers are 52 mW and 143 mW respectively. In comparison to a single-pass amplifier, this amplifier shows a gain enhancement of about 14 dB and noise figure penalty is about 2 dB.

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## 1. Introduction

The sudden increase in traffic due to various applications such as internet, multimedia, video on demand and electronic banking causes constraint on the available bandwidth. The L-band (1565-1620 nm) of the Erbium-doped fiber amplifier (EDFA) is widely used in wavelength division multiplexing (WDM) systems, together with the C-band (1530-1565 nm). WDM systems with transmission rate Tb/s have been recently demonstrated by utilizing both C-band and L-band [1]. The L-band EDFA in parallel with C-band EDFA may provide a practical gain level but its efficiency is poor because of relatively inefficiency of L-band EDFA [2]. B. Min et.al. utilizes ASE from C-band EDFA to increase the gain of L-band EDFA [3]. Some other novel configurations have also been reported to achieve practical gain level and flatness [4-7]. Currently intense research has been done on the development of Raman amplifiers

along with conventional optical amplifier based on Tm-doped fiber [8-10]. These amplifiers have enabled impressive gain, noise figure and system performance but they have not matched conventional Erbium-doped fiber amplifiers (EDFAs) in terms of efficiency, simplicity, reliability and cost.

In this paper we have proposed a cost-effective and simple design of a two-stage double-pass L-band EDFA to improve gain and flatness in L-band region.

## 2. System design

The schematic diagram of the two-stage double-pass L-band EDFA is shown in Fig. 1. The first stage utilizes 15 m Erbium doped fiber (EDF) while the second utilizes 70 m EDF. Pumping in first stage is carried out by a 980 nm laser diode of power 52 mW using a forward pumping scheme.

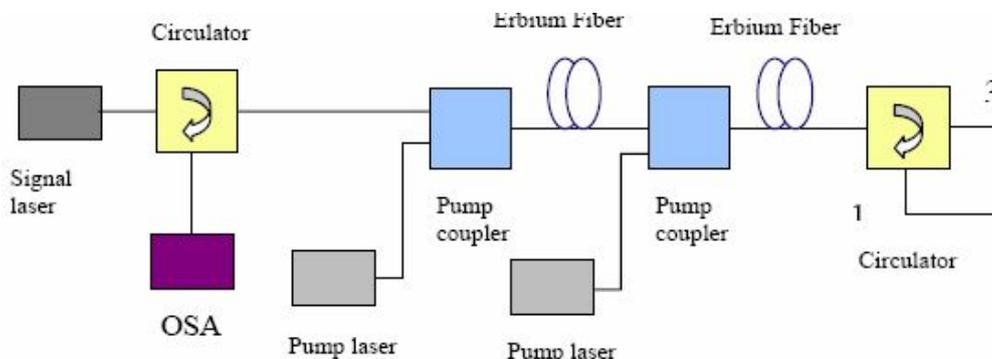


Fig. 1. Schematic design of two-stage double-pass L-band EDFA.

The second stage utilizes forward pumping at 1480 nm with a diode laser of power 143 mW. Two

wavelength-selective couplers are used to combine the pump with test signal. The port 1 of the optical circulator

in the second stage is connected to the port 3 to allow double-pass propagation of test signal. Optical circulator in the first stage routes the amplified signal into an optical spectrum analyzer (OSA). A tunable laser source is used for the evaluation of the amplifier performances.

### 3. Results and discussion

In order to evaluate the gain and noise performances, the gain and noise figure are measured as a function of signal wavelength for both single pass and double pass configurations. The total pump power and input signal powers are fixed at 195 mW and 0.1  $\mu$ W respectively. For the single-pass amplifier, a gain of about 30 dB is obtained. Initially it shows very low gain but as the

wavelength rises it increases rapidly and gets saturated at about 30 dB, on the other hand, almost flat gain of about 45 dB is observed for the double-pass configuration as shown in Fig. 2. The gain reaches to the maximum of 48 dB and after that it become constant to near 44 dB with gain variation of less than  $\pm 1$  dB. Compared to the single-pass amplifier, double-pass amplifier shows a gain enhancement of about 15 dB. The gain enhancement is due to the double propagation of test signal in double-pass amplifier, which increases the amplified spontaneous emission (ASE) level. This increases the efficiency of energy transfer to L-band wavelengths, which in turn improves the gain. The double-pass amplifier shows a higher noise figure as compared to the single-pass amplifier as shown in Fig. 3.

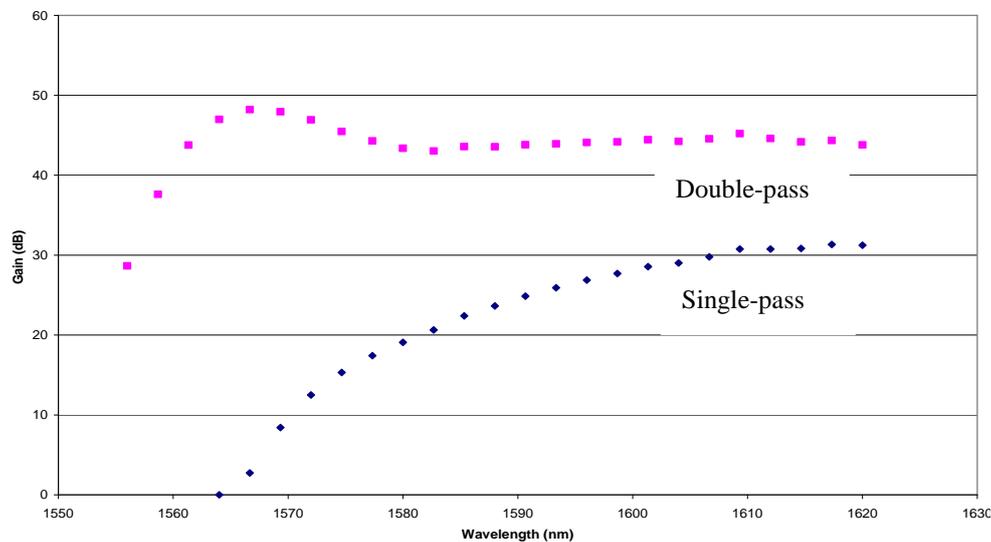


Fig. 2. Gain as a function of signal wavelength.

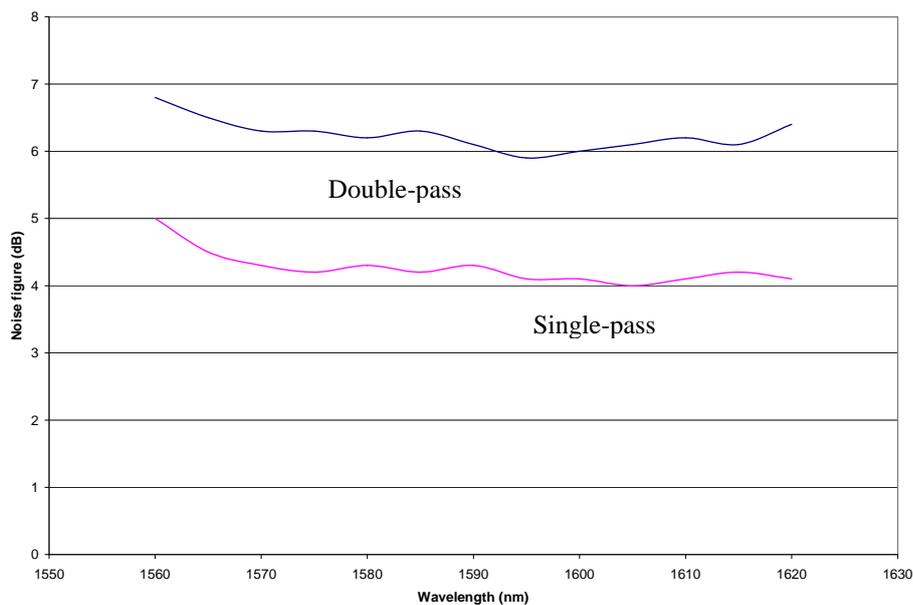


Fig. 3. Noise figure as a function of signal wavelength.

The noise figure penalty is attributed to the higher counter-propagating ASE at the input part of the amplifier. This reduces the population inversion at the input part and hence enhances the noise figure of the amplifier. It can be observed that for same fiber length, pump power and signal strength the double-pass configuration performs better.

#### 4. Conclusions

A two-stage L-band Erbium-doped fiber amplifier (EDFA) in double-pass configuration is presented. With this configuration 44 dB gain and almost 45 nm flat bandwidth is obtained. Compared to single-pass configuration, this amplifier shows a gain enhancement of about 14 dB at the expense of noise figure penalty almost 2 dB.

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