Gain Flattening and Noise Figure Analysis of EDFA WDM Configuration for L-band Optical Communication using Wavelength Selective Attenuator

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Abstract—In Erbium Doped Fiber Amplifier, there are basically two main techniques for gain flattening: one is use external wavelength filters to flattenedthe gain while the other one relies on modifying the amplifying fiber properties to flatten the gain spectrum. The paper presents the study of simulation of a gain flattened EDFA WDM network for L-band optical communication using a Wavelength Selective Attenuator. The design provides a high gain of 34.63dB at 1593nm and gain flatness (P-P) 0.38dB by using a wavelength selective attenuator in the entire L-band at room temperature. Very promisingly, a noise figure of less than 11dB was found in the entire 37nm (1571nm-1608nm) region. The variation has also been studied for various values of fiber length and pump power.

Optical fiber communication is seen as one of the most reliable, fastest and secure telecommunication technologies to achieve consumer needs for present and future application. It is reliable in handling and transmitting data through hundreds of kilometers with an acceptable bit error rate. The Wavelength Division Multiplexing (WDM) technique is the preferred way to increase the information transmission capacities of a fiber system. An erbium doped fiber amplifier is a suitable component for optical fiber networks serving as a wide range of applications from WDM network repeaters to a CATV power amplifier and an inline amplifier. Nowadays the conventional wavelength band (C-band) transmission window (1530-1560nm) has been extended into the Long Wavelength Band (1570-1610nm) [1-2].

The main attraction of EDFAs is their large gain bandwidth while simultaneously amplifying a large number of channels at different wavelengths within the spectrum without narrowing the gain. The gain flattened EDFA is a key component in a long-haul multichannel light wave transmission system [3-4]. There are several methods to design a flat spectral gain EDFA by using Fiber Bragg Grating [5], Long Period Grating [6], by changing the fiber host material [7], and by using Chirp Bragg Grating [8-9].

This paper investigates a design which provides gain flattened EDFA using a Wavelength Selective Attenuator for L-band optical communication.

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Figure 1 shows the schematic diagram of the proposed gain flattened EDFA WDM configuration for amplification in the L-band.

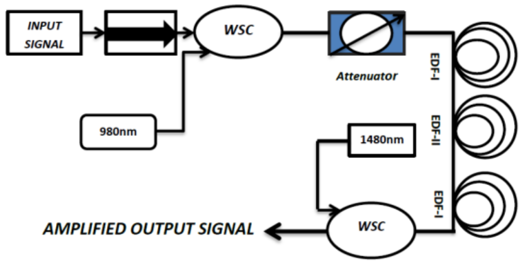

Fig.1. Schematic diagram of a proposed gain flattened EDFA WDM configuration.

Here we used a GainMaster™ simulator manufactured by Fibercore limited. The Gain Master is a software package intended to assist optical engineers in the design of an Erbium Doped Optical Amplifier reducing the amount of time involved in bringing a successful amplifier design to production. This software allows for schematic representation of an optical amplifier to i/p via graphical user interface. An ITU-T laser source operates with 200GHz channel spacing. The source transmitting 23 signal channels and transmitting the power of each channel is a −30dBm/channel. An isolator is placed after the ITU-T laser source, providing unidirectional propagation and restricting back reflection. It has isolation of 20dB, insertion loss −0.2dB and input and output return loss −60dB and 55dB, respectively. A wavelength selective coupler (WSC) has been fixed with an of insertion loss 0.2dB and pump and signal isolation of 20dB and 30dB, respectively. A wavelength selective attenuator is used for flattening the gain spectrum in the entire L-band region. It can superimpose wavelength channels. As a result, we get less crosstalk (below −35dB) high optical performance, increased bandwidth for long distance communication, reduced insertion loss and improved resolution. At present, the optical attenuator is a device used to reduce the power level of an input signal. By this device we can select those wavelengths which are distortionless and give high flattening gain without the use of a costly gain flattening filter. So, we can say this procedure is controllable and less complex, less costly. The attenuation [in dB] of the wavelength selective attenuator as a function of wavelength [in nm] is depicted in Fig. 7. It has an input return loss of 60dB and output return loss −55dB. Two laser pumps of 980nm and 1480nm are used bi-directionally to provide better gain and noise characteristics. The specifications of EDFs are shown in Table I.

TABLE I. Specifications of the Amplifiers Used

Parameters	Erbium Doped Fiber–I *I-4*[a]
Fiber Diameter	125±1μm
Cut-off Wavelength	870-970nm
Attenuation at 1200nm	≤ 10dB/km
Saturation Parameter	3.0910 × 10^{15}/ms
Parameters	**Erbium Doped Fiber-II** ***I-25***[a]
Fiber Diameter	125±1μm
Cut-off Wavelength	870-970nm
Attenuation @1200nm	≤10dB/km
Saturation Parameter	1.605 × 10^{16}/ms

a. A product of Fibercore, UK

Figure 2 shows that the variation of gain for different signal wavelengths at different temperatures. At 5°C temperature, the gain increases monotonically and gives a maximum gain of 34.13dB at the 1605nm signal wavelength. The gain flatness (point-point) of 2.355dB occurs over the entire band (1571nm-1608nm). If the temperature is increased, the gain first increases up to a certain temperature value called optimum temperature after that it decreases. At room temperature (25°C), the maximum gain of 34.626dB at the 1593nm wavelength and gain flatness of 0.379dB occurs over the 37nm wavelength region. Such a configuration is a cost effective alternative of today's optical network for a WDM transmission system.

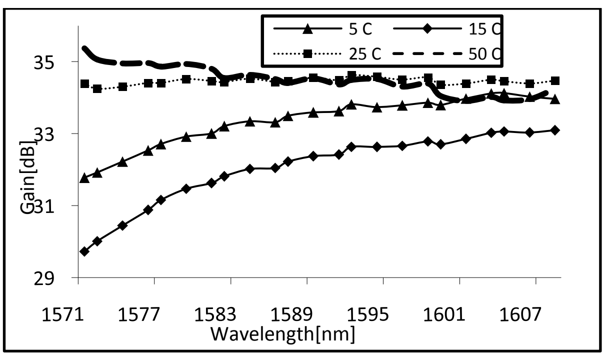

Fig. 2. Gain variation for different Signal Wavelengths at Different Temperatures with a Wavelength Selective Attenuator value.

Gain variation with different signal wavelengths for different pump powers is depicted in Fig. 3. At 60mW pump power, the gain curve increases monotonically and achives a mximum gain of 28.52dB but a poor gain flatness of 12dB occurs in the entire L-band region. Poor power coversion efficiency and Quantum Conversion Efficiency of 6.8% and 8.8% occur in the L-Band region. But by increasing the pump power, the gain increases but the gain flatness decreases because gain is a function of the pump power.The wavelength selective attenuator acts as a gain flattening filter for the flattened gain. At 120mW pump-power, the maximum gain obtained was 33.96dB while the gain flatness of 1.16dB was obtained with the power and quantum conversion efficiency of 22% and 28%, which is around three times higher than the 30mW pump power. A further increase in the pump power to 150mW results in the maximum gain of 34dB and the gain flatness (p-p) of 0.38dB. This was so because if we increase the pump power, it creates more and more population inversion, and once all erbium ions in the fiber are in an excited state, no more erbium ions are available and the gain is saturated. So with the 150mW pump power, the EDFA configuration is feasible for gain flattend WDM tranmission in the L-band optical communication system.

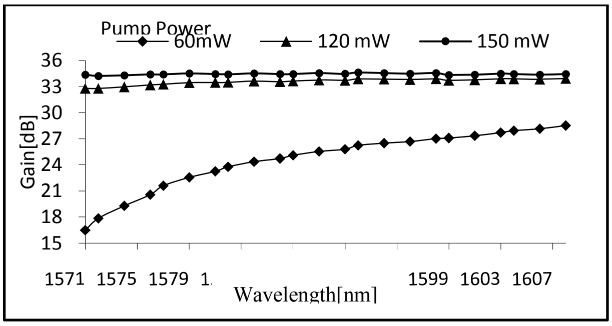

Fig.3. Gain vs. wavelength for different pump power levels. Input signal power: -30dBm/channel; EDF-I and EDF-II length are both 10m.

Figure 4 shows the gain variation with a fiber length for different values of a signal wavelength. At 10m erbium doped fiber length, the gain spectrum is almost flat in the 37nm region with a mximum gain of 34.63dB and gain flatness(p-p) of 0.379dB. After increasing the fiber length, the gain flatness increases and the level of gain decreases.

Figure 5 presents the variation of a noise figure of EDFA for different temperatures. At the 5°C temperature, the noise figure of 10dB was obtained. After increasing the temperature, the noise figure increases because the rise in temperature increases the number of erbium ions at the metastable state for a constant amplifier length and pump power.

Figure 6 shows the variation of a gain spectrum for different pump powers. At the 60mW pump power, the gain curve shows an exponential decay with a different signal wavelength with a high gain of 32.2dB while the gain flatness (p-p) of 13.16dB was obtained. But increasing the pump power, the gain falls and the gain flatness increases. Along with the fiber, the input pump power plays a pivotal role in the overall gain of the system. As pump power increases, the gain decreases because no more inversion occurs and it gets saturated. As the ASE keeps on increasing, in the absence of any gain, the overall system gain decreases.

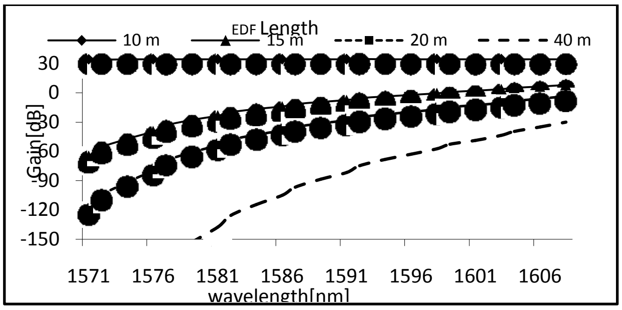

Fig.4. Variation of Gain with EDF length for diffrerent values of signal wavelength.

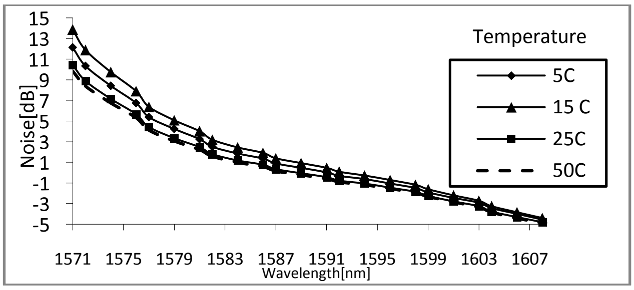

Fig.5. Noise Figure spectrum of EDFA for different temperature at constant EDF's length of 10m and pump power of 120mW.

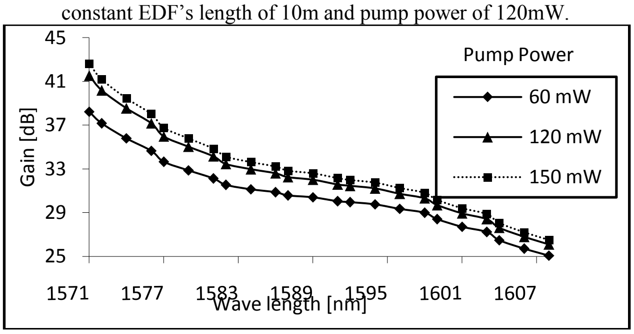

Fig.6. Gain Spectrum for different pump power without using a Wavelength Selective Attenuator at -30dBm input signal power and 10m EDF's length.

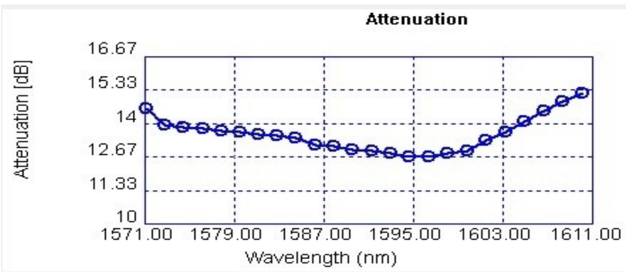

Fig.7. Attenuation spectrum for different wavelengths for a Wavelength Selective Attenuator.

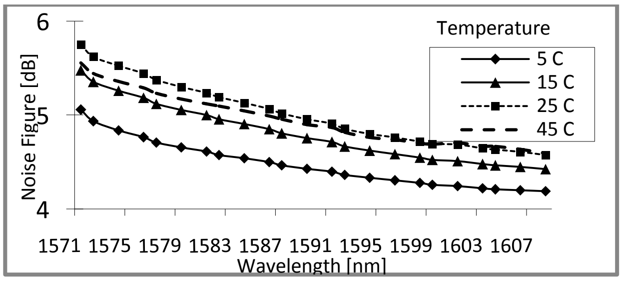

Fig.8. Noise Figure Spectra with a different signal wavelength for different temperatures without using a Wavelength Selectve Attenuator.

Figure 8 presents the variation of the noise figure with a different signal wavelength for a different temperature. This is so because the noise figure strictly depends on the absorption and emission cross section [10]. As shown in the figure, if the temperature increases above 5°C and below 45°C, the noise figures increase linearly. But at 45°C, the noise figure decreases and gives a noise figure of less than 5.5dB because at high temperature the inversion increases and the ASE noise decreases.

An attempt has been made in this paper to present investigations on simulation studies of Gain Flattening and noise figure analysis of EDFA WDM configuration for L-band optical communication using a Wavelength Selective Attenuator. This configuration gives a high gain of 34.63dB at 1593nm and gain flatness (P-P) of 0.38dB by using a Wavelength Selective Attenuator Value. A noise figure of less than 11dB was found routinely. This configuration shows that we can achieve Gain Flattened EDFA without using a Gain Flattening Filter (GFF).

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