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International Journal Of Engineering And Computer Science ISSN:2319-7242
Volume 3, Issue 11 November, 2014 Page No. 9093-9096

Performance Analysis of Optical Amplifiers

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***Abstract-** It is an increasing demand of high bandwidth and high data rate without loss of any information in any communication system. To meet almost all the requirements optical communication system is preferable. For long distance transmission optical amplifiers such as Erbium doped fiber amplifier (EDFA), Semiconductor Optical amplifier (SOA), Raman Amplifier, Parametric Amplifier etc. are being used at the receiver side. It is a very important that parameter of these amplifier are analyzed such a way that it can perform better for the specific optical communication application. Pumping scheme at receiver side is also a potential candidate for the 'last mile' transmission. In this paper performance of Erbium doped fiber amplifier for parameters like Bit rate, Bit Error rate, fiber length, Signal to Noise ratio (SNR), Q-factor, gain, Noise figure are analyzed in optsim5.0 software environment in L-band 1520-1610 nm range and for higher bit rate to get optimum signal at receiver side and also the effect of changing various parameters on system performance have been shown to improve the efficient optical communication.*

Keyword: EDFA, SOA, BER, Q-factor, Gain, Noise figure, length.

I-INTRODUCTION

Optical network provides increased bandwidth and improved fiber performance. The information carrying capacity of a transmission system is directly proportional to the carrier frequency of the transmitted signals. The optical carrier frequency is in the range from 10^{13} to 10^{15}. The most favorable merit of amplification lies in its capability of minimizing the signal power variation along the transmission span which provides the best tradeoff between the noise figure and fiber nonlinearities.

There are mainly two types of optical amplifiers can be classified as semiconductor optical amplifiers (SOAs), active or doped fiber amplifiers (DFAs). Other types are based upon scattering effect because of fiber non-linearity like Raman scattering and Birrouline scattering. All optical amplifiers increase the power level of incident light through a stimulated emission. The emitted photon will always have same direction and phase as the stimulating photon. Some of the photons are also emitted spontaneously.

In order to create an optical amplifier stimulated emission should dominate spontaneous emission. This will happen when population inversion is created in the medium. Therefore to create an optical amplifier population inversion is needed which is created and maintained by a suitable pumping methods. The population inversion means that population of excited ion; atoms or molecules are more than the population of ion, atoms and molecules in ground state.

The organization of this paper is as follows. The principles of EDFA and SOA are briefly described in Section II. In section –III experimental results and discussion of the EDFA and SOA is discussed respectively. Section-IV the gain characteristic of EDFA in L-band is analyzed.

II-WORKING PRINCIPAL

i) Erbium doped fiber amplifier

Optical signals propagating along the EDFA interact with the local population densities, resulting in power gain or loss via stimulated emission and absorption. Spontaneous emission and its subsequent amplification also occur.

Pumping is primarily done optically with the primary pump wavelengths at 1480 nm and 980 nm. As indicated atoms pumped to the 4I (11/2) 980 nm band decays to the primary emission transition band. Pumping with 1480 nm light is directly to the upper transition levels of the emission band. 10-20 mW absorbed pump power can produce 30 to 40 dB amplifier gain at this wavelength.

The gain of the EDFA can be given by following equation

$$g(w) = \frac{g0}{1+(w-w0)\wedge 2 * T2 \wedge 2 + \frac{P}{Ps}} \ldots (1.1.1)$$

In equation g_o is the peak gain, w is the optical frequency of the incident signal, w_0 is the transition frequency, P is the optical power of the incident signal, T_2 is the dipole relaxation time, and P_s is the saturation power.

Spontaneous emission is also present in any amplifier. Small amount of this spontaneous emission gets amplified and comes out along with signal as amplified spontaneous emission (ASE) noise. The ASE noise is generally modeled as white noise with power spectral density

$$S_{sp} = n_{sp}\,(G - 1)\,hf \ldots (1.1.2)$$

Here n_{sp} is spontaneous emission factor, G, the amplifier gain, h the Plank's constant and f is the frequency of optical signal. The value of n_{sp} generally lies between 1.5 and 3.0.

Noise figure can be calculated by following equation

$$NF = \frac{1}{G(v)}\left[1 + \frac{\rho ASE(v)}{hv}\right] \ldots\ldots (1.1.3)$$

Here G (v) is the signal gain, h is the Plank's constant, v is the optical frequency, and ρASE output spectral density.

ii) Semiconductor Optical Amplifier

The SOAs are basically semiconductor lasers which operate below lasing threshold. The population inversion in these is achieved by means of electrical energy. An SOA has two end facets, and the reflectivities of these facets decide whether the device will operate as an SOA or a semiconductor laser.

Polarization dependent – require polarization maintaining fiber. Relatively high gain ~20 dB. Output saturation power 5-10 dBm. Large BW. Can operate at 800, 1300, and 1500 nm wavelength regions. Compact and easily integrated with other devices. Can be integrated into arrays. High noise figure and cross-talk levels due to nonlinear phenomenon such as 4-wave mixing.

Both the edges of the SOA have low reflectivity so the no unwanted reflection occurs within the semiconductor itself. Population inversion is achieved by forward biasing the p-n junction.

III-EXPERIMENTAL RESULTS

Experimental setup for SOA and EDFA as shown in figure Fig.1 SOA and in Fig. 2 EDFA, transmission part consists of binary sequences, electrical generator, CW laser and external modulator. PRBS produces a maximal length pseudo-random binary sequence. With the help of electrical generator converts an input binary signal into an output electrical signal. The output signal may be specified as either voltage or current. The user parameters are used to configure the electrical signal output.

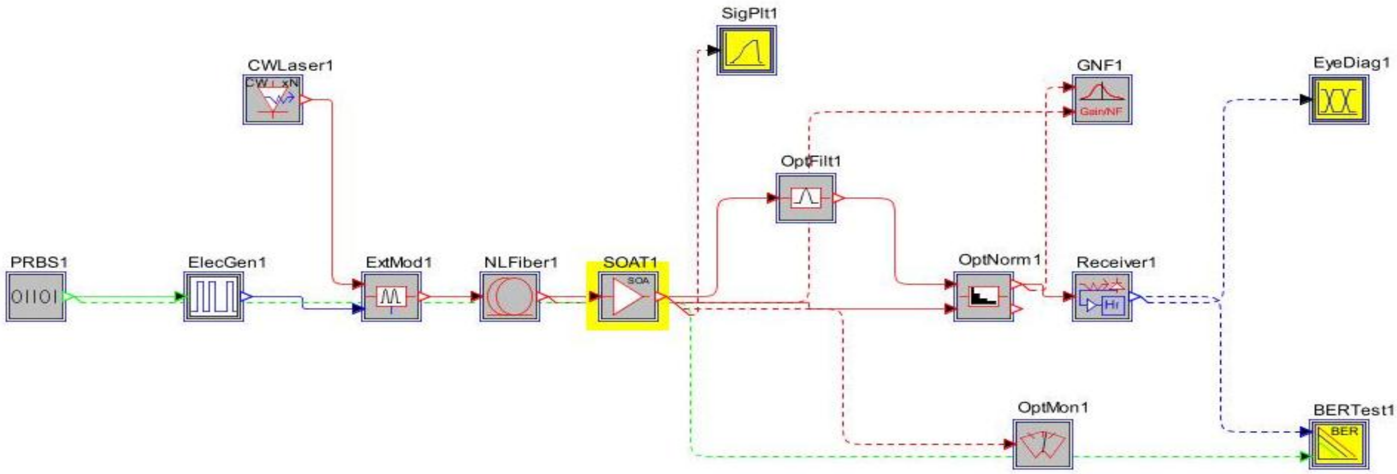


Figure 1: Experimental setup for Semiconductor optical amplifier in OptSim5.0 software.

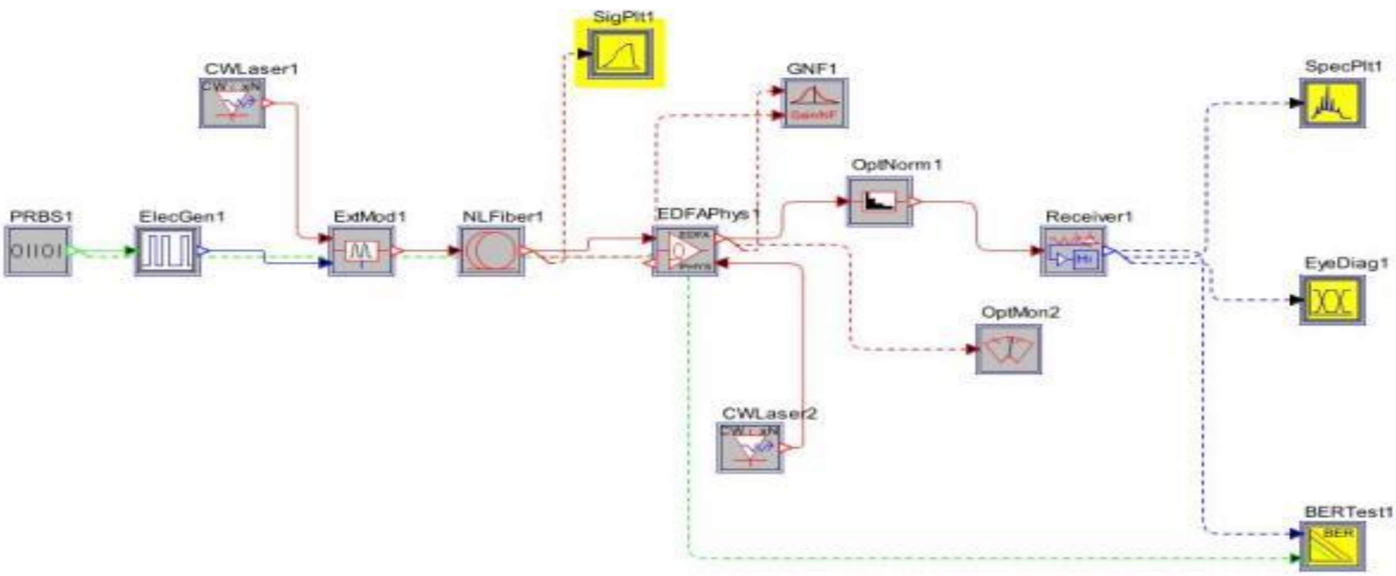
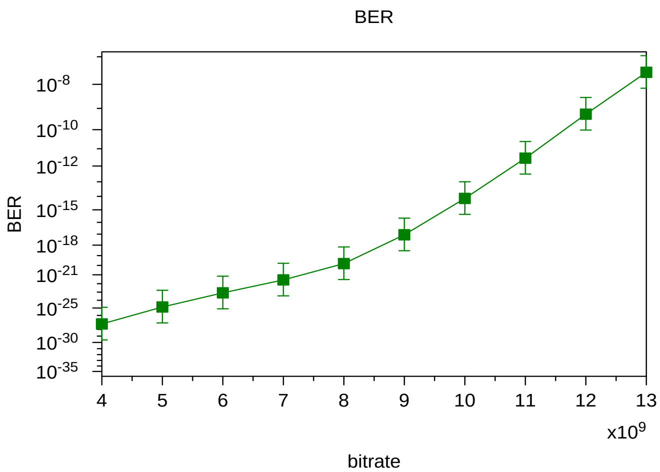
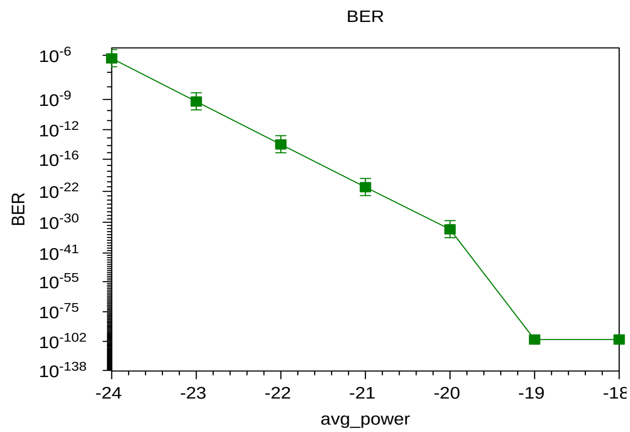


Figure 2: Experimental setup for Erbium doped fiber amplifier in OptSim5.0 software.

1) Semiconductor optical amplifier:



(a)



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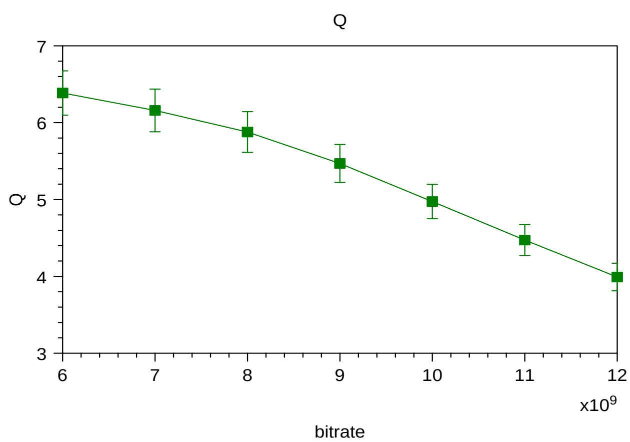

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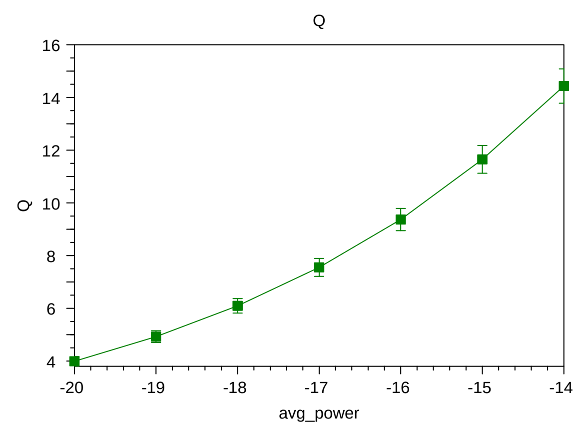

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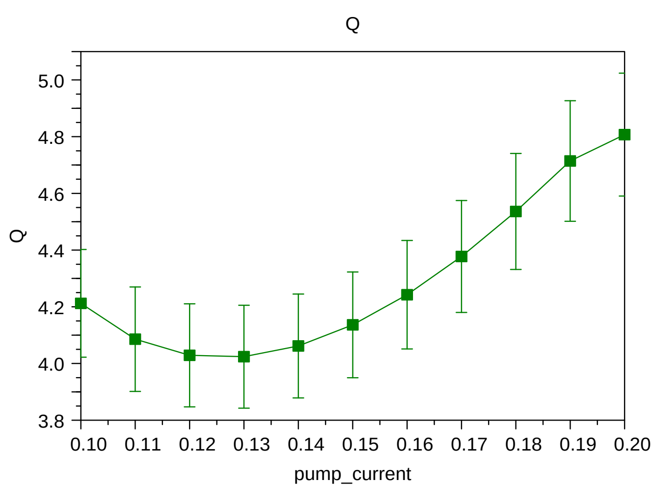

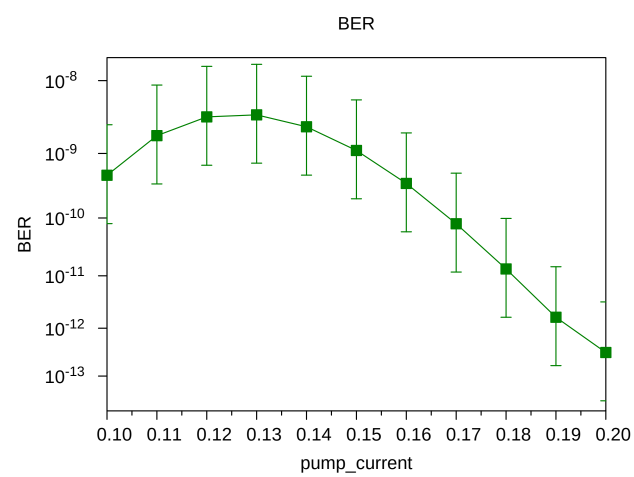

Figure 3: (a) Bit error rate vs. bit rate (b) Bit error rate vs. receive power (c) Q-factor vs. bit rate (d) Q-factor vs. receive power (e) Q-factor vs. pump current (f) Bit error rate vs. pump current