CHAPTER 4

FIBER OPTIC AMPLIFIERS

4.1 Introduction

Typically, there are two classifications for the optical amplifiers when we come to the gain medium, there are semiconductor and fiber optic amplifier, and when we come to the amplification mechanism there is the linear and nonlinear optical amplifier. This chapter, focuses on the fiber optic amplifier (FOA).

4.2 Amplifier Classes

The FOA can be classified into three classes as depicted in:

⇨Booster (power) amplifiers: Boost power into transmission fiber, low NF, high P_{sat}.

⇨In-line amplifiers: Periodically amplify signal due to fiber attenuation, high G, high P_{sat}.

⇨Receiver pre-amplifiers: Boost power into receiver, low NF, high G.

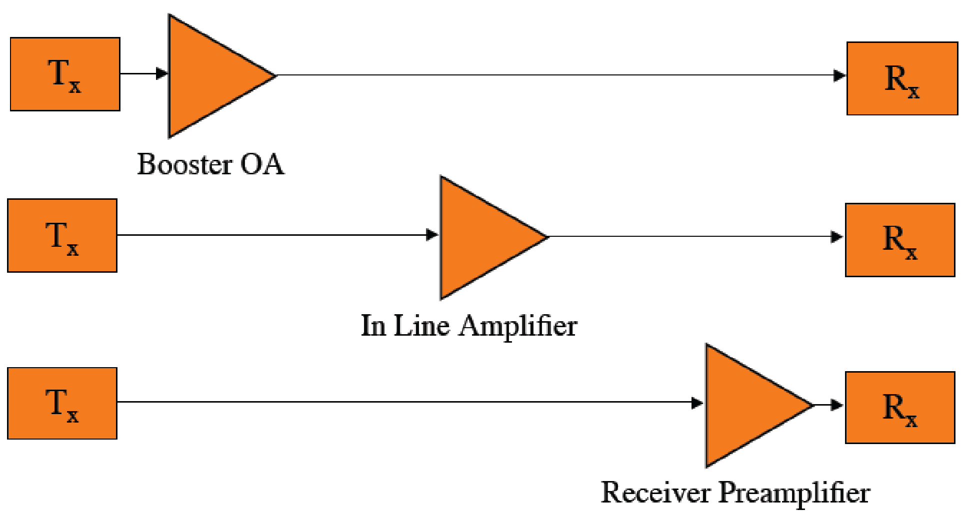

Figure 4.1: Classes of the FOA.

4.3 Design Parameters

The FOA design parameters include:

1. Input signal power
2. Input Signal Wavelength
3. Pump Power Level
4. Pump Wavelength

4.4 Performance Parameters

The performance parameters for any system can be considered as measures of the efficiency of that system and used to determine the quality of the techniques involved. In this section, the main performance parameters of this type of amplifier are defined.

4.4.1 Amplifier Gain

The amplifier gain or the signal gain can be considered as the one of the most important parameters of optical amplifier which is defined as [119]:

$$G = \frac{P_{out}}{P_{in}}$$

where: G is the amplifier gain, Pin and Pout are the input and output signal powers, respectively. However, several parameters related to amplifier gain are used to evaluate the gain performance, such as; average gain, gain variation, gain bandwidth illustrated in Figure 4.2 and gain saturation demonstrated Figure 4.3. These parameters are explained as follows:

4.4.1.1 Average Gain

The amplifier gain can be expressed in term of average gain through specific bandwidth form (λ_1 to λ_n) in which the average gain equal the summation of gain values divided by the number of wavelengths entire the bandwidth as:

$$G_{av} = \frac{G(\lambda_1) + G(\lambda_2) + \ \dots . + G(\lambda_n)}{n}$$

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Where: Gav is the average gain of the optical amplifier, $G(\lambda_1)$ is the amplifier gain at specific wavelengths λ_1 and n is the number of wavelengths entire the bandwidth.

4.4.1.2 Gain Variation

In addition, another parameter based on the gain of optical amplifier is important to describe the gain flatness that is the gain variation which represented through specific gain bandwidth by:

$$G_{var} = G_{max} - G_{min}$$

where: G_{var} is gain variation, G_{max} and G_{min} are the maximum and minimum gain, respectively.

4.4.1.3 Gain Bandwidth

The gain bandwidth or amplification bandwidth is the width of the optical frequency range in which significant gain is available from an amplifier. In addition, the gain bandwidth can be defined as the full width at half–maximum (FWHM) of the logarithmic gain, measured in decibels [46].

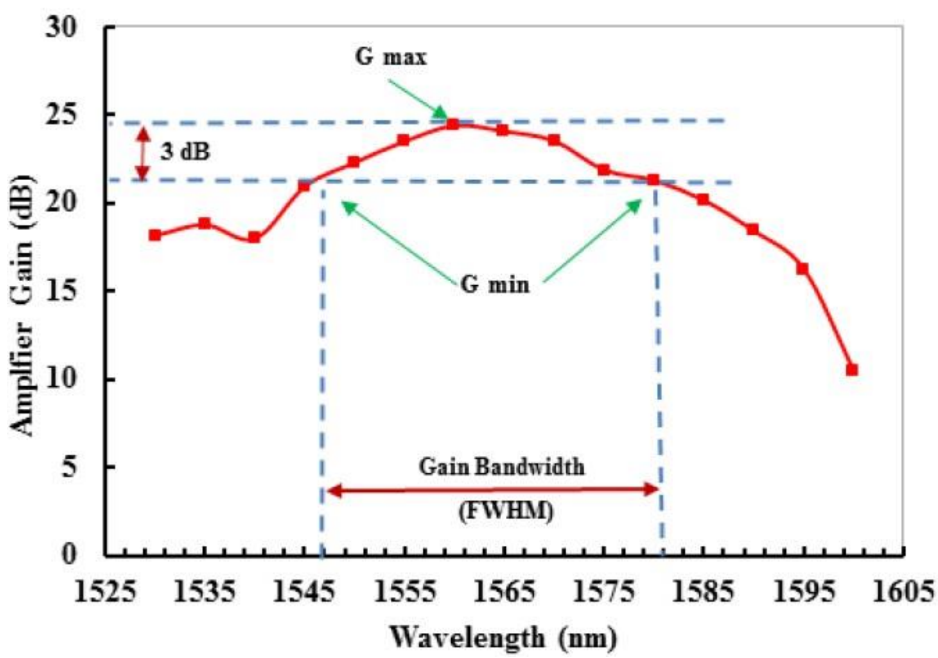

Figure 4.2: Gain parameters used to evaluate the amplifier gain.

4.4.1.4 Gain Saturation

The gain saturation occurs when the signal power increases, the amplifier saturates and cannot produce any more output power, therefore the gain reduces. Saturation is also commonly known as gain compression. The gain saturation is occurring in RFA due to the SBS effect, when the input signal exceeds the SBS threshold, a portion of the input signal is reflected in opposite directions with red shift about 0.08 nm in wavelength. While the gain reduces in EDFA due to the following;

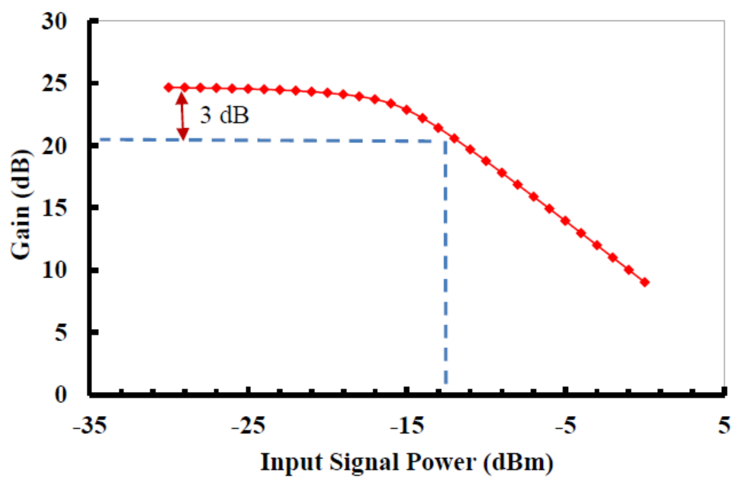

Figure 4.3: Gain saturation.

4.4.2 Power Conversion Efficiency

Power conversion efficiency (PCE) or sometimes known as pump conversion efficiency describes the relation between pump–to–signal power conversion efficiency. PCE is defined as:

$$PCE = \frac{P_s(L) - P_s(0)}{P_0} \times 100$$

Where: Ps(0), Ps(L) and P0 are the input, output signal power and input pump power, respectively.

4.4.3 Noise Figure

The optical noise figure is a parameter used for quantifying the noise penalty added to a signal due to the insertion of an optical amplifier. That is, before the light enters an amplifier the signal to noise ratio is SNR_{in}, after amplification it is SNR_{out}. Thus, the optical noise figure