PERFORMANCE OPTIMIZATION OF

ERBIUM DOPED FIBER AMPLIFIER

IN WAVELENGTH DIVISION MULTIPLEXING SYSTEM

FOR LONG HAUL TRANSMISSION

LEE CHIA TIANG

This report is submitted in partial of the requirement for the award of Bachelor of Electronic Engineering (Telecommunication Electronics) With Honours

Faculty of Electronic and Computer Engineering

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ZAITON BT ABDUL MUTALIP
Lecturer
Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya, 76100 Durian Tunggal,
Melaka, MALAYSIA

"I hereby declare that this report is the result of my own work except for quotes as cited in the references"

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Author : LEE CHIA TIANG

Date : 2 MAY 2011

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Name : PUAN ZAITON BINTI ABDUL MUTALIP

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Special dedication to my late father, Lee Seng Guan and my mother, Liew Neuk Lan.

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ABSTRACT

This project explores how to optimize the Erbium Doped Fiber Amplifier that being used in Wavelength Division Multiplexing Long Haul Optical Transmission System. This report explains the fundamental knowledge, the characteristics of Erbium Doped Fiber Amplifier and the simulation process involved in completing the project. The methods used to achieve the objectives are also clarified throughout the report. Recommendations for future improvement were also included.

ABSTRAK

Projek ini mengkaji kaedah untuk mengoptima penguat "*Erbium Doped Fiber"* yang digunakan dalam Sistem "*Wavelength Division Multiplexing"* pemancaran Optik. Laporan ini menerangkan pengetahuan asas dan sifat-sifat penguat "*Erbium Doped Fiber*". Kaedah-kaedah yang digunakan untuk mencapai objektif juga dijelas seluruhnya dalam Laporan. Cadangan-cadangan pembaikan untuk masa depan telah dimasukkan.

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LIST OF ABBREVIATIONS

EDFA	-	Erbium Doped Fiber Amplifier
WDM	-	Wavelength Division Multiplexing
ASE	-	Amplified Spontaneous Emission
SDH	-	Synchronous Digital Hierarchy
BER	-	Bit Error Rate
OSNR	-	Optical Signal Noise Ratio
SOA	-	Semiconductor Optical Amplifier
ER^{3+}	-	Erbium Ion
NF	-	Noise Figure

CHAPTER 1

INTRODUCTION

Chapter one is focusing on the project background, project's objectives, and problem's statements, scope of work, methodology and thesis structure.

1.1 Overview of the project:

Optical Amplifier can lessen the effects of dispersion and attenuation allowing improved performance of long-haul optical systems. With the demand for longer transmission lengths, optical amplifiers have become an essential component in long-haul fiber optic systems.

In optical fiber network, amplifiers are used to regenerate an optical signal, amplify and then retransmitting an optical signal. In long-haul optical systems, many amplifiers are needed to prevent the output of signal seriously attenuated. In order to reduce the cost, the amount of amplifiers can be reduced by increase the spacing between them. Current spacing of Erbium Doped Fiber Amplifier (EDFA) is in the range of 80km to 100km.

The gain spectrum of EDFA is not inherently flat. For single channel systems, the gain variation is not a problem. However, in optical fiber network, as the number of channel increases, the transmission problem arises. The gain flatness is importance for EDFA's wavelength division multiplexing (WDM) which is important technique for long haul optical transmission link system. They typically present gain peaking at about 1530 nm and the useful gain bandwidth may be reduced to less than 10 nm.

There are one major problem of EDFA which is amplified spontaneous emission (ASE) generated by stimulation emission during amplification of input signals. The ASE is a background noise. This noise signal were being amplified with the input signal when pass through another amplifier.

The output signal power increases will the decreases in the spacing of the EDFA. The output signal power can be optimized by maximizing the gain. Moreover, the gain is the parameter of the doping concentration and doping profile of the erbium doped fiber, length of the fiber, windows wavelength of input signal, input powers and the pump power. But the length of the fiber is the spacing of repeater where is one of the project outcome of this project.

OPTISYSTEM is a design and simulation software for fiber optics application. OPTISYSTEM enables users to design and simulate next generation optical networks, current optical networks, SONET/SDH ring networks, amplifiers, receivers, transmitters. This software has many analysis such as tools eye diagrams, BER, Q-Factor, Signal chirp, polarization state, constellation diagrams, signal power, gain, Noise Figure, OSNR, data monitors, report generation, and etc.

1.2 Objectives of Project

This project simulates and optimizes the performance parameter of EDFA is WDM system. The objectives of this project are outlined as below:

1. to increase output signal power .
2. to flatten the gain of EDFA.
3. to reduce the ASE of EDFA.

1.3 Problem Statement

In order to have a high capacity transmission system, there are several ways such as by using WDM technique, increase the power of output transmission system, reduce the losses in transmission system and etc. By increase the number of optical amplifier in long haul transmission system is able to increase the output power of transmission system but this will increase the costs. Thus, the best solution is to optimize the performance of optical amplifier.

The output signal power is mainly affected by gain of the EDFA. The gain is affected by many factors which are the doping concentration and doping profile of the erbium doped fiber, length of the fiber, wavelength windows input signal, input powers and the pump power. The increase the input signal power certainly will increase the output signal power but the gain decreases. The wavelength of input signal of EDFA can be in 1530nm to 1565nm (C-band) or 1570nm to 1605nm (L-band). The gain of C band is greater than L-band but the absorption is also large.

ASE noise of EDFA amplified together with the input signal. To obtain high output power, the EDFA need high optical pump power and high inversion. Thus, the higher the inversion applied in EDFA, the higher the ASE noise. In the others word, Noise Figure will increase with the gain of EDFA.

Gain flatness is a function of inversion level. Typically 40% to 60% inversion leads to broadest gain with lowest ripple. The gain at the L band is flatter than C band but the C band has lower gain. The use of gain flattening filter can be a solution of gain flatness problem but it will decrease output signal power.

1.4 Scope of the Project

This project only involves the optimization of EDFA. The other types of optical fiber amplifiers are not involved. This project focuses on the simulation using OPTISYSTEM software and does not involve any development of hardware. In addition, reduction of the noise covered in this project which covers ASE noise only and does not covers any others' noises such as thermal noise, human noise and etc. The optimization of Erbium Doped Fiber output signal power is included in this project. This project is focus on the long haul transmission system where using the single mode fiber only.

1.5 Project Outcomes

At the end of the project, The EDFA simulated with increased gain flatness. In the addition, the EDFA simulated with high output power and the spacing of repeaters were increased but the ASE noise will be in small amount.

1.6 Methodology

The basic information of optical fiber amplifier was obtained from the reference book and from internet sources. The information obtained is the basic configuration of optical amplifier in optical transmission link, advantages and disadvantages of EDFA, the ASE

Noise and etc. Second methods of data and information collections are from journal, magazine and reference books. The data and information is more advance such as the effect of ASE noise, analysis of gain flatness of EDFA, the relationship between ASE noise and pump power and etc.

1.7 Thesis Structure

Chapter 1: In this chapter, the objectives of the project were introduced. In overview of the project will introduce the basic idea of project and some basic knowledge related in this project. The problems and the expected outcome of this project were also stated.

Chapter 2: In this chapter, the research to background related of this project will be discussed. The concept structure of future work of this project will be come out by literature review. How to solve the problem stated in chapter 1 by applying the correct theory were explained in details.

Chapter 3: The procedures of solution to the stated problems in this project were explained in this chapter. The choices of procedures were obtained and the chosen options were explained in details. The problems of problems' analysis and collection of were included.

Chapter 4: The results of this project were thoroughly explained in this chapter. The results include simulation of the transmission link and analysis of the performance transmission link. The discussions of the results were also stated.

Chapter 5: The objective, discussion on the findings and conclude the limitation of this project are being justified in this chapter. Some recommendations on how to improve the project were discuss at the end of this chapter.

CHAPTER 2

LITERATURE REVIEW

This chapter discussed all the useful theory and data about this project. The literature review was referring the journal, article, reference books and data sheet. These sources were collected from the library, internet and IEEE library website.

2.1 Introduction

Optical fiber has three main types of property which are dispersion, absorption, and scattering. These properties have caused attenuation, power losses, output power decrease where bring disadvantages to the long haul transmission. Dispersion occurs when the light travelling down a fiber optic cable “spreads out,” becomes longer in wavelength and eventually dissipates. Absorption is resulting by the impurities such as hydroxyl ions where will cause the optical power dissipated as heat power. Scattering is another major mechanism of attenuation in optical fiber. It happens when the light changes direction or diffuse where caused by the light striking the small particles or the in-homogeneity of transmitting material.

Attenuation, a reduction in the transmitted power, has long been a problem for the fiber optics community. The increased in data loss over the length of a fiber has hindered widespread use of fiber as a means of communication. However, researchers have categorized three main sources of this loss: absorption, scattering, and, though it is not commonly studied in this category, dispersion.

With the demand for longer transmission lengths, optical amplifiers have become an essential component in long-haul fiber optic systems. An optical amplifier is a device that amplifies an optical signal directly, without the need to first convert it to an electrical signal. By Optical amplifier, the capacity of optical transmission system is increases. Stimulated emission in the amplifier's gain medium will cause amplification of incoming light.

Semiconductor optical amplifiers (SOAs), EDFA, and Raman optical amplifiers lessen the effects of dispersion and attenuation allowing improved performance of long-haul optical systems.

There are many transmission windows (wavelength bands) as shown in Table 2.1. Each effect that contributes to attenuation and dispersion depends on the optical wavelength. Raman Amplifier have broadest band among the optical amplifiers where from O band to U band. Whereas, EDFA is mostly work on C band or L band.

Table 2.1 Transmission windows (wavelength bands) [1].

Band	Description	Wavelength Range
O band	original	1260 to 1360 nm
E band	extended	1360 to 1460 nm
S band	short wavelengths	1460 to 1530 nm
C band	conventional ("erbium window")	1530 to 1565 nm
L band	long wavelengths	1565 to 1625 nm
U band	Ultra-Long wavelengths	1625 to 1675 nm

2.2 Erbium Doped Fiber Amplifier

The invention of the EDFA in the late eighties was one of the major events in the history of optical communications. It provided new life to the optical fibre transmission window centred at 1550 nm and the consequent research into technologies that allow high bit-rate transmission over long distances. EDFA has cores doped with atoms of an element that light from an external laser can excite to a state in which stimulated emission can occur. Pump light from the external laser steadily illuminates one or both ends of the fiber and is guided along the fiber length to excite the atoms in the core.

The basic configuration for incorporating the EDFA in an optical fibre link is shown in Figure 2.1. The signals and pump are combined through a WDM coupler and launched into an erbium-doped fibre. The amplified output signals can be transmitted through 60-100km before further amplification is required.

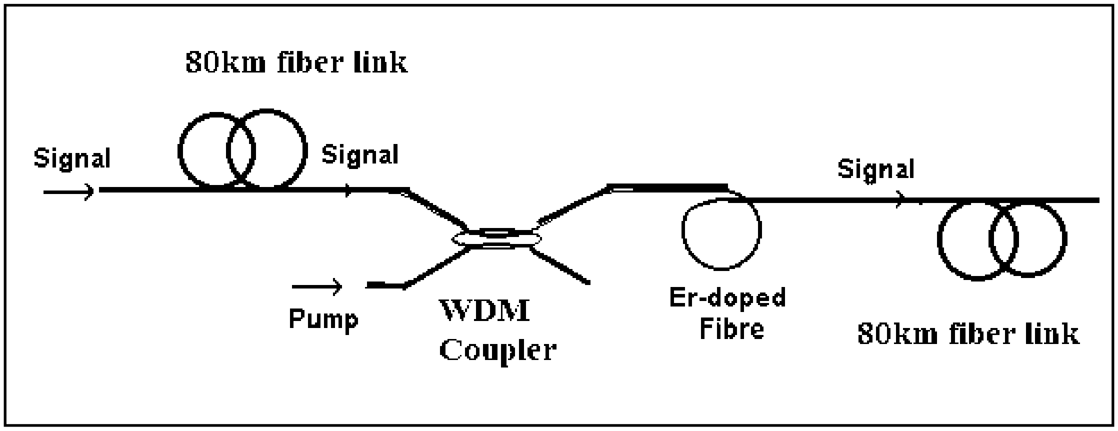

Figure 2.1 Basic configuration for the incorporation of an EDFA in an optical fiber link.

Figure 2.2 shows amplification in the erbium-doped fiber amplifier. Small quantities of erbium are present in the fiber core. When light excites the erbium atoms, a weak signal in the erbium amplification band guided along the fiber core stimulates emission, and the signal grows in strength along the length of the fiber.