WIDEBAND OPTICAL AMPLIFIER USING HIGH CONCENTRATION ERBIUM DOPED FIBER IN SINGLE-PASS CONFIGURATION

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ABSTRACT

This report explores the wideband optical amplifier using high concentration erbium doped fibre in single-pass configuration. The main objective is to study the design of Erbium doped Fibre Amplifier (EDFA) with low pump power to satisfy the requirements for green technology specification. The design parameter for the optimised circuit needs to be determined to evaluate the performance of the amplifier so that it is able to transmit data efficiently. All the parameters and the fundamental theory are described in details. The simulation result obtained will be analysed and discussed.

ABSTRAK

Laporan ini menerokai penguat optik jalur lebar yang menggunakan “Erbium Doped Fiber” berkepekatan tinggi dalam konfigurasi pas-tunggal. Objektif utama adalah untuk menganalisis bentuk “Erbium Doped Fiber Amplifier” (EDFA) dengan kuasa pam yang rendah bagi memenuhi keperluan spesifikasi technology hijau. Parameter reka bentuk litar optimum perlu ditentukan untuk menilai prestasi penguat ini supaya ia dapat mengantar data dengan berkesan. Semua pamameter dan teori asas akan diterangkan secara terperinci. Keputusan simulasi yang diperolehi akan dianalisis dan dibincangkan.

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ABBREVIATION

OA	-	Optical Amplifier
EDFA	-	Erbium Doped Fibre Amplifier
SOA	-	Semiconductor Optical Amplifier
RA	-	Raman Amplifier
NF	-	Noise Figure
SNR	-	Signal-to-Noise Ratio

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CHAPTER 1

INTRODUCTION

Chapter one focuses on the project's overview, project's objective and problem statement, scope of work, methodology and thesis structure. It will explain the basics for the project which is wideband optical amplifier using high Erbium Doped Fibre Amplifier in single-pass configuration. These will be explained in this chapter to give guidance to what the project is about.

1.1 Overview of the Project

In order to transmit signals over long distances (more than 100 km) it is compulsory to calculate and compensate the attenuation losses within the fibre, during travelling and also due to few other factors. Originally, this was performed using the optoelectronic module that consisted of the optical receiver, regeneration and equalisation system and also an optical transmitter to transmit the data. Even though this arrangement was functional, it is limited by the optical to electrical and electrical to optical conversions. Since that, several types of optical amplifiers have been demonstrated to replace the optical-electrical electronic regeneration system [1].

Erbium doped fibre amplifiers (EDFAs) is an optical repeater device that is used to magnify the intensity of optical signals that are being carried through a fibre optic telecommunication system. Commonly, an optical fibre is doped with the rare earth element Erbium, which means that the Erbium is added to the fibre core material as a dopant. This is so that the glass is able to absorb light at one frequency and emits light at another frequency. Fibre amplifiers are developed to support the Dense Wavelength Division Multiplexing (DWDM) and to extend to the other wavelengths supported by fibre optics. An external semiconductor laser couples light into the fibre at infrared wavelengths of either 980 or 1480 nanometres. This operation will excite the erbium atoms. Additional wavelengths between 1530 and 1620 nanometres infiltrate the fibre and stimulate the excited erbium atoms to emit photons at the same wavelengths as the incoming signal. This operation amplifies a flaccid signal to a greater power, affecting a magnification in the signal strength.

This project simulated and evaluates the performance of the Erbium Doped Fibre Amplifier in an optical transmission systems using the OptiSystem Software. The performance of the amplifier is affected by few parameters, which are; Optical Signal-to-Noise Ratio (OSNR), Bit Error Rate (BER), and Noise Figure (NF). The problem faced on conducting this project is to find the most excellent design parameter for the maximum utilization of the Erbium Doped and with compact size using the Erbium Doped Fibre Amplifier.

1.2 Objectives

The objectives of this project are:

a. To study the design of wideband optical amplifier using high concentration erbium-doped Fibre using the OptiSystem software.

b. To provide the design parameters for low power and compact for optical amplifier using high concentration Erbium Doped Fibre.

c. To evaluate the performance of the high concentration Erbium Doped Fibre amplifier based on the amplifiers gain and Noise Figure (NF) and to analyse the simulation data obtained from the OptiSystem software.

1.3 Problem Statement

Optical amplifiers have become an essential component in the long haul fibre optic systems due to the demand for the longer length of transmission. During the transmission of the signal through the fibre cable, there bound to be some losses due to few factors that cannot be avoided. The reasons why the optical amplifiers are required are:

- Typical fibre loss for 1.5 μm is 0.2 dB/km.
- After travelling for about 100km, the signals will be attenuated by 20 dB.
- The optical signal needs to be amplified so that the Optical Signal-to-Noise Ratio (OSNR) of the detected signal is not too low and the Bit Error Rate (BER) does not becomes too high.
- The previous amplifier which is the Optical-Electrical-Optical amplifier conversions is much more expensive as it requires expensive high-speed electronics.

- The most efficient and effective solution is to amplify the signal optically by using the fibre amplifier because it is lowest in cost, most efficient and most stable.

In order to increase the output power of the transmission system, the amount of the optical amplifier will also need to be increased. However this will also increase the costs. Therefore the best solution is by optimizing the performance of the optical amplifier.

Currently, the most effectual solution in optimizing the performance of the optical amplifier is by using the Erbium Doped Fibre Amplifier. This is because their high gain and the ability to operate with low pump power. Therefore, this project is to analyse the performance of the high concentration Erbium Doped Fibre amplifier at different pumping value. The effectiveness of the amplifier will be based on the value of the output that will be obtained. The length of the fibre that is to be used in the amplifier will also need to be reduced to reduce the cost needed for the construction of the amplifier. The solution to this is by using the high concentration Erbium in the fibre to enhance the energy excitement on the amplifier.

The design for the EDFA must fit the criteria of the objective, that it:

- It must be compact (try to minimize the length of fibre to be used in the experiment.
- Try to use the lowest possible pump power to operate the system, but with efficient result.

1.4 Scope

This project will focus primarily on the simulation of the wideband optical amplifier using high concentration Erbium Doped Fibre in single pass configuration. The simulation and tests will be done using the OptiSystem Software. The performance of the optical amplifier will be evaluated based on the amplifier's gain and Noise Figure (NF) obtained from the simulation of a single mode fibre transmission link for wideband wavelength. The fabrication or development of hardware of the high concentration of Erbium Doped Fibre Optical Amplifier (EDFA) will not be covered in this project.

1.5 Project Outcomes

It is expected that by the end of this project, the parametric study for the design of the high concentration EDFA in single-pass configuration that is to be used for the wideband with desired parameter of high gain value and low noise figure value can be obtained. In addition, the EDFA will be able to simulate with low power and is compact size.

1.6 Methodology

This project starts off with acquiring the source and information pertaining to the optical amplifier using high concentration Erbium Doped Fibre. The sources and information are obtained from journals, reference books, e-Books, magazines and also the internet. The information attained will be based on the fundamental configuration of the optical amplifier in a transmission link, advantages and disadvantages of EDFA, the parameters related with EDFA. The circuit schematic diagram of the optical amplifier using high concentration Erbium Doped Fibre is determined and then simulated and tested using the OptiSystem software. The parameters involved and varied are the number of pump (Single Pump or Bidirectional Pump), the pump power (from 10 mW until 200 mW), the pump wavelength (980 nm or 1480 nm), the fibre length (from 1 m until 2.5 m for C-band application and from 7 m until 8.5 m for L-band application) and the input signal power (0 dBm or -30 dBm). The amplifiers gain and Noise Figure (NF) obtained from the simulation is analysed. The simulation process is repeated until the compatible design parameter for the wideband optical amplifier is obtained.

1.7 Thesis Structure

Chapter 1 introduces the project and gives general idea regarding the project. It includes the overview of the project, the objective, problem statement, scope of project and project outcomes which will provide basic idea and knowledge related with this project.

Chapter 2 illustrates and discusses the projects fundamental and background. The concept and theory of the circuit diagram that will be used in the project will be explained in details in this chapter.

Chapter 3 proposes the methodology of the project. The procedures that will be used in conducting the project will be explained more thoroughly in this chapter.

Chapter 4 presents the results that are obtained from the simulation of the high concentration EDFA. The results obtained will also be discusses and analysed in this chapter,

Chapter 5 will conclude all the information collected based on the projects result. The results will be evaluated based on the findings and the objectives of the project. Recommendations on how to enhance the project will also be included in this chapter.

CHAPTER 2

LITERATURE REVIEW

Chapter two focuses on the project's background and other relevant information related to the project such as the fundamentals of Erbium Doped Fibre Amplifier. It will explain the basics for the project which is wideband optical amplifier using high Erbium Doped Fibre Amplifier in single-pass configuration.

2.1 Introduction

Since its invention in the early 1970s, the use and the demand of optical fibre have excessively grown. The applications of optical fibre today are quite abundant [1]. With the eruption of the information traffic generated with the use of internet, electronic commerce, computer network, multimedia, voice, data and video, the requirement for a transmission medium with the bandwidth capabilities for handling such enormous amount of information is essential. Fibre optics, with its comparatively infinite bandwidth has proven to be the solution. When optical is the only transmission that can keep up with and stay ahead of the accelerating demand for long haul requirements, this means that the technology of the optical system is an essential part of the human system [2]. Therefore, it is vital that we study the system in order to develop the most intelligent fibre optic amplifier that fits the current needs to allow for a more cost effective advance network infrastructure.

2.2 Benefits of Fibre Optics

The optical fibre system possesses several advantages over metallic-based communication system [3]. These advantages include:

- Long distance signal transmission
  The optical systems admits longer interval of signal transmission than the metallic-based systems due to the low attenuation and superior signal integrity.
- Large bandwidth, light weight, and small diameter
  The present applications has the need to an ever increasing amount of bandwidth. Therefore, it is important to acknowledge the space constraints of many end users. The small diameter and light weight of the optical cable makes the installation simple and practical, and helps to save the conduit space.
- Non-conductivity
  Due to its dielectric nature and no metallic components, the optical fibres can be installed even in the areas with electromagnetic interference (EMI) and radio frequency interference (RFI). It is also ideal to be installed for the areas if high lightning strike incidence.
- Security
  The dielectric nature of the optical fibre also makes it impossible to remotely access the optical fibre. Accessing the fibre will require

intervention that will be easily discovered by the security surveillance. The conditions make the fibre favoured to governmental bodies, banks and others with security concerns.

- Designed for future application needs

  Fibre optics is affordable today, as the prices of the electronics fall and the price of the optical cable remaining low. In the increasing demands of the bandwidth as the technology advances, fibre will continue to play an essential role in the long term accomplishment of the telecommunications.

2.3 Basic Fibre Optic Communication System

The fibre optics is used as medium to carry information from one point to another in the form of light. As the fibre optic is not electrical in nature like the copper form of transmission, a basic fibre optic system is made up of a transmitting device that converts an electrical signal into a light signal, an optical fibre that carries the light and a receiver that accepts the light signal and convert is back to electrical signal. The complexity of a fibre optic system can range from a very simple system to a very prominent system. A conventional optical communication system that is for the usage of long distance, high bandwidth telecommunication that employs wavelength-division multiplexing uses the Erbium doped fibre amplifier, an external modulation that uses the DFB lasers with temperature compensation, fibre Bragg gratings and high speed infrared photo-detectors [4].