# OPTIMIZATION OF RAMAN FIBER AMPLIFIER

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# ABSTRACT

Optical amplifier has been an essential component in long haul optic system in transmission system. In order to enhance the capacity of an optical system, the optimization of the signal parameters and system components is a critical task. In the real system, there are many parameters that can be adjusted to achieve the desired performance levels. However, this requires implementation of time–consuming procedures. This project simulates WDM system design in order to optimizing the pump powers of a Raman Fiber Amplifier for a target gain and best gain flatness using OptiSys 7.0 software. Many parameters related Raman Amplifier such as length of amplifier, wavelength of pump power and input pump power have been optimized in order to obtain Noise Figure (NF), Optical Signal Noise Ratio (OSNR), gain, Bit Error Rate (BER) and Q Factor performances. These parameters were varied from a certain range of pump power 500mW to 1W, length of amplifier 23 km to 25 km and wavelength 1450nm to 1460nm and results viewed using Dual Port WDM Analyzer and BER Analyzer.

# ABSTRAK

Penguat optik telah menjadi satu komponen penting dalam perjalanan jauh bagi sistem penghantaran isyarat optik. Bagi meningkatkan keupayaan satu sistem optik, pengoptimuman parameter isyarat dan komponen-komponen sistem ialah satu tugas kritikal. Dalam sistem sebenar, terdapat banyak parameter yang dapat diselaraskan bagi mencapai peringkat prestasi sistem yang ditetapkan. Namun demikian, hal ini memerlukan tempoh masa yang lama dan prosedur yang rumit. Projek ini adalah ilustrasi rekabentuk sistem WDM yang menggunakan kuasa input yang optimum untuk menjana penguat optik Raman sekaligus mencapai objektif projek ini dengan menggunakan perisian *OptiSys 7.0*. Banyak parameter telah diselaraskan dengan optimum berkenaan dengan penguat optik Raman seperti panjang penguat optik, panjang gelombang dan nilai kuasa pam bagi mendapatkan *Noise Figure (NF),* nisbah isyarat kepada hingar optik, gandaan, kadar kesilapan bit dan faktor Q. Parameter ini dibuat perkadaran dari julat tertentu iaitu nilai kuasa pam dari 500mW kepada 1W, panjang penguat optik dari 23 km kepada 25 km dan panjang gelombang dari 1450nm kepada 1460nm dan semua hasil dinilai dengan menggunakan *Dual Port WDM Analyzer* and *BER Analyzer.*

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| | |
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| APD | Avalanche Photo Diode |
| ASE | Amplified Spontaneous Emission |
| BER | Bit Error Rate |
| CapEx | Capital Expenditures |
| dB | decibel |
| DRS | Double Rayleigh Scattering |
| EDFA | Erbium Doped Fiber Amplifier |
| IEEE | Institute of Electrical and Electronic Engineering |
| LAN | Local Area Network |
| LH | Long Haul |
| MAN | Metropolitan Area Network |
| NF | Noise Figure |
| NRZ | Non Return Zero |

| | |
|---|---|
| OpEx | Operational Expenditures |
| OSNR | Optical Signal to Noise Ratio |
| RFA | Raman Fiber Amplifier |
| SMF | Single Mode Fiber |
| SOA | Semiconductor Optical Amplifier |
| ULH | Ultra Long Haul |
| WDM | Wavelength Division Multiplexing |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Overview of Project

The main purpose of this project is to investigate and determine the characteristics of Raman Fiber Amplifier and its performance in telecommunication system. This is done by optimizing certain parameters. The desired parameters such as length of the amplifier, wavelength used in transmission and pump powers are some of the parameters that are being considered in order to achieve the desired objectives. The simulation of this optimization WDM transmission system Raman Fiber Amplifier is done using OptiSys 7.0 software.

Raman Fiber Amplifiers are being used in almost every new long haul and extra long haul fiber optic which is more than 4000km in transmission system and becomes one of the first widely commercialized nonlinear optical devices in telecommunications. Distributed Raman Amplifiers improved the Noise Figure (NF) and reduced the nonlinear parameter in fiber optic, allowing for a longer amplifier's span, high bit rates, closer channel spacing and operate under zero dispersion wavelengths. Raman Fiber Amplifier is also an important part of long distance, high capacity and high speed optical communication system.

One of the key developments for Raman Fiber Amplifier is the availability of high pump power laser diodes or cladding pump fiber lasers. By increasing the number of amplifier in order to get higher power transmission, will also increased the cost. Thus, it cannot be considered as a good approach due to the relatively high cost and complexity of the overall amplification system. The best approach is to optimize the amplifier parameter and system may turn out to be a solution.

OptiSys 7.0 software is an innovative, rapidly evolving, and powerful simulation design tool that enables users to plan, test, and simulate almost every configuration of optical parameter. Hence, this software is used in order to optimize the parameters in this optical Raman Fiber Amplifier.

## 1.2 Objectives of Project

There are several objectives that have been outlined in order to complete this optimization of Raman Fiber Amplifier. There are to:

- determine the limitation of high capacity transmission system.
- optimize pump powers of a Raman Fiber Amplifier for a target gain.
- determine the parameters that able to optimize the amplifier's performance in term of Bit Error Rate (BER), Optical Signal Noise Ratio (OSNR) and etc.
- analyze the eye diagram obtained from OptiSys 7.0.

## 1.3 Problem Statement

In the transmission system, optical amplifiers have been an essential component in long haul fiber optic system. Optical amplifier can serve several purposes in the design of fiber optic communication system with the aim of long transmission distance and high capacity per fiber. In order to provide high capacity there are some limitations

that need to be improve which are in term of power, dispersion and attenuation. One of the ways to improve the performance of the optical amplifier is the power limitation. The launch power should be reduce as much as possible but amplifier noise forces for a certain minimum power to maintain the OSNR and manage the loss and dispersion. Besides, in order to maintain the performance of the amplifier, the span loss should be reduced, the signal power should be increase and decrease the Noise Figure and increase the number of the amplifier.

For a transmission system, the best scenario is if the signal could propagate along the fiber with no loss and with no amplification. Its OSNR would be equal to its input value and Noise Figure equal to one. The worst case is if the signal experiences the full loss of the span and then it is amplified. So, full optimization of the Raman Fiber Amplifier is the best method to maintain the performance of the transmission signal. Raman Fiber Amplifier is claimed that has high power pump laser and a Wavelength Division Multiplexing (WDM) or directional coupler.

## 1.4 Scope of the Project

This project is based on the simulation analysis of quality of received signal (Q), Noise Figure (NF), Bit Error Rate (BER) and Optical Signal Noise Ratio (OSNR) by using OptiSys 7.0 software. Besides, the analysis is also based on the eye diagram which provides visual information that can be useful in the performance evaluation and troubleshooting of optical transmission systems.

## 1.5 Project Outcomes

The expectation outcomes from this project are:

1. The pump powers of Raman Fiber Amplifier can be optimized.

2. The parameters such as OSNR, BER and Q can be determined to optimize the amplifier
3. Able to analyze the eye diagram such as the size of eye diagram's opening which is optical signal to noise during sampling, plus the magnitude of the amplitude and timing errors.

## 1.6 Methodology

This project begins with collecting data and information either from primary or secondary resources. Some of the information's are taken from the journal, book, book, magazine and web site. All the information gathered are scanned and skimmed in order to understand the concept of fiber optic especially on how Raman Fiber Amplifier working principle and its characteristics. All the concepts, limitation and parameter that are required for optimizing this amplifier have been considered. This is followed by simulating those parameters using Optisys 7.0 software and finally an analysis has been done to obtain the desired result.

## 1.7 Thesis Structure

Chapter 1: The first chapter introduces brief idea of the project. It focused on the overview of the project, detailing the objectives, the problem statement, scope and outcome of the project.

Chapter 2: Project's background is discussed in this chapter. The method, concept, theory, and some characteristics of fiber amplifier such as OSNR, gain and etc are thoroughly explained in this chapter. Chapter 2 contains a definition of terms used throughout the report.

Chapter 3: The third section is the methodology's chapter. This chapter explains the procedure taken throughout the project. Methodology chapter is a schedule or steps that need to be complete, detailed reports of studies done to achieve aimed objectives.

Chapter 4: All the simulations, data collection and analysis obtained were discussed in detail. The results were compared with the outlined objectives in order to state some hypothesis and conclusion.

Chapter 5: Conclusions are detailed out in this chapter. It is followed by some recommendations on how to improve the performance of Raman Fiber Amplifier based on the desired results.