AN IMPROVED OPTICAL COMMUNICATION SYSTEM USING FIBER BRAGG GRATING IN EDWA

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I dedicate this entire work to my honorable lecturer and supervisor, to my beloved family and all my close friends for their support and encouragement that has constantly been a part of this success.

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ABSTRACT

Fiber optic communication gives impact in all aspect of communication field and this technology is continuing development from time to time and now being the dominant technology of most of the country. In 1998, Wavelength Division Multiplexing (WDM) become new era of optical communication due to ability to send many independent optical channels on a single fiber. Since the development of this technology, sort of problems have encountered especially in increasing gain. An optical amplifier (OA) is a term commonly given to a component, module, or sub-system that increases optical signal power without performing Optical-to-Electrical (O/E) and Electrical-to-Optical (E/O) conversions [7]. One of optical amplifier used is erbium-doped waveguide amplifier (EDWA. In this project the design of EDWA by adding fiber Bragg grating will be designed by using OptiSystem software. The simulation of this project will investigate the effect of gain bandwidth by varying some of the parameters. Some of the parameters that will control gain include the effect of erbium ions concentration, pump power, signal power and waveguide length. The most reliable design will be determine the performance of this optical amplifier. Finally, simulation results of EDWA by adding FBG analysis are presented in this report.

ABSTRAK

Komunikasi gentian optik memberikan kesan dalam semua aspek bidang komunikasi dan pembangunan teknologi ini masih berterusan dari semasa ke semasa dan sekarang menjadi teknologi yang dominan di kebanyakan negara. Pada tahun 1998, Multiplexer Pembahagian Panjang Gelombang (WDM) menjadi era baru dalam komunikasi optik disebabkan oleh keupayaan untuk menghantar banyak saluran optik bebas ke atas satu gentian.Sejak perkembangan teknologi ini,beberapa masalah yang dihadapi terutama untuk meningkatkan gandaan. Penguat optik (OA) adalah satu terma biasanya diberi kepada komponen, modul atau sub-sistem yang meningkatkan kuasa isyarat optik tanpa melakukan penukaran Optik-ke-elektrik (O/E) dan elektrik-ke-optik [1]. Satu daripada penguat optik digunakan ialah *erbium-doped waveguide amplifier (EDWA)*. Dalam projek ini, rekaan EDWA dengan menambah FBG akan direka dengan menggunakan perisian OptiSystem. Simulasi projek akan menyiasat kesan gandaan jalur lebar dengan mengubah beberapa parameter. Beberapa parameter yang akan mengawal gandaan termasuklah kesan kepekatan ion Erbium, kuasa pum, kuasa isyarat dan panjang pemandu gelombang. Reka bentuk yang boleh diharap akan menentukan prestasi penguat optic ini. Akhirnya, keputusan simulasi analisis EDWA dengan menambah FBG akan dibuat dalam laporan ini.

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LIST OF ABBREVIATIONS

EDFA	-	Erbium-doped fiber amplifier
EDWA	-	Erbium-doped waveguide amplifier
FBG	-	Fiber Bragg grating
WDM	-	Wavelength Division Multiplexing
LPG	-	Long period grating
UV	-	Ultraviolet
OADM	-	Optical add-drop Multiplexer
BER	-	Bit error rate
PSM I	-	Projek Sarjana Muda I (Final Year Project I)
PSM II	-	Projek Sarjana Muda II (Final Year Project II)
CIDF	-	Component Iteration Data Flow
MAN	-	Metropolitan Area Network
LAN	-	Local Area Network
CATV	-	Community Access Television or Community Antenna Television
TDM	-	Time-division multiplexing
PON	-	Passive optical network
FTTx	-	Fiber to the x
FSO	-	Free space optic
ROF	-	Radio over fiber
SONET	-	Synchronous optical networkin
SDH	-	Synchronous digital hierarcy
LED	-	Light emitting diodes
MUX	-	Multiplexer

DEMUX	-	Demultiplexer
Q-factor	-	Quality factor
ISI	-	Intersymbol interference

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CHAPTER I

INTRODUCTION

This chapter consists of project background, problem statement, objectives of the project, scope of the project, methodology and thesis outline

1.1 Project Background.

The development of optical amplifier become commercially used since the revolutionized in communication system in the late 1980s. EDWA is an optical amplifier that uses a waveguide to enhance an optical signal, analogous to an EDFA. The usage of optical amplifier become more important in development of communication systems since the ability of this device to amplify the optical signal directly, without converting it to an electrical signal and change back to optical signal. Now, due to the success of EDFA has been used in long-distance fiber communications link, EDWA also can play the same role since the concept of Er doping for both optical amplifiers.

Several methods can be used to increase the gain bandwidth of an amplified light wave system. In this project, an improvement of optical transmission system will be investigated by adding Fiber Bragg grating (FBG) to EDWA. Fiber gratings have now become of one the solution because of application for optical feedback, wavelength control, filtering, sensing, or as dispersive elements [10]. For this project the application for filtering becomes main reason to use in this project. The design of EDWA using FBG also responsible to analyze the performance characteristics in terms of gain, the effect of Erbium ions concentration, pump power, signal power and waveguide length.

1.2 Problem Statement

Due to conventional EDWA has intrinsic non-uniform gain, the problem will occur during transmission when number of channel increases and not to a single channel. To overcome this problem, the usage Bragg technology is very important to improve the gain bandwidth and performances of many channels in high density Wavelength Division Multiplexing (WDM) system. The capabilities of Bragg gratings combined with its all-fiber configuration make them an ideal candidate for high channel count density components such as multiplexer/demultiplexer, optical interleaver and add/drop filter[14].

1.3 Objectives of Project

i. To design and simulate of EDWA in FBG by using OptiSystem software.
ii. To analyze the performance characteristics in term of gain, the effect of Erbium ions concentration, pump power, signal power and waveguide length.
iii. To increase gain bandwidth by producing a working optical waveguide amplifier (EDWA) using fiber Bragg grating method.

1.4 Scopes of Project

The scope that will be covered in this project includes make further reading and research on EDWA, fiber Bragg grating and also factor that increase EDWA gain. The parameters involved in terms of gain, the effect of Erbium ions concentration, pump power, signal power and waveguide length.

The second scope is about modeling and makes the simulation of EDWA in fiber Bragg grating by using OptiSystem software. The designing and modeling of the EDWA is based on EDFA as analogous of the waveguide amplifier in fiber Bragg grating.

Lastly, the performance characteristics in terms of gain, the effect of erbium ion concentration, pump power, signal power and waveguide length will be analyzed. These parameters are very important to make sure the optimization of gain bandwidth that will be obtained.

1.5 Thesis Outline

This report is divided into 5 chapters which cover introduction, literature review, project methodology, result and analysis as well as conclusion. The project background, problem statement, objectives and scopes of this research project have been explained earlier in this chapter. Chapter two covers the literature review that explains about the EDWA, differences and advantages EDWA over EDFA, parameters affecting EDWA gain, FBG, application of FBG and fiber Bragg grating in EDWA. Chapter three focuses in project methodology which covers for design such as project planning, software that used simulation tools, design parameters, performance parameters, design specification and components description. For Chapter 4 the result and analysis will be covered and lastly conclusion and future works will be concluded at Chapter 5.

CHAPTER II

LITERATURE REVIEW

This chapter will discuss precisely about the project, including the concept used, and overview of the implementation of EDWA and FBG in optical communication system. Important parameters such as the Erbium ions concentration, pump power, waveguide length and signal power that need to be considered to increase the gain are introduced.

2.1 Erbium-Doped Waveguide Amplifier (EDWA)

The Erbium doped waveguide amplifier is another kind of emerging ultra-compact optical amplifier targeting the metro/access networks [1]. In EDWA contains of optical waveguide that embedded in an amorphous erbium doped glass substrate. For manufacturing of EDWA, there are two steps involved. The first step is to prepare doped material; the second step is to make the optical waveguide. According [1] EDWA also can operate if very high doping erbium ion concentration (more than 10^{26} atoms/m^3) without causing significant ion-cluster effect in erbium host medium of alumino-silicate and alumino-phosphate. By using this host medium, the erbium ion concentration can be used at least 100 times higher than that in silica glass. Usually obtaining dB/cm gain coefficient with acceptable length of doped optical waveguide the high erbium doping level and parasitic effects must be taken into account.

According to [1] EDWA has the advantages over other single-chip amplifier, such as SOA in terms of relative low noise figure, low polarization dependent effects, and the absence of inter-channel crosstalk. Table 2.1 lists the typical performance of EDWA products available on the market place. Usually the noise and gain characteristic of EDWA is worse than EDFA because of butt coupling loss and propagation loss in optical waveguide. Polarization dependent problem also can occur in EDWA due to mismatch of mode field between waveguides and fibers and asymmetrical mode field.

Table 2.1: Typical performance of EDWA on the marketplace [1]

Parameter	Pre-amp		Booster amp
Wavelength range (nm)		1350-1560	
Output power at 0 dBm input (dBm)	N/A		7
Typical signal power at -30 dBm input (dB)	15		N/A
Noise figure (dB)	6.0		6.0
Operating temperature (^{o}C)		0-70	
Power consumption (W)		10	
Dimension (mm)		81 x 35 x 12	

2.2 Principle of Operation

Erbium has several important properties that make it a good choice for an optical amplifier. The erbium atoms provide the glass with gain in the 1,550-nm fiber-optic window. That gives them the ability to amplify signals in a band where high-quality amplifiers are most needed. Erbium's quantum levels also allow it to be excited by a signal at 980nm. At this state optical waveguide can carry signal without too much losses, but not in the middle of the signal wavelengths.

Erbium also has trivalent charge state (Er3+) [2]. A number of energy levels will increase due to spin-spin and spin orbit coupling in the incompletely filled 4f shell as shown in Figure 2.1 [2]. At approximately 1.54 µm wavelength, the transition from the first excited state ($^4I_{13/2}$) to the ground state ($^4I_{15/2}$) will occur. Due to 4f shell is shielded from its surroundings by the filled 5s and 5p shells, emission of wavelength are relatively insensitive to the host material.

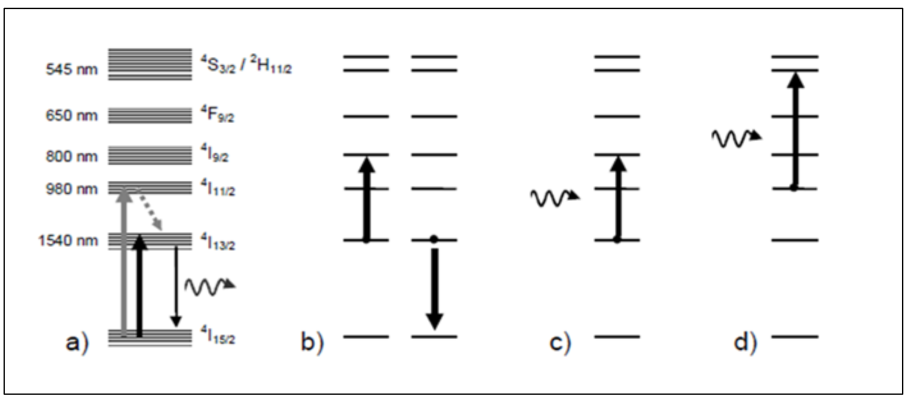

Figure 2.1: Schematic representation of the Er^{3+} intra 4f energy levels. Figure a) shows the 1.54 mm transition, and the upward arrows indicate excitation using 1480 nm pump light and 980 nm pump light respectively. Figure b) show the process of co-operative up conversion, where interaction between two excited Er^{3+} ions leads to the population of higher lying energy levels. Figure c) and d) show the process of excited state absorption of a 1480 nm or a 980 nm pump photon respectively [2].

2.3 The Differences EDFA and EDWA

The main differences of EDFA and EDWA is in fabrication aspect which is EDFA are made from loop of erbium-doped fiber as gain material while for EDWA are made from a much shorter and straighter waveguide gain material built by using higher erbium concentration, that allows gain in a shorter distance.

Besides that, passive optical component also can be integrated in the same chip in EDWA. For EDFA, the erbium-doped fiber can splices in line with other fiber optic component whereas for EDWA a waveguide to fiber cannot be spliced because of the coupling effect in free space. The coupling effect will make light in the fiber couple into the end of waveguide and amplify and then coupled back into the fiber. The coupling process in EDWA make the light transverse in free space and during this process other components such as free-space optical isolator or pump can be added rather than use a fiber-coupled pump.