UNIVERSITI PUTRA MALAYSIA

DESIGN AND EVALUATION OF A DUAL CORE ERBIUM DOPED FIBER AMPLIFIER (DC-EDFA)

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By

ABDULLATIF MOHAMMED ALSHARJABI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, In Partial fulfillment of the Requirements for the Degree of Master of Science

June 2003

DEDICATION

To all mankind

Abstract of thesis presented to the Senate of the Universiti Putra Malaysia in partial fulfillment of the requirement for degree of Master of Science

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Traditional erbium doped fiber amplifiers EDFA (unidirectional signaling) can only amplify signals propagating in a single direction, as some isolators must be installed to eliminate the reflections from end faces and fusion points. This means the amplifiers only amplify signal in one direction over a fiber. For long haul transmission, many amplifiers are placed along each single mode fiber. Total numbers of the amplifiers will be the number of the amplifier over a fiber multiply by the number of the fibers in the cable. This means a large number of amplifiers are required thus increasing a high cost. In order to reduce the system cost, and increase the capacity, many studies have been done using bi-directional signaling in a single fiber (duplex), through one or two separate amplifiers.

In this work, a bi-directional signaling technique has been exploited, this in order to amplify the signals bi-directionally, over two single mode fibers (unidirectional). This is achieved by using two circulators instead of isolators at the terminals of the EDFA. The main goal is to reduce the number of amplifiers in the optical communication system, which results in a decrease in the system cost. The new system is tested by laboratory experiments. From the results, it is found that the system has the same characterizations as bi-directional EDFA amplifiers, (i.e. independent amplification, medium gain, low ASE), as expected. Reflections also occur. The system has high reflection when the difference in the input powers of the bidirectional signals is high. This causes different gains and different amplified powers. The reflection of the signal which has higher input power is associated with the other main signal (over the other fiber). The system shows the best performance, when the difference in the input powers (for the two fibers) is small and is even better when the bidirectional signals have the same input powers.

In conclusion, the project objectives have been achieved, and the system can reduce the number of the amplifiers to as much as 50% of that in a unidirectional propagating system, due to the fact that, two fibers can now share one amplifier and results in cost reduction by almost 50%. Furthermore, the approach is flexible and simple.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian keperluan untuk Ijazah Master sains

REKABENTUK DAN PENILAIAN PENGUAT FIBER TERDOP ERBIUM DUA TERAS

Oleh

ABDULLATIF MOHAMMED ALSHARJABI

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Secara tradisinya EDFA (Erbium Doped Fiber Amplifier) adalah penguat satu hala yang mana ia hanya menguatkan isyarat yang merambat didalam satu arah sahaja. Isolator mestilah dipasang untuk mengelakkan belakunya balikan dari arah yang bertentangan ke titik penghantar. Ini bermakna penguat hanya akan menguatkan isyarat di dalam satu hala sahaja. Bagi penghantaran jarak jauh, penguat di gunakan di beberapa tempat di sepanjang fiber untuk menguatkan isyarat. Jumlah keseluruhan penguat yang di gunakan didalam sistem, merupakan jumlah penguat yang di gunakan didalam setiap fiber didarab dengan jumlah bilangan fiber yang di gunakan. Ini bermakna banyak penguat di perlukan serta memerlukan kos yang tinggi. Bagi mengurangkan kos serta meningkatkan kapasiti, banyak kajian telah di jalankan menggunakkan penisyaratan dua hala didalam satu fiber melalui satu atau dua penguat yang berasingan.

Didalam kajian ini teknik pengisyaratan dua hala di perkenalkan dalam usaha untuk menyuatkan isyarat di dalam dua arah bagi dua fiber satu mode. Ini dapat dicapai dengan menggunakan dua Isolator berbanding satu Isolator pada terminal EDFA. Tujuan utama adalah untuk mengurangkan bilangan penguat di dalam sistem komunikasi optik yang mana akan dapat mengurangkan kos keseluruhan sistem. Sistem baru ini telah diuji di dalam makmal. Bagi membolehkan simulasi sistem dapat di buat, isyarat yang telah di modulat daripada Penanalisa SDH di biarkan melalui Fiber 1, manakala Sumber Tunable Laser di laraskan pada lebarjalur yang berlainan untuk menghasil isyarat pada fiber 2. Daripada keputusan yang di perolehi, sebagaimana yang telah di anggarkan sistem tersebut mempuyai ciri-ciri yang sama dengan penguat EDFA dua hala, yang mana penguat mempunyai gandaan bebas dan sederhana serta mempunyai rendah ASE disamping itu balikan juga terjadi. Sistem akan mempunyai balikan yang tinggi apabila terdapat perbezaan antara kuasa masukan bagi isyarat duahala yang tinggi. Selalunya balikan terjadi daripada isyarat yang kuasa masukan yang tinggi. Manakala sistem mempunyai prestasi yang baik apabila kuasa masukan isyarat dua hala adalah sama.

Sebagai kesimpulan, objektif projek ini telah di capai, dimana penggunaan penguat dapat di kurang kan sehingga 50% bagi sistem perambatan satu hala. Ini adalah kerana dua fiber akan berkongsi satu penguat dan dapat mengurangkan kos sebanyak 50%. Sistem baru ini adalah fleksible, mudah dan mempunyai cirri-ciri EDFA dua hala.

ACKNOWLEGEMENTS

In the name of Allah, the Most Beneficent, the Most Merciful

I would like to express my sincere gratitude to my thesis supervisor, Associate Professor Dr. Mohd Khazani Abdullah for his invaluable guidance, enthusiastic encouragements and support at every stage of this research project. A research project as this entails a lot of sacrifice in term of time, energy, money etc, not only on my part but also on that of my supervisor. He introduces me into the field of optical amplifiers and provided me the resources necessary for the completion of this project. These include writing of surveys, turning ideas into implementation, and getting through the inevitable research setbacks.

I am also grateful to Professor Dr. Borhanuddin Mohd Ali for his guidance, comments and advices throughout the entire project.

I also say thank you to Associate Professor Dr. Kaharudinn Dimyati for accepting to be on my committee.

I am indebted to all the people at the photonics laboratory for creating the conducive and encouraging atmosphere.

Finally, I want to express my deepest feeling to my family for their constant support and encouragement during my study period. I also say sorry to them for being far away from home for too long.

I certify that an Examination Committee met on 17th June 2003 to conduct the final examination of Abdullatif Mohammed Alsharjabi on his Master of Science thesis entitle "Design and Evaluation of a Dual Core Erbium Doped Fiber Amplifier (DC-EDFA)" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981 The Committee recommends that the candidates be awarded the relevant degree Members of the Examination Committee are the follows

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institution.

ABDULLATIF ALSHARJABI

Date: 30/6/2003

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LIST OF ABBREVIATIONS

1R	Repeaters Perform Reamplification the Signal
2R	Repeaters Perform Reamplification and Reshaping
3R	Repeaters Provide Regenerators and Reshaping And Retiming
ASE	Amplified Spontaneous Emission
BEDFA	Bidirectional Erbium Doped Fiber Amplifier
BER	Bit Error Rate
D	Directivity
dB	A Unit of Measurement Indicating Relative Power on a Logarithmic Scale
dBm	Abbreviation for Decibel Relative to Milliwatt.
DC-EDFA	Dual Core Fiber EDFA
DP	Design Parameters
EDF	Erbium Doped Fiber
EDFA	Erbium Doped Fiber Amplifier
G	Gain
I	Isolation
i/P	Input Power
IL	Insertion Loss
InGaAs	Abbreviation For Indium Gallium Arsenide.
InGaAsP:	Abbreviation For Indium Gallium Arsenide Phosphide.
IR	Infrared
MCVD	Modified Chemical Vapor Deposition Method

MUX/ DEMUX	Multiplexer / Demultiplexr
NF	Noise Figure
O/P	Output Power
OA	Optical Amplifier
OC-12	Standard For Optical Carrier Level at 622.08 Mbps In Sonnet
OC-192	Standard For Optical Carrier Level at 10 Gbps
OSA	Optical Spectrum Analyzer
OSI	Open System Interconnection
PP	Performance Parameters
SDH	Synchronous Digital Hierarchy
SM	Single Mode
SMF	Single Mode Fiber
SOAs	Semiconductors Optical Amplifiers
SONET	Synchronous Optical Network
STM	Synchronous Transport Modules
STM-1	Standard for Optical Carrier Level at 155 Mbps in SDH
STM-4	Standard for Optical Carrier Level at 622 Mbps in SDH
TAT-12,13	Transatlantic cable system
TLS	Tunable Laser Source
TPC-5	Transpacific cable system
UEDFA	Unidirectional Erbium Doped Fiber Amplifier
WDM	Wave Division Multiplexer

CHAPTER I

INTRODUCTION

Light has been used for thousands of years for communications, a feat which man being an intellectual creature needs. This need has created a myriad of astonishing devices employed in communication systems used for sending messages from one point to another at a distant place.

Many forms of communication systems have appeared over the years. The basic motivation behind each new form is to improve the transmission fidelity, increase the data rate so that more information can be sent, and increase the distance between the relay stations. Fiber optic communication systems could overcome almost all shortcoming and problems found in conventional communication systems.

1. 1 The Importance of Fiber Optics Communication

The major characteristic of a telecommunication system is unquestionably its information- carrying capacity; capacity is the most prized feature that most users need.
A copper wire can carry a signal up to 1MHz over a short distance. A coaxial cable can propagate a signal up to 100MHz. Radio frequencies are in the range of 500MHz to 100MHz. Microwaves, including satellite channels; operate up to 100GHz [1]. Fiber

optic communication system uses light as the signal carrier; light frequency is between 100 and 1000THz. The explosive growth of Internet traffic, deregulation and the increasing demands of users forced the telecommunications companies (Telco's) to increase the capacity of their networks. Only optical networks could deliver the required capacity as the bandwidth on demand is now synonymous with wavelength on demand. Beside the large capacity of optical communications bandwidth, there is still a number of extremely attractive features of optical systems such as weight/size of the fibers, signal security, low transmission loss, flexibility and the reliability. System reliability is generally enhanced in comparison with conventional electrical conductor systems. Furthermore, the reliability of the optical components is no longer a problem with predicted lifetimes of 20 to 30 years [2]. All these factors also tend to reduce the maintenance time and costs.

The telecommunications industry's insatiable appetite for capacity, the bandwidth of commercial systems has increased more than a hundredfold, the potential information that can be carried by a single fiber optic channel is estimated at 50 terabits a second (Tbit/s). However from a practical standpoint, commercial links have transmitted far fewer than 100 Gb/s, already an astonishing amount of data in itself that cannot be achieved with any other transmission medium. Researchers and engineers are working to develop new techniques that approach the potential capacity limit. Two recent major technological advances; Wavelength Division Multiplexing (WDM) and Erbium Doped Fiber Amplifier (EDFA), have boosted the capacity of existing systems. They have brought significant improvements in the capacity of the system now in development;

WDM is fast becoming the technology of choice in achieving smooth, manageable capacity expansion.

1.2 The Need for Optical Amplifiers

The essential elements for telecommunication networks are a transmitter, a transmission medium and a receiver, and in an optical system these devices are represented by a semiconductor laser, an optical fiber, and a photodiode, respectively. However, a look back over the history of telecommunications also reveals how amplifiers have played a vitally important role in the field. Without amplifiers, the present boom in communications system would have been impossible, let alone prospects of amplifying extremely weak signals from deep space probes. In this sense, the realization of optical amplification technology involving the direct amplification of light signals has long been a dream of many people who are working in fiber optic communication field. Optical amplification technology has a wide range of possible uses. Not only it is applicable to trunk transmission lines to compensate the loss; it is also used in the optical networking to compensate for the signal splitting losses in the access networks.

1.2.1 Loss in the System

Every transmission line introduces some loss in the signal power. In general all losses in optical fiber can be classified into two general categories: intrinsic and extrinsic. Intrinsic losses are those associated with a given fiber material and cannot be removed by any improvements in the fabrication and operation processes. Extrinsic losses are those associated with fabrication, cabling, and installation process, and theoretically, can be eliminated under ideal conditions.

Loss which is also known as attenuation is the decrease in light power during the propagation of light along an optical fiber. Attenuation plays a major role in the design of an optical system because it determining the maximum transmission distance between the transmitter and the receiver or on inline amplifier system. The attenuation takes place in a fiber due to absorption, scattering and radiative losses of optical energy [3].

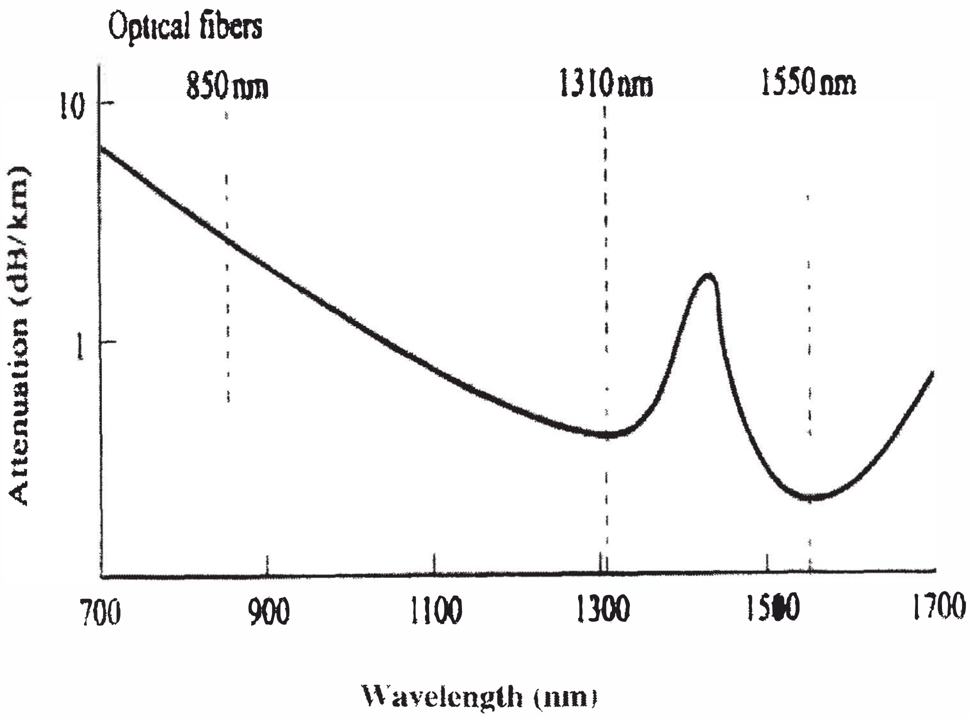

Figure 1.1: The Basic Attenuation vs. Wavelength

The basic attenuation versus wavelengths characteristics is shown Figure1.1. Losses are mainly contributed by absorption, scattering and bending.