ERBIUM-YTTERBIUM CODOPED FIBER AMPLIFIERS

by

CHAN WAI YEE
JABATAN FIZIK
FAKULTI SAINS
UNIVERSITI MALAYA

DISSERTATION PRESENTED FOR THE DEGREE OF MASTER OF SCIENCE
UNIVERSITI MALAYA
KUALA LUMPUR

TAHUN 1999/2000

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude and appreciation to my supervisor, Professor Harith b. Ahmad, for his guidance and invaluable advice, and also Mr. P.Poopalan and Mr. M.A.Mahdi for their assistance and useful discussions. I also wish to thank my family for their full support and encouragement.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude and appreciation to my supervisor, Professor Harith b. Ahmad, for his guidance and invaluable advice, and also Mr. P.Poopalan and Mr. M.A.Mahdi for their assistance and useful discussions. I also wish to thank my family for their full support and encouragement.

ABSTRACT

The amplification characteristics of an Erbium/Ytterbium codoped fiber amplifier(EYDFA) pumped in both the 800nm and 980nm pump bands is reported. With ~3m long Er-Yb fiber, the 813nm pumped-EYDFA shows small-signal gain exceeding 20dB over a 20nm bandwidth in the 1.5μm region where the peak gain of 38.4dB is achieved at 1535nm. A low noise figure of ~3.6dB is also achieved at 1550nm. However, it is found that 980nm pumped-EYDFA suffers lower gain due to the effect of nonsaturable absorption by Yb^{3+} ions which causes high pump power loss, thus degrades the signal amplification in Er^{3+} system. Compared to the same length of erbium-doped fiber amplifier(EDFA) at 813nm pump wavelength, EYDFA demonstrates a higher performance and has potential as a low cost effective optical amplifier.

ABSTRAK

Ciri-ciri pembesaran bagi suatu pembesar gentian Erbium/Ytterbium (EYDFA) yang dipamkan oleh kedua-dua 800nm dan 980nm jalur dilaporkan. Dengan menggunakan gentian Er-Yb yang panjangnya lebih kurang 3m, EYDFA yang dipamkan oleh 813nm menunjukkan penambahan yang melebihi 20dB dengan 20nm lebar jalur pada kawasan 1.5μm di mana puncak penambahan pada 1535nm dapat dicapai sebanyak 38.4dB. Kebisingan yang rendah dengan nilai yang lebih kurang 3.6dB dapat dicapai pada 1550nm juga. Bagaimanapun, EYDFA yang dipamkan oleh 980nm mengalami penambahan yang lebih rendah disebabkan oleh kesan penyerapan yang tidak mencapai ketepuan oleh ion-ion Yb^{3+} di mana ini akan mengakibatkan kehilangan kuasa pam yang tinggi, dan seterusnya mengurangkan kesan penambahan isyarat di dalam sistem Er^{3+}. Berbanding dengan EDFA yang dipamkan pada 813nm, EYDFA menunjukkan keputusan yang lebih baik dan mempunyai keupayaan sebagai pembesar yang kosnya lebih rendah dan lebih efektif.

CONTENTS

ACKNOWLEDGEMENTS

ABSTRACT

CHAPTER 1 INTRODUCTION

1.1 Historical Perspective of the Progress in the Field of Fiber Optics 1

1.2 Brief History of Optical Fiber Amplifiers 2

1.3 Overview 4

References 5

CHAPTER 2 LITERATURE REVIEW OF THEORETICAL BACKGROUND

Introduction 6

2.1 Host Glasses and Rare-Earth Ions 7

2.2 General Concepts of Three- and Four-Level Optical Amplifier System 15

2.3 Amplification Characteristics of an Optical Amplifier 17

2.3.1 Gain Characteristics 18

2.3.2 Amplified Spontaneous Emission (ASE) and Excited State Absorption (ESA) 22

2.3.3 Noise Characteristics 25

2.3.4 Applications of Optical Amplifiers 30

2.4 Model of Er^{3+}/Yb^{3+} Codoped Fiber Amplifier 32

References 38

CHAPTER 3		**EXPERIMENTAL RESULTS AND DISCUSSION I**	
		Introduction	41
	3.1	Experimental Setup	41
	3.2	Insertion Loss of Passive Optical Components	46
	3.3	Absorption Spectrum of the Er^{3+}/Yb^{3+} Codoped Fiber	52
	3.4	Yb^{3+} Fluorescence Emission Spectrum of the Er^{3+}/Yb^{3+} Fiber	58
		References	70
CHAPTER 4		**EXPERIMENTAL RESULTS AND DISCUSSION II**	
		Introduction	72
	4.1	Determination of Optimum Pump Wavelength in the 800nm Band	73
	4.2	Performance of a 813nm-pumped EYDFA	
		4.2.1 Counter-pumped Configuration	75
		4.2.2 A Comparison of EYDFA Performance Between Backward Pumping and Forward Pumping Configuration	91
	4.3	A Comparison of Amplifier Performance Between EDFA and EYDFA at 813nm Pump	94
	4.4	A Comparison of EYDFA at 980nm and 813nm Pump	101
		References	108
CHAPTER 5		**CONCLUSIONS AND SUGGESTIONS**	
	5.1	Conclusions	111
	5.2	Suggestions For Future Work	113
APPENDIX			115