

(R) -

ACA - 1835  
INVC.....

# NON LINEAR EFFECT IN SINGLE MODE OPTICAL FIBER

by  
FRASER JOHN PERERA, B.Sc. (Hons)  
PHYSICS DEPARTMENT  
FACULTY OF SCIENCE  
UNIVERSITY MALAYA

PERPUSTAKAAN UNIVERSITI MALAYA

DISSERTATION PRESENTED FOR THE  
DEGREE OF MASTER OF SCIENCE  
UNIVERSITY OF MALAYA,  
KUALA LUMPUR.  
(1996)

Perpustakaan Universiti Malaya



A506172289

Dimikrofiskan pada 19.01.2000  
No. Mikrofis. 14435  
Jumlah Mikrofis. 2

HAMSI AH BT. MOHAMAD ZAHARI  
UNIT REKOD RAFI  
PERPUSTAKAAN UTAMA  
UNIVERSITI MALAYA

UPR

## ACKNOWLEDGEMENT

I am very grateful to my supervisor Associate Professor Dr Harith Ahmad for all his invaluable guidance, criticism, suggestion and help, during the whole duration of this project. I am specially grateful to him too for taking me back into the academic field after having worked for five years in the industry since my graduation and from my initial discussion with him, I decided not to procrastinate my decision to further my studies any longer.

I am also indebted to Mr. Rajaratnam from the Laser Laboratory, who had always been there when my lasers and I needed him. To my colleagues Mr. Y.C. Hooi, who had helped me with the calibration of the Optical Multichannel Analyser and gave me first hand training on optical fibres, Mr. P. Prabakaran and Mr. A.L. Anis who were always willing to share with me their ideas, optical tools, computers, jokes, etc. and also to all the final year students who have rendered help and lightened up the environment. I would also like to thank Prof. Dr S. Radhakrishna for all his invaluable guidance on Raman scattering.

I dedicate this work to my ever growing family whom I love very much, who have supported and encouraged me and my wild ideas, through the years. Also to my one and only Ms. Ang Li Li, who herself is a graduate physicist, have been a constant source of support and inspiration. She was the driving force behind me that propelled me to complete my further studies in the shortest time possible. She not only help proof read my thesis but perceptively suggested areas for improvement and also helped type a better part of this thesis.

## ABSTRAK

Sifat optik tak-linear telah dipertunjukkan di dalam gentian optik silika terutamanya serakan Raman teransang dengan menggunakan Nd-YAG laser pada 1064 nm dan 532 nm. Serabut optik dalam kajian ini telah dibekalkan oleh Newport dan OPCOM. Beberapa jenis serakan Raman teransang telah diperhatikan, terutamanya serakan Raman teransang tertib pertama yang menjadi sumber pam kepada serakan Raman teransang tertib kedua dan seterusnya tertib kedua ini yang menjadi sumber pam kepada serakan Raman teransang tertib ketiga. 'Walkoff' antara tertib pertama serakan Raman teransang dan pam telah diukur dan dikaji.

'Amplifier' jenis pam hadapan dan jenis pam belakang telah dibina dengan menggunakan gentian optik dari Newport. Sumber pam telah diambil dari harmonik kedua Nd-YAG laser dan isyarat pula diambil dari sebuah dye laser, pada 546 nm. Pembesaran isyarat sebanyak 17 dB telah dicapai. Bandingan kecekapan antara 'amplifier' jenis pam hadapan dan jenis pam belakang telah dikaji. Kajian juga dilakukan untuk mengukur 'Raman gain' untuk gentian optik dan nilai yang diukur itu setanding dengan nilai yang telah dilaporkan untuk gentian optik silika.

## ABSTRACT

Non linear effects had been demonstrated in single mode pure silica fibre, in particular stimulated Raman scattering, using Nd-YAG laser as the pump, both at 1064 nm and at frequency doubled 532 nm. The fibres used in this study was supplied by Newport and by OPCOM. Under intense pump power, various stimulated Raman scattering orders had been observed, mainly the first order stimulated Raman scattering pumping the second order and the second order stimulated Raman scattering pumping the third order. The walkoff between the first order stimulated Raman and the intense pump had been measured.

A Raman fibre amplifier had been constructed both in the forward and backward configuration, using the Newport silica fibre. The pump was taken from the second harmonic generation of a Nd-YAG laser. Signal was taken from a dye laser and fixed at 546 nm. Amplification of the signal as high as 17 dB had been recorded. Also measured were the relative efficiencies of both the fibre amplifiers. The Raman gain of the fibre had also been measured and the value tally with previous reported data.

## CONTENT

	Page
<b>Chapter One : Introduction.</b>	
1.1 Introduction. ....	1
1.2 Thesis Outline. ....	1
 <b>Chapter Two : Introduction to Non Linear effects in optical fibre.</b>	
2.1 Stimulated Raman Scattering. ....	4
2.2 Four Photon Mixing. ....	5
2.3 Stimulated Brillouin Scattering. ....	6
2.4 Continuum Generation. ....	7
2.5 Second harmonic generation. ....	10
 <b>Chapter Three: The Theory of Non Linear effects in optical fibres.</b>	
3.1 Introduction. ....	12
3.2 Raman scattering. ....	14
3.2.1 Spontaneous Raman Scattering. ....	14
3.2.2 Stimulated Raman Scattering. ....	15
3.2.2.1 Amplification of Stokes and absorption of Anti-Stokes. ....	17
3.2.3 Raman Gain Spectrum. ....	19
3.3 Four Photon Mixing. ....	22
3.3.1 Phase Matching. ....	23

3.3.1.1	Phase matching using fibre modes.	23
3.3.1.2	Phase matching using birefringence.	24
3.3.1.3	Phase matching by divided pump.	24
3.3.1.4	Phase matching by small frequencies shift.	24
3.3.1.5	Phase matching near the zero dispersion region.	24
 <b>Chapter Four : Stimulated Raman scattering in pure silica fibre.</b>		
4.1	Experimental set up.	26
4.2	Forward and backward stimulated Raman scattering in pure silica fibre.	28
4.2.1	Stimulated Raman scattering threshold.	30
4.2.2	Polarisation dependence.	40
4.3	Dispersion Measurement in pure silica fibre.	46
4.3.1	Experimental results.	47
 <b>Chapter Five : Raman Fibre amplifier.</b>		
5.1	Introduction to Raman fibre amplifier.	52
5.2	Experimental set up - Backward Raman fibre amplifier.	54
5.2.1	Experimental results.	57
5.2.1.1	Raman Gain	59

5.2.1.2	Pump depletion in backward Raman fibre amplifier.	62
5.3	Experimental set up - Forward Raman fibre amplifier.	68
5.3.1	Experimental results.	69
5.3.1.1	Raman Gain	70
5.3.1.2	Pump depletion in forward Raman fibre amplifier.	72
5.4	Comparison between forward and backward Raman fibre amplifier.	75
5.4.1	Efficiency comparison between forward and backward Raman fibre amplifier.	78
5.4.2	Raman Gain.	80
 <b>Chapter Six : General conclusion.</b>		
6.1	Advantages of a Raman fibre amplifier.	82
6.2	Disadvantages of a Raman fibre amplifier.	84
6.3	Suggestion for further work.	85
 <b>Appendix A : Error Calculation.</b>		
		87
 <b>Appendix B : Fibre Parameters.</b>		
		92
 <b>Appendix C : Publications.</b>		
		94
 <b>References :</b>		
		95