University of Moratuwa

HIGH DATA RATE OPTICAL SOLITON COMMUNICATION SYSTEMS

J P D S ATHURALIYA

The thesis was submitted to the department of Electronic and Telecommunication Engineering of University of Moratuwa in partial fulfillment of the degree of Master of Science in Telecommunications.

Department of Electronic and Telecommunication Engineering
Faculty of Engineering
University of Moratuwa
Sri Lanka

July 2008

The work presented in this dissertation has not been submitted to any other institution for the fulfillment of any other degree

UOM Verified Signature

Dr R P Thilakumara

UOM Verified Signature

J P D S Athuraliya

(Candidate)

UOM Verified Signature

Prof (Mrs) I J Dayawansa

(Supervisors)

This thesis is dedicated to my loving thatha, who is not lucky to see any of her daughters work, my loving amma, my loving sons Wimukthi and Samish and my loving husband Lasantha.

ABSTRACT

Optical solitons are attractive at very high bit rates as linear systems are impossible at such high bit rates due to dispersion effect. In a soliton propagation system no dispersion compensation fibers are used. The pulses propagate partly as a soliton between repeaters, and at the latter part as the power decreases the system exhibits linear properties. As the system exhibits quasi-soliton propagation effects, the system cannot be evaluated by soliton equations. Such a system can only be evaluated using modeling.

As the optical soliton is of the envelope of light waves whose fundamental properties are described by the Nonlinear Schrödinger Equation (NLSE), the NLSE can be used to present the soliton concept for application to communications. The NLSE is solved using one of the numerical modeling, split step Fourier method.

Therefore the solution of the NLSE is used to present the soliton concept for application to communications. In this research, Short laser pulses are used to make the soliton communication system. The simulated results of 40Gbps single channel transmission of standard fiber and LEAF fiber are compared.

The results of the 40Gbps single channel transmission of standard fiber indicate that the maximum distance the pulse could travel is about 500km with a repeater spacing of 50km and the results of the 40Gbps single channel transmission of LEAF fiber indicate that the maximum distance the pulse could travel is about 1250km with a repeater spacing of 50km.

Acknowledgements

I would like to express my sincere appreciation to my supervisors Dr R P Thilakumara for all the valuable advice, guidance, comments, suggestions given and assistance provided in collecting information throughout the research and Prof (Mrs) I J Dayawansa for the valuable advice, comments, suggestions and encouragement provided throughout the research. If not for their help, advice and the moral support, my thesis would not have been a reality.

I am grateful to Professor R Perera, the chairman of the final defense committee and my supervisors Dr R P Thilakumara & Prof (Mrs) I J Dayawansa who were present at the final defense committee for their kind assistance given.

I also thank the non academic staff for various support given throughout the project.

I am very thankful to the management of Arthur C Clarke Institute for Modern Technologies for sponsoring me for the course on MSc in Telecommunications.

My most sincere appreciation goes to Kumidini Amaradasa, my former colleague at Arthur C Clarke Institute for Modern Technologies for the numerous assistance and support given and Kamani Edirweera and Champika Janashanthi, my colleagues at Arthur C Clarke Institute for Modern Technologies for the numerous support given.

My special gratitude is extended to my father who is not in this world to see his daughter's work, and my mother, sister and brother for the courage and hope.

Last, but not least my sons, Wimukthi & Samish for their boundless patience and understanding, and Lasantha for everything.

J P D S Athuraliya
July 2008

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviation	Extension
ADC	Analogue to Digital Conversion
AM	Amplitude Modulation
ASK	Amplitude Shift Keying
DBR	Distributed Bragg Reflector
DFB	Distributed Feed Back
EDFA	Erbium Doped Fiber amplifier
FBG	Fiber Bragg Grating
FM	Frequency Modulation
GVD	Group Velocity Dispersion
LAN	Local Area Network
LEAF	Large Effective Area Fiber
LED	Light Emitting Diode
MQW	Multi Quantum Well
NLSE	Non Linear Schrödinger Equation
NRZ	Non Return to Zero
OFC	Optical Fiber Communication
PM	Phase Modulation
PSK	Phase Shift Keying
QW	Quantum Well
RZ	Return to Zero
SPM	Self Phase Modulation
USP	Ultra Short Pulses
WDM	Wavelength Division Multiplexing

GLOSSARY OF SYMBOLS

A = Amplitude of the pulse envelope

A_{eff} = Effective core area

AAg = Recombination coefficient

B = The bit rate

BBg = Recombination coefficient

C = Velocity of propagation

CCg = Recombination coefficient

D = Dispersion parameter

e = Electronic charge

Eo = Amplitude of plane wave

g = Differential gain

I = Injected current

K = wave number

M = Order of Bragg diffraction

N = The order of the soliton

N_c = Carrier density

N_0 = Transparency carrier density

n = Effective refractive index of the waveguide without the grating

n_2 = Nonlinear index coefficient

P = Photon lifetime

P_{max} = Peak power

q_0 = The separation between neighboring solitons in normalized units/2

R_1, R_2 = Facet power reflectivities

S = Dispersion Slope

t = Time

T_0 = Pulse width of the soliton

T_B = Duration of the bit slot

V = Laser active region volume

z = Length of fiber

Z_0 = Soliton period

α_{cav} = The ratio of photons lost as the signal travels a unit length

α_{int} = Internal loss that includes free-carrier absorption, scattering and other possible mechanisms

β = Spontaneous coupling coefficient

β_1 = Inverse of the group velocity

β_2 = Group Velocity Dispersion coefficient

β_3 = Related to the dispersion slope S by $(2\pi c/\lambda^2)^2 \beta_3 + (4\pi c/\lambda^3)\beta_2$

Γ = Optical Confinement factor

Γ = Nonlinearity parameter

Λ = Grating period

λ = Optical wavelength

ν = The laser frequency

ν_g = The group velocity

$\Delta\nu$ = Spacing between longitudinal modes

τ_p = Photon life time in the cavity

τ_c = Rate at which spontaneous emission occurs

ω = Frequency