Ain Shams university

Faculty of Engineering

M.Sc. Thesis

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Titled :"Semiclassical Calculation of The gain in Semicuductor Multiple Quantum Well Lasers"

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DATE 29 /12 /1993

STATEMENT

This dissertation is submitted to Ain Shams University for the degree of M.Sc. in electrical Engineering.

The work included in this thesis was carried out by the auther in the department of Electronic and Communications Engineering. Ain Shams University from Dcember 1990 to December 1993.

No part of this thesie has been submitted for a degree or a qualification at any other University or Institution.

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بسم الله الرحمن الرحيم

AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

"SEMICLASSICAL CALCULATION OF THE GAIN IN SEMICONDUCTOR MULTIPLE QUANTUM WELL LASERS"

BY

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A THESIS

Submitted in partial fulfilment for the requirements of the degree of M.Sc. *in Electrical Engineering Electronics and Communications*

SUPERVISED BY

Prof Dr. Mahmoud Hanafi Ahmad

CAIRO 1993

ACKNOWLEDGMENT

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I would like to express my sincere appretiation and deepest gratitude to my research director Prof. Mahmoud Hanafi Ahmad for his guidance, valuable suggestions, constant encouragement , unlimited effort and precious advice during all phases of this work.

I am also greatful to Eng. Mahmoud Samy Hammad for allowing me to use his computer facilties in the calculations done in this work.

Lastely. I am greatful to all who have a hand in the presentation of this thesis.

LIST OF SYMBOLS

A	vector potential
A_{21}	Spontaneous emission rate between levels 1 & 2
B	Einstein coefficient for stimulated emission
B_{eff}	effective recombination constant of semiconductor material in the case of QWL
c	light velocity in free space
D_n, D_p	electron and hole diffusion constants
e	Electron charge
E_g	Energy gap
E_{nx}	nth quantized energy level in the x-direction
E_c	Energy measured from the conduction band edge
E_v	Energy measured from the valence band edge
E_{fc}	Quasi fermi level for electrons
E_{fv}	Quasi fermi level for holes
$E_n(t)$	Fourier components of electric field in frequency domain
f	frequency
f_c	fermi dirac probability distribution for electrons
f_v	fermi dirac probability distribution for holes
$F_{\omega\beta}(x)$	normalized electric field distribution in x direction of the optical mode having angular frequency ω and probagation constant β
g	optical gain of the medium
g_{mod}	modal optical gain
g_{th}	threshold gain
h	Plank's constant

H magnetic field intensity

$\mathcal{H}$ Hamiltonian of carriers

$\mathcal{H}_o$ Hamiltonian of the carriers in absence of electromagnetic field

$\tilde{\mathcal{H}}$ perturbation hamiltonian due to external field

J current density

J_{macro} macroscopic current density

j microscopic current density operator

J_{th} Threshold current density

$k_{x,y,z}$ The wave vector componentsin x,y and z direction

K Poltzman's constant

Lx width of the active layer

m_c Effective mass of electrons in the conduction band

m_v Effective mass of holes in the valence band

$|M|$ density matix of ttransition probability

n Refractive index of the medium

N carrier distribution

N_t transparency carrier density

N_{th} Threshold carrier density

$P(\hbar\omega)$ incident photon density per unit energy

$p(z,t)$ polarization density

p_{macro} nmacroscopic polarization density

$p_n(t)$ Fourier component of polarization density in fraquency domain

r_{st} stimulated emission rate

$r_{\parallel}$ position vector in the plane of interface between layers

R_{ch} Transition probability for electrons from conduction to valence band

R	mirror or facet reflectivity
S	photon flux
T	Absolute temperature
t	time
u_k	Bloch wave function
$U_n(z)$	Fourier component of electric field in k-domain
v_g	Group velocity of the mode
$V(x)$	potential energy distribution
V_{int}	interation energy of an atom with external electric field
x	Aluminioum fraction in Al Ga As
$Y^{\omega\beta}_{n,m}$	overlap integral of nth electroin sublevel and mth hole sublevel wavefunctiopns with electic field distribution
x,y,z	position coordinates
$\alpha_{ac,ba}$	optical loss in bulk material of active and barrier regions
β	propagation constant in the longitudinal direction
Δ	splitt off energy
ε_o	permitivity of free space
ε_r	relative permitivity of the medium
ϕ	envelope of the carrier wave function in
Γ_g	optical confinment factor of the optical mode
Γ	state decay matrix
γ	fraction of spontaneous emission coupled to the mode
$\gamma_{a,b}$	decay rate of states a & b
ψ	carrier wave function
λ	excitation rate matrix
μ_o	permiability of free space
μ	matrix elment of dipole moment
μ_n,μ_p	electron and hole mobilities

$\langle\mu\rangle$	expectation vale of thedipole moment
ρ	density matrix
$\rho_{aa},\rho_{ab},\rho_{ba},\rho_{bb}$	elements of density matrix
ρ'	density matrix in absence of electric field with zero injected current
ρ''	density matrix in absence of electric field uder injected current condition
ρ_c	energy densitty of states of electrons in the conduction band
ρ_v	energy density of states of holes in the valence band
ρ_{red}	reduced density of states
ρ_{QW}	density of states in quantum well structure
σ	conductivity of the medium
τ_n	carrier life time
τ_p	photon life time
τ_{in}	intraband relaxation time
ω	angular frequency
ω_n,ϕ_n	angular frequency and phase of the nth Fourier component of electric field or polarization density
Ω_n	nth circular frequency of a passive Fabry-Perot cavity
χ	complex susceptibility of the medium

CONTENTS

CONTENTS

CHAPTER V:

CARRIER WAVEFUNCTION AND FIELD DISTRIBUTION IN MQWL STRUCTURE

CHAPTER VI: SEMICLASSICAL GAIN CALCULATION IN MQW LASER