بسم الله الرحمن الرحيم

شبكة المعلومـــــات الجامعية

التوثيق الالكتروني والميكروفيلم

شبكة المعلومات الجامعية

جامعة عين شمس

التوثيق الالكتروني والميكروفيلم

قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
علي هذه الأفلام قد اعدت دون آية تغيرات

يجب أن

تحفظ هذه الأفلام بعيداً عن الغبار

في درجة حرارة من 15 – 20 مئوية ورطوبة نسبية من 20-40 %

To be kept away from dust in dry cool place of
15 – 25c and relative humidity 20-40 %

بعض الـوثـــائق

الأصـليـة تـالفــــة

بالرسالة صفحات

لم ترد بالأصـــــل

Ain Shams University

Faculty Of Engineering

Transport Effects On Modulation Characteristics Of Quantum Well Lasers

<u>By</u>

Eng./Salwa Mohsen El Taweel

Submitted in partial fulfillment for the requirements
of the degree of M.Sc.

<u>Supervised By</u>

Prof. Dr./ Mahmood Hanafy Ahmed
Prof. Dr./ Mohamed Mohamed Seddik

Cairo 1996

ACKNOWLEDGMENT

I wish to express my appreciation and gratitude to ***Prof. Mahmoud H. Ahmed*** *for his guidance, valuable suggestions, great effort and his useful discussions. I would also like to thank* ***Prof. Mohamed Seddik*** *for his effort, patience and encouragement.*

My most sincere appreciation are due to ***Prof. Refaat R. Basily*** *for his encouragement, patience and faithful support.*
I am sincerely grateful to ***Prof. Kamel M. Hassan*** *for his valuable encouragement, scientific advises and moral support.*

Deepest thanks to ***Dr. Salah Gamal, Dr. Diaa Khalil*** *and* ***Dr. Mohamed Yehya*** *for their sincere help, encouragement and their interesting discussions.*
My particular thanks to ***Eng. Hatem Hany*** *and* ***Eng. Marwa*** *for their effective contributions and their great effort in preparing and presenting this thesis.*
I am thankful to all my colleagues in the physics department and the optical communication lab. for their support and help during the previous year.

Abstract

Strained Quantum well lasers were theoretically expected to have very high modulation bandwidths, around 90 Ghz, owing to their high differential gain compared to bulk double heterostructure DH lasers. Experimentally it was found that multiple quantum well lasers have modulation bandwidths lower than half the expected value, while single quantum well SQW lasers have bandwidths even less. This reduction in bandwidth is suggested to depend on several factors, the non-zero capture time of the carriers in the well, the emission time of carriers out of the well and the transport effects of carriers specially holes, in wide undoped separate confinement heterostructure SCH barriers. A model is constructed which takes into consideration the above three factors simultaneously. This model can also account for the effect of placing the QW away from the center SCH to study the relative effect of the transport of holes against electrons. The model is based on continuity equations for electron and hole currents, and the rate equations which describe photon and carrier dynamics with the gain compression included. A linearized small signal single mode solution for these coupled equations is obtained analytically. The frequency response results are analyzed and compared to published experimental work. The results show that the capture time, although very small around 1ps, cannot be neglected as it is multiplied by large weighting factor that depends on the width of the SCH, and affects both the -3 dB modulation bandwidth BW and the damping coefficient of the laser response. On the other hand the transport affects only the BW and rather less dominantly and can be neglected for small SCH width. The model also predicts that damping depends on the ratio of capture to emission times, in accordance with previous work.

List of Symbols

$\hat{a}_x, \hat{a}_y, \hat{a}_z$	Unit vectors in x,y, and z directions.
A	Area normal to the injected current.
A_{21}	Transition probability coefficient.
α_i	Internal loss coefficient.
α_m	Mirror loss.
α_{SCH}	Differential SCH transport factor.
B_{12}, B_{21}	Transition probability coefficient.
β_{sp}	Fraction of the spontaneous emission coupled to the lasing mode.
β	μ_n / μ_p
c	Velocity of light.
χ	Transport factor.
d	Width of active layer.
D	Slope of f_o versus $\sqrt{P_L}$.
D_a	Ambipolar diffusion coefficient.
D_n	Electrons diffusion constant.
D_p	Holes diffusion constant.
δf_{st}	Shawlow and Townes linewidth.
e	Electron's charge.
E	Energy of the electron.
$E(x)$	Electric field.
E_b	Effective barrier height.
E_F	Fermi level.
E_g	Band gap energy.
ε	Gain compression or nonlinear gain coefficient.

f	Frequency.
f_o, f_{oc}	Relaxation oscillation frequency.
$f_c(E)$	Probability of finding an electron in the conduction band.
$f_v(E)$	Probability of finding an electron in the valence band.
$F(E)$	Fermi-function.
F_c	Quasi-Fermi level for electrons.
$F_n(t), F_s(t)$	Langevin noise sources.
F_v	Quasi-Fermi level for holes.
g_o	Differential gain.
g_{eff}	Effective differential gain.
g_{th}	Threshold gain.
G_o	Gain coefficient.
γ, γ_c	Damping coefficient.
Γ	Confinement factor.
h	Planck's constant. $\hbar = h/2\pi$
H_o	System Hamiltonian.
η_{eq}	Ratio of number of carriers in SCH to number of carriers in the quantum well at equilibrium.
i	Amplitude of small signal component of pump current.
I	Pump current.
I_o	Steady state component of pump current.
J_n	Electron current.
J_p	Hole current.
J_{th}	Threshold current density.
k	Wave vector.
k_x, k_y, k_z	Wave vector component in x,y and z direction.
K	Damping factor.
k_B	Boltzman's constant.

L	Length of optical cavity.
L_a	Ambipolar diffusion length.
L_{eff}	Effective quantum well depth.
L_s	Width of SCH between the quantum well and any of the claddings.
L_w	Width of quantum well.
λ	Wavelength.
m_o	Mass of free electron.
m^*	Effective mass.
μ_n	Electron mobility.
μ_p	Hole mobility.
n_c , N_c	Electron concentration.
n_g	Refractive index.
N_b	Barrier or confinement region carrier number.
N_T	Transparency carrier concentration.
N_{th}	Threshold carrier concentration.
N_v	Hole concentration.
N_w	Number of wells.
ν	Frequency.
ν_p	Frequency of the gain peak.
$P_n(\omega)$	Noise power spectral density.
P	Electromagnetic power/unit area.
P_L	Optical power.
P_m	Momentum operator.
P_{w2}	2D carrier density in the quantum well.
P_{w3}	3D carrier density in the quantum well.
P_{w3}	Hole concentration.
q_x,q_y,q_z	Positive integers.
r	Position vector.
R_1, R_2	Mirror reflectivities.
R_{sp}	Spontaneous emission rate.
R_v	Ratio of width of SCH to width of quantum well.

$\rho(E)$	Density of states.
$\rho_{red}(h\nu)$	Reduced density of states.
S	Total Photon density.
S_o	Steady state component of photon density.
S_s	Amplitude of small signal component of photon density.
T	Temperature.
τ_n, τ_a	Carrier life time.
τ_c	Capture time.
τ_e	Thermionic life time.
τ_{ph}	Photon life time.
τ_s	Ambipolar transport time.
τ_{sn}	Average transport time for electrons.
τ_{sp}	Average transport time for holes.
$u(r)$	Bloch function.
$u(n,p)$	Recombination rate.
v_g	Group velocity.
$V(r)$	Potential created by the crystal lattice.
V, V_w	Volume of the well.
V_{SCH}	Volume of SCH.
$W(h\nu)$	Electromagnetic density.
ω_o, ω_{oc}	Relaxation oscillation angular frequency.
Ψ	Electron wave function.

Key Words

BW	Bandwidth.
MQW	Multiple quantum well.
RIN	Relative intensity noise.
SCH	Separate confinement heterostructure.
SHB	Spectral hole burning.
SQW	Single quantum well.
QW	Quantum well.