AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
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MODULATION OF OPTICAL BEAM IN SEMICONDUCTOR LASER

BY

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A Thesis

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الله

بسم الله الرحمن الرحيم

قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا
عَلَّمْتَنَا إِنَّكَ أَنْتَ الْعَلِيمُ الْحَكِيمُ .

صدق الله العظيم
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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 Electronics and Communication Engineering, Ain Shams University.

No part of this thesis has been submitted for a degree or a qualification at any other university or institution.

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ABSTRACT

Direct modulation of semiconductor lasers is of a great importance for optical fiber communication systems. A detailed analysis is presented for the modulation performance of an inhomogeneously - pumped s.c. laser using the rate - equations model. This laser is composed of two sections, one for gain, the other acts as an absorber, and they are coupled optically but isolated electrically. It has many applications in optical switching.

The laser threshold current may be reduced by reducing the absorber length, or by increasing its pumping current. The stability analysis of the laser identifies the pulsation and cw operation region. For a shorter absorber length the stable region extends to a lower value of the absorber pumping current. Increasing the absorber pumping current results in an increase in both the modulation bandwidth and the optical output power.

The gain compression reduces the peak height of the modulation response by about 10 dB in a good agreement with the previous results for a homogeneously pumped s.c. laser.

An inhomogeneously pumped s.c. laser has a better modulation response than a homogeneously pumped laser, when a suitable pumping current is applied to the absorber section.

Negative electronic feedback reduces the output power and has a weak effect on the modulation response, but it increases the dynamic stable region.

List of Symbols

A_i	Loop gain .
A_2	Proportionality spontaneous constant .
B	Phase constant .
B_{12}	Absorption proportionality constant .
B_{21}	Stimulated proportionality constant .
c	Velocity of light .
E	Energy level .
E_c	Conduction band energy .
E_v	Valence band energy .
E_g	Gap energy .
E_f	Fermi level energy .
E_{ph}	Photon energy .
$F(E)$	Fermi function .
f_c	Occupation probability for electrons in the conduction band .
f_v	Occupation probability for holes in the valence band .
f_o	Relaxation oscillation frequency .
G_o	Linear gain .
g	Cavity gain .
h	Planck's constant .
I	Injection current .
I_f	Feedback current .
I_{th}	Threshold current .
J_n	Injected electrons .
J_p	Injected holes .
k	Feedback parameter .
L	Cavity length .
L_{abs}	Absorber length .
m_e	Effective mass of electrons .

m_h	Effective mass of holes .
M_p	Height of the resonance peak .
n	Carrier density .
n'	Real part of refractive index .
n''	Imaginary part of refractive index
n_o	Carrier density at the transparency .
n_i	Intrinsic carrier concentration .
n_{th}	Carrier density at threshold .
n_{sp}	Spontaneous emission rate .
n_1	Carrier density for gain section .
n_2	Carrier density for absorber section .
n_{o1}	Carrier transparency of gain section .
n_{o2}	Carrier transparency of absorber section .
P	Concentration of holes .
P_o	Optical power .
r_1	Fraction volume of gain section .
r_2	Fraction volume of absorber section .
r_{12}	Absorption rate .
r_{21}	Rate stimulated emission .
r_s	Beam splitter reflectivity.
r_{sp}	Spontaneous emission rate .
R	Mirror reflectivity .
R_p	Responsivity of a photo-diode .
S	Photon density .
T	Absolute temperature .
T_o	Characteristic temperature .
V	Active region volume .
υ_g	Group velocity .
α'	Linewidth enhancement factor .
α_m	Cavity mirror loss .
α_s	Cavity loss .
β	Differential loss coefficient .
ε	Gain compression coefficient .

γ_d	Damping factor .
η_i	Internal quantum efficiency .
μ	Refractive index .
τ_e	Carrier life time of gain section .
τ_t	Carrier life time of absorber section .
τ_i	Intra-band relaxation time .
τ_{Ph}	Photon life time .
ω_o	Oscillation frequency .
ω_d	Damping frequency .
ω_p	Frequency of resonance peak .
ω_{-3dB}	-3dB frequency .
ρ	Electron state density .
λ	Emission wave length .
Γ	Confinement factor .
υ	Frequency of optical wave .
Δ_D	Dip in the modulation response .

CONTENTS