IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 7, Issue 5 Ver. II (Sep. - Oct. 2015), PP 85-88
www.iosrjournals

Study of Time Behavior of Carriers and Photon Densities for Vertical Cavity Surface-Emitting Lasers

Rawaa A. Abd Ali[1], Bushra H. Mohammed[1], Fouad N. Ajeel[1]
[1](*Department of Physics, College of Science, Thi Qar University, Nassiriya, IRAQ*)

Abstract: *In this paper, we study the dynamics of Vertical cavity surface-emitting lasers(VCSEL)such as photon density (S) and carriers number (N) for different values of injection current and photon lifetime. It is found that the increasing of the injection current leads rising and increasing the photon density and the carrier number as a result of increasing the carriers in the active region, and the rising time of the laser output with increasing the current. The increasing in the photon lifetime, which is affected on the output of the laser and reducing the transient region (reducing) of the laser output and it is observedthat the decreasing of carriers number where the increasing of the photon lifetime leads to decreasing the losses of the system.*
Keywords:*VCSEL,injection current, photon density, carriers number.*

I. Introduction

Vertical cavity surface-emitting lasers (VCSEL's) have attracted considerable interest in recent years due to their single-longitudinal-mode operation [1]. Because of large, mode-hop free tuning range, low power consumption, high integration density and the compatibility with current optoelectronic fabrication processes, wavelength tunable vertical-cavity surface-emitting lasers have been of great interest in various applications including optical networks, bio- or chemical molecular sensing technology, such as absorption spectroscopy, fiber Bragg grating measurement and trace gas monitoring [2-4]. Short-wavelength tunable VCSELs can serve as efficient and low cost transmitters for wavelength-division multiplexing in the short distance reconfigurable optical interconnect to provide larger bandwidth. GaAs-based vertical-cavity, surface-emitting lasers with InGaAs quantum-well (QW) active layer have recently emerged as promising candidates as low-cost 1.3-mm sources for fibre-optic communication links [4-6].

In comparison to VCSELs based on the InP system, they benefit from high refractive index contrast and high thermal conductivity of lattice-matched AlGaAs/GaAs-distributed Bragg reflectors (DBRs) as well as higher QW conduction band offset, leading to improved high-temperature performance [1,2]. The performance of conventional vertical-cavity surface-emitting lasers is generally limited by the extremely low roundtrip gain in the cavity. Thus, VCSEL devices require high mirror reactivity but also are characterized by an increase in the threshold current density compared to edge emitting lasers. To overcome this distinct disadvantage, diode cascade VCSELs are proposed as excellent candidates to improve the performance of VCSEL structures with bulk [1] and quantum well [2] active layers. Such a VCSEL can also exhibit high differential quantum efficiency well exceeding unity that may be interesting for low noise applications. The increase in roundtrip gain is also of interest for high-power VCSEL applications [4,5].

II. Theoretical Model

The rate equations are a set of differential equations that describe the time evolution of the laser cavity field, population and polarization of the active medium. One can imagine the rate equations as a simple conservation mechanism. Figure 1 shows the various mechanisms that occurs in the laser cavity[1,7].
In the state of the carrier's dynamics on the SC such as vcsels, the rate of change of the population difference N can be written as[8,9]:

$$\frac{dN}{dt} = injection - sponteneous\ emission - stimulated\ emission - losses \qquad (1)$$

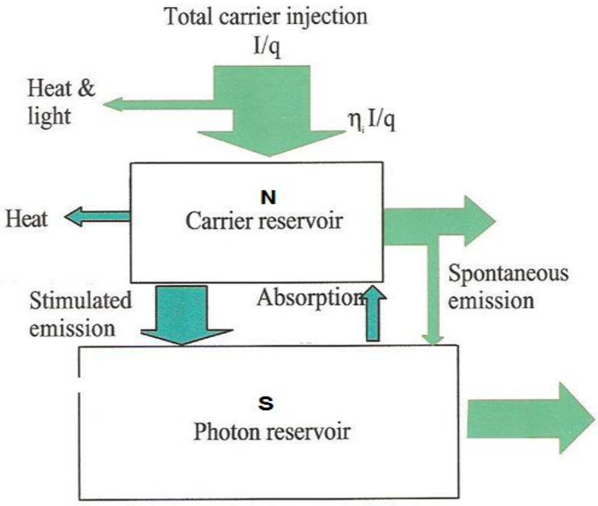

Figure 1: The laser dynamics mechanisms, where I is the injection current, q is the electron charge, N is the number of carriers and S is the number of photons[10].

The rate equations that describe the dynamics of the system of VCSELs is given by[7]:

$$\frac{dN}{dt} = \frac{\eta_i I}{q} - \frac{N}{\tau_n} - \frac{G_0(N - N_0)S}{1 + \varepsilon S} \qquad (2)$$

$$\frac{dS}{dt} = -\frac{S}{\tau_P} + \frac{\beta N}{\tau_n} + \frac{G_0(N - N_0)S}{1 + \varepsilon S} \qquad (3)$$

where N is the carrier density, S is the photon number, η_i is the injection efficiency,τ_n is the carrier recombination lifetime,G_0 is the gain coefficient,N_0 is the carrier transparency number,τ_P is the photon lifetime, $\beta$is the spontaneous emission coupling coefficient, and ε is the gain-compression factor.

III. Results and discussion

The rate equation of the VCSEL system is solved by using the numerical methods of the Matlab program with initial values of the dynamics of the laser system. Simulation processes of the laser dynamics such as photon density S and carriers number N with number of parameters (Table1)that are used in these processes.

Table1:Simulation parameters of VCSELs [7].

Symbol	Value
η_i	1
β	10^{-6}
τ_n	5 ns
G_0	$1.6 \times 10^4\ s^{-1}$
N_0	1.94×10^7
τ_P	2.28ps

The injection current (I) that evaluated at steady state with photon density (I = 1mA) as shown in figure2.

Figure3 represents the temporal behavior of photons density at different values of injection currents (I= 2mA,5mA,10mA,15mA,20mA). And figure 4 acts temporal behavior of carriers number at different values of injection currents (I= 2mA,5mA,10mA,15mA,20mA).

Figure 5 acts the temporal behavior of photons density at different values of the photon lifetime(τ_P= 2.88ps, 5ps, 10ps, 15ps, 20ps) and for the carriers number with changing the lifetime of photons the figure6 gives the temporal behavior of carriers number at different values of photon lifetime(τ_P= 2.88ps, 5ps, 10ps, 15ps, 20ps).

It is found that the photon density (S) and carriers number (N) for different values of injection current and photon lifetime. It is noted that, the increasing of the injection current leads rising and increasing the photon density and the carrier number as shown figures (3 and 4, respectively).

The increasing on the photon lifetime which is affected on the output of the laser and reducing the transient region (reducing) of the laser output and observe the decreasing of carriers number as shown in figures (5 and 6,respectively).

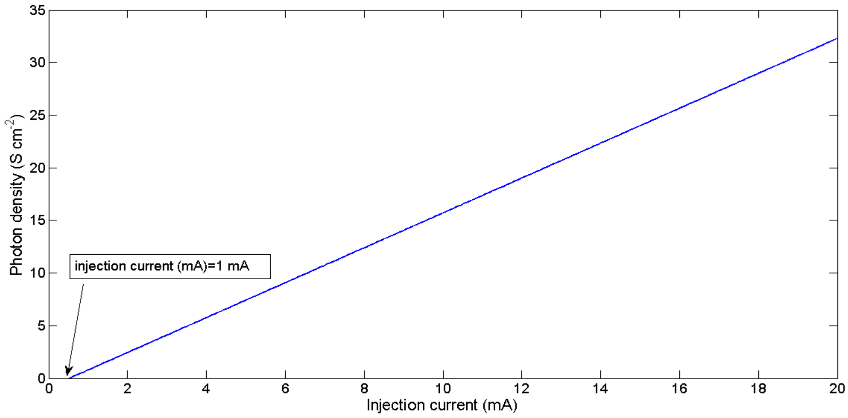

Figure 2: Steady-state input-output characteristic: simulated photon densityvs. injection current. The threshold injection current $I = 1$ mAwith using the parameters in Table.1.

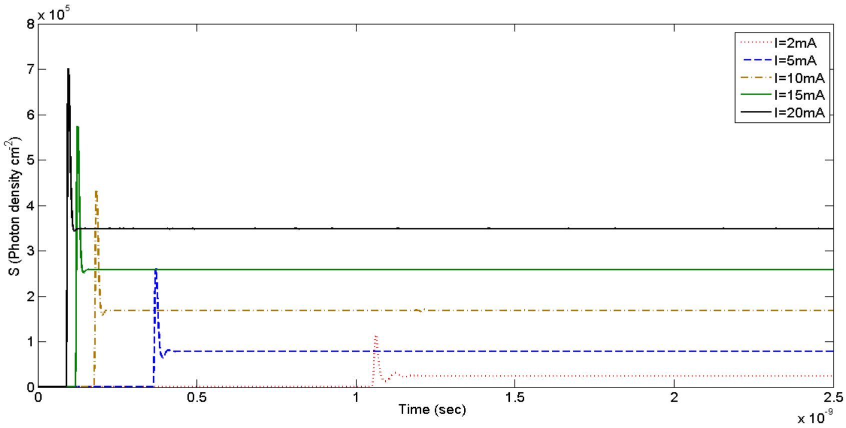

Figure3: Temporal behavior of photons densityat different values of injection currentss.

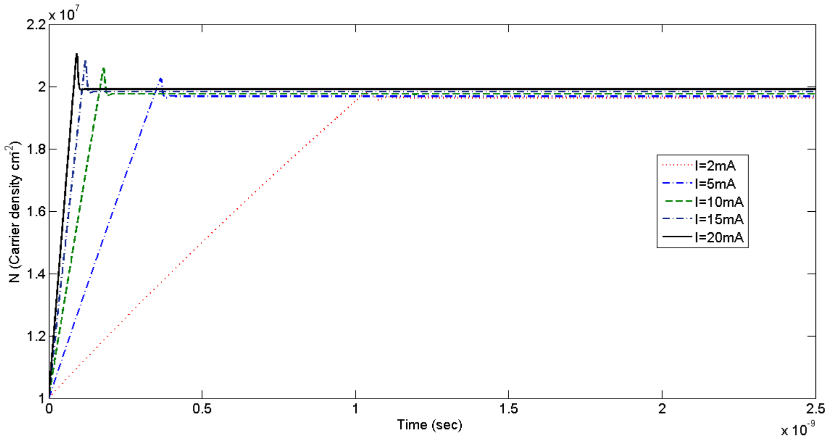

Figure4: Temporal behavior of carriers numberat different values of injection currents.

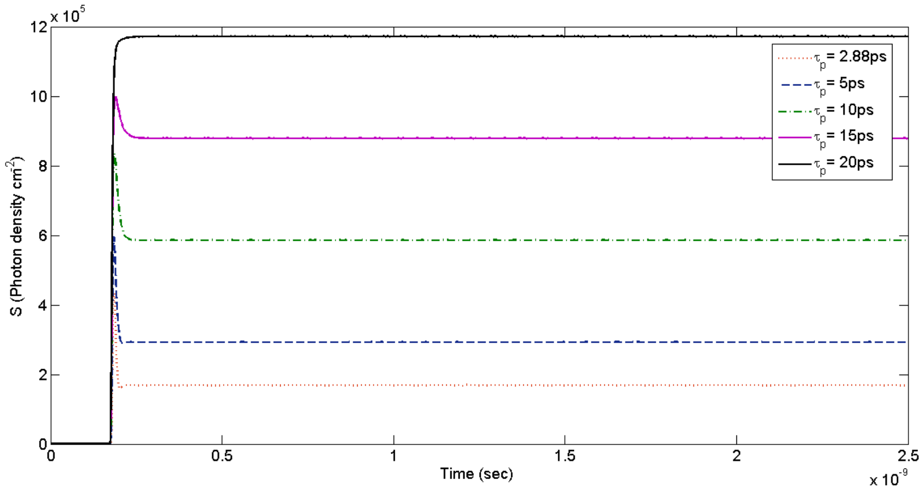

Figure5: Temporal behavior of photons density at different values of photon lifetimes.

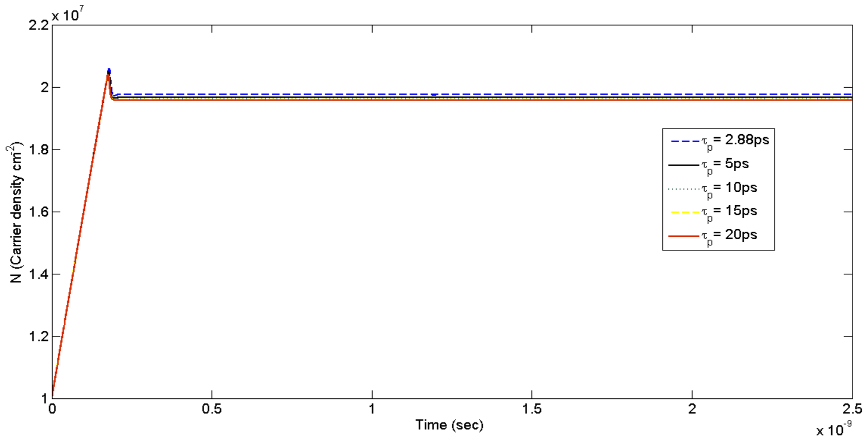

Figure6: Temporal behavior of carrier number at different values of photon lifetime.

IV. Conclusions

We conclude from the previous results that the increasing of injection current as an important factor leads to increasing the output of the laser and carriers number as a result of enhancing the carriers on the active region and thus, the leasing processes are producedatthe shortest time with increasing current. We observed that the effect of changing the photon lifetime for high values leads to decreasing the losses on the laser cavity and this effect enhances the photon density in the laser medium.

Acknowledgements

The authorsthank the Ministry of Higher Education and Scientific Research of Iraq for its support of scientific researches through the Iraqi Virtual Science Library (IVSL).

References

[1] E. Gehrig and O. Hess, Spatio- Temporal Dynamics and Quantum Fluctuations in Semiconductor Lasers, Springer Verlag, Berlin (2003).
[2] T. Numai, Fundamentals of Semiconductor Lasers, SpringerVerlag, new York (2004).
[3] A.Valle, J. Sarma, and K. A. Shore,“Spatial holeburning effects on the dynamics of vertical cavity surface-emitting laser diodes,” IEEE J. Quantum Electron., vol. 31, pp. 1423–1431, Aug. 1995.
[4] Angel Valle, J. Sarma, Alan Shore,“Secondary pulsations driven by spatial hole burning in modulated vertical-cavity surface-emitting laser diodes,” J. Opt. Soc. Amer., pt. B, vol. 12, no. 9, pp. 1741–1746, 1995.
[5] C. Ye, Tunable External Diode Lasers, Word Scientific Publishing Co., Singapore (2004).
[6] P. Harrison, Quantum Wells, Wires and Dots, Wiley Intersci.,London (2005).
[7] T. Suhara, Semiconductor Laser Fundamentals, Marcel Dekker, Int., New York (2004).
[8] A.Valle, J. Sarma and K. A. Shore, Opt. Comm., 115,297 (1995).
[9] P. V. Mena, Member, J. J. Morikuni, Member, S.-M. Kang, Fellow, A. V. Harton, Member, and K. W. Wyatt, A Simple Rate-Equation-BasedThermal VCSEL Model, Journal of Lightwave TECHNOLOGY, vol. 17, NO. 5, 865 ,1999.
[10] J. Mulet, Ph.D. thesis, University of Les illes Balears (2002).
[11] P. Ouger, Introduction to Power Diode Lasers, Springer-Verlag, Berlin (2000).
[12] D. Sands, Diode Lasers, IOP publishing Ltd, London (2005).