International Journal of Thin Films Science and Technology

http://dx.doi.org/10.18576/ijtfst/130109

Output Performance Behaviors for Vertical Cavity Surface Emitting Laser (VCSELS)

Anwa.r. N. Hussein, Fatimah rabeea JeJi, Mustafa Hussein Jazea, Mushtaq O. Oleiwi[*]

Department of Physics, College of Education for Pure Sciences, University of Thi-Qar, Nasiriyah, 64001, Iraq

Received: 12 Mar. 2023, Revised: 12 Apr. 2023, Accepted: 10 Dec 2023.

Abstract: In this paper, we study the kind of semiconductor laser that has several benefits and applications is the VCSEL. We instigate an inclusive model that addresses the various dynamics in this article. The system model is solved by the Matlab software. output power is l seemed to be impacted by an increase in injection current and with increase the gain. The findings that the switch on times arise with threshold injection.

Keywords: Dynamics; VCSELs; Laser Output; Temperature.

1 Introduction

Semiconductor laser technology has recently advanced with a focus on Vertical cavity surface emitting lasers (VCSELs), which differ from traditional Edge-emitting lasers (EELs). The VCSEL's optical cavity is formed via growth direction, and distributed Bragg reflectors placed at consistent intervals throughout the device create reflective mirroring effects. This presents several benefits such as confined area size-spots for devices, two-dimensional integration capabilities within arrays, and an ability to conduct on-wafer probe testing. Due to their small size, these devices have high modulation bandwidth potential. Vertical-cavity surface-emitting devices have extensive potential applications, ranging from automotive headlights to medical procedures such as sterilization and augmented reality displays [5][6]. However, difficulties with electrical injection mechanisms & mirror formation currently hinder their production. Overcoming these challenges [3-6] would unlock significant prospects for using this light source in data communication. Its low threshold current feature combined with exceptional performance enables seamless integration into complex systems [7].

2 Rate equations

To investigate the movement patterns of semiconductor lasers, a system comprising interconnected rate equations that factor in both region 1's carrier density and cavity photon density must be developed adhering to established standards. By concentrating on single-mode rate equations, one can comprehend how these VCSELs exhibit modulation behavior naturally. In situations where SCH transfers carriers into QWs at finite rates, an unwanted drop in frequency response similar to parasitic effects may arise; it is imperative to meticulously assess this aspect irrespective of circumstances [5–10].

In order to account for certain effects, the active zone carriers are treated differently than those in the SCH. This allows for three equations instead of two within rate equation formalism [10]. However, due to the narrow and graded nature of our used VCSEL architecture's SCH region, carrier transport effects have little impact. Therefore, we confidently utilize the referenced procedures and apply only two rate equations denoted as:

$$\frac{dN}{dt} = I_{in} - I_{sp} - R_{st}S \qquad (1)$$

$$\frac{dS}{dt} = (R_{st} - \gamma_i - \gamma_m)S + R_{sp} \qquad (2)$$

The first equation shows that the time increase in the number of charge carriers in the cavity, N, corresponds to the charge carrier injection rate, I_{in}, and the charge carrier injection rate is related to it. Dissipation due to spontaneous recombination, I_{sp}, and stimulated release, R_{st} S, must be subtracted. [11-13].

The second equation can be derived from the wave equation 69. It states that the net increase in the number of photons S is equal to the velocity of the photons produced by spontaneous mission R_{sp} and stimulated emission R_{st} S minus the internal losses γi S and the photons produced by the mirror .Loss is lost,γ_{ms}. Output coupling is expressed in the term γ_{m}S. The in eternal loss rate γi takes into account the absorption of photons due to scatter in g and the absorption of free carriers. The term R_{sp} is the amount of spontaneous e mission that resonates with the cavity and is in the same longitude in al mode as the coherent light. The spontaneous recombination current *Isp* represents their combination of electrons in the conduction band and holes

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[*] Corresponding author E-mail: mushtagobaid@utq.edu.iq

in the valence band. This recombination can occur radioactively, with the emission of photons, or non-radiatively. Defects within the crystal or on the surface of the crystal can cause carriers to recombine in localized states without emitting light. Another possible nonradiative recombination process is Auger recombination, where a third carrier absorbs the energy released during electron-hole recombination as kinetic energy. To simplify offset current calculations, it is recommended to incorporate static thermal effects and opt for straightforward replacement options like polynomial functions that indicate temperature changes [1]. One writes G as reference [2] to account for the phenomenological feature that gain is compressed at high photon density [5-9].

3 Results and discussion:

VCSEL rate equations model is solved using the ode45 method in a Matlab application. with the chosen settings as indicated by table.1 under the starting circumstances. The threshold current is $I_{th} = 2.5\,mA$ .One see that raising the injection current has an impact on gain, carrier density, and output power. All parameters are taken from reference [10]. The output power is given by:

$$P = \gamma_m S = \frac{\gamma_m}{\gamma_i + \gamma_m}(I - I_{sp}) \qquad (3)$$

Table 1: Output power peak values with selected currents.

Output Power (mW)	Current (mA)
0.72	3
1.71	3.5
3.85	4
4.65	4.5
4.85	5
4.76	5.5
3.43	6
1.32	6.5

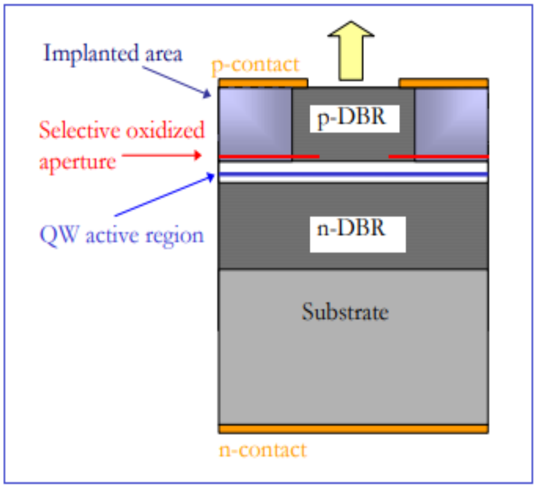

Fig. 1: Diagram for VCSEL.

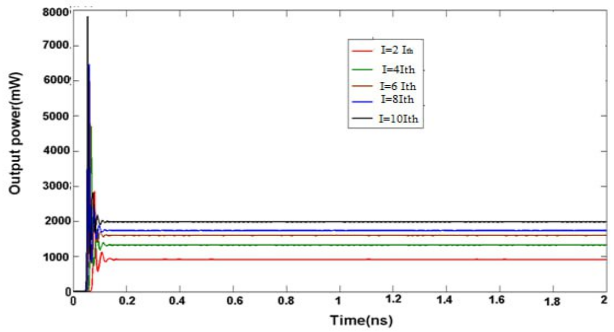

Fig. 2: Time series of laser output at different values of injection currents.

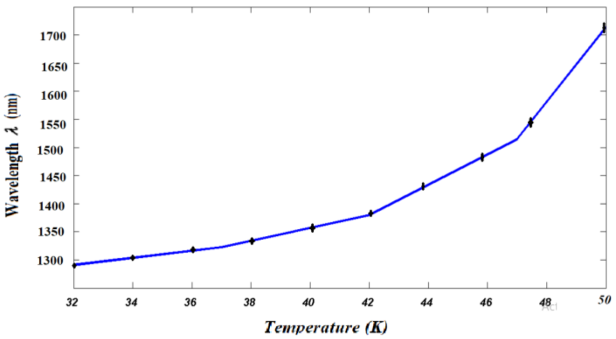

Fig. 3: Variation of wavelength with temperature.

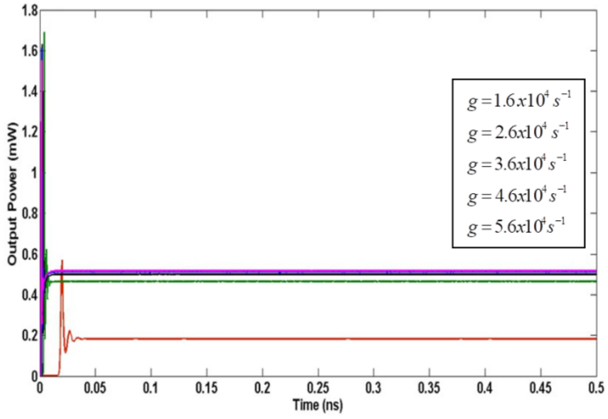

Fig. 4: Output power time series at various gain values.

The values of output power with different values of temperature are appeared in figure.5.

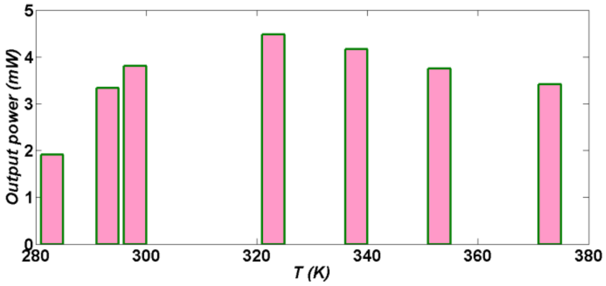

Fig. 5: Output power with different values (Peaks) of temperatures.

Although the VCSEL exhibits diode-like properties that enable a thorough analysis of its [12-14] for simplicity's sake when representing device variation of switch on time threshold currents.

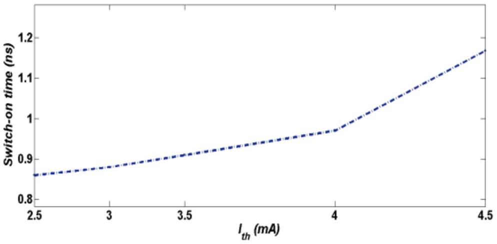

Fig. 6: Switch –on time with threshold input currents

4 Conclusions

The team formulated a simplistic rate-equation model that incorporates thermal influences by incorporating an output power in the assessment of VCSEL's with gain and current effects. This method was evaluated on various devices and demonstrated congruity with experimental results, implying its flexibility for different types of VCSELs. Furthermore, their findings show the switch on times are increased with threshold injection currents.

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