Design and Analysis of Equivalent Circuit Model Laser VSCEL Parameters Using Photonics

Hamed Moradi, Tayieb Namdaran, Pourya Roostami Gooran, Eiman Pouradad, Moohamad Rasool Aivazie

Research Scholar, Iran

Abstract

In this paper, we review and implementation of the orbital radiation from the semiconductor laser (VCSEL) described above. At that time, different parts of which this section are: the introduction of laser - The VCSEL - like the former scheme and the new proposal is made. The new proposal aims we have tried to use the software MATLAB and HSPICE simulator analyst can through the circuit thermal modeling VCSEL characteristics of this semiconductor laser to obtain the equivalent circuit. In this study, we have been able Vissel laser circuit model through numerical parameters and formulations to obtain the necessary plans and charts. This modeling through software analyst Hspice, Matlab've done. as follows: A: Characteristic curve IV B: The power output characteristic curve C: The frequency response characteristic curve

In this study, the innovation that has been done is that we've been able to model using HSPICE circuit and VCSEL thermal circuit characteristic curve and get it in quantities and using MATLAB software again these quantities in the case heat acquired and the output of both software analyst to compare and examine the state to the conclusion that the values are equivalent circuit VCSEL.

Keywords: VSCEL - characteristic IV - power output - frequency response - optical emission
A : Introduction VCSEL

Due to the emergence and development of optical communication are short, VCSEL lasers in the past few years, as a component of internal communications and light, has been proposed. Rapid advances in technology current and VCSEL, the laser diode, for different user constituencies and competition than the laser player - alongside or marginal and broadcast diode (emitter) light (LED), the replacement has become (assuming LED laser operation while the cost of the desired effect and to count[1]. Vertical cavity surface with emitting laser In the years 1975-1977 emerged: the photonic integrated flat to limitations of the technology available at the time of its Microelectronics. First, the researchers suggested the rays deviation based laser diodes. After two years, Professor k.Iqha suggested that the best way to play laser - surface material GaInAsP / Inp and ALGaAs / GaAs ( the active material for optical fiber communications, optical drives, optical sensors and optical processing). Professor Igha first goal of the integrated structure of the wafer and test the components before the end of the first laser in 1979 emitted from the surface of the structure of GaInAsP / InP at k 77 under pulses was obtained.[2] Now the threshold current of 1.3 mA 900 at a wavelength of 1.5μm. In 1983 the first laser at room temperature (RT) under pulse operation with GaAs active region was the higher threshold current of the laser was broadcast by Ali Despite the weak performance of the VCSEL in the day, the program microelectronic technology to researchers the opportunity to VCSEL structure in terms of lowering the threshold at RT to improvement.[2]

B : Thermal model rate equations

Model to provides an accurate description of the characteristics of the terminal VCSEL. Our first model based on the speed of the spatial dependence of the VCSEL will have to discuss. Then a simple empirical relationship for the active layer depends on the temperature, see the data and space velocity equation obtains independence. We then a simple rate equation that means temperatures (laser) as a function of the model waste heat, as well as the relationships that VCSEL output power and electrical characteristics of the models they offer. Heat heavy reliance VCSEL can consider some of the mechanisms. Although mating drill and optical absorption losses between-valence band plays a role in the thermal behavior, the dominant effects due to the temperature-dependent optical and carrier leakage area are active. [7]-[8]

C : Dependence rate equations

I had an injection flow; S is the total number of photons, efficiency Bashshd flow injection; T is the temperature of the VCSEL; G of the light; q is the electron charge, and carrier lifetime and thermal leakage current. The second equation, which describes the number of photons of S, will be equal to:

This is a comprehensive approach that includes-rate equation to describe the characteristics of the Laser_. N the number of carriers in the active region and is described. That and the diffusion coefficient of self-to-self and life are photons. In addition to the aims described the behavior of the spatial dependence of the VCSEL, Equations 1 and 2 can also provide a method and carrier leakage-dependent thermal efficiency can be modeled with. In the above equation, carrier leakage current and operation model with G model. Using simple empirical relationship for the two terms, because the exact physical definition can avoid complex computational Ferrand. [7]-[9]
Independent circuit equations and thermal space:
If we ignore our space equations and relationships will be easier to primary circuit can not VCSEL that the temperature dependence of our model as follows.[12]

Independent circuit equations and thermal space
If we ignore our space equations and relationships will be easier to primary circuit can not VCSEL that the temperature dependence of our model as follows.
Here In inflow, Node node between the voltage of the carrier density and photon density is S node voltage node.
The following outlines the parameters described here. This circuit is sent regardless of the effects of space because space for model-dependent rate equations are not suitable surface-orientation. As you know, the independent-heating is the dominant factor that affects the characteristics of the VCSEL. In order to simplify the model and calculation of spatial effects are ignored. [7]

\[
\frac{\partial N(r,t)}{\partial t} = \frac{\eta I(r,t)}{q} - \frac{N(r,t)}{\tau_n} G(r,t,T)S - \frac{I_1(N,T)}{q}
\]
(1)

\[
\frac{\partial S(t)}{\partial t} = \frac{S(t)}{\tau_p} + \frac{\beta N(r,t)}{\tau_n} + G(r,t,T)S(t)
\]
(2)

\[
\frac{dN(t)}{dt} = \frac{\eta I(t)}{q} - \frac{N(t)}{\tau_n} G(t)\frac{(N - N_{tr}(t))S}{1 + \varepsilon S}
\]
(3)

\[
\frac{dS}{dt} = -\frac{S}{\tau_p} + \frac{\beta N}{\tau_n} + \frac{G_o(N - N_o)S}{1 + \varepsilon S}
\]
(4)

\[
G(T) = \frac{G_T(T)(N - N_{tr}(T))}{(1 + \varepsilon S)^b}
\]
(5)
The GT of light is dependent on the temperature; Ntr number of carriers transparency is dependent on the temperature, the compression ratio; and b is a constant value that our article is intended for two-level model.

Put Gt and Ntr as functions of temperature, the temperature dependence can be a simple equation without resorting to complex calculations described. As in the release-edge lasers had, Gt and Ntr as a linear function of temperature, or exponential functions of temperature, modeled. In the VCSEL, the use of the same heat. Our model is based on a more analytical way we develop our Bdilita and Scott. These are commonly accepted empirical equations are described below:

\[ G_T(T) = G_0 \left( \frac{a_0 + a_1 T + a_2 T^2}{b_0 + b_1 T + b_2 T^2} \right) \]

(6)

Using the thermal circuit model equations and parameters of the VCSEL can use Matlab and Hspice count. Thermal circuit model VCSEL can see in Figure 18. The model helps us to focus on software modeling Hspice functions:
1. The voltage and current characteristics
2. thermal characteristics
3. The characteristic frequency response
4. The characteristic output
And outputs it to obtain account.

![Figure 2: Thermal equivalent circuit model VCSEL](image)

Figure 3, 4 Typical circuit with characteristic source of IV below. The waveform under the IV characteristic curve and frequency response, power output and analysis shows it. It should be noted that the two previous schemes, were analyzed using Matlab software and waveform derived from this software. [6]-[7] software. [6]-[7]
Flow curve - voltage is achieved for a given temperature. With an increase in current, voltage also increases exponentially.

Figure 13 IV VCSEL characteristic curve obtained in Matlab to see. This curve is determined by the input voltage.

**D : Output Characteristic Curve**

As well as the power curve flow curve - voltage is an exponential curve that depends on temperature and flow. This curve is an upward curve which means that the increase in flow, high returns can be exponentially. Operating temperature limits can be considered parameters.

The output power curve is one of the main figures in the design and analysis circuit is VCSEL. The curve of the two main factors we use to get the output [8]

A - the flow
B - The Temperature

Output characteristic curve
As well as the power curve flow curve - voltage is an exponential curve that depends on temperature and flow. This curve is an upward curve which means that the increase in flow, high returns can be exponentially. Operating temperature limits can be considered parameters.[11]

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A - In general, we can conclude that the increase in temperature and increase the flow is directly related to the increase in power output.[13]

During squared increasing output, the current can be divided into two streams:
They cause irritability. Carriers flow temperature increases, the rate of increase during the course of the production process offset the increases will be offset. And it is directly related to increased exponentially heat.

B - the threshold: This occurs when the current carriers increase the mobility of carriers is high, the carrier irritability other carriers and the poor is being created.
In Figure 7, and 10 and 20, we can see that the type of material and the VCSEL has a direct impact on the current density and the type of material on the heat and the effect of temperature on mobility Flow is also a direct relationship. In the meantime, we can have the impression of waveform mentioned, each of the waveform at different temperatures (20 to 130 °C) is created and depending on the type of ingredients such as: GaAs and AlGaAs and AlGaInP is.

a rate and to an amount not start from a certain point of the graph, but depending on the type of values each corresponding to manifest a certain amount on the waveform graph.
In short, the laser power to factors such as:
1. Temperature - T
2. The offset current (depending on temperature) - IOFF
3. The threshold current - Ith
Depends on the laser efficiency.[20]-[7]

II : simulation software HSPICE

E : Current and Voltage Characteristic Curve

\[
V = 1.721 \times 10^7 I + 2.439 \times 10^4 I^2 + 1.338 \times 10^6 I^3
-4.154 \times 10^7 I^4 + 6.683 \times 10^8 I^5 - 4.296 \times 10^9 I^6
\]

(7)
Net flow curve list - voltage on the basis of modeling (Figure 2) on the circuit thermal model has been implemented VCSEL. This model includes:

1. Input (dependent voltage source and series resistance)
2. The current sources (photons + thermal)
3. The resource output voltage.

1) each of the sources on the basis of their relations.
2) The definition of circuit nodes and their relation to specific input and output nodes.[17]
3) notes the following list includes the DC curve and generally in the article are defined by the following equation is obtained:

**F : Relationship Current - Voltage:**
1. The definition of a DC input (dc current source to a value of 1 mA).
2. to draw curves of current - voltage DC must scan analysis 0 to 20 mA. By changing the voltage value exponentially increases Yabd.hmchnyn changed and defined the following form: [16]
   DC IS 0.1m 20m 0.01m.
3. In order to draw the curves of current - voltage Probe command is used.
4. PARAM order to define constant values are, for example, in this project the thermal resistance is defined as follows:
   PARAM Rth = 2600
5. The definition of voltage-dependent current source that, for example, in the scheme is defined as follows:
   Gs1 0 s CUR = 'Gamma * tau_s * beta * V (N) * zn * k / (tau_n * (V (S) + delta))'.
6. output dependent voltage source that is defined with the following command:
   Eout OUT 0 VOL = '(V (S) + delta) * (V (S) + delta) / k * k_power'.
7. The final line instructs the end of the program

**G : Output Characteristic Curve**
The power curve as the curve - a curve DC voltage dependent changes are underway. Then, as the previous curve mainly on Internet block lists are similar to each other and the base model (Figure 2) is used in the article.

1. like curves of current - voltage net fixed list of parameters is like ..........  
   PARAM pi = 3.1415926535898  
   PARAM q = 1.60217733e-19  
   PARAM h = 6.6260755e-34
PARAM T0 = 300
PARAM a0 = 1.246e-3
PARAM a1 = -2.545e-5
PARAM a2 = 2.908e-7
PARAM a3 = -2.531e-10

2. The definition of the DC analysis is to draw the laser output power.
3. Define output curves are drawn, each curve for a given temperature. (Curve of 20 °C for 130 °C Payam start and done.)
4. The output of the PRINT statement is used to draw the curve.

D: The dynamic modeling

A: part modeling with MATLAB

Frequency response characteristic curve Interest curve depends on the wavelength and the changes underway. Peak flows are less likely to have greater interest. The curve obtained for a given temperature.[18]-[19]

Frequency response is a frequency spectrum output to the input frequency spectrum.it (system or equipment) will be given. In simple cases, if a sine wave at a given frequency in a given system, a linear system in the same frequency will respond with a certain amplitude and phase angle of the input. Also for a linear system to double the amount of input, output will double to continue if the system interminable. At the time, the frequency response also will change with time. The use of frequency response analysis linked to but different from each other two goals. Audio systems aim may reproduce the input signal without distortion. A smooth surface and uniform size of the response to the bandwidth of the signal delay caused by the same amount of time at all frequencies exact needs. This delay can be recorded in the second week or month.[20]

The Figure of 11 and 12 and 13 Nmvadr waveform is such that no matter how the flow is less than the peak value increased frequency and peak wavelength has a sharp tip that the sharp peak 0.28mA current value is visible, however the current levels will increase in the frequency spectrum, which has a peak wavelength decreases and the disruption is a sharp peak in broadcast mode.

In the frequency spectrum in terms of frequency response function is specified in the diagram, voltage AC voltage level for the purpose of hail. The yen waveform based on several important factors in waveforms that are different in frequency response function.[10]

A - The current injection at the specified time
B - the frequency spectrum of the current carriers and their density is achieved
C - depending on the amount of waveform parameters and parameter values that vary with the type of broadening Anchors
D - wave shape depending on the type of material and its wavelength is different manufacturer
H - frequency spectrum, depending on the length depends Modulation, which has the consistency and harmony (arranged) in harmonic harmonic frequency. If this is not adhered the output frequency response is wrong and error.[10]

In general, and the overview it can be stated that 0.5mA current waveform has a waveform is good because we do not have waveforms as well as peak broadening in the needle yet. The causes of the error
and the noise of the frequency response. It should also be noted that the current relationship is better than it did, and in some cases also used. Interest can be influenced by parameters such as .... are:
1. The carrier density ratio
2. The type of structure and material such as AlGaAs or GaAs laser
3. The construction parameters such as channel length, efficiency and ........
4. The threshold current density
5. The wavelength is proportional to the number of carriers will change as a result of repayments, the laser affects the flow.
• modeling software with HSPICE

Frequency response characteristic curve:
To obtain the curve (Figure 2) Net change list is as follows:
1. independent AC input current source IS
2. Change the output for various streams of parameters such as tn, tp and ...... achieved. The above parameters are frequency dependent, and in terms of drawing.[15]
3. The need to draw AC analysis is done using the following command:
   AC dec 50 10 16 giga
4. The frequency curve depends on the parameter of interest. Such as:
   PARAM g0 = 8.486e5
   Param tp = 2.884e-12
5. Finally, after analysis of the output curve is obtained as follows:[12]

Conclusion
By doing simulation and implementation of simulation earlier in this thesis we have been able to determine the quantity of VCSEL so that the output characteristic curve can answer VCSEL circuit output waveform in both MATLAB and HSPICE to a and the precision is high. It can be concluded that their study found that the characteristic curve is identical in both software and product output characteristic curve it is also monitoring the state equivalent circuit modeling suggests VCSEL.
At the same time with the circuit characteristics of the circuit VCSEL using software Hspice to the conclusion that, in this research advantage created the orbital modeling software with Hspice analysis and resulting questions Kynm output compared with Matlab software. That this process would be an advantage and innovation of the research in this simulation.
Using the parameters of the manufacturing process of semiconductor laser VCSEL has come to us and using mathematical formulas functions can be in control of the VCSEL at a constant temperature (room temperature) and calculate variable temperature. After obtaining the heat quantity can be calculated and plotted orbital circuit and VCSEL circuit by circuit KVL or KCL able to determine the quantity and orbital parameters and formulas required by the Software analyst can obtain the required characteristic. It should be noted that VCSEL has several examples and in various industrial and commercial applications. As well as the difference in the type of VCSEL that makes them different is that this process is making changes in some parameters of its construction. So with that said, we conclude that any different VCSEL
manufacturing model and its orbit would have to get the equivalent circuit parameters and formulas of the kind of VCSEL used to achieve the output is exactly right, and with the accuracy.

Using software analyst HSPICE have been able to obtain the quantities characteristic curve:
A - the voltage and current characteristic curve
B - output characteristic curve
C - Frequency response characteristic curve

Use of this thesis is that Vsrt which type VCSEL is specified, then the mathematical formulation parameters and thermal conditions at a constant temperature and variable are obtained (using Matlab) and then characteristic curve with Matlab simulation, and then using Matlab output parameters and formulas can be simulated with software Hspice circuit model VCSEL and obtain characteristic curves.

Figure 5: Characteristic Curve IV – MATLAB

Figure 6: characteristic curve of constant temperature over time – MATLAB
Figure 7: output characteristic curve - MATLAB

Figure 8: characteristic curve IV - Hspice
Figure 9: Attribute IV [8]

Figure 10: output characteristic curve – Hspice
Figure 11: Frequency response characteristic curve - MATLAB

Figure 12: Frequency response characteristic curve – Hspice
Figure 13: Frequency response characteristic curve [8]

Figure 14: Carrier transient analysis features - MATLAB

Figure 15: Characteristics of transient thermal section - MATLAB
Figure 16: Carrier transient analysis features - HSPICE

Figure 17: transient analysis features photon - HSPICE

Figure 18: Characteristics of transient thermal sector – HSPICE
Figure 19: Comparison between measured values (points) and IV curves simulated (lines) for the VCSEL. [7]

Figure 20: The input current characteristics in terms of power output [8]

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