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Analysis of VCSEL for different input signals with Gaussian and white noise for optical interconnects applications

Anamika Singh, Dr. Gurjit Kaur

School of ICT,
Gautam Budhha University,
Greater Noida U.P. India

Abstract

VERTICAL CAVITY SURFACE EMITTING LASERS (VCSELs) are a type of new generation semiconductor laser that used as an attractive optical source for short distance optical interconnects. Electrical interconnects are approaching their fundamental limits and presents the present performance bottleneck. So Optical interconnect is a good solution for electrical interconnects. The main objective of this work is to model and simulate the VCSEL based optical interconnect transmitter. VCSELs are the most efficient, lowest cost and most widely used laser source for interconnects. This paper gives brief summary of VCSEL to be used in optical interconnect. In this paper VCSEL model is simulated in MATLAB and analysis has done of VCSEL for different input signals with Gaussian noise and white noise for optical interconnect applications.

Keywords: *VCESL's, Optical interconnect, Transmitter.*

I. INTRODUCTION

Vertical-cavity surface emitting lasers (VCSELs) are very useful because of small size of cavity, and it improves the coupling of the optical output to a fiber. In very large scale integrated circuits (VLSI), the transistor density is increasing day by day and the limited pin number in the off chip communication leads to a problem in electronics. OE-VLSI circuits using short distance optical interconnect. Advantages offered by optical interconnects provides strong motivation to further develop methodologies for analysing optical interconnect links.

Vertical-cavity surface emitting laser (VCSEL) is currently the most agreeable optical source for optical interconnects. A VCSEL is a semiconductor laser diode that emits light perpendicular to the upper surface of the semiconductor wafer of which the laser is composed. Optical interconnects have negligible frequency dependent loss, low cross talk and high band-width. We can also reduce latency in optical interconnects using very low duty cycle, return to zero encoding. Short pulses also offer many advantages in communication.

VCSEL allows the use of optical interconnects in short distance interchip and also in intra chip communication. The success of VCSEL is determined by their different kind of physical properties. The Si based optical interconnects is a best and cheaper alternative to the GaAs-based VCSEL.In order to design the next generation of VCSELs with even better performance, it is compulsory to model the optical, electrical, and thermal effects that come into play in these devices. The internet has become an important business and entertainment tool. The power consumed by the internet is rising from around 45% of the world's electricity in a few years. Optical interconnects is more than a thousand times lower than electrical signal attenuation at 10 Gb/s so fibre optic data transmission is very efficient. Problems with electrical interconnects are crosstalk, signal distortion, high power consumption, high latency.

Fiber optics has advantages like low-loss transmission at high frequency. NO crosstalk between adjacent signals, free from electrical short circuits also no impedance matching required. Performance of electrical interconnect will saturate in some years.

II. OPTICAL INTERCONNECT MODEL

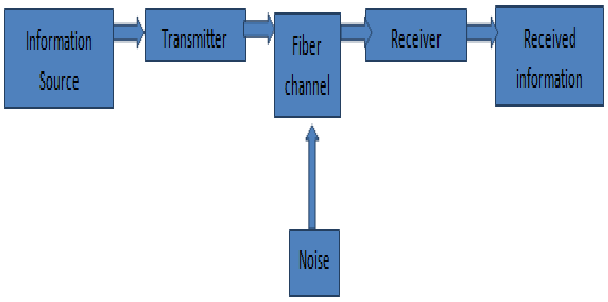
Interconnect basically has transmitter and receiver part. A model developed consists of transmitter and receiver circuit for optical communication system. A interconnect is a device that is used to link two things together. Thus connect the optical transmitter and receiver circuit by using a interconnect. This model is simply called a optical communication link. Pspice tool is used for the analysis of this model.

Transmitter circuit- In transmitter circuit, Vin is used as a sine wave in input signal. Signal is amplified through a speaker.

Receiver circuit-In the receiver circuit input is light pulses being detected by phototransistor.

III. Basic Model for Optical Communication System

A. This work used an optical transmitter and a receiver circuit. The transmitter circuit creates a series of light pulses that encode an audio signal by using pulse frequency modulation. The receiver detects the light pulses and demodulates.



B. Equations

In this work, a rate equation has used which is a comprehensive technique that considers rate equation to describe laser characteristic,

First equation which describe carrier number N in active region;

$$\frac{dN}{dt} = \frac{\eta i(I - Ioff(T))}{q} - \frac{N}{\tau n} - \frac{Go(N - N0)S}{1 + \varepsilon S}$$

$$\frac{dS}{dt} = -\frac{S}{\tau p} + \frac{\beta N}{\tau n} + \frac{G0(N - N0)S}{1 + \varepsilon S}$$

$$-Po = kS$$

$$Ioff(T) = \alpha 0 + \alpha 1(T) + \alpha 2(T^2) + \alpha 3(T^3) + \ldots$$

Where S(t) is photon density,

N(t) is active region carrier density,

Po is optical output power,

ηi is injection efficiency,

τn is carrier recombination lifetime,

Go is the gain coefficient,

No is carrier transparency number,

τp is photon lifetime,

β is spontaneous emission coupling coefficient,

and ξ is a gain compression factor,

k is a scaling factor accounting for the output efficiency of VCSEL.

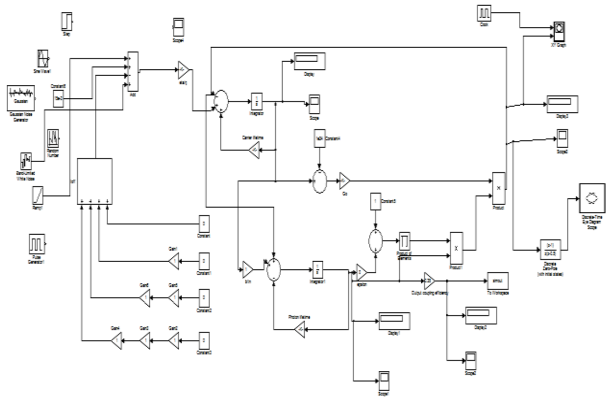


Figure 1. Simulink model of VCSEL

IV. Results

The optical operation of a VCSEL can be described by rate equations that describe the time evolution of the carrier (N) and photon (S) densities in the cavity. Formula shows the spatially dependent rate equations; for an explanation of the different parameter.

Parameters Used in Simulink model

Parameter	**Description**	**Values**
B	Spontaneous emission coupling factor	$4*10^{-4}$
G_o	Gain coefficient	$3*10^{-6} cm^3$/sec
τ_n	Carrier lifetime	3 ns
τ_p	Photon lifetime	1ps
E	Epsilon	0
η_i	Injection efficiency	1
K	Output coupling efficiency	$2.6e^{-8}$
No	Optical transparency density	$1.2*10^{18} cm^3$

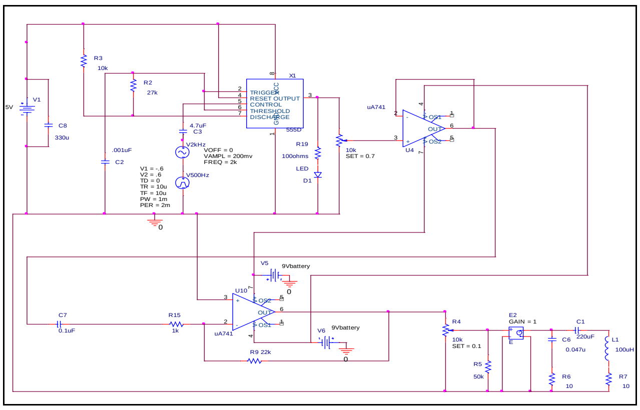


Figure 2. PSPICE model of optical interconnect model

V. NEED OF OPTICAL INTERCONNECTS

The constant degradation of VLSI devices is main reason of rapid growth of VLSI technology. Feature size is very important aspect. Effects of interconnects become more prominent. These Effects consist of delays, crosstalk, power/ground noise and signal noise. If we use VCSEL based transmitter then above problems can be minimized.

VI. PROBLEMS IN EXISTING INTERCONNECTS

Optical interconnects with low signal attenuation and crosstalk could be very useful in short distance bandwidth sensitive applications. It is predicted that for 70 to 80% of the signal delay is caused because of interconnects.

Optical interconnect model connects the transmitter and receiver circuit. in transmitter circuit laser has been used. In receiver, phototransistor is used.

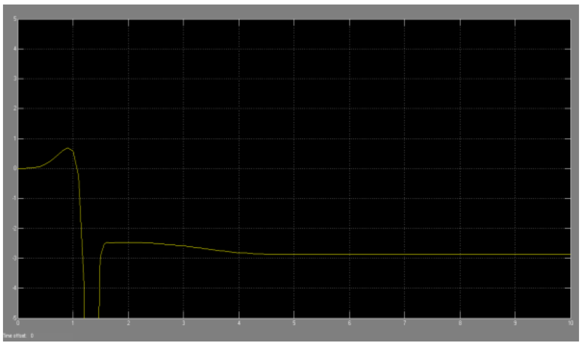


Figure 3.Simulated transient response of VCSEL

In this graph X-axis represents the time offset and Y-axis represents the Signal amplitude that shows the transient analysis and shows that it is non- oscillatory.

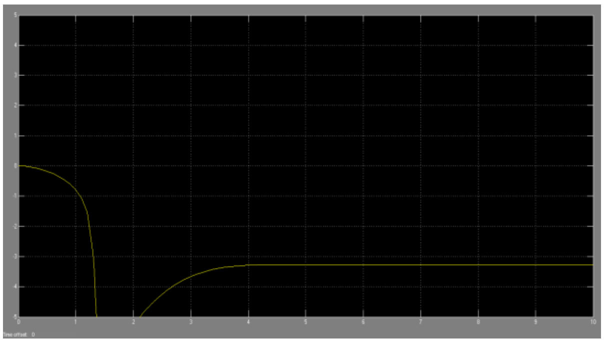


Figure 4: Simulated carrier density response of laser

Carrier density response represents that there is some delay after the application of step input, after the threshold value a stedy state photon density of VCSEL is obtained.

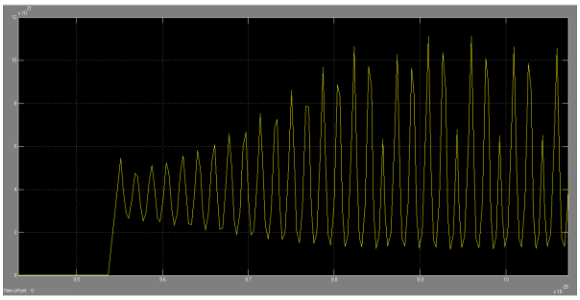


Figure 5: Simulation of VCSEL with white noise and ramp input

In this graph, noise in VCSEL model appears like a ramp signal it ramps up or down.

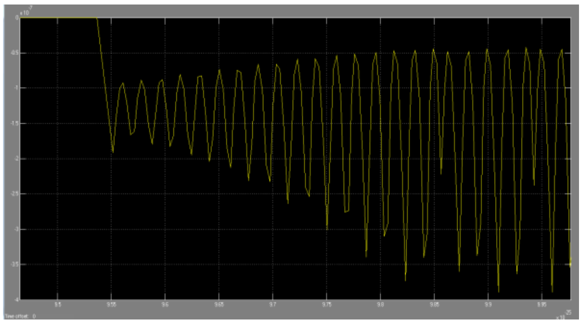


Figure 6.Simulation of VCSEL with white noise and step input

With step input graph obtained is opposite in nature as that of ramp signal.

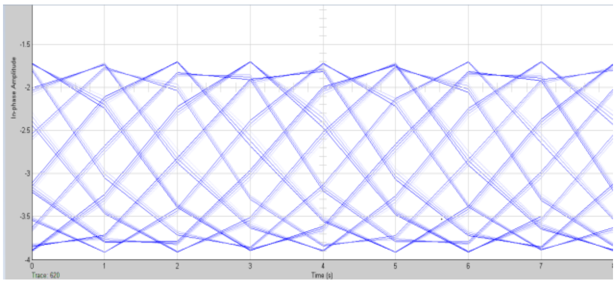


Figure 7. Eye diagram for VCSEL with sine wave input

VCSEL model is instantiated with default parameters that give much result than a real device at this operating frequency should yield. Eye diagram predicts that how clearly the optical signal is transmitting. This eye diagram signifies that digital data repetitively sampled and applied to the vertical input.

VII. CONCLUSION AND FUTURE SCOPE

This model was developed using MATLAB Simulink tool, we obtained results for carrier density and power output response. The behavior of VCSEL is modeled with a set of equations we discussed above in section III. Analysis has done by using noise terms for compatibility with real world. Researchers simulated a VCSEL model in MATLAB, For different input signals in this research paper have analysed. The performance using various inputs i.e. ramp signal, step signal and pulse generator even by including Gaussian noise and band limited white noise. Results show analysis by adding noise. The output is not stable and starts oscillations. Further a PSPICE model is simulated for the optical interconnect system.

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