Journal of Electron Devices, Vol. 10, 2011, pp. 420-422

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Journal of Electron Devices
www.jeldev.org

A NONLINEAR EQUIVALENT CIRCUIT MODEL FOR PACKAGED VCSELs

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Received 26/04/2011, Revised 2/05/2011, Online 8/05/2011

Abstract

In this paper, a nonlinear circuit model for the input of VCSELs based on rate equations is presented. Both parasitic and thermal effects have been included in our model. The model parameters are extracted in two steps, DC and AC measurements. There is an acceptable agreement between simulation results and measured data at 3 MHz to 3GHz.

Keyword Circuit optimization, nonlinear circuits, parameter extraction, vertical-cavity surface-emitting lasers (VCSELs).

I. INTRODUCTION

Vertical-Cavity Surface-Emitting Lasers (VCSELs) have become one of the most important components for the optical interconnections. Until now, various circuit models have been presented, which models both intrinsic behavior of VCSELs and also their inputs. In [1], a VCSEL circuit model has been presented, which is based on thermal rate equation and describe the internal behavior of the laser. In [2] and [3] simple RLC and LC models have been introduced for input modeling. In [4] there are two LC stages which model wire-bonding and package lead parasitic and a resistor for intrinsic VCSEL modeling. In [5], a compact nonlinear equivalent circuit model has been developed for input modeling which uses the model in [1] for intrinsic VCSEL model. This input model includes circuit model for text fixture, package leads and wire-bonds. In [6-7] other equivalent circuit models have been discussed. At higher frequencies, there is lower accuracy compared with measured data. In order to overcome this limitation, we have developed a more accurate model for parasitic effects. In section II, we will describe this model. In section III, we see how the parameters of the model are extracted, and in section IV, results are presented. Section V concludes the paper.

II. MODEL DESCRIPTION

In this paper, we present a new input VCSEL circuit model for wire-bonds, which can achieve better match between simulated and measured data at higher frequencies 2-3 GHz. In [5], Minoglou *et al* modeled text fixture with L_0, R_0, C_0, and package leads with C_l and L_l. We use the same model for test fixture and package leads, but implement Sutono's model [6] for wire-bonds. Our first proposed model is shown in Fig. 1.

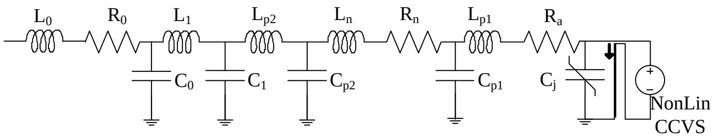

Fig. 1. First proposed equivalent circuit model for the input of the VCSEL

In this model, L_n represent the wire inductance, R_n represent radiation loss, C_p represent substrate capacitance and the wire capacitance to ground , and L_p represent end inductance caused by the bonds and is constant.
The intrinsic model is based on Minoglou's model, which uses a nonlinear temperature-dependent current-controlled voltage source in shunt with a nonlinear capacitance C_j, and a series resistance R_a. The second model has also been developed, which uses a complete transmission line model for wire-bonds. At high frequency, elementary model for line has low accuracy and needs to use this precise model. Our second proposed model is shown in Fig. 2

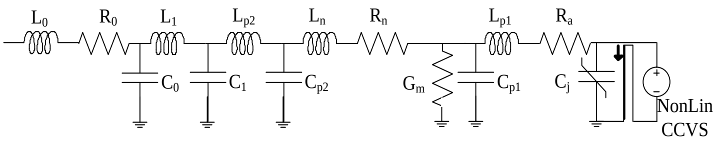

Fig. 2. Second proposed equivalent circuit model for the input of the VCSEL

In wire-bonds model, G_m and C_m are added due to transmission line model. We use C_p for combination of C_m and the previous C_p.

III. PARAMETER EXTRACTION

For extraction of the first model's parameters involving in current-controlled voltage source equation (equation (1) in [5]), DC measurement data is required and it is extracted with Matlab fitting, which employs Levenberg method. For the second step of parameters extraction, we use the S_{11} measurement data and the previous extracted parameters in ADS simulator for optimization of initial values. Thus, the second set of the parameters (L_0, R_0, C_0, L_l, C_l , L_p , C_p , C_j) is extracted. The extraction values for DC and AC parameters are given in Table 1. Fig. 3 illustrates the measured and modeled V-I data. These data are used for extracting DC parameters. AC parameters are extracted from measured S_{11} data. At the next step, we use a complete transmission line model for wire-bonds.

Table 1: Parameters resulted from fitting the VCSEL model to experimental data

Parameter	Initial value	VCSEL
R_{in}(Ohm)	35	45.78
T_0(kelvin)	165	171.4
n_f (V/kelvin)	2e-4	2.097e-4
B (A)	2e-5	3.629e-5
E_g/2k	5e3	6e3
n	2	2.7
C_{p1} (pF)	40	0.308
L_{p1} (nH)	5	0.001
C_{p2} (pF)	0.01	0.044
L_{p2} (nH)	0.5	1.1
C_l (pF)	7	6
L_l (nH)	11	2.75
C_o (pF)	1.4	4.56
R_o (Ohm)	2	0.54
L_o (nH)	3.2	3.242
R_n (Ohm)	5	6.8
L_n (nH)	0.2	0.6
G_m (mmho)	2	3.7

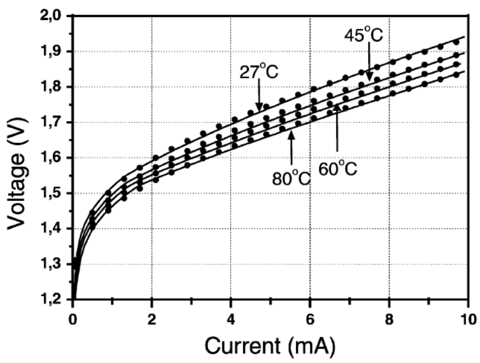

Fig. 3. Measured values (dotted line) and simulated (continuous line) V–I characteristics of VCSEL at various ambient temperatures.

IV. RESULTS

Using parameters of Table 1, we have simulated the device. In Fig. 4, which belongs to our first model, it can be seen that at higher frequency (2-3GHz), there is a better agreement with measured data. It can be improved in Fig. 5 with the second model. In Fig. 6, it can be seen that the second proposed model has performance better than the first one at higher frequencies.

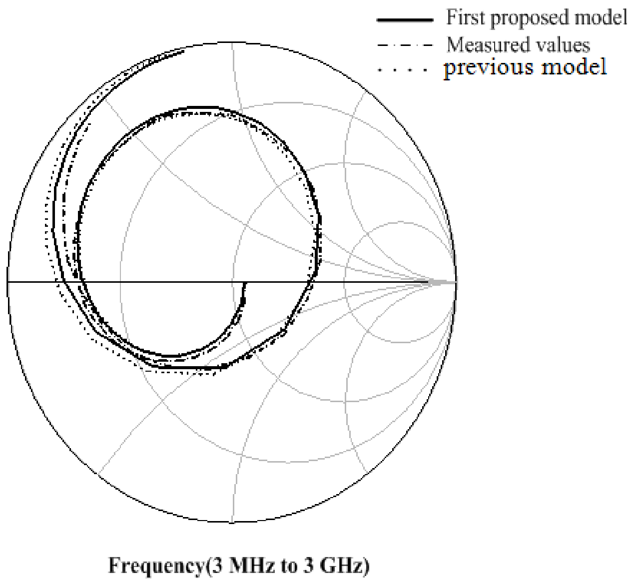

Fig. 4: Measured values, previous model [5], and the first proposed model S-parameters for VCSEL at the bias current of 5 mA.

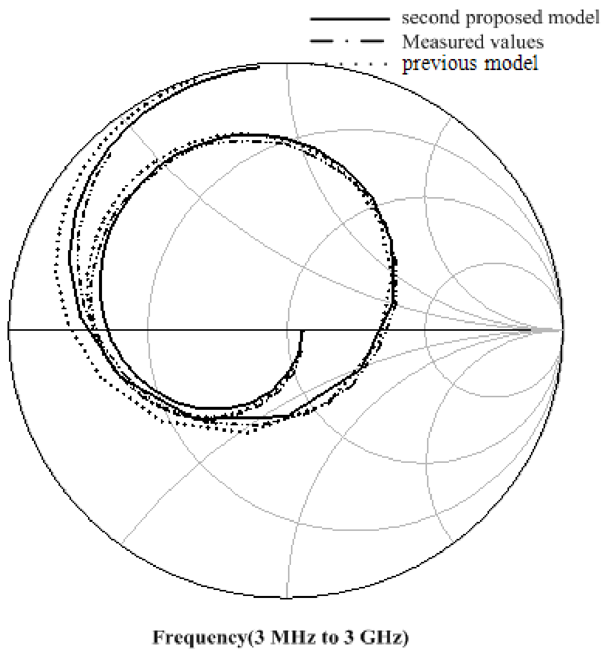

Fig.5: Measured value, previous model [5] and the second proposed model S parameters for VCSEL at the bias current of 5 mA.

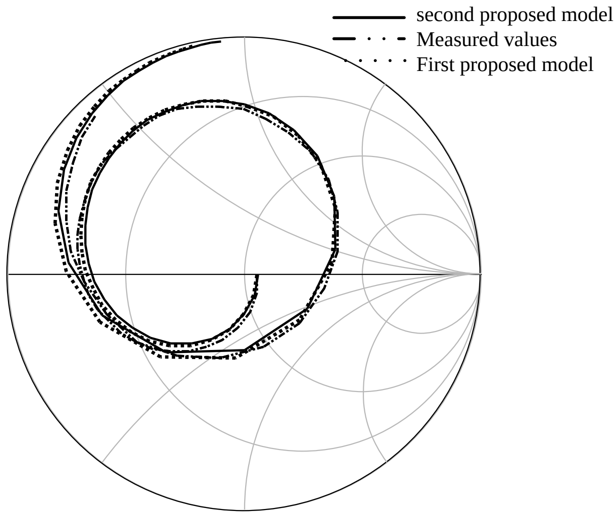

Fig. 6. Measured values, first proposed model, and second proposed model S parameters for VCSEL at the bias current of 5 mA.

V. CONCLUSION

An efficient model has been provided for modeling of parasitic elements of VCSEL. The model uses complete transmission line model and connection parasitic elements for wire-bands modeling. The parameters are extracted from DC and AC measurement data. This model has more accurate match agreement with the measurements. This model can be used for the IC designer who needs an accurate nonlinear model for the input of VCSEL.

REFERENCES

[1] P. V. Mena, J. J. Morikuni, S.-M. Kang, A. V. Harton, and K. W. Wyatt, "A comprehensive circuit-level model of vertical-cavity surface-emitting lasers," *J. Lightwave Technol.*, vol. 17, pp. 2612–2632, Dec. 1999.

[2] M. Bruensteiner and G. C. Papen, "Extraction of VCSEL rate-equation parameters for low-bias system simulation," *IEEE J. Select. Topics Quantum Electron.*, vol. 5, pp. 487–494, May/June 1999.

[3] D. Wiedenmann, R. King, C. Jung, R. Jager, R. Michalzik, P. Schnitzer, M. Kicherer, and K. J. Ebeling, "Design and analysis of single-mode oxidized VCSEL's for high-speed optical interconnects," *IEEE J. Select. Topics Quantum Electron.*, vol. 5, pp. 503–511, May/June 1999.

[4] J. K. Guenter, J. A. Tatum, A. Clark, R. S. Penner, R. H. Johnson, R. A. Hawthorne, J. R. Biard, and Y. Liu, "Commercialization of Honeywell's VCSEL technology: Further developments," in *Proc. SPIE*, vol. 4286, pp. 1–14, 2001.

[5] K. Minoglou, D. Efstathios, K. Bitzaros, "A Compact Nonlinear Equivalent Circuit Model and Parameter Extraction Model for Packaged High-Speed VCSELs" *Journal of Lightwave Technology*, vol. 22, no.12, pp. 2823-2827,Dec. 2004.

[6] F. Emami, and A.H. Jafari, "An equivqlent circuit model for dual-cavity QW-VCSELs," *International Conference on Electrical and Computer Engineering, ICECE 2008*.

[7] A. Bacou, A. Hayat, V. Iakovlev, A. Syrbu, A. Rissons, J.-C. Mollier, and E. Kapon, "Electrical Modeling of Long-Wavelength VCSELs for Intrinsic Parameters Extraction," IEEE Journal of Quantum Electronics, vol. 46, pp. 313-322, Mar. 2010.