PHYSICAL SIMULATION OF OPTOELECTRONIC SEMICONDUCTOR DEVICES

by

DAVID WELLS WINSTON

B.S., West Virginia University, 1990

B.A., West Virginia University, 1990

M.S., University of Colorado, 1993

A thesis submitted to the

Faculty of the Graduate School of the

University of Colorado in partial fulfillment

of the requirement for the degree of

Doctor of Philosophy

Department of Electrical and Computer Engineering

1996

This thesis for the Doctor of Philosophy degree by

David Wells Winston

has been approved for the

Department of

Electrical and Computer Engineering

by

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Russell E. Hayes

_____

Bart Van Zeghbroeck

Date _____

Winston, David Wells (Ph.D., Electrical Engineering)

Physical Simulation of Optoelectronic Semiconductor Devices

Thesis directed by Professor Russell E. Hayes

The operation of optoelectronic semiconductor devices couple electrical, optical, and thermal effects that are difficult to analyze. Simulation tools help device designers determine how these various effects interact. This thesis describes the SimWindows optoelectronic device simulator. The author of this thesis developed SimWindows as the first simulator to combine the major physical models necessary for simulating optoelectronic devices such as surface emitting lasers and quantum well solar cells. The software extends many of the traditional electrical models by adding effects such as quantum confinement, tunneling current, and complete Fermi-Dirac statistics. The optical model includes computing electromagnetic field reflections at interfaces and determining the resonant frequency of laser cavities. SimWindows implements two thermal models which either compute the lattice temperature or the electron temperature. This combination of models can predict many aspects of optoelectronic devices that traditional simulation programs can not. SimWindows provides a large degree of flexibility for the user to control and modify the models in SimWindows. The user can also add new models depending on the circumstances.

This thesis will present results for two examples: a vertical cavity surface emitting laser (VCSEL) and a multi-quantum well solar cell. SimWindows results will focus on the two Bragg reflectors of the VCSEL and evaluate designs to improve the reflectors. Simulation results will analyze how the improved reflectors affect the overall characteristics of the VCSEL. The main result from this VCSEL analysis will

be that despite similarities between the two Bragg reflectors, their design must be independent to achieve the best VCSEL design.

For the multi-quantum well solar cell, SimWindows results will focus on the impact of hot electrons on the characteristics of the solar cell. Results will show that hot electrons can reduce unwanted recombination in the quantum well absorption regions, but also yield an undesirable backward diffusion of hot electrons. The main result will be that the relative size of these two effects determines the short circuit current and open circuit voltage of the solar cell.

Dedication

To my parents for their never ending support

and to the following composers
who break those technological chains

Johann Sebastian Bach, Ludwig van Beethoven,
Modest Moussorgsky, Carl Orff, Antonio Vivaldi

All creatures drink of joy
at Nature's breast
All, whether good or evil,
follow her rose-strewn path.
She gave us kisses and vines,
a friend, proved faithful unto death.
Delight was given even to the worm,
and the cherub stands before God.

Ode to Joy - Friedrich Schiller
trans. by Steven Ledbetter

Acknowledgments

I wish to thank Russell Hayes for his direction and realistic insight; Arnoldo Majerfeld, Bart Van Zeghbroeck, Garret Moddel, and Y.C. Lee for serving on my thesis committee; Henryk Temkin for experimental data; Hamid Fardi for his help with the Hot Electron Model; Arthur Nozik, Richard Ahrenkiel, Zhenghao Lu, and Mark Hanna for invaluable feedback on SimWindows. Special thanks goes to Scott Dickey for our fruitful discussions of solid state physics and gaming tactics, and to Mac "things are going pretty well" Culver for our discussions of all things Trek. This work was supported by the Optoelectronics Computing Systems Center at the University of Colorado and Colorado State University.

Software tools used for this project: Microsoft Word v. 6.0; Microsoft Excel v. 4.0; Microsoft PowerPoint v. 4.0; Visual Numerics Incorporated Stanford Graphics v. 3.0b; Borland International C++ six versions from 3.1 to 4.52; Wolfram Research Inc. Mathematica v. 1.2 for Ultrix.