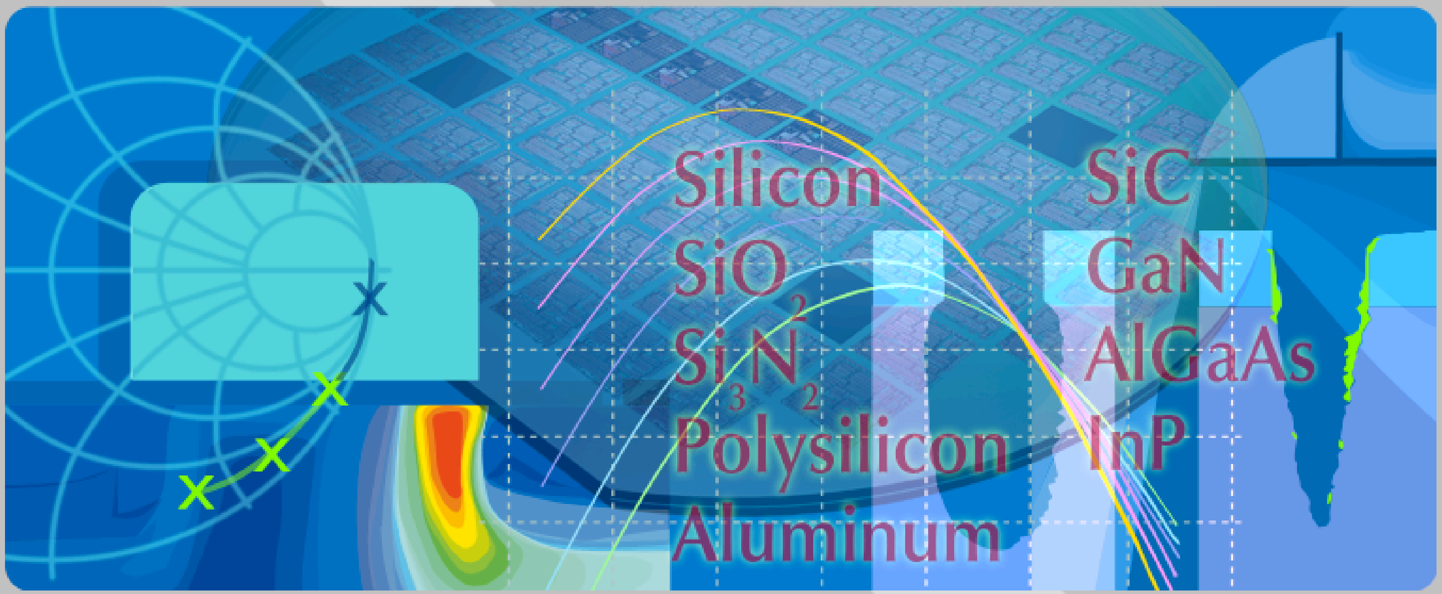
Quantum Device Simulation



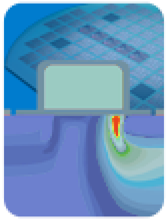
30A MOS CV Curve – Quantum Currents – and PHEMTs

Introduction

- Why a Quantum Mechanical based simulator is necessary
- Introduction to QM issues and theory
- Implementation and syntax
- Practicalities of use
- Examples (MOS, PHEMT, Diode)

Introduction (con't)

- Why Use a QM simulator
  - Reduction in device size => coherence length of electrons
  - Thin gate oxides => CV shift
  - Channel sheet carrier shift => MOS/HEMT
  - Heterojunction tunneling
  - Pulse doping 'smear'

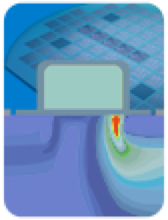


Quantum Issues

- Quantization “carrier confinement”
  - 1D/2D/3D => Quantum Well/Wire/Dot
  - Schrodinger's Equation

$$-\left(\frac{h^2}{2m^*}\frac{d^2}{dx^2} + V(y)\right)\psi_i(y) = E_i\,\psi_i(y)$$

  - Eigen Value Problem



Quantum Issues (con't)

- Results appear as a sequence of
  - Eigen energies => Discrete energies where electrons may reside
  - Eigen functions => Probability distribution of electrons along each slice
- Schrodinger -Poisson => Spacial distribution of electrons to replace classical one

Quantum Issues (con't)

- Transport
  - Transmission, Deflection
  - Concentration
- Quantum corrections to standard transport equations
- Provided by Quantum moments equation

$$Uq = - \frac{\hbar^2}{8m^*} \nabla^2 Ln(n)$$

- Based on second moments of the Wigner distribution function
- Quantum Temperature => Quantum diffusion term
- Bohm Quantum Potential

Implementation and Syntax

- Schrodinger-Poisson Solver
  - models Schrodinger Eigens =15
- Quantum Moments
  - models quantum
  - solve qx.damp=1.0
- Bohm Quantum Potential
  - BQP

Electrostatic Potential, Classical and Quantum Electron Concentrations

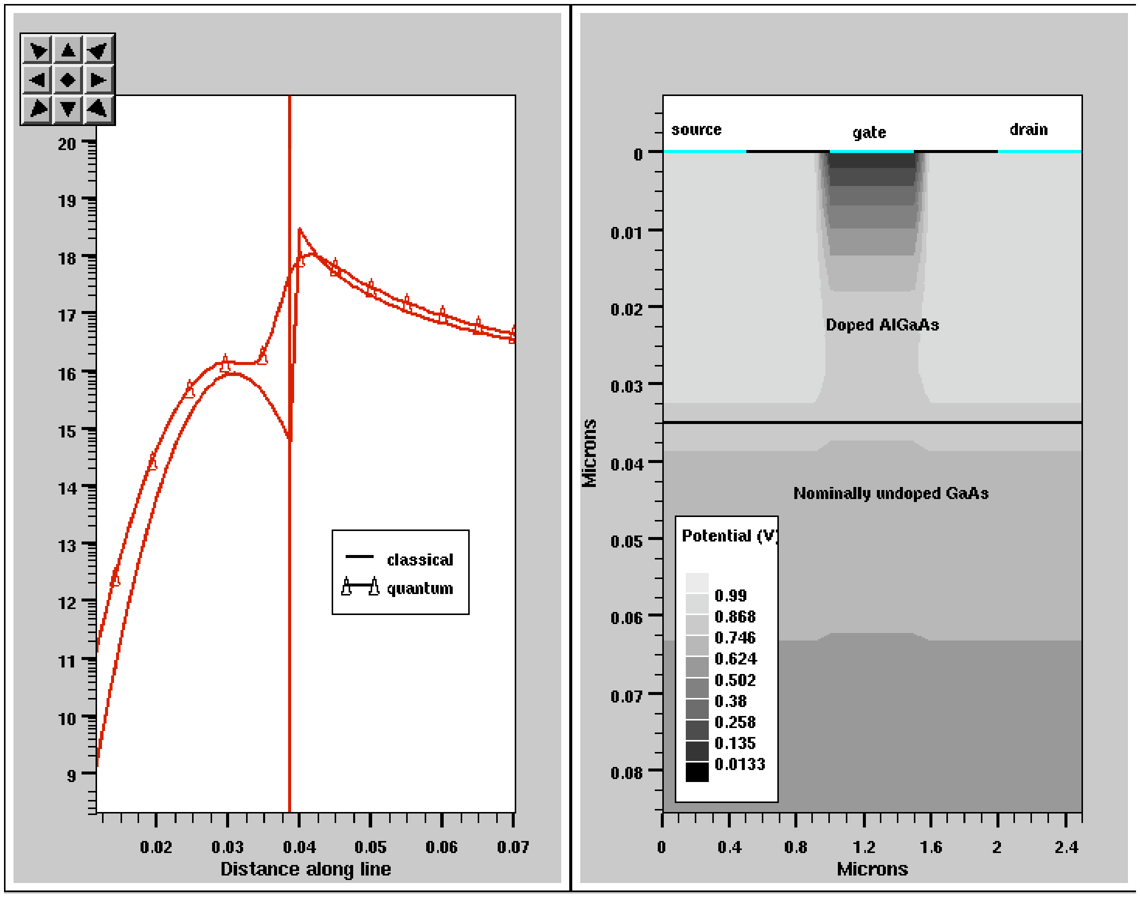


Figure 1.

Eigen Wave Functions and Energy Levels

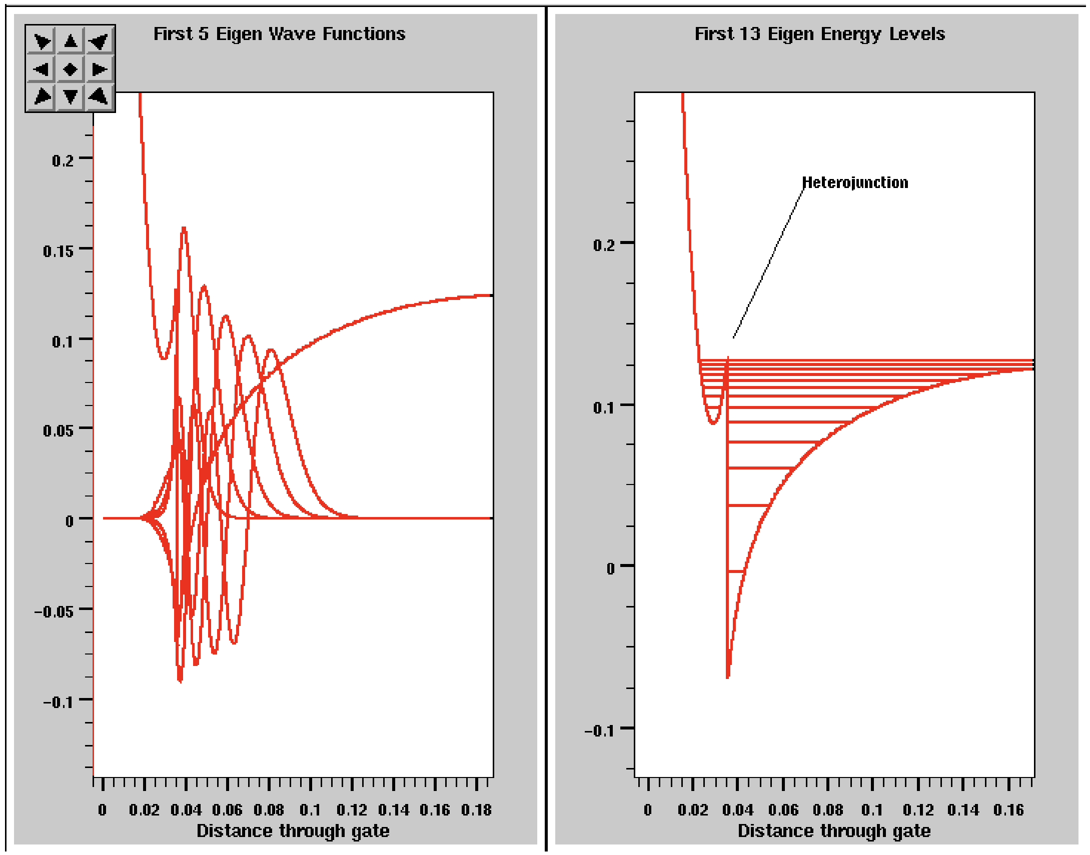


Figure 2.

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MOS 30A Gate – CV Curve

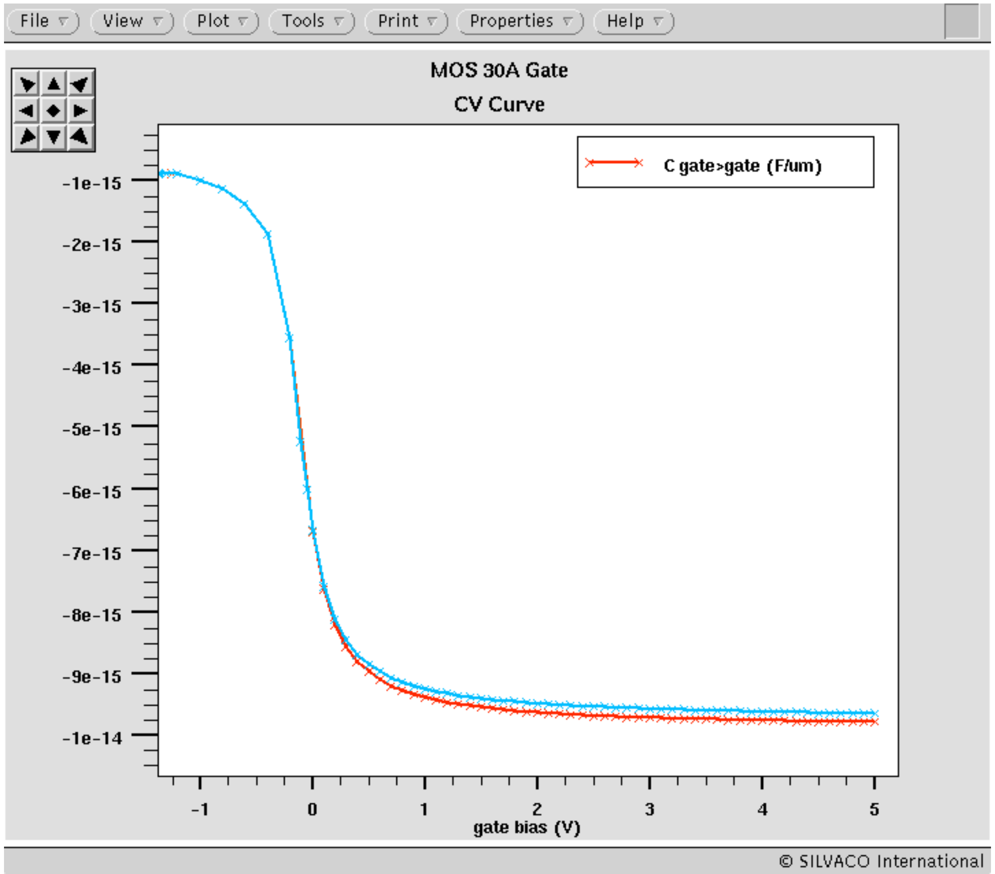
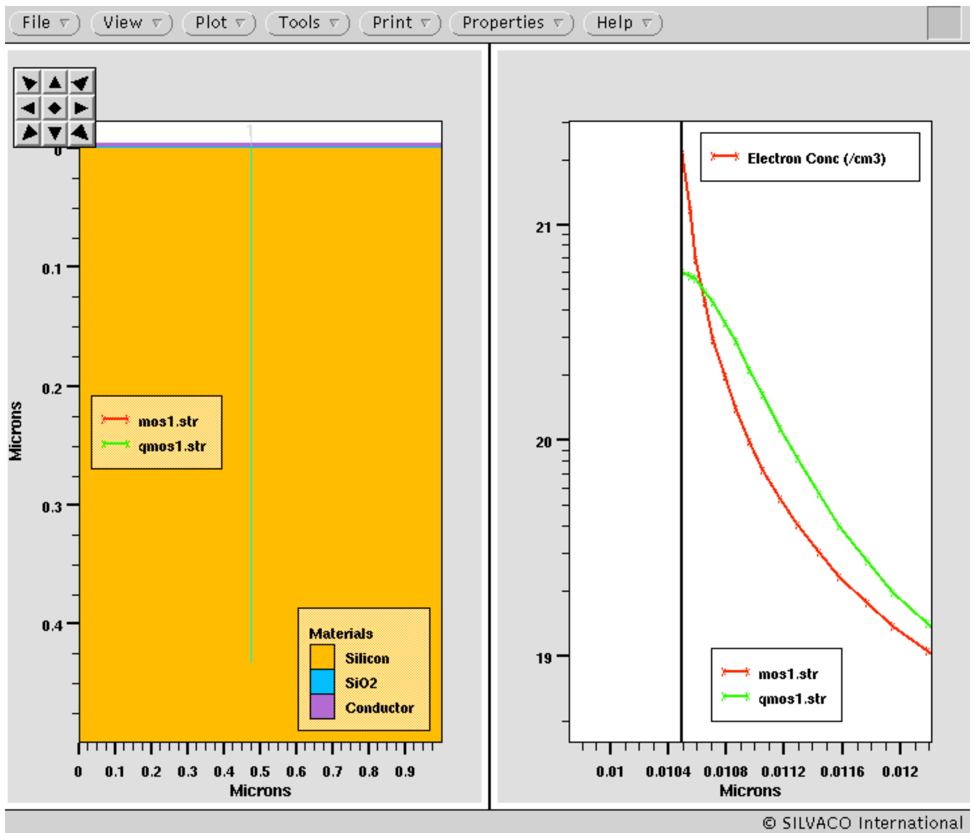


Figure 3.



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Microns
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Materials
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SiO2
Conductor
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Electron Conc (/cm3)
21
20
19
mos1.str
qmos1.str
0.01
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0.0108
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Microns
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Figure 4.

Classical and Quantum Electron Concentrations

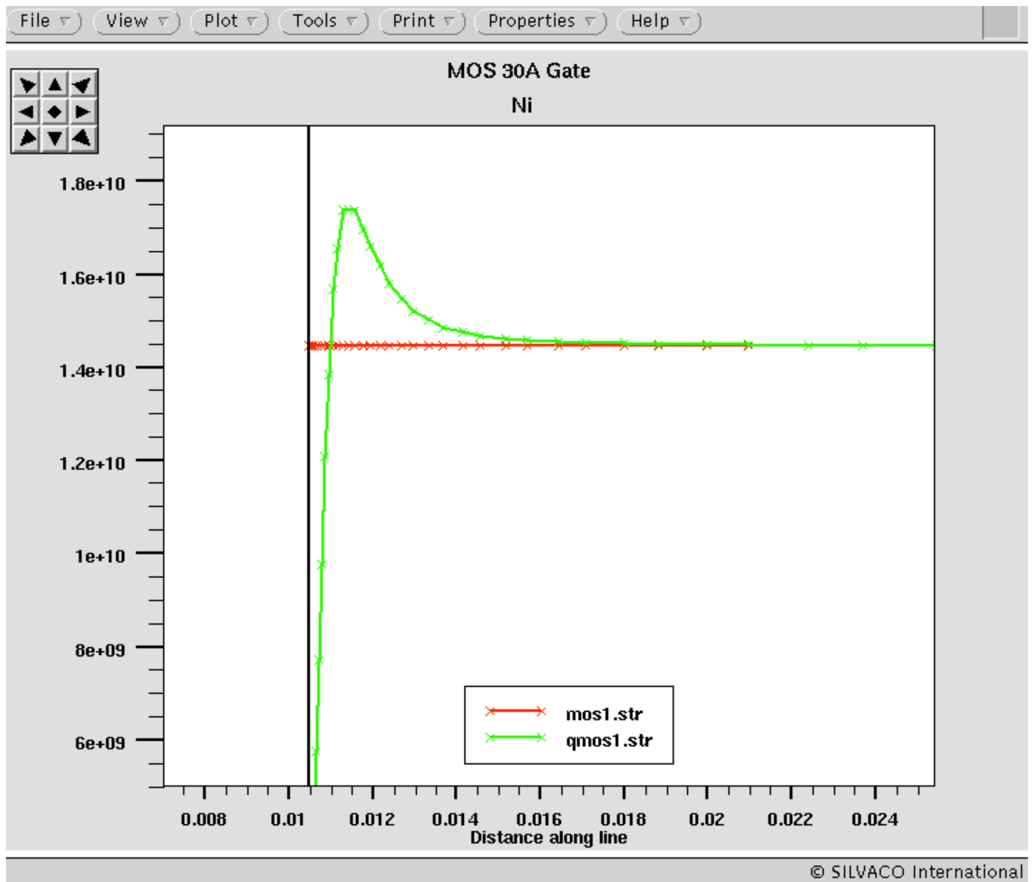


Figure 5.

HDiode

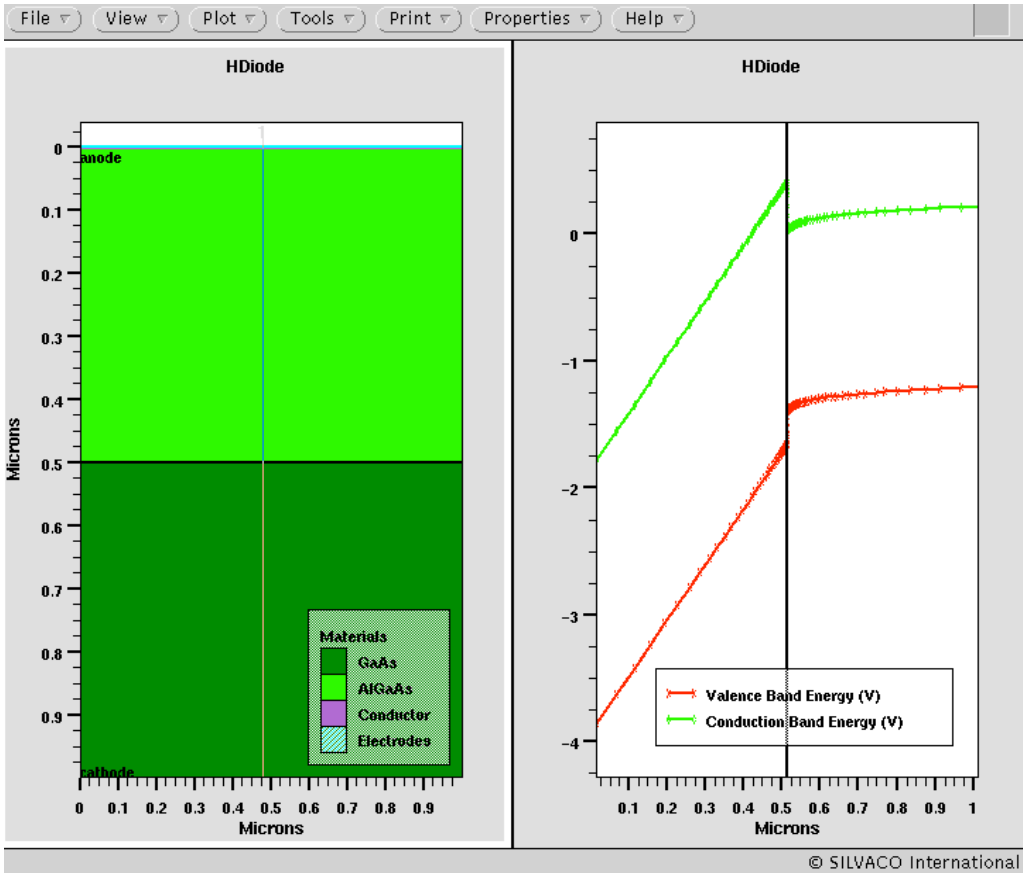


Figure 6.

Classical and Quantum Electron Concentrations

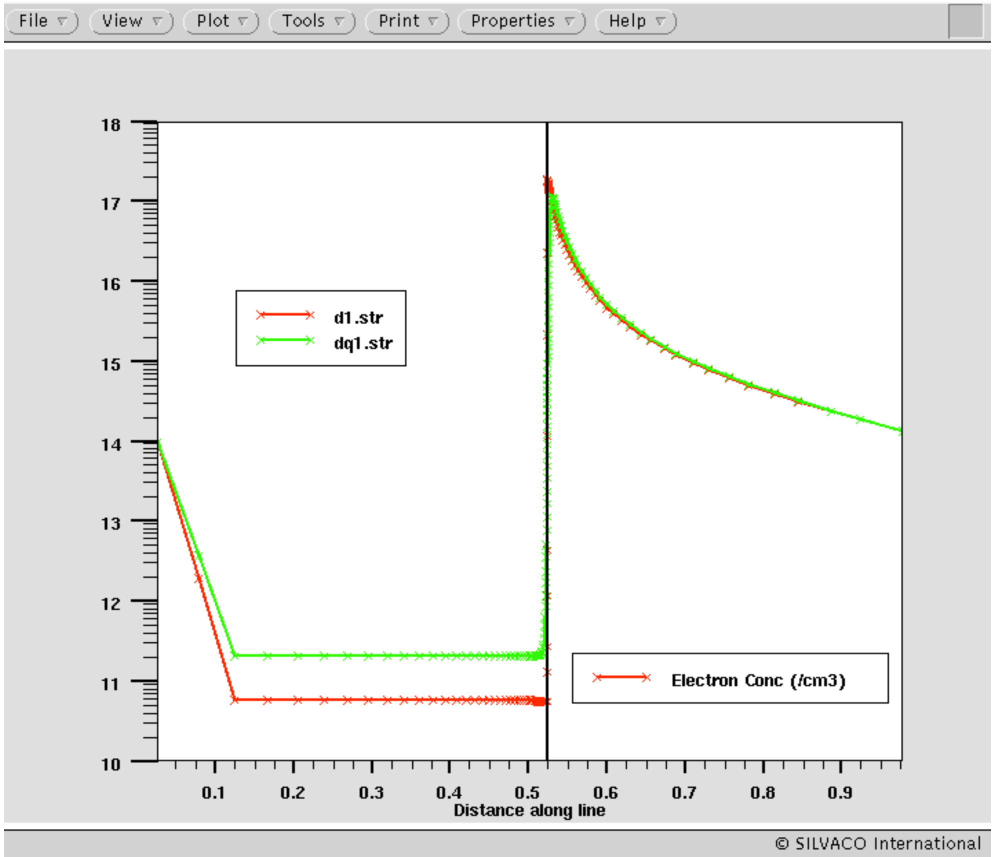


Figure 7.

Classical and Quantum Currents

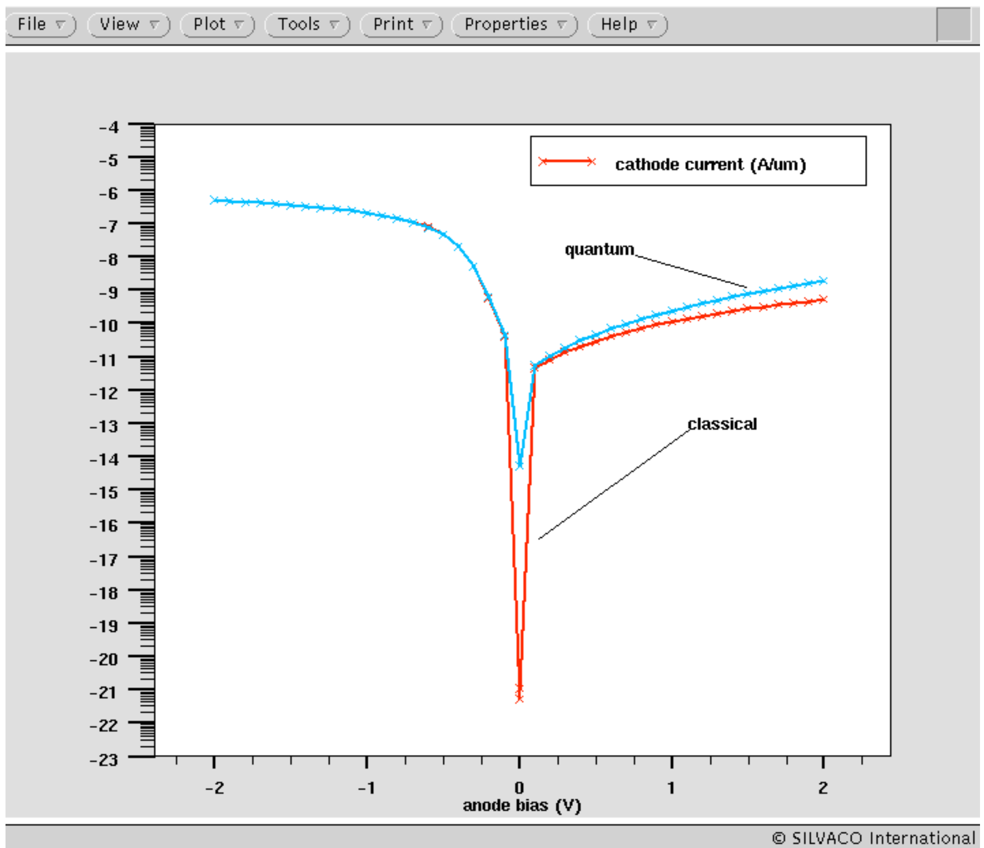


Figure 8.

PHEMT – Zero Bias Case

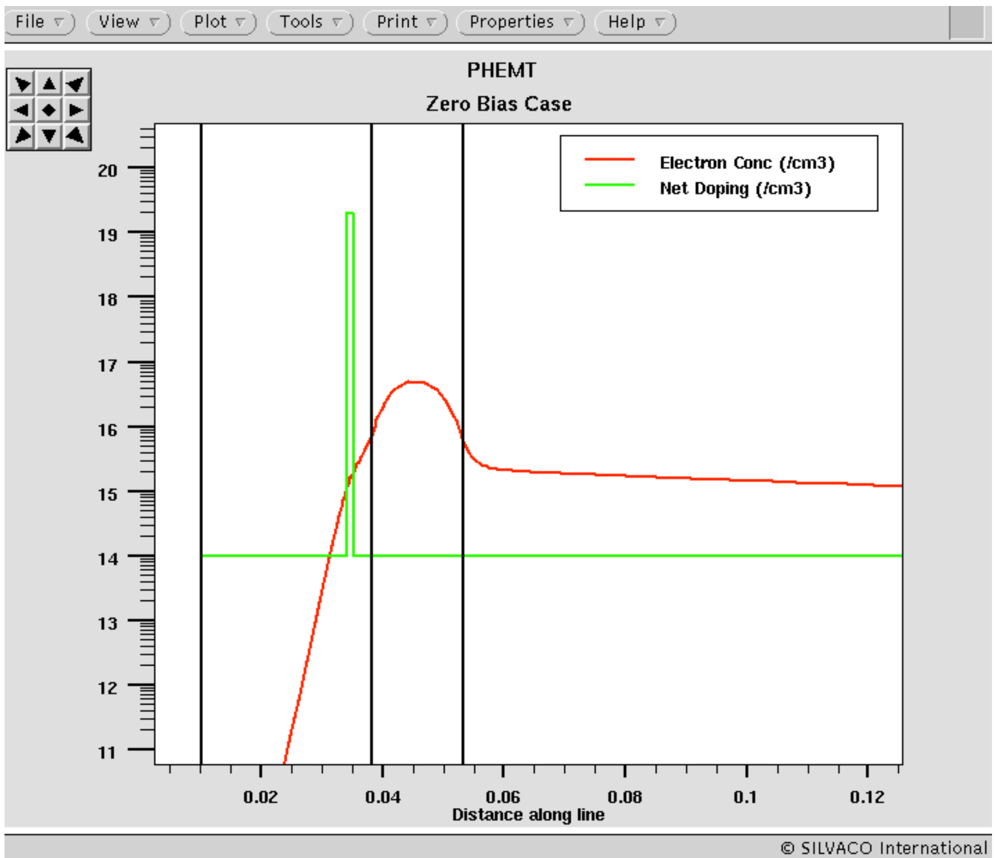


Figure 9.

PHMET

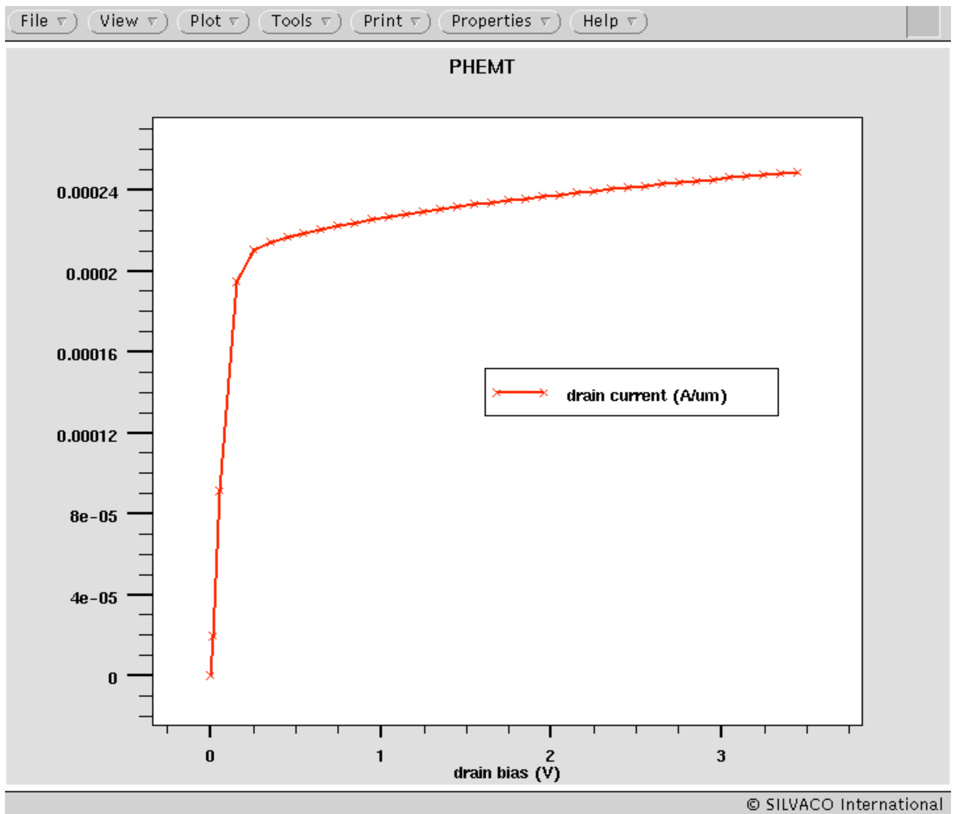
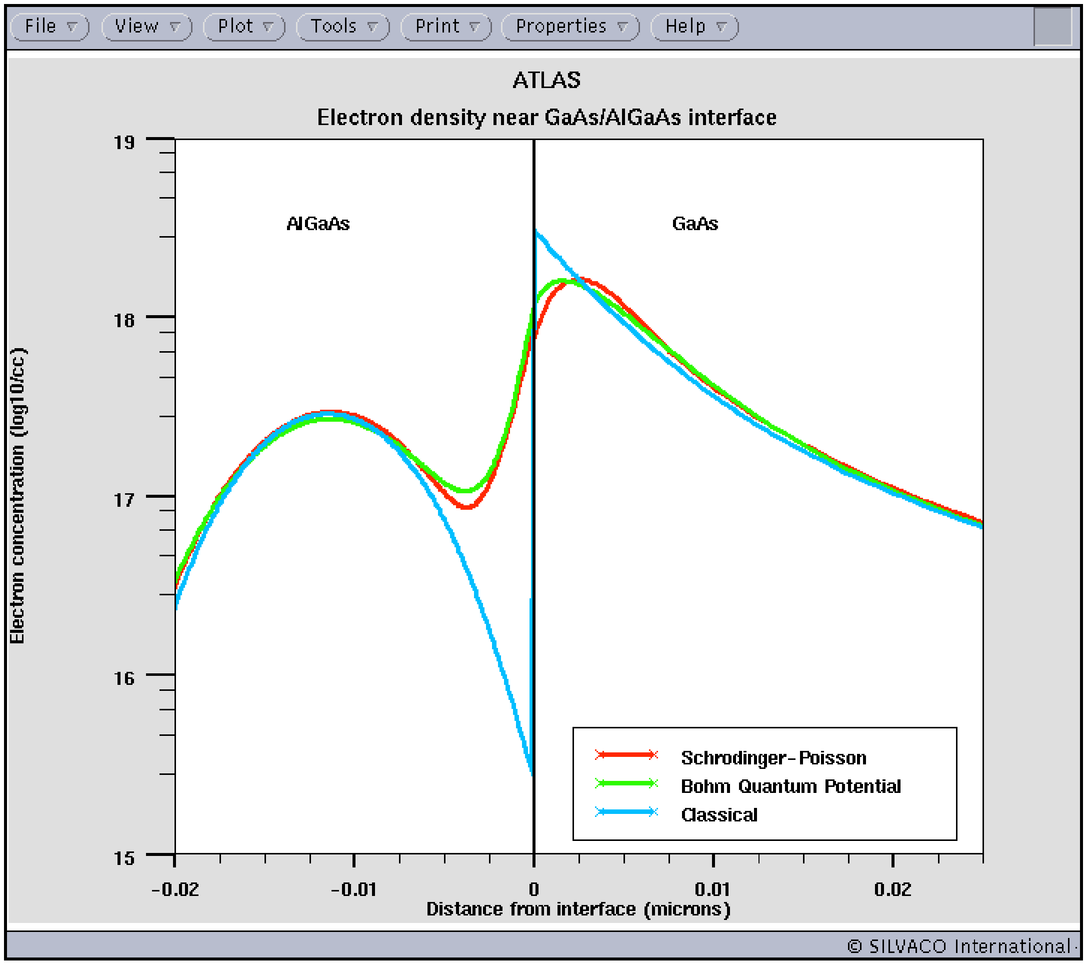
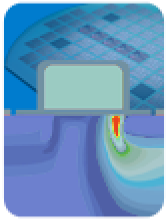


Figure 10.

Model Comparison





Conclusion

- As a device dimenstions shrink, qunatum effects become more significant
- Schrodinger-Poisson solve provides calculations of bound state energies, carrier wave functions and carrier concentrations
- Quantum effects included in carrier transport by using quantum moments models