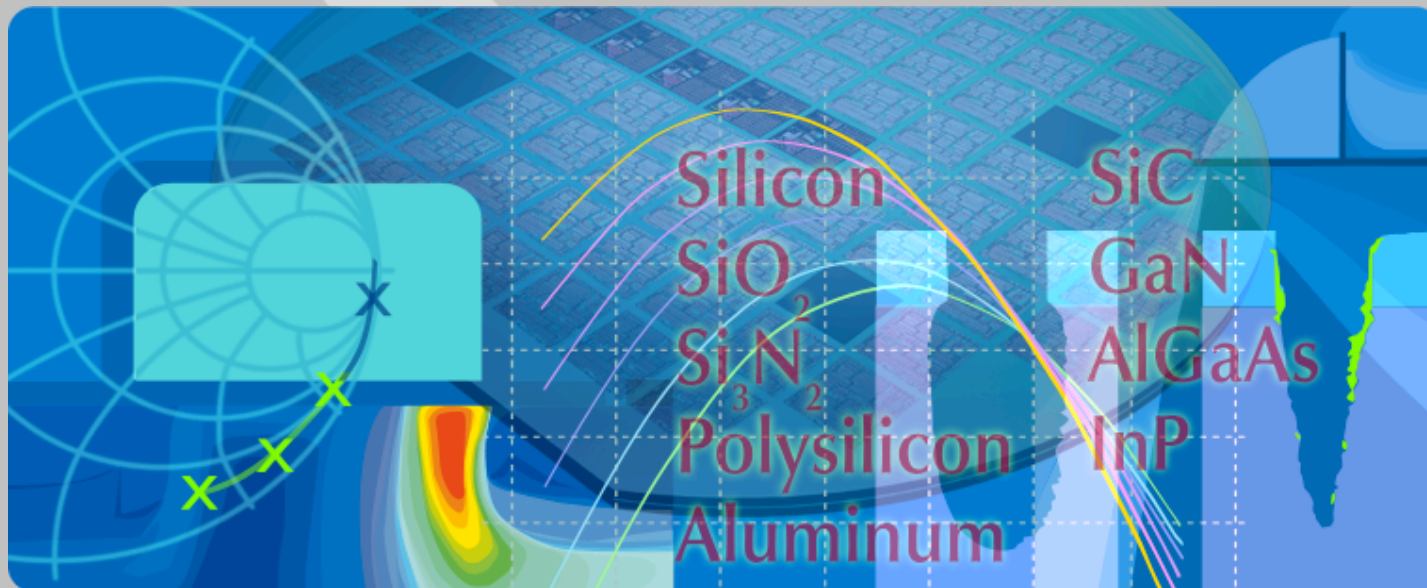


Quantum Device Simulation



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

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

- 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

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

- 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

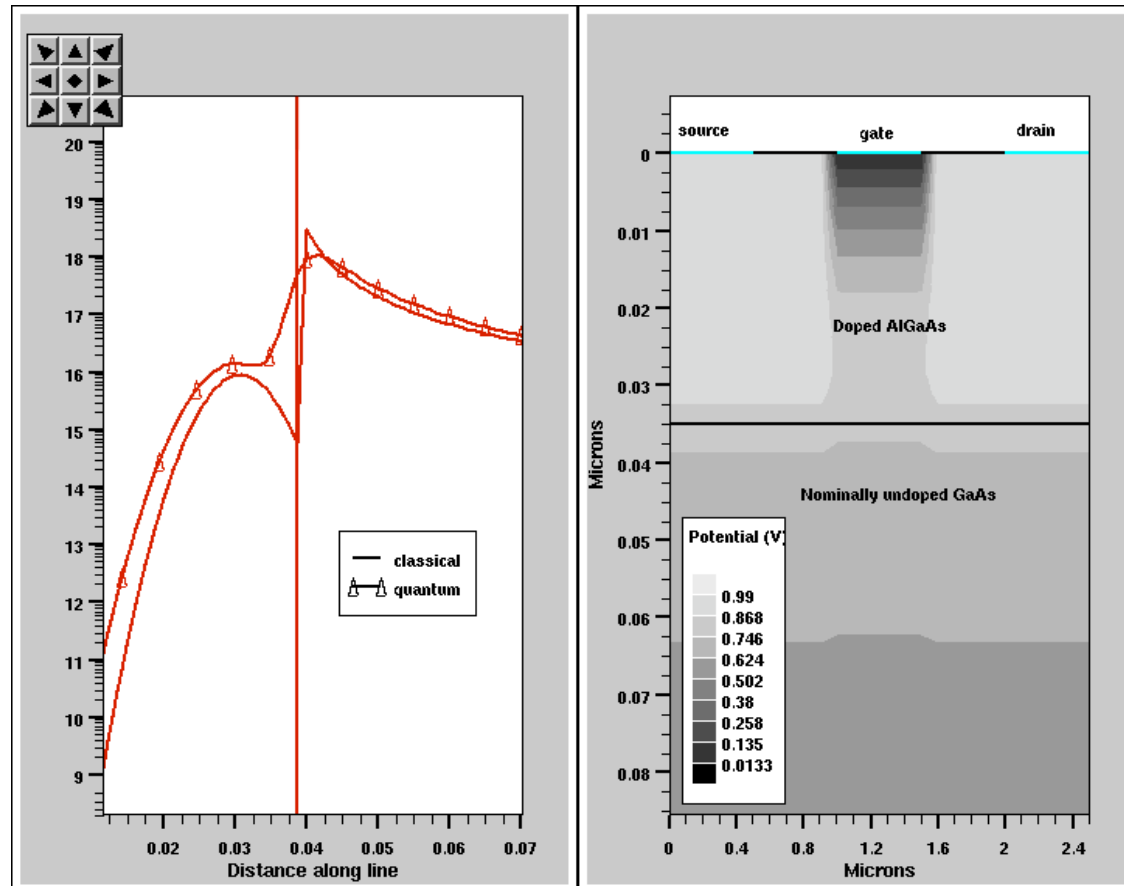


Figure 1.



Eigen Wave Functions and Energy Levels

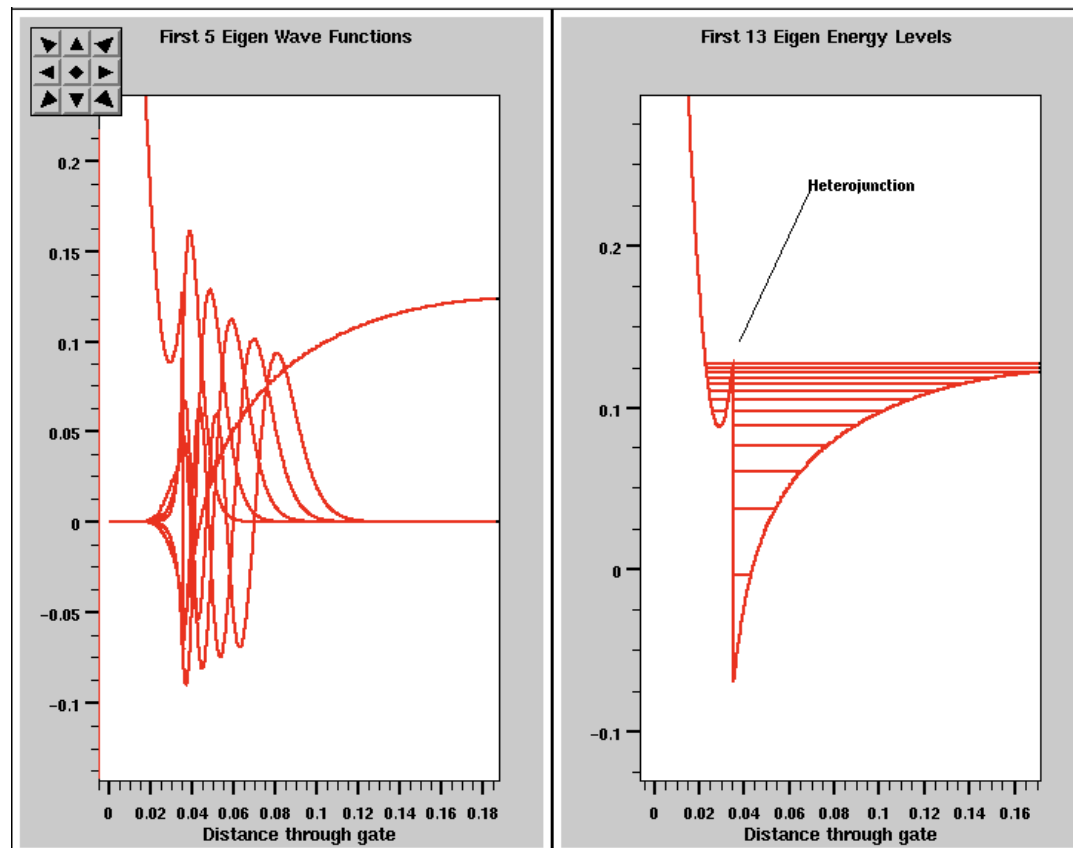


Figure 2.



MOS 30A Gate – CV Curve

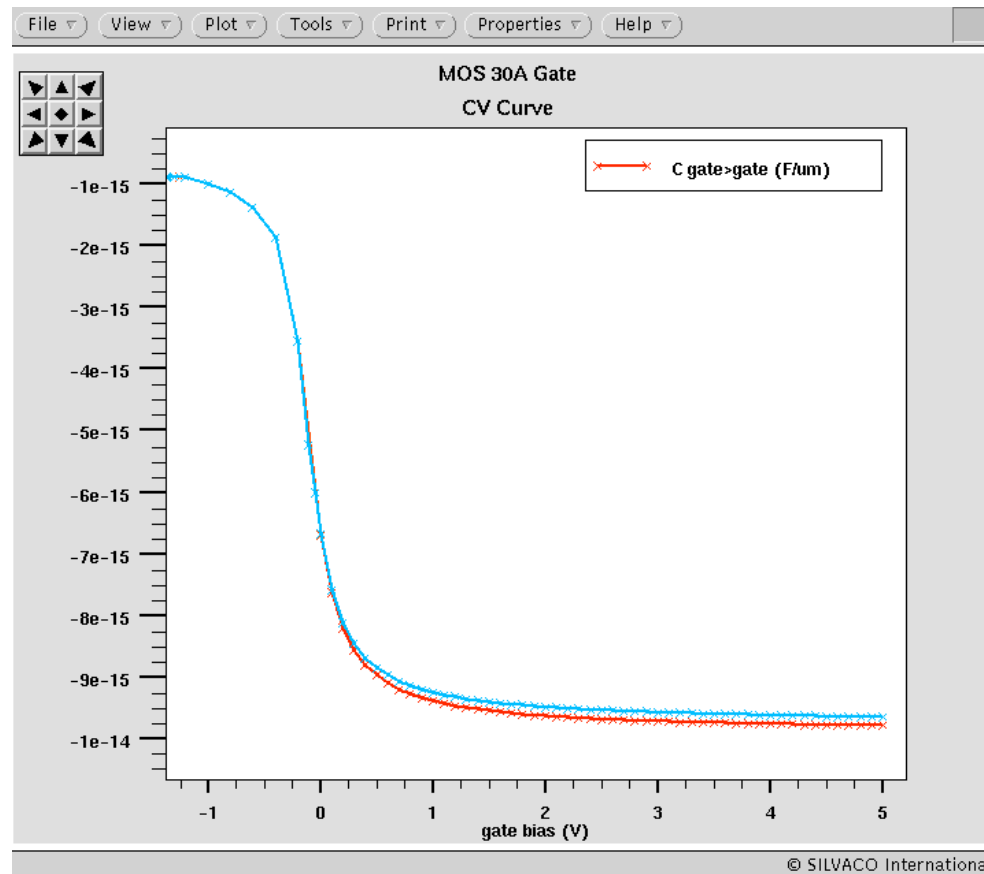


Figure 3.

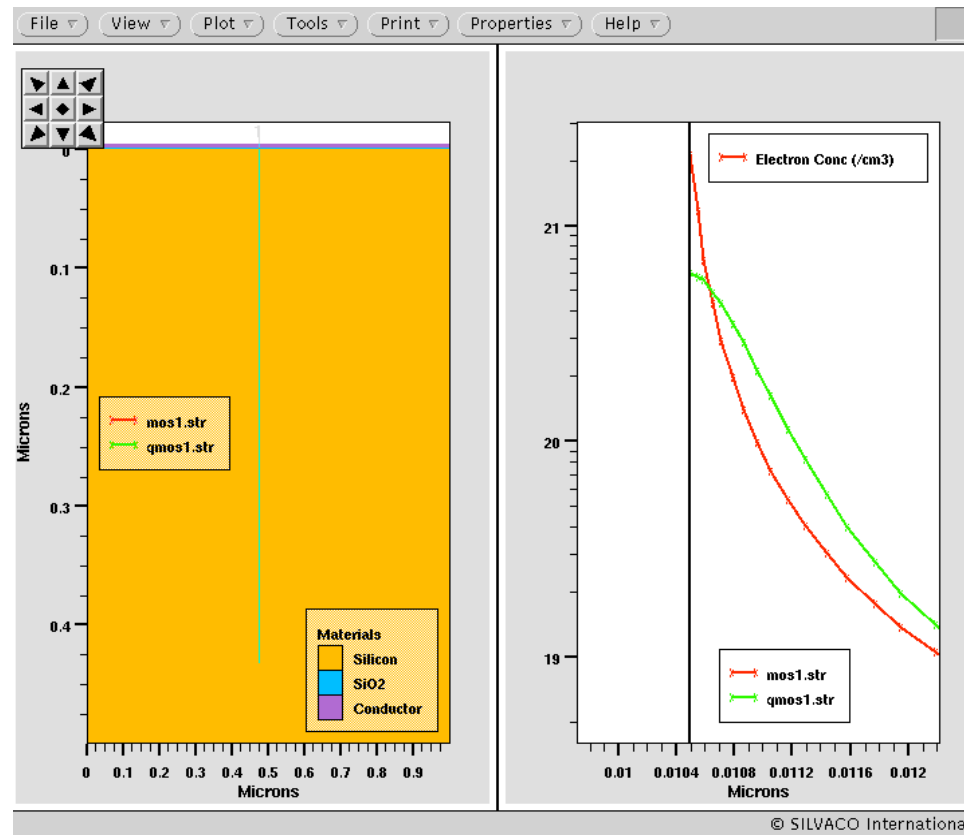


Figure 4.



Classical and Quantum Electron Concentrations

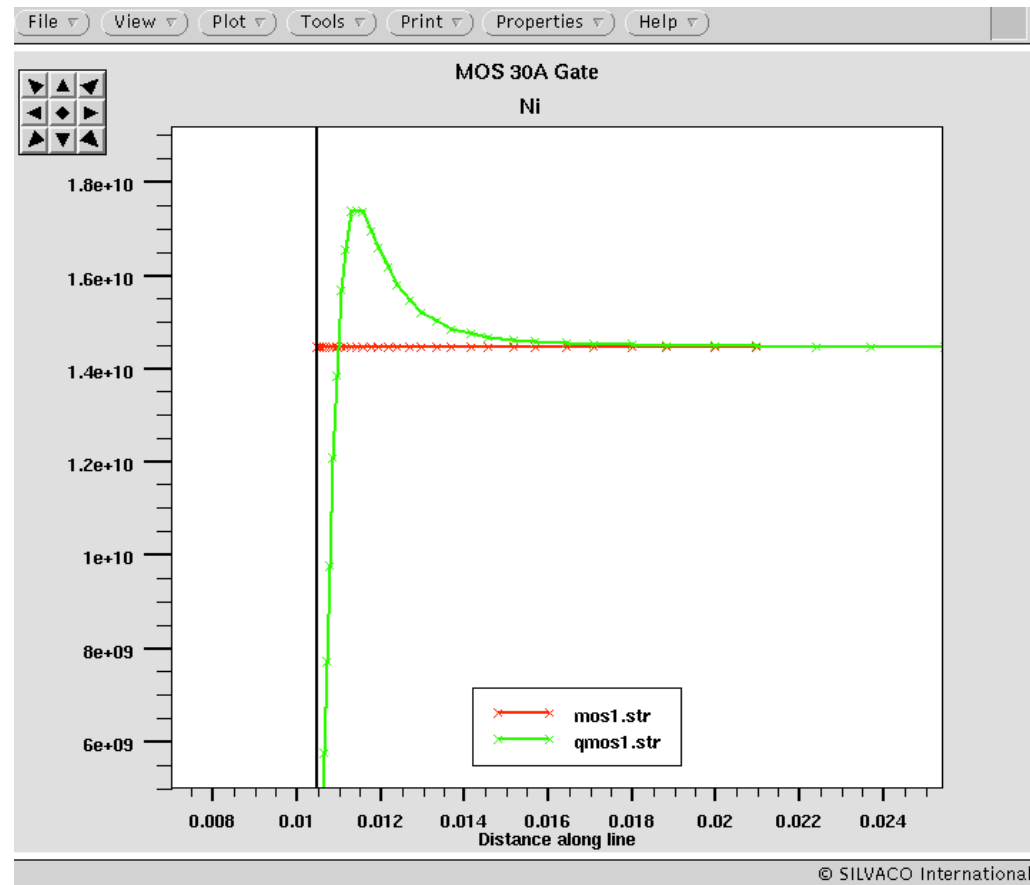


Figure 5.



HDiode

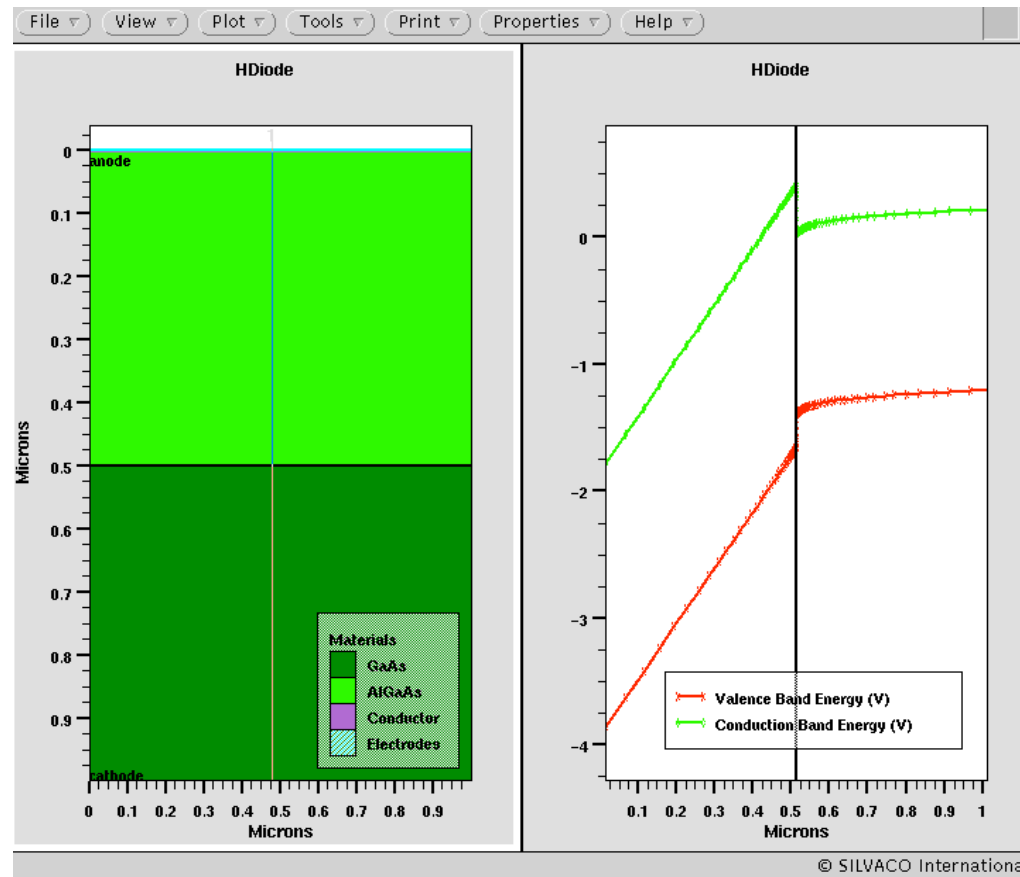


Figure 6.



Classical and Quantum Electron Concentrations

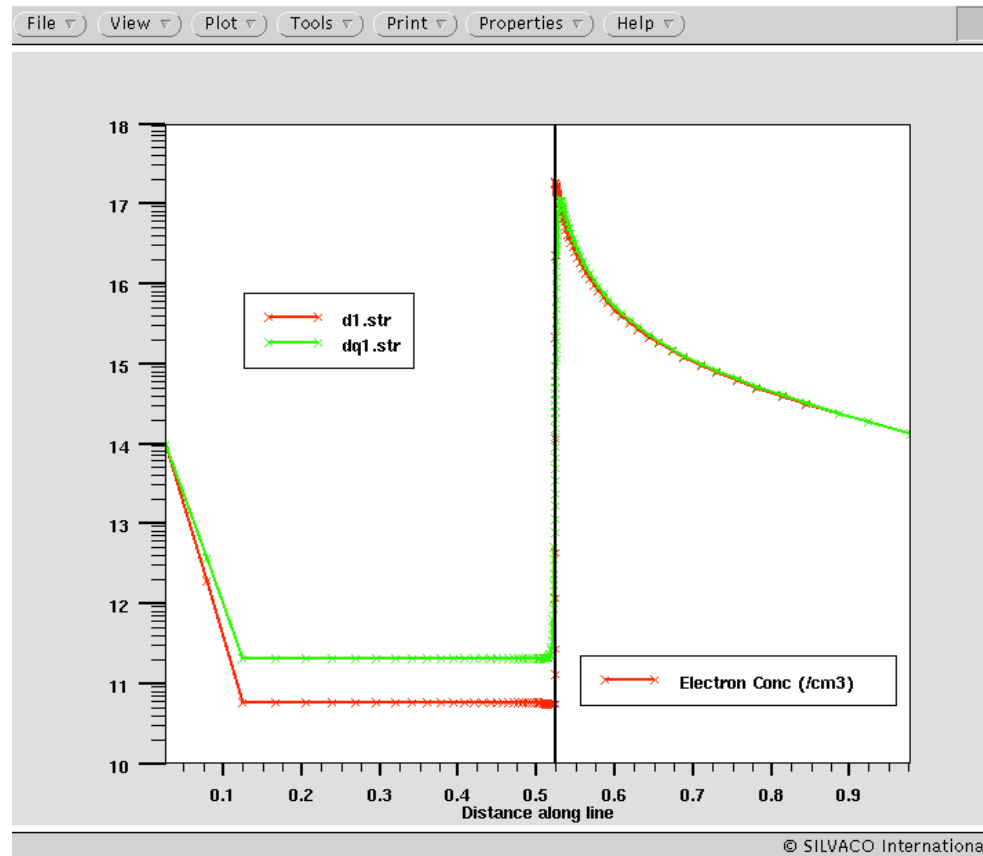


Figure 7.



Classical and Quantum Currents

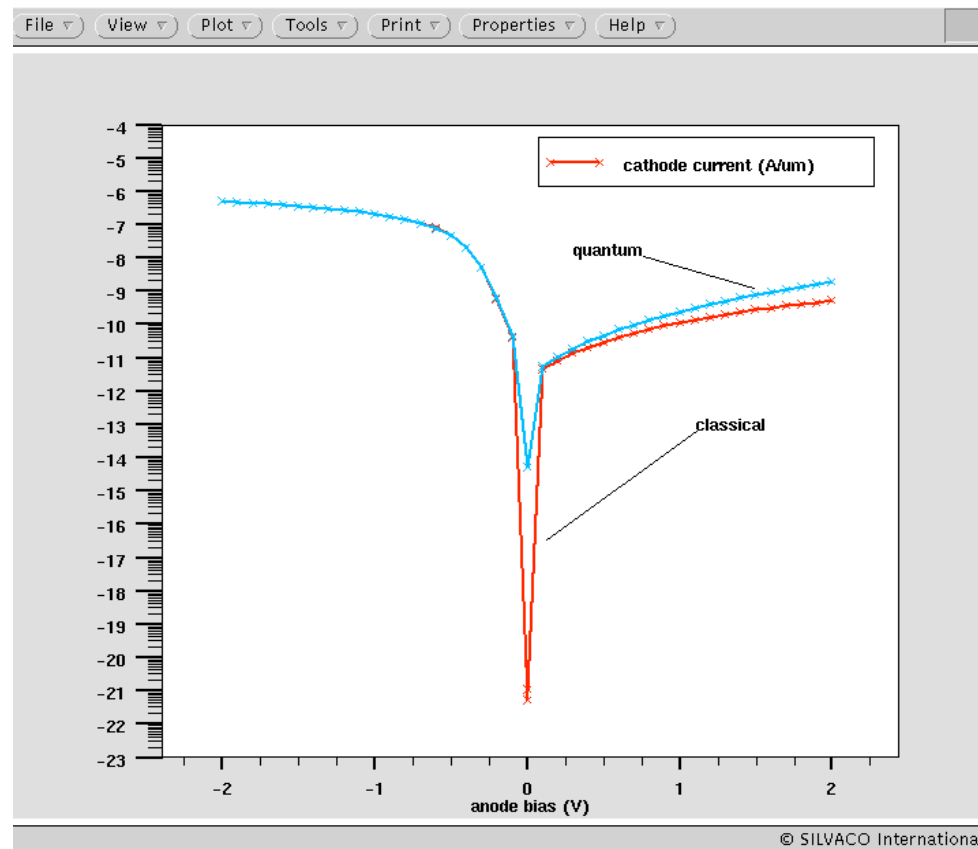


Figure 8.



PHEMT – Zero Bias Case

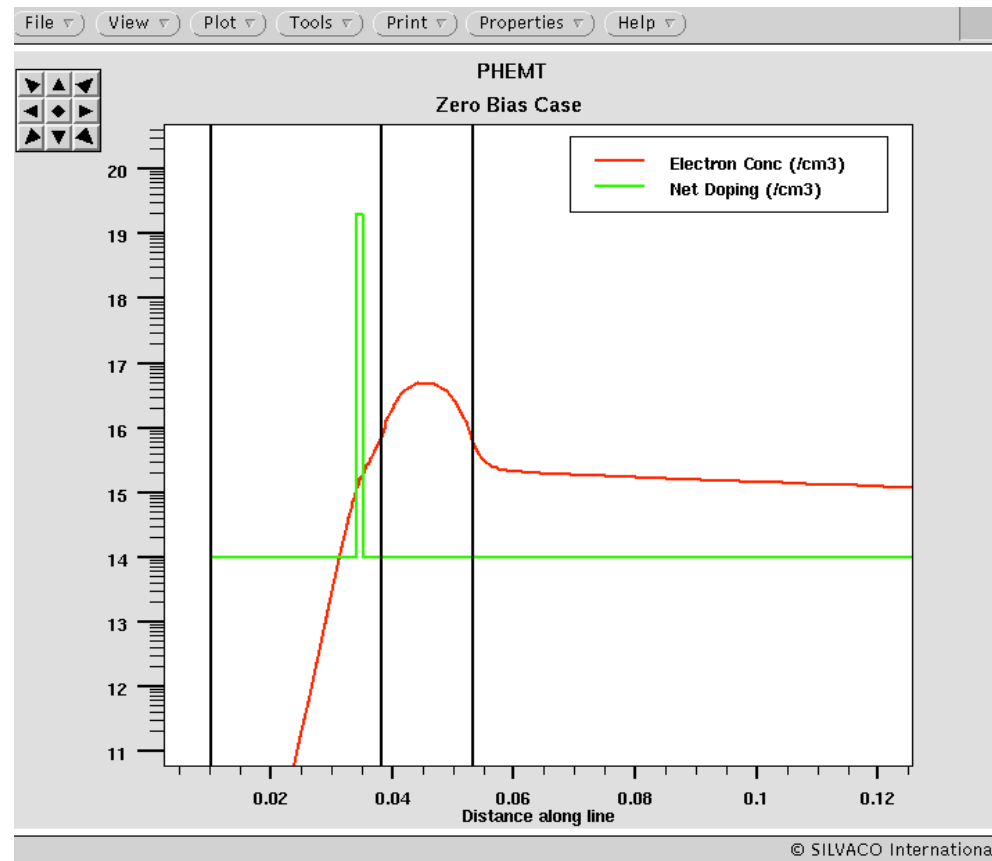


Figure 9.



PHMET

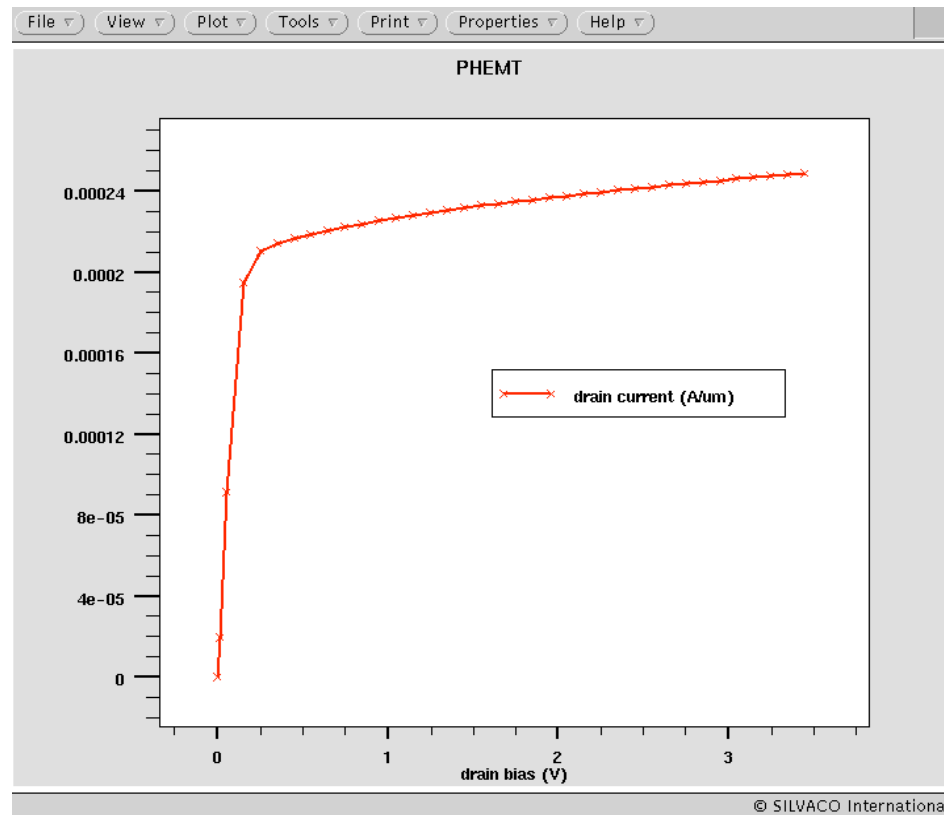
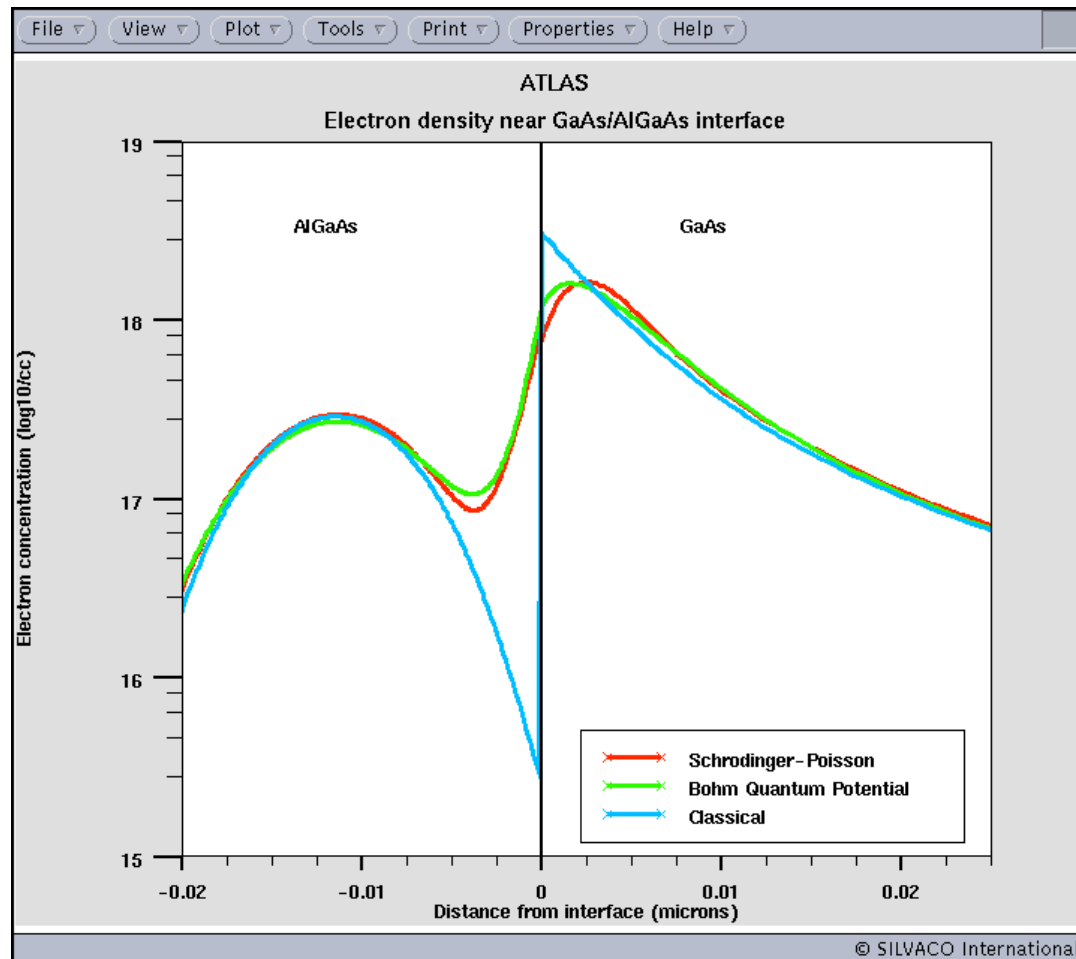


Figure 10.



Model Comparison





Conclusion

- As a device dimensions shrink, quantum 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