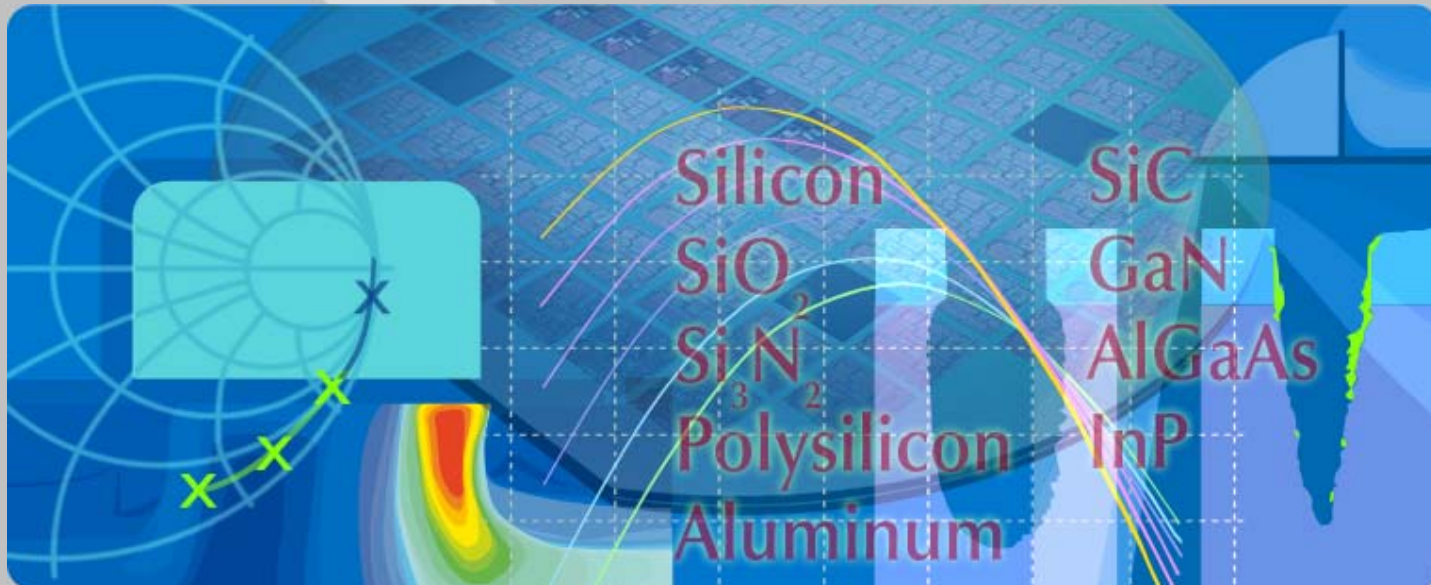


Simulation of Optoelectronic Devices



Günther Zandler



Outline

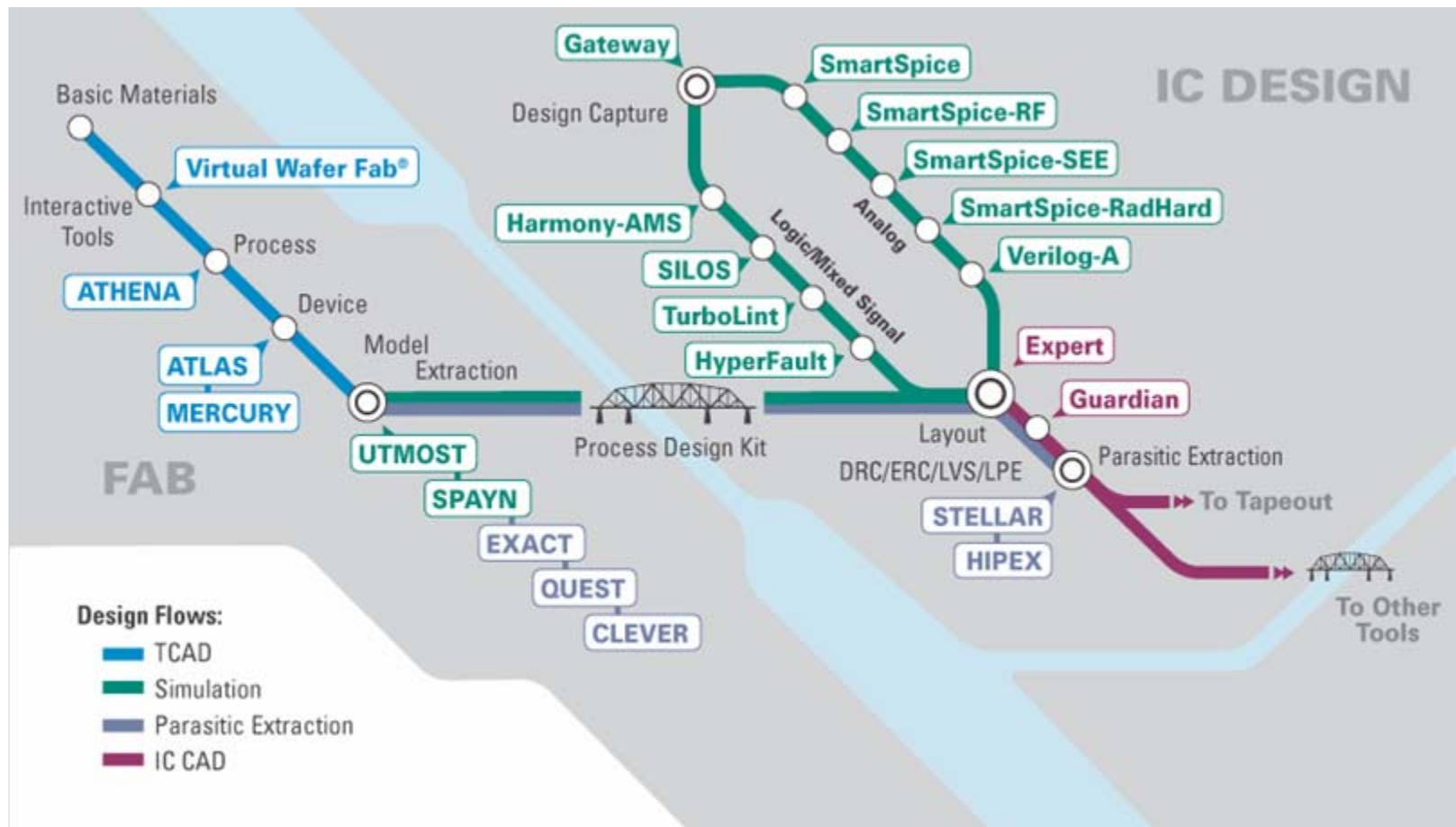
- Silvaco
- ATLAS
- General Optoelectronic Capabilities
- InGaN/GaN Material System
- Optical Coupling
- Micro-Ring Device

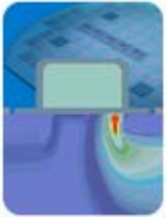


Silvaco Background

- Founded in 1984 by Dr. Ivan Pesic
- Market Leader in SPICE Simulation, TCAD, and IC CAD
- Large Customer Base of Foundry, IDM, ASIC, and Fabless Semiconductor Companies
- Headquarters in Silicon Valley with 11 Offices Worldwide
- Privately Held, Profitable Since Inception, Debt-free
 - Grown from Retained Earnings, No VC Funding
- Currently Employs Over 220 Professionals
 - 80% with Advanced Engineering Degrees (MS, PhD)
- Worldwide Technical Support and Training
- Active Programs with Leading Foundries, EDA Vendors, Universities, Industry Standards, and Government Agencies

Connecting TCAD to Tapeout – Design Flow

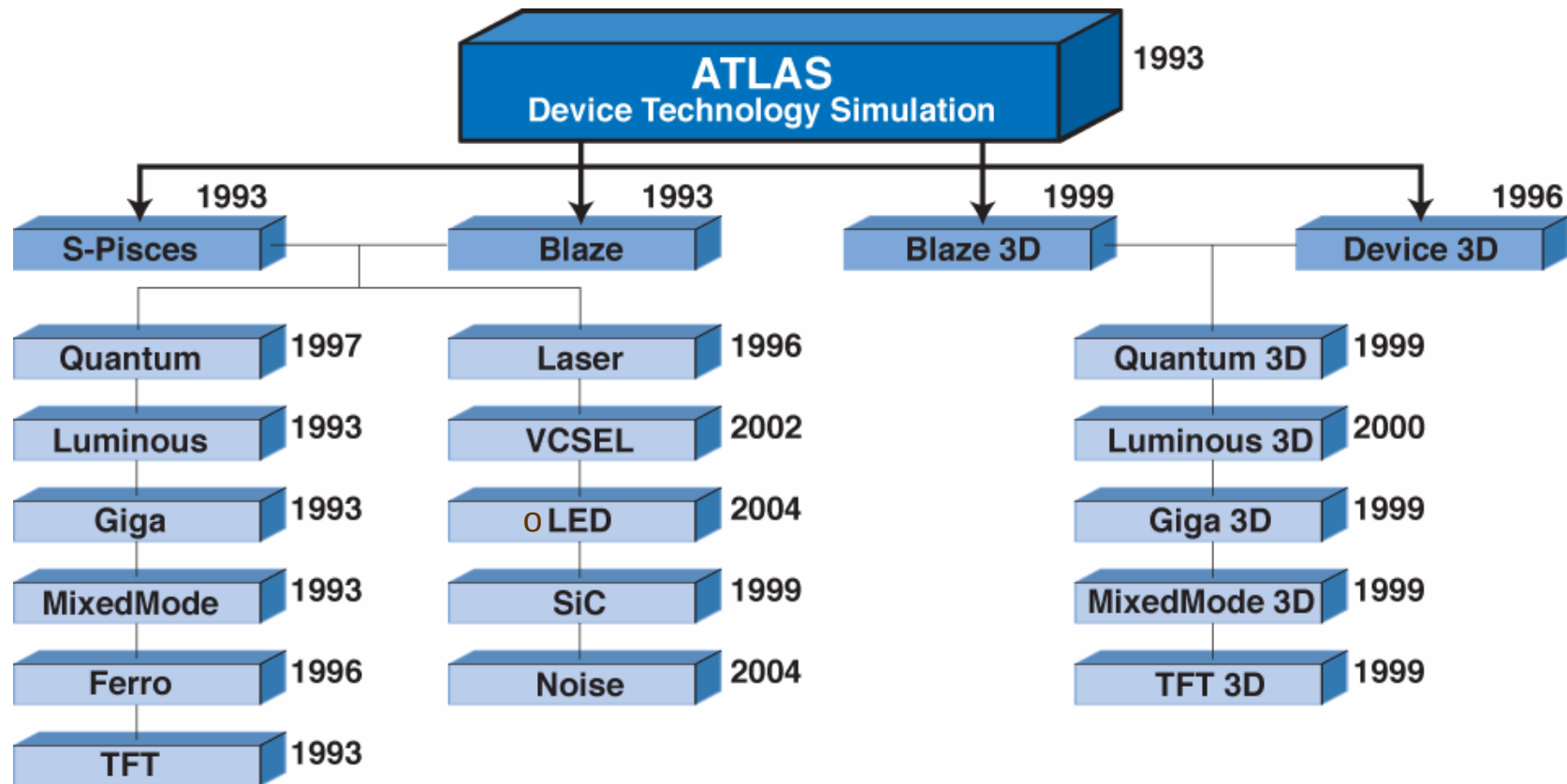




ATLAS Physical Models

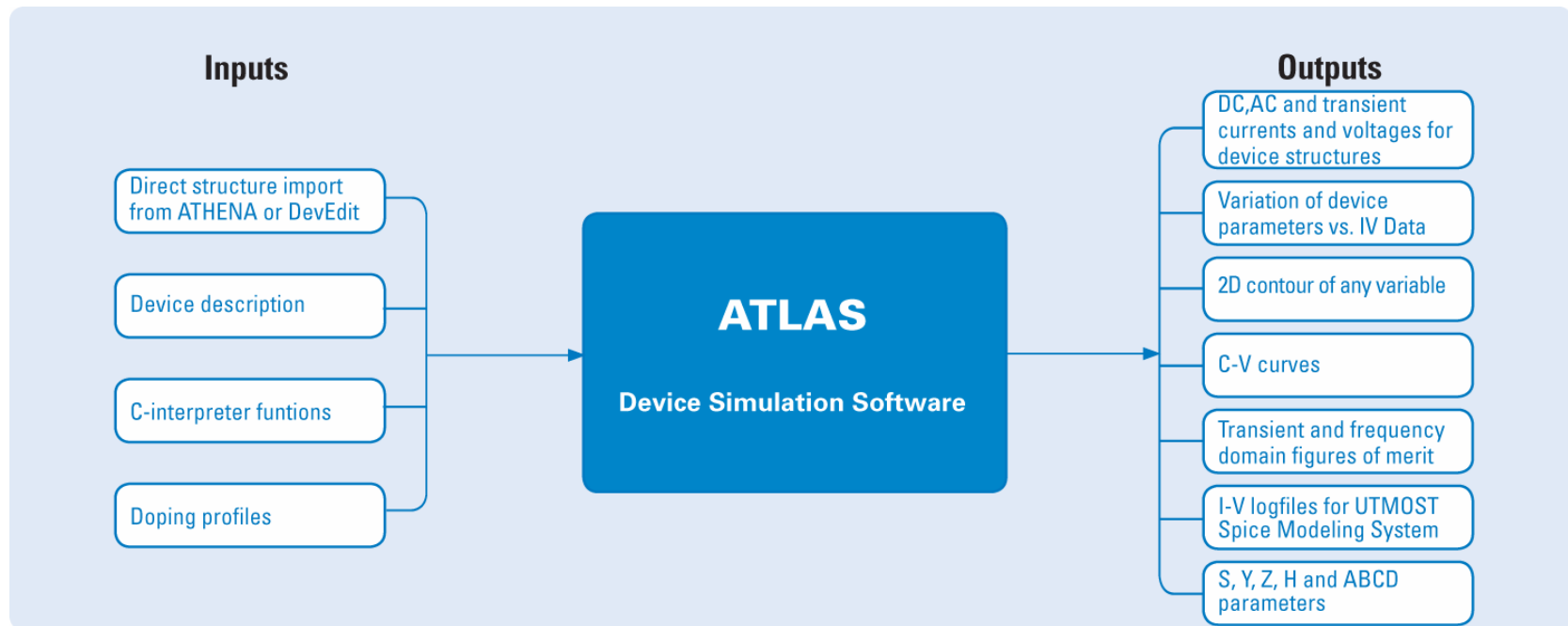
- Drift Diffusion
(Hetrojunctions)
- Heat flow
- Imbedded Circuit
- Energy Balance/Hydrodynamic
- Traps/Amorphous
- Photodetection
(Ray Trace, BPM, Waveguide)
- Quantum Effects
(MOS, S-P, QM, BQP)
- Light Emitters
(LED, Laser, VCSEL)
- C-Interpreter

ATLAS Product Hierarchy

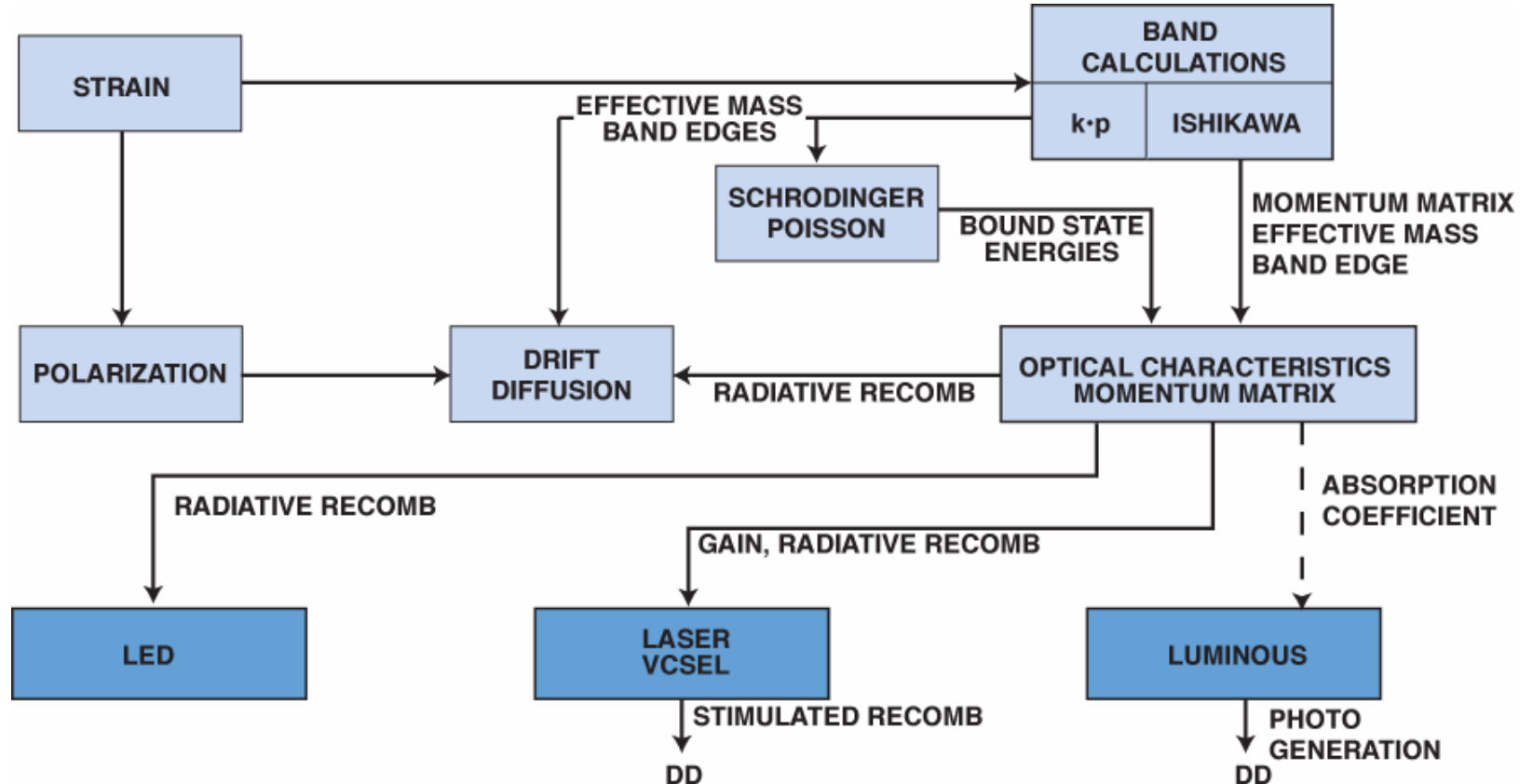




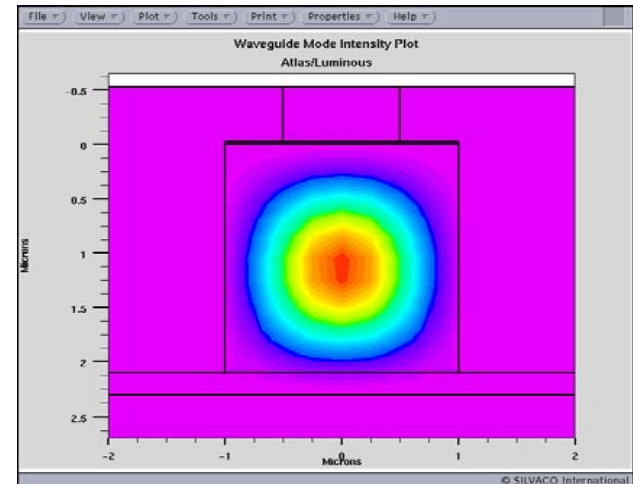
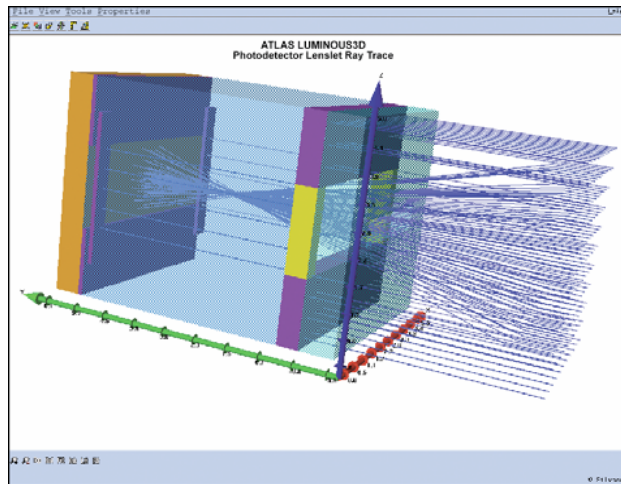
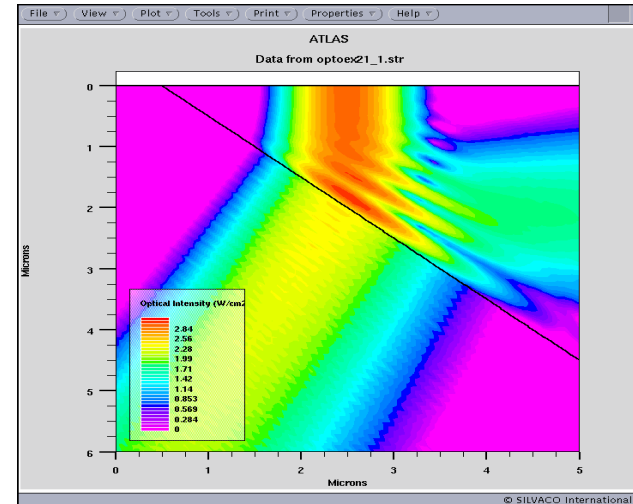
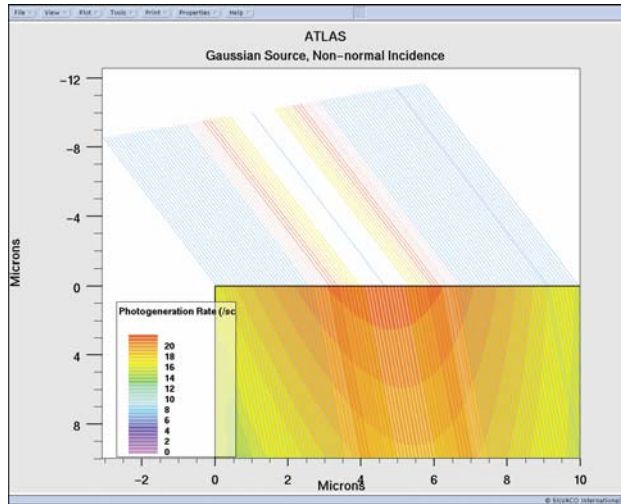
ATLAS Context



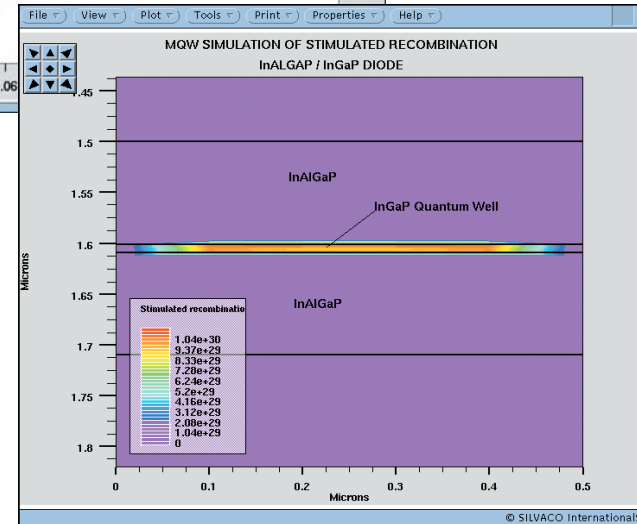
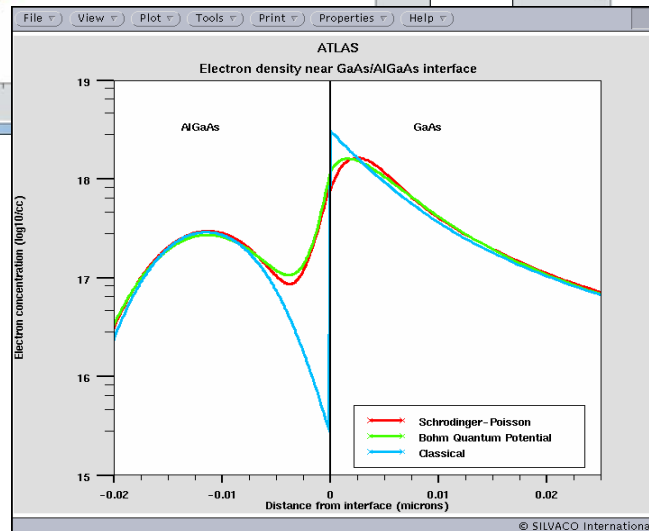
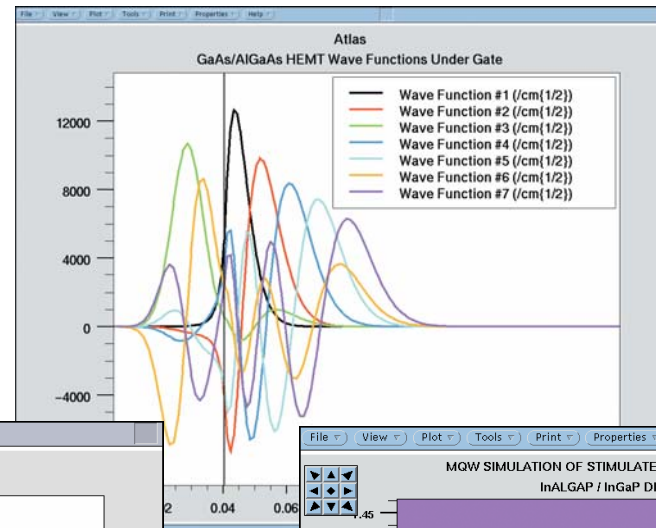
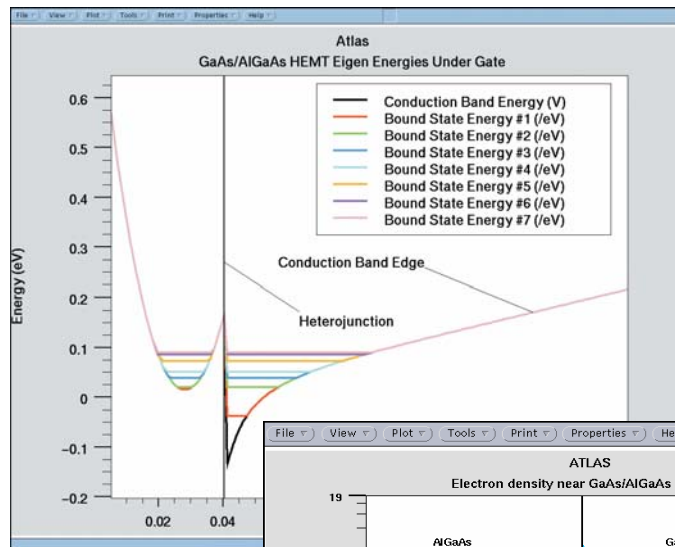
Optical Models



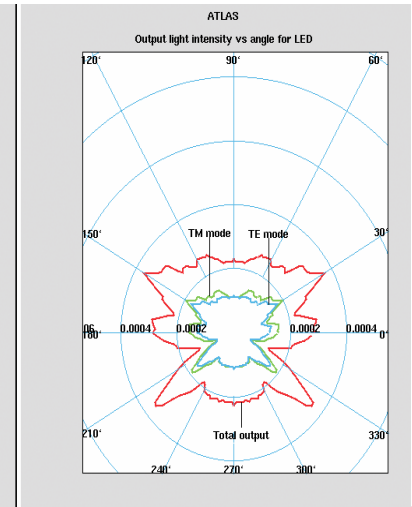
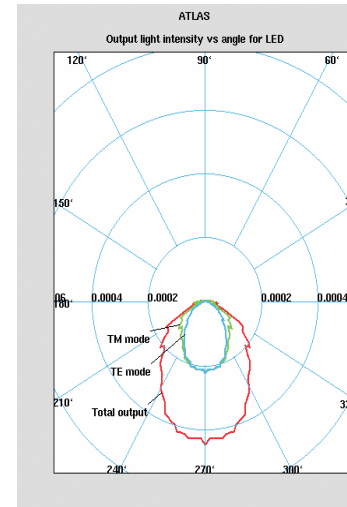
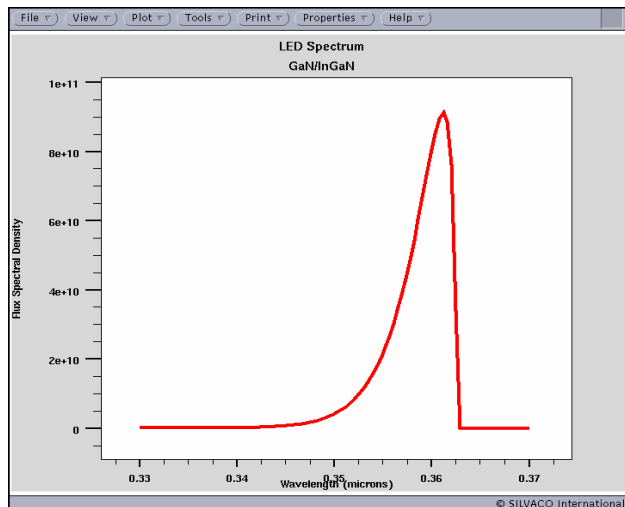
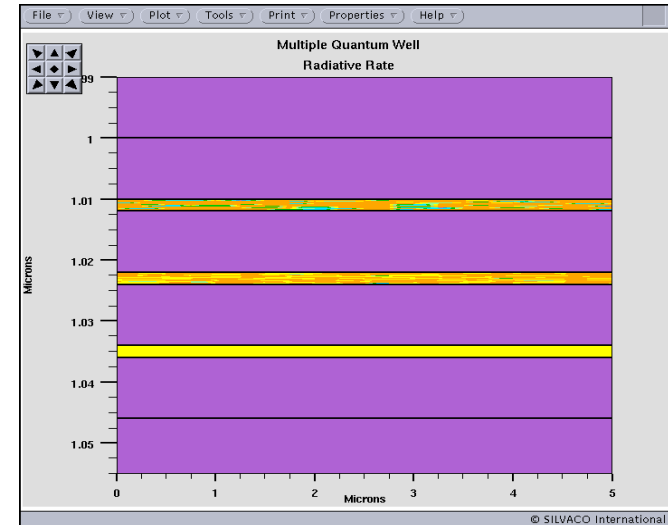
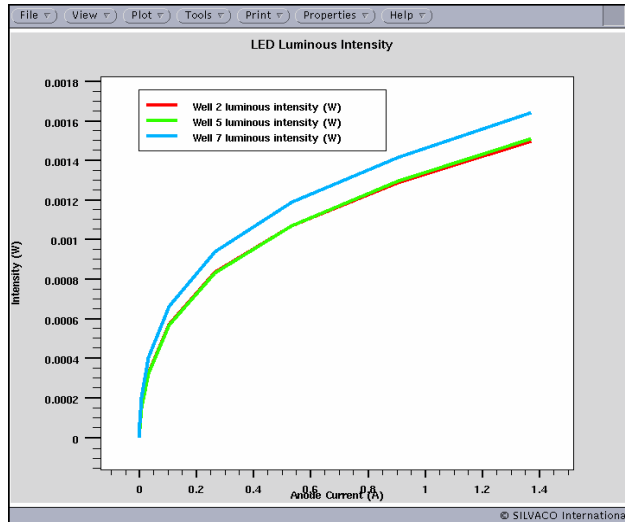
ATLAS – Luminous



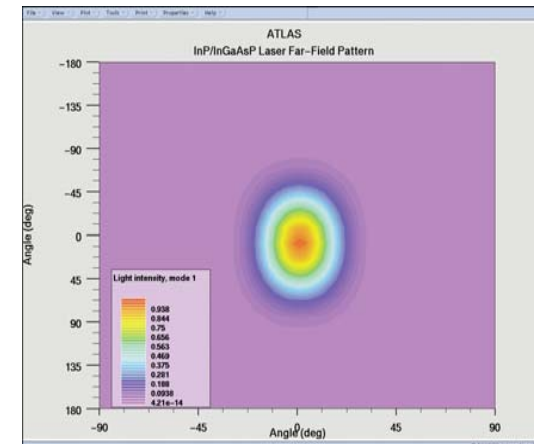
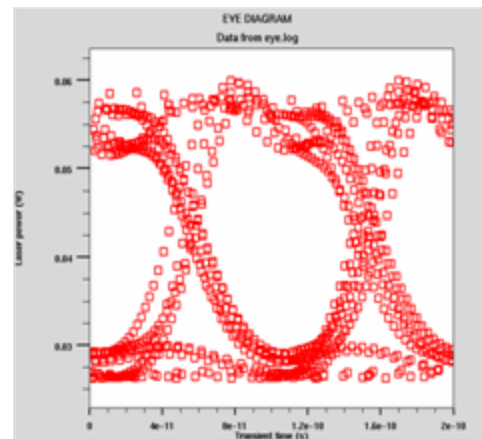
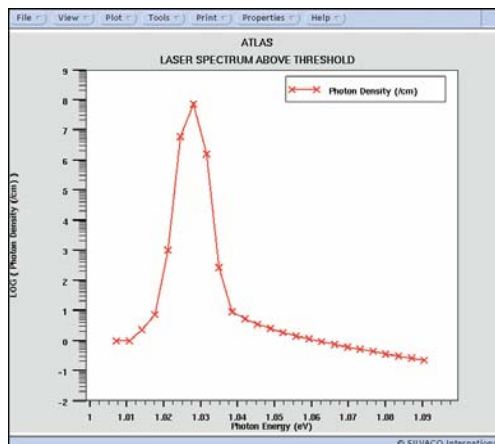
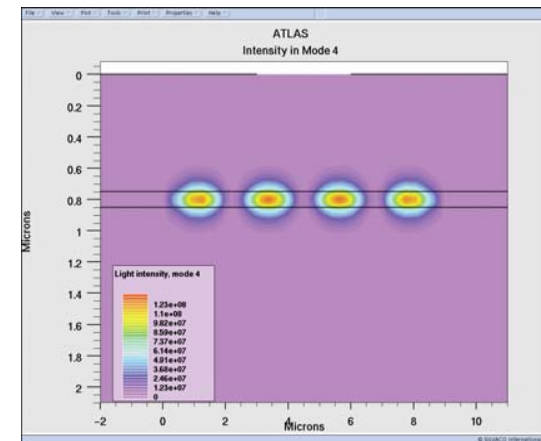
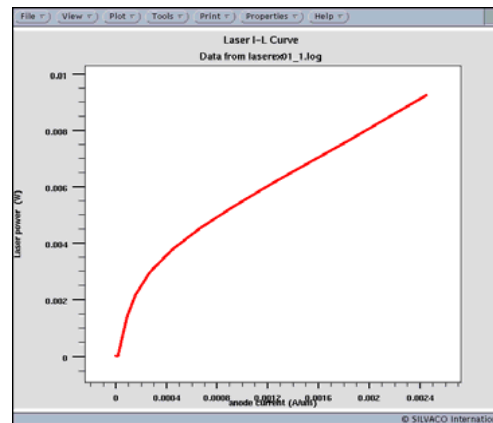
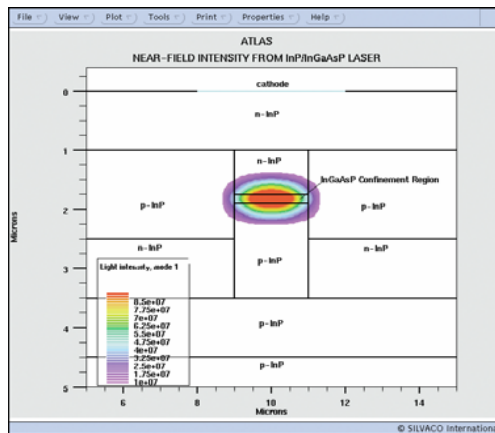
ATLAS – Quantum Selected Results



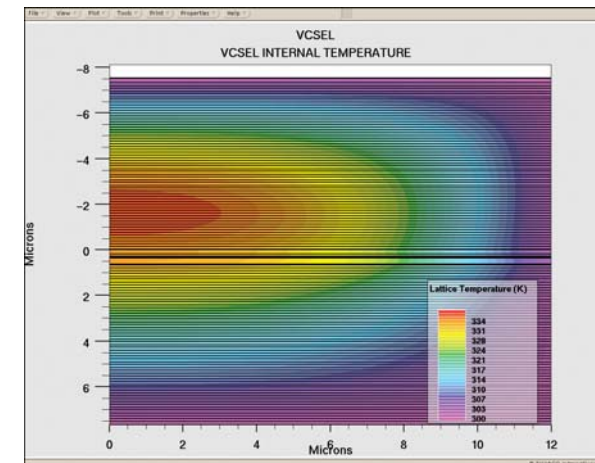
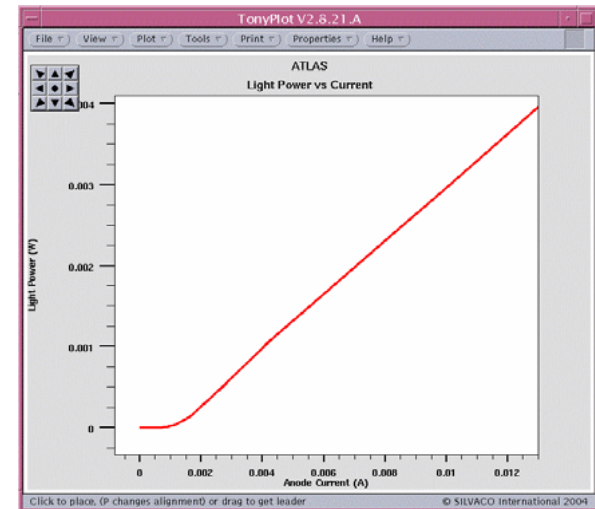
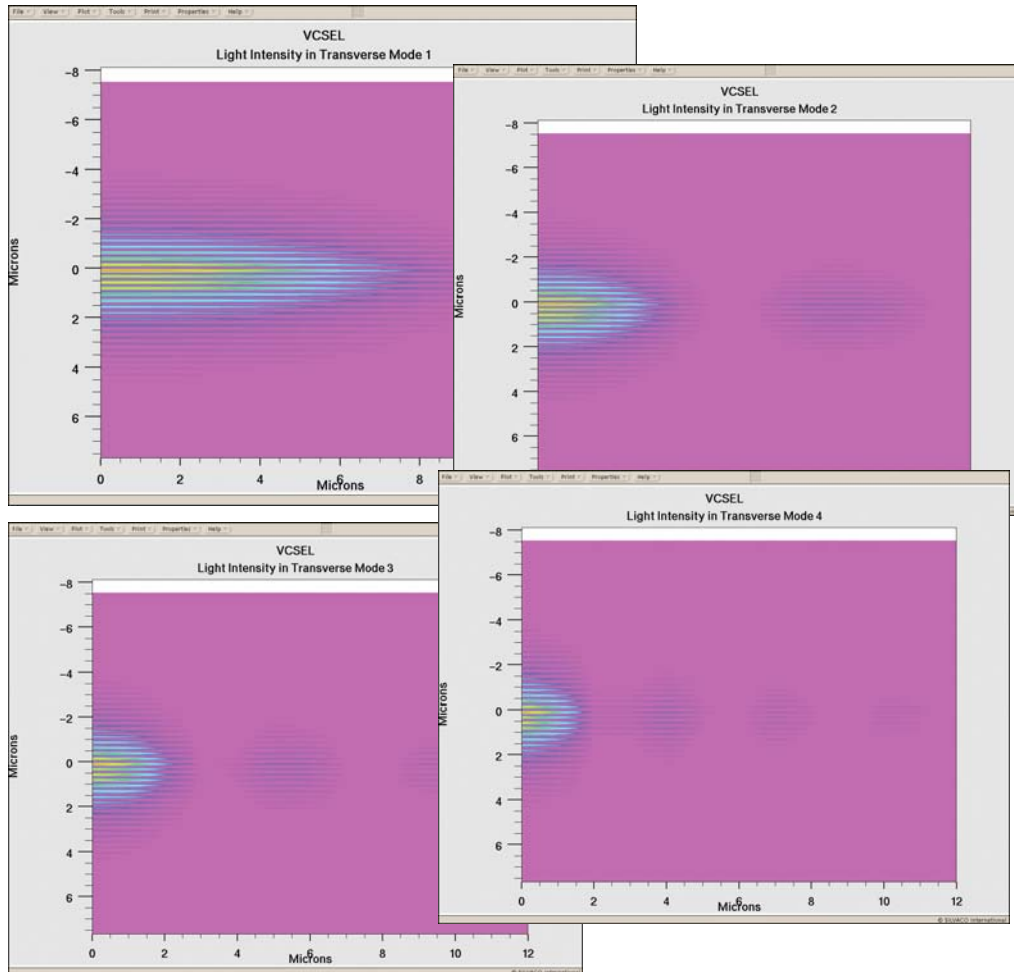
ATLAS – LED



ATLAS – Laser Selected Results

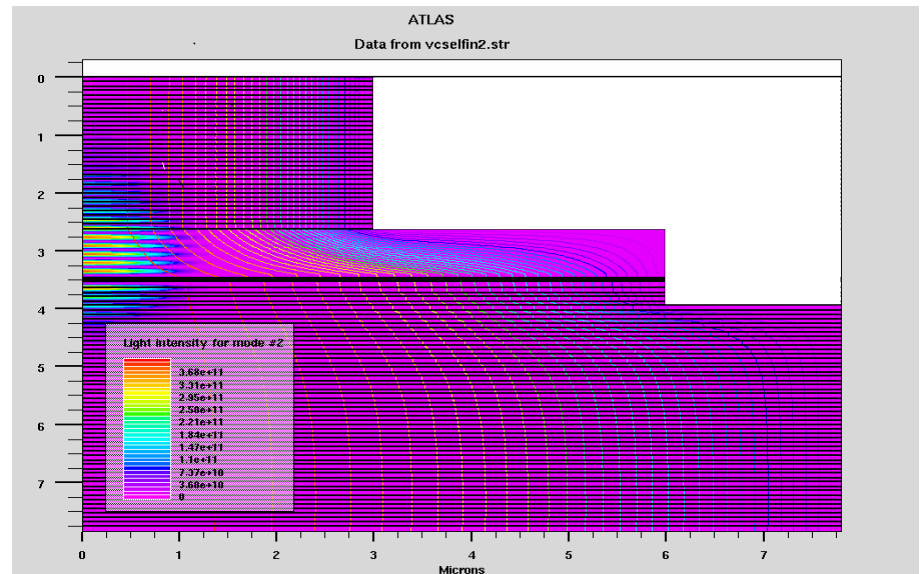
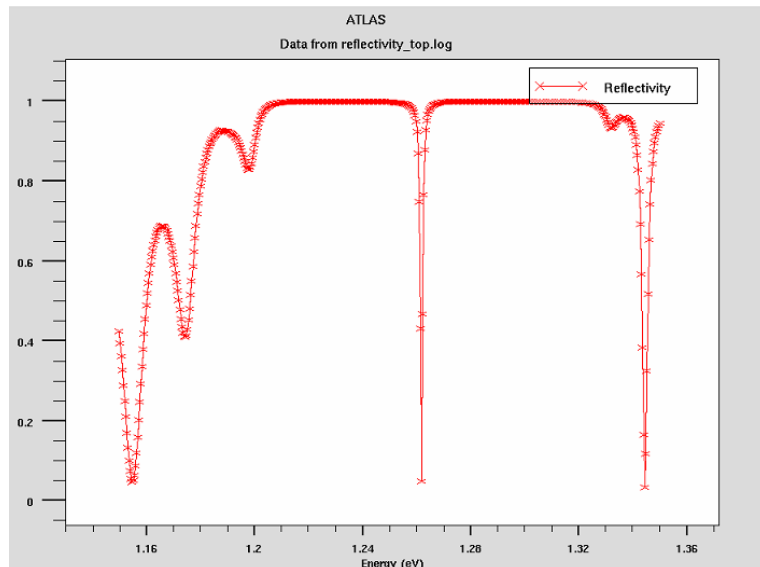


ATLAS – VCSEL

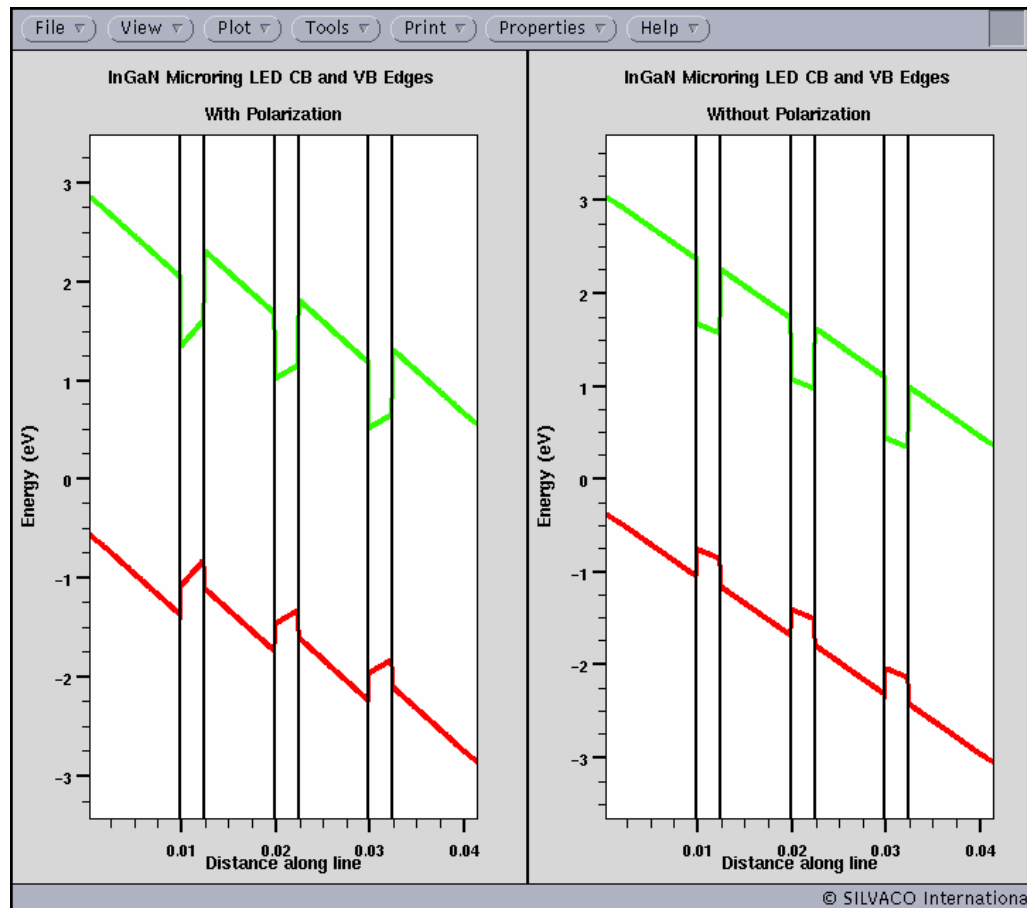


VCSEL structures

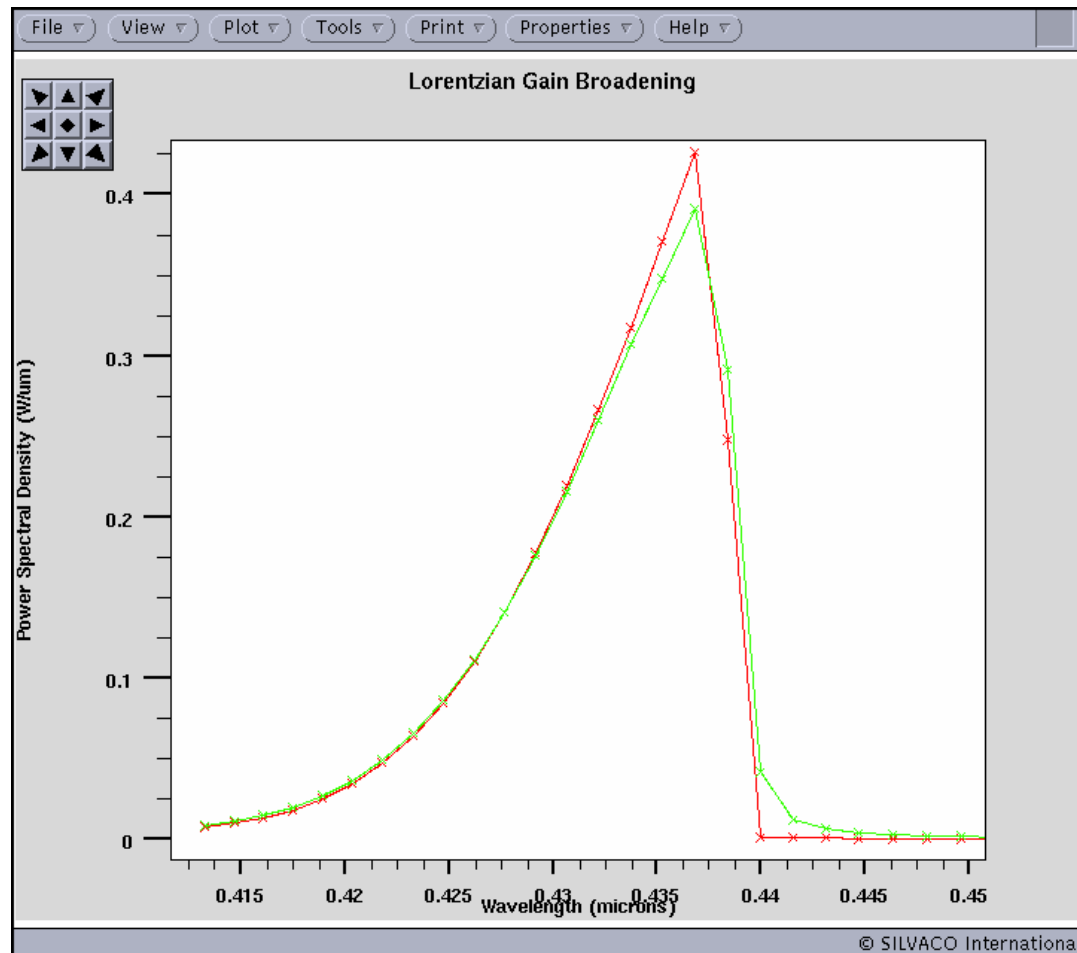
- Cold cavity analysis
- Easy overlay of optical and electrical quantities



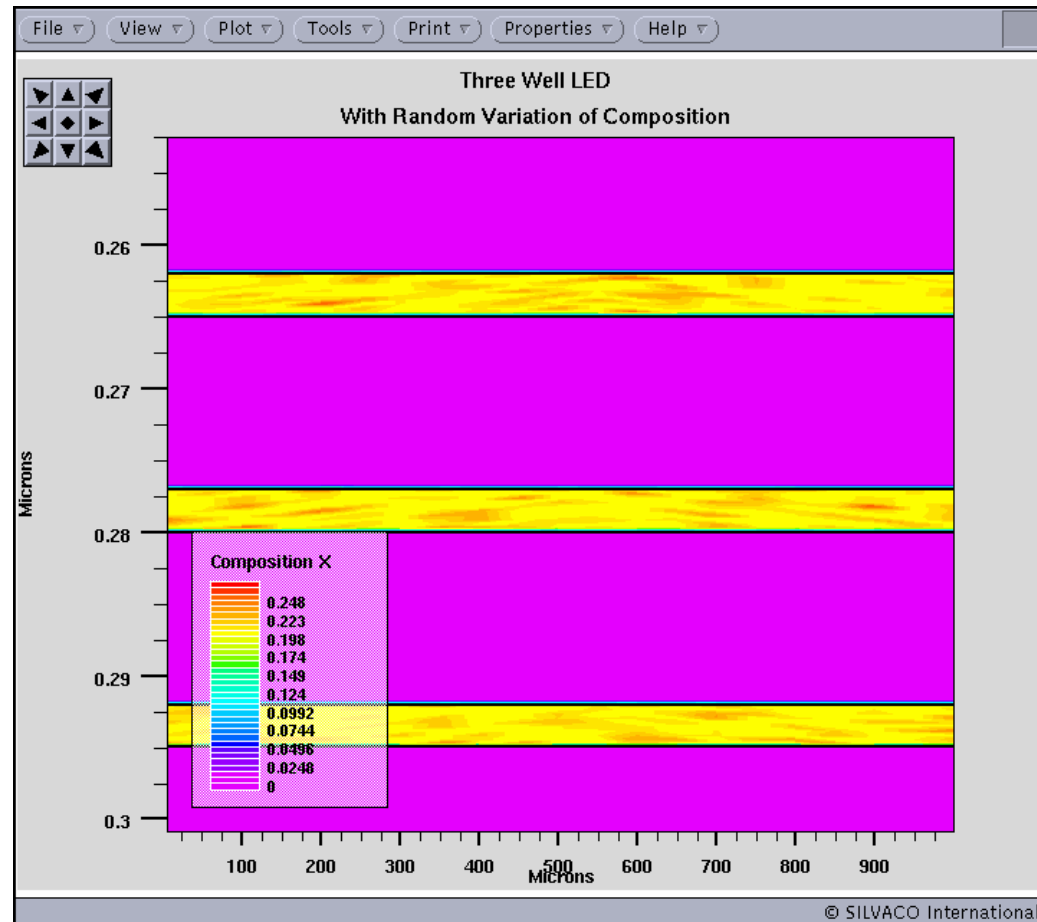
Polarization Effects on Band Edges in InGaN Microring LED



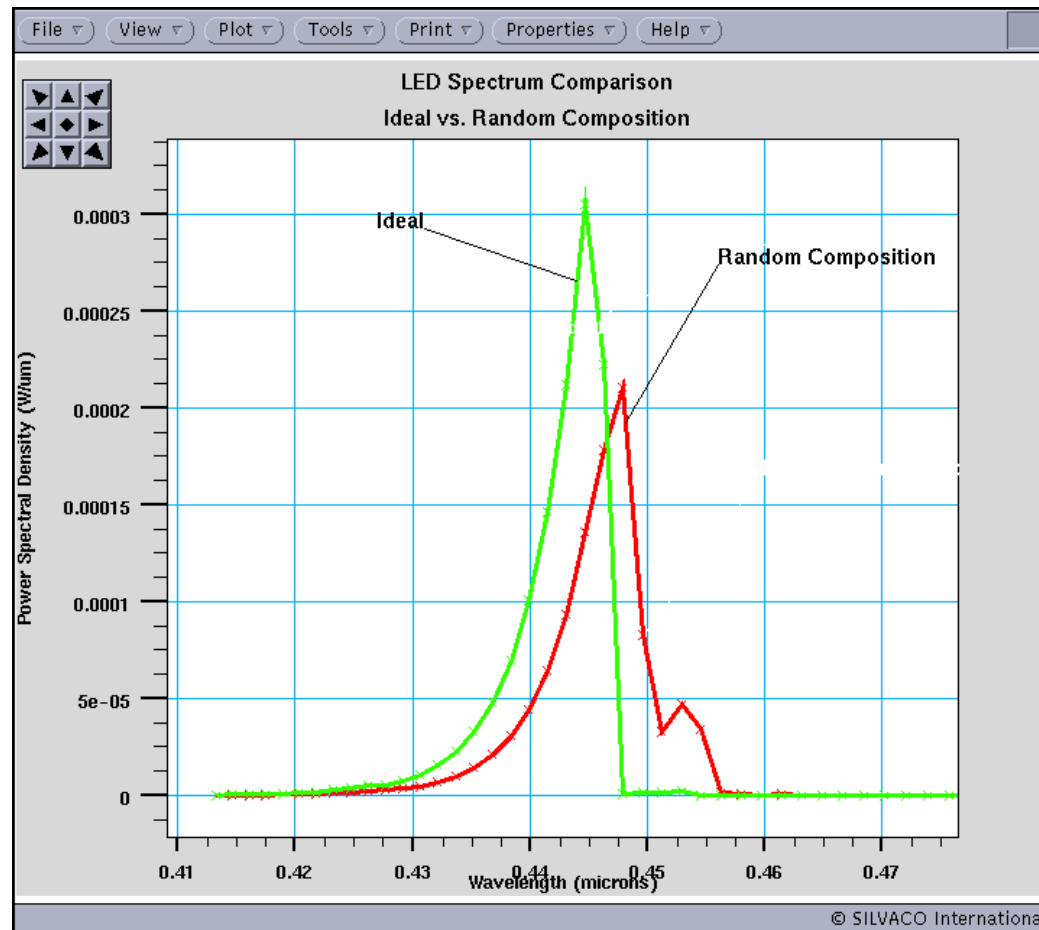
Lorentzian Broadening



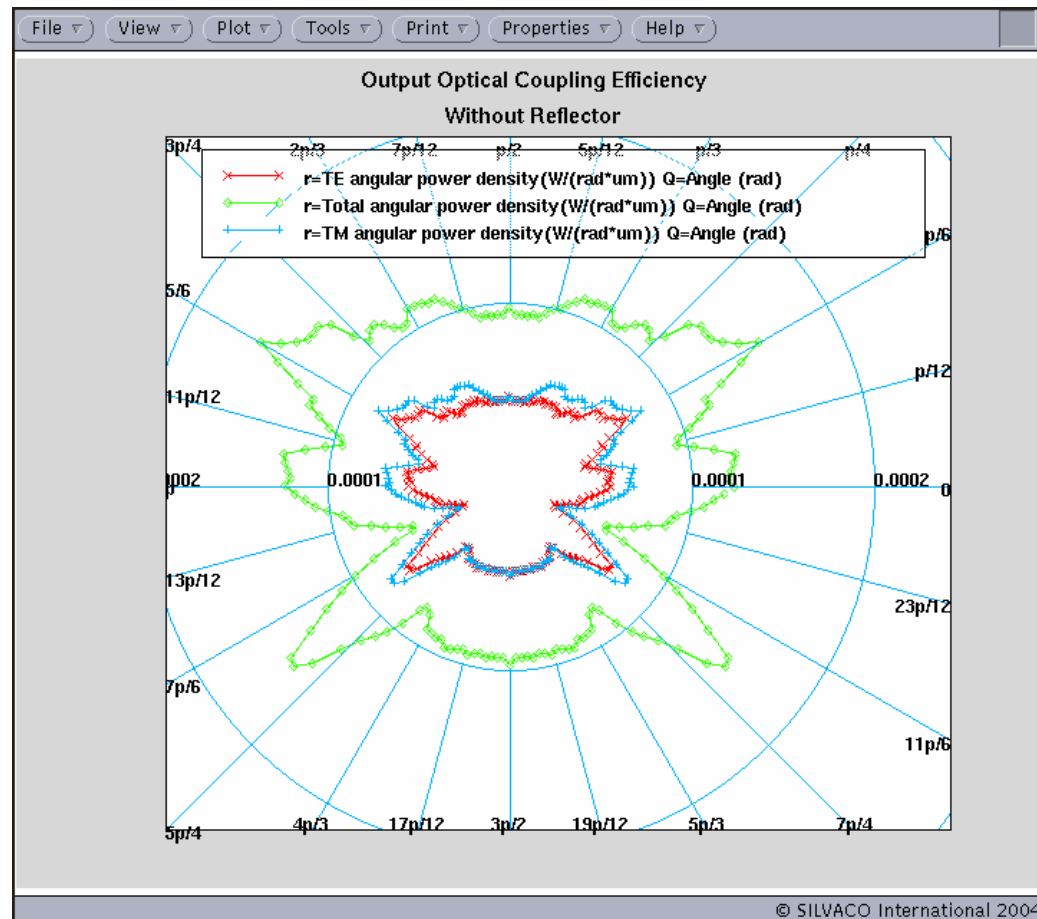
Three Well LED with Random Composition Variation



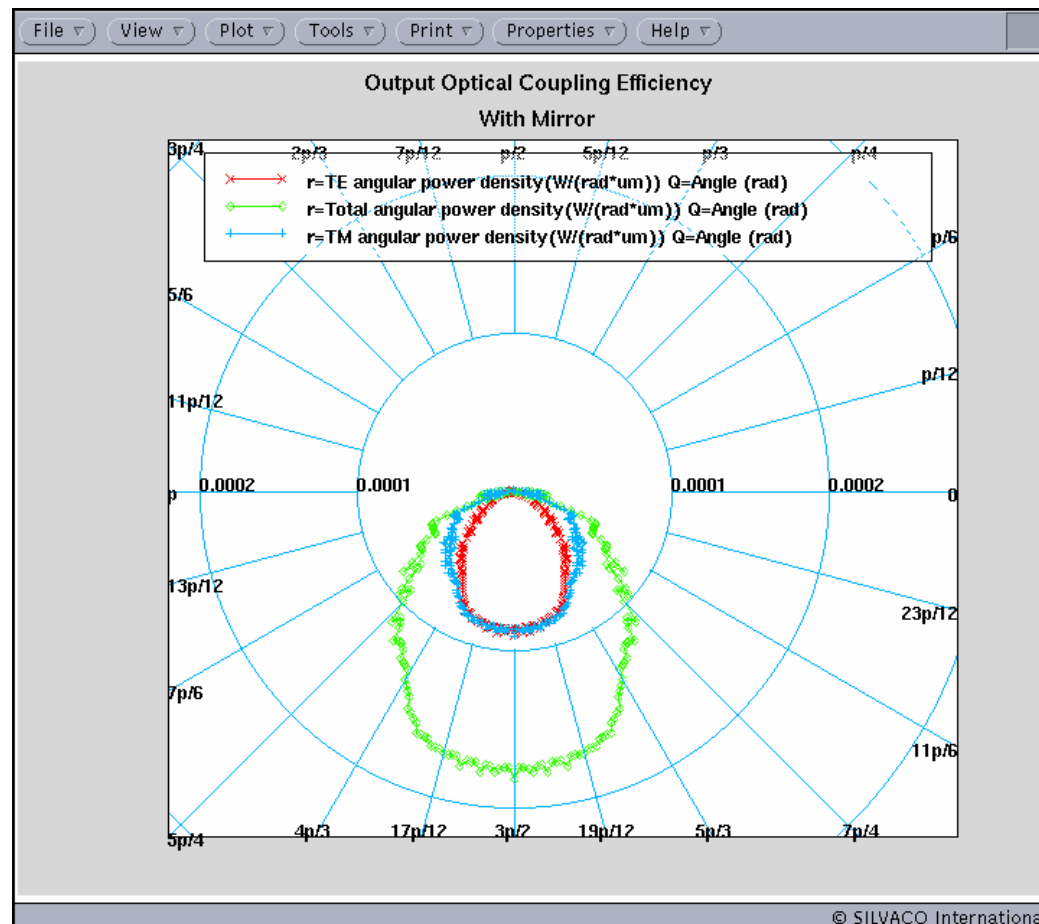
LED Spectrum Effects of Random Composition



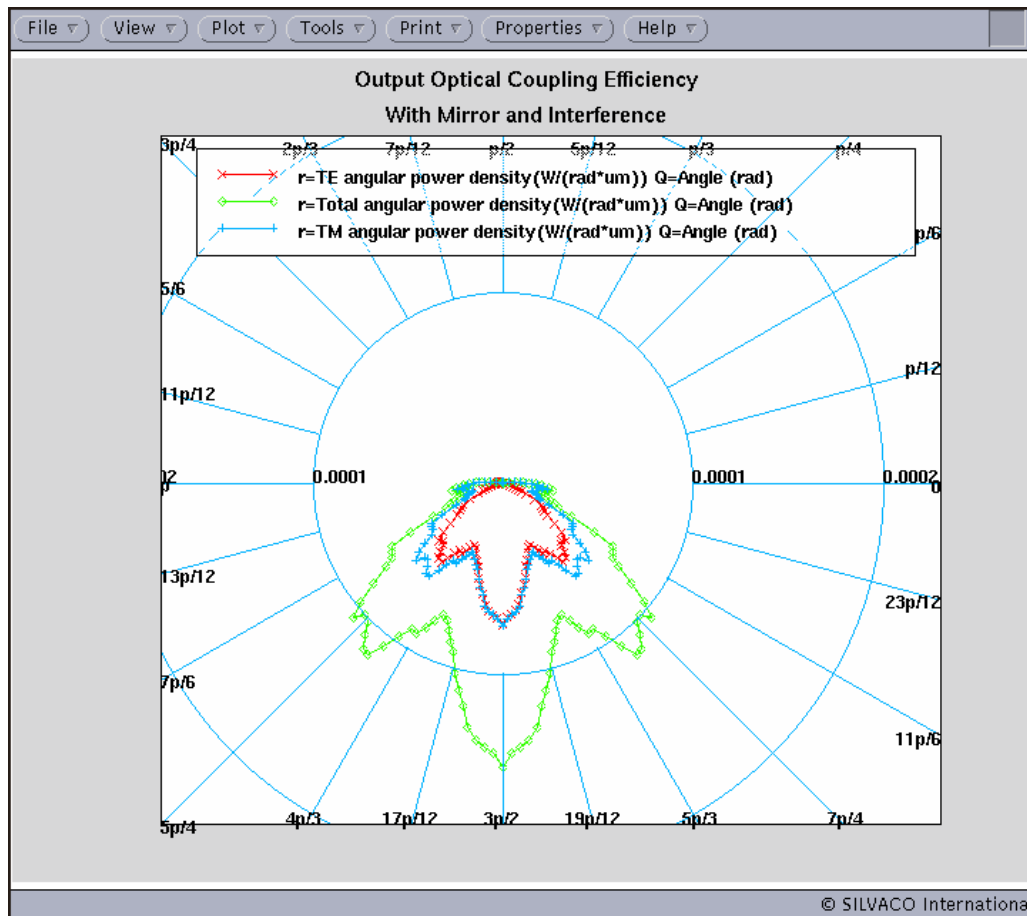
LED Output Coupling Efficiency Without Reflector



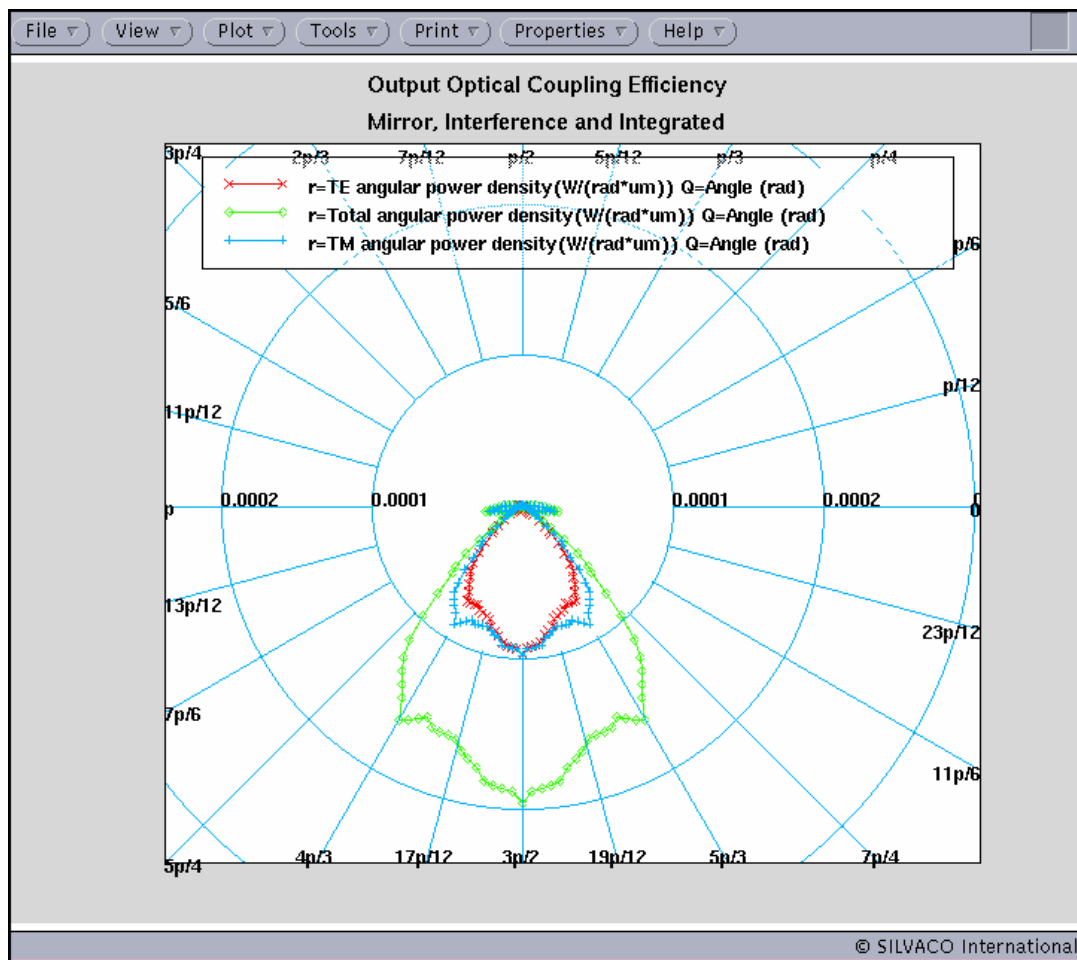
LED Output Coupling Efficiency: With Mirror



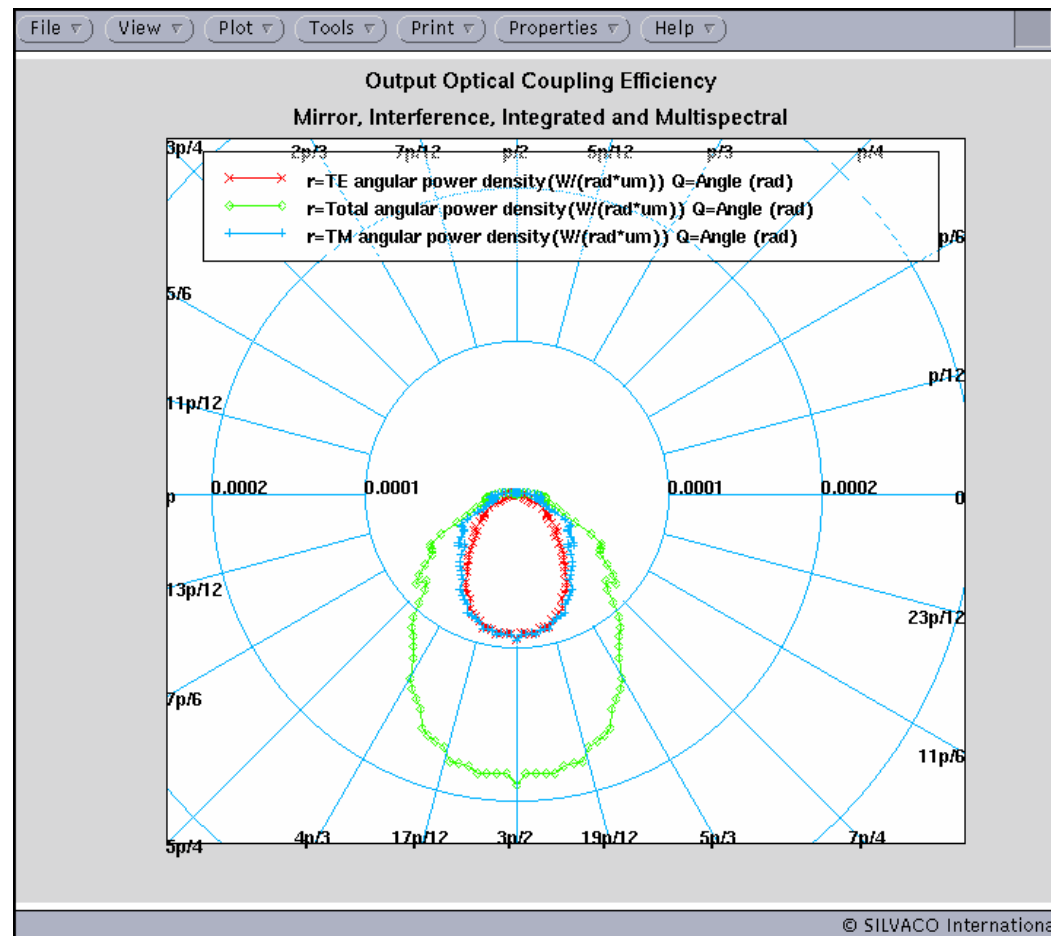
LED Output Coupling Efficiency: With Mirror and Interference



LED Output Coupling Efficiency: Mirror, Interference and Integrated



LED Output Coupling Efficiency: Mirror, Interference, Integrated and Multispectral



Organic Materials

- Poole Frenkel Mobility Models
- Langevin Recombination Models
- Defect Distributions (oTFT)
- Dynamic Equations for Excitations (Singlet & Triplet)
- Various Recombination Rates can enter in Reverse Ray Tracing

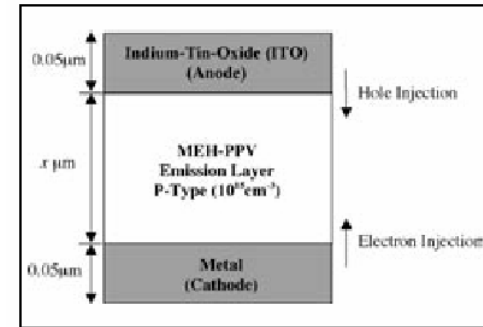


Figure 1 Schematic diagram of the simulation structure.

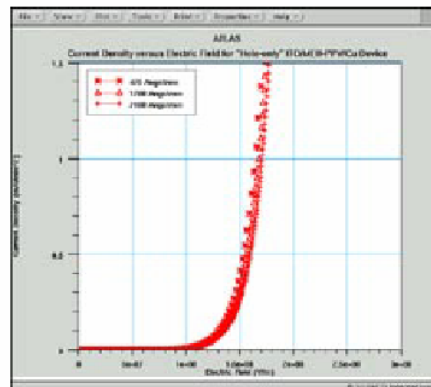


Figure 4a Simulated current density versus electric field of "hole-only" ITO/MEH-PPV/Cu device for different polymer thickness.

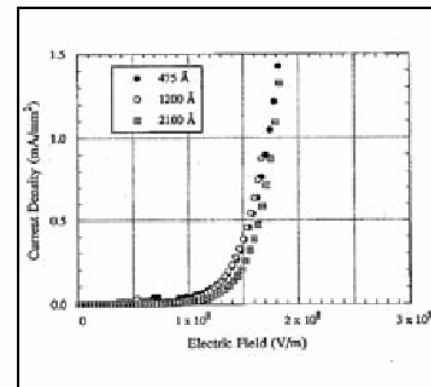
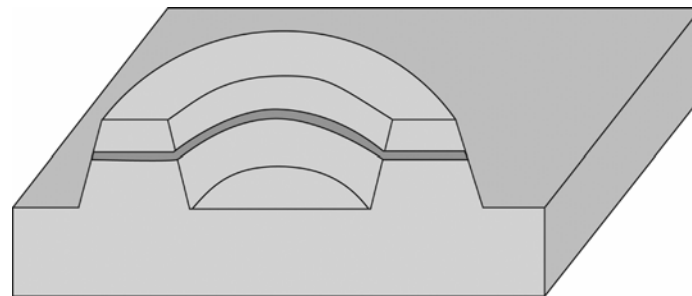
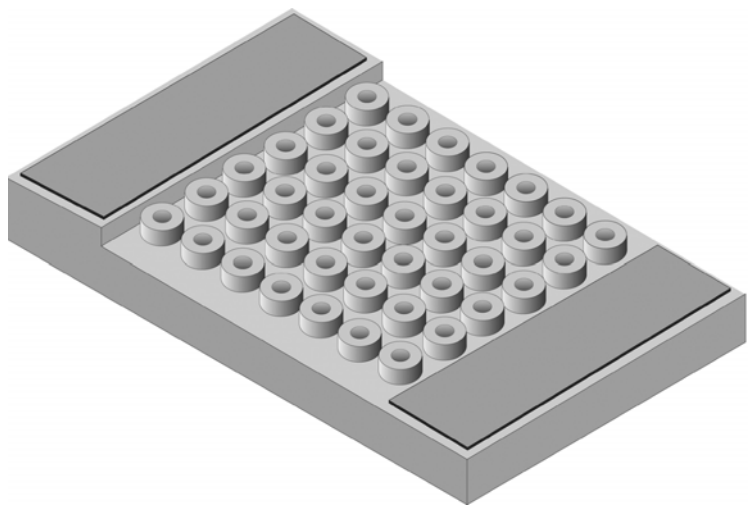


Figure 4b Experimental current density versus electric field of "hole-only" ITO/MEH-PPV/Cu device obtained from figure 4b of [2].

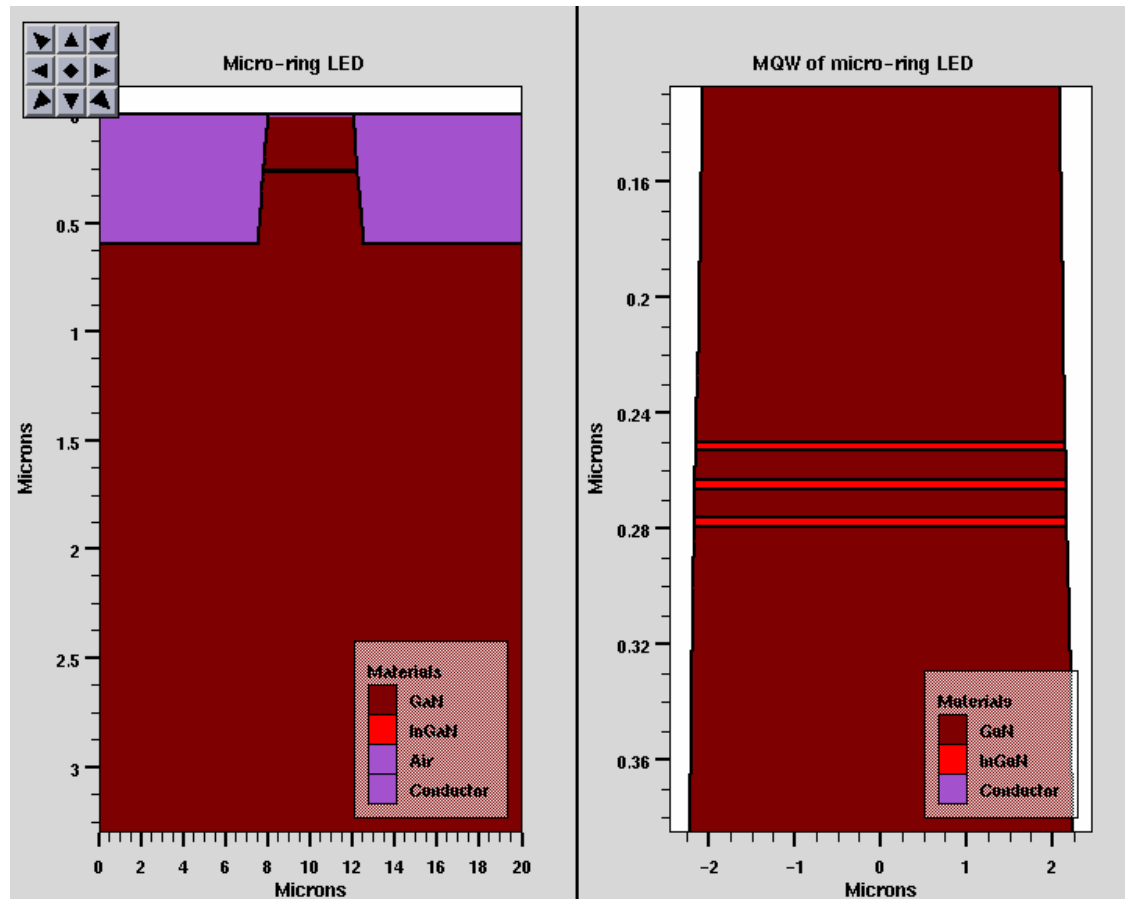


Micro-ring Device Structure

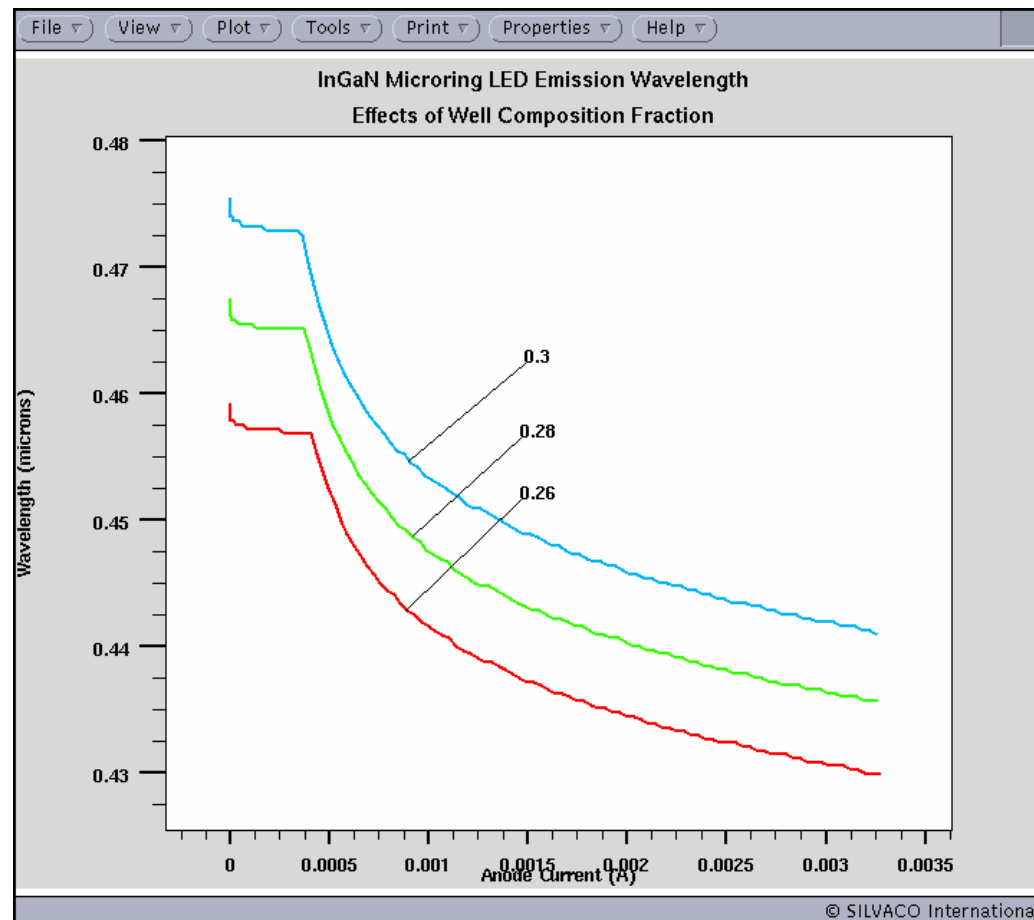


Reference: Choi, H.W. et.al., "High extraction efficiency InGaN micro-ring light-emitting diodes", Appl. Phys. Lett., Vol. 83, No. 22, pp. 4483-4485.

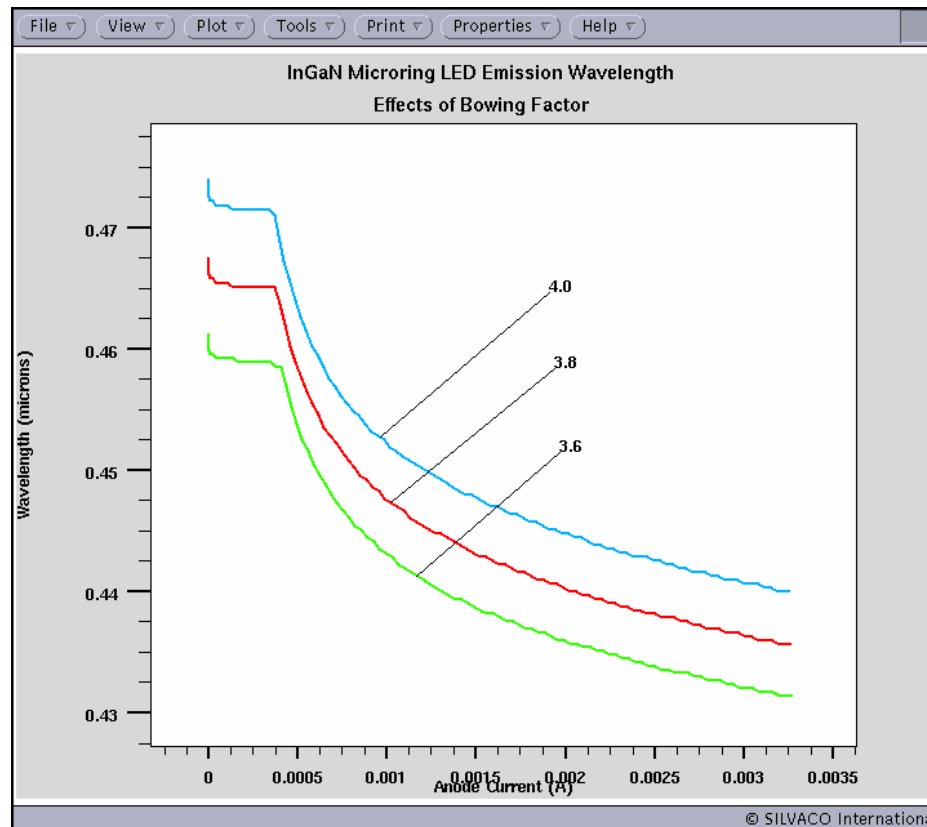
Micro-Ring LED structure in ATLAS



Effects of Choice of Well Composition on Simulated Emission Wavelength

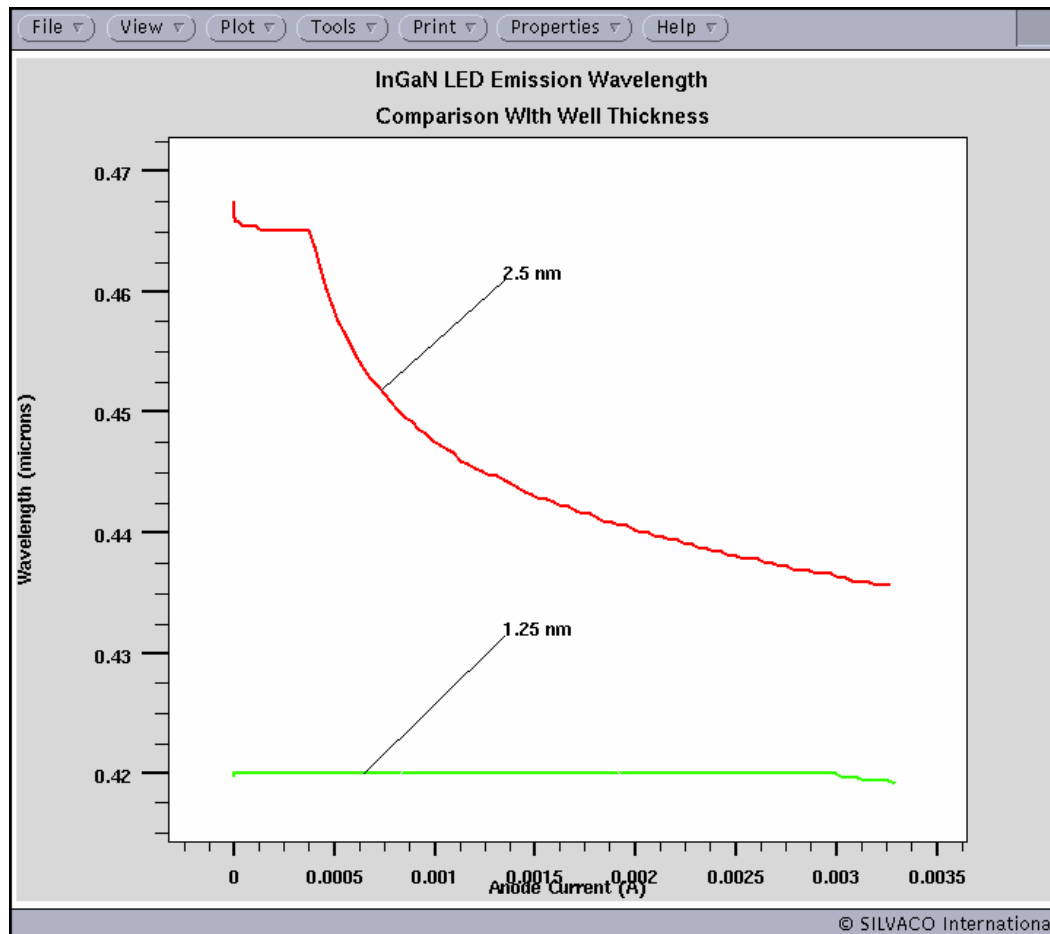


Effects of Choice of Bowing Factor on Simulated Emission Wavelength



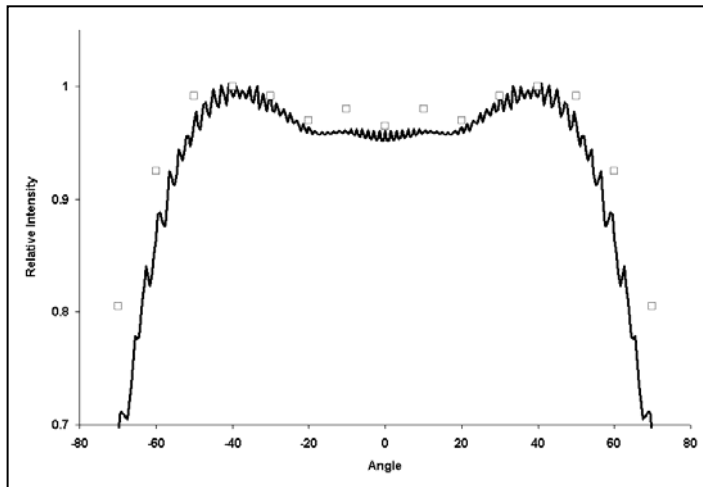
Reference: Piprek, J. "Semiconductor Optoelectronic Devices Introduction to Physics and Simulation", Academic Press, UCSB, 2003, pp. 142 and 143.

Effect of Well Thickness on Blue Shift

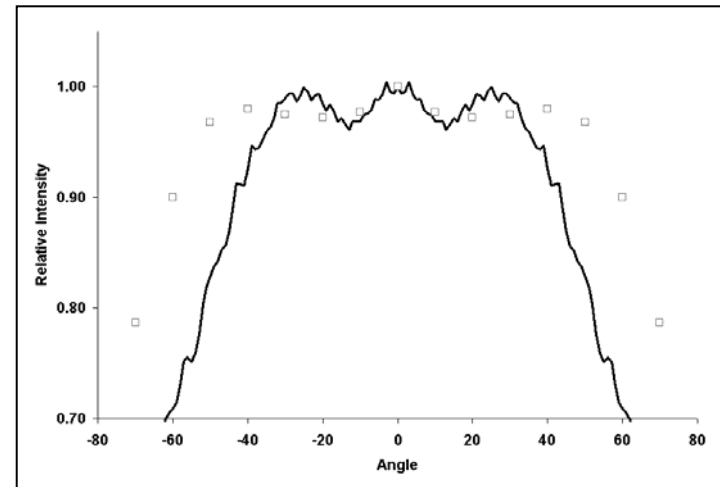


Broad Area / Micro-ring LED

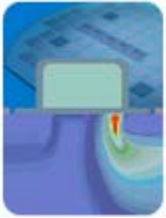
Broad Area LED



Micro-ring LED



- Shortcomings of the proposed micro-ring design are shown
- Improvements of coupling efficiency and insignificant changes of radiation profile are confirmed



Conclusion

- Simulation of various types of devices in absorptions and emission
- Wide range of physical models for coupled electrical and optical simulation
- Support for novel materials and materials systems