


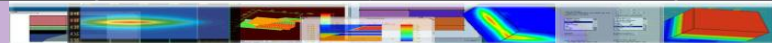


3D TCAD Simulation of GaN-based LED






© 2011 - Crosslight Software Inc.

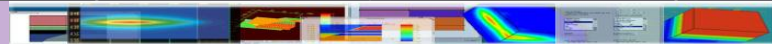
Content

-  Advanced physical models
-  3D TCAD examples
-  Summary







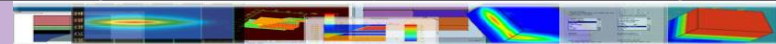
Advanced physical models for MQW

-  k.p based quantum mechanical solver.
-  Self-consistent iteration between quantum well solution and drift-diffusion solutions.
-  Polarization charge model including piezoelectric and spontaneous charges.
-  State of the art nitride material data macro incorporating latest understanding of mechanisms leading to LED efficiency droop.
-  Self-consistent coupling of drift-diffusion equation solver and thermal/heat-flow solver.



Start of the art 3D TCAD tools for LED

-  User-friendly GUI LayerBuilder used to set up MQW layer structures.
-  Mask data (usually in GDS format) are used to construct the 3D geometry. Advanced process simulator CSuprem is used to generate the 3D mesh and doping profile.
-  Efficient and convergent device simulator APSYS is used to simulate electrical behavior (such as IQE) and the thermal behavior.
-  Optionally Crosslight Optowizard may be used to model the optical extraction behavior with raytracing or FDTD.



MQW layer design using LayerBuilder

LayerBuilder

File Edit Layer Column Mesh Series Insert Options View Help

Column No.: 1
Column width: 300.00
Column mesh: 2,1
Contact Top:ohmic,
0.0-300.0
Contact Bottom:ohmic,
0.0-300.0

Layer No.: 10
Thickness:0.0022
Bulk_macro: ingan, 0.11
Active_macro: InGaN/InGaN,
0.11, 0, 0, 0
Layer mesh: 5,-1.3
Coordinate: (3.748, 3.068)

Modify Layer

Layer_Mesh	DFB/DBR grating setting	Vcsel	Label Position
Size_Info	Material	Doping	Contact
			Column_Mesh

Bulk Material Macro

ingan

old style
 free style

- accuglass
- ag
- ag_old
- air
- al
- al_ptype
- alax_oxide
- alassb
- algaas
- alqaas.2005

Show Load Macro Param

Active Layer Macro

InGaN/InGaN

old style
 free style

- AlGaAs
- AlGaAs/AlGaAs
- AlGaN
- AlGaN/AlGaN
- C545T:Alq3
- cx-AlAsSb
- cx-AlGaAs
- cx-AlGaAsSb
- cx-AlGaN
- cx-EuSe

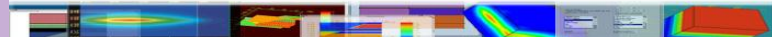
Show Active Macro Param

Composition grading:
Which composition parameter do you wish to grade?

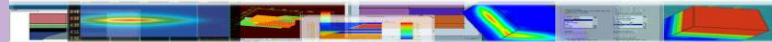
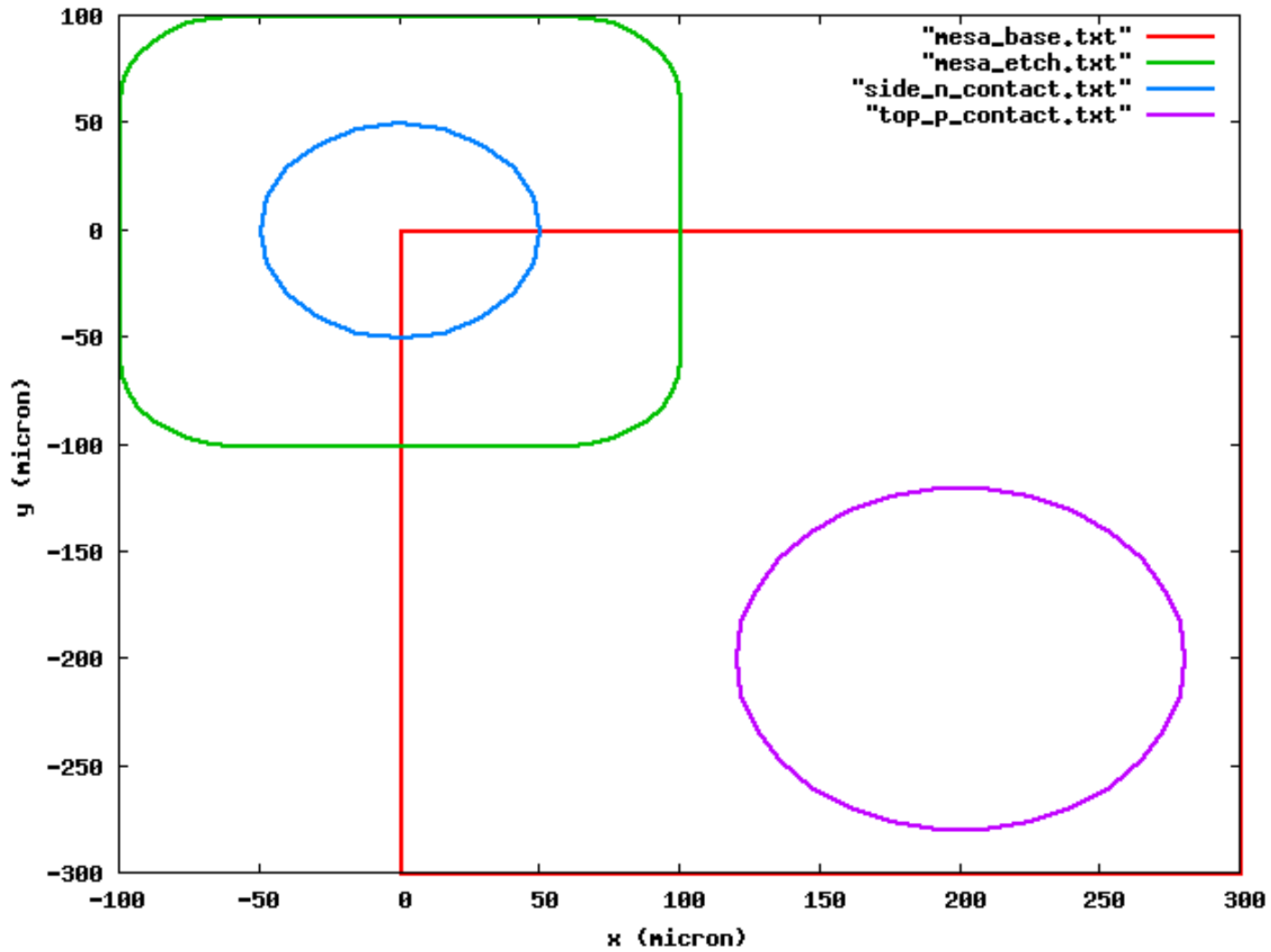
0 1 2
 3 4

Crosslight OK Cancel

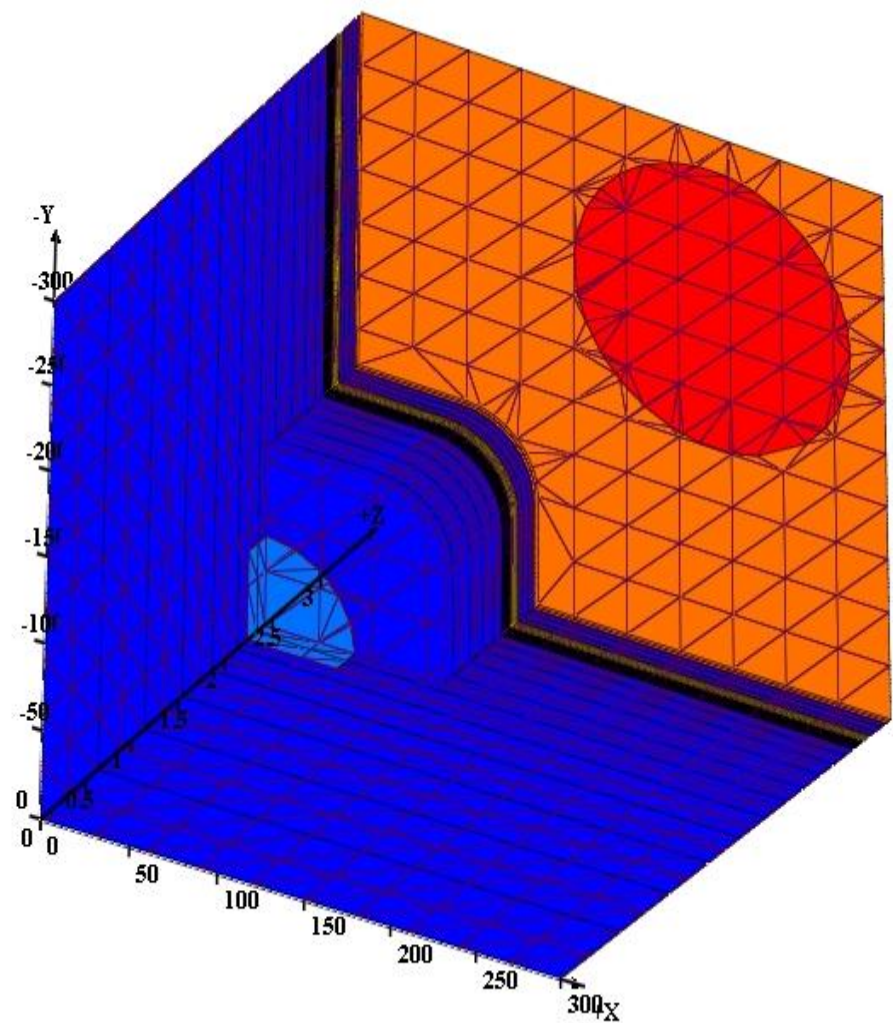
Next step prompt
Drag to move the device, or
press two buttons to zoom
in or out



Using mask data for mesa and contact design

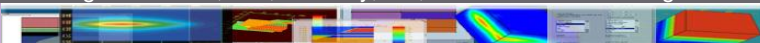


Example 1: Corner side contact LED

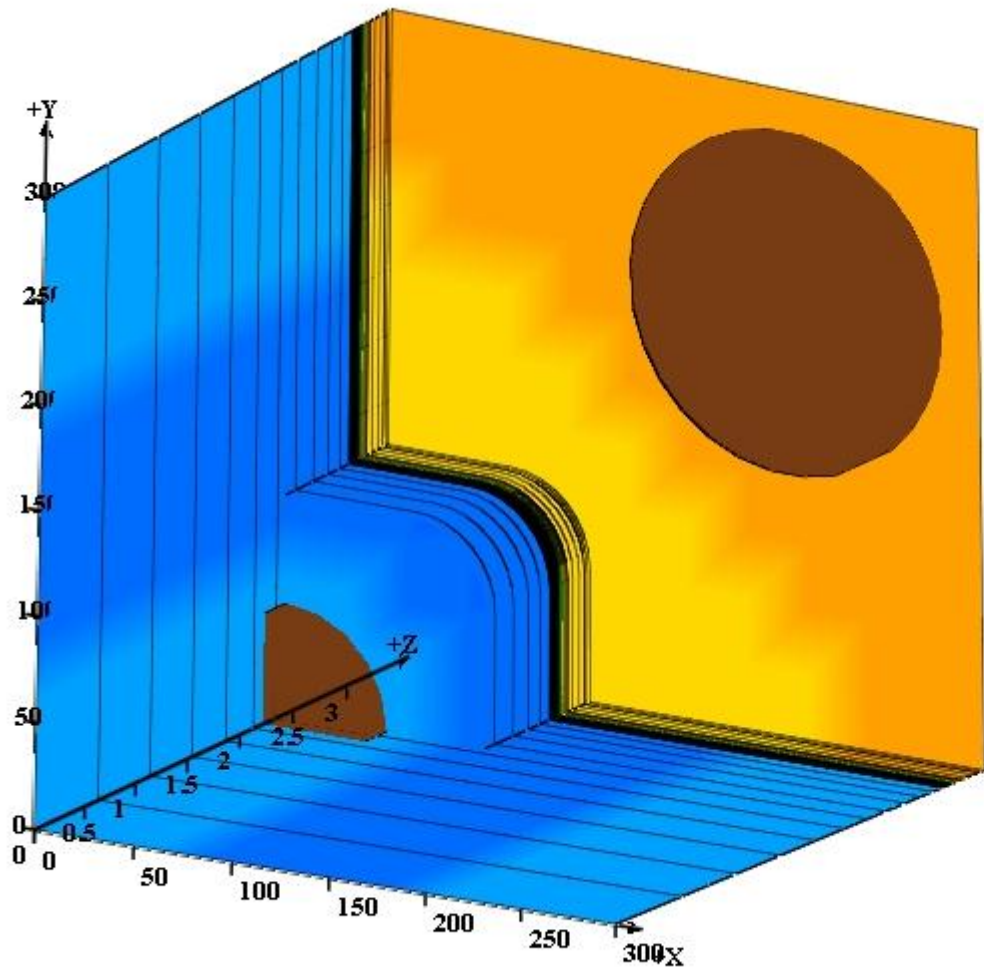


Material Number

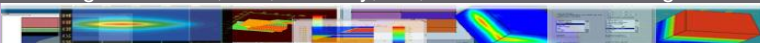
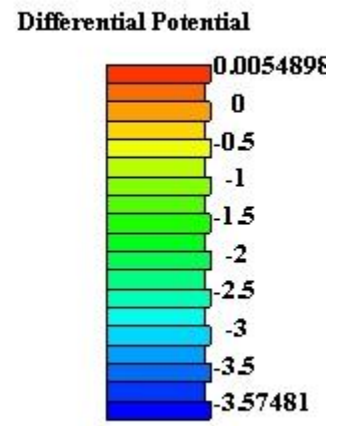
Red	contact_2
Orange	ito
Yellow	algan_2
Light Green	ingan_5
Green	ingan_4
Bright Green	ingan_3
Cyan	ingan_2
Light Blue	ingan
Blue	contact_1
Dark Blue	algan



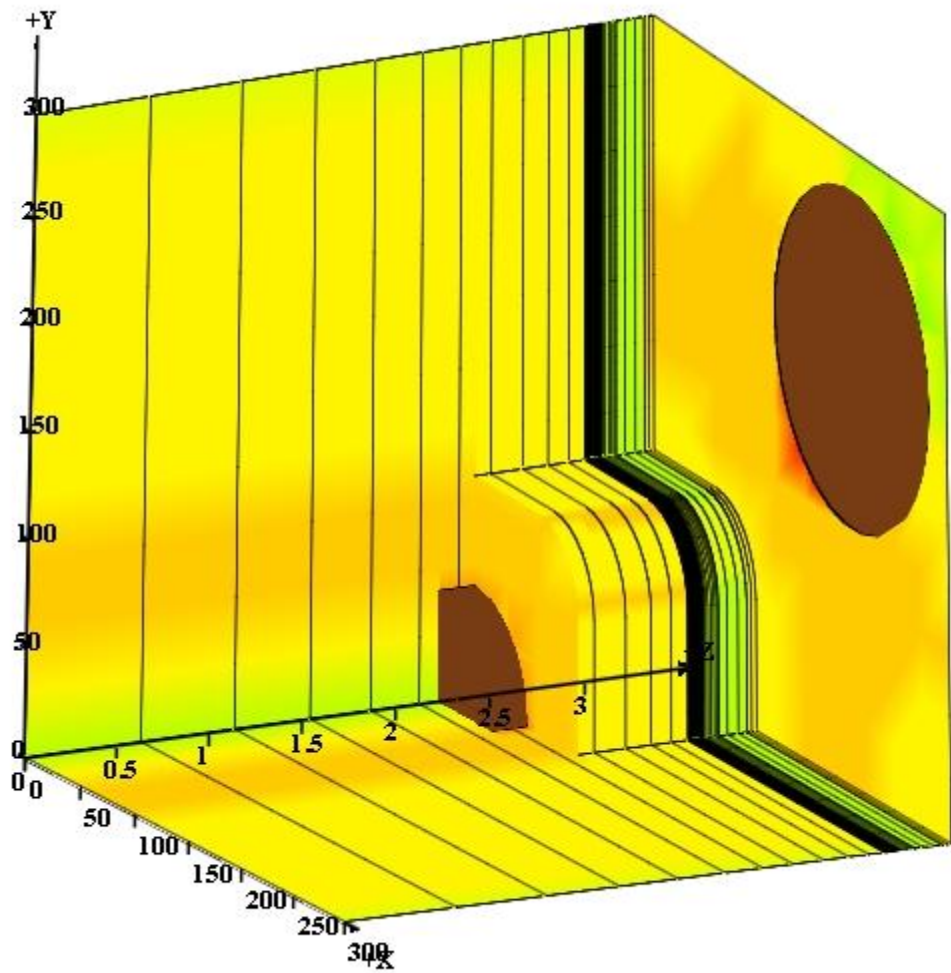
Example 1: Corner side contact LED



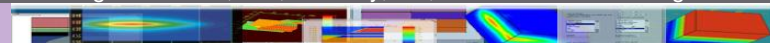
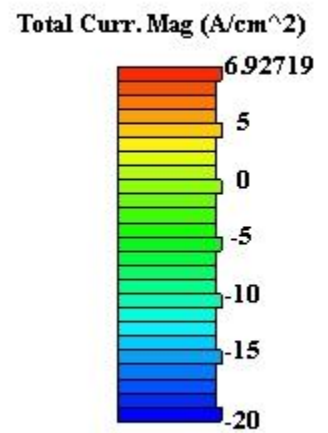
3D voltage drop within the MQW LED



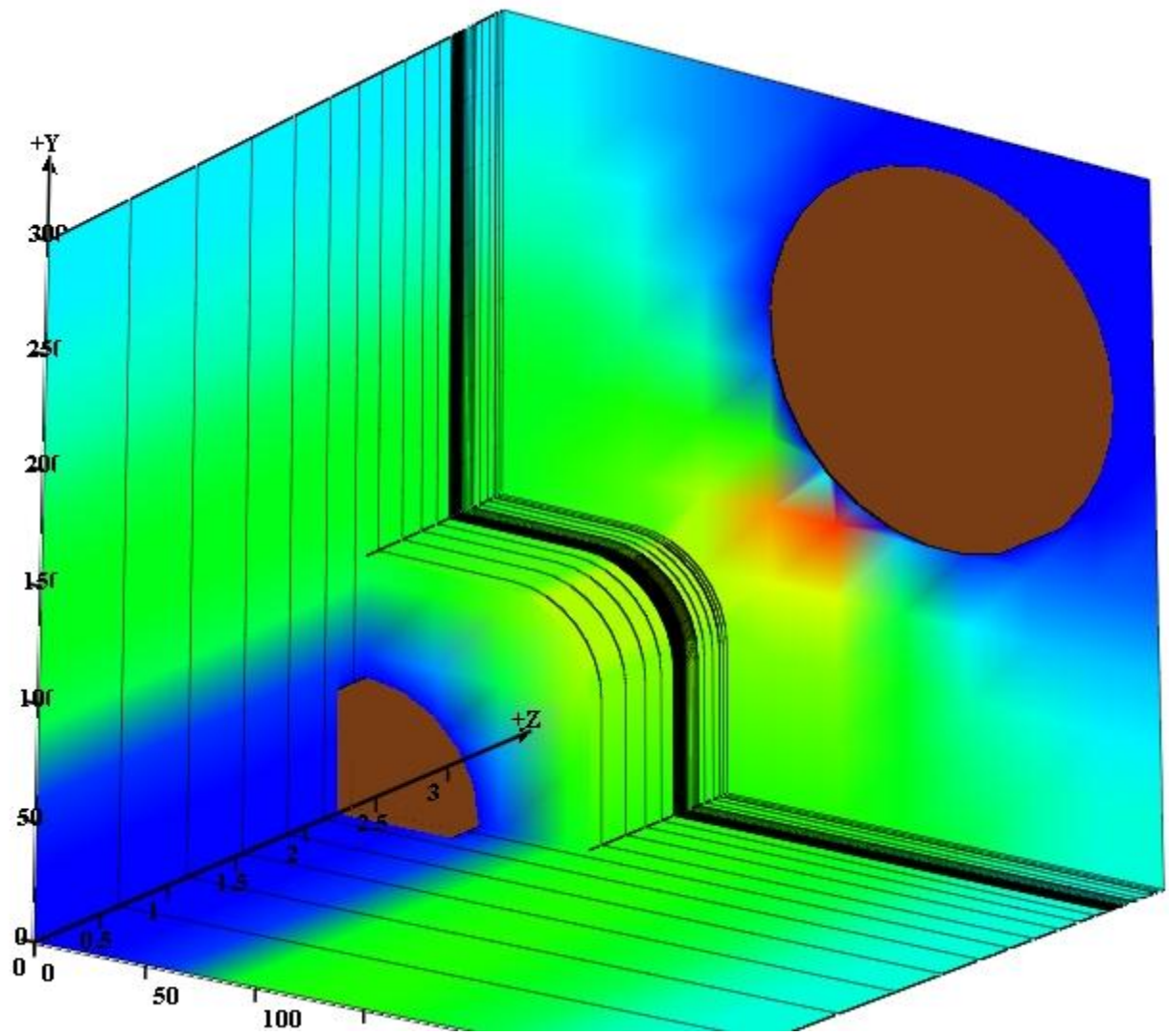
Example 1: Corner side contact LED



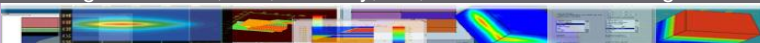
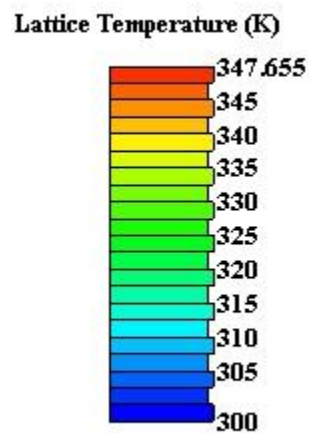
3D profile of current magnitude within the InGaN/AlGaIn MQW LED



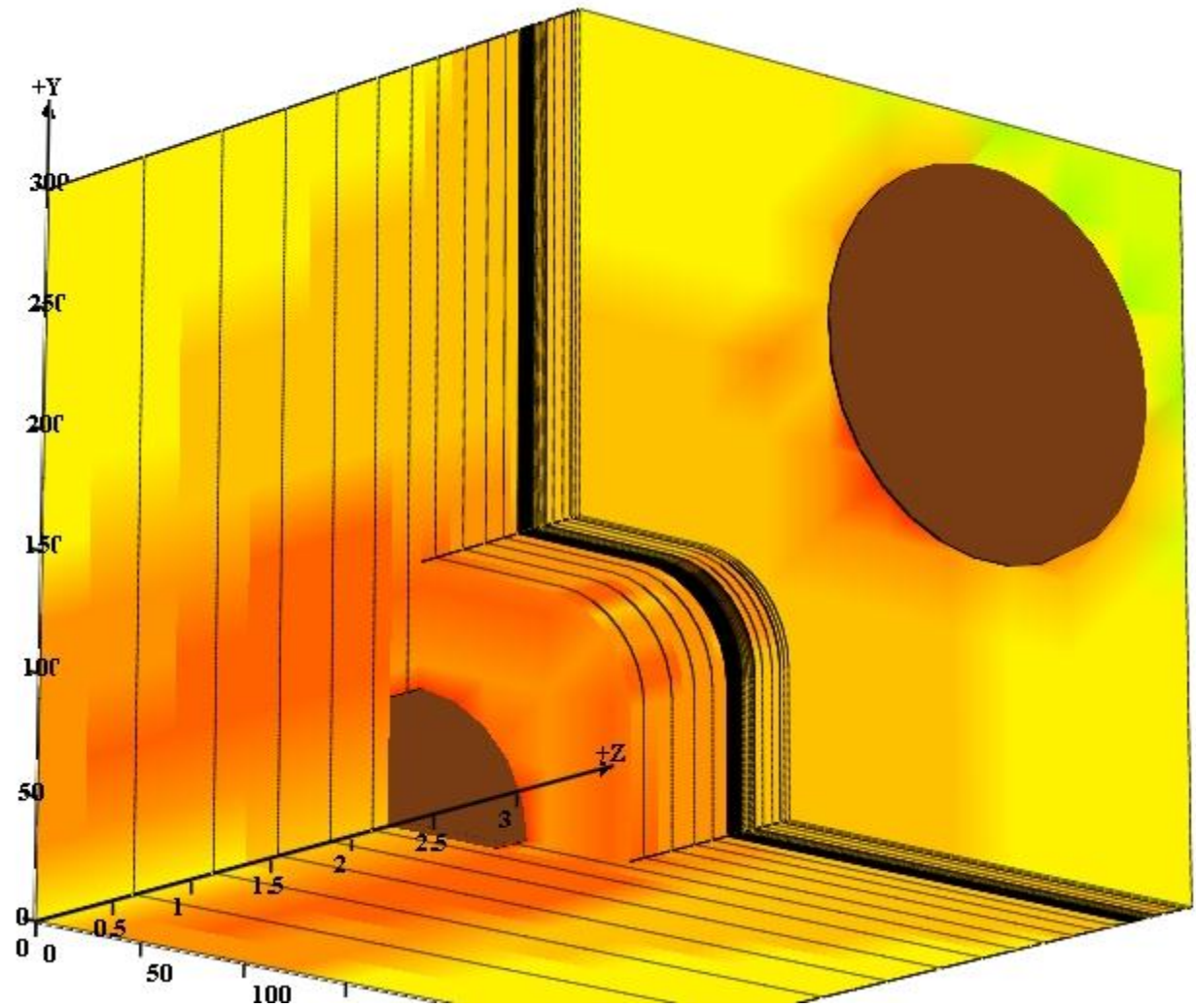
Example 1: Corner side contact LED



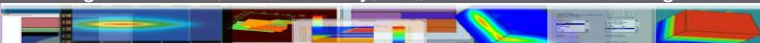
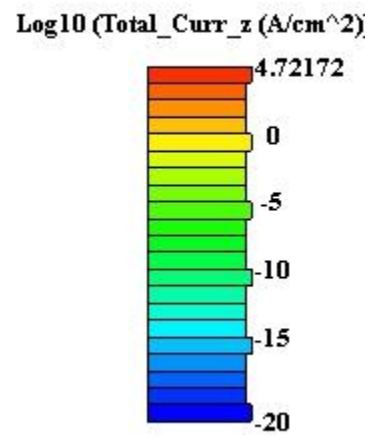
3D distribution of temperature due to self-heating



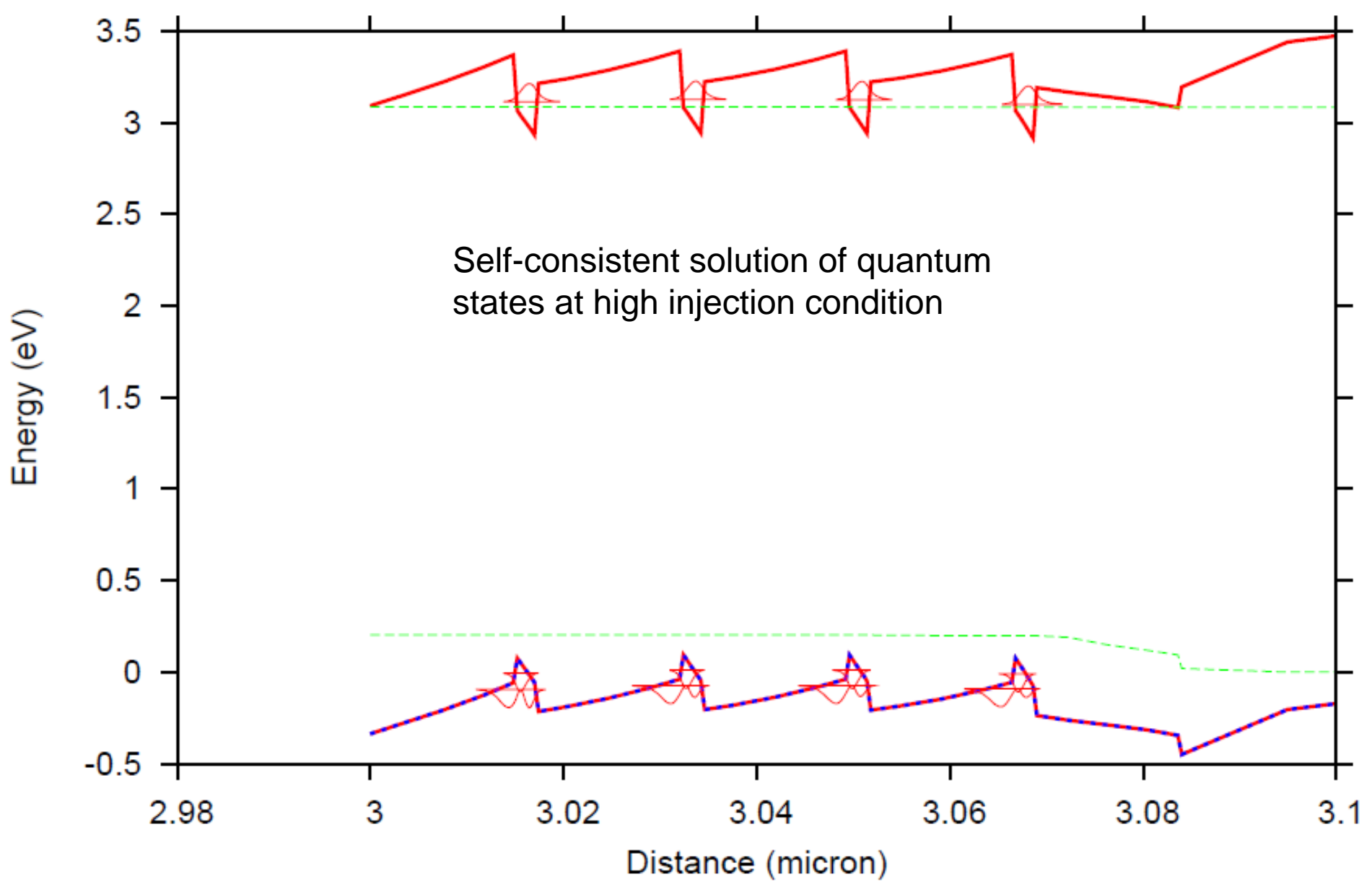
Example 1: Corner side contact LED



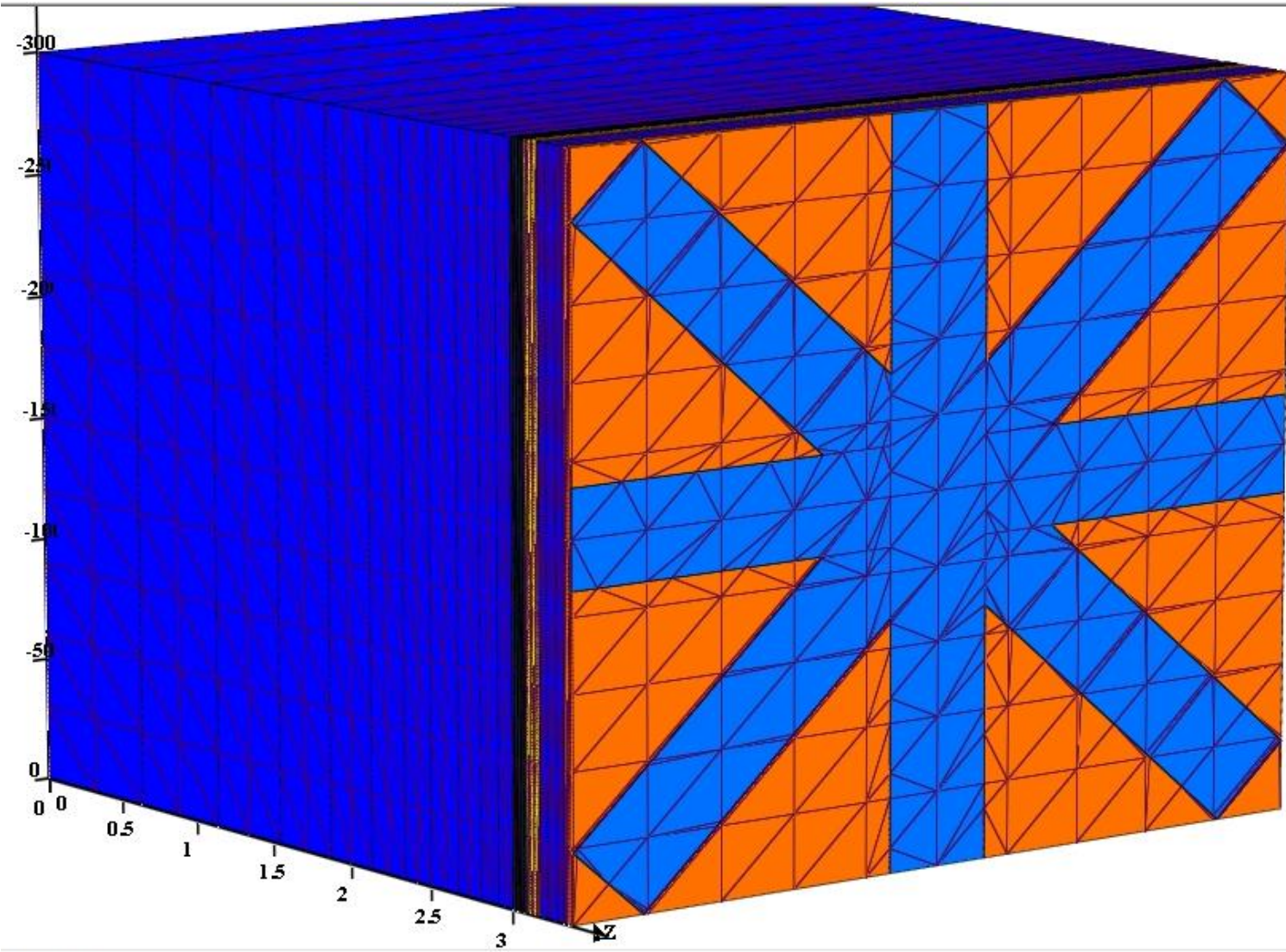
3D distribution of z-component of current within the InGaN/AlGaIn MQW LED



Example 1: corner side contact LED



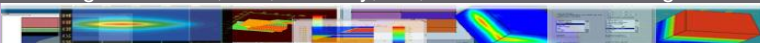
Example 2: LED with star-shaped top contact



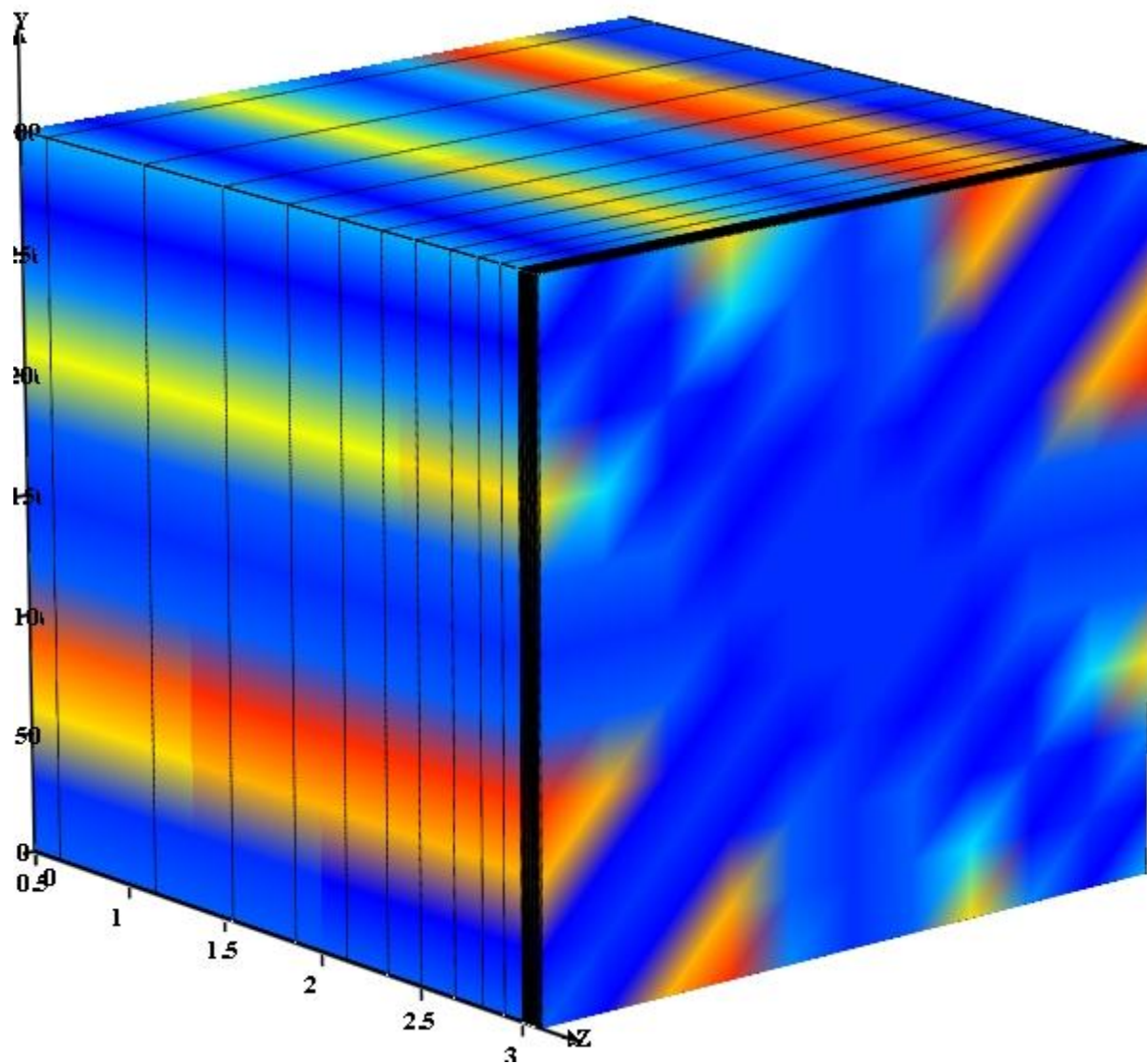
Material Number

Blue	contact_1
Orange	ito
Yellow	algan_2
Light Green	ingan_5
Green	ingan_4
Bright Green	ingan_3
Cyan	ingan_2
Light Blue	ingan
Dark Blue	algan

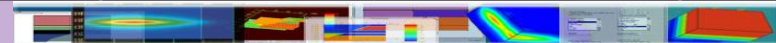
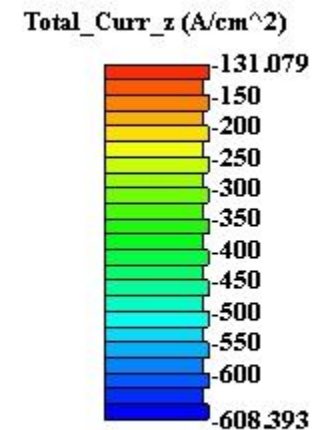
i, Z=2.59476



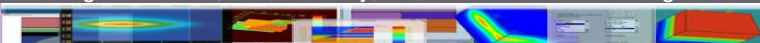
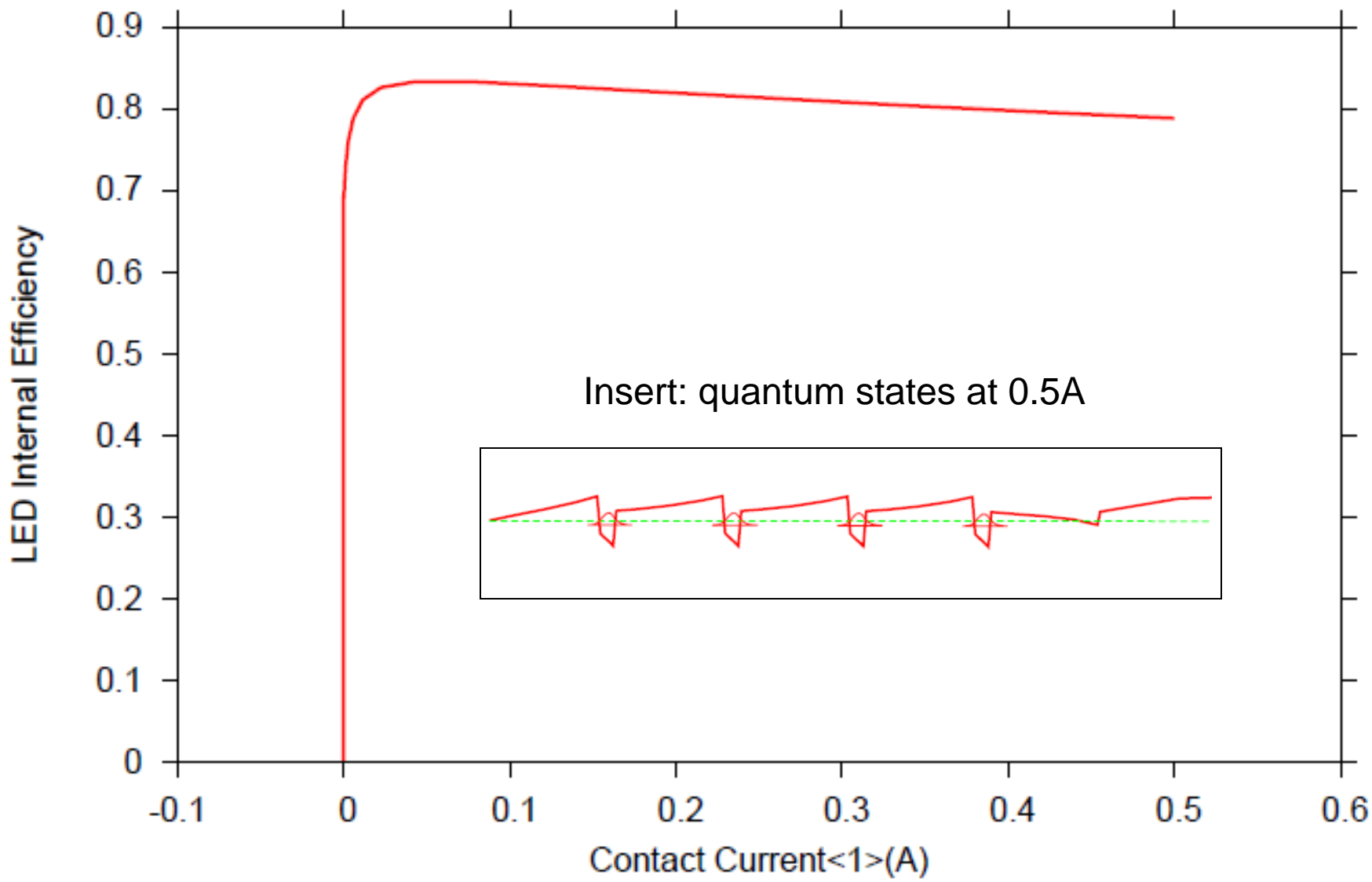
Example 2: LED with star-shaped top contact



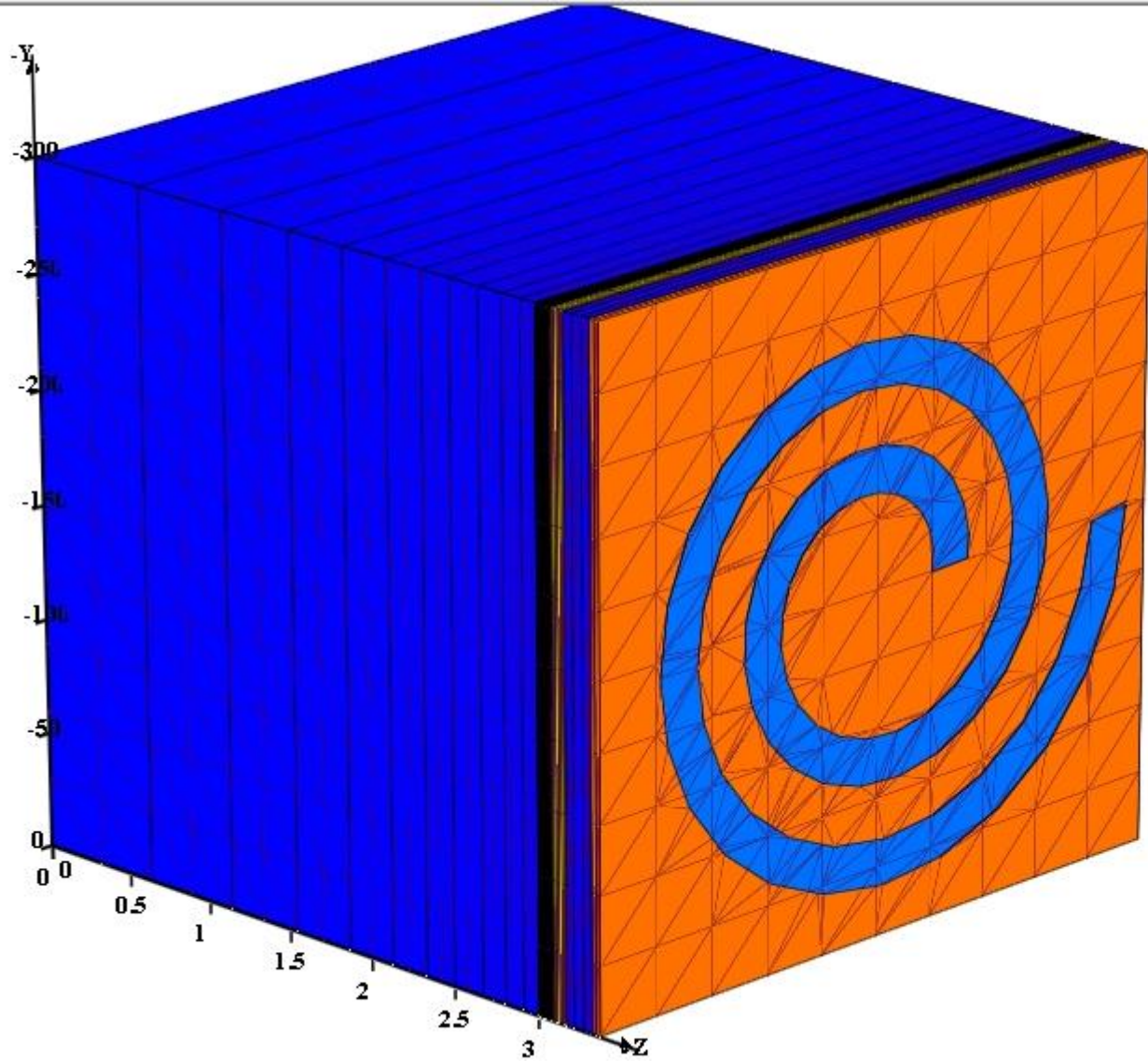
3D current distribution plot with top layers removed and MQW layer exposed.



Example 2: LED with star-shaped top contact

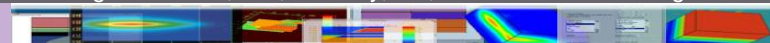


Example 3: LED with spiral top contact

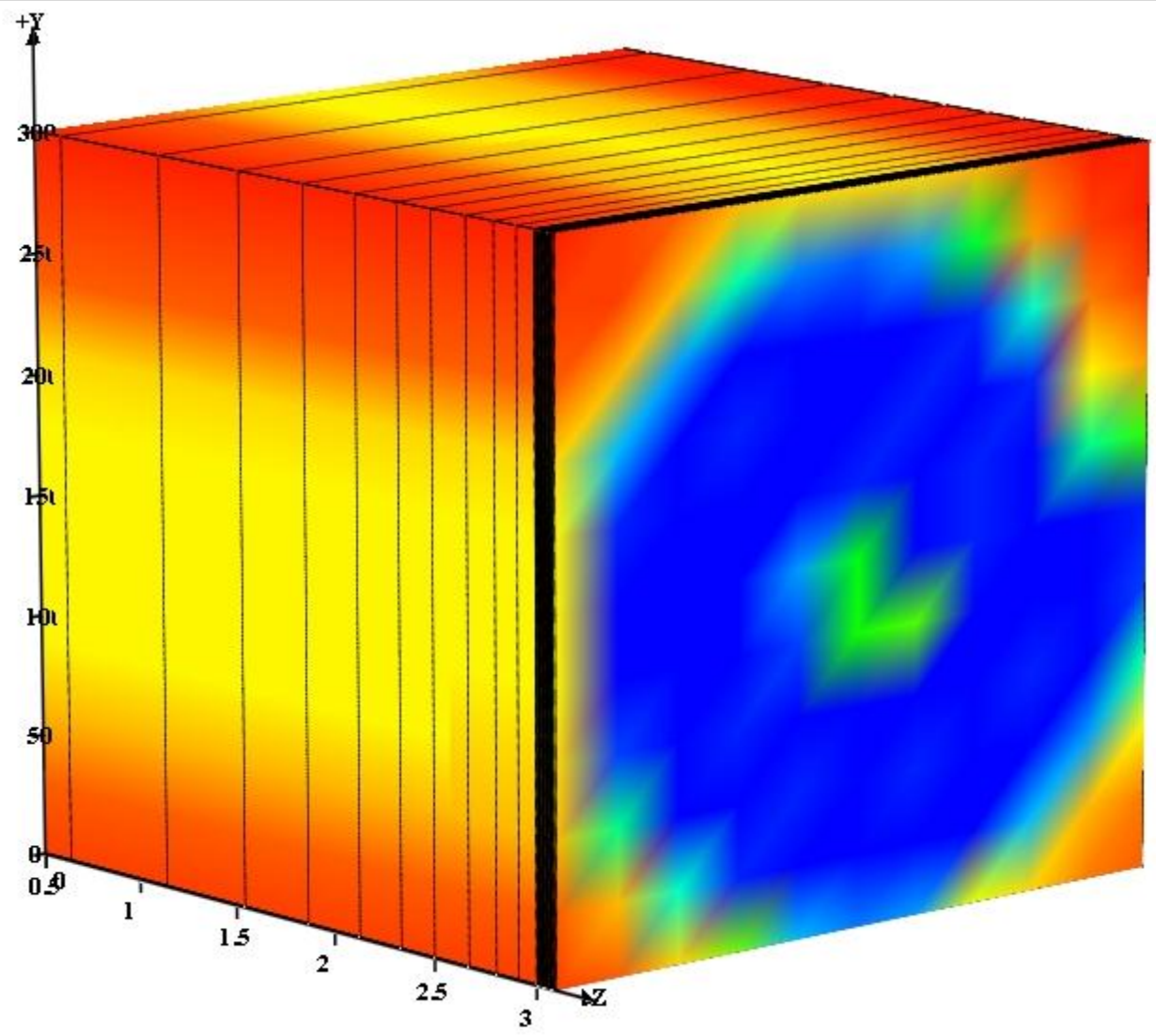


Material Number

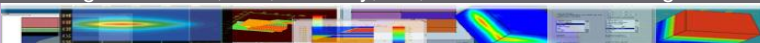
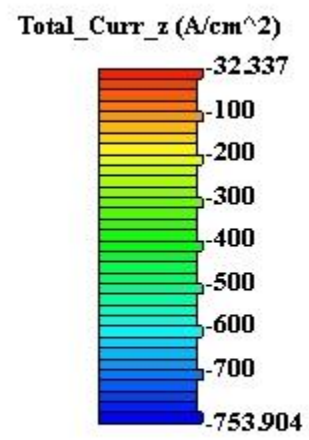
Blue	contact_1
Orange	ito
Yellow	alga_n_2
Light Green	inga_n_5
Green	inga_n_4
Light Blue	inga_n_3
Dark Blue	inga_n_2
Light Cyan	inga_n
Dark Blue	alga_n



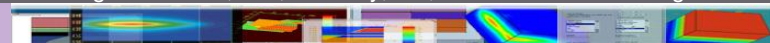
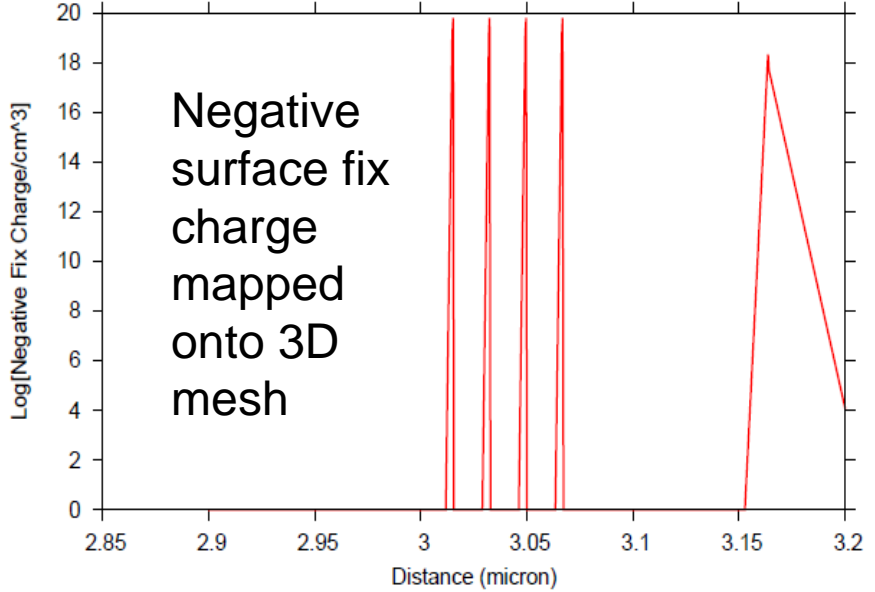
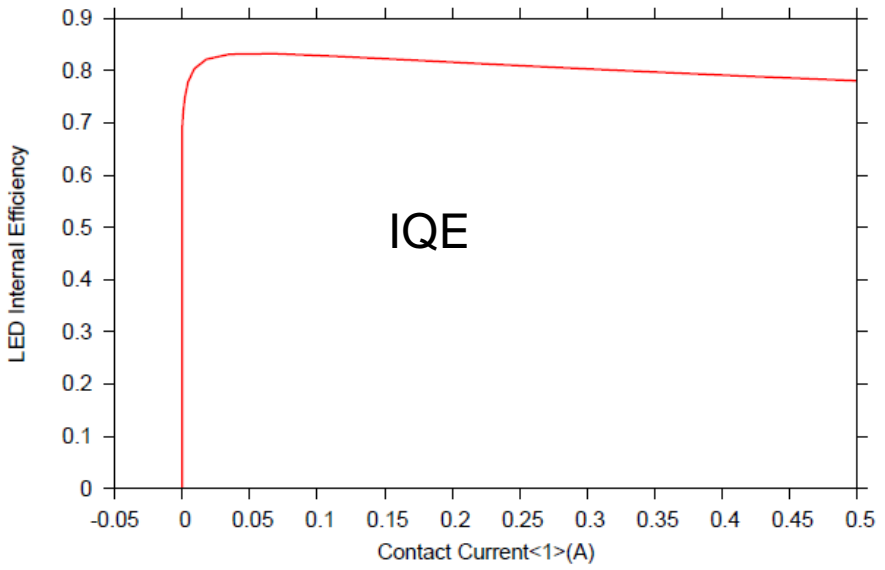
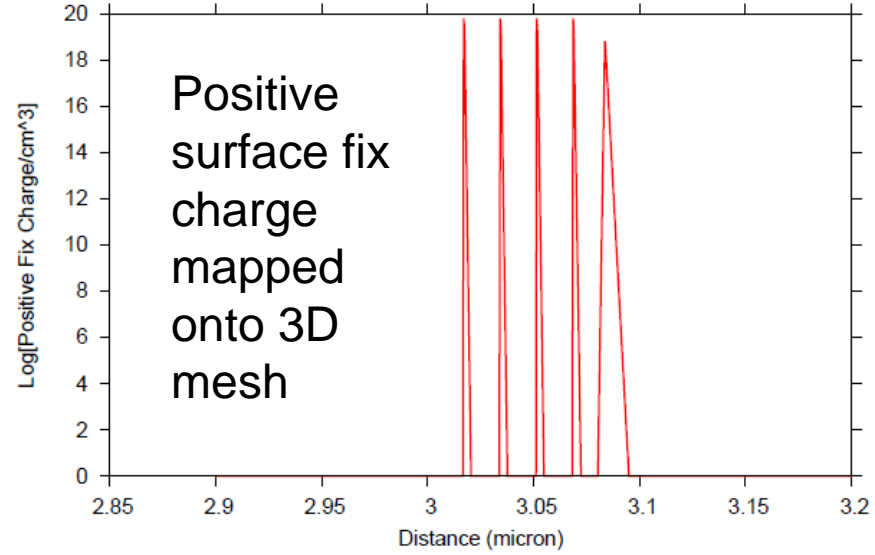
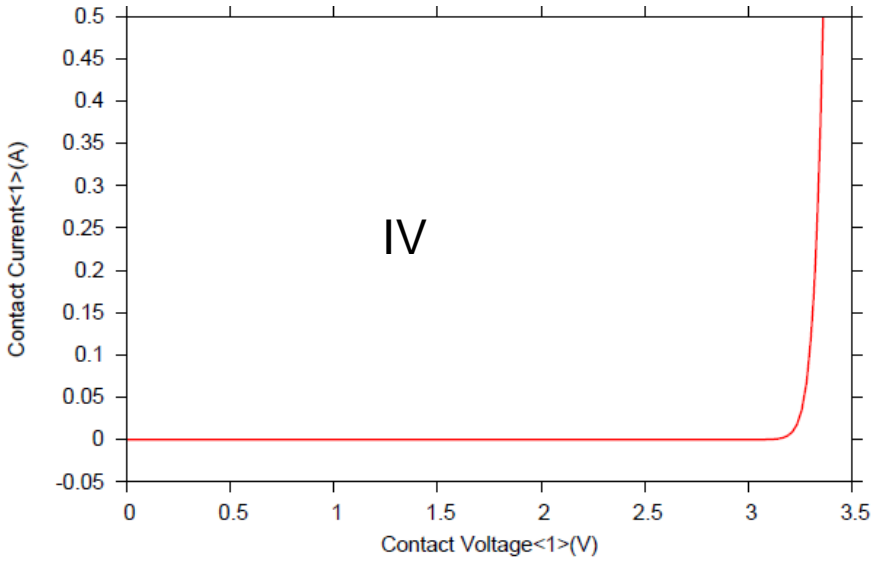
Example 3: LED with spiral top contact



3D current (z-component) plot with top layer removed and MQW layers exposed.

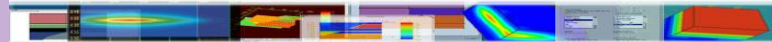


Example 3: LED with spiral top contact



Summary

- 🚀 Comprehensive 3D TCAD simulation provided by CSuprem and APSYS packages for MQW LED.
- 🚀 Results range from quantum levels, optical transition energies, to 3D temperature and current distribution.
- 🚀 Suitable for practical device optimization with typical simulation time ranging from 20 minutes to several hours depending on the structural complexity.



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