

3D Optical, Electrical and Thermal Simulation of Multimode Interference Laser Diode

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Physical models

- Self-consistent calculation combining quantum mechanical solution with drift-diffusion simulation. $k \cdot p$ based strained treatment for MQW.
- Self-consistent computation of interaction of optical gain with electrical and thermal simulation.
- Thermal model treating self-heating from various sources such as Joule heating, optical absorption, recombination and radiative cooling.
- Very mature material library for InGaAsP/InP or InGaAlAs/InP.
- Free carrier optical absorption model.
- Beam propagation method (BPM) computation performed on 3D refined cubical mesh.



Simulation Procedure

- Top view MMI structure defined by MaskEditor; may also import from GDSII data. MaskEditor generates the mask commands needed by CSuprem program.
- Construction of CSuprem input file by MaskEditor. Edit input file as needed.
- Run CSuprem to generate the 3D mesh.
- A minimal mesh 3D demonstration only needs 5000 mesh points and runs in mere on an i7 PC.



Design consideration

- Use of multimode interference (MMI) principle to achieve single mode output and minimum coupling loss.
- Broad area in the middle of MMI to reduce self-heating.
- Broad area in MMI also reduces top p-metal contact resistance and overall injection resistance.



MaskEditor GUI to set up MMI-LD structure

The screenshot displays the MaskEditor software interface. The main workspace shows a vertical pink structure centered at 0 on the x-axis, extending from approximately -100 to 100 on the x-axis and from -40 to 560 on the y-axis. The grid has major ticks every 100 units on both axes. The interface includes a menu bar (File, Edit, Action, View, Options, Help), a toolbar with various icons, and a left-hand panel with several functional buttons.

Left Panel Buttons:

- GDS Import GDS
- Simulation Area
- Default area
- Basic mesh
- Segmented mesh
- Add cut planes
- Z planes
- 2D mask location
- Renummer layers
- On all layers
- Off all layers
- On/off cut lines

Layer List Table:

No.	Label	Color	Purpose	Polarity	Bend
<input checked="" type="checkbox"/>	1	Blue	general	p	<input type="checkbox"/>
<input checked="" type="checkbox"/>	2	Purple	general	n	<input type="checkbox"/>

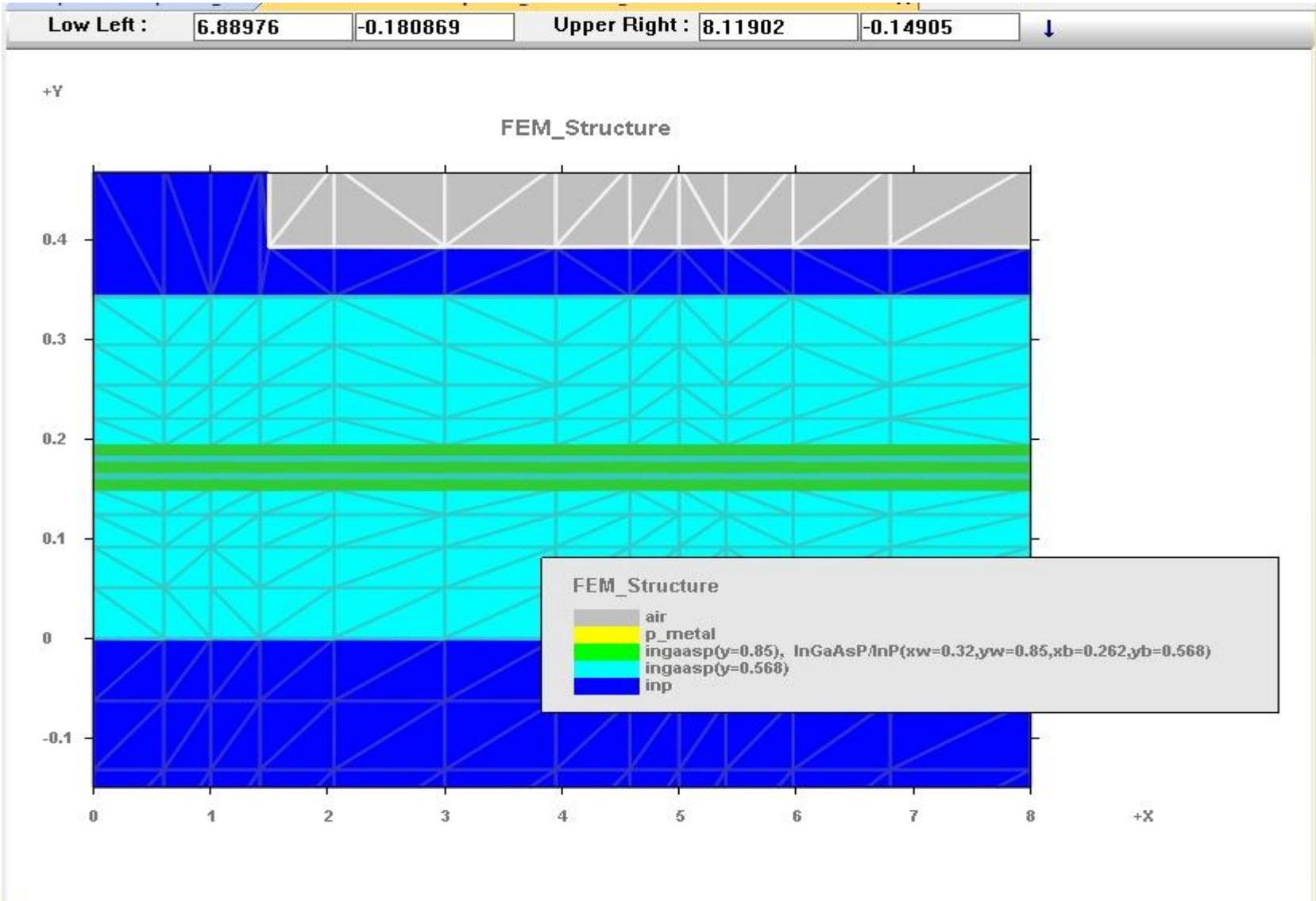
Bottom Panel Buttons:

- 2D extension cut
- 3D save and cut

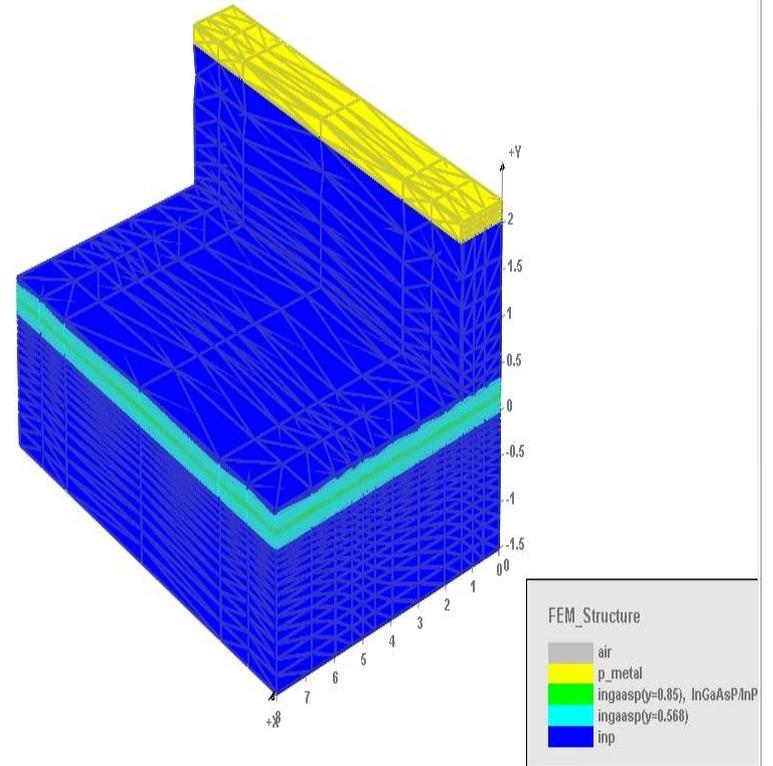
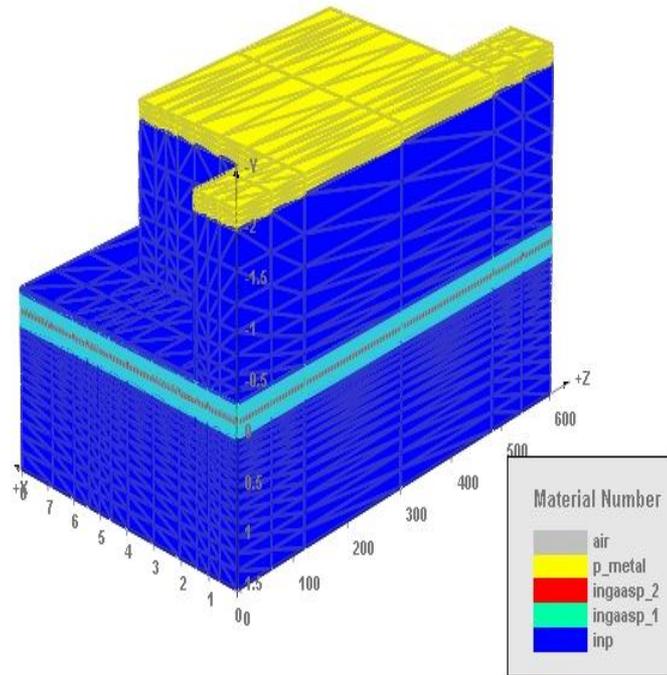
Ready | Wheel to Zoom. Right drag to pan. All units are in um | (-107.516 637.025)um



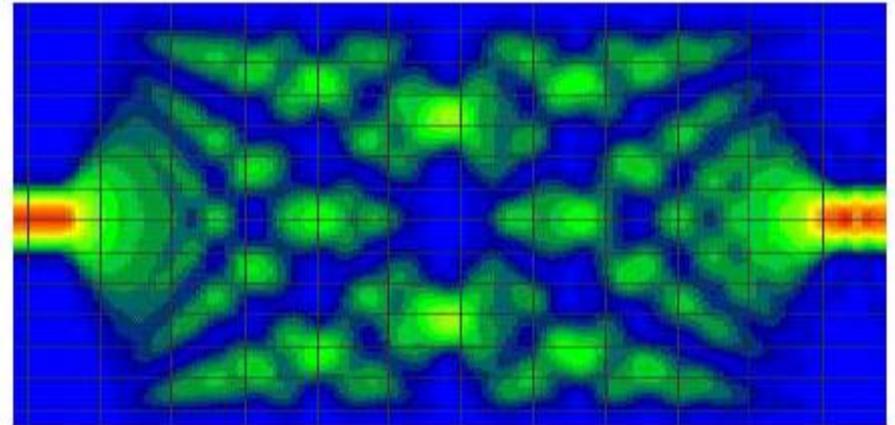
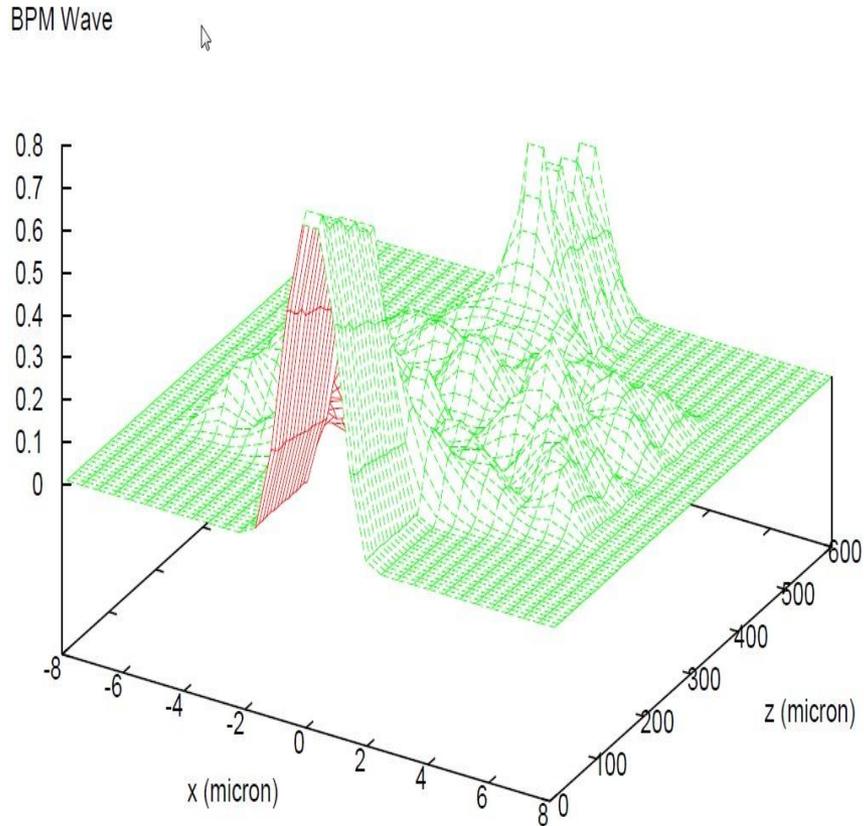
MQW structure



MMI-LD 3D structure and a reference structure



XZ plane of 3D BPM wave intensity



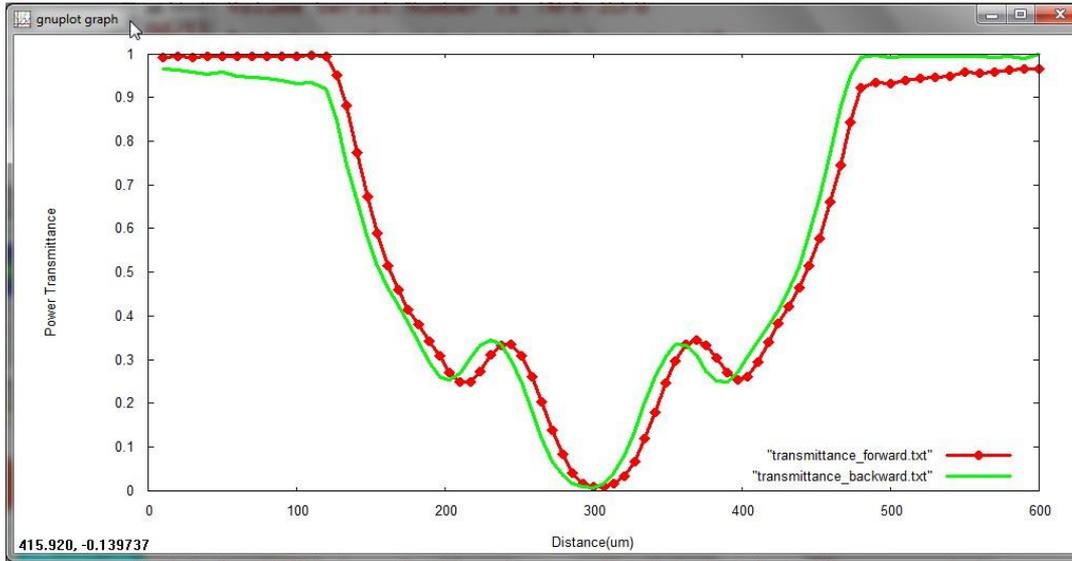
Comparison with 2D BPM simulation in ref. [1]

[1] Rui YIN, Jinghua Teng , Junhong Lin , Soojin Chua, "Semiconductor Laser Using Multimode Interference (MMI) Principle,"

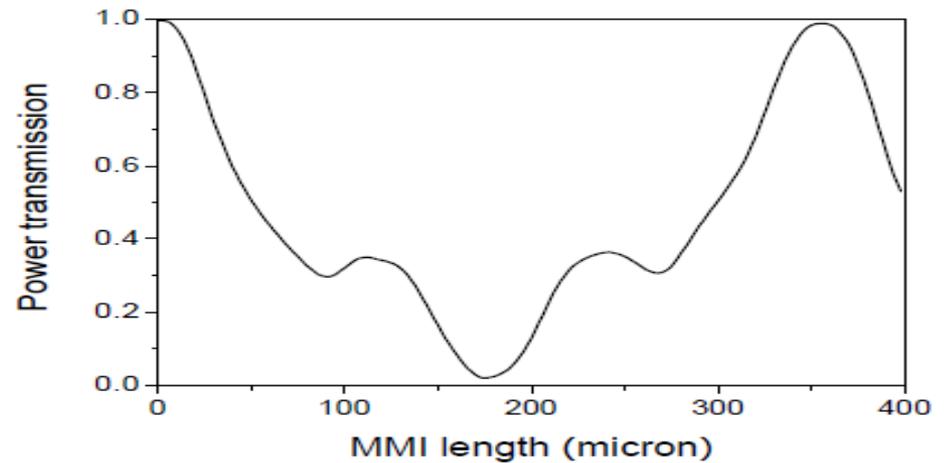
Photonics Global Conference, Singapore, 2008. IPGC 2008. IEEE, 8-11 Dec. 2008.



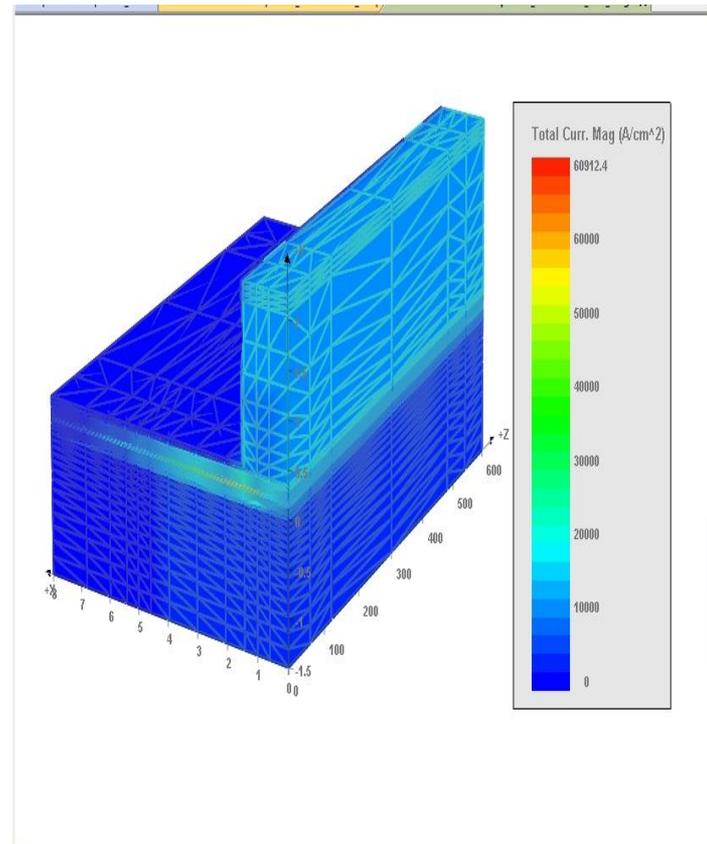
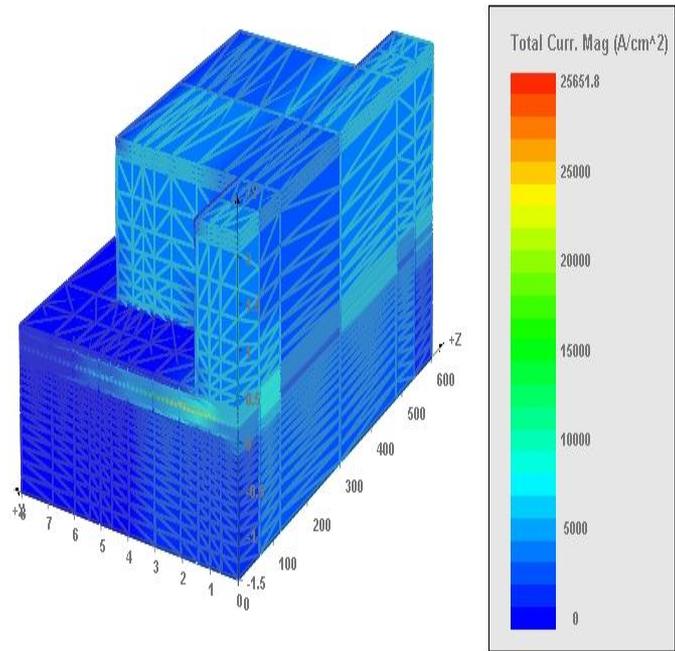
Transmittance from 3D BPM



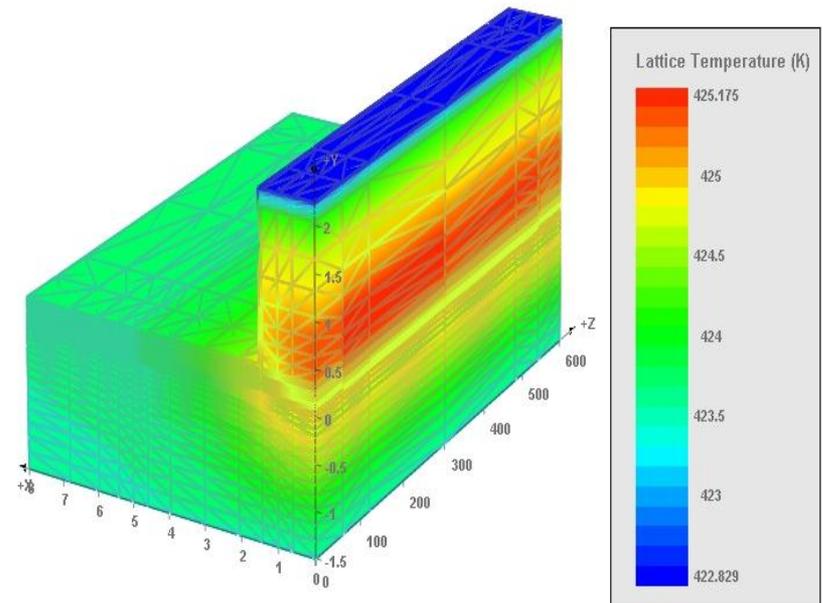
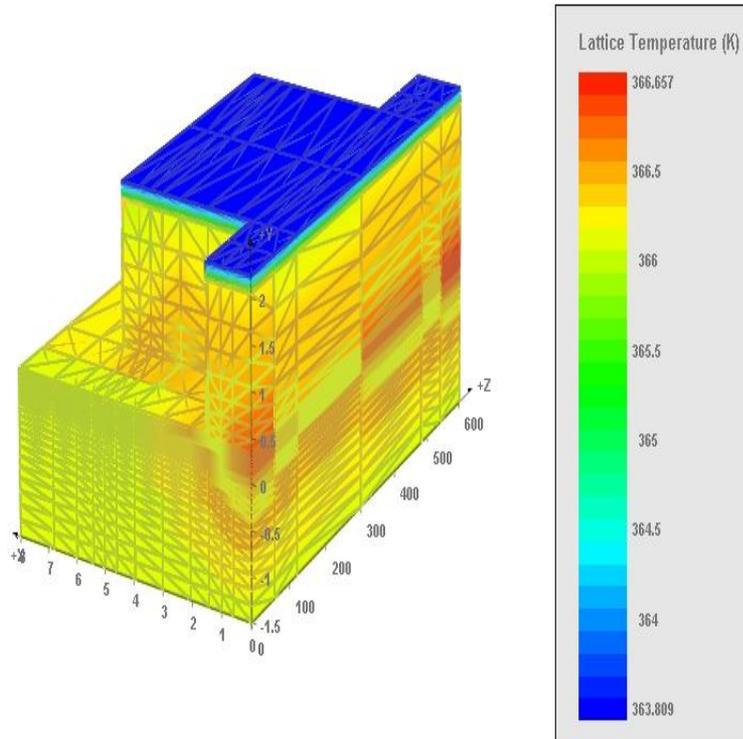
Comparison with 2D BPM
results from ref. [1]



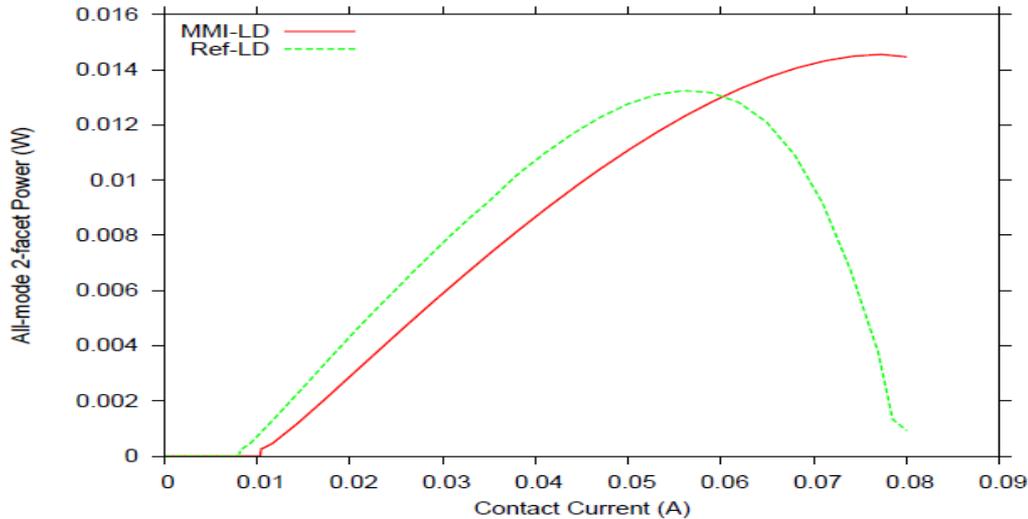
Current flow magnitude distribution (80mA)



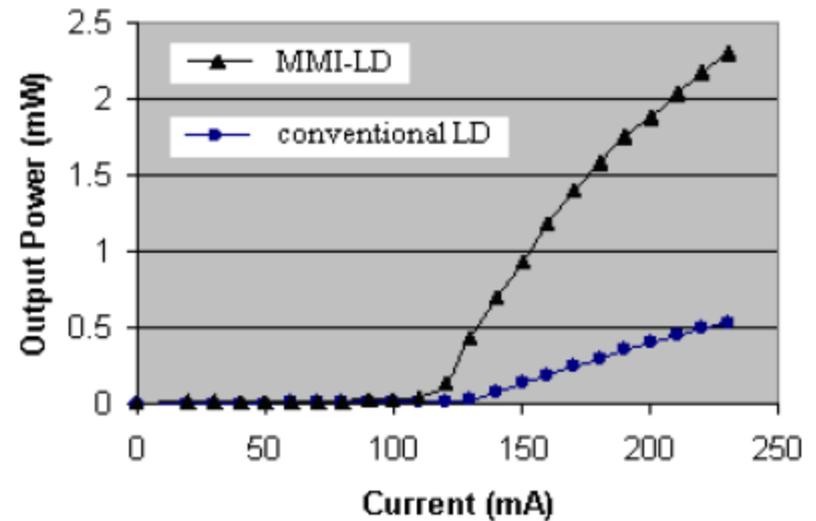
Temperature distribution



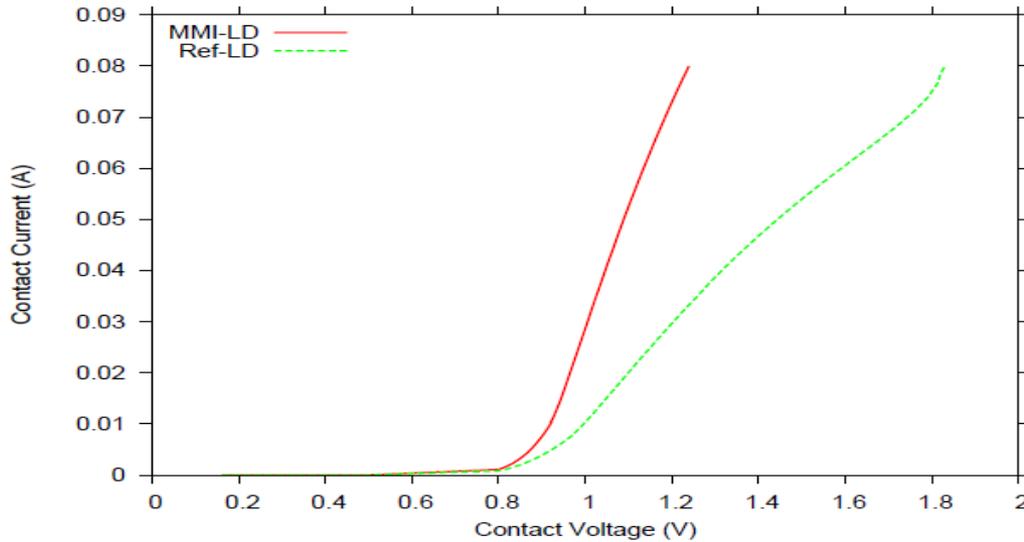
Light vs. current



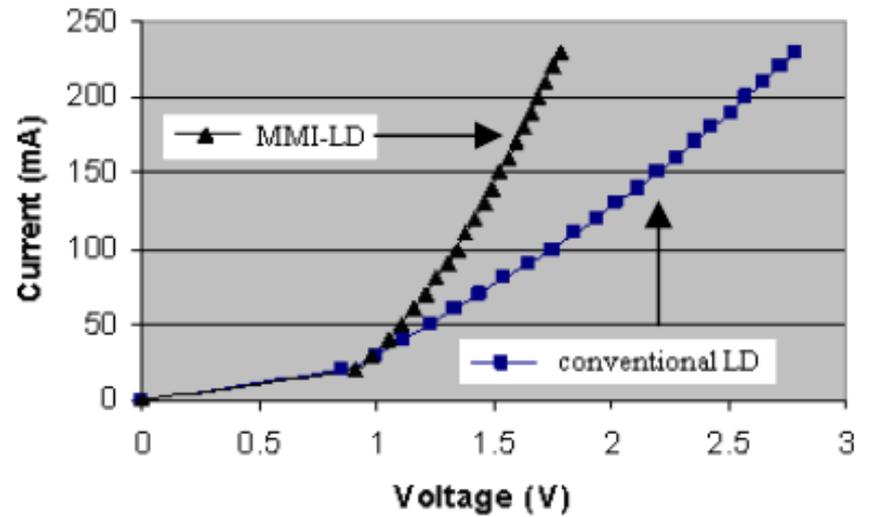
Comparison with two similar devices measured at 10 C from ref. [1]



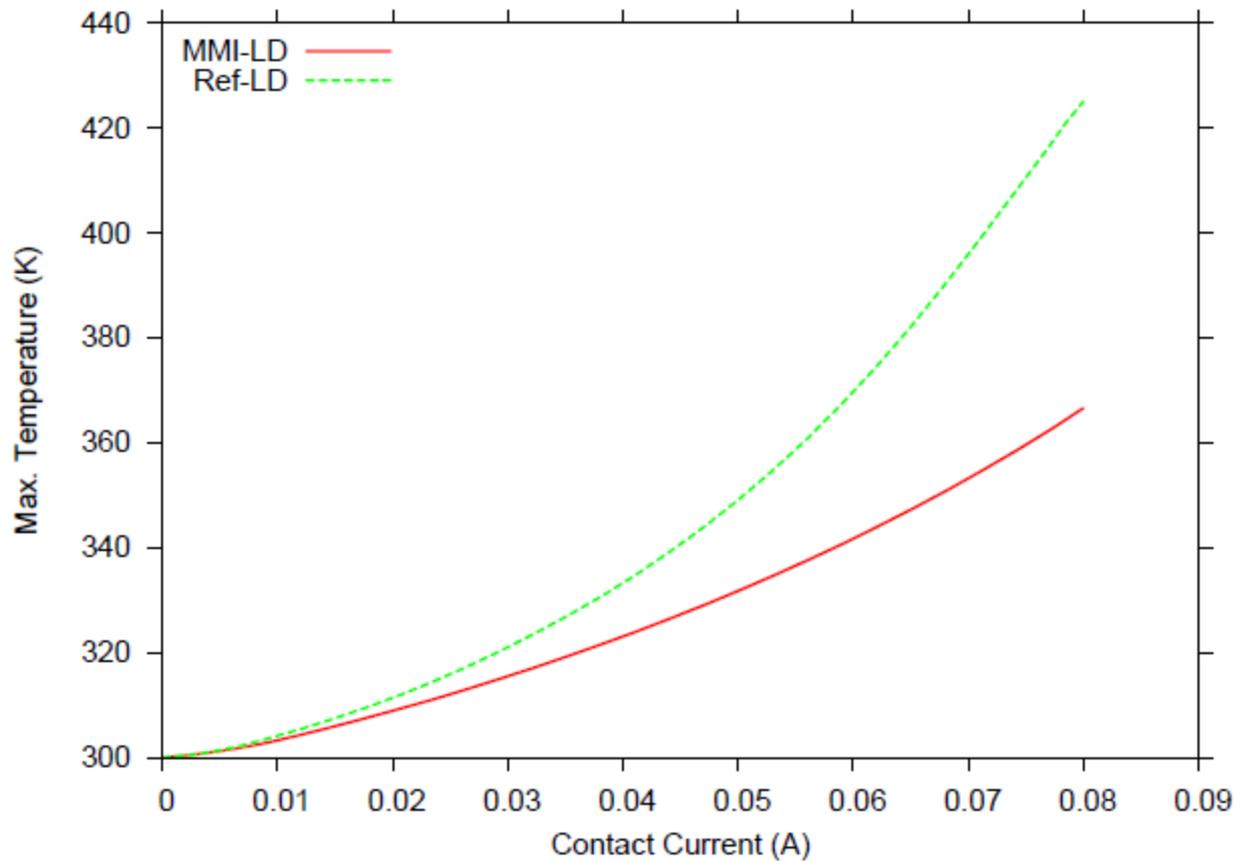
I-V curves



Comparison with two similar devices measured at 10 C from ref. [1]



Maximum temperature vs. current



Conclusions

- Efficient numerical simulation with advanced physical models established for multimode interference laser diodes.
- Initial simulation with minimal mesh shows reasonable physical trend indicating the importance of thermal simulation.
- Tuning of MMI cavity is critical for optimization.



Crosslight Software

A Glimpse

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- ▶ Complete product portfolio for 2D/3D semiconductor device simulation
- ▶ *Café-time Simulator*. Windows based, user friendly graphic user interface makes simulation more enjoyable.



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