Thermal & multimode modeling of high-power SCOWL laser

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Motivation

- Challenge to couple large amount of power into fiber systems
    - Ridge waveguide lasers => problems with heat dissipation
    - Tapered structures => problems with astigmatic output beam
    - Angled-gratings DFBs => hard to make, large aspect ratio of beam hard to couple into fiber.
- SCOWL laser solves many of these issues

SCOWL laser

- Acronym for Slab-Coupled Optical Waveguide Laser
- Device structure allows for high power with large spot size to facilitate heat removal
- Mode is not confined in active region so the beam does not suffer from astigmatism
- Mode can be nearly circular with appropriate waveguide design
- Far field output nearly diffraction-limited
- Works well in coherent beam-combining techniques to achieve even higher power from slabs

SCOWL laser:Introduction

Ref: Chan et al. APL 89, 201110

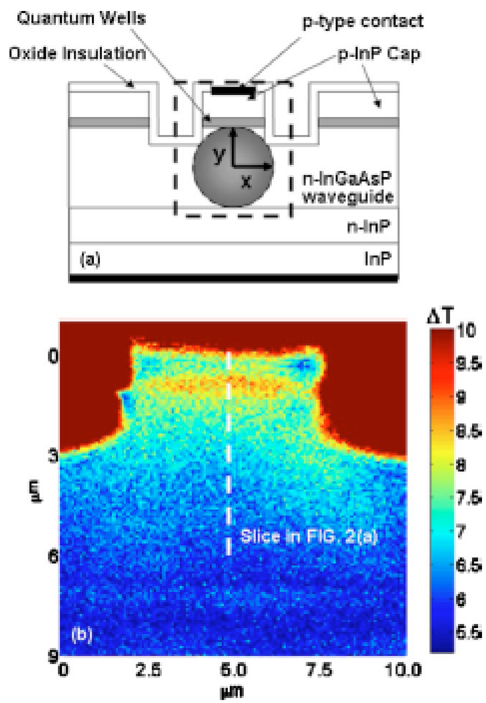
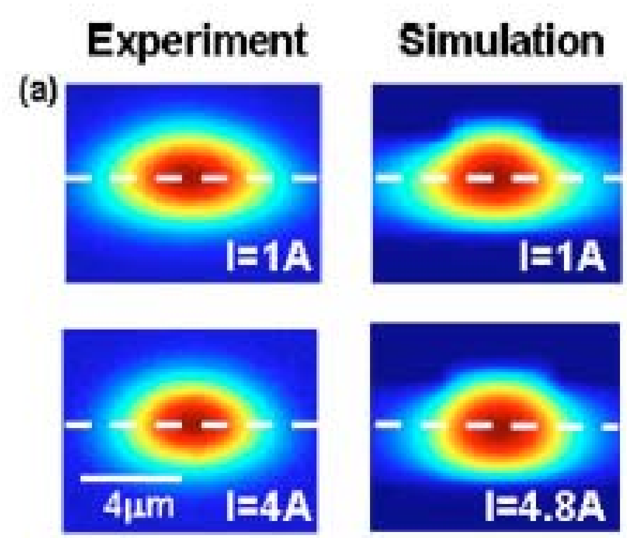


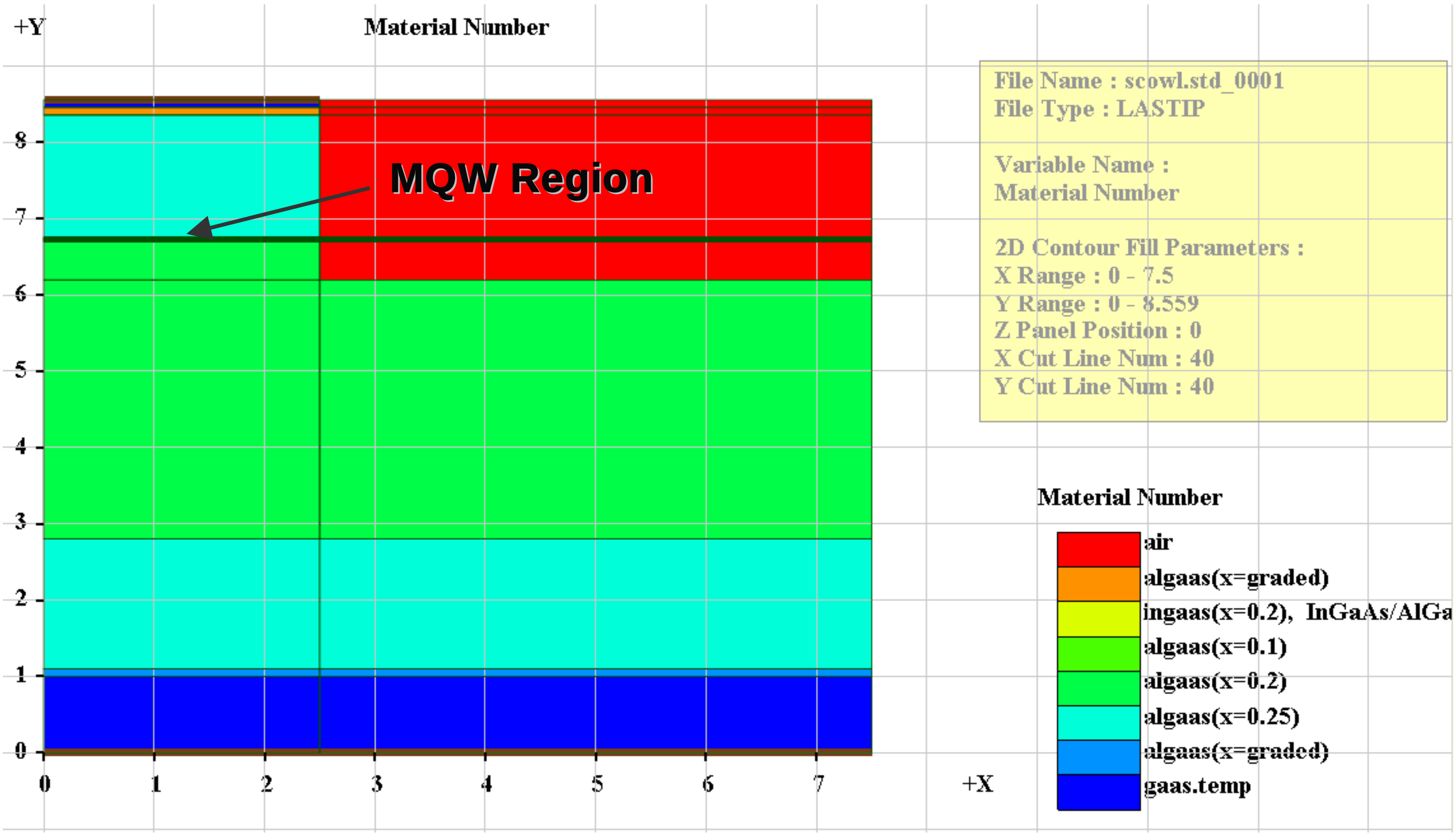
FIG. 1. (Color online) (a) Structure of SCOWL and (b) 2D temperature map of the device at a bias of 2.4 A.



Peculiarities of SCOWL laser

- Large rib width and height ~ 4-5 um
- Mode is confined far away from the active region
- Low modal gain value is needed to maintain single-mode lasing behavior so we need a low confinement factor
- To get high power lasing under these conditions, low background losses and long cavity lengths are required

Simulated Structure



Donnelly & al: IEEE Photon. Tech. Lett. 2002

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Simulation parameters

- Simulation using Crosslight's LASTIP software for Fabry-Perot lasers
- 3 MQW InGaAs/AlGaAs structure @ 980nm
- 10 mm device length with cleaved facets (R=0.32)
- background loss = 140 m^-1
- Rib region is ~ 5 um x 5 um
- Arnoldi direct eigenvalue solver with 30 lateral modes
- Refractive index change as a function temperature/carrier concentration modeled by interband optical transition and plasma effect.

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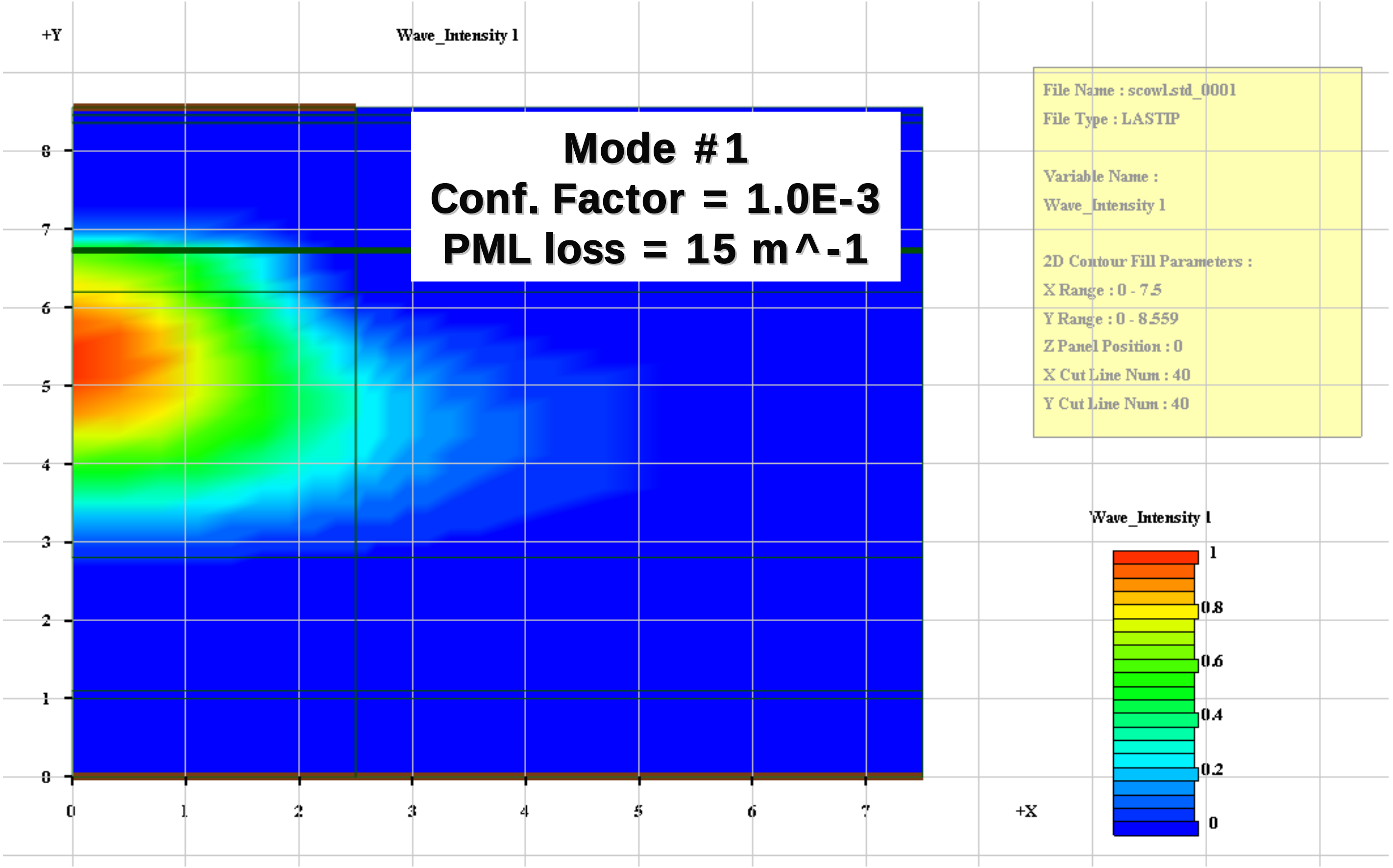
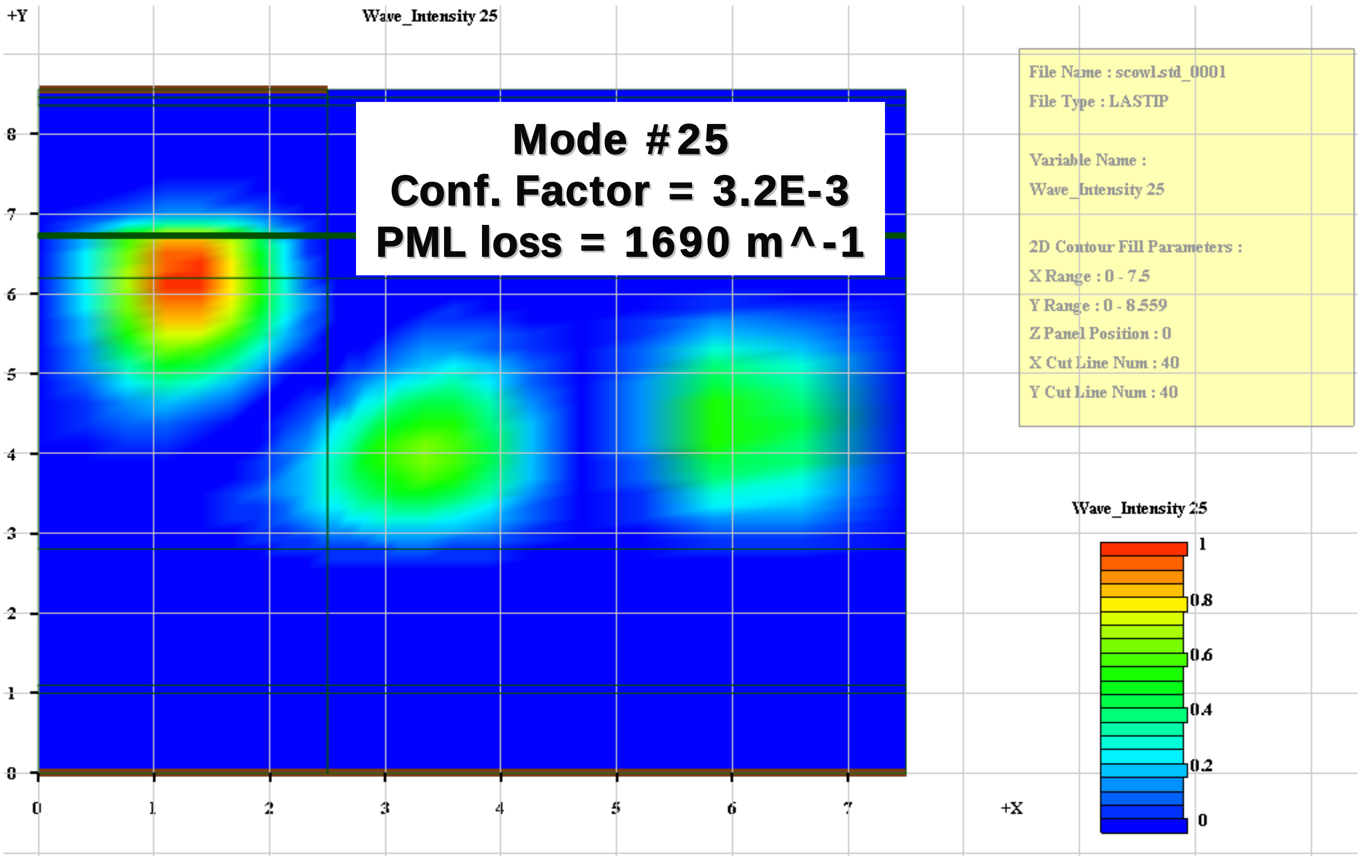
Multimode behaviour

- Waveguide supports many lateral modes
- Some higher-order modes have higher confinement factor than fundamental mode !!!!
- Higher order modes are leaky so only fundamental mode is above threshold
- Proper boundary conditions, especially including PML radiation losses are essential to get the correct mode
- Low gain value in active region reduces the possible appearance of gain-guided modes. Higher gain values run the risk of compensating the radiation losses and allow lateral mode competition.

Multimode behaviour



Multimode behaviour



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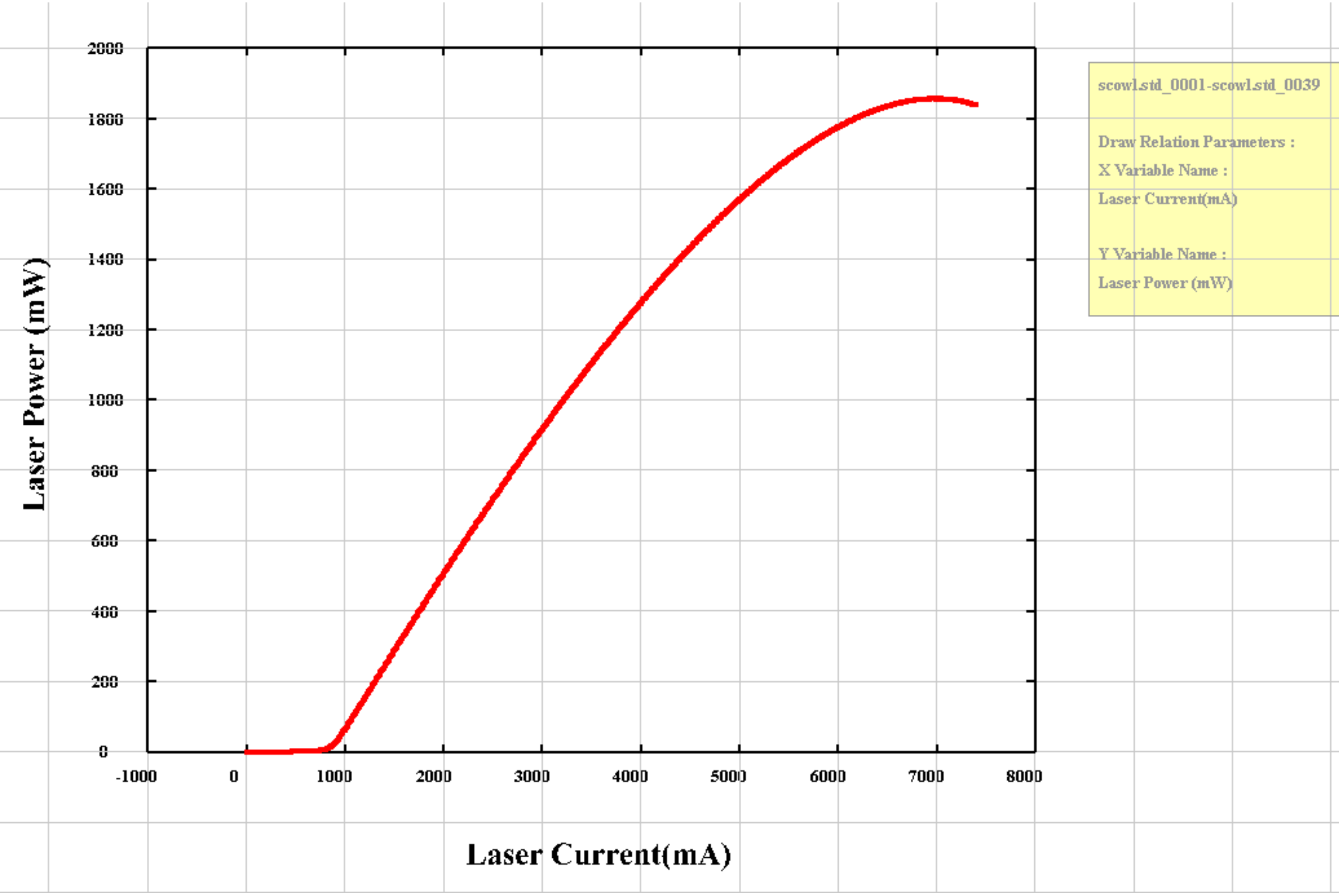
Thermal behaviour



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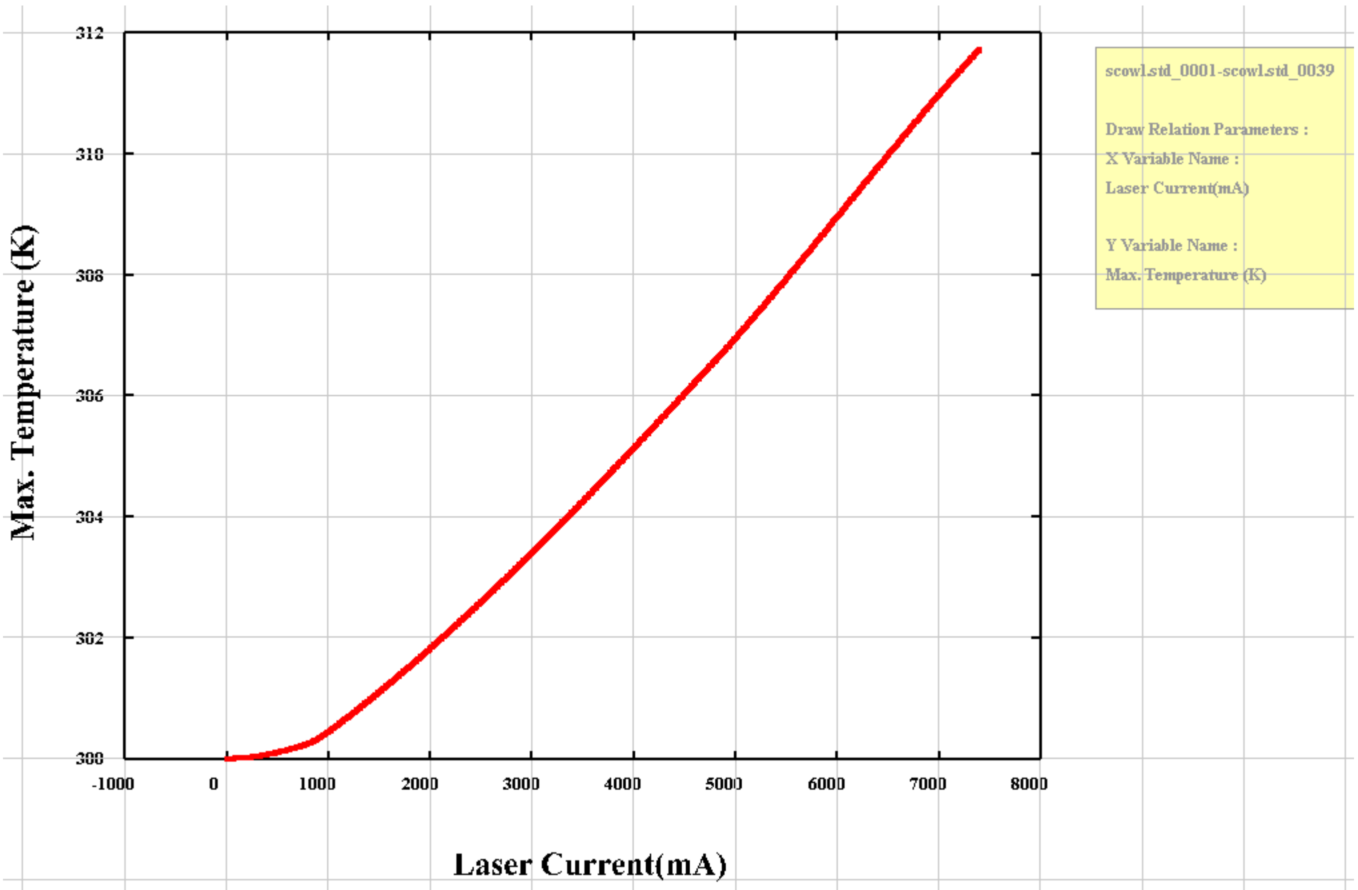
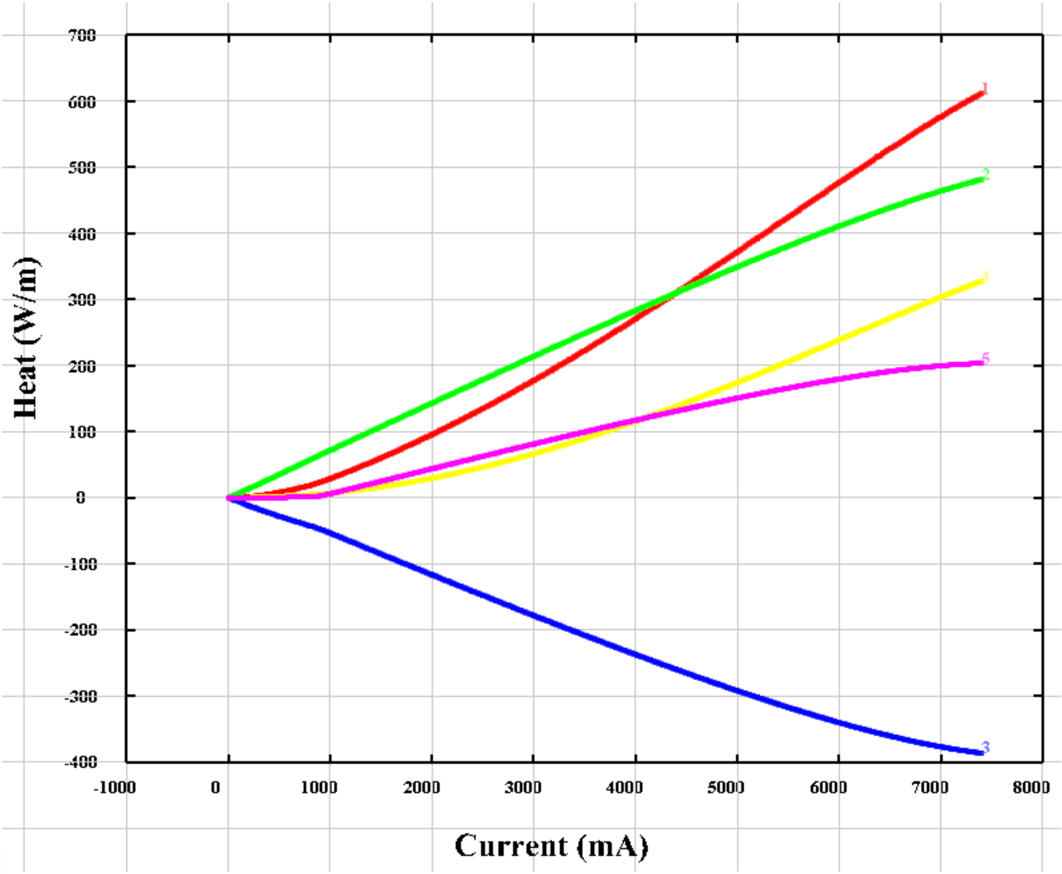
Thermal behaviour

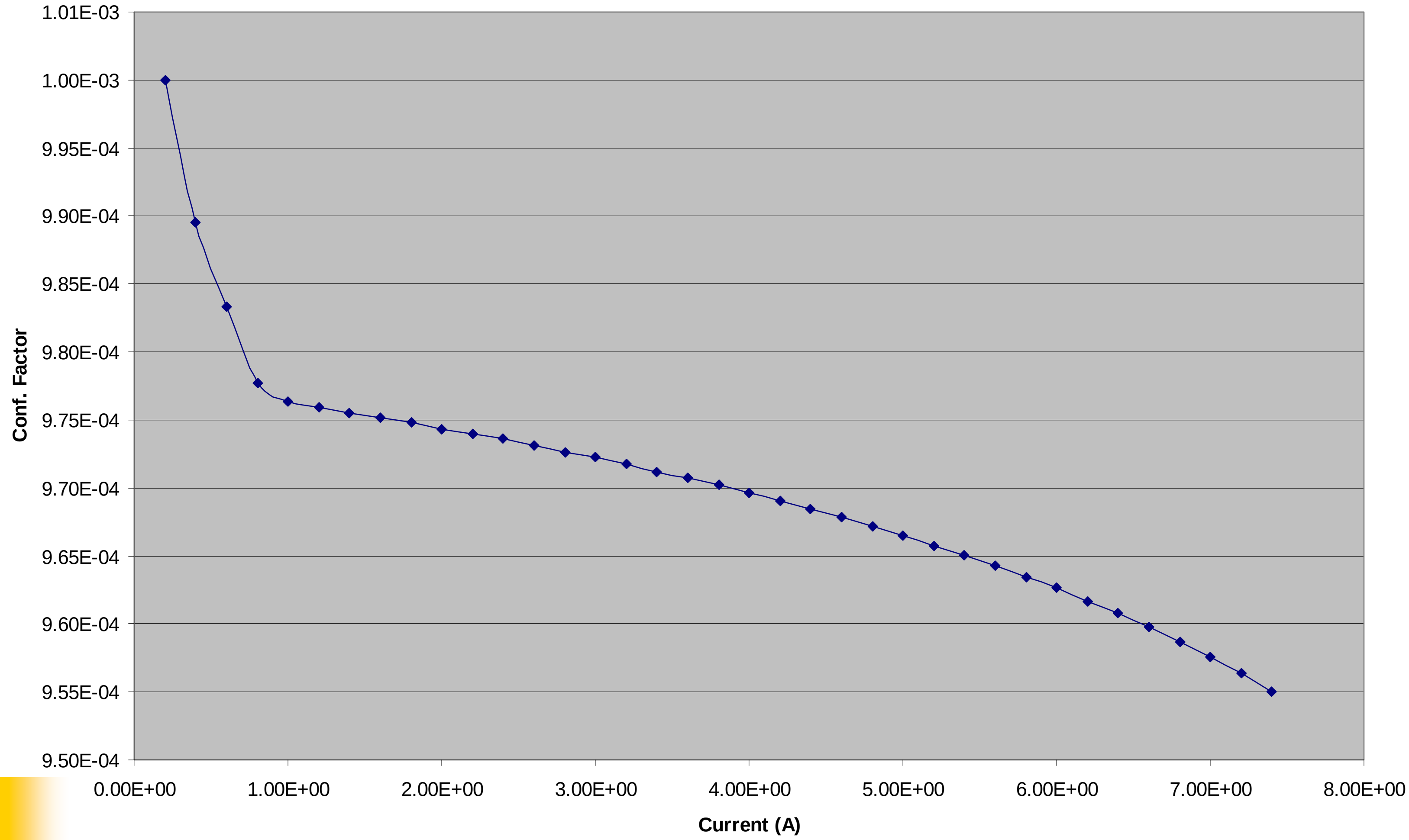


Thermal behaviour



- Radiative cooling
- Recombination heat
- Joule Heat
- Optical absorption Heat
- Total Heat

Confinement factor vs. current



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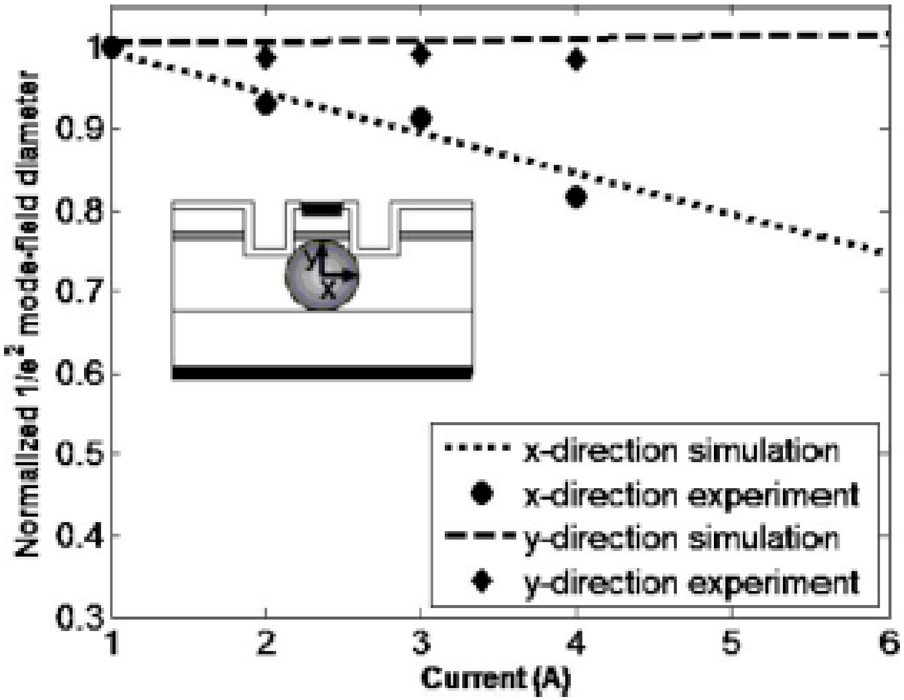
Thermal behaviour

- Good thermal behaviour with relatively slow temperature increase:
    - Long device length & wide rib => low current density
    - Large optical spot & low loss => low optical absorbtion heat
    - High power level => high radiative cooling
- Thermal roll-over is mostly due to loss of optical confinement (~4.5%) due thermal index changes
    - Comparison with experiments: thermal lensing expected ?

Thermal behaviour



- Recent experiments on similar device also expect reduction in confinement

P.K.L. Chan, K.P. Pipe & al: Appl. Phys. Lett. 2006

Summary

- Thermal dependence of index change mechanisms using Kramers-Kronig, free carrier/plasma model appear to give reasonable results.
- LASTIP offers accurate account of lateral modal bahevior in SCOWL type of high power lasers.
- Further research: Due to long cavity, inclusion of longitudinal spatial hole burning and facet optical damage effect (COD) may be required using PICS3D.