Thermal & multimode modeling of high-power SCOWL laser
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, 2011

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
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.
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

Mode #1
Conf. Factor = 1.0E-3
PML loss = 15 m^-1
Multimode behaviour

Mode #25
Conf. Factor = 3.2E-3
PML loss = 1690 m^-1
Thermal behaviour

![Graph showing laser power versus laser current]
Thermal behaviour
Thermal behaviour

- Radiative cooling
- Recombination heat
- Joule Heat
- Optical absorption Heat
- Total Heat
Confinement factor vs. current
Thermal behaviour

- Good thermal behaviour with relatively slow temperature increase:
  - Long device length & wide rib $\Rightarrow$ low current density
  - Large optical spot & low loss $\Rightarrow$ low optical absorption heat
  - High power level $\Rightarrow$ 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

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 behavior 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.