WB4.2: Surface-Etched Laterally Structured Semiconductor Laser Diodes for Mode Engineering

Pawel Strzebonski*, Kent Choquette*

*strzebo2@illinois.edu

Photonic Devices Research Group
Electrical and Computer Engineering Department
University of Illinois, Urbana, Illinois 61801 USA
Motivation

- Want high power, high brightness, and high efficiency semiconductor lasers for pump lasers
- Let’s focus on high brightness
- Key to high brightness is mode control and engineering
- We want to decrease the number of lasing modes, favor modes with better beam qualities, and perhaps even engineer modes with better beams
The Approach

- Beam brightness is primarily determined by the transverse mode structure, and higher order modes tend to deteriorate brightness
- In broad area edge emitting lasers, largely the lateral (not longitudinal or epitaxial) dimension determines the transverse modes
- Use laterally etched structures (ridges) to control and engineer the lateral/transverse modes
Transverse Index Structure: Conventional vs Surface-Etched

Comparing the transverse index profile for a conventional and mode-engineered 100 \( \mu \text{m} \) wide waveguide:

Structured #1

Structured #2

Unstructured
Simulation: Conventional vs Laterally Etched Waveguide Modes

Comparing modal confinement factors for conventional and mode-engineered structures. Orange points represent cut-off to have same $\Delta \Gamma$ as in a conventional 10 $\mu$m wide waveguide:

Structured #1  Structured #2  Unstructured
Simulation: Conventional vs Laterally Etched Waveguide Modes

Comparing mode intensity profiles for the mode with highest confinement for conventional and mode-engineered structures:

Structured #1
Structured #2
Unstructured
Implementation

- Start with InP/InGaAsP large optical cavity epitaxy
- Dry etch the mode engineering patterns through the surface (including the same patterns shown in simulation)
- Deposit thick gold contacts to backfill the etches and act as an ion implant mask
- Ion implantation for electrical confinement
Implementation

Top-view microscope images of the fabricated devices:

Structured #1  Structured #2  Unstructured

Although contacts are sunk into the etched regions, they are contiguous.
Comparison of LIV measurements of structured and unstructured devices:

Structured #1
Unpackaged laser bars with uncoated facets, uncooled room temperature operation, 40 µs pulses

Structured #2

Unstructured
Modal Performance

Comparison of optical spectra of structured and unstructured devices:

Structured #1
Unpackaged laser bars with uncoated facets, uncooled room temperature operation, 40 µs 5A pulses

Structured #2

Unstructured
Comparison of peak-power normalized optical spectra on a linear scale:

Unpackaged laser bars with uncoated facets, uncooled room temperature operation, 40 µs 5A pulses
Near-Fields

Comparison of near-field images of structured and unstructured devices:

Structured #1  Structured #2  Unstructured

Unpackaged laser bars with uncoated facets, uncooled room temperature operation, 40 $\mu$s 5A pulses
Far-Fields

Comparison of far-field images of structured and unstructured devices:

Structured #1  Structured #2  Unstructured

Unpackaged laser bars with uncoated facets, uncooled room temperature operation, 40 $\mu$s 5A pulses
Comparison of lateral cross-section of far-fields for structured and unstructured devices:

Structured #1
Unpackaged laser bars with uncoated facets, uncooled room temperature operation, 40 \( \mu \)s 5A pulses

Structured #2

Unstructured
Conclusions and Future Work

- We surface-etched lateral ridges into 15XX nm InP edge-emitting lasers
- Our surface-etched devices show deteriorated electrical/power performance vs un-etched control devices
- The surface-etched devices show more distinct peaks in the optical spectrum and obvious lobes in near-fields
- The coherence, or lack thereof, between the near-field lobes has not yet been determined
- Next generation devices with regrowth-buried ridges may improve electrical/power performance
THANK YOU