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

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Motivation

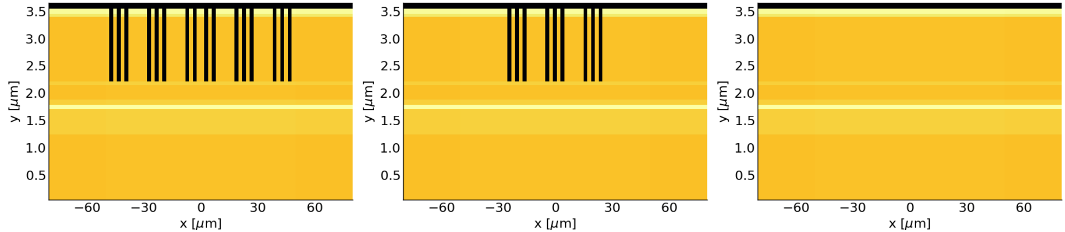
- Want high power, high brightness, and high efficiency semiconductor lasers for pump lasers
- Let's focus on high brightness
- Key to high brightness is mode control and engineering
- We want to decrease the number of lasing modes, favor modes with better beam qualities, and perhaps even engineer modes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



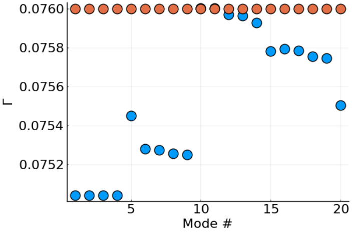
Structured #1

Structured #2

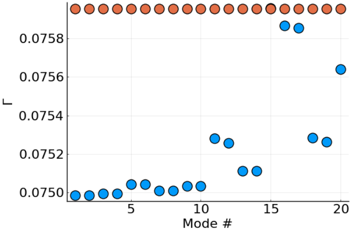
Unstructured

Simulation: Conventional vs Laterally Etched Waveguide Modes

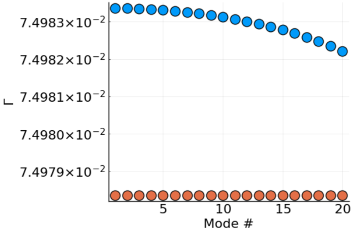
Comparing modal confinement factors for conventional and mode-engineered structures. Orange points represent cut-off to have same $\Delta\Gamma$ as in a conventional 10 μm wide waveguide:



Structured #1



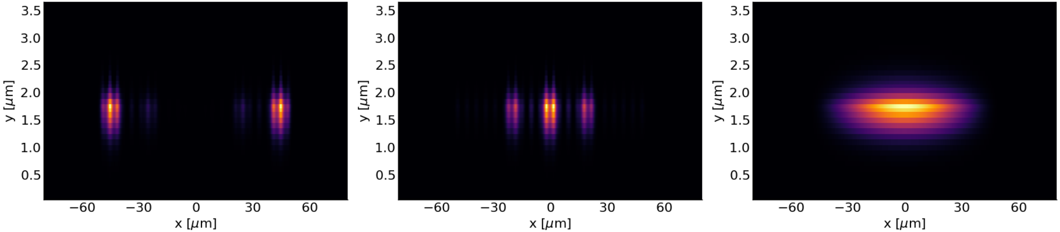
Structured #2



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

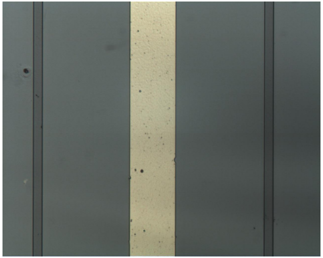
- Start with InP/InGaAsP large optical cavity epitaxy
- Dry etch the mode engineering patterns through the surface (including the same patterns shown in simulation)
- Deposit thick gold contacts to backfill the etches and act as an ion implant mask
- Ion implantation for electrical confinement

Implementation

Top-view microscope images of the fabricated devices:

Structured #1

Structured #2

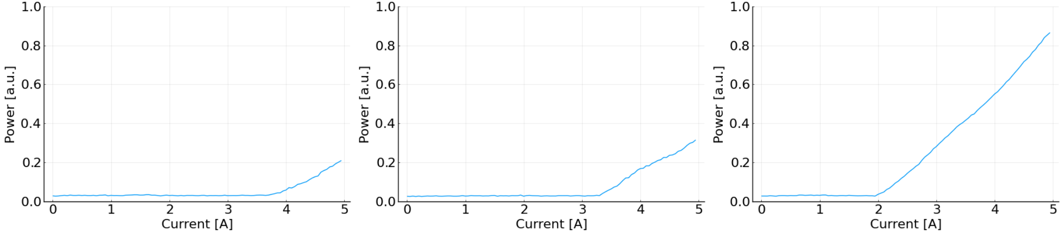


Unstructured

Although contacts are sunk into the etched regions, they are contiguous.

Electrical/Power Performance

Comparison of LIV measurements of structured and unstructured devices:

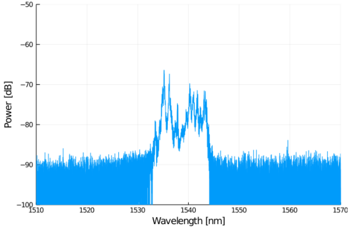


Structured #1 Structured #2 Unstructured

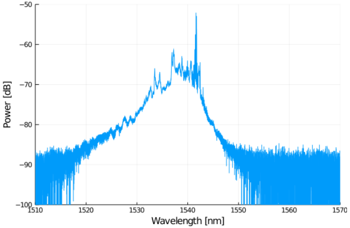
Unpackaged laser bars with uncoated facets, uncooled room temperature operation, 40 μs pulses

Modal Performance

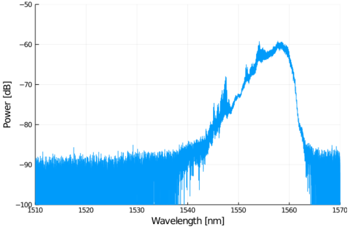
Comparison of optical spectra of structured and unstructured devices:



Structured #1



Structured #2

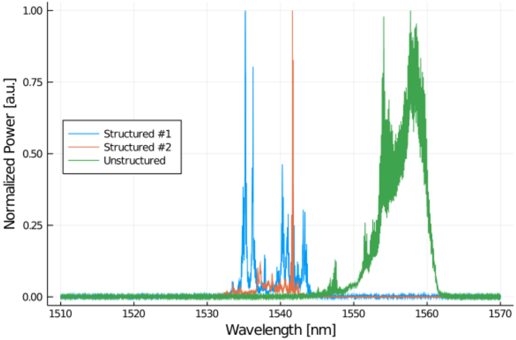


Unstructured

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

Modal Performance

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

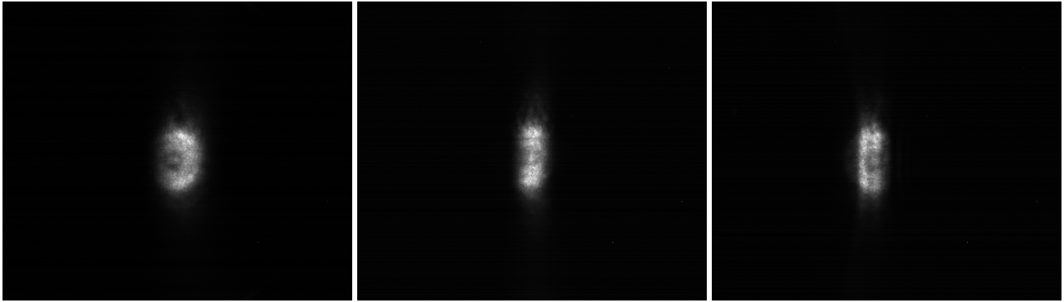
Comparison of near-field images of structured and unstructured devices:

Structured #1 Structured #2 Unstructured

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

Far-Fields

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

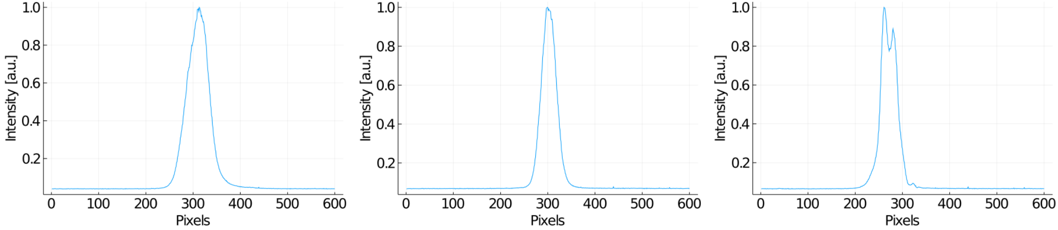


Structured #1 Structured #2 Unstructured

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

Far-Fields

Comparison of lateral cross-section of far-fields for structured and unstructured devices:



Structured #1 Structured #2 Unstructured

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

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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