Analysis of Beam Quality Limitations in High Brightness Gain Guided Tapered Lasers

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Work supported by IST project 1999-10356 ULTRABRIGHT, and of CICYT (Spain) through projects TIC1999-0645 and TIC2000-2030-CE.
Introduction: tapered lasers

Simulation model

Beam limitations of gain guided tapered lasers.

Optimization:
- Ridge length
- Index step
- Taper angle

Conclusions
Tapered lasers

**Tapered section**

**Beam spoilers**

**HR**

**Straight section**

AR

20 – 200µm

1 – 3mm

20 – 4µm
Tapered lasers

Maximum power per emitter $\sim 4$ W cw
Goal of this work

To apply a quasi-3D simulation model to optimize the design of the geometry in gain-guided tapered lasers
Outline

- Introduction: tapered lasers
- **Simulation model**
  - Beam limitations of gain guided tapered lasers. Optimization:
    - Ridge length
    - Index step
    - Taper angle
- Conclusions
Simulation model

**Electrical, thermal and optical model**

- **Electrical model (3D)**
  - Self-consistent 3D solution
  - Continuity equations (electrons y holes), Poisson and capture/escape

- **Thermal model (3D)**
  - Heat flow equation + local heat sources

- **Optical model (2D)**
  - Wide-angle beam propagation method (WA-BPM)

**Inputs**

- Epitaxy
- Geometry
- Bias current

**Outputs**

- Current and power
- 3D carrier distribution, Fermi levels ...
- 2D photon distribution
- Figures of merit: divergence, $M^2$, astigmatism ...

Steady-state and single frequency approximations
Validation of the model

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Conclusions
Beam deterioration in gain-guided devices

Reasons for beam deterioration

Abrupt deterioration ↔ Maximum power

Poor spatial filtering

Index-induced effects
  Carrier lensing
  Self-focusing
Optimization of the ridge length

Longer straight section: better filtering
Longer tapered section: lower power density

$L_{\text{ridge}} = 500 - 750 - 1000 - 1250 - 1500 \quad L_{\text{tot}} = 2750 \ \mu m$

Emission wavelength: 808 nm
No beam-spoilers

Photon density @ output facet (au)

The straight section must be the shortest to guarantee proper filtering
Optimization of the ridge length

Forward field

Photon density @ filtering section output (au)

Lateral axis (µm)

808 nm

$L_{total} = 2.75 \text{ mm}$

$L_{ridge} = 500, 750, 1000, 1250 \text{ y } 1500 \text{ µm}$
Optimization of the ridge design

Etch depth / Index step

Wavelength: 975 nm
Cavity length: 600 + 2400 µm
Beam spoilers
Index steps: $6 \cdot 10^{-4}$, $28 \cdot 10^{-4}$ and $38 \cdot 10^{-4}$

Optical power (W)

$M^2 (1/e^2 \text{ method})$
Optimization of the ridge design

Improvement by increasing the free diffraction angle
Optimization of the taper angle

Length: 500 + 1500 µm  \( \lambda = 975 \text{ nm} \)
Ridge width = 3 µm  \( \Delta n = 30 \times 10^{-4} \)
Diff. Angle passive RW = 5.4º (@1/e²)

Angles: 5º, 4º, 3º and 2º

![Optical power graph](image)
Optimization of the taper angle

- The taper angle optimization affects the power per facet width (mW/µm) and the far-field profile (°).
- The graphs show the intensity (a.u.) at different powers (P ~ 0 W, P ~ 1 W, P ~ 1.7 W).
- The far-field profile (°) is measured for individual taper angles: 5°, 4°, 3°, 2°.
Conclusions

Design guidelines

- Beam spoilers + short RW section.
- Long cavity length
- High free diffraction angle (high step index in RW section).
- Electrode angle selection:
  - slightly lower than the free diffraction angle to maximize absolute power
  - much lower (~2°) to maximize brightness in laser bars
• 3D simulation tool applied to optimize gain guided tapered lasers
• Beam quality limited by poor spatial filtering and/or carrier lensing.
• Design parameters studied:
  - Ridge length
  - Index step in the RW section
  - Electrode angle in the tapered section
• Design guidelines proposed