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

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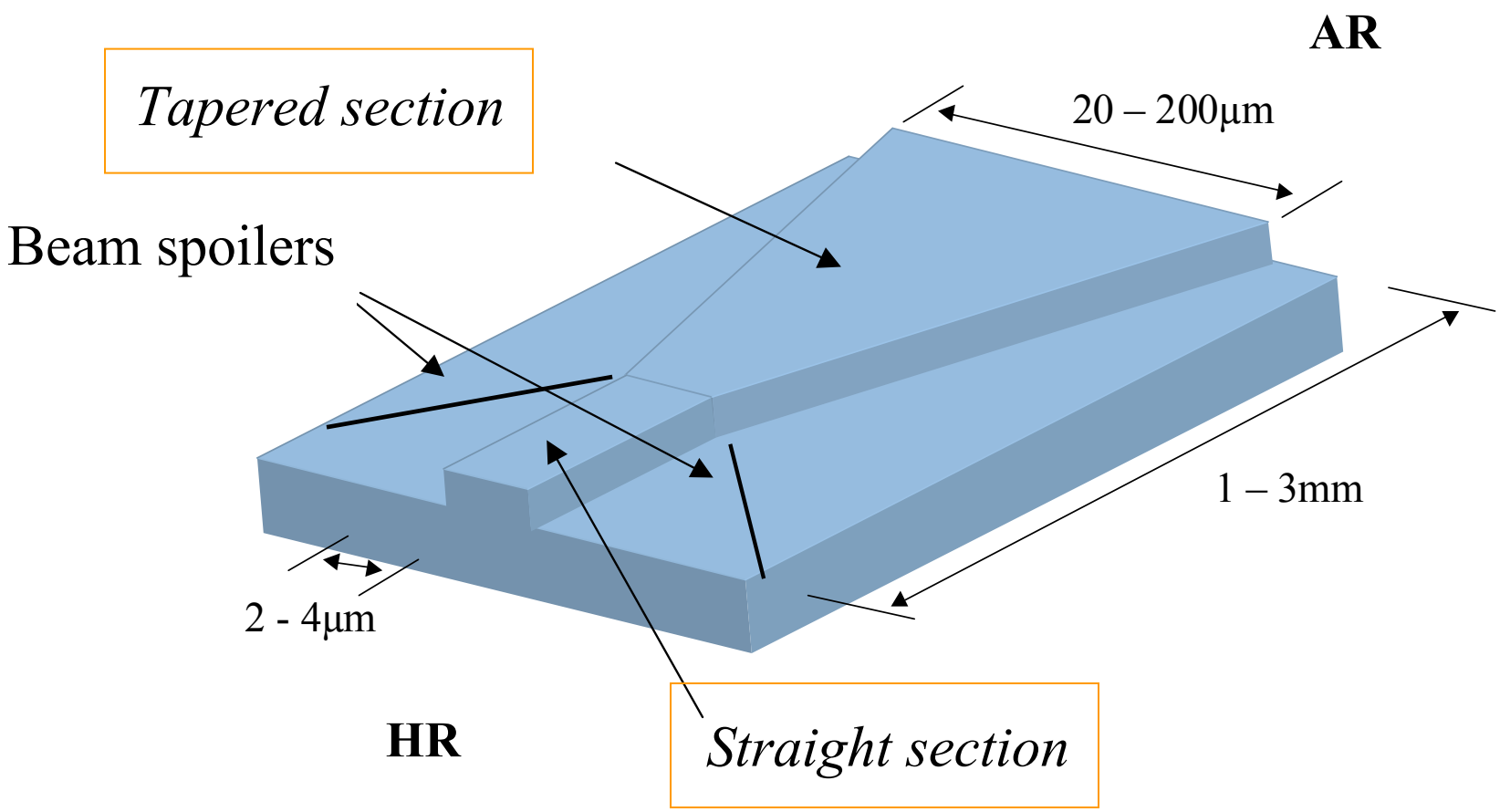
# Outline

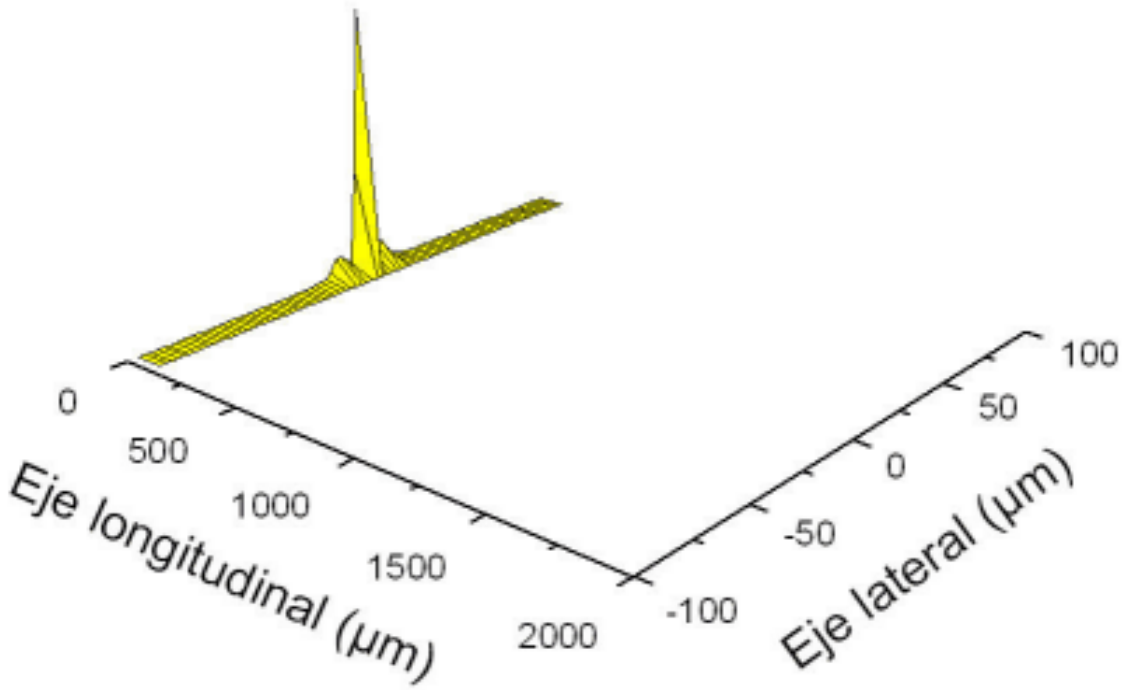
- Introduction: tapered lasers
- Simulation model
- Beam limitations of gain guided tapered lasers. Optimization:
  - Ridge length
  - Index step
  - Taper angle
- Conclusions

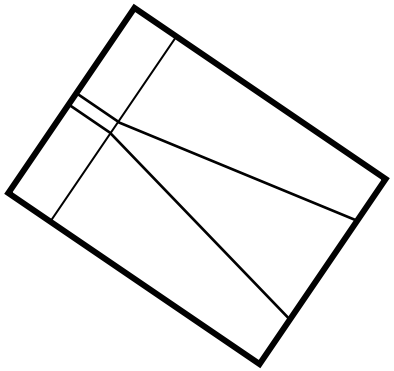
# Tapered lasers



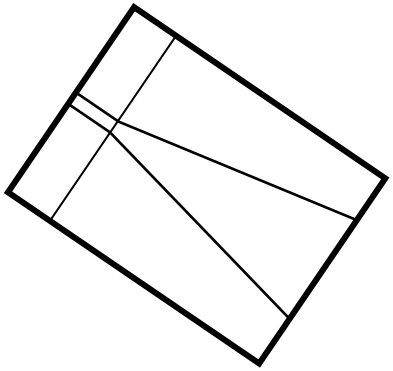
# Tapered lasers

Maximum power per emitter ~ 4 W cw



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



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## Electrical, thermal and optical model

### Electrical model (3D)

Self-consistent 3D solution

Continuity equations (electrons y holes), Poisson and canture/escape

Steady-state and single frequency approximations

### 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**

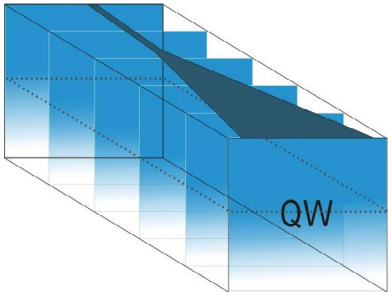
Current and power

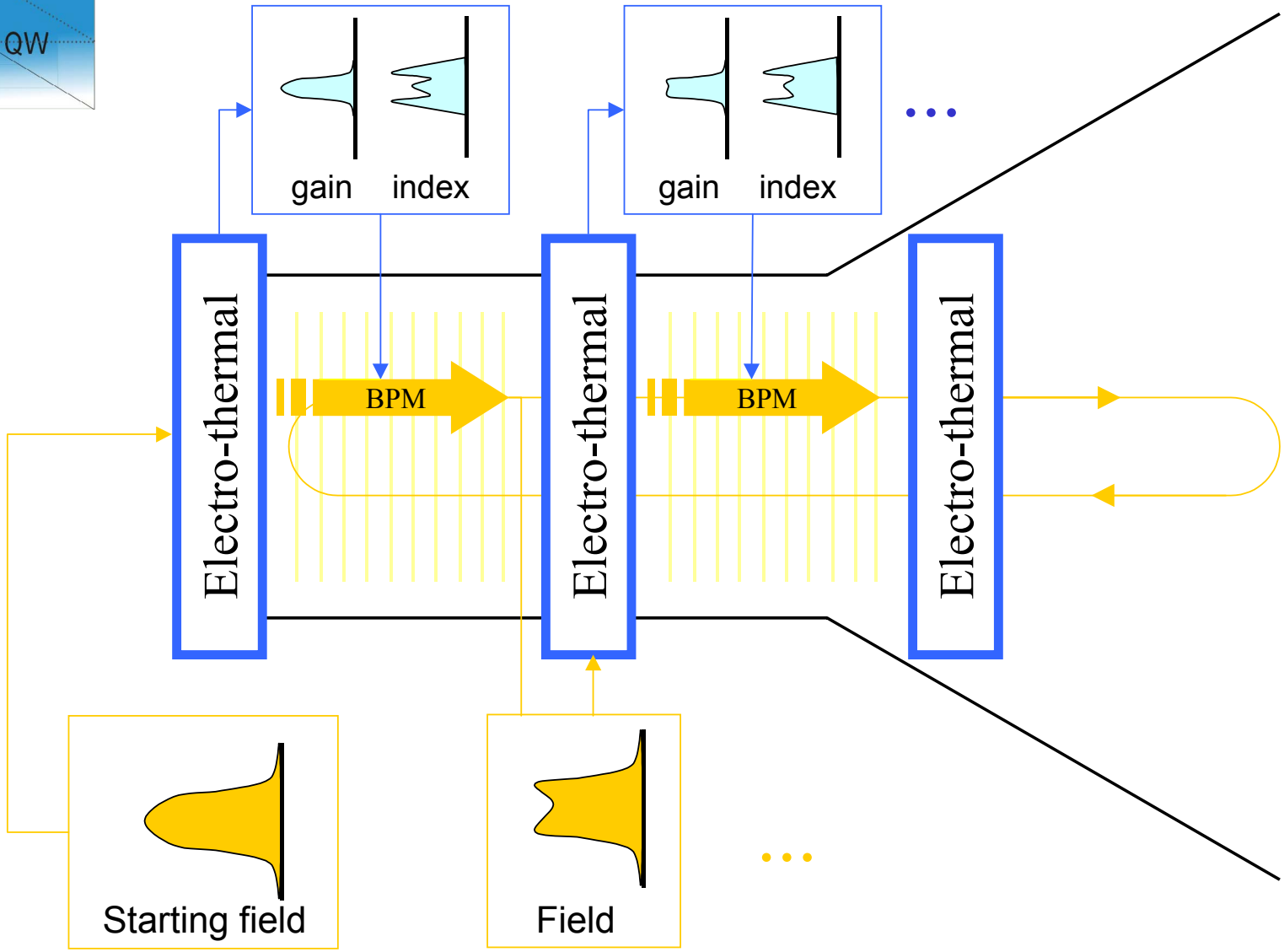
3D carrier distribution, Fermi levels ...

2D photon distribution

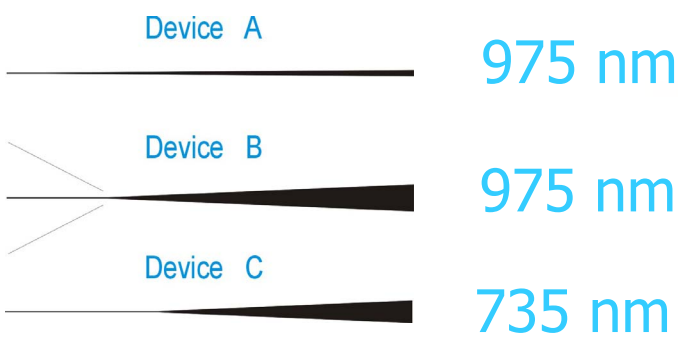
Figures of merit: divergence, $M^2$, astigmatism ...

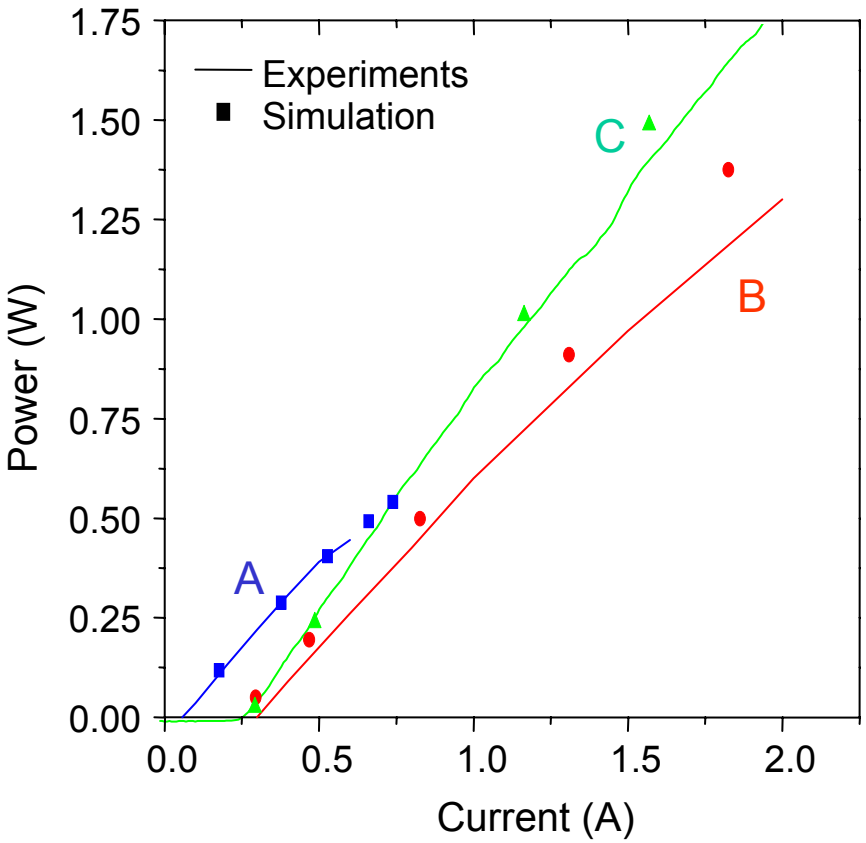
# Flow diagram

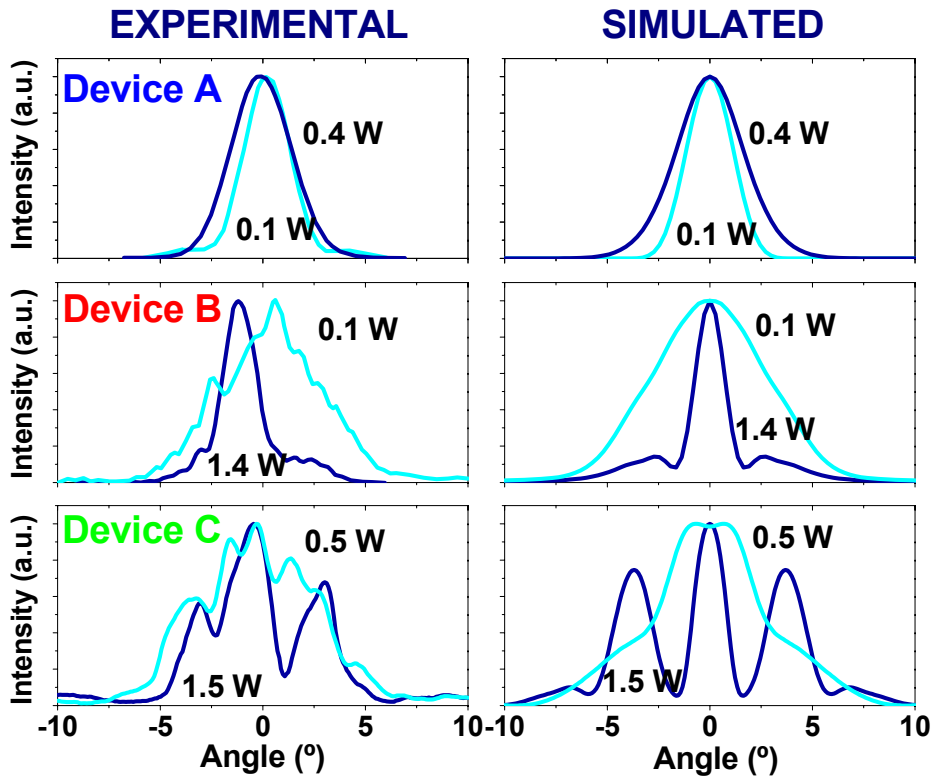


# Validation of the model




Borruel et al., "Quasi-3D Simulation of High-brightness Tapered Lasers", JQE 40, p.463, 2004.

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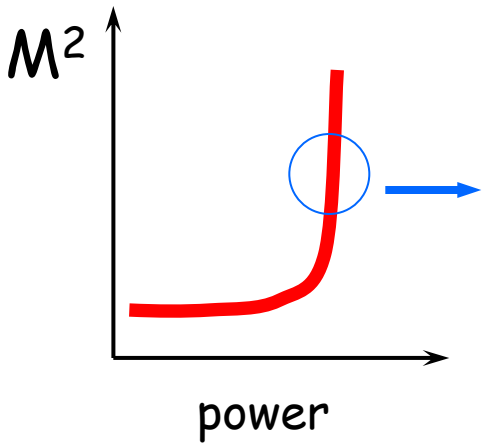
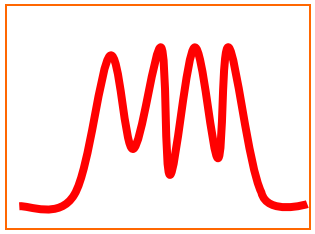
# Beam deterioration in gain-guided devices




Abrupt deterioration ⟷ Maximum power

Reasons for beam deterioration

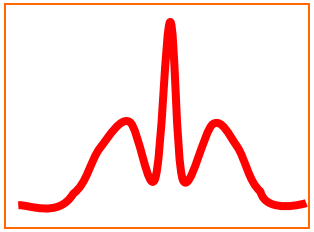
Poor spatial filtering



Index-induced effects

Carrier lensing

Self-focusing



# Optimization of the ridge length

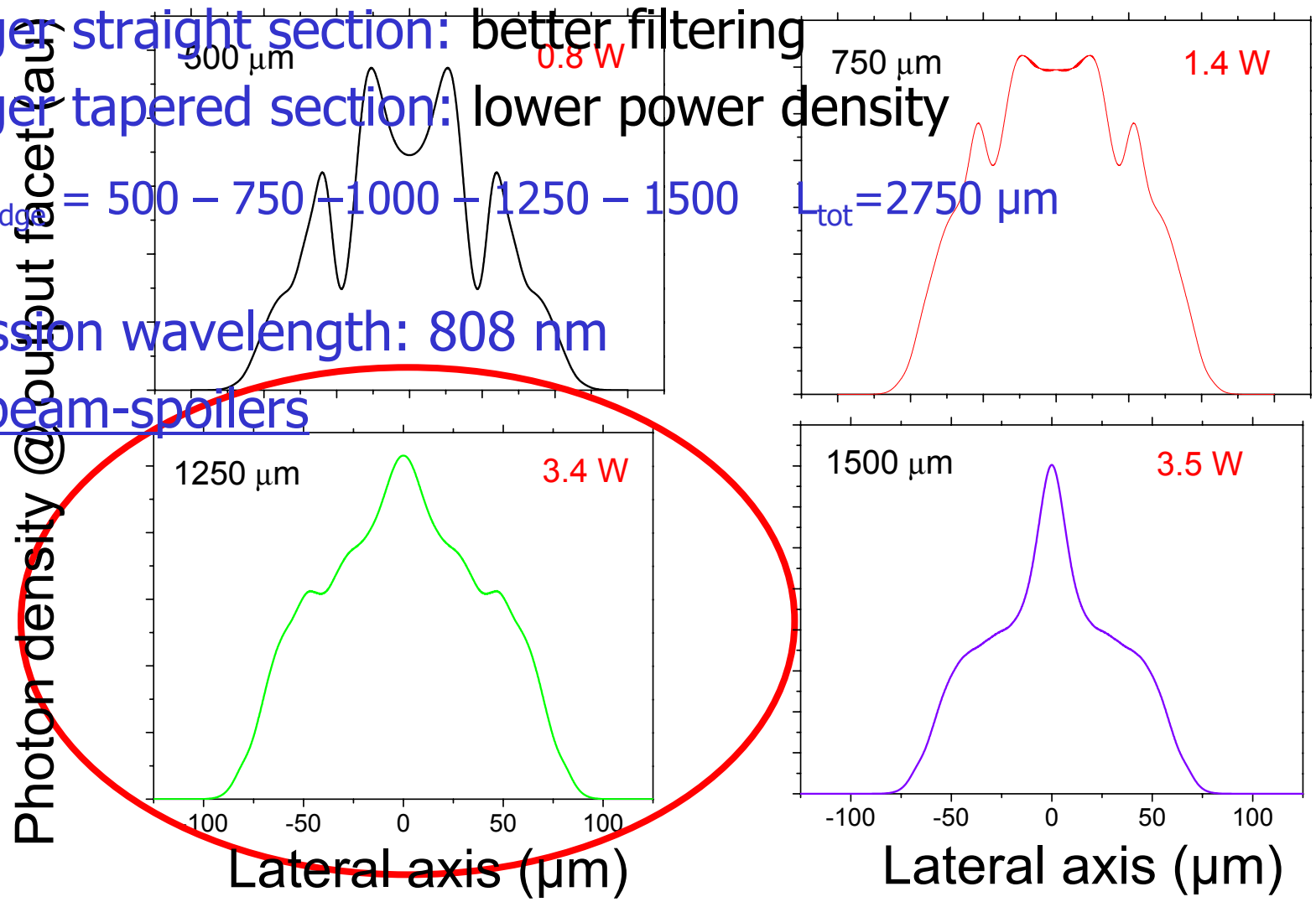
Longer straight section: better filtering

Longer tapered section: lower power density

$L_{ridge}$ = 500 – 750 – 1000 – 1250 – 1500  $L_{tot}$=2750 µm

Emission wavelength: 808 nm

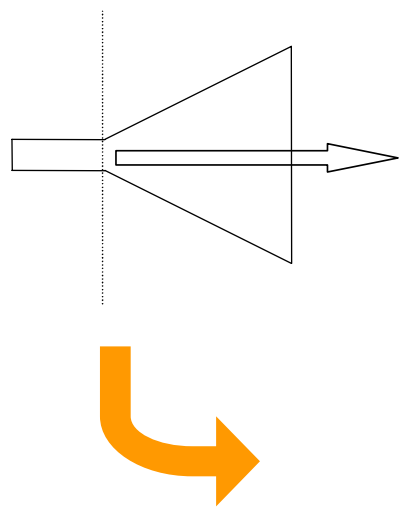
No beam-spoilers

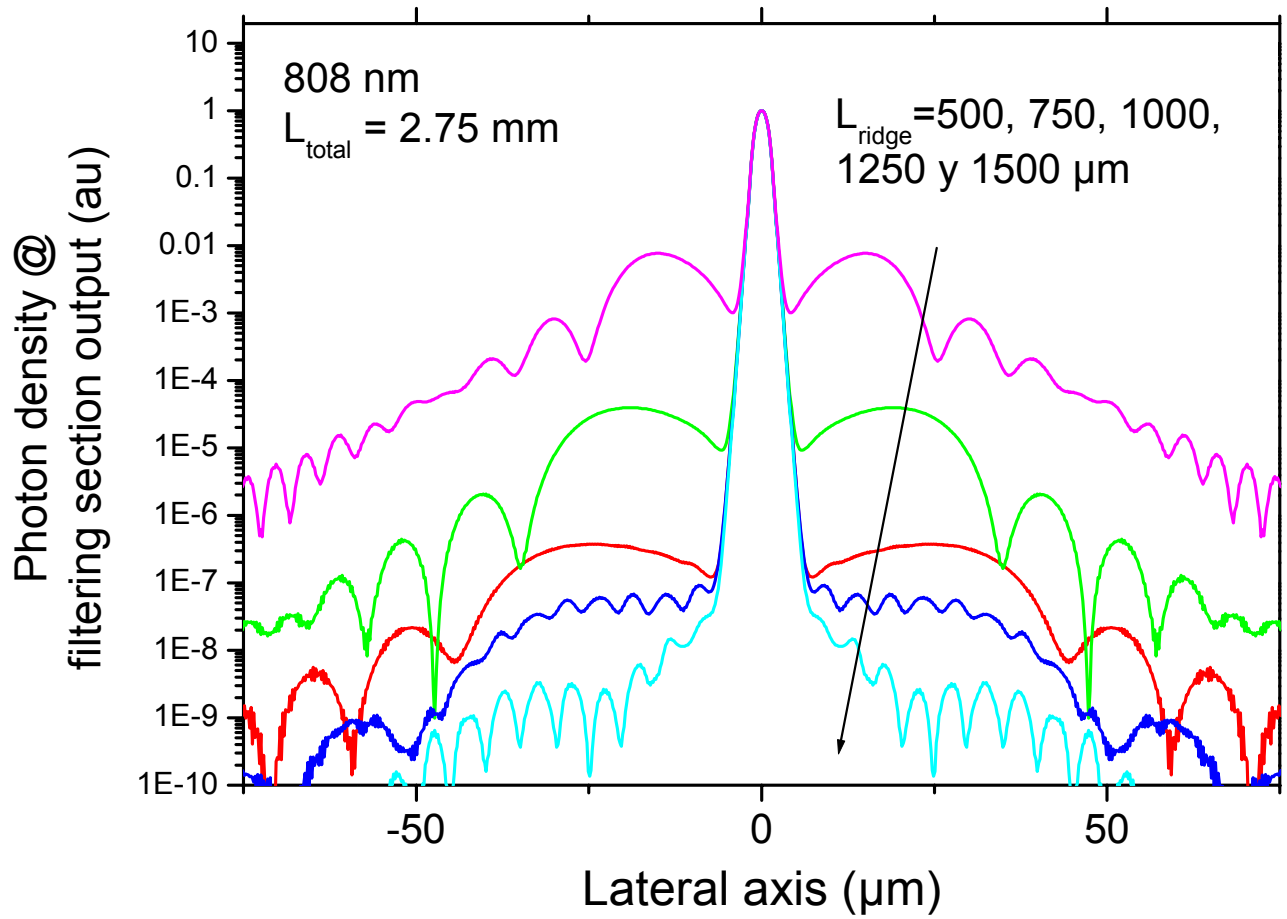



The straight section must be the shortest to guarantee proper filtering

# Optimization of the ridge length

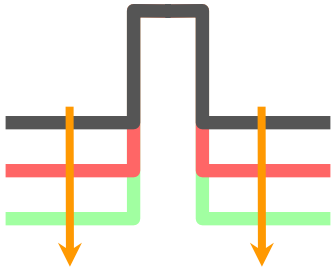
Forward field





# Optimization of the ridge design

## Etch depth / Index step

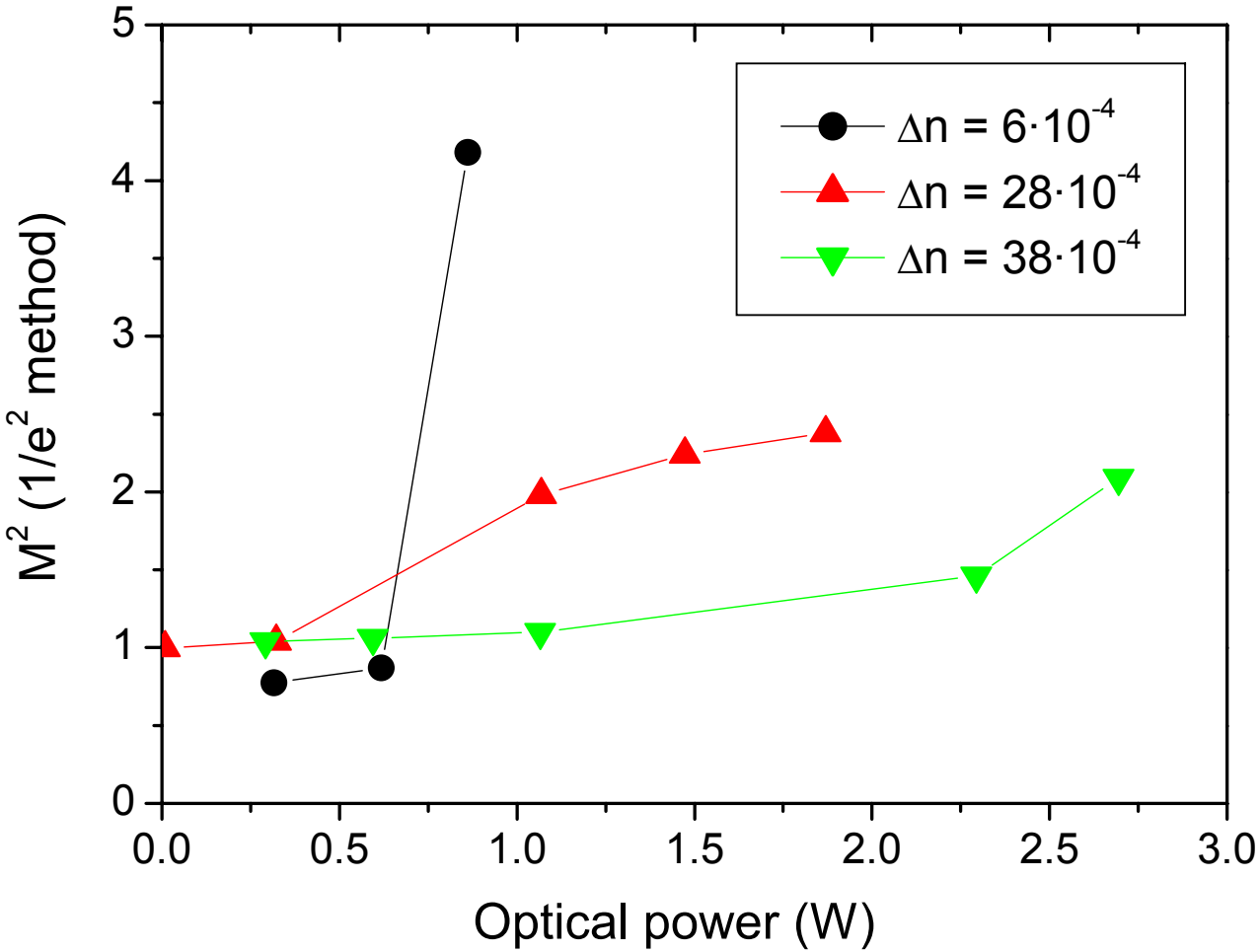


Wavelength: 975 nm

Beam spoilers

Cavity length: 600 + 2400 µm

Index steps: $6 \cdot 10^{-4}$, $28 \cdot 10^{-4}$ and $38 \cdot 10^{-4}$



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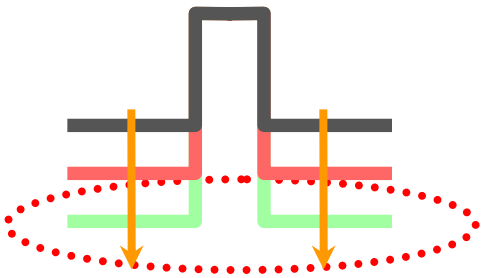
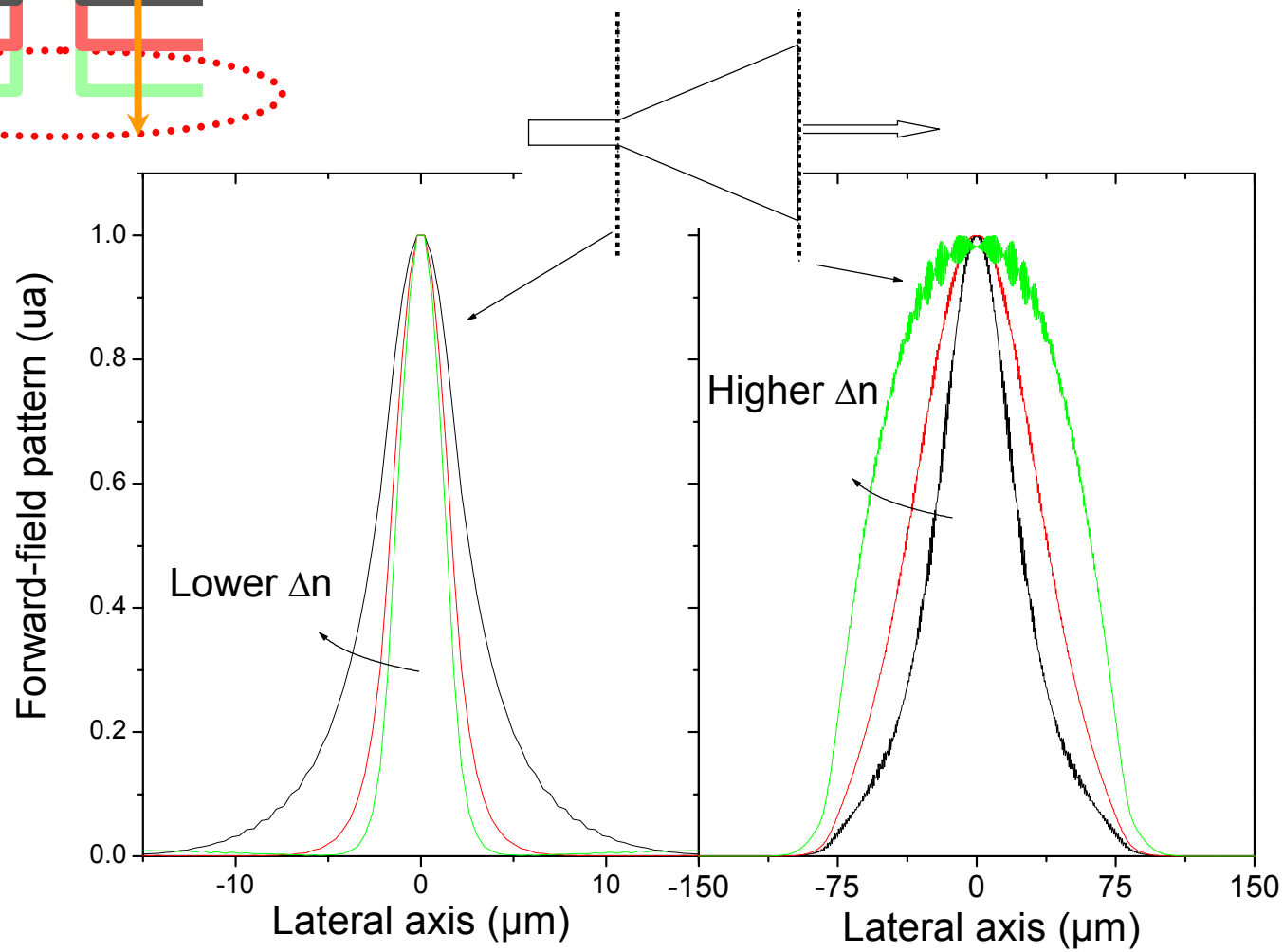
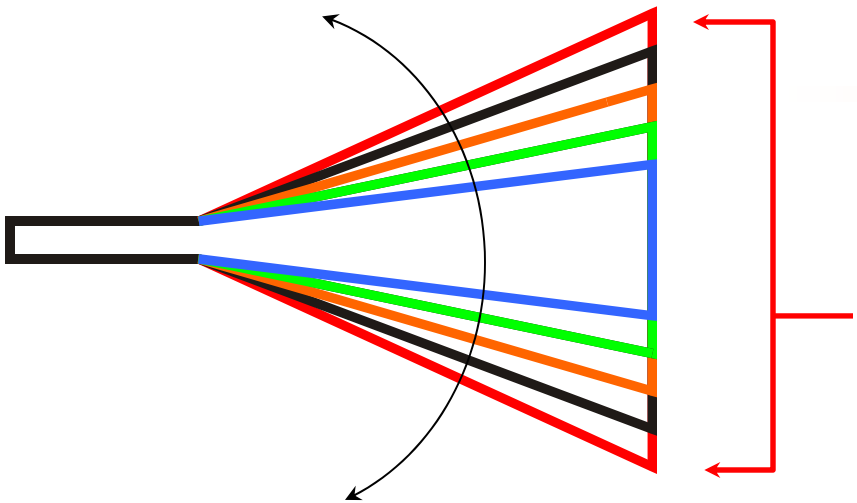




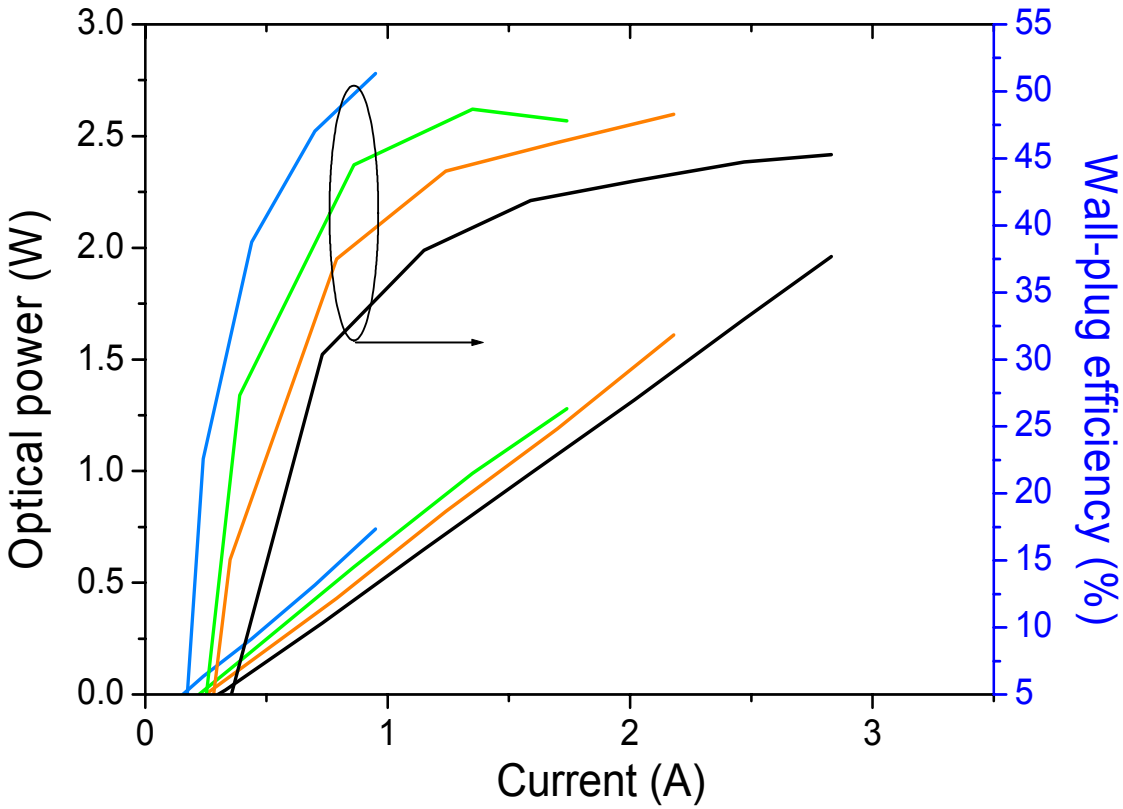

Improvement by increasing the free diffraction angle

# Optimization of the taper angle



Length: 500 + 1500 μm  $\lambda$=975 nm
Ridge width = 3 μm  $\Delta n = 30 \cdot 10^{-4}$
Diff. Angle passive RW = 5.4º (@1/$e^2$)

Angles: 5º, 4º, 3º and 2º



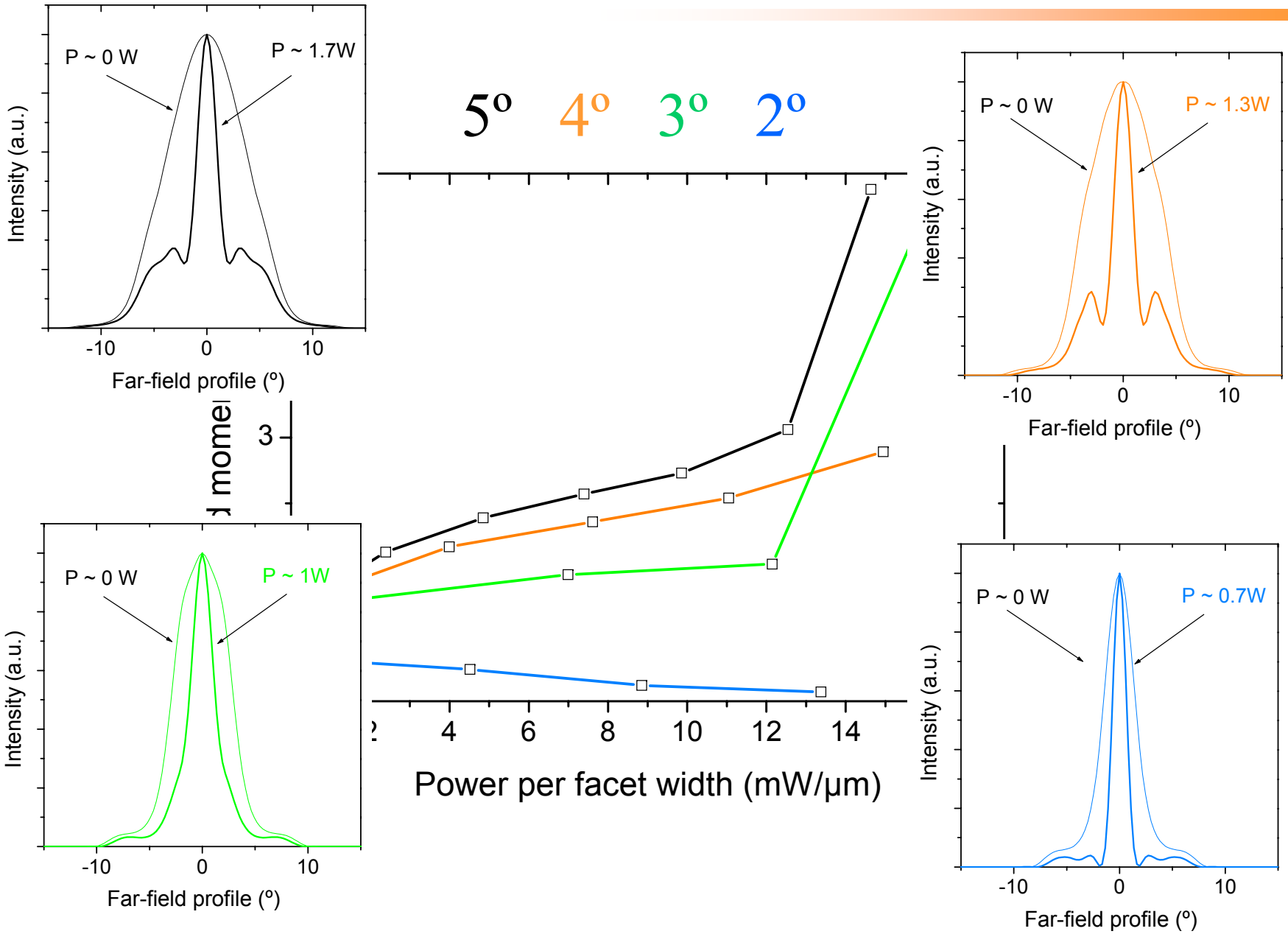

2º

3º

4º

5º

# Optimization of the taper angle



## 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 (~2º) to maximize brightness in laser bars

# Summary

- 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