8th International Conference on Numerical Simulation of Optoelectronic Devices

# Design of 1060 nm Tapered Lasers with Separate Contacts

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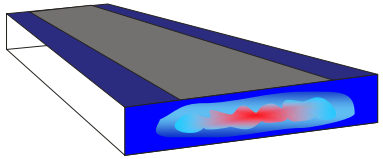
III-V lab
ALCATEL-THALES

# Outline

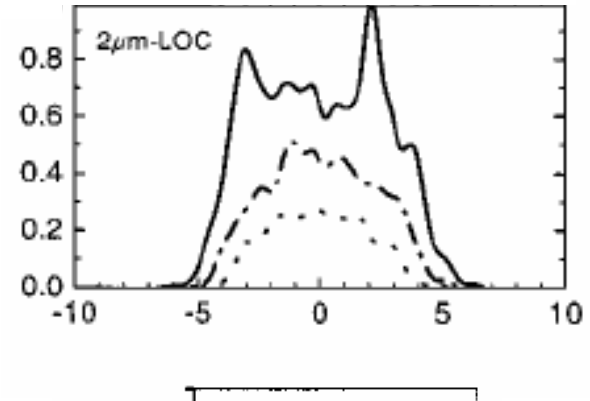
- Introduction and goal
- Simulation model
- Results :
  - Initial experimental results and simulations
  - Proposal of new design
  - Experimental validation
- Conclusions

# High Brightness Lasers: Tapered Lasers

➢ Broad-area Lasers

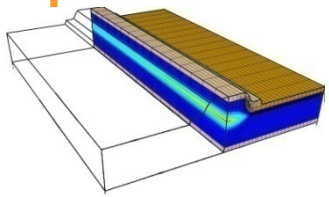


☺ Simple processing technology.
High output power & efficiency
☹ Poor lateral far field patterns.

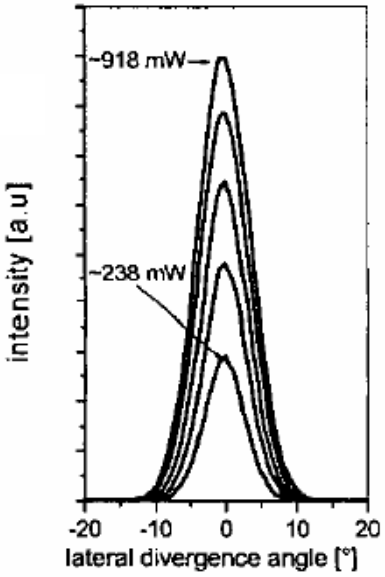



**Maximum output power ~ 10 W**

➢ Ridge lasers

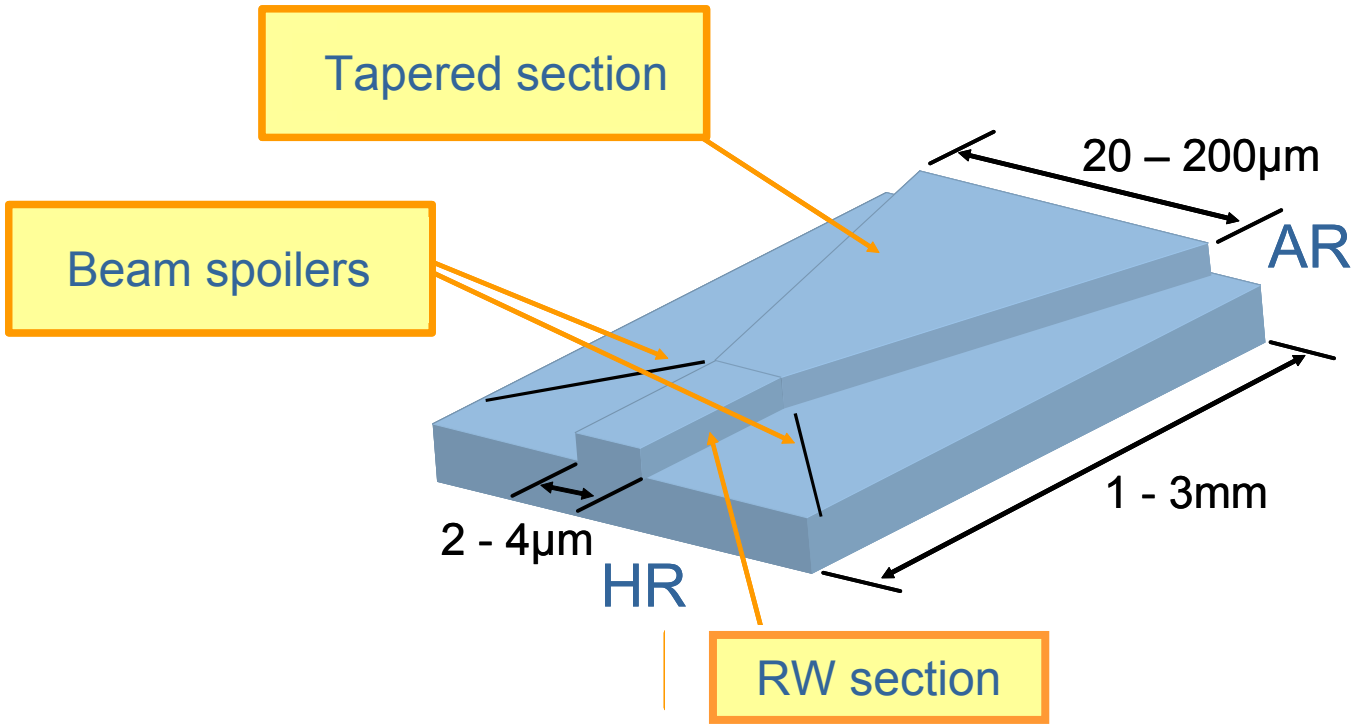


☺ Single-mode in the lateral direction:
Good beam quality.
☹ High optical densities. Poor thermal behavior and low COD level.



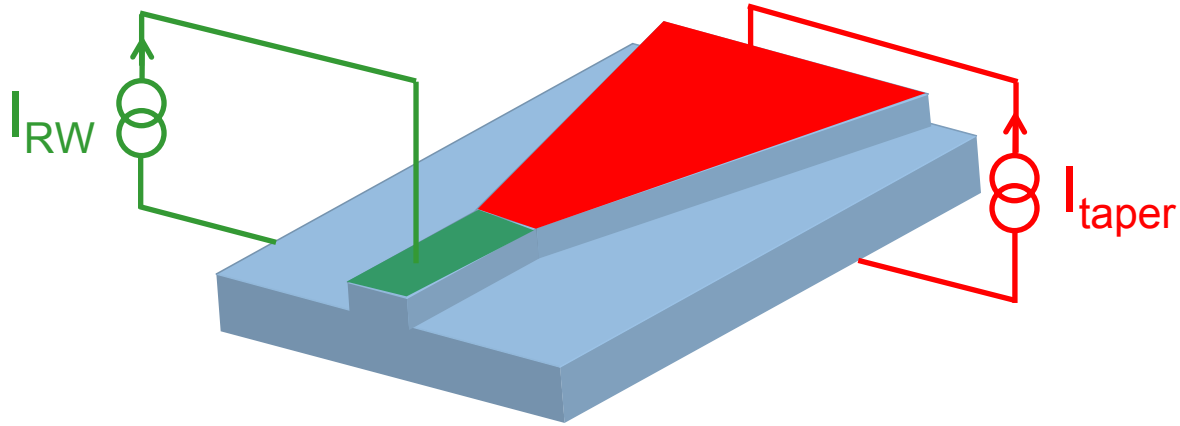

**Optical output power 300 mW – 1 W**

# Tapered Lasers




- $M^2$ values one order of magnitude lower than BA lasers
- Beam degradation limits maximum power (P ~ 10 W)

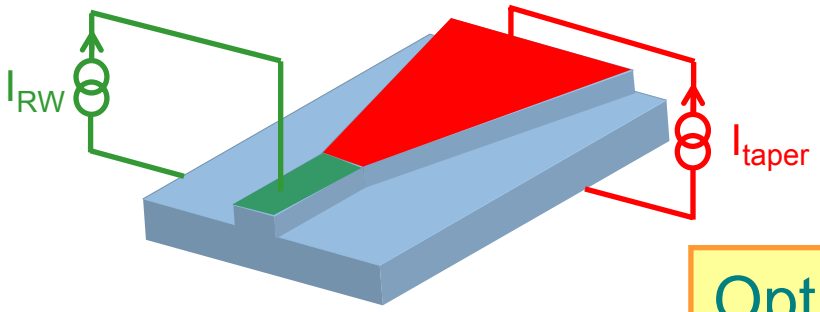
# Tapered Lasers with separate contacts




- Added versatility for the improvement of the brightness (Pashke JQE 06, Odriozola JQE 08)

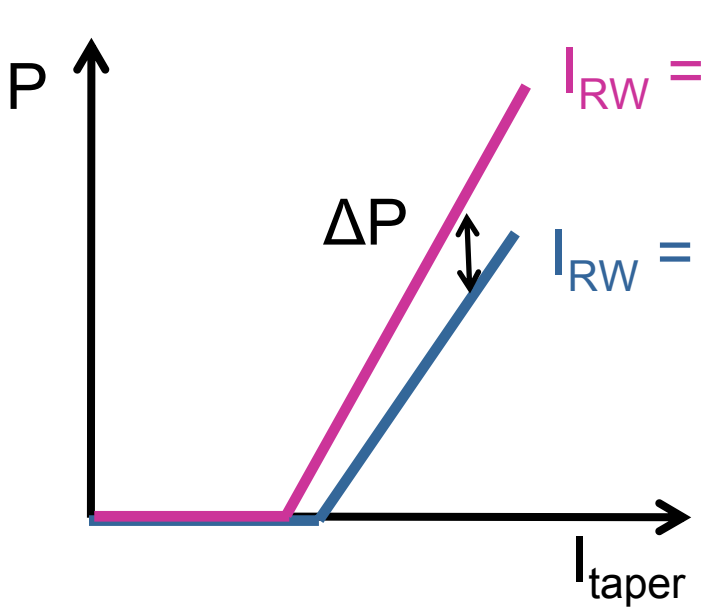
- Option for direct modulation of high power with low modulation current opens new application fields: Free space optical communications, laser projection displays

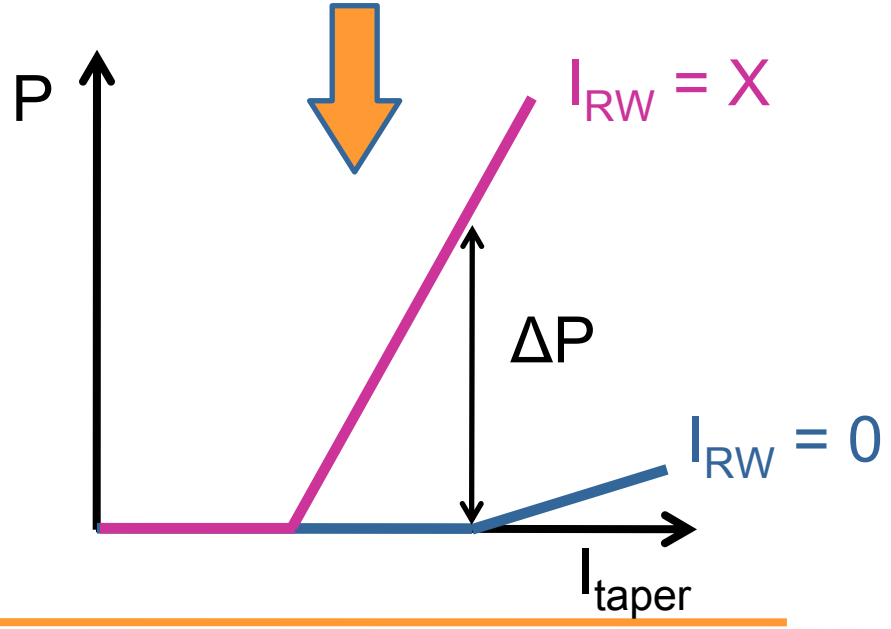
# Tapered Lasers with separate contacts




Modulation Efficiency = $\frac{\Delta P}{\Delta I_{RW}}$

Optimum design: high power and brightness + high modulation efficiency



# Goal

- **Design and fabrication of Separate Contact Tapered Lasers at 1060 nm with high power and high modulation efficiency**

# Simulation model *

- **Electrical model (3D)**
  - Continuity equations (electrons and holes), Poisson and capture/escape, QW gain model

- Self-consistent quasi-3D solution

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

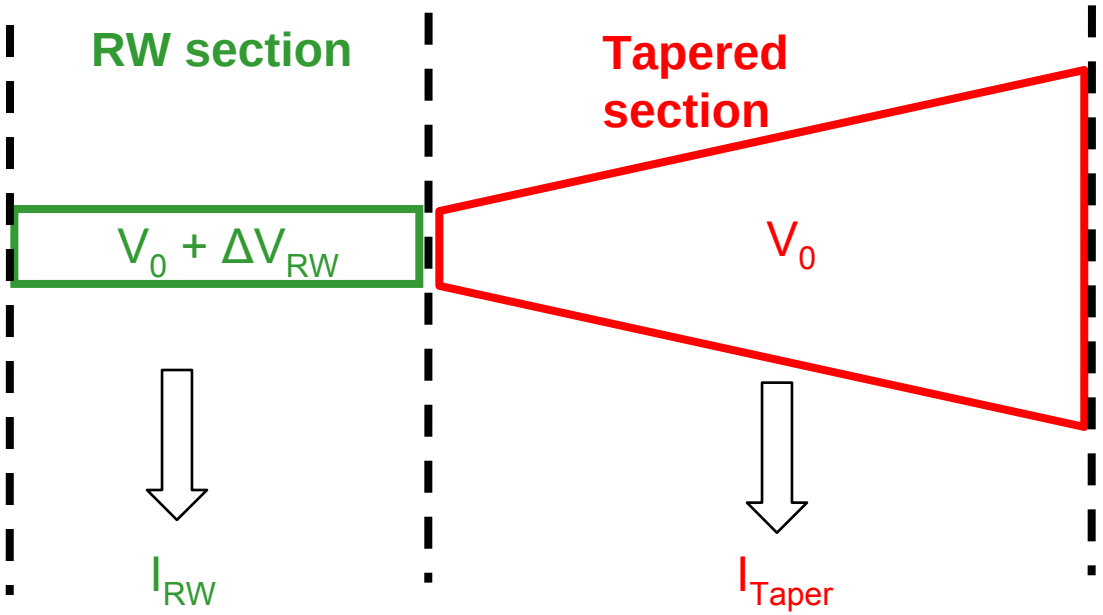
- Steady-state and single frequency approximations

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

*** Developed in collaboration with University of Nottingham**

# Simulation model

- **Simulation of Tapered Lasers with separate contacts***




- $V_0$ used for initialization and reference
- $\Delta V_{RW}$ being positive or negative to achieve the desired $I_{RW}$
- $I_{RW}$ and $I_{Taper}$ calculated by integration of the current density

*** H. Odriozola et al. IEEE JQE, accepted for publication**

# Initial results

**1D Simulation**

EPITAXIAL STRUCTURE


BROAD AREA LASERS

| | Exp. | Sim. |
|---|---|---|
| Vertical far field - FWHM (º) | 32 | 31.4 |
| $\alpha_i$ ($cm^{-1}$) | 0.9 | 0.5 |
| $\eta_i$ | 98 | 97.3 |
| $J_0$($A/cm^2$) | 64 | 65.1 |
| $\Gamma G_0$ ($cm^{-1}$) | 13.8 | 13.7 |

Fitting parameters:

- InGaAsP refractive index
- Trap density
- Internal scattering losses

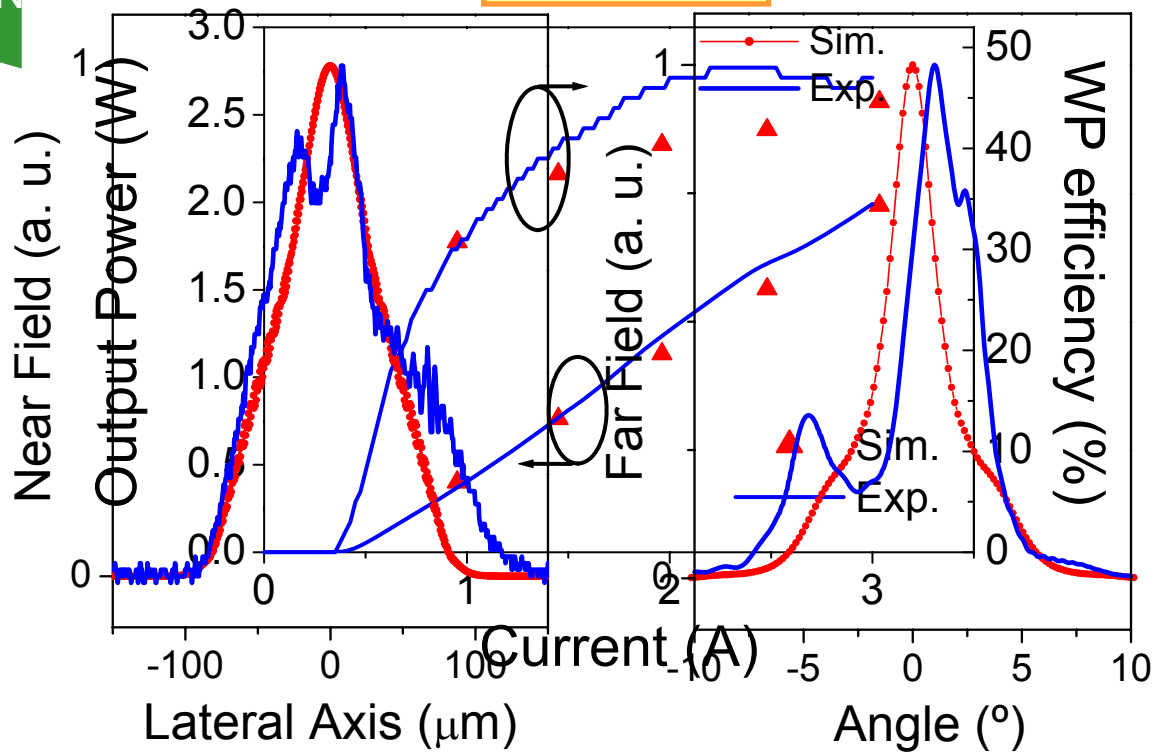
# Initial results

## TAPERED LASERS WITH COMMON CONTACTS

**INITIAL DESIGN:** $L_{total}$ = 3 mm, $R_{FF}$= 2.5%, angle = 4° and 6°

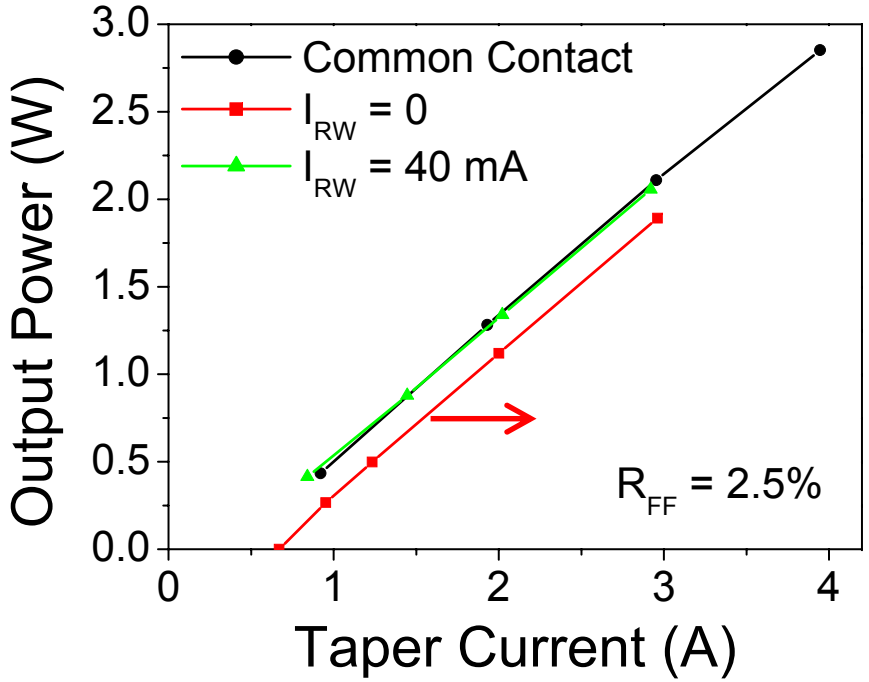
COMMON

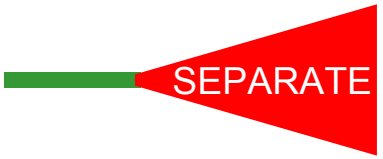
$P_{out}$ = 1 W



# Tapered lasers with separate contacts

**INITIAL SIMULATION:** $L_{total}$ = 3.4 mm, $R_{FF}$= 2.5%, angle = 4°

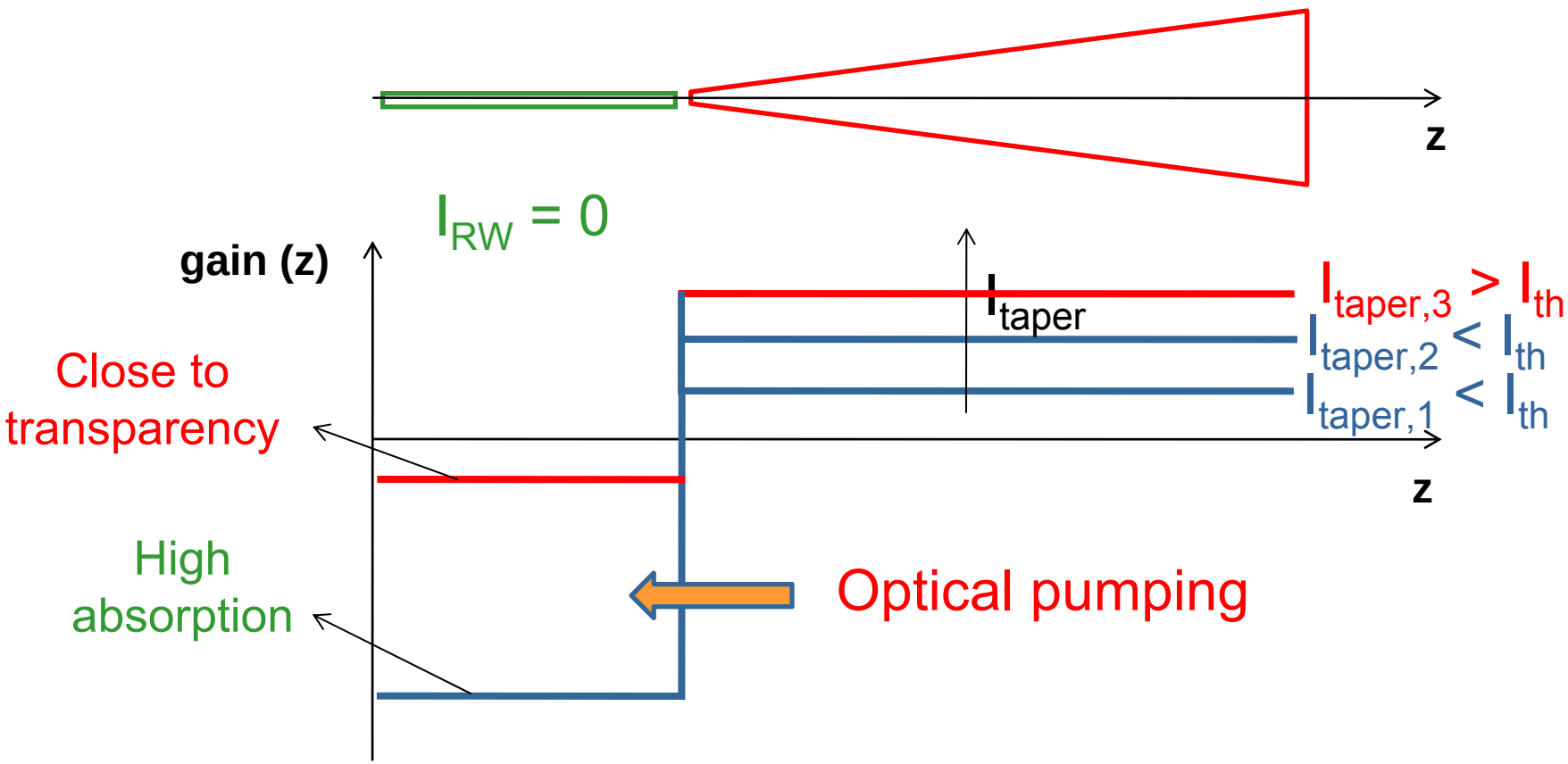



- Device lasing even when the $I_{RW}$ = 0
- Only a small change in $I_{th}$ by changing $I_{RW}$ from 0 to 40 mA

How to increase $I_{th}$ with $I_{RW}$ = 0 ?

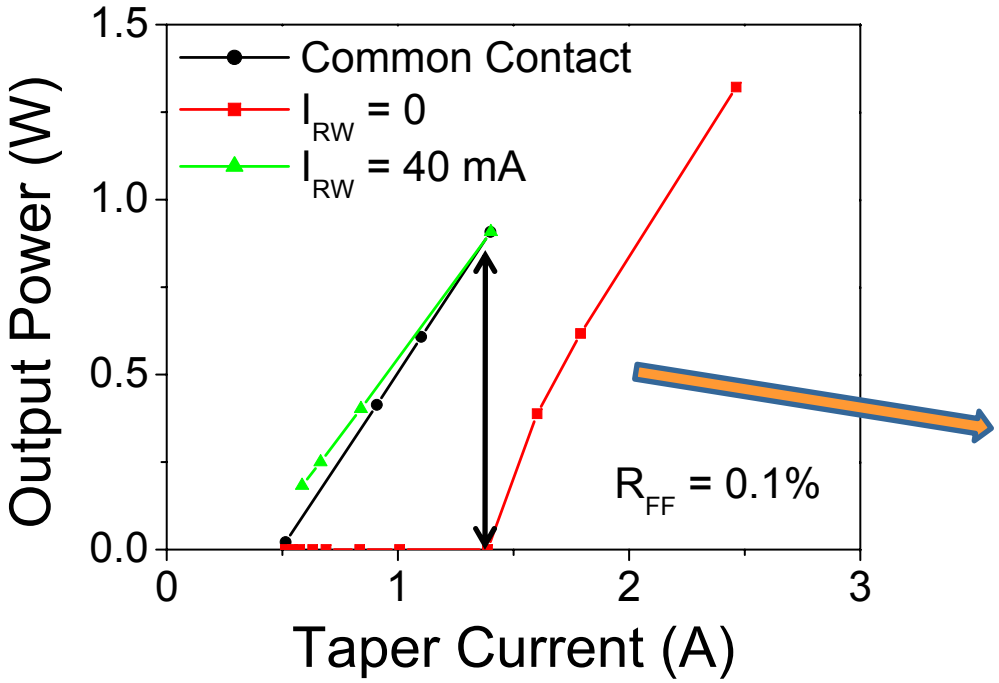
# Tapered lasers with separate contacts

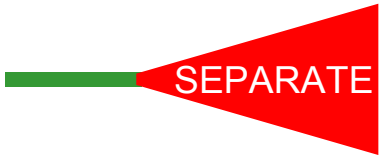



To ↑ $I_{th}$ ($I_{RW} = 0$) ⇨ ↓ Optical Pumping ⇨ ↓ $R_{FF}$

# Proposal of new design

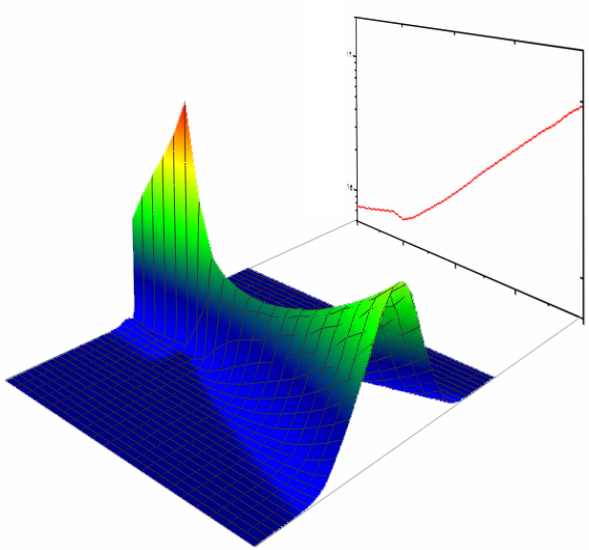
**DESIGN PROPOSAL:** Low front facet reflectivity ⇒ $R_{FF}$= 0.1%,

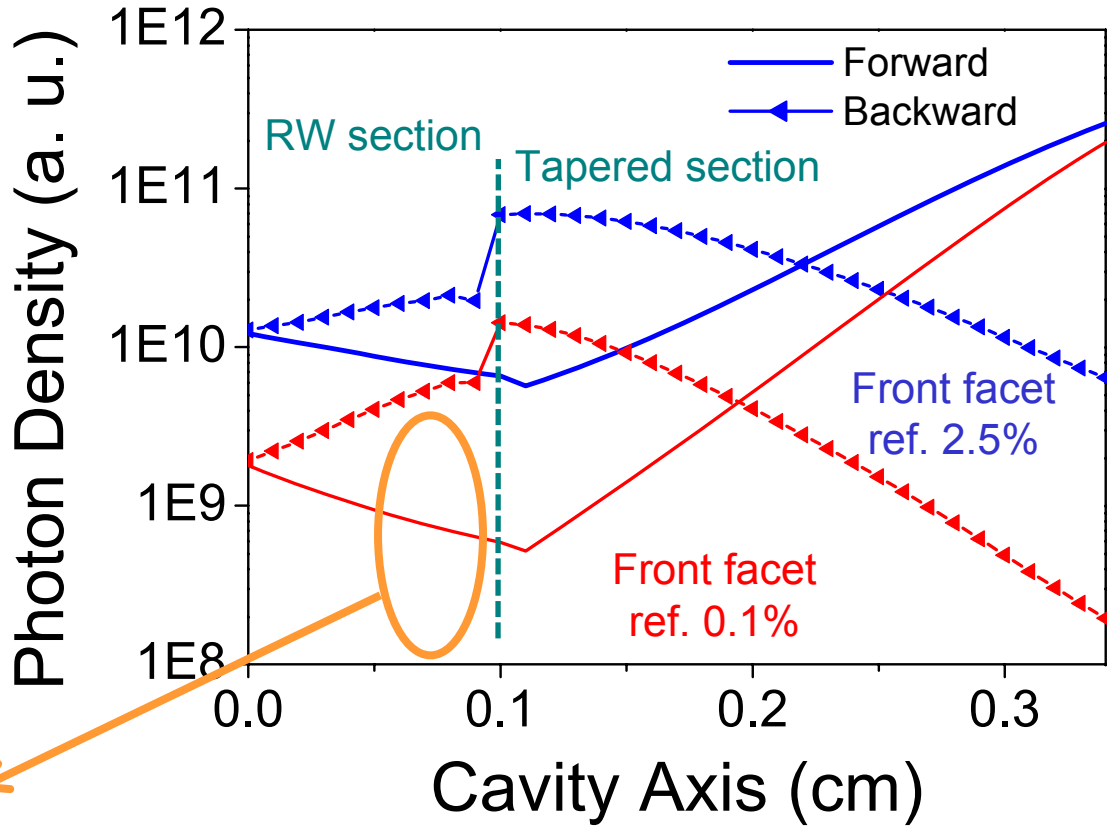



- Change in the $P_{out}$ from 0 to ~1W by changing $I_{RW}$ from 0 to 40 mA.
- Modulation efficiency of 25 W/A!

# Proposal of new design






Low $R_{FF}$

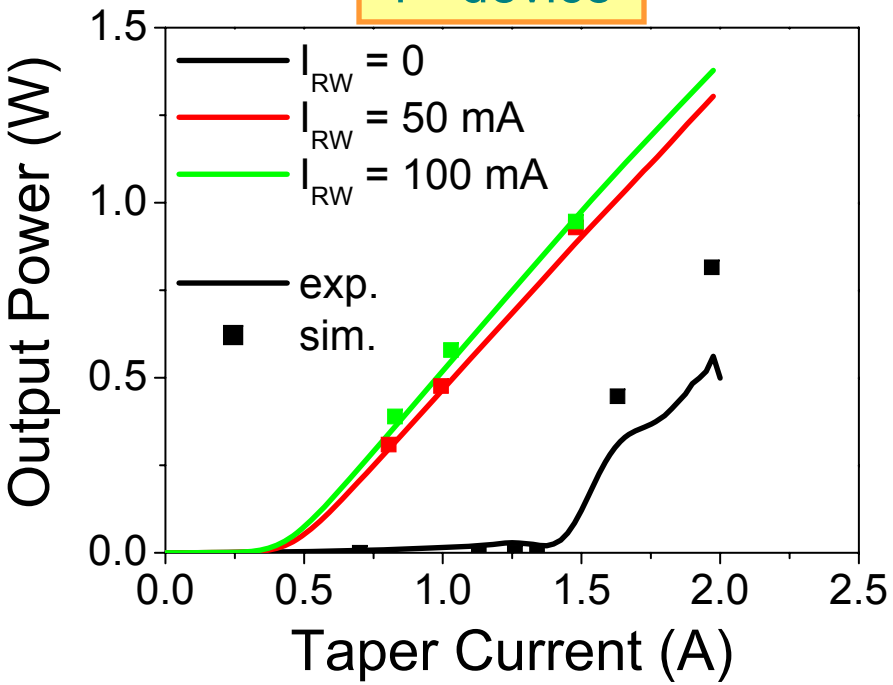
⇩

High Absorption in RW

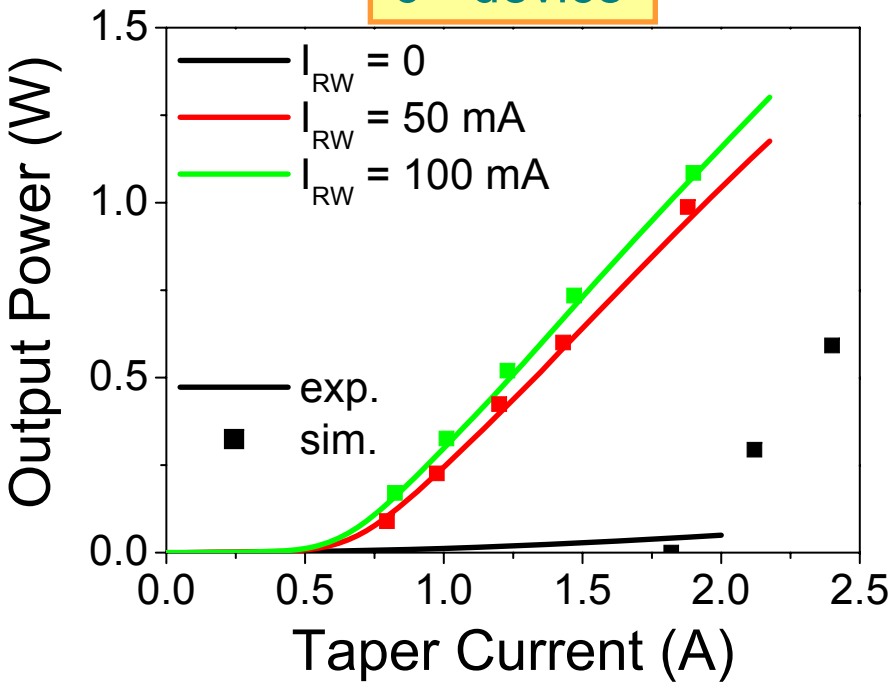
# Experimental validation

**FINAL DESIGN:** $R_{FF}$ = 0.1%, 4 mm, 4° and 6°

4 º device




6 º device




- Excellent agreement in terms of P-I
- 6° device ⇨ $\Delta P/\Delta I_{RW}$ ~ 20 W/A !

# Conclusions

- Simulation model is a useful tool for the design of tapered lasers with separate contacts
- Good agreement between modelling and experiments
- New design with low front facet reflectivity achieves experimetally high modulation efficiency