Physics-based VCSELs simulations

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Fundamental contributions:
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Why VCSELs?

Focus on *Vertical-Cavity Surface-Emitting Lasers* (VCSELs):

- Low threshold currents and power consumption (w.r.t. **EEL**)
- Ideal for **optical fiber coupling** (circular output beam)
- Excellent dynamic properties (small active size)
- Low production, testing and packaging costs
- Easy **2D arrays** production

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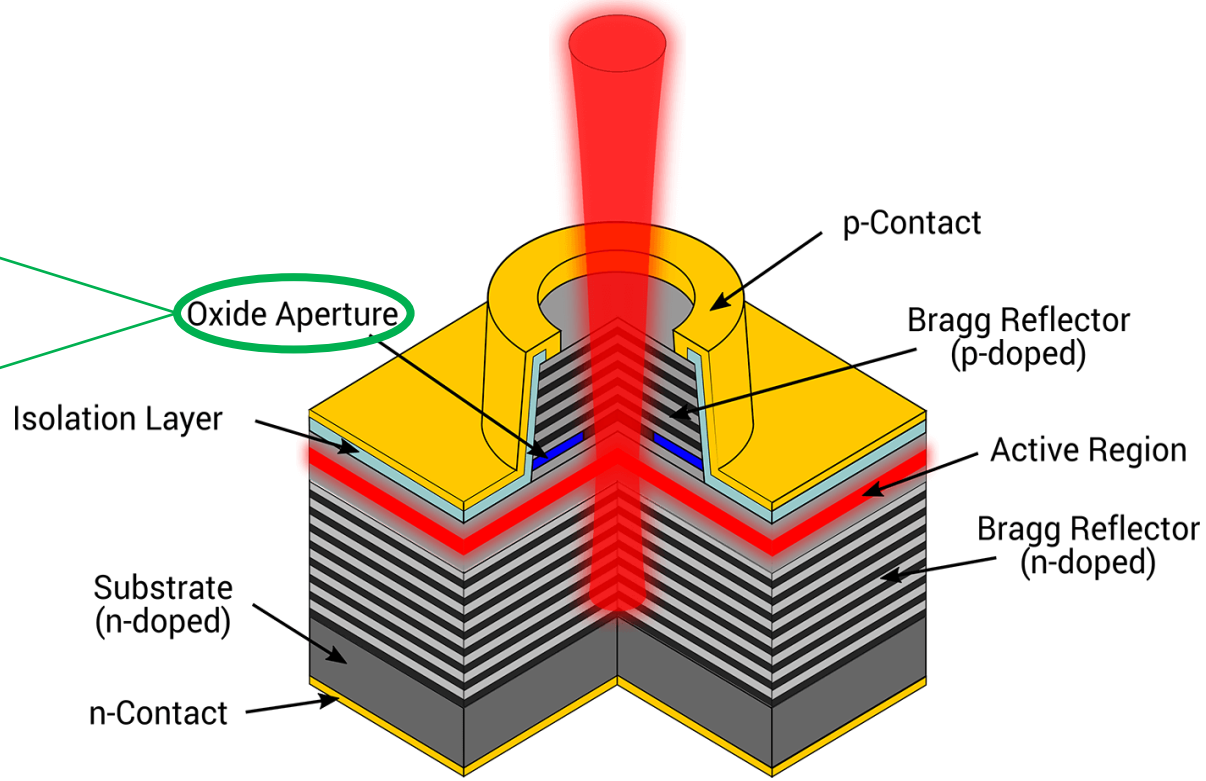
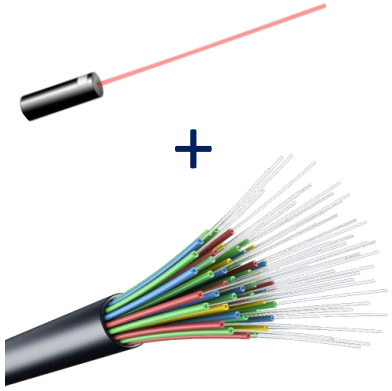
pin-like devices



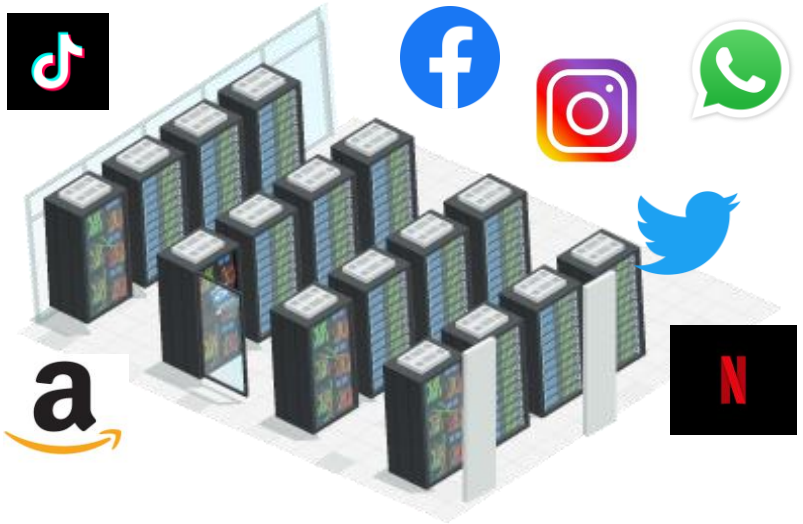
AlGaAs VCSELs applications (1)

The global internet infrastructure relies on short haul communications in **datacenters**.

Oxide-confined AlGaAs VCSELs emitting at 850-980 nm are currently dominating the optical interconnects, maintaining stable and fast operations (**small active size**, defined by the oxide aperture diameter):



Optical interconnects…



crucial in server racks!

AlGaAs VCSELs applications (2)

Apple TrueDepth (from iPhone X)

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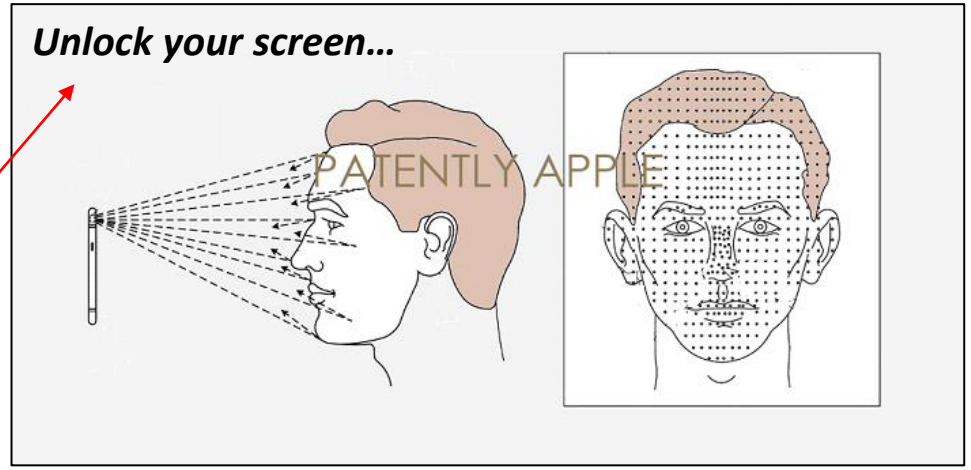
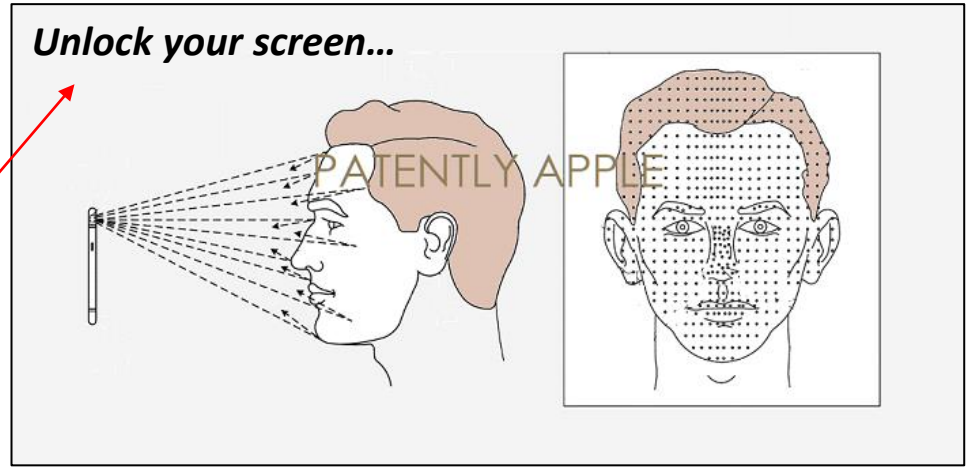
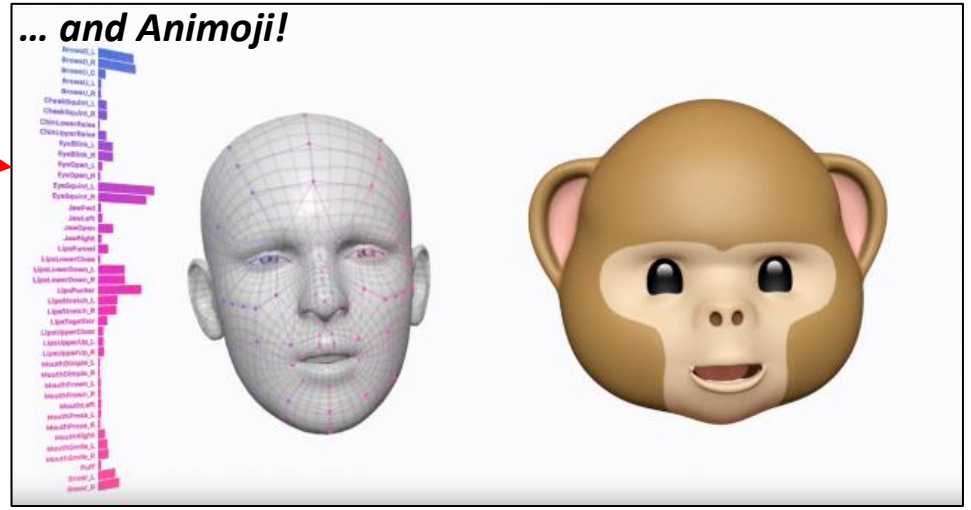


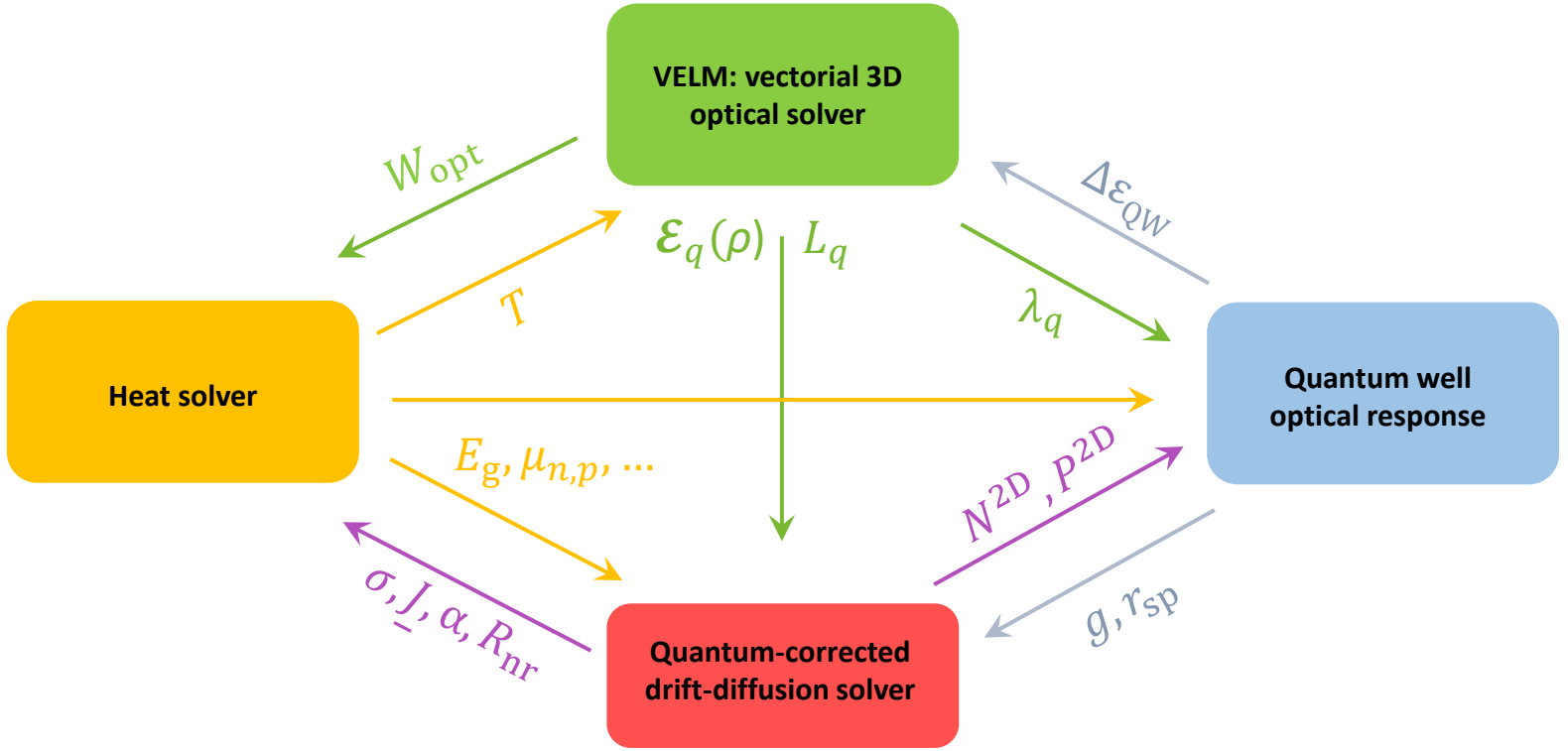
AlGaAs VCSELs applications (2)

Apple TrueDepth (from iPhone X)





VENUS: our in-house VCSEL solver



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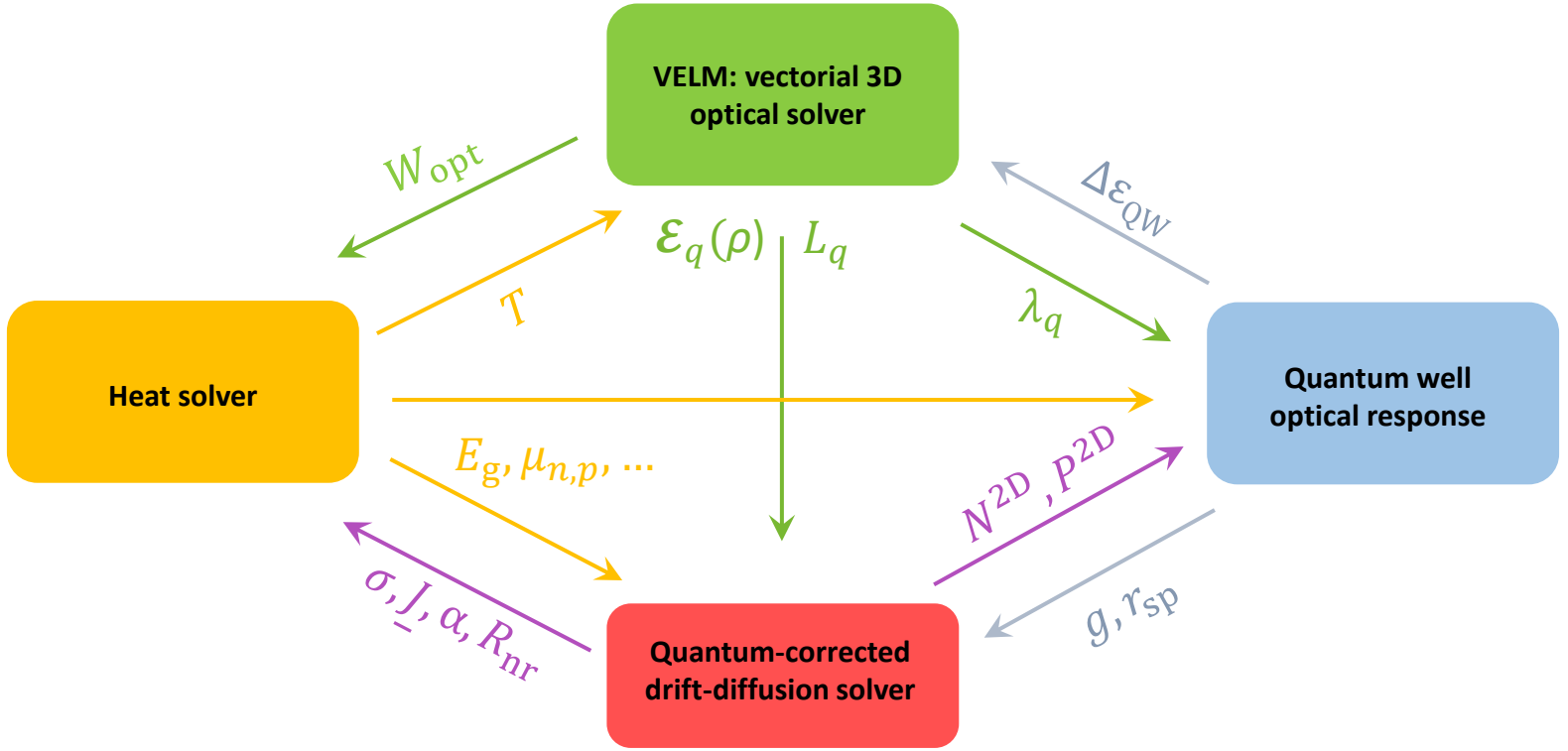

IEEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS, VOL. 25, NO. 6, NOVEMBER/DECEMBER 2019 1500212

VENUS: A Vertical-Cavity Surface-Emitting Laser Electro-Opto-Thermal NUmerical Simulator

Alberto Tibaldi, Francesco Bertazzi, Michele Goano, *Member, IEEE*, Rainer Michalzik, and Pierluigi Debernardi

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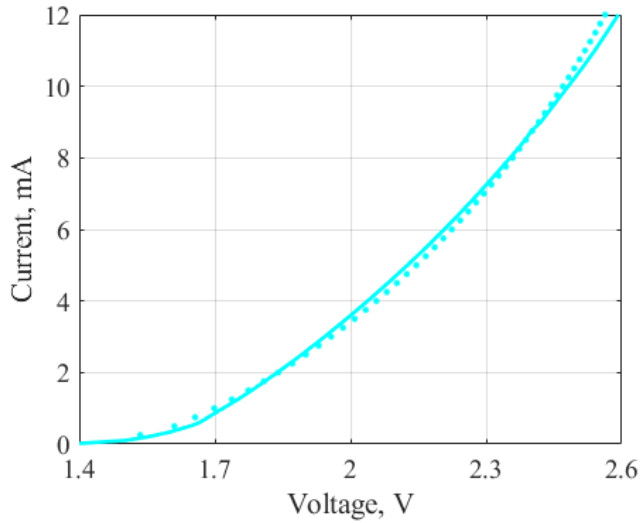
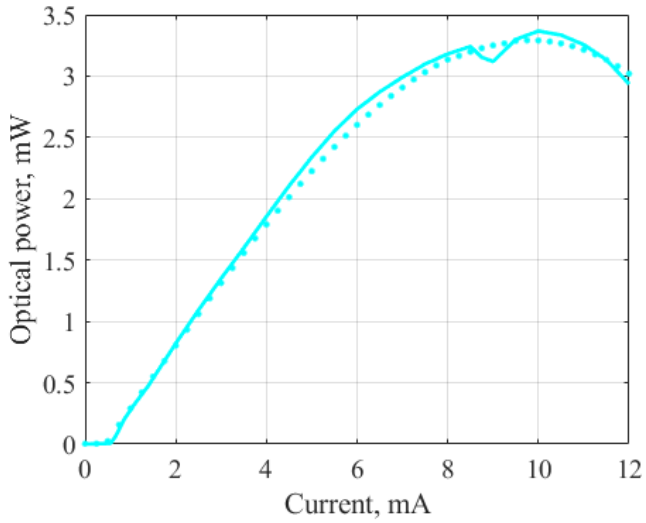
Probing Thermal Effects in VCSELs by Experiment-Driven Multiphysics Modeling

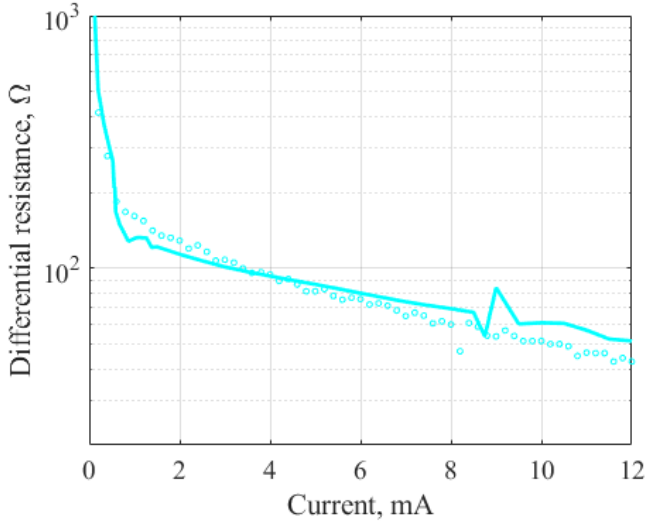
Pierluigi Debernardi, Alberto Tibaldi, Markus Daubenschüz, Rainer Michalzik, Michele Goano, and Francesco Bertazzi

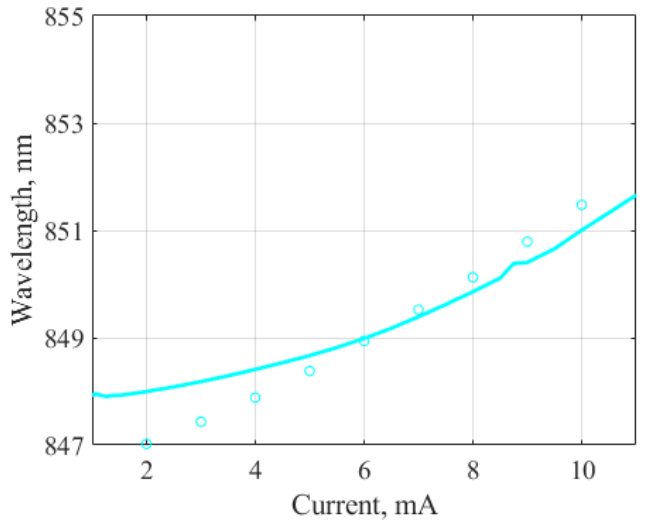
VENUS results: *pin* static curves

T = 20 °C









VENUS results: *pin* static curves

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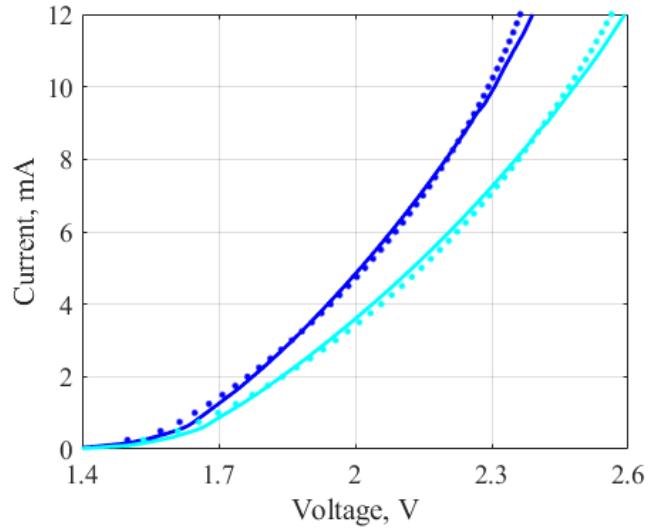
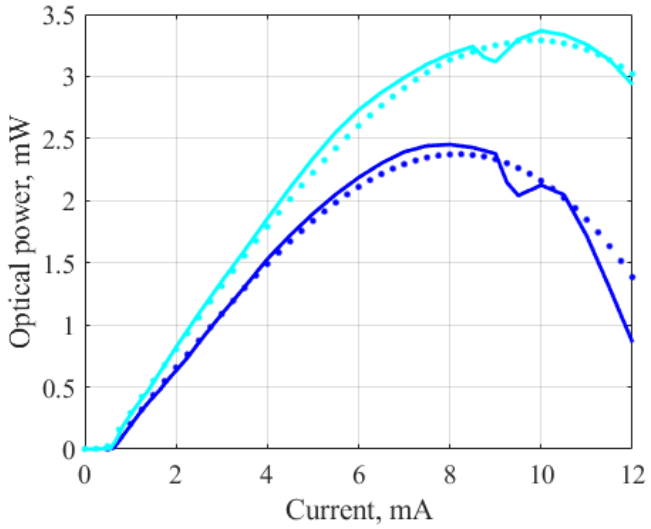
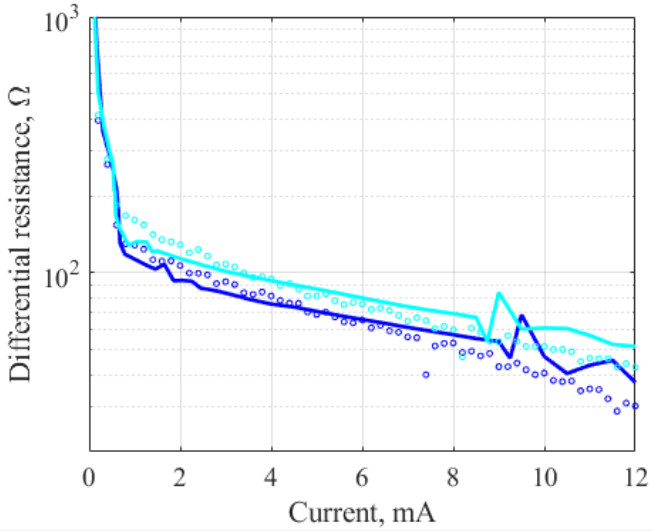
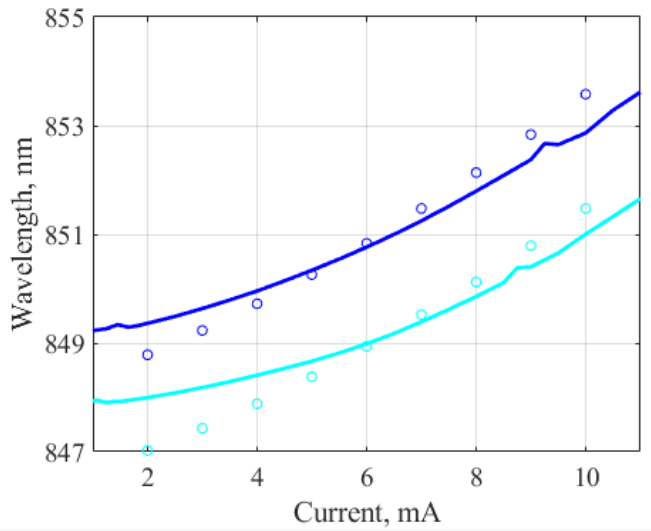
T = 50 °C



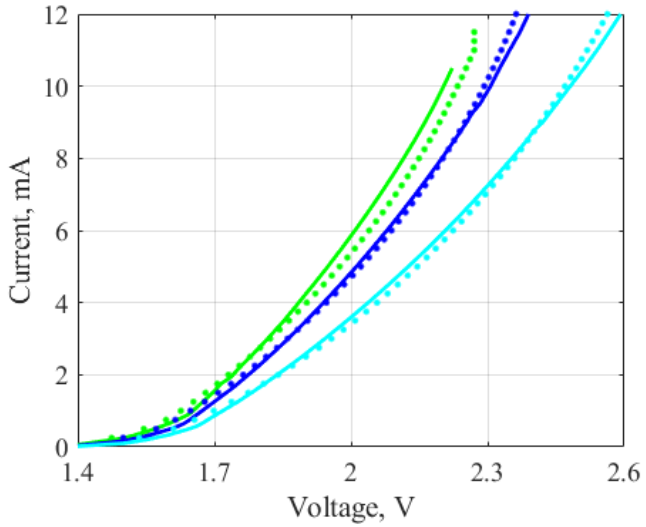


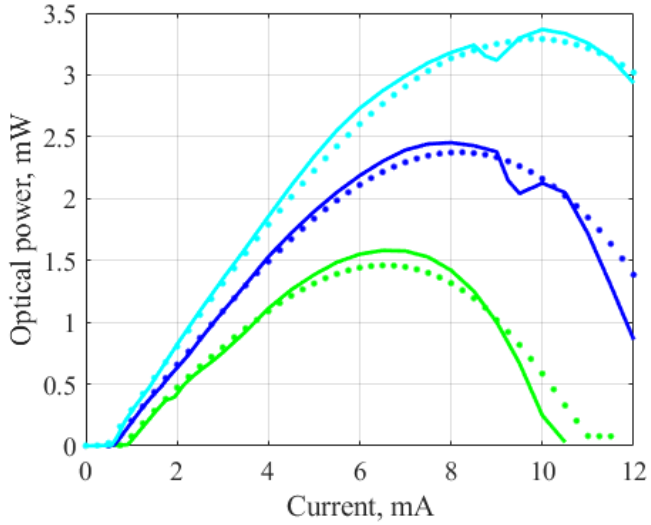


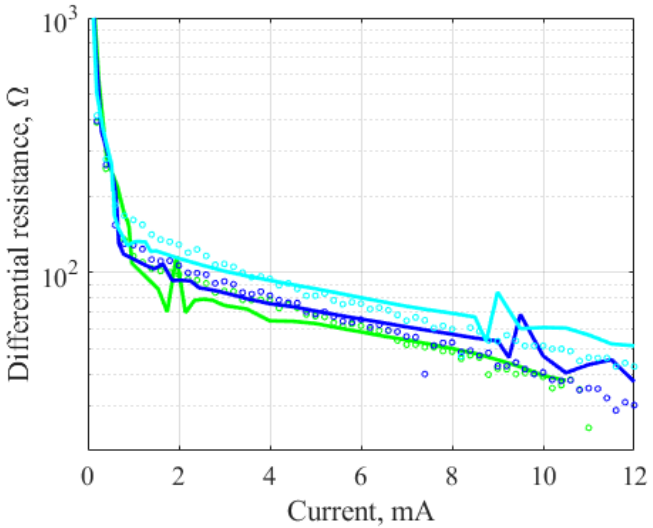


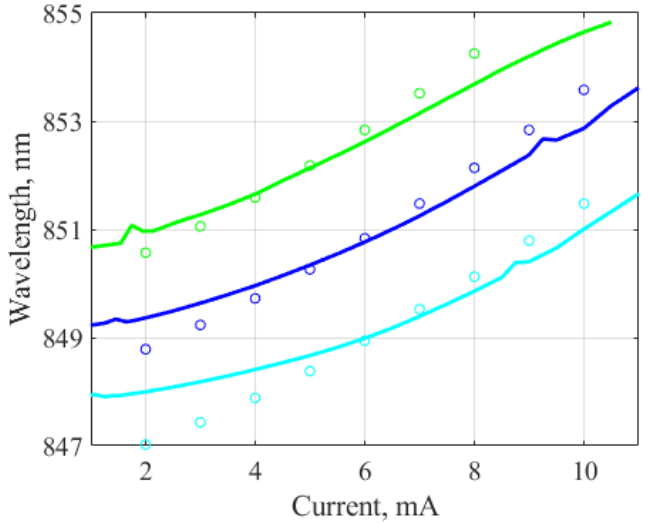
VENUS results: *pin* static curves

T = 20 °C
T = 50 °C
T = 80 °C









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T = 20 °C
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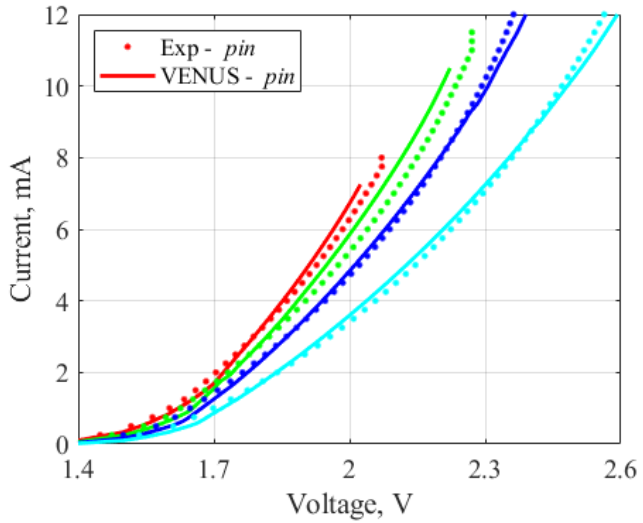
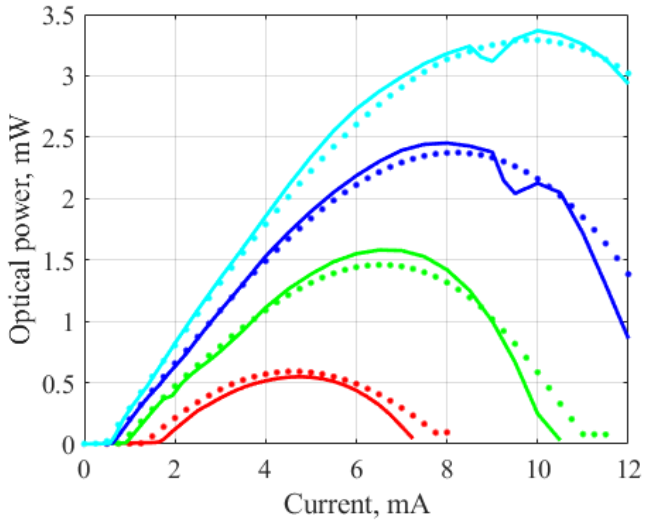
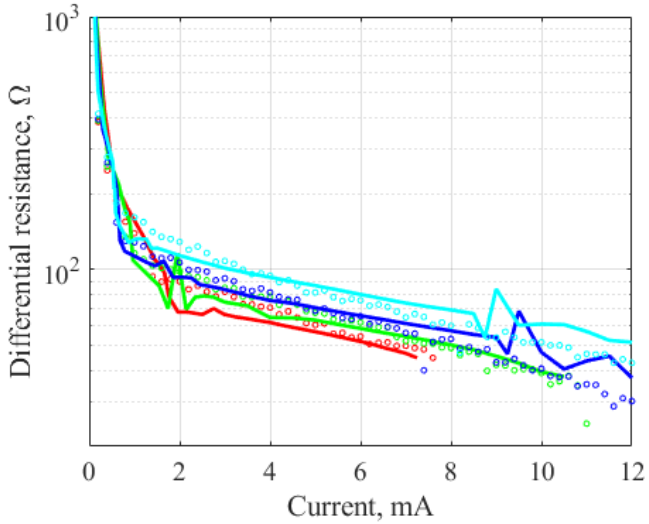
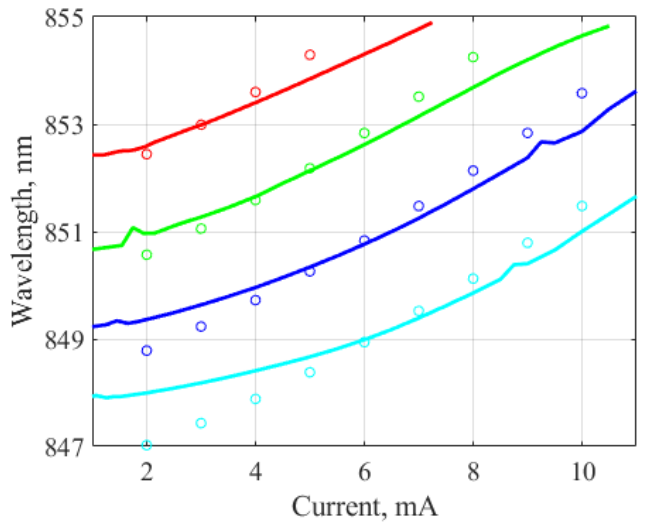
T = 110 °C

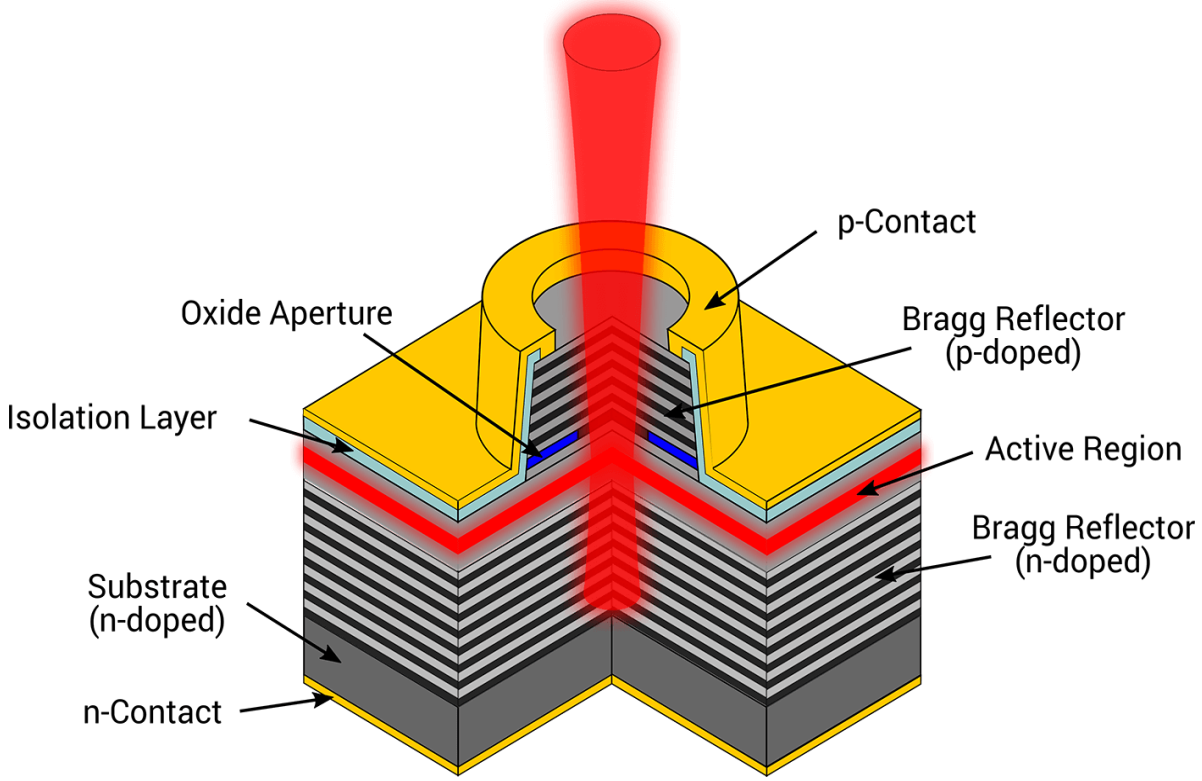








VENUS: TJ-VCSELs



pin - VCSELs

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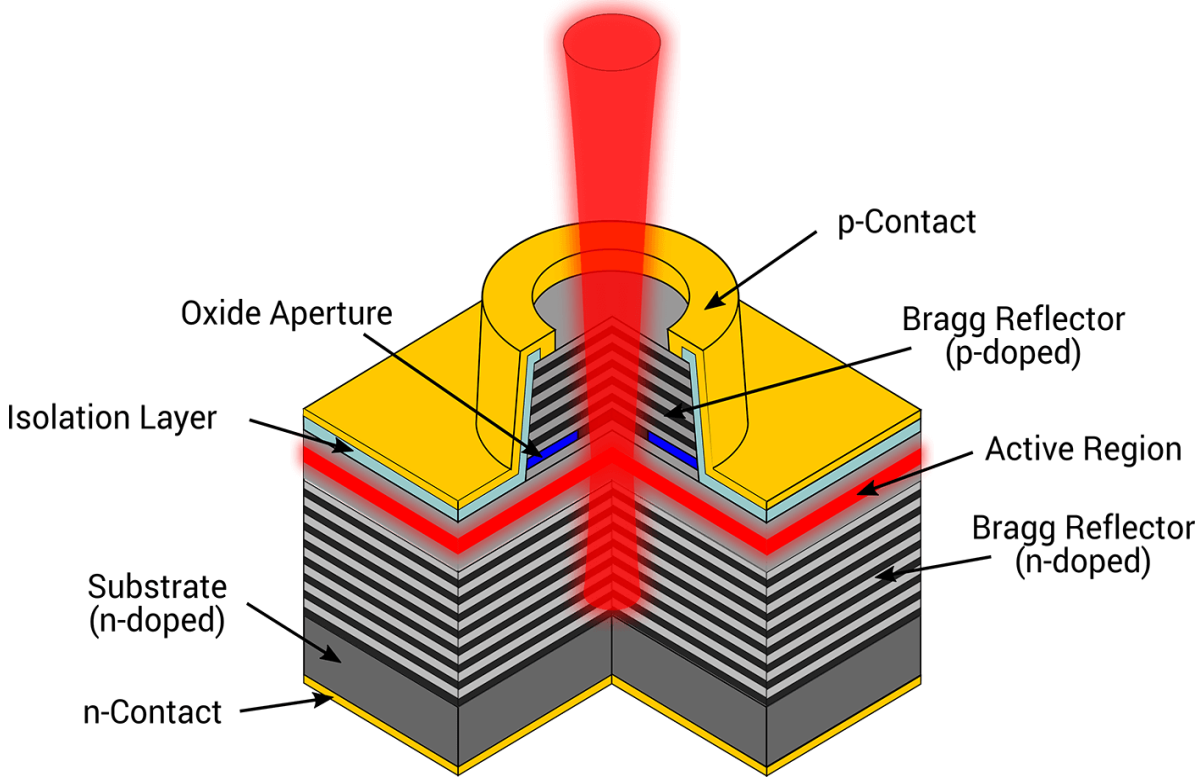

pin - VCSELs → TJ-VCSELs

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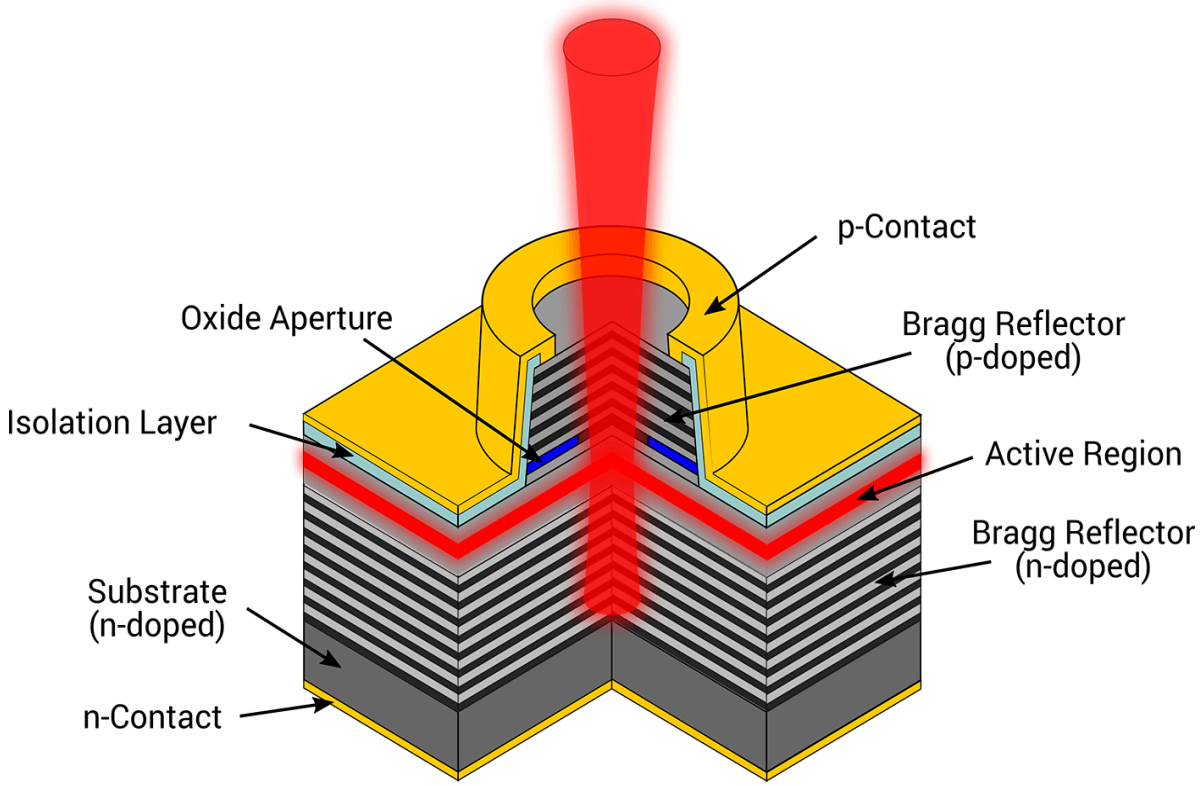

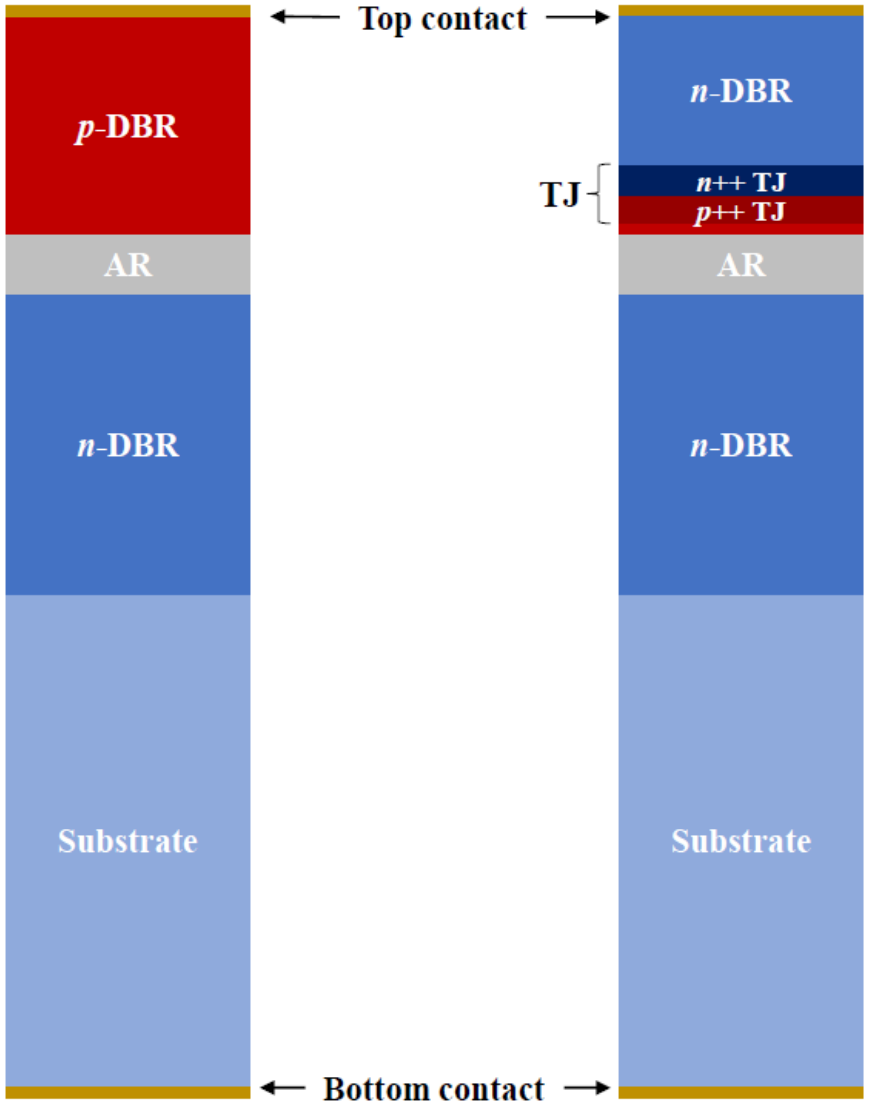

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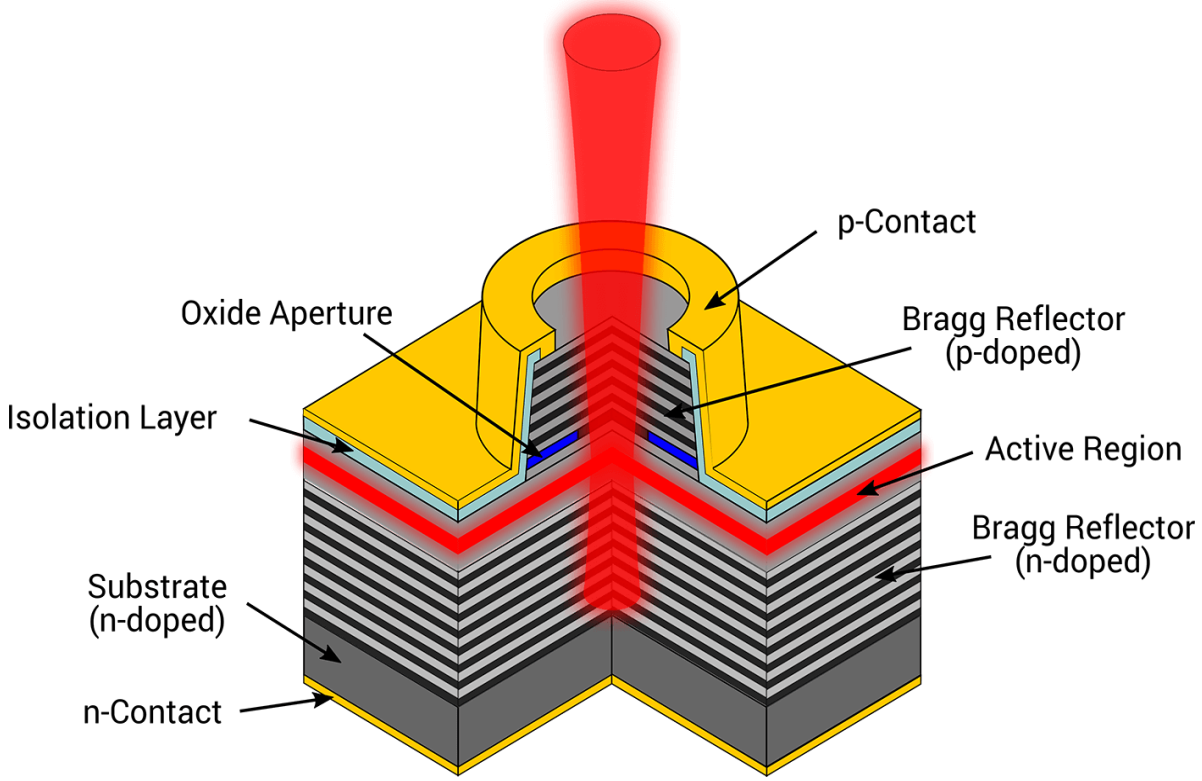
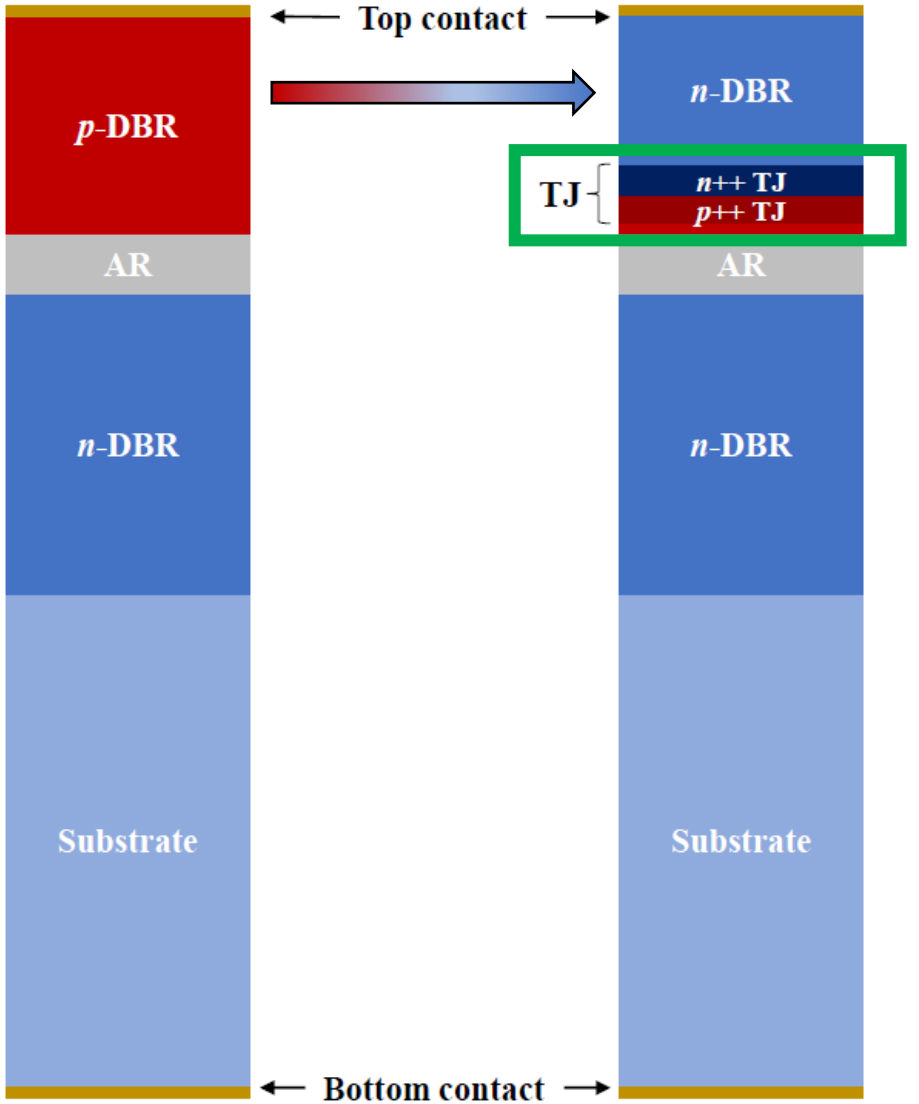
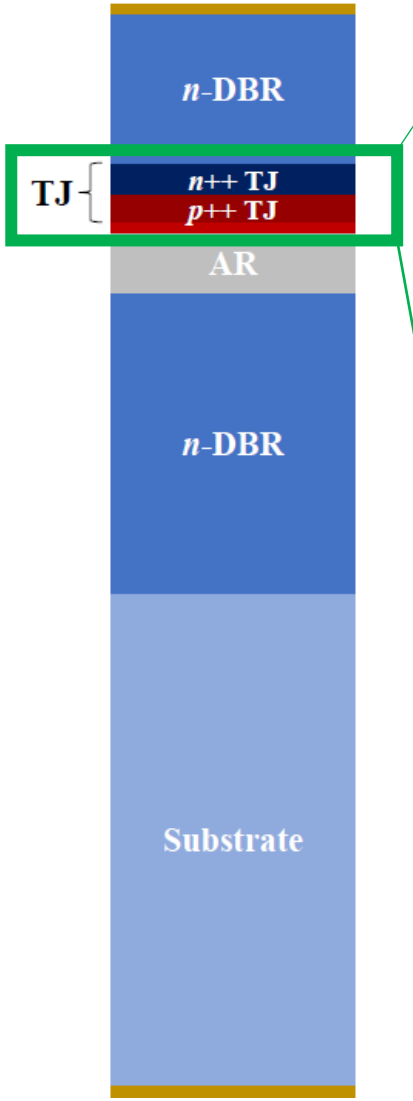
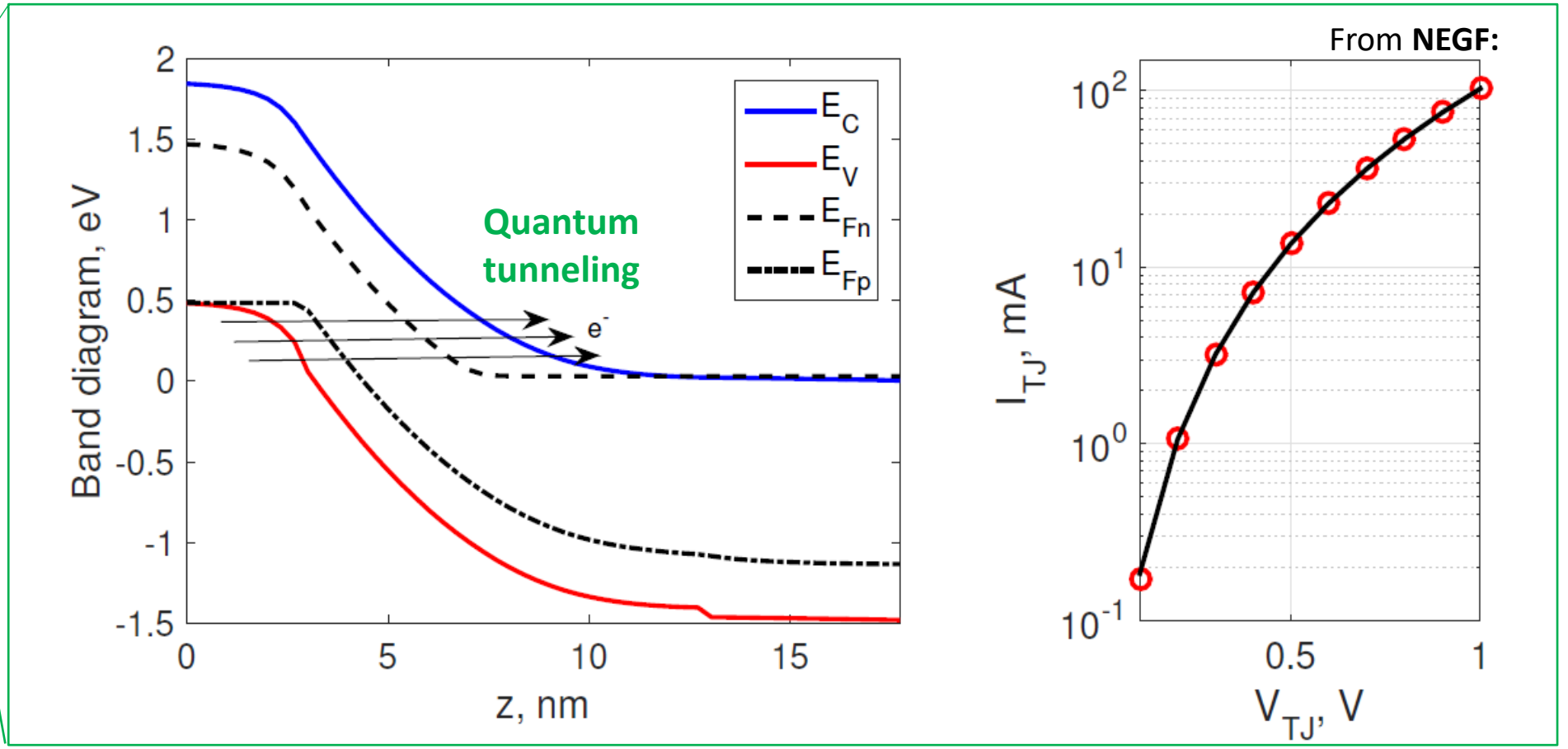




pin - VCSELs → TJ-VCSELs

VENUS extension: TJ treatment

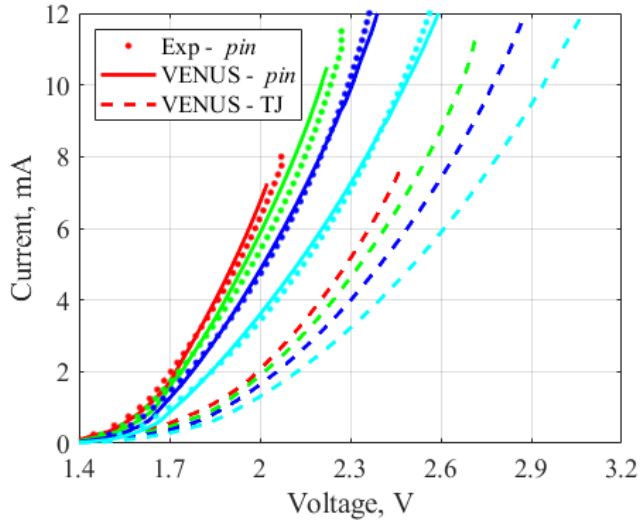


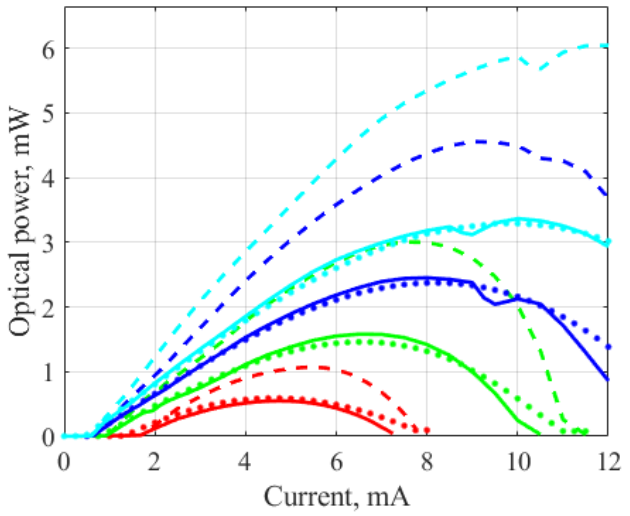


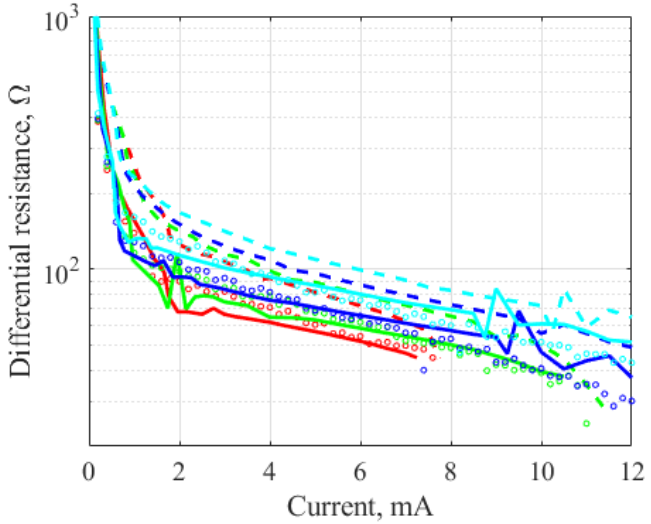
Holes injection in active region through tunneling (modelled with **NEGF**):

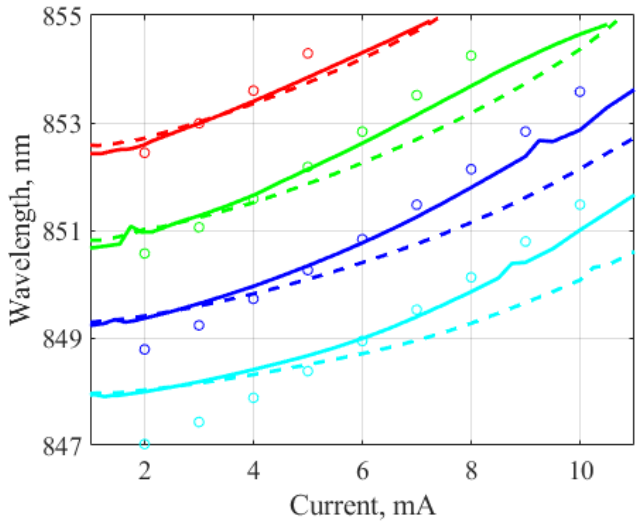
- Top-DBR is *n*-doped

VENUS extension: TJ-VCSEL results









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- **Solid**: *pin* VCSEL
- **Dashed**: TJ-VCSEL

Thank you for your attention!