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MIXSEL RTD 2009

FNSNF

Electrically Pumped VECSELs and MIXSELs

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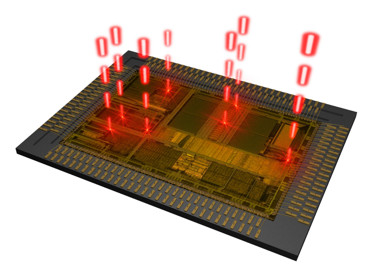
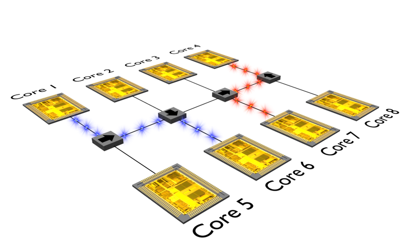
ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

Motivation for pulsed semiconductor lasers

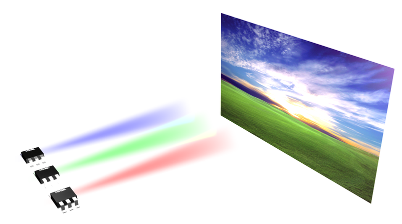
Pulsed semiconductor lasers are highly attractive for many applications:



Multi-core clocking



Optical interconnects



RGB projection

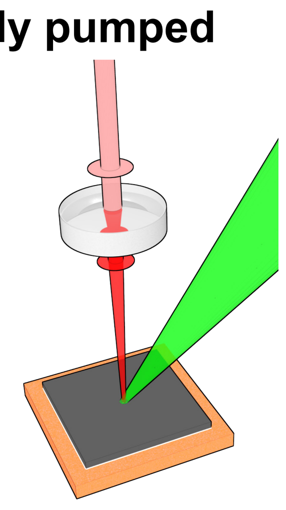
➡ SESAM[1]-modelocked VECSELs[2] ideally suited for pulse generation in GHz regime

[1] SESAM: Semiconductor Saturable Absorber Mirror (U. Keller, et al., IEEE J. Sel. Top. Quantum Electron. **2**, 435-453 (1996))
[2] VECSEL: Vertical External Cavity Surface Emitting Laser (M. Kuznetsov, et al., IEEE Photon. Technol. Lett. **9**, 1063-1065 (1997))

Approach: Electrical pumping

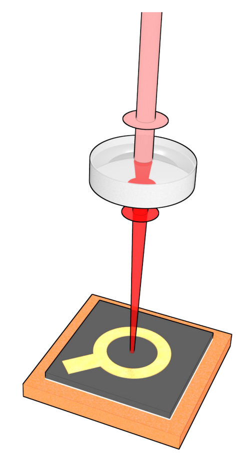
Achieved with optically pumped VECSELs:

- 1.05 W in 784 fs pulses [1]
- sub-100-fs pulses [2]
- but: bulky pump optics



Electrically pumped VECSELs:

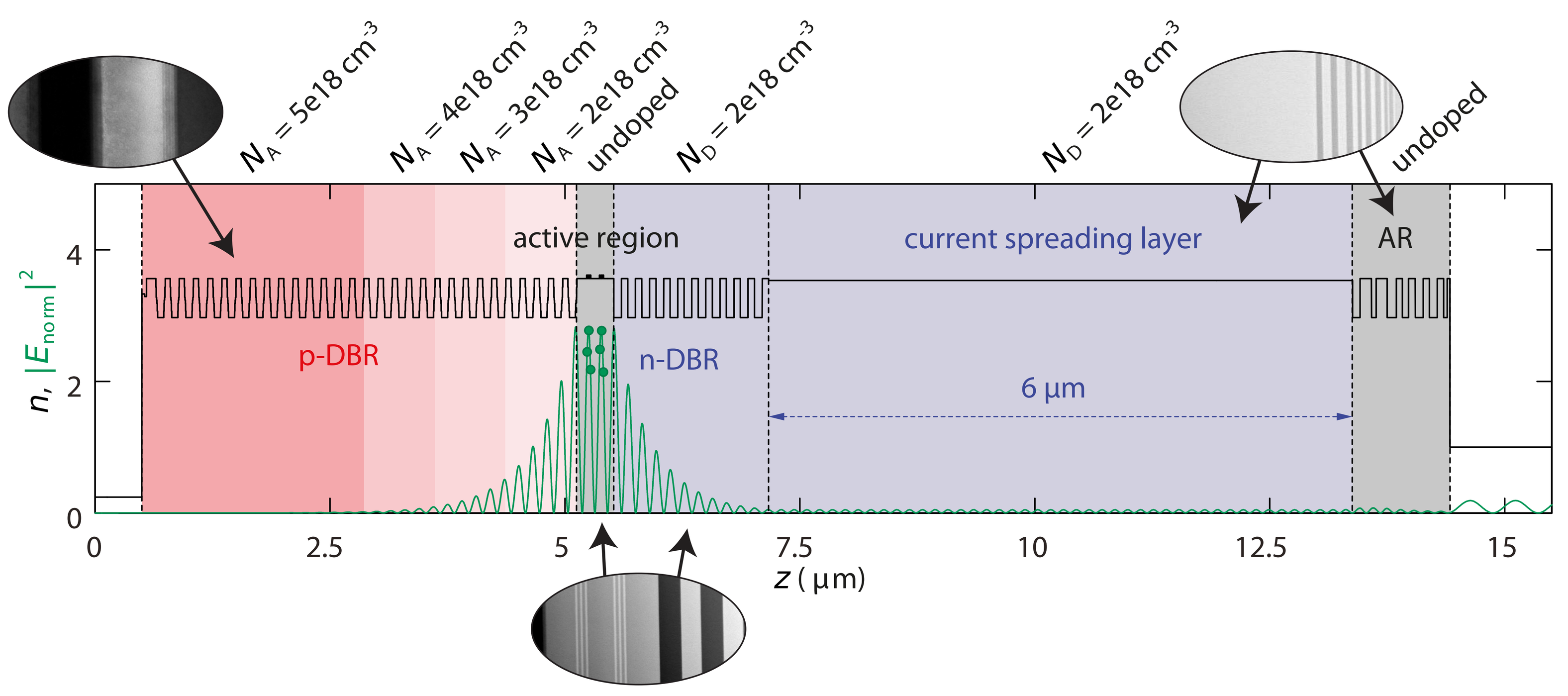
- compact and reliable
- cost-efficient
- high power
- excellent beam quality
- multi-GHz repetition rate



[1] M. Hoffmann, O. D. Sieber, V. J. Wittwer, I. L. Krestnikov, D. A. Livshits, T. Südmeyer, U. Keller, Opt. Express, vol. 19, No. 9, pp. 8108-8116, (2011)
[2] A. Quarterman, K.G. Wilcox, V. Apostolopoulos, Z. Mihoubi, S. Elsmere, I. Farrer, D.A. Ritchie, A. Tropper, Nat. Phot. **3**, 729-731 (2009)

Design of the electrically pumped VECSEL

Gain structure



Refractive index profile, normalized electrical field distribution and doping profile of the EP VECSEL* gain structure with TEM insets

* EP VECSEL: Electrically Pumped Vertical External Cavity Surface Emitting Laser

EMEZ Electron Microscopy ETH Zurich

Design [3]

Optical-electrical trade off
optimized doping profile
p-DBR with compositional or digital alloy grading
intermediate n-DBR for increased gain

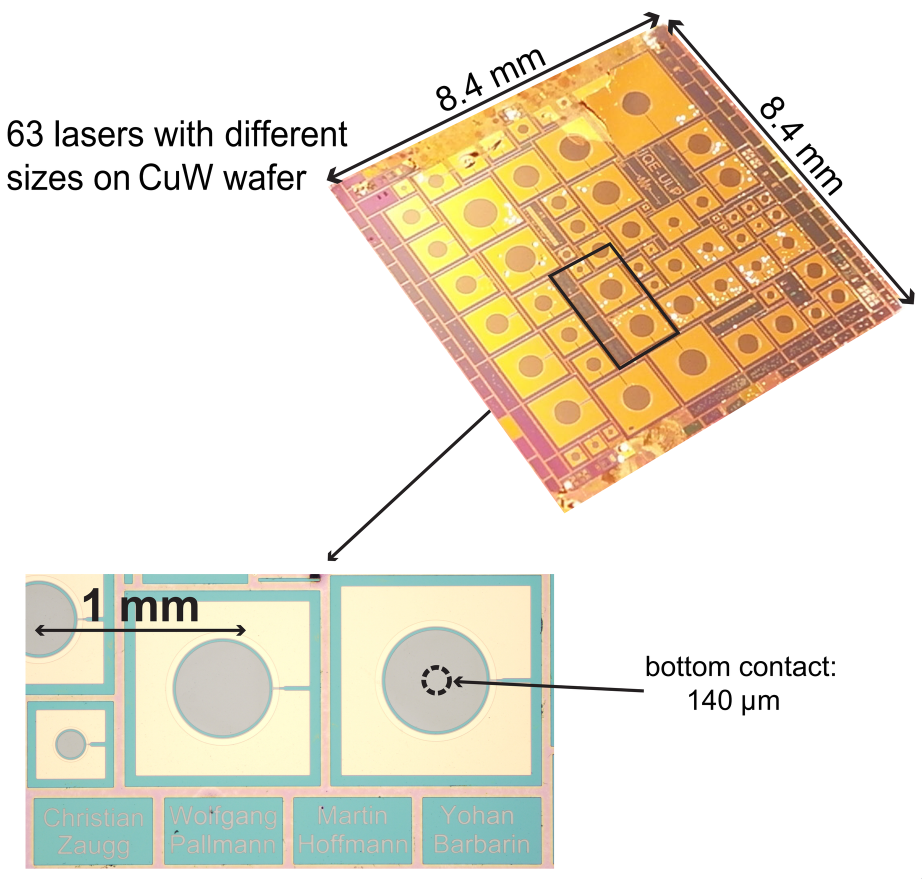
Power scalability
substrate removal
large apertures possible
high power achievable

Suitable for modelocking
optimized AR section
6 µm current spreading layer
confined current injection: good beam profile

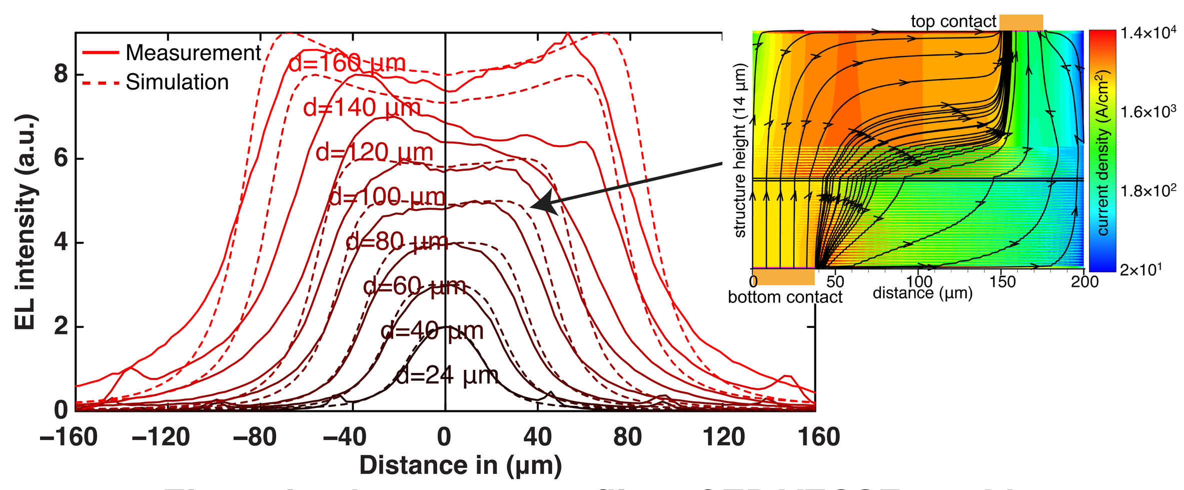
[3] P. Kreuter, B. Witzigmann, D. J. H. C. Maas, Y. Barbarin, T. Südmeyer, U. Keller, Appl. Phys. B **91**, 257-264 (2008)

Realized lasers

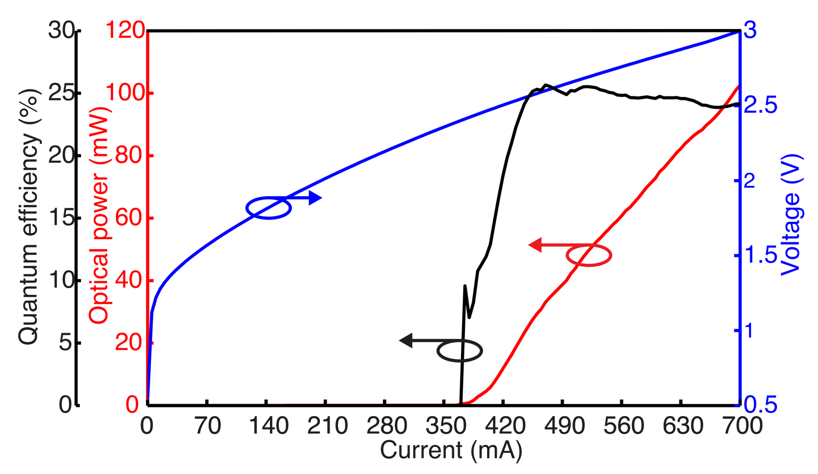
63 lasers with different sizes on CuW wafer



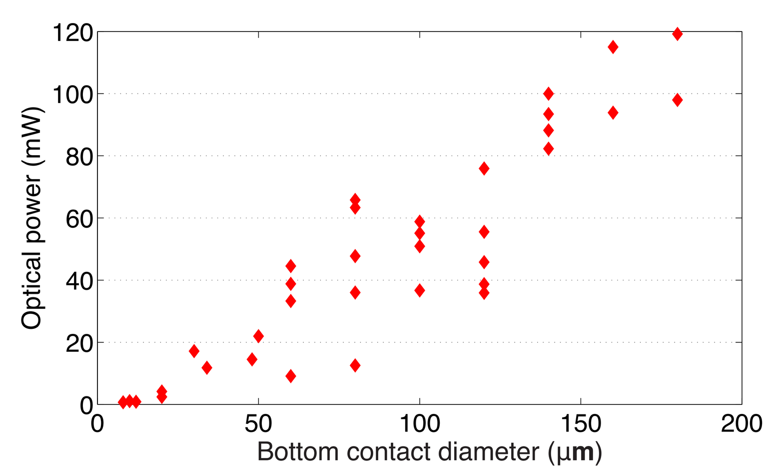
Experimental results of the first generation lasers



Electroluminescence profiles of EP VECSELs with different back contact diameters at high current injection



L-I-V curve and quantum efficiency of laser A41 using an OC with 5% transmission in a simple straight cavity

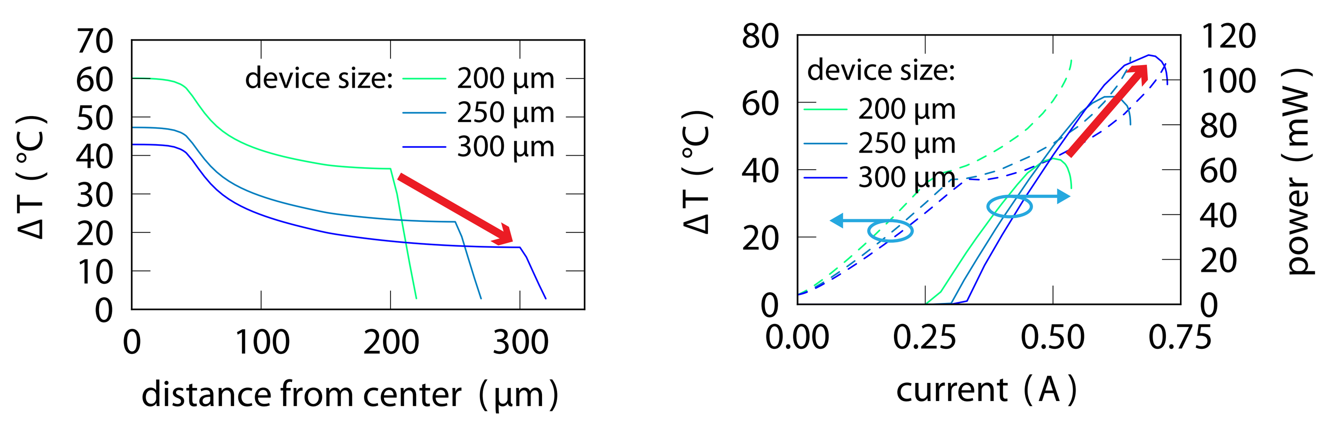


Output power of lasers with different bottom contact diameters measured with OC with 10% transmission

Y. Barbarin, M. Hoffmann, W. P. Pallmann, I. Dahhan, P. Kreuter, M. Miller, J. Baier, H. Moench, M. Golling, T. Südmeyer, B. Witzigmann, U. Keller, IEEE J. Selected Topics in Quantum Electronics (JSTQE), vol. 17, No. 6, pp. 1779-1786, (2011)

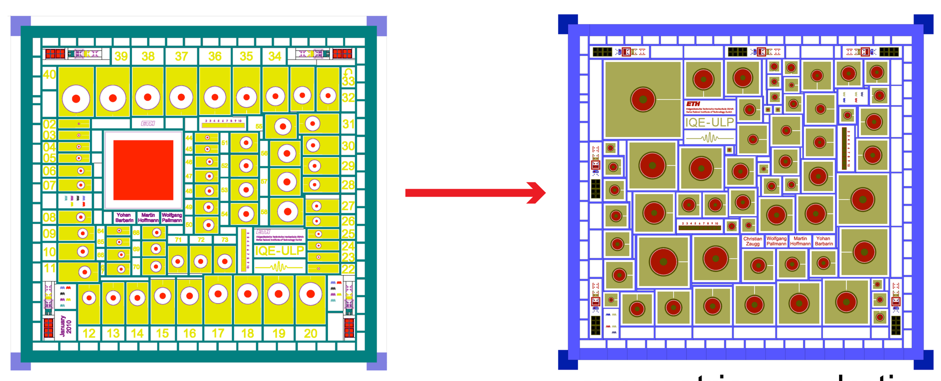
Optimization using numerical methods

Example: simulation of device internal temperature



➡ increase in output power by scaling the heat transfer area

New mask design for improved thermal management



small, asymmetric devices

symmetric, quadratic devices with improved thermal management

Expected improvements:

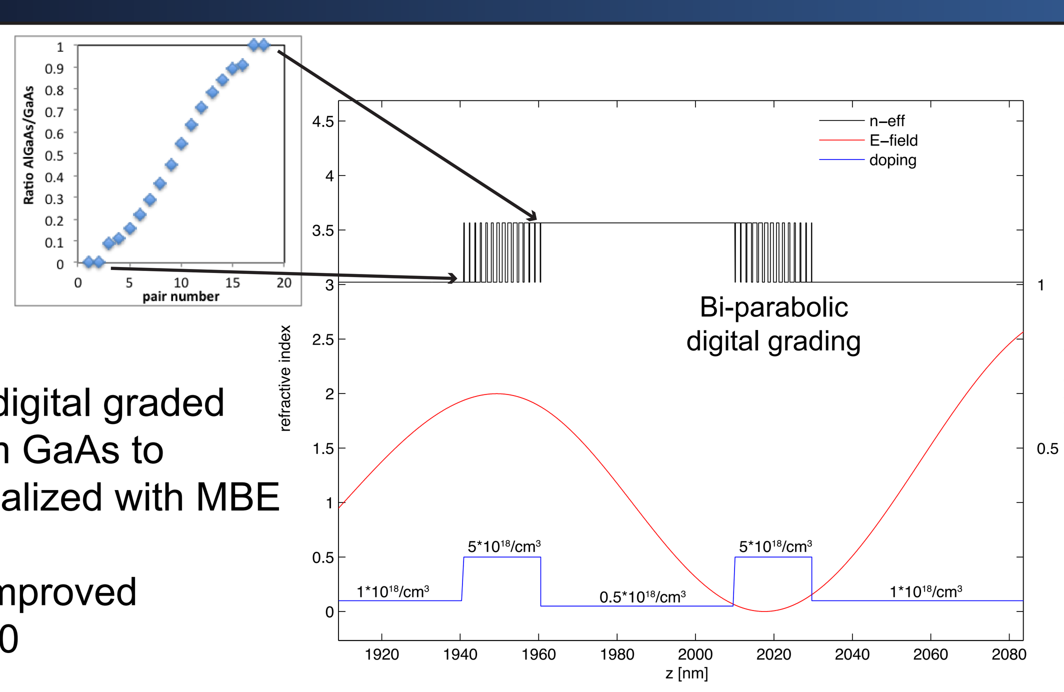
more efficient lateral heat removal

higher modal gain

symmetric beam profile

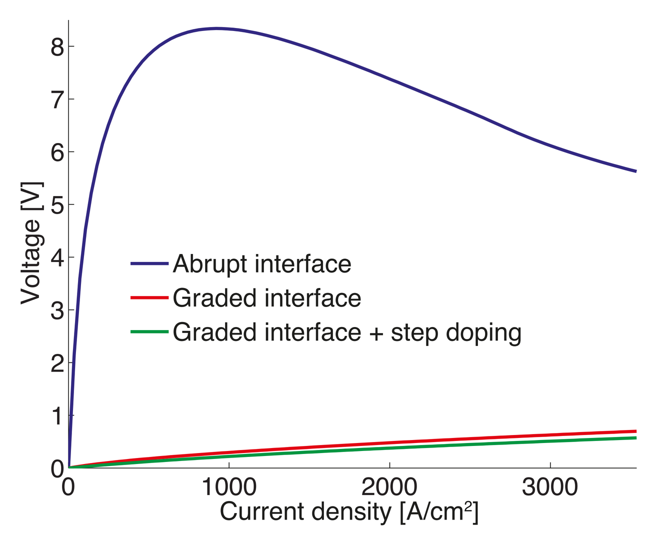
➡ **higher power in fundamental transversal mode (TEM00) expected**

p-DBR optimization



Bi-parabolic digital graded interface from GaAs to $Al_{90}Ga_{10}As$ realized with MBE

Resistance improved by factor of 10



I-V curve of different 15 pair p-DBRs with abrupt and digital alloy interfaces

Outlook

Near future:

improve beam quality and group delay dispersion

passively modelocked devices

optimize electrical properties

Goal: EP MIXSEL

➡ **Ultracompact device with GHz repetition rate, high power and excellent beam quality**

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