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MIXSEL2

RTD 2012

FNSNF

Electrically Pumped VECSELs and MIXSELs

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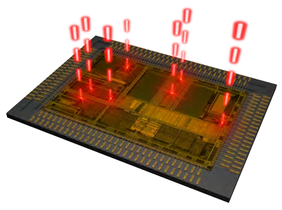
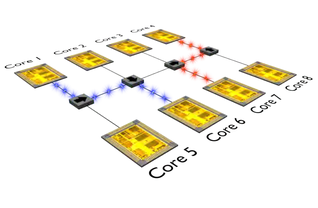
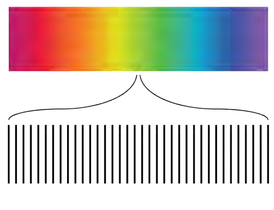
Ultrafast semiconductor lasers



multi-core clocking



optical interconnects



GHz frequency combs

➡ SESAM-modelocked VECSELs ideally suited for pulse generation in GHz regime

Recent achievements from VECSELs:

- 3.3 W in 400 fs pulses [1]
- first f_{CEO} detection from a VECSEL[2]

Recent achievements from MIXSELs:

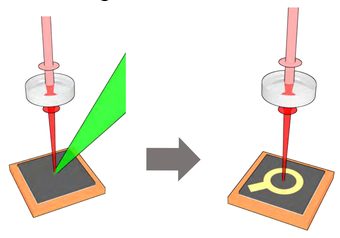
- high-power femtosecond pulses [3]
- 5 to 100 GHz repetition rate [4]

[1] K. G. Wilcox et. al., Opt. Exp. 21 (2), 1599-1605, 2013.
[2] C. A. Zaugg et. al., submitted to 6th EPSQEOD Europhoton Conference, 2014
[3] M. Mangold et. al., Opt. Exp. vol. 21 (21), 24904-24911, 2013
[4] M. Mangold et. al., Opt. Exp. vol. 22 (5), 6099-6107, 2014

Electrically Pumped VECSELs

Why electrical pumping?

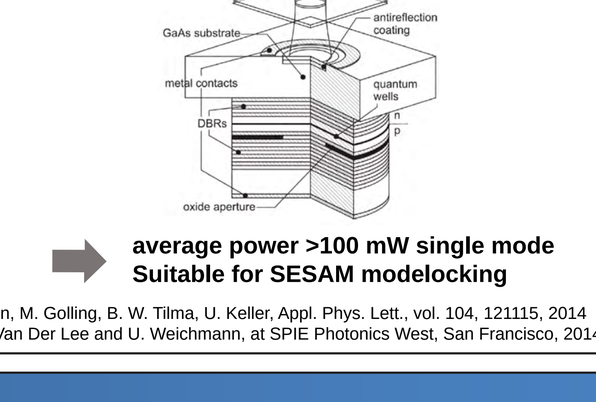
- much more compact (no pump!)
- mass producible
- inexpensive fabrication
- keep advantages (e.g. beam quality, power scaling, suitable for modelocking)



OP-VECSEL (cw) ➡ **EP-VECSEL (cw)**

Recent results:

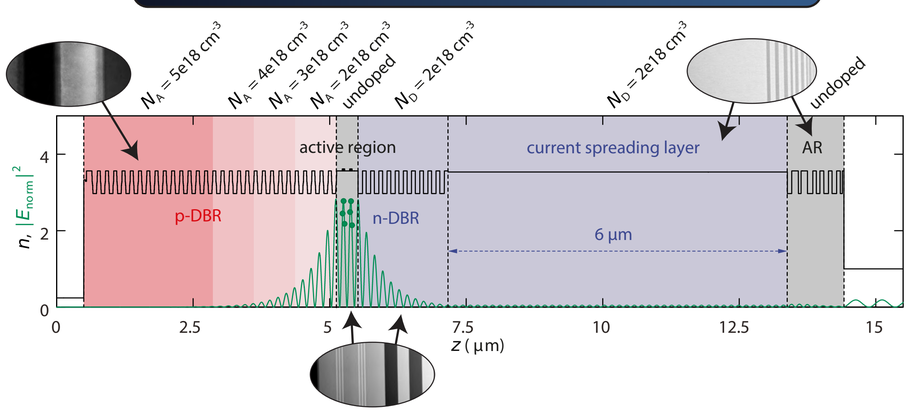
13.1 mW with 7.3 ps pulses [5]



[5] W. P. Pallmann, C. A. Zaugg, M. Mangold, I. Dahhan, M. Golling, B. W. Tilma, B. Witzigmann, U. Keller, “Ultrafast electrically pumped VECSELs” IEEE Photonics Journal, vol. 5, Nr. 4, 1501207, 2013

VECSEL gain chip, SESAM and cavity setup

Principle of EP-VECSEL gain chip



refractive index profile, normalized electrical field distribution and doping profile of the initial EP VECSEL gain structure with TEM insets [5]

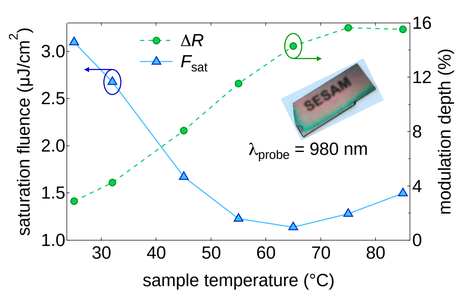
EMEZ Electron Microscopy ETH Zurich

Improved SESAM

requirements for EP-VECSEL modelocking

low saturation fluence | high modulation depth | fast recovery time

➡ **low-temperature, AlAs embedded QW-SESAM highly resonant dielectric top-coating: [6]**



Improved gain chips

optimized gain chip from Philips [7]

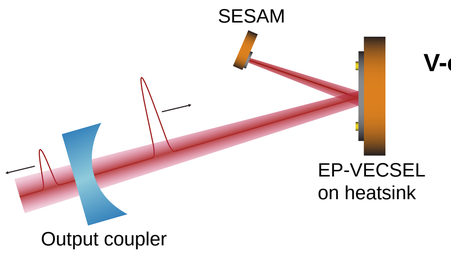
high power | high beam quality (TEM_{00}) | low resonance in active region

➡ **average power >100 mW single mode Suitable for SESAM modelocking**

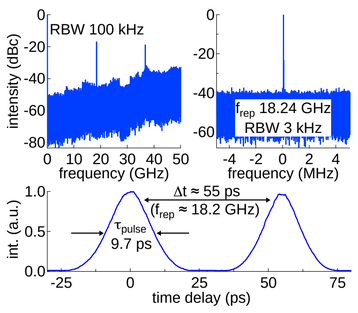
[6] C. A. Zaugg, S. Gronenborn, H. Moench, M. Mangold, M. Miller, U. Weichmann, W. P. Pallmann, M. Golling, B. W. Tilma, U. Keller, Appl. Phys. Lett., vol. 104, 121115, 2014
[7] H. Moench, A. Andreadaki, S. Gronenborn, J. S. Kolb, P. Loosen, M. Miller, T. Schwarz, A. M. Van Der Lee and U. Weichmann, at SPIE Photonics West, San Francisco, 2014.

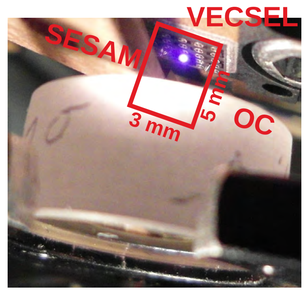
Experimental results:

Highest repetition rate



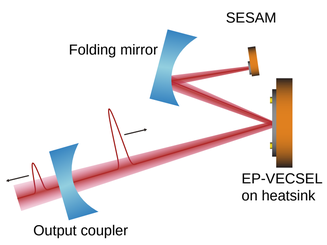
V-cavity:
very compact
repetition rate 9-18 GHz

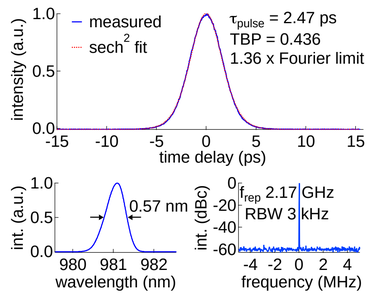




➡ **repetition rate: >18 GHz!** *2

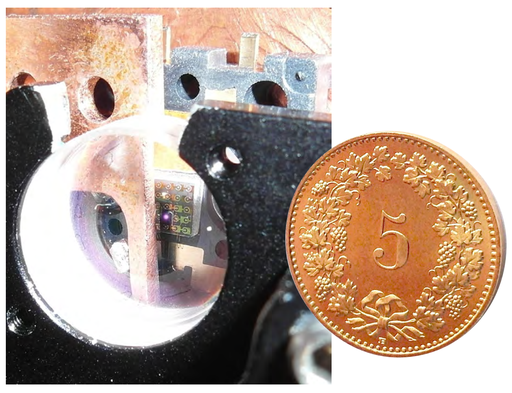
Shortes pulses





Z-cavity:
flexible design
repetition rate 2.2 GHz

➡ **pulse duration: 2.5 ps!** *3

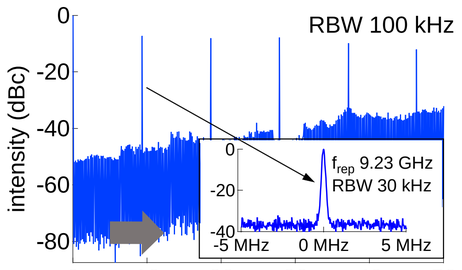


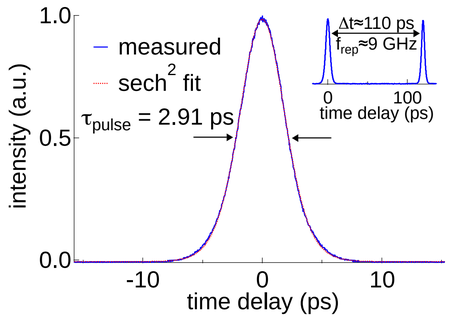
Summary of new results

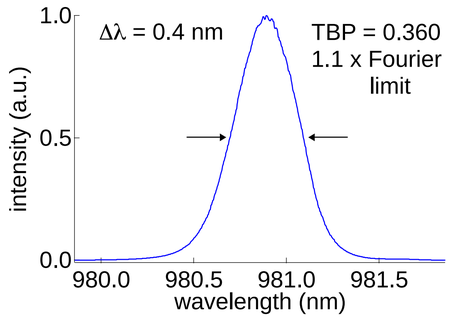
	P_{avg}[mW]	f_{rep}[GHz]	T_{pulse}[ps]	P_{peak}[W]
*3	**53.2**	9.2	2.91	1.74
*2	10.1	**18.2**	9.48	0.05
*1	15.9	2.2	**2.46**	2.62
	35.0	2.2	3.03	**4.73**

➡ **Record performance from modelocked EP-VECSEL:**
Highest average power
Highest repetition rate
Shortest pulses
Highest peak power

Highest average power







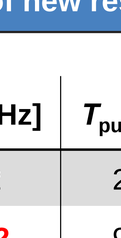
➡ **average power: >50 mW!** *1

Outlook

near future:

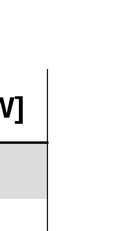
further increase power towards 500 mW

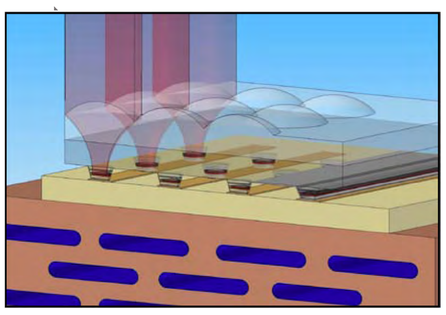
decrease pulse duration by less resonant chips



goal: EP MIXSEL

integration of SESAM into EP VECSEL ➡





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ultracompact device with:
- GHz repetition rate
- high power
- excellent beam quality

wafer-scale integration scheme possible!

our work is supported by: nano-tera.ch | FIRST Center for Micro- and Nanoscience