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MIXSEL RTD 2009

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Towards a high-power femtosecond MIXSEL

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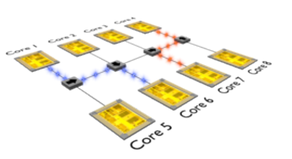
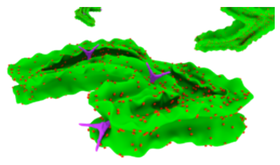
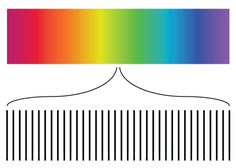
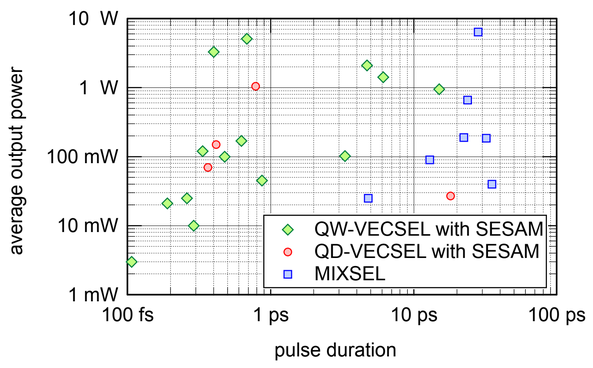
Motivation

Applications of SESAM-modelocked Vertical External Cavity Surface Emitting Lasers (VECSELs) and Modelocked Integrated eXternal-cavity Surface Emitting Lasers (MIXSELs)









first Watt-level femtosecond VECSEL [1]

- 784-fs-pulses with >1 W output power in a 5.4 GHz V-cavity

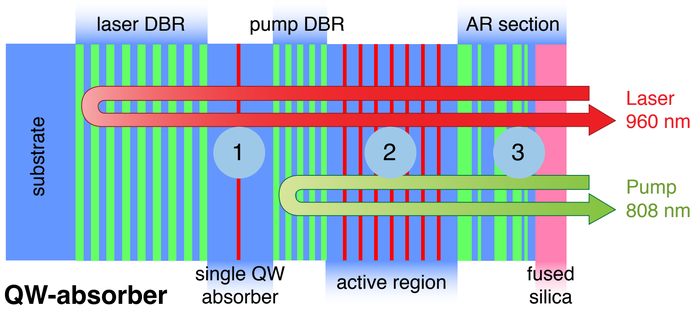
femtosecond VECSEL with tunable repetition rate [2]

- 625-fs-pulses with 169 mW output power in a cavity tunable from 6.5 - 11.3 GHz

[1] M. Hoffmann *et. al.*, Optics Express (2011) vol. 19, 8108-8116
[2] O. D. Sieber *et. al.*, Optics Express (2011) vol. 19, pp. 23538-23543

MIXSEL with fast absorber

structure

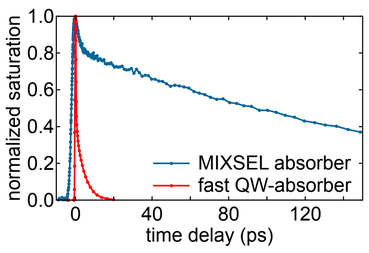


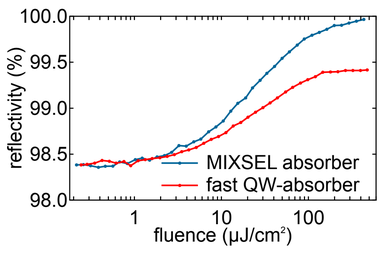
QW-absorber MIXSEL

1. **single quantum-well absorber** fast absorber with low saturation fluence
   - **shorter pulses possible**
2. **quantum-well active region**
3. **low dispersion AR coating** semiconductor / fused silica
   - **±100 fs² over broad wavelength range**

absorber characterization

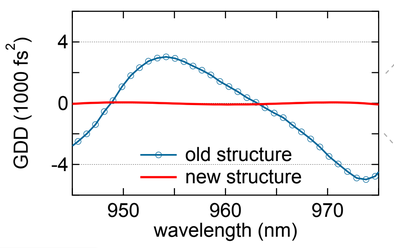
- **10 times faster absorber recovery**
- **comparable low saturation fluences**

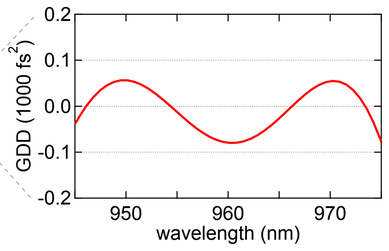




coating for low group-delay dispersion

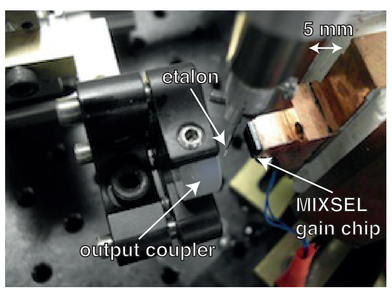
- **flat group delay dispersion around lasing wavelength**
- **essential for the generation of femtosecond pulses**





modelocking results

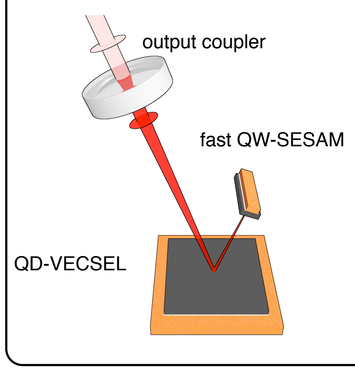
pulse duration	output power	repetition rate
4.8 ps	25 mW	2.9 GHz
6.8 ps	8 mW	20.8 GHz



- **3 times shorter pulse duration than with slow QD-absorber** [3]
- **highest repetition rate of any MIXSEL**

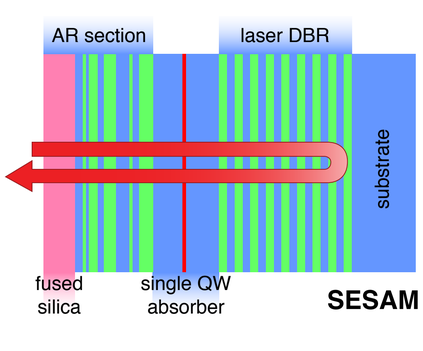
[3] V. J. Wittwer, O. D. Sieber, M. Mangold, M. Hoffmann, C. J. Saraceno, M. Golling, B. W. Tilma, T. Südmeyer, U. Keller, "MIXSEL with a Quantum Well Saturable Absorber: Shorter Pulse Durations and Higher Repetition Rates", CLEO US 2012, San Diego

fast absorber for femtosecond operation



pulse duration	output power	repetition rate
364 fs	70 mW	4 GHz

- **absorber as in QW-MIXSEL**
- **low-GDD section**
- **fast absorber with capability of femtosecond operation**

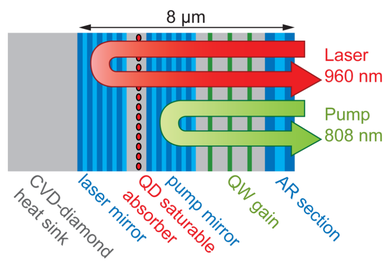


High Power MIXSEL

integration concept

- semiconductor based
- integrated QD absorber
- power scalable
- potential for monolithic design

Modelocked Integrated eXternal-cavity Surface Emitting Laser



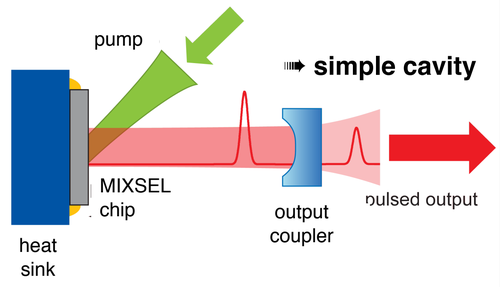
anti-resonant MIXSEL concept

modelocking results

- **highest output power of a modelocked semiconductor laser** [4]

pulse duration	output power	repetition rate	peak power
28.1 ps	6.4 W	2.5 GHz	80 W
16.9 ps	2.4 W	10 GHz	41 W

- **highest output power of a modelocked 10 GHz laser**

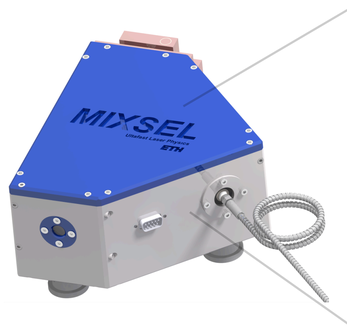


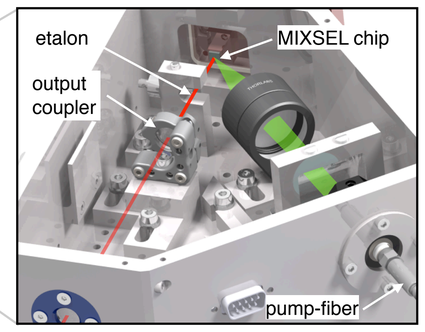
- **simple cavity**

[4] B. Rudin, V. J. Wittwer, D. J. H. C. Maas, M. Hoffmann, O. D. Sieber, Y. Barbarin, M. Golling, T. Südmeyer, and U. Keller, Opt. Express (2010) vol. 18 (26) pp. 27582-27588
[5] V. J. Wittwer, M. Mangold, M. Hoffmann, O. D. Sieber, M. Golling, T. Südmeyer, U. Keller, Electronics Lett., vol. 48, No. 18, pp. 1144, 2012

Noise characteristics of the MIXSEL

small footprint prototype housing





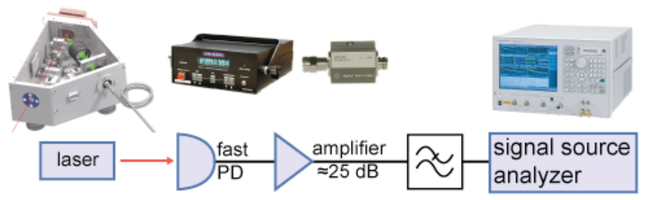
- **water-cooling for high-power operation**
- **fiber-coupled pump**

pulse duration	output power	repetition rate
16 ps	660 mW	1.97 GHz

measurement scheme

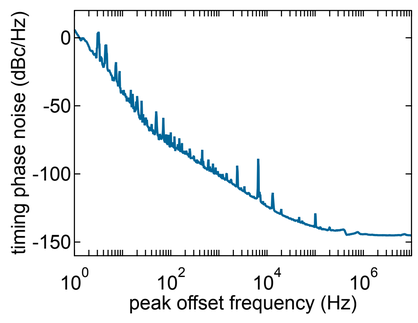
rms timing jitter

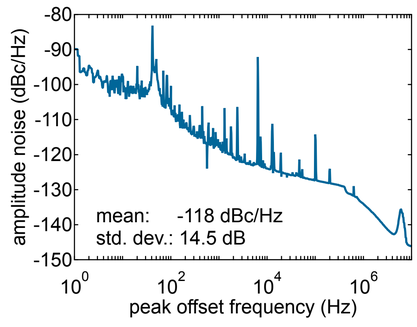
$$\sigma_T = \frac{\sqrt{2\int_{f_{low}}^{f_{high}} P_F(\Delta f)\, d\Delta f}}{2\pi f_{rep}}$$



measurements

f_{low}	100 Hz	300 Hz
f_{high}	10 MHz	10 MHz
rms timing jitter	157 fs	90 fs

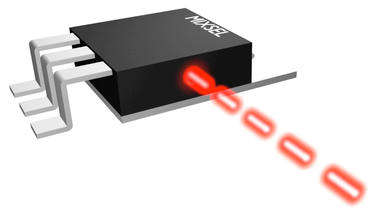




➡ **next step: stabilizing the cavity length and reducing the timing jitter**

Outlook

high-power QW-absorber-MIXSEL on → **femtosecond MIXSEL**



pulse duration	output power	repetition rate	peak power
200 fs	1 W	1 GHz	4.4 kW

compact, low cost laser with high peak power for frequency comb generation

our work is supported by:

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