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MIXSEL2 RTD 2012

FNSNF

Ultrafast vertical external cavity surface-emitting laser (VECSEL)

ETH zürich

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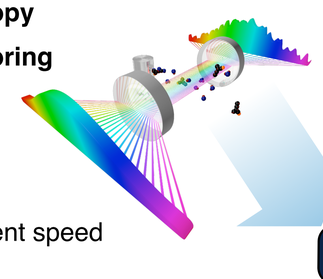
Motivation

Spectroscopy

ABB

- **Gas spectroscopy**
- **Process monitoring and control**



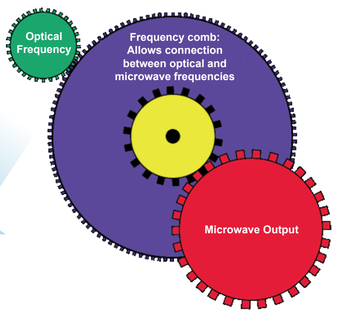
Requirements

- Broad spectrum
- Fast measurement speed
- Spectral stability
- Mechanical compactness

Metrology Applications

METAS

- **Optical clock**
- **Precise frequency calibration**



Requirements

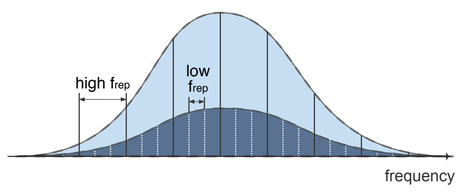
- Compact system
- Gigahertz repetition rates

Frequency Combs

Requirements for self-referenceable frequency comb

- Low noise
- Sub-200-fs pulses combined with high average power

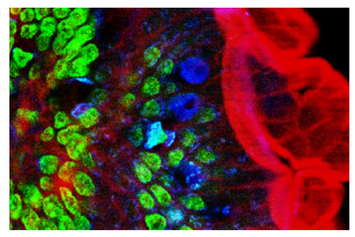
VECSEL: potential compact frequency comb source with gigahertz repetition rate



- ➠ easier to access to individual lines
- ➠ higher power per mode
- ➠ increased S/N ratio

Biomedical Imaging

LMSC Light Microscopy and Screening Center



Multiphoton microscopy:

- ➠ high penetration depth
- ➠ high sensitivity
- ➠ flexibility (fluorescence plus second harmonic or third harmonic image)

Requirements

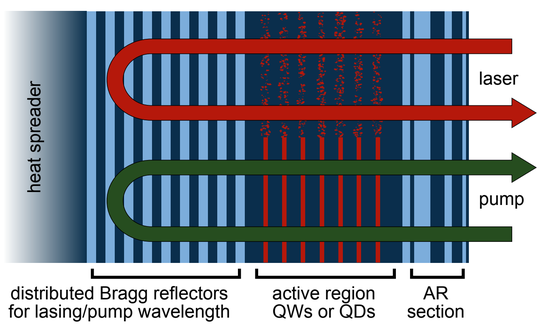
- Pulsed IR-source
- Cheap (compared to currently used Ti:Sapphire systems)

VECSEL: compact & cheap pulsed laser source in the IR spectral range

Ultrafast VECSELs

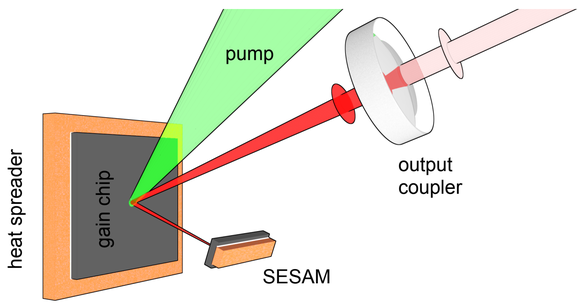
VECSEL Chip Structure

- Distributed Bragg reflector (AlAs/GaAs)-pairs grown on GaAs for laser reflection
- Active region: Laser light amplification in quantum wells (QW) or quantum dots (QD)
- Antireflection-coating: Minimizing losses and tuning group delay dispersion (GDD)



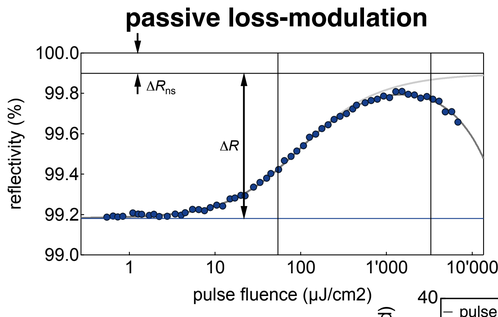
Cavity Design

- V- or Z-shape cavity
- Pumping under 45°
- SESAM: SEmiconductor Saturable Absorber Mirror to obtain self-starting pulsed operation

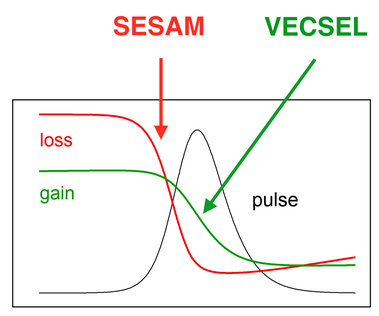


Pulse Formation Mechanism

SESAM: passive loss-modulation

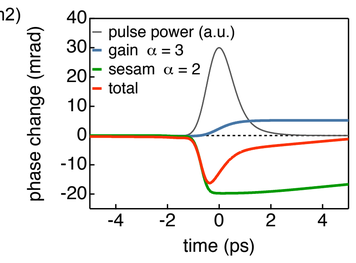


Dynamic gain saturation
Losses decrease faster than gain
➠ net gain window



saturation + **positive** GDD
➠ quasi-solitons [1]

Phase shift by saturation (Kramers-Kronig)



experimentally verified in picosecond regime [2]

[1] R. Paschotta, R Häring, A Garnache, S Hoogland, A.C Tropper, U Keller, Appl. Phys. B **75** (2002), 445
[2] M. Hoffmann, O.D. Sieber, D.J.H.C. Maas, V.J. Wittwer, M.Golling, T. Südmeyer and U.Keller, Opt Express **18** (2010), 10143

Current Status

Experimental Results

First Watt-level femtosecond QD-VECSEL [3]

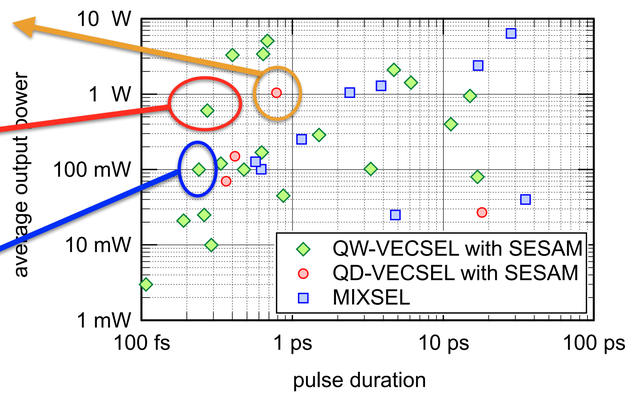
- ➠ 784-fs-pulses with >1 W output power in a 5.4 GHz V-cavity

Sub-300 femtosecond QW-VECSEL

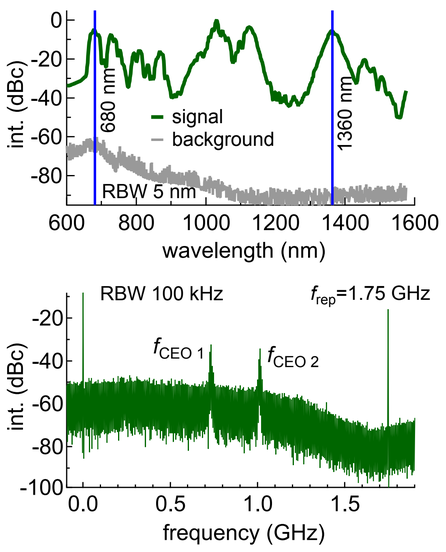
- ➠ 273-fs-pulses at 605 mW of average output power in a 1.8 GHz-cavity

First CEO-frequency detection of a SESAM-modelocked VECSEL [4]

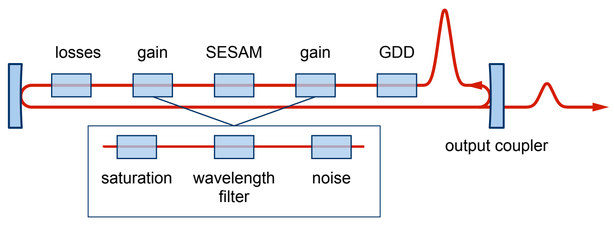
- ➠ amplified and recompressed 240-fs pulses from a 100-mW VECSEL



[3] M. Hoffmann *et. al.*, Optics Express (2011) vol. 19, 8108-8116
[4] C.A. Zaugg *et. al.*, submitted to 6th EPS-QEOD Europhoton Conference



Theoretical Investigations & Simulations



- Iterative application of cavity elements on the pulse
- Macroscopic measurable parameters as input parameters

correct prediction of output power and pulse duration + design guidelines

[5] O. D. Sieber, V. J. Wittwer, M. Mangold, M. Hoffmann, M. Golling, T. Südmeyer, U. Keller, Optics Express **19** (2011), 3538, 2011

Conclusion & Outlook

Chip Design Goals

FIRST Center for Micro- and Nanoscience

VECSEL

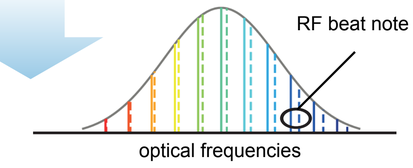
saturation fluence	gain	GDD
high gain saturation fluences for short pulse generation and high output power	**high small signal gain** for high power operation	**low and slightly positive GDD** for femtosecond pulses

SESAM

saturation fluence
low saturation fluences of SESAM for short pulse generation

low noise + **Sub-200-fs pulses combined with high average power**

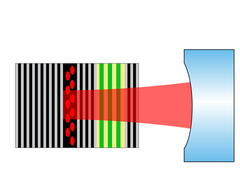
compact self-referenceable frequency comb from a VECSEL



Cavity Design Goals

1:1 mode-locking (spot size on SESAM = spot size on VECSEL)

Integration of the absorber



MIXSEL

Modelocked Integrated External-Cavity Surface Emitting Laser