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FNSNF

Toward a fully-stabilized frequency comb from a VECSEL prototype

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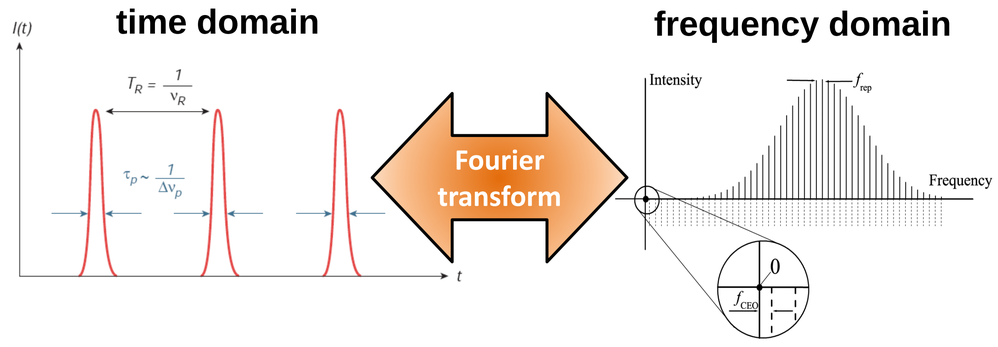
Motivation



Optical frequency combs are frequency rulers made of several hundred of thousands of equidistant optical frequencies. They provide a phase-coherent link between the RF domain and optical frequencies

Stabilized-frequency combs

Stabilized ultra-fast pulsed lasers with fs-pulse duration and GHz-repetition rate find applications in many fields such as

- Metrology applications for the measurement of absolute optical frequencies
- High-precision spectroscopy
- Biomedical imaging
- Telecommunications
- Dual comb spectroscopy

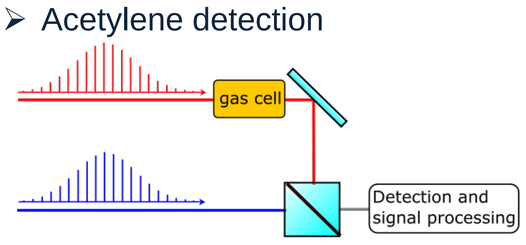
Dual comb spectroscopy

Need

- Two fully-stabilized lasers with a slightly different repetition rate

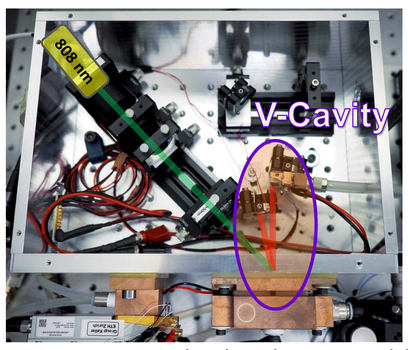
Application with METAS and ABB

- Acetylene detection



VECSEL prototype

Vertical External Cavity Surface Emitting Laser (**VECSEL**)

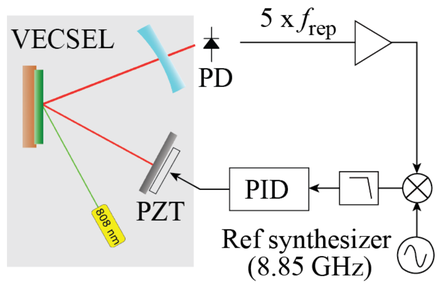


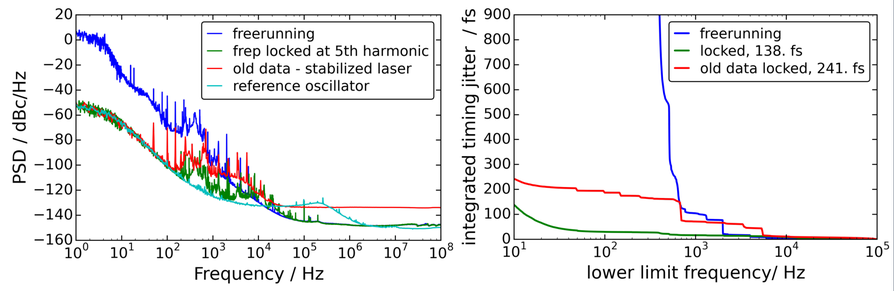
VECSEL prototype developed at ETH Zürich

Pulse duration: 300 fs
Output power: 100 mW
Repetition rate: 1.77 GHz
Center wavelength: 1034 nm

Repetition rate characterization and stabilization

Stabilization of the VECSEL repetition rate with a piezo actuator (PZT)





- Improved f_{rep} stabilization
- Noise limited by the reference synthesizer
- Stabilized timing jitter : 30 fs from 100 Hz to 1 MHz

First CEO characterization in a modelocked VECSEL

CEO measurement scheme

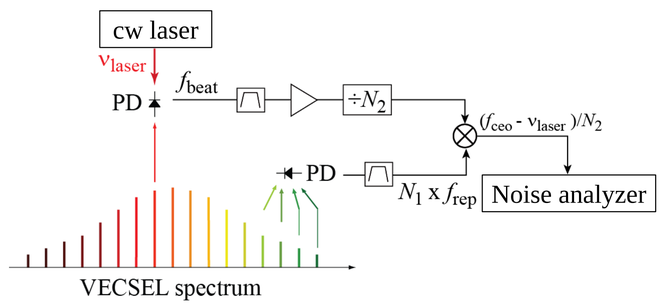
An appropriate combination of two signals:

$N_1 \cdot f_{rep}$ -from the VECSEL

$f_{beat} = f_{CEO} + N \cdot f_{rep} - \nu_{laser}$ -from its beating with a cw-laser

enables the cancellation of the repetition rate

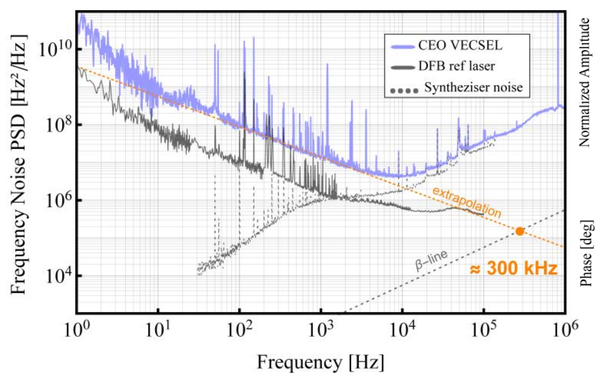
$$f_{OUT} = \frac{f_{beat}}{N_2} - N_1 \cdot f_{rep} = \frac{f_{CEO} - \nu_{laser}}{N_2}, \qquad N = N_1 \cdot N_2$$



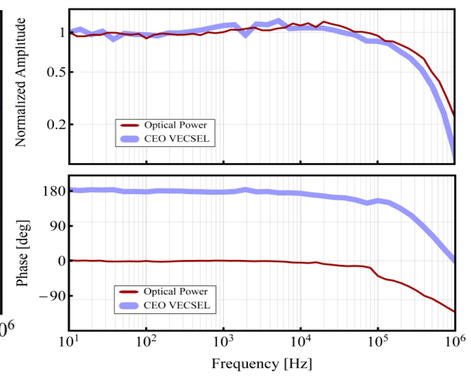
- Low noise laser ⇒ negligible compared to CEO noise
- We can access the CEO noise without detecting f_{CEO}

Measurements

CEO frequency noise



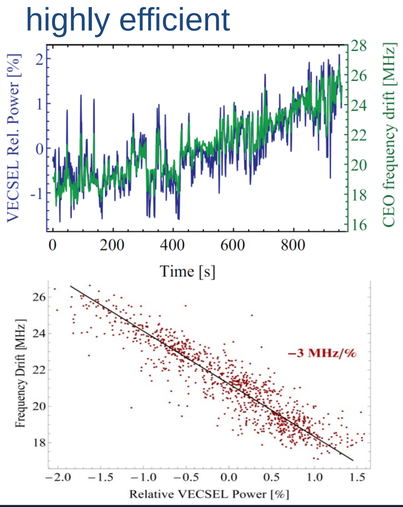
CEO transfer function (pump current modulation)



- The high frequency noise is limited by the RF reference used in the set-up
- The required feedback bandwidth to achieve a tight CEO lock in a future stabilization loop is estimated to ~300 kHz
- The transfer function of f_{CEO} shows that a modulation bandwidth >200 kHz is achievable with the pump current, making feasible a tight CEO lock in the future

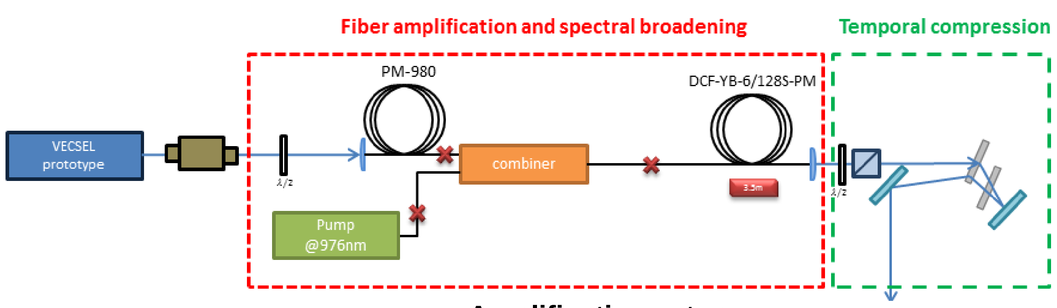
CEO drift correlation with output power

- CEO drift likely results from pump power fluctuations ⇒ a feedback loop acting on the pump current should be highly efficient



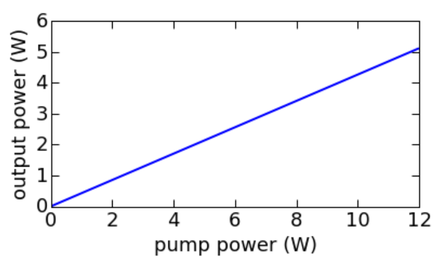
Laser amplification

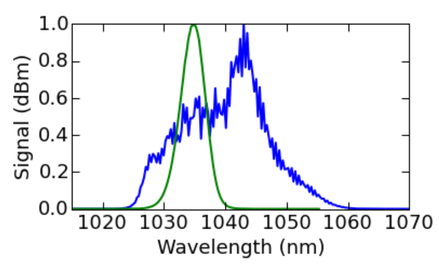
In the current situation, the amplification and compression of the laser pulses are necessary to generate an octave-spanning supercontinuum spectrum and detect the CEO beat by *f*-to-2*f* interferometry



Amplification setup

- It is done in a small core ytterbium-doped fiber





Next steps:

- Generate a supercontinuum in a PCF fiber and detect the CEO frequency with an *f*-to-2*f* interferometer
- Stabilize the CEO frequency by feedback to the pump current using a home-made fast modulation electronics
- Develop a compact dual comb spectrometer (in collaboration with METAS and ABB) for high resolution and traceable spectroscopic measurements