UNIVERSITY OF TWENTE.

LPNO Laser Physics and Nonlinear Optics

Waveguide-based External Cavity Semiconductor Laser Arrays

A Smart Optical Systems project

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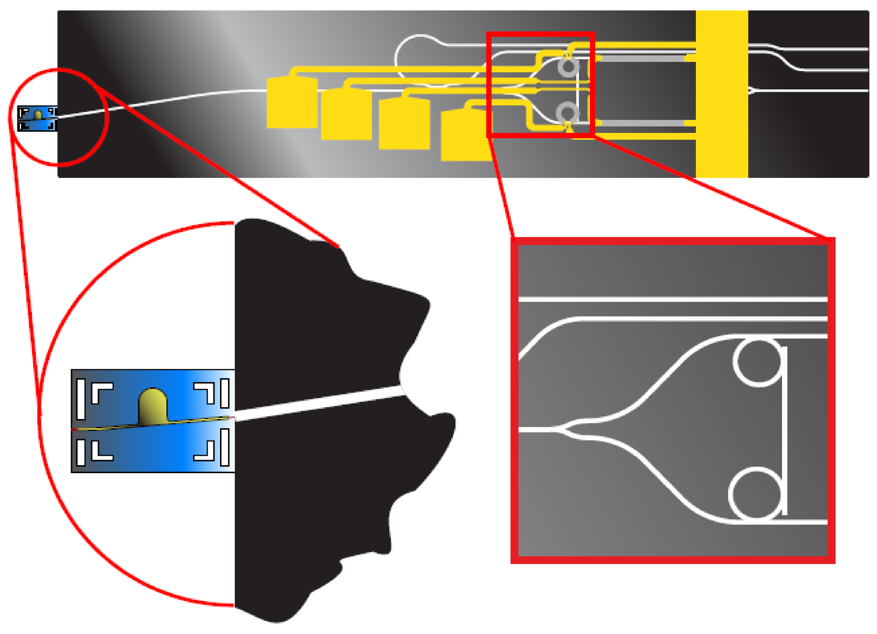
Waveguide based external cavity semiconductor laser (WECSL)

Goal

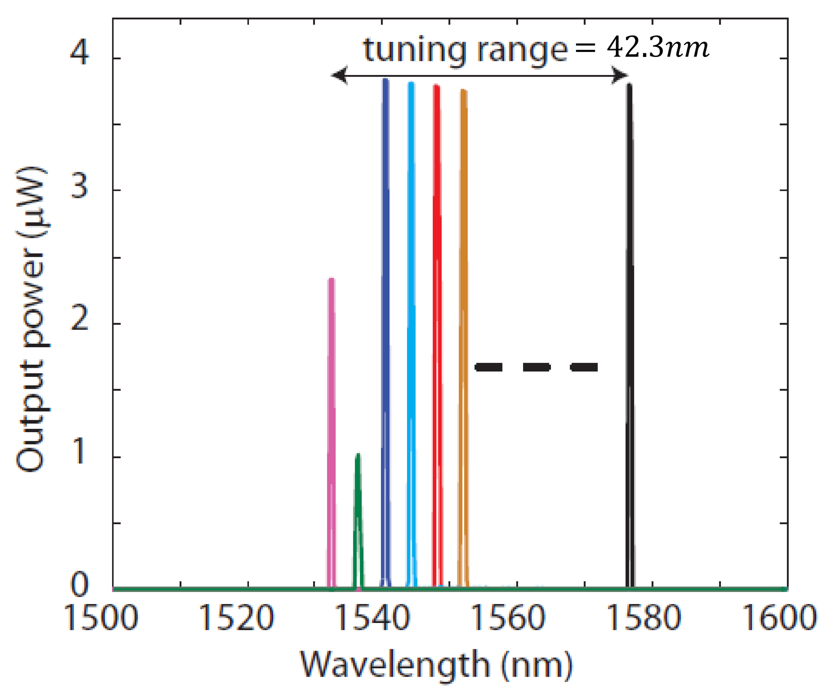
- Widely tunable
- Single longitudinal oscillation
- Narrow linewidth
- Small footprint (~mm²)



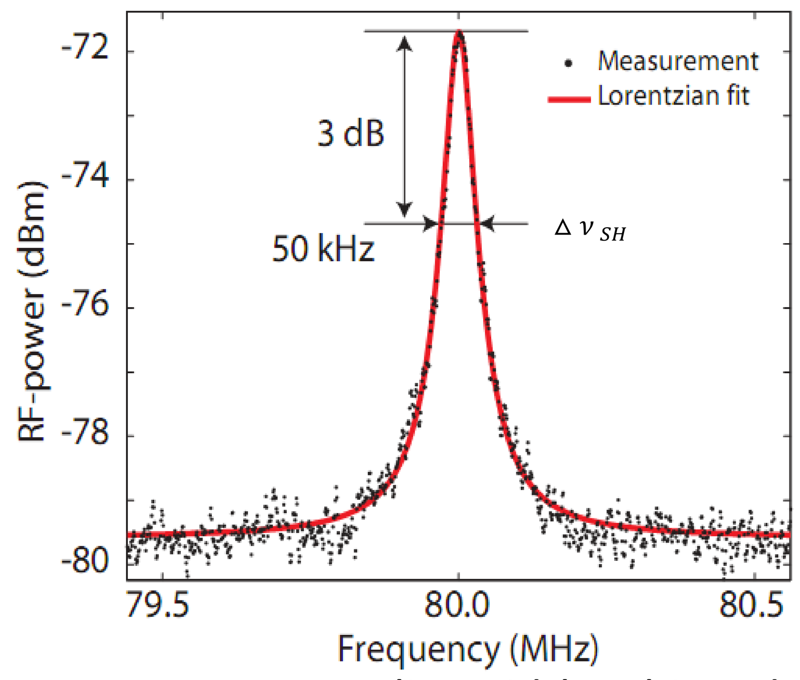
Techniques

- Low loss external waveguide circuit
- Mirror-like device for spectrally filtered feedback (double-ring resonators)
- Hybrid integration of active material (InP) and passive material (Si_3N_4)

Measured tuning WECSL output



Self-heterodyne measurement of line width



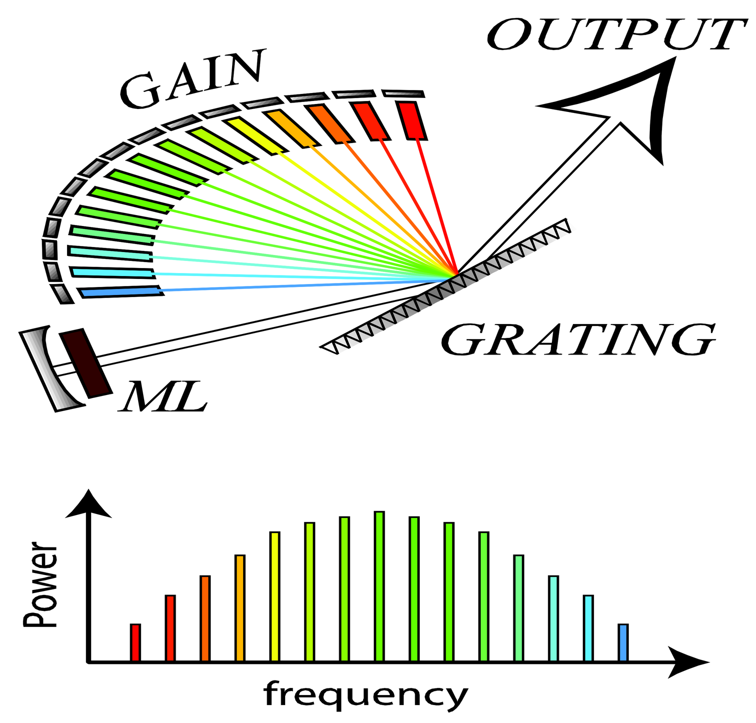
- Very narrow linewidth achieved

$$\Delta\nu = \frac{1}{2}\Delta\nu_{SH} = 25kHz$$

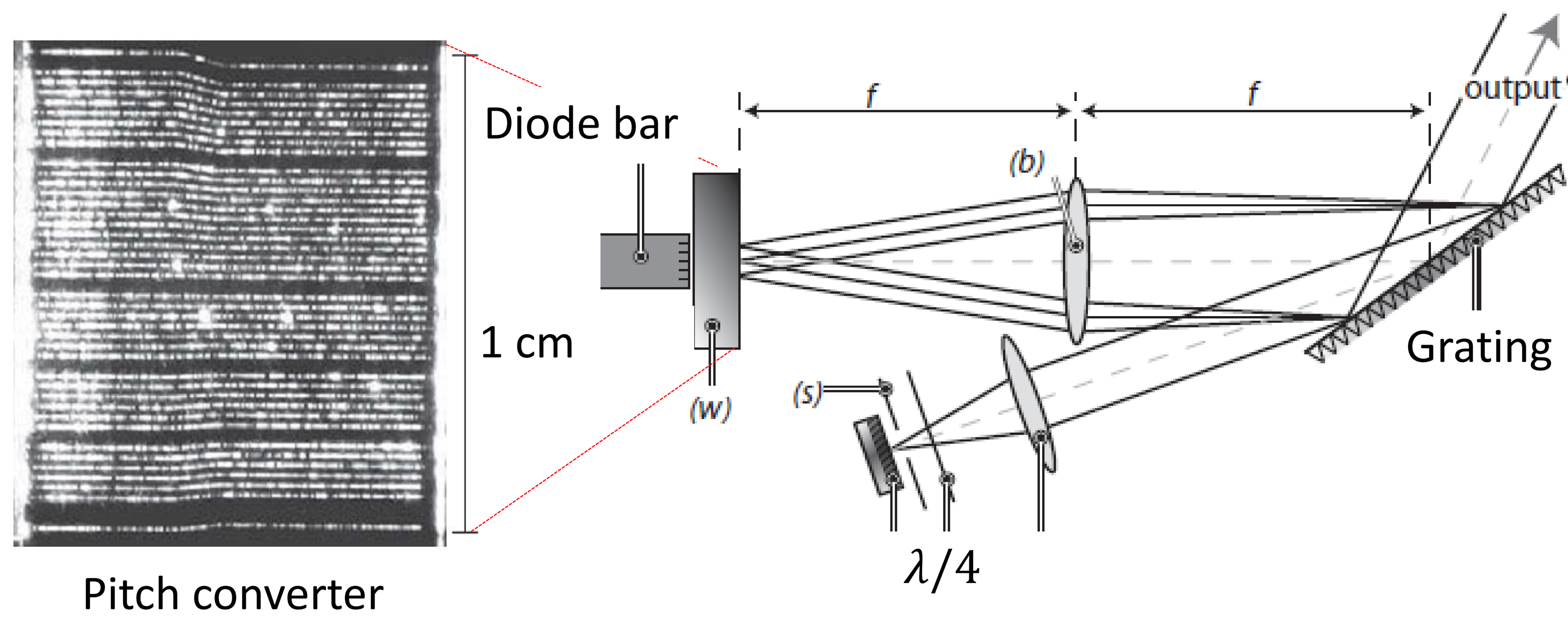
Separate gain (SEGA) mode locking

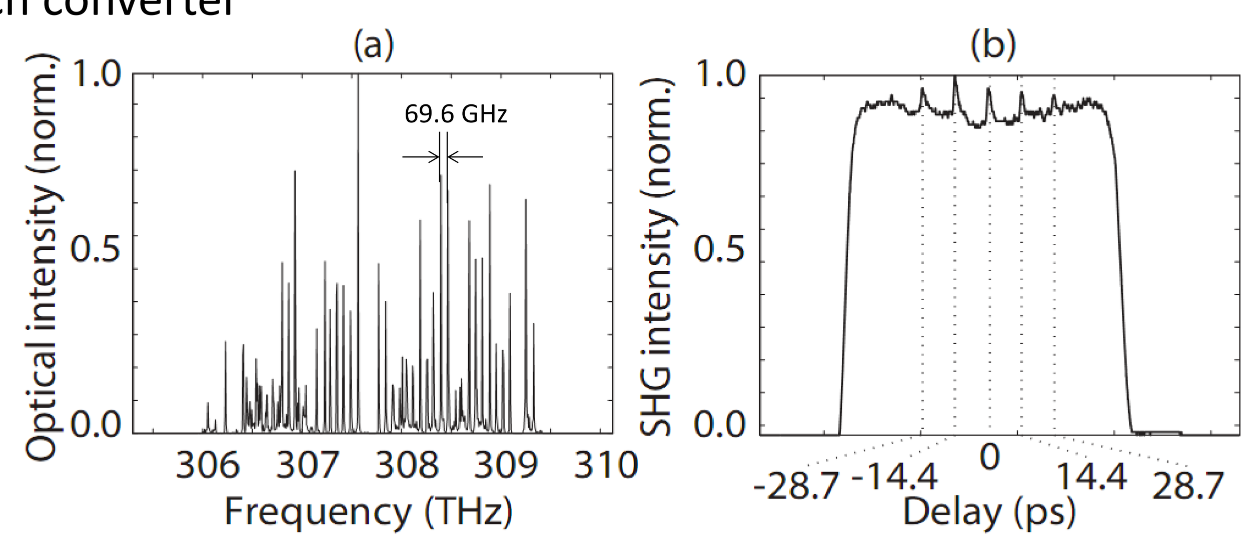
Goal

- High repetition rate mode lockied laser
- More elements = Higher output power
- Broader spectrum = reduced pulse duration



Experiment setup





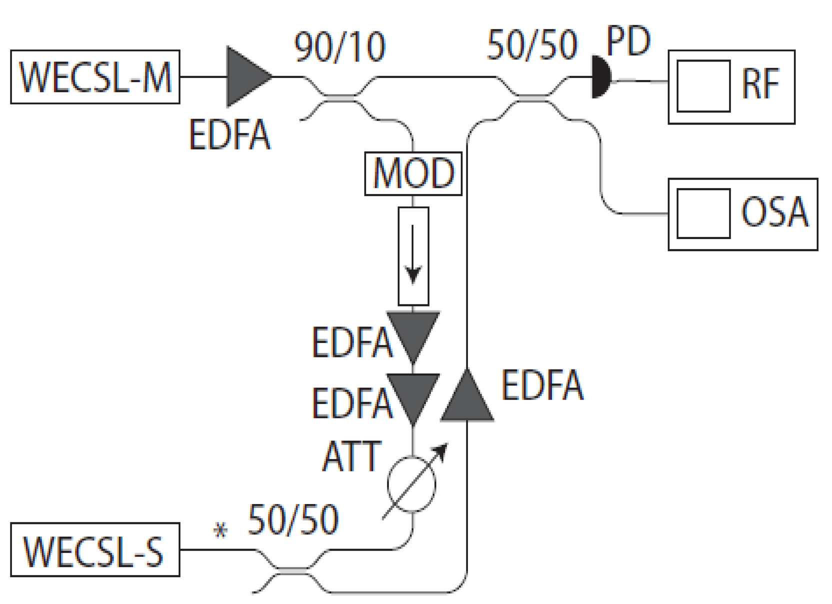
- Measured frequency comb, $\Delta f = 69.6\,GHz$
- Intensity autocorrelation

Injection locking of a WECSL

Goal

- Investigate the potential to build WECSL arrays with locked frequency and phase
- Verify injection locking as a tool to measure the Q-factor of complicated cavity with unknown losses.

Experiment setup

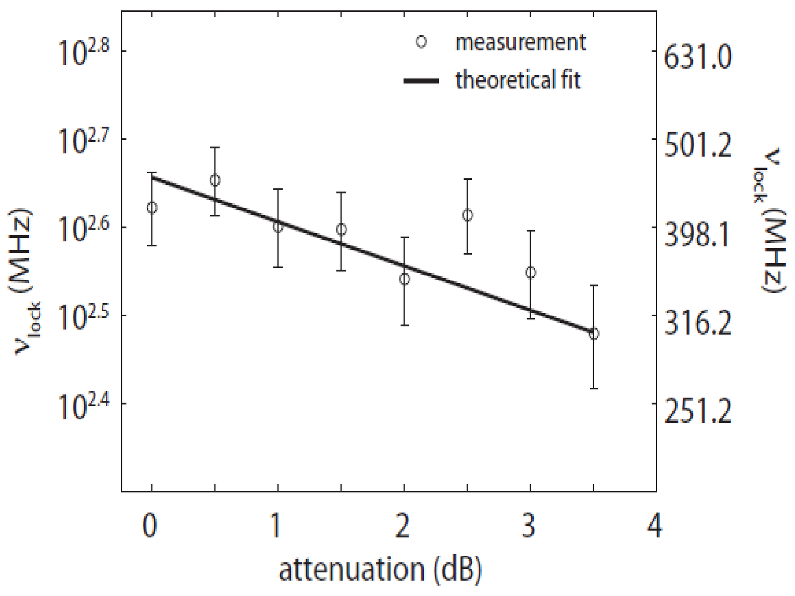


Theory

- When subject to light injection from a Master laser, the frequency of the Slave laser could be locked within the range

$$\nu_{lock} = \frac{\nu_{SL}}{Q}\sqrt{\frac{P_i}{P_{SL}}}$$

Main result



- Successful injection locking observed
- Estimated Q-factor = 7.7·10⁴
- Q-factor inferred from measured WECSL linewidth = 1.5·10⁵

High precision wavelength estimation

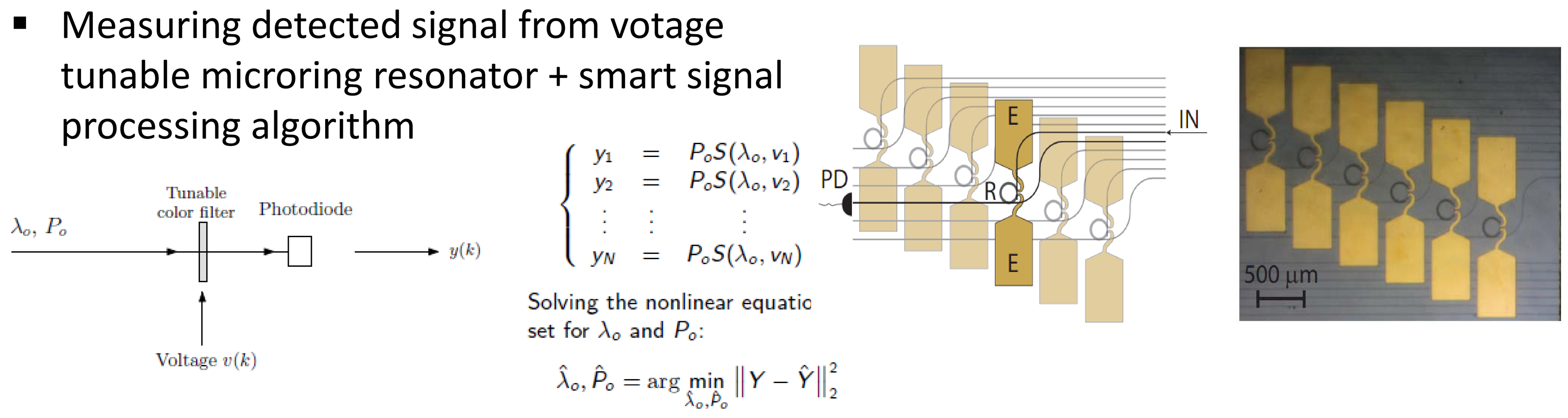
Goal

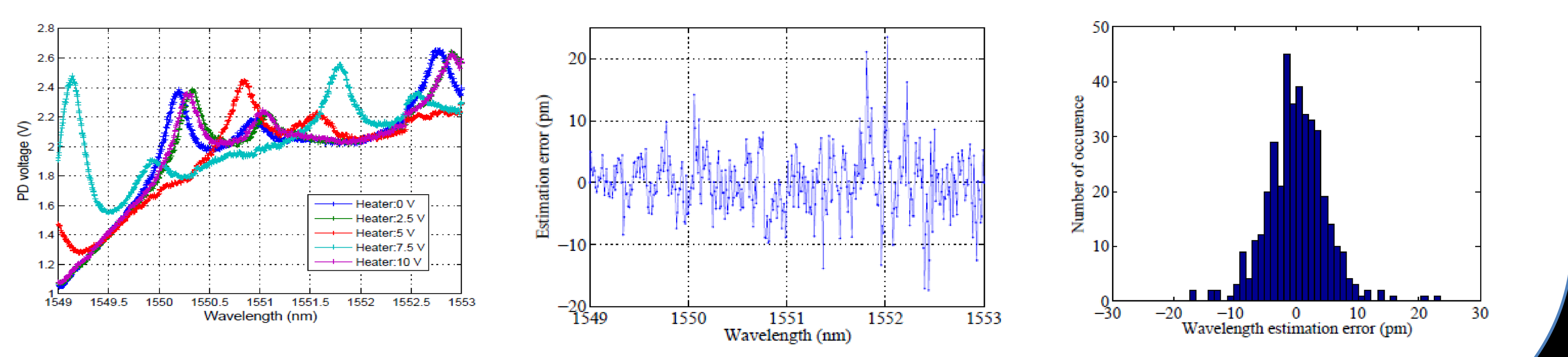
- Accurate wavelength monitoring devices for all integrated optics

Method

- Measuring detected signal from votage tunable microring resonator + smart signal processing algorithm

Layout **Microscope picture**





- Spectral sensitivity by voltage tuning the microring resonator
- Wavelength estimation of high precision
- Histogram of the wavelength estimation error

1. Oldenbeuving, R.M., Klein, E.J., Offerhaus, H.L., Lee, C.J., Song, H. & Boller, K.J, "25 kHz narrow spectral bandwidth of a wavelength tunable diode laser with a short waveguide-based external cavity", *Laser physics letters*, ***10*(1)**, 015804-1-015804-8.
2. R Oldenbeuving, C.J. Lee, P.D. van Voorst, HL Offerhaus, K.-J. Boller, "Modeling of mode locking in a laser with spatially separate gain media", *Optics express*, **18**, 22996-23008 (2010).
3. Oldenbeuving, R.M., Song, H., Schitter, G., Verhaegen, M., Klein, E.J., Lee, C.J., Offerhaus, H.L. & Boller, K.J, "High precision wavelength estimation method for integrated optics", *Optics express*, ***21*(14)**, 17042-17052.

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