Spectral linewidth control of a wide range tunable high repetition rate solid state laser

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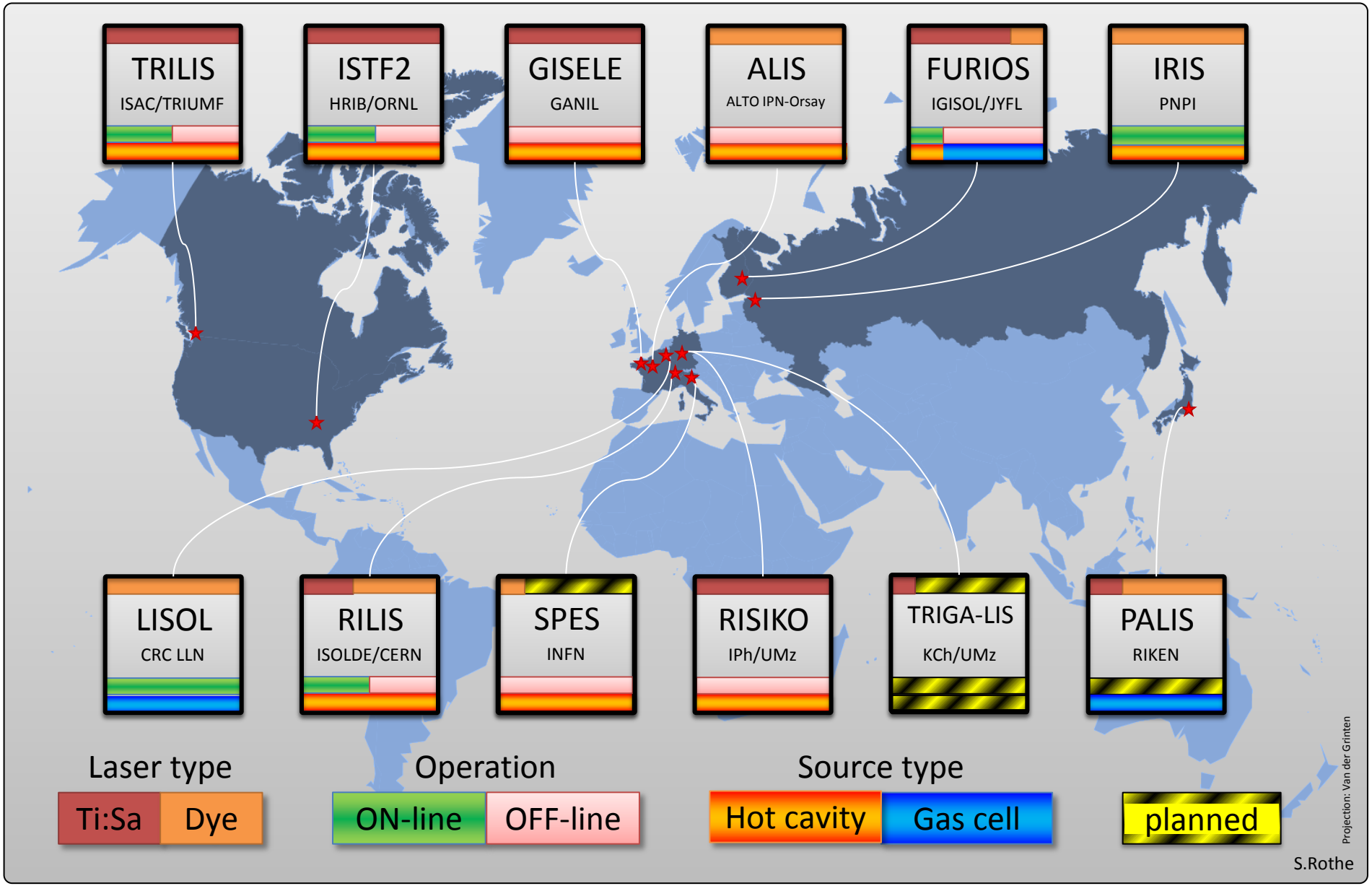
Outline

- Laser systems for resonance ionization laser ion sources
- Standard operation
  - Linewidth
  - Spectral pulse-to-pulse jitter
- Narrowband operation
  - Calculations
  - Linewidth
  - Remote control
  - First applications
- Conclusion & Outlook

Laser Ion Sources Worldwide



High Repetition Ti:sapphire Lasers

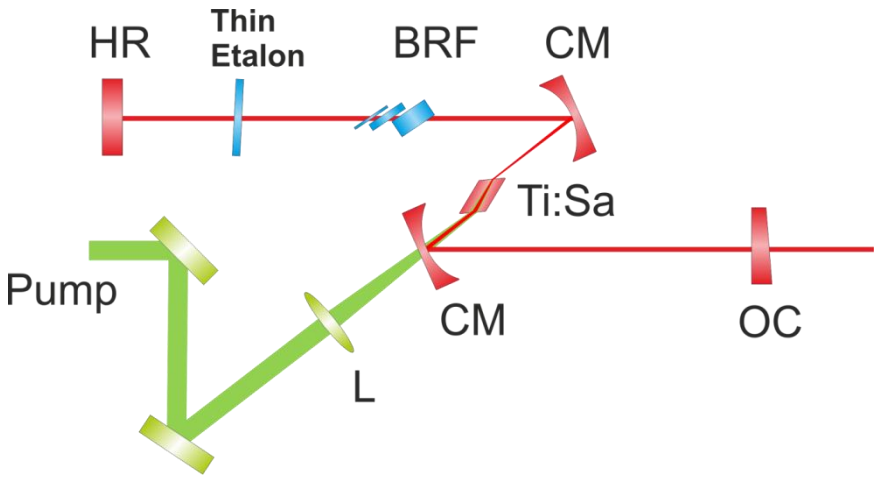
Details already discussed in previous talks *(V. Sonnenschein & S. Rothe)*

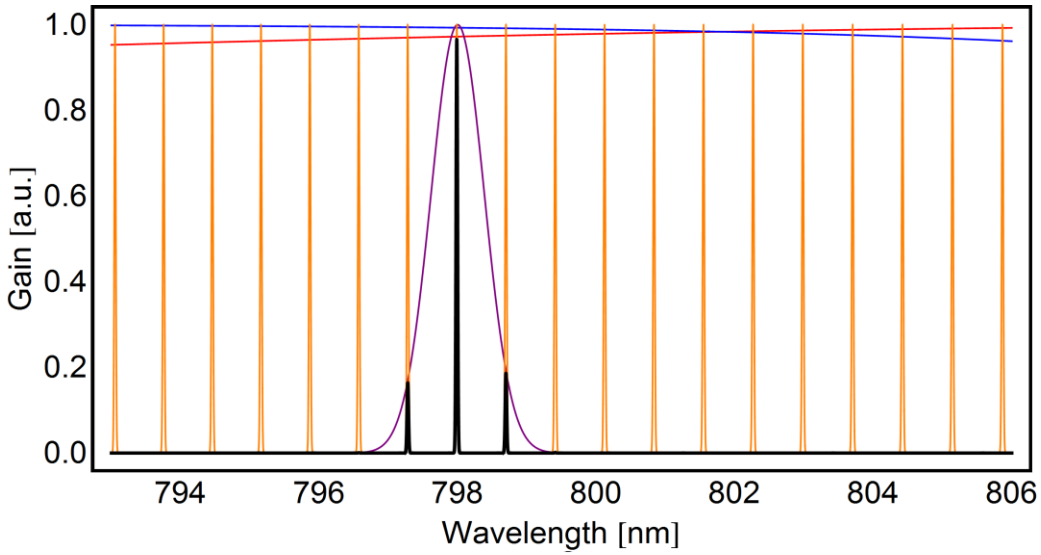
Pulsed 10 kHz rep. rate	→	Lowest losses due to duty cycle Good efficiency for generating higher harmonics
Broad tunability + SHG, THG & FHG	→	Access to a maximum number of elements
Reliable, stable + high power	→	Well suited for time-critical on-line experiments

Standard Operation

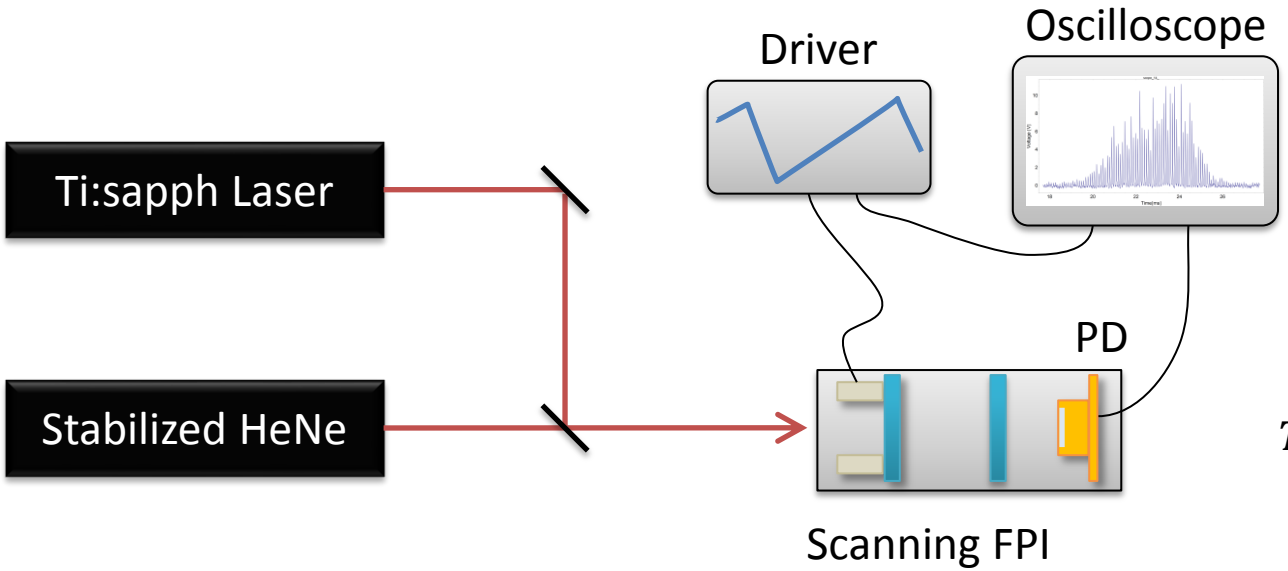
Frequency Selection:

- **Mirror Set** (4 different sets)
- **Birefringent Filter**
- **Thin Etalon** (FSR 325 GHz)





Investigation of Linewidth - Setup



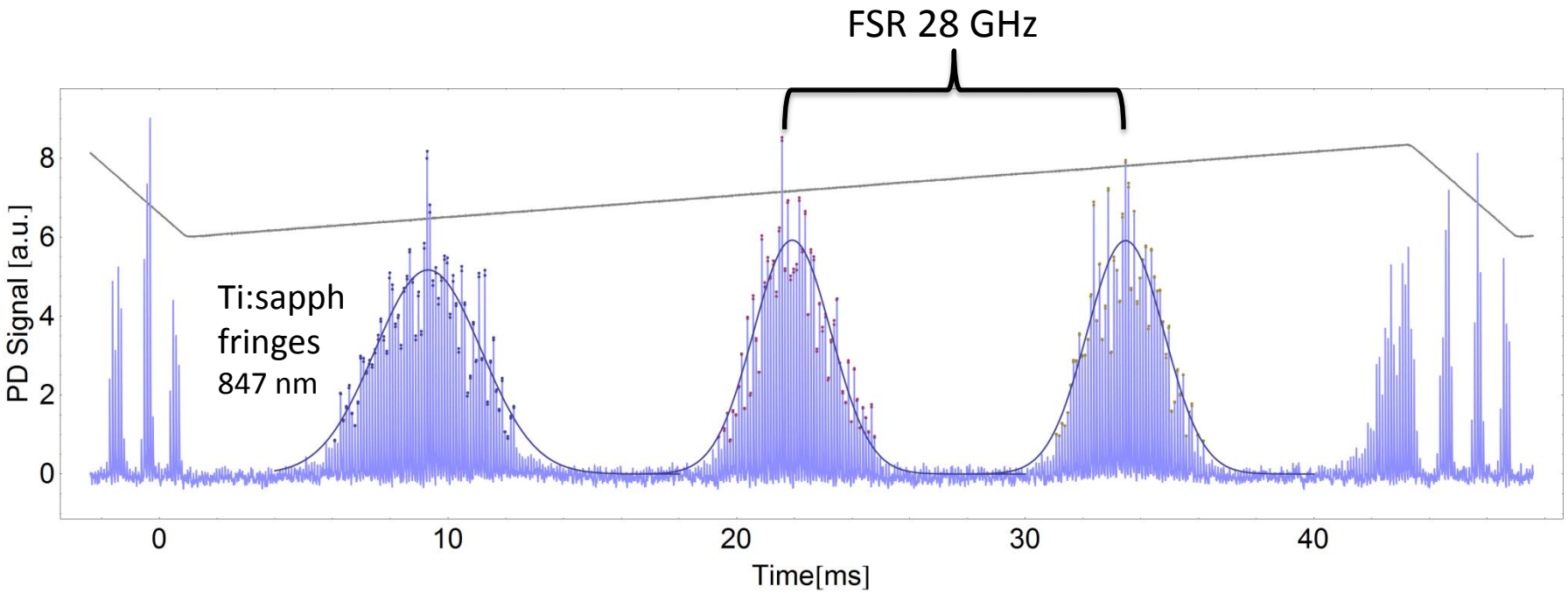
$$T = \frac{1}{1 + q\,Sin^2(\theta)}$$

$$FSR = \frac{c}{2nd} = 28\ \text{GHz}$$

- Oscilloscope with up to 8 million sample points ⟶ Resolving every single Ti:sapph pulse
- HR mirrors (99.9 %) ensure high finesse of the Fabry-Pérot interferometer

Standard Linewidth

New data from Monday



- High time resolution
- Fits to pulse peaks
- Power dependence

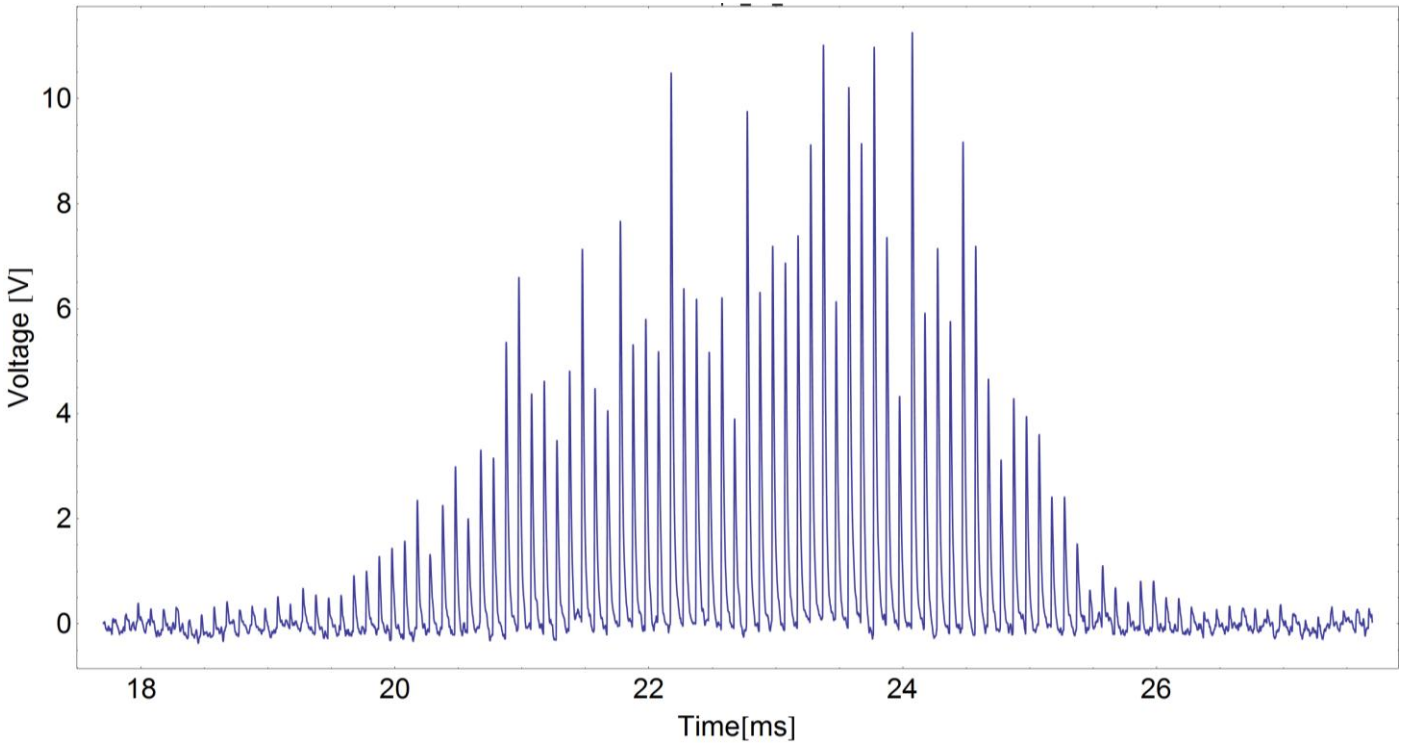
9.4(3) GHz @ 3.2 W

FWHM : 8.2(3) GHz @ 2.0 W

7.4(2) GHz @ 1.6 W

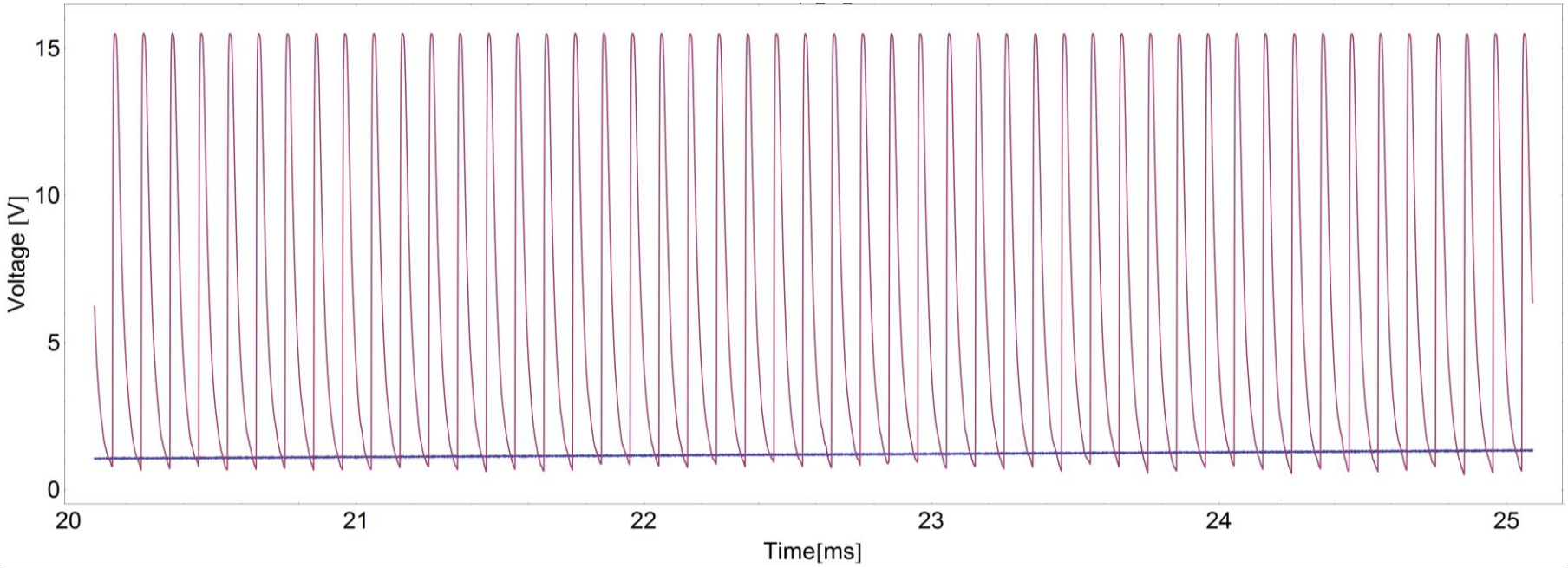
Signal to Noise Ratio

Pulse power is not following the expected transmission curve



Spectral Pulse-to-Pulse Jitter

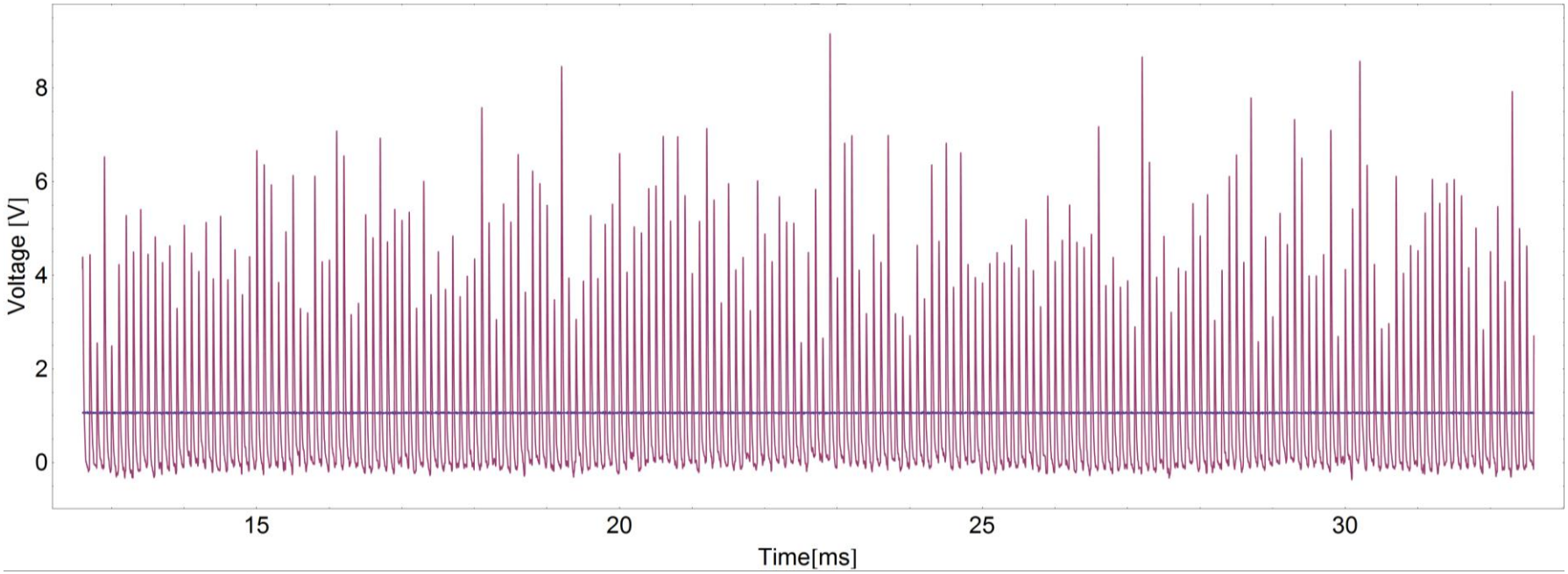
Laser pulses measured before FPI ⟶ constant pulse energies



Spectral Pulse-to-Pulse Jitter

Fluctuating pulse energies after non-ramping FPI

⟶ spectral pulse-to-pulse jitter



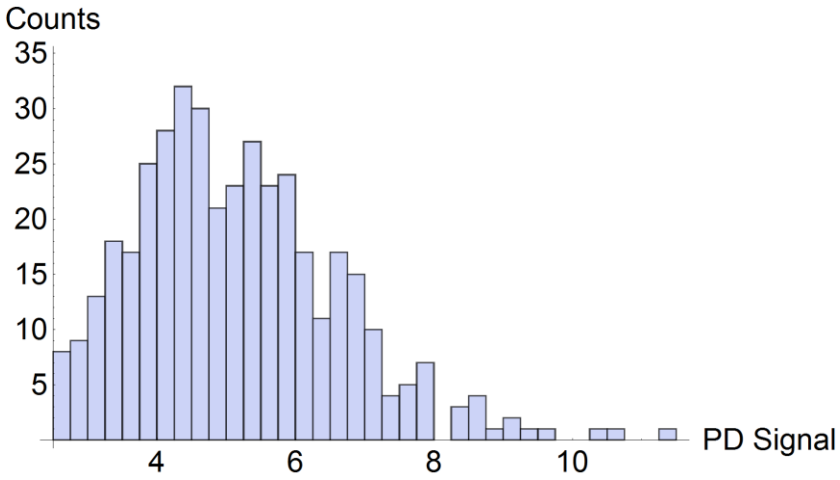
Jitter Distribution

Under further investigation

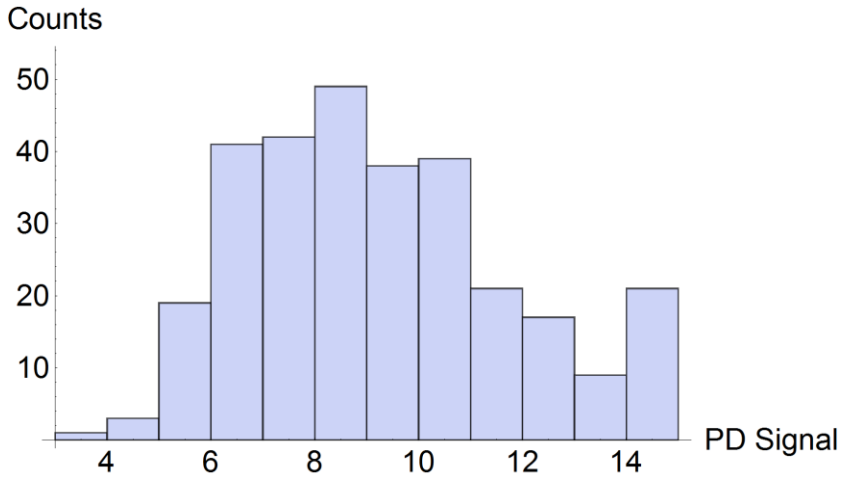
Steep slope of FPI transmission curve

↓

Spectral jitter of several 100 MHz
has a huge effect on transmission



On ½ of max signal



On max. signal

Signal distribution is not Gaussian

- Upper transmission limit
- Bigger probability for small values

Higher Resolution

In-Jet Spectroscopy

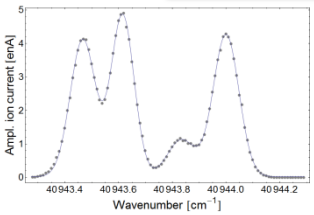
Collinear Spectroscopy

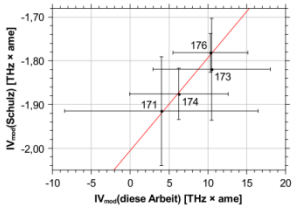
Demand of smaller linewidth

Hyperfine structure

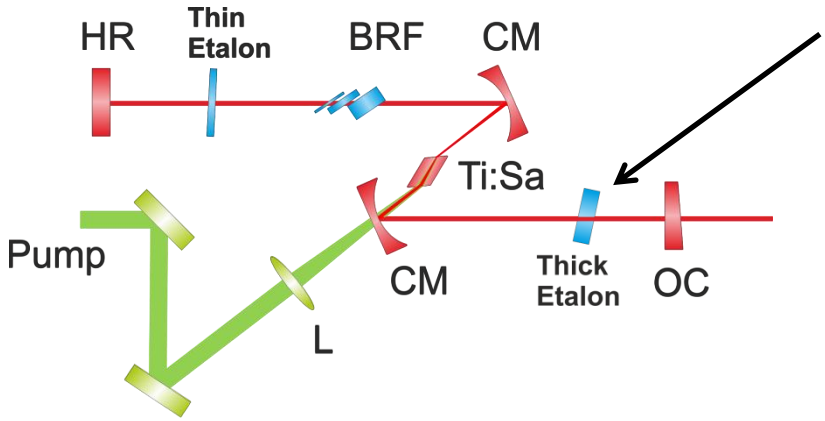
Isotope Shift

Isomer Selection





Narrowband Operation

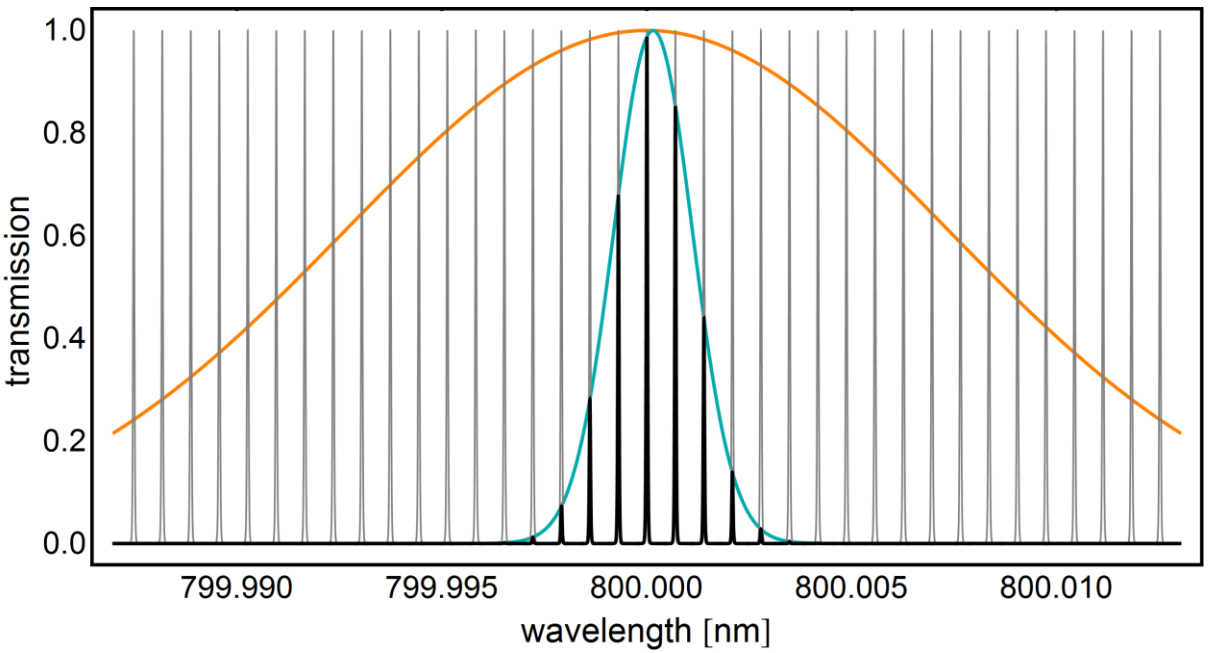


Second Etalon

6mm YAG uncoated, FSR 13.6 GHz,
~ 8% reflectivity

Linewidth of < 1 GHz possible

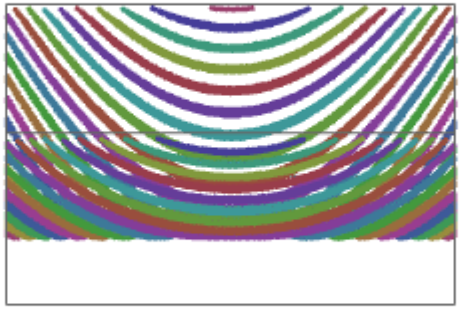
Only a small number of cavity modes oscillate



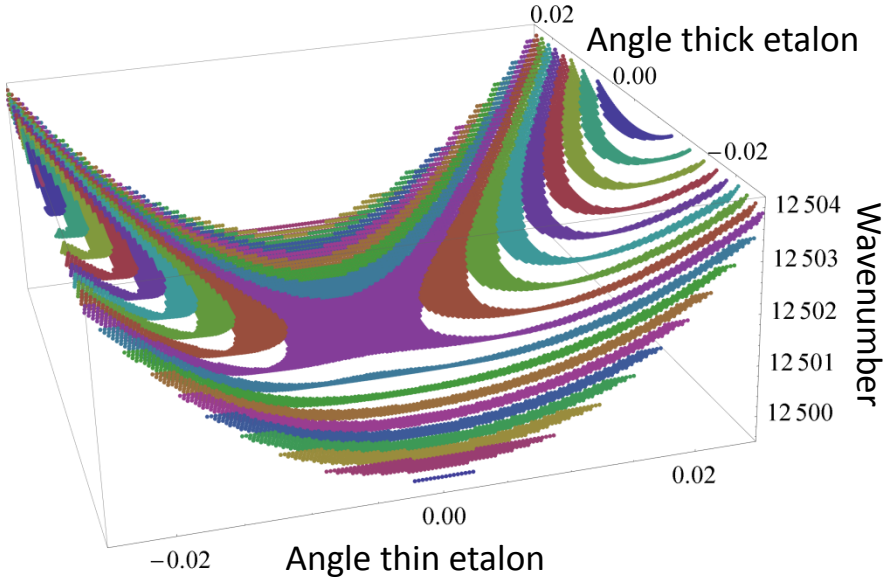
Calculations

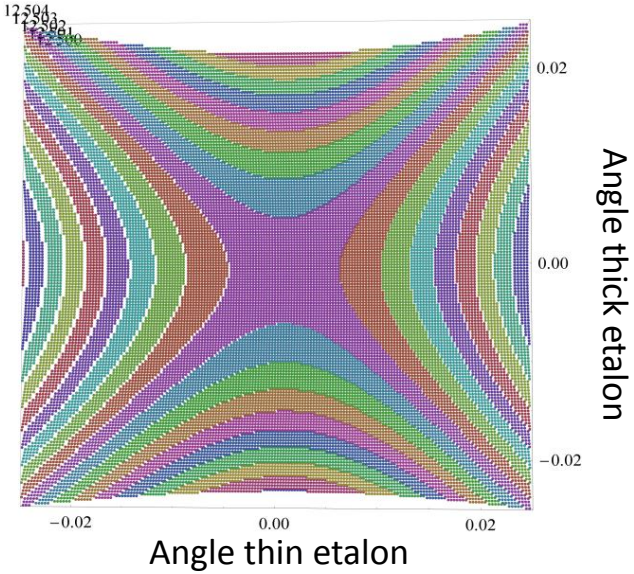
Complex control of frequency selection

due to two tuning elements with different FSRs



Colors indicate different modes of thick etalon

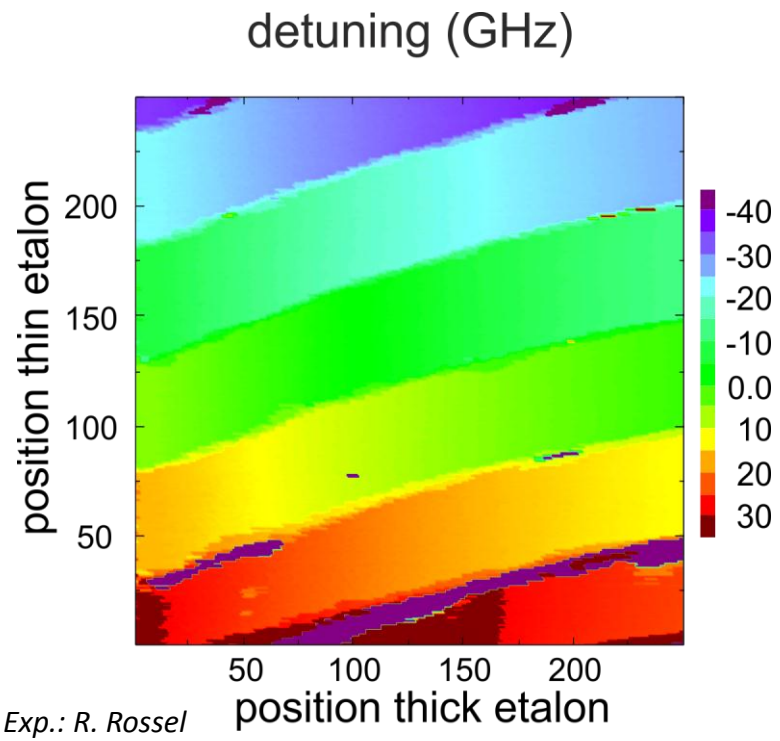




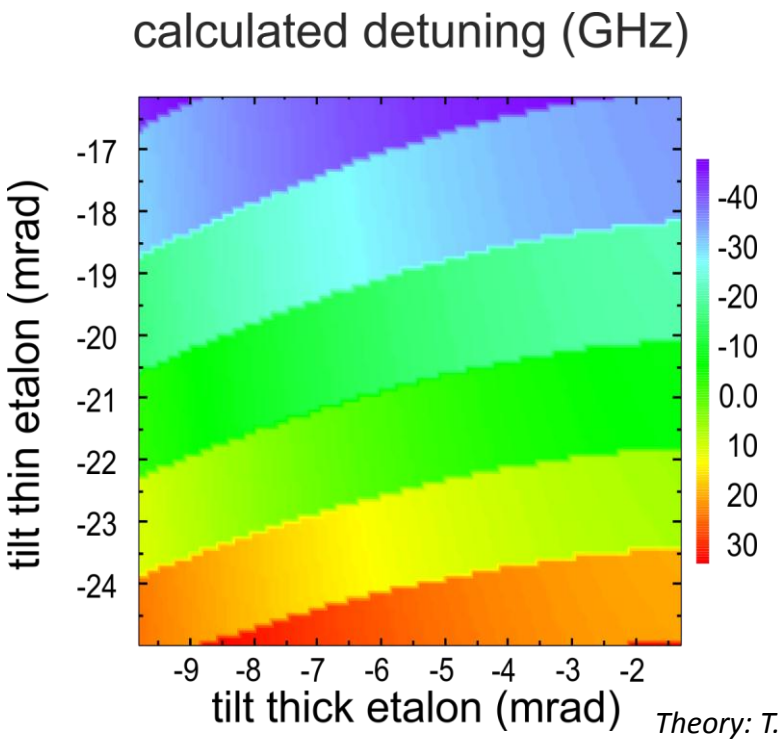
Challenge: mode hop free scanning

Narrowband Characteristics

Comparing experiment with calculation



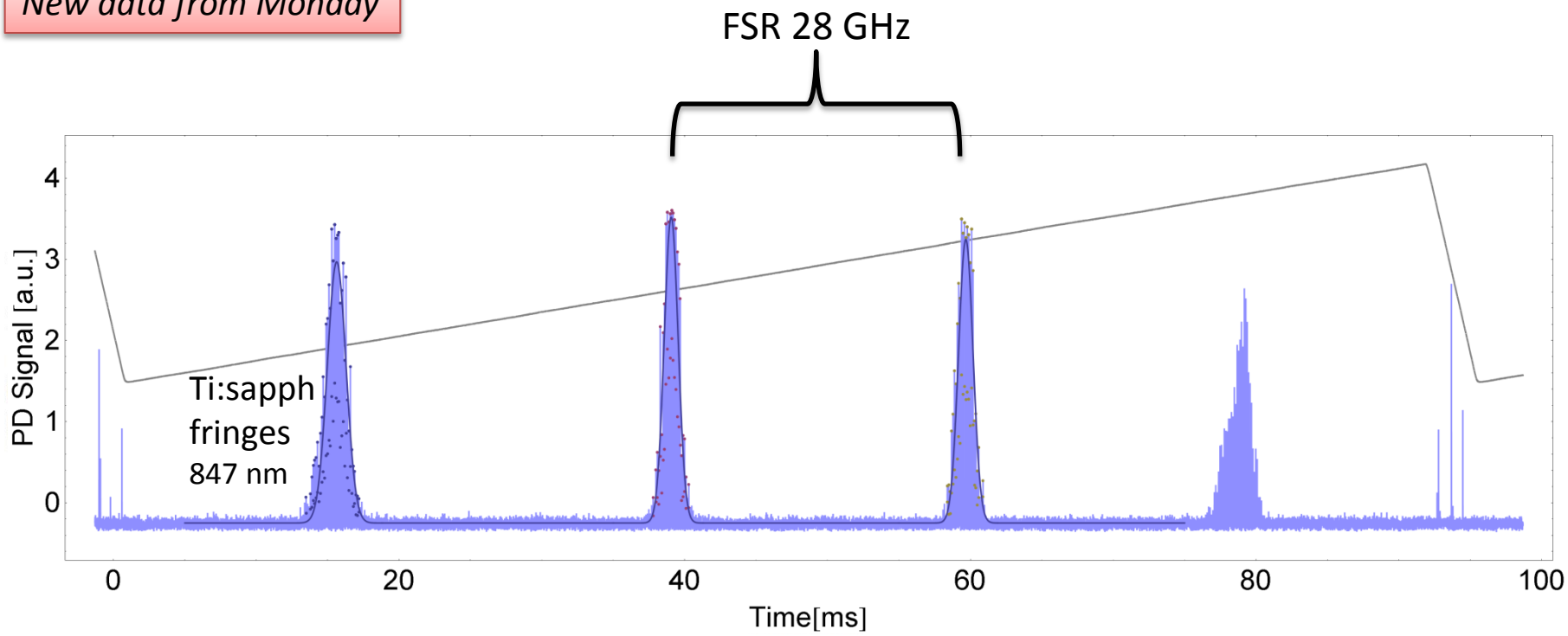
Exp.: R. Rossel
S. Rothe



Theory: T. Kron

Reduced Linewidth

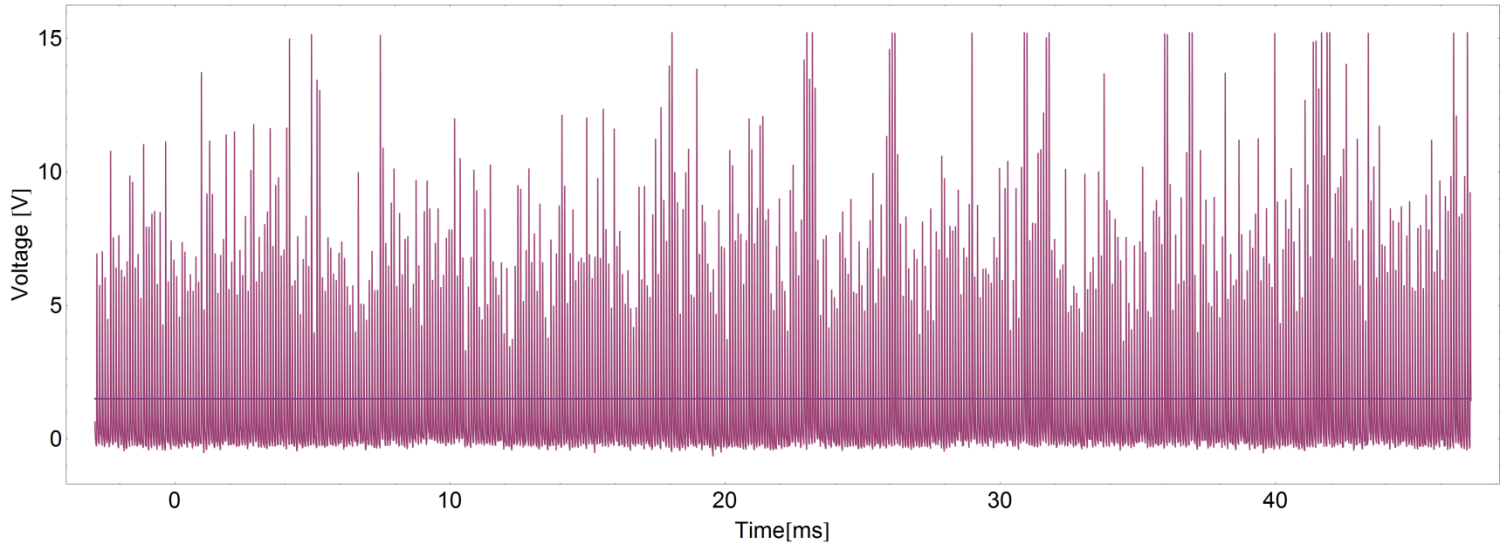
New data from Monday



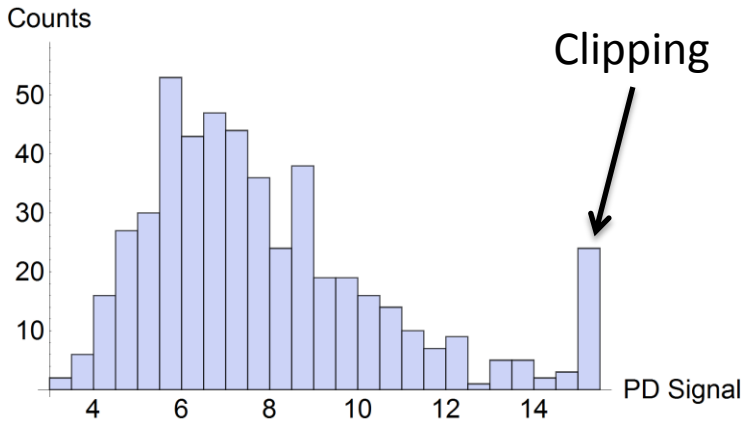
- Decrease of a factor of 5 in agreement with other measurements
- Appr. 8 cavity modes oscillate
- 1 GHz and lower reported

FWHM : 2.04(7) GHz @ 1.8 W
1.95(6) GHz @ 0.8 W
1.57(5) GHz @ 550 mW

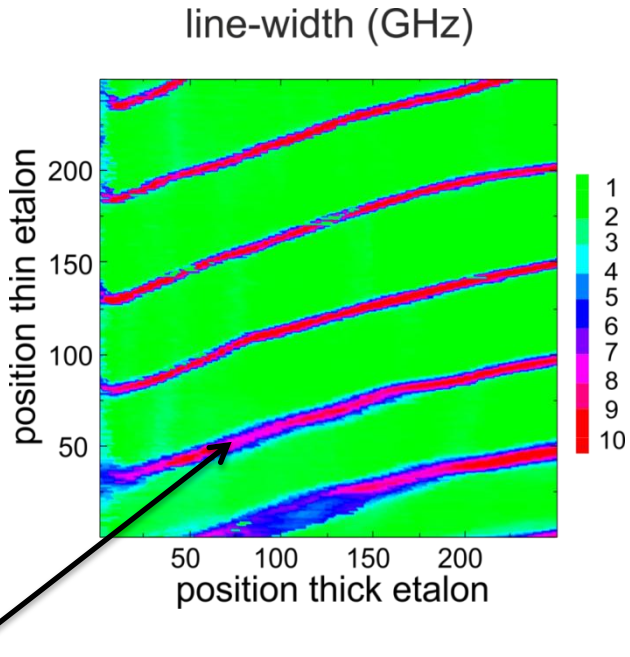
Narrowband Jitter

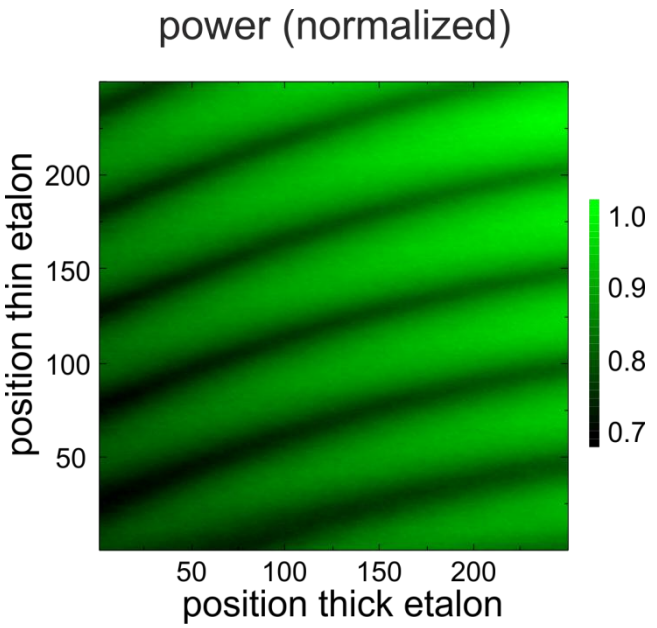


Similar pulse-to-pulse jitter as for standard mode

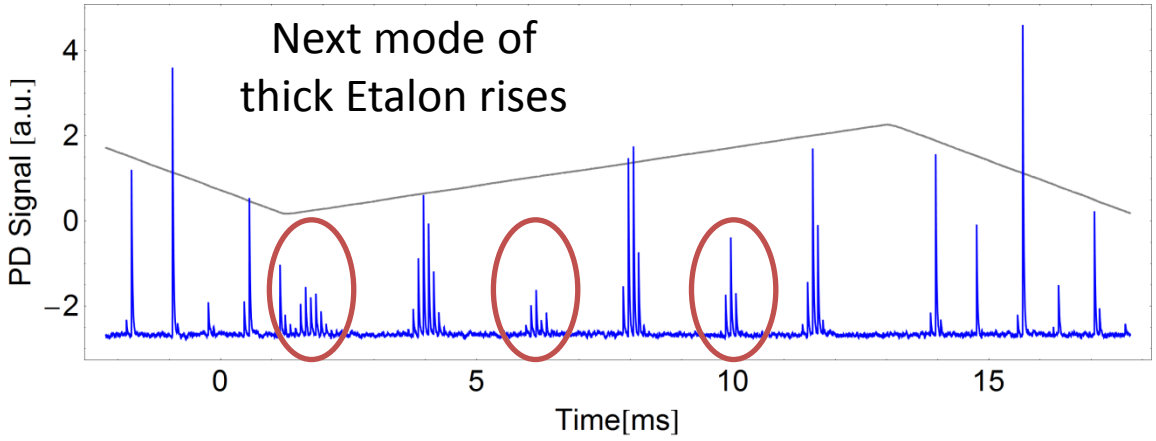


Narrowband Characteristics





Increase in linewidth due to two oscillating modes of thick etalon



Remote Control

- Goal: reliable, tunable, fully automated, remote controlled narrow linewidth laser
- Wavelength stabilization and automated scanning
- Avoids mode hops
- Power stabilization possible
- First stages of development are already implemented

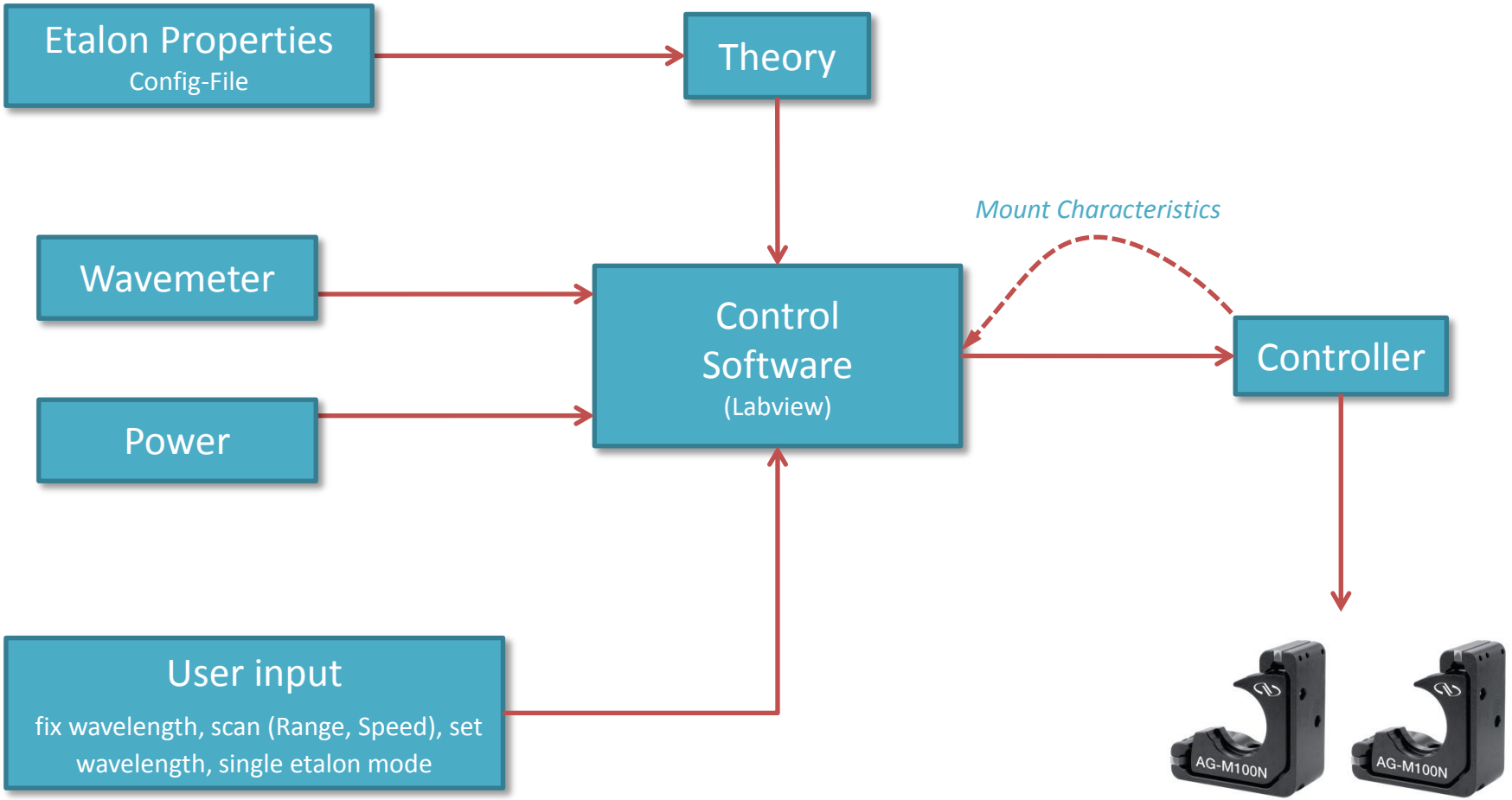
S. Rothe, EMIS proceeding, to be submitted

Ongoing further development:

- Optimizing scanning procedure
- Optimum power due to choice of order of transmission

Piezo driven mount

Software - Mindmap

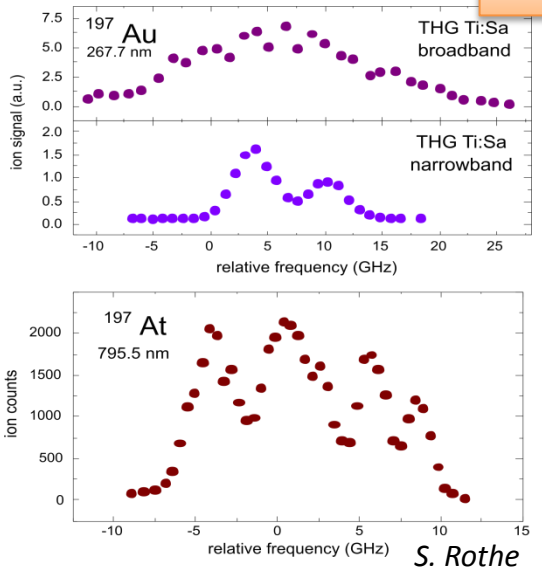


Piezo Mounts

First Applications

RILIS @ ISOLDE

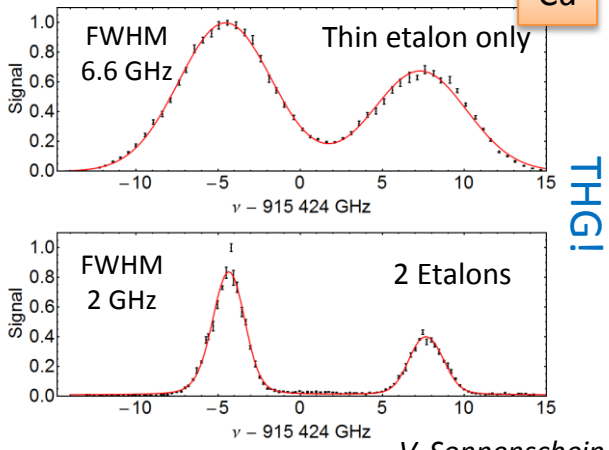
Au, At, Po



S. Rothe

FURIOS @ IGISOL-4

Cu

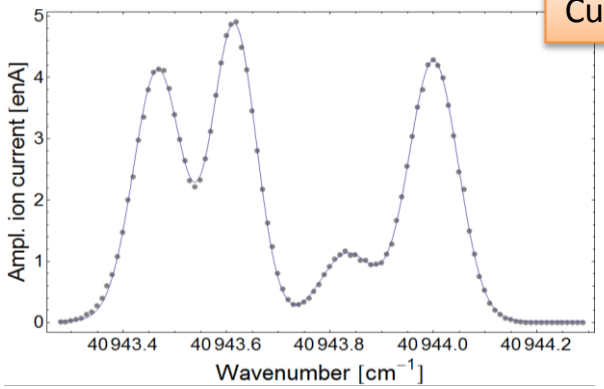


THGi

V. Sonnenschein

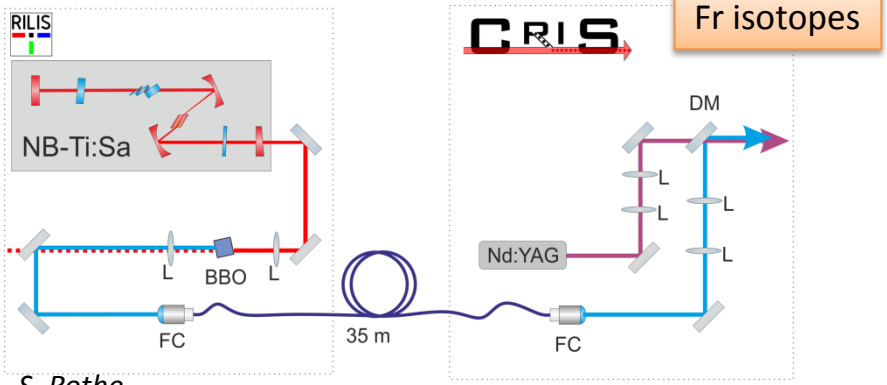
LARISSA @ LISOL

Cu



RILIS + CRIS

Fr isotopes



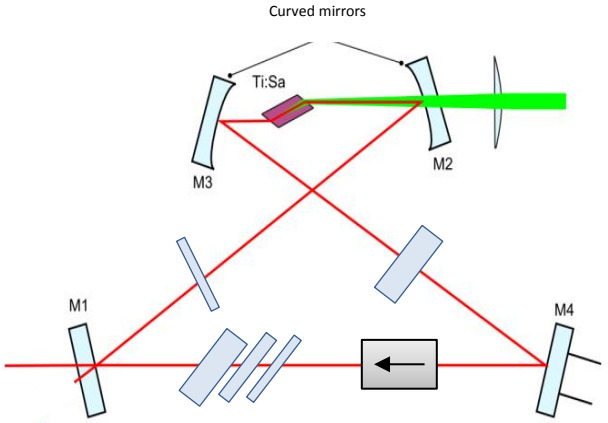
S. Rothe

Conclusion

- Linewidth of established high repetition Ti:sapphire laser system can easily be decreased by a factor of 5 down to the region of 1 GHz
- Expanding application in the high resolution area
- Higher spectral power density
- Development of further linewidth decreasing is ongoing

Outlook

- Higher resolution with 4 GHz FPI
- Further investigation of spectral jitter
- Compare linewidth between intracavity and normal SHG
- Check alternative etalons (air-spaced etalon)
- Optimizing remote control
- Avoid spatial hole burning
  - Ring Cavity setup on breadboard platform (S. Rothe)
  - Reduce oscillating cavity modes; maybe down to one single mode
  - Further linewidth reduction
- Setup of two NB lasers for CRIS



Thank you for your attention!