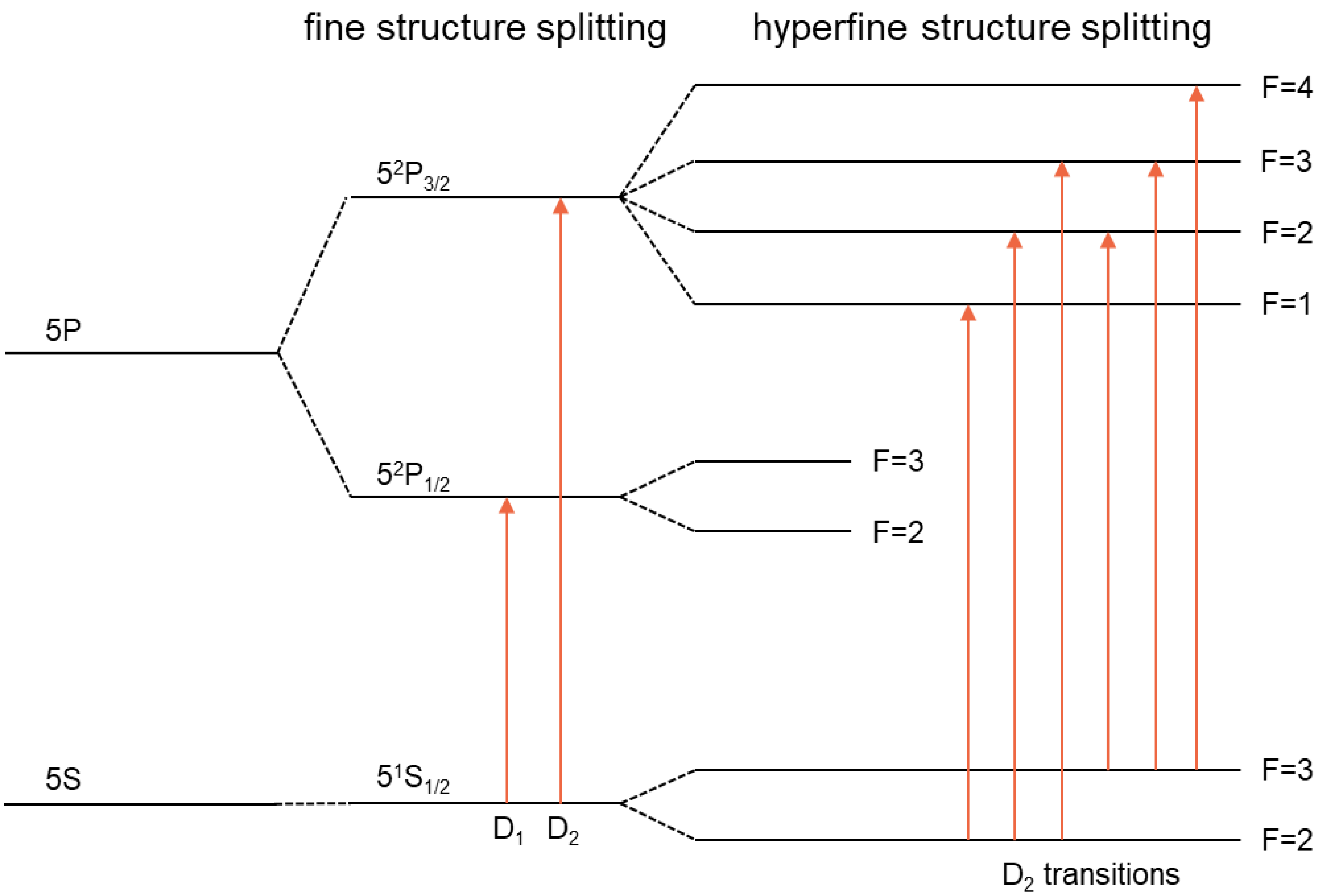
Saturation Spectroscopy

Celine Beier 9.11.2019 CUPC 2019

Hyperfine Structure in ^{85}Rb

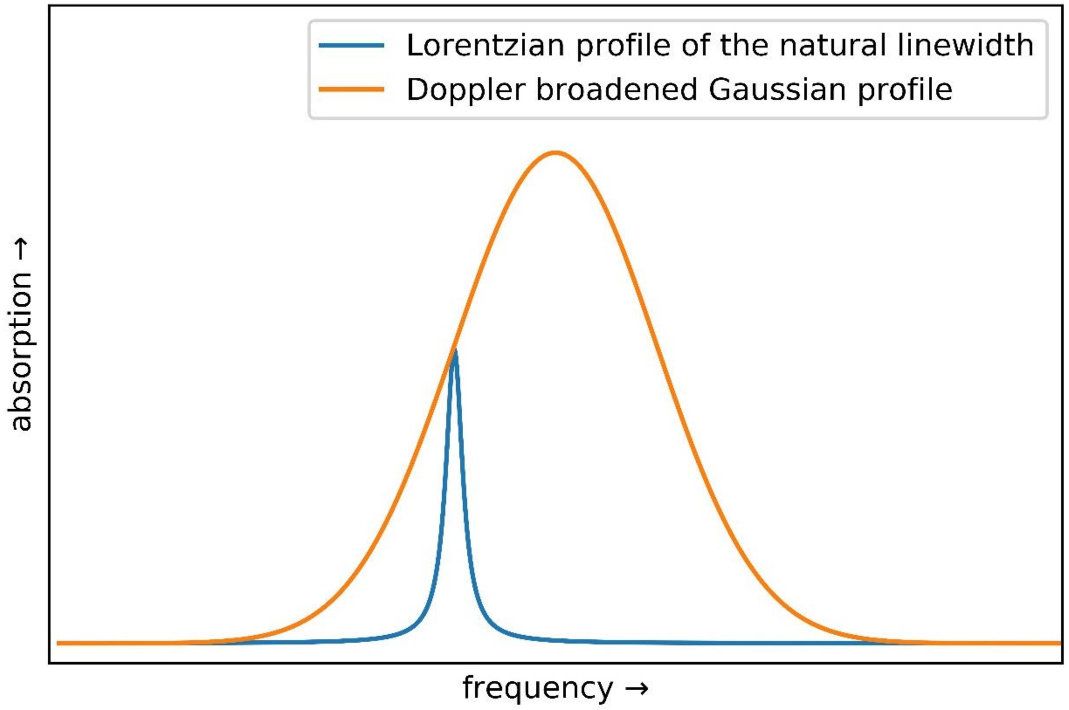


selection rule for hyperfine structure transitions:

$\Delta F = 0, \pm 1$

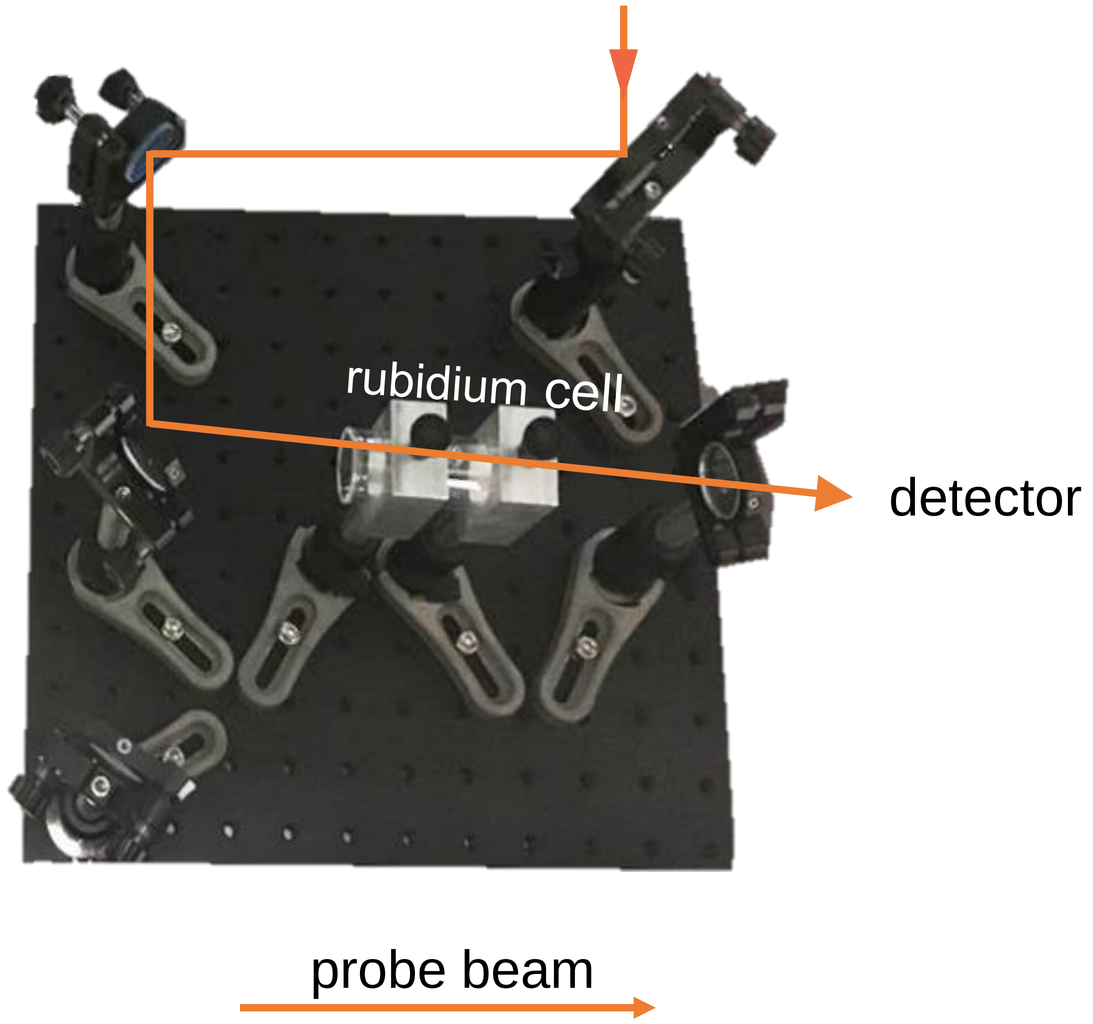
Natural linewidth and Doppler broadening

- natural linewidth determined by the finite lifetime of the exited state, Lorentzian profile
- thermal velocity distribution causes Doppler shifts in the transition frequencies (thermal Doppler broadening)



Saturation Spectroscopy Set-up

- probe beam is overlapped with a counterpropagating pump beam with a higher intensity
- on resonance, pump and probe beam excite the same velocity class of atoms
- due to the higher intensity atoms are more likely to absorb photons from the pump beam → absorption minimum in the probe beam
- cross-over peaks for frequencies between transitions



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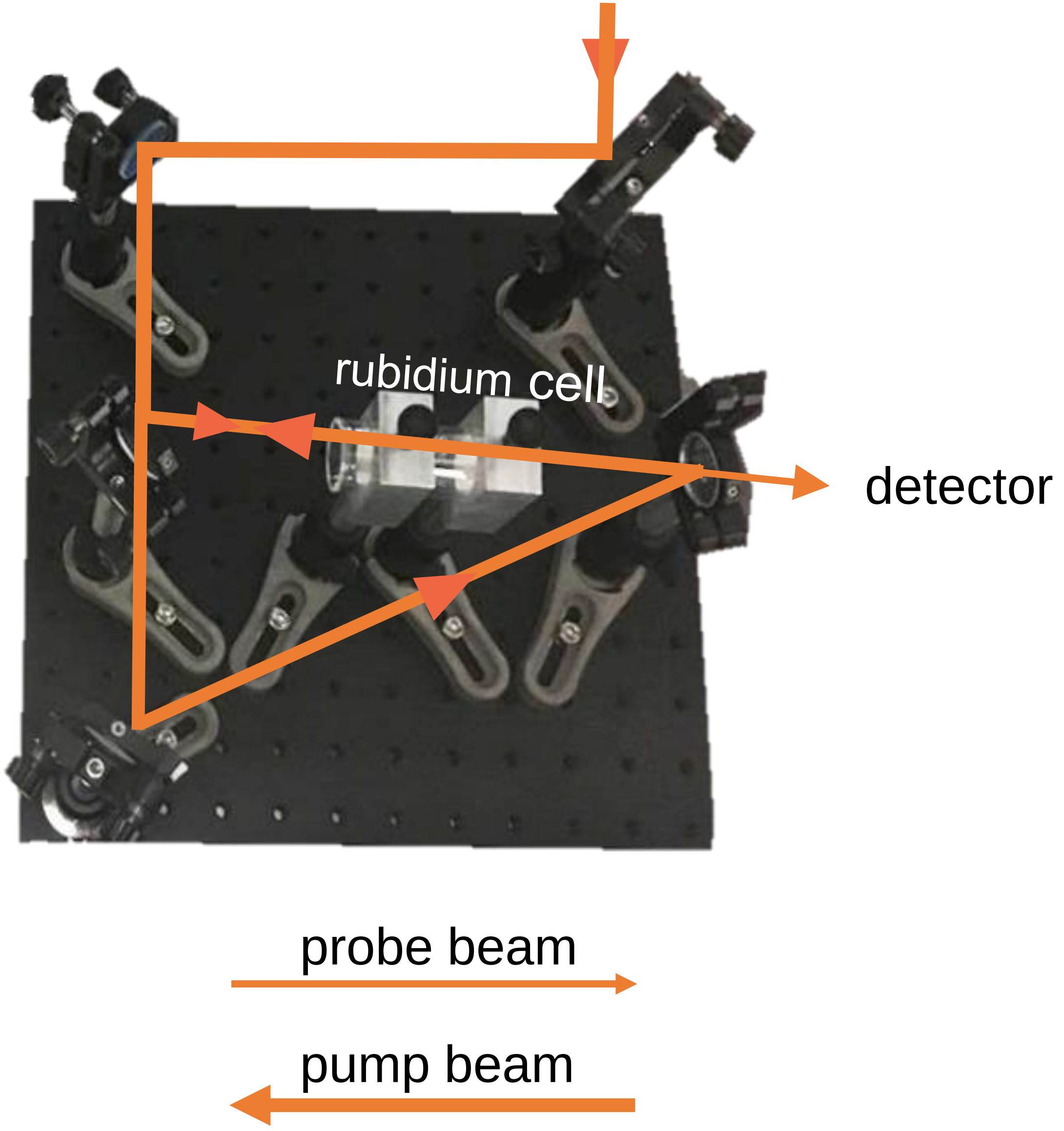
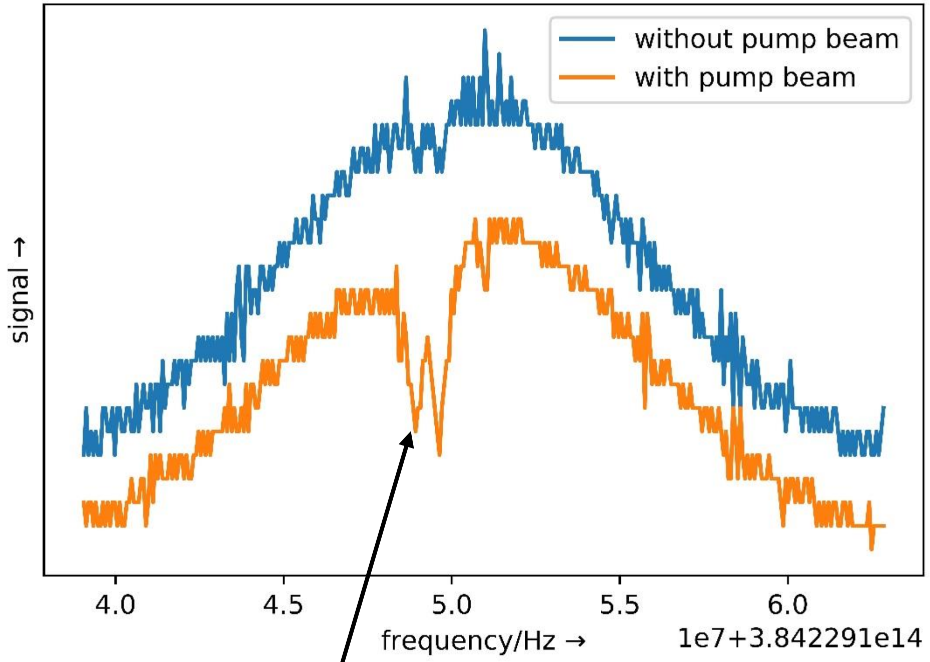


Results for ^{85}Rb, D_2, F=3

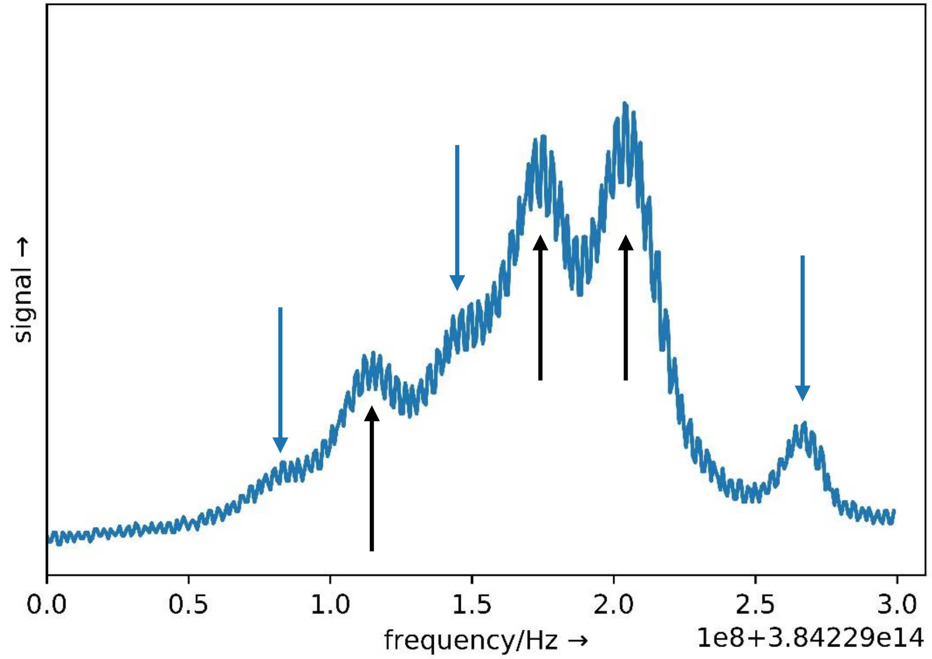
signals with and without the pump beam



Lamb dips

difference of the signals

Hyperfine structure transitions



cross-over peaks

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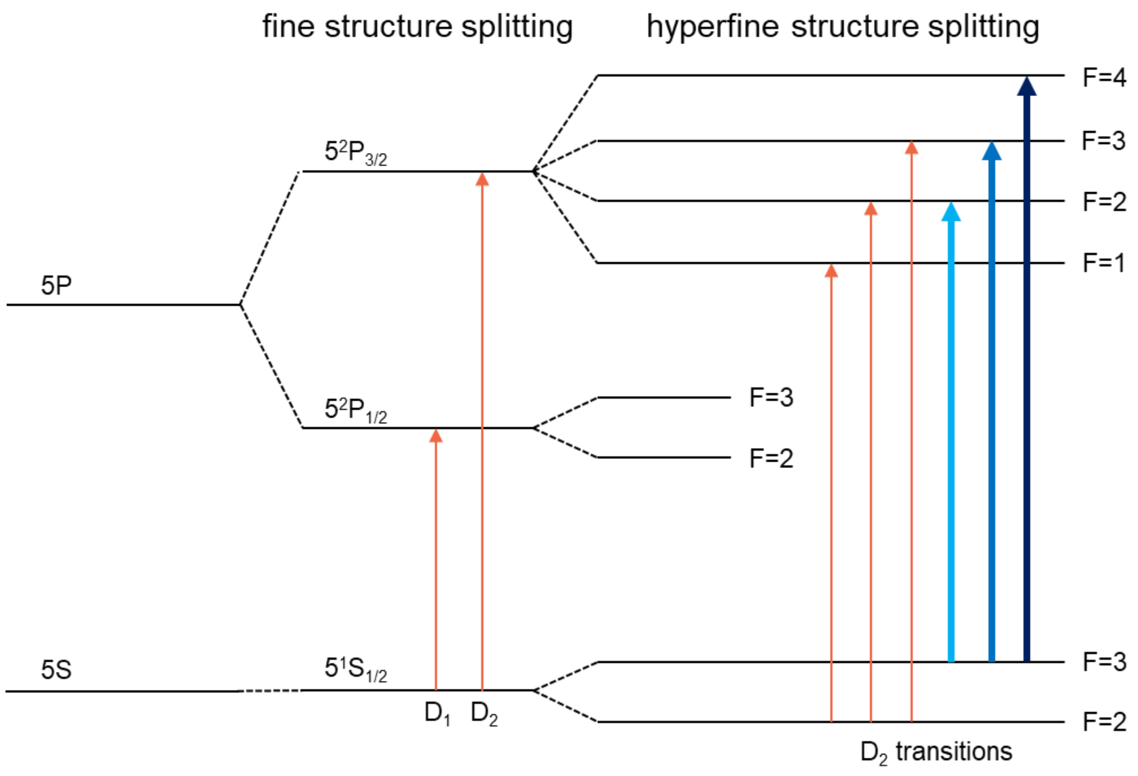
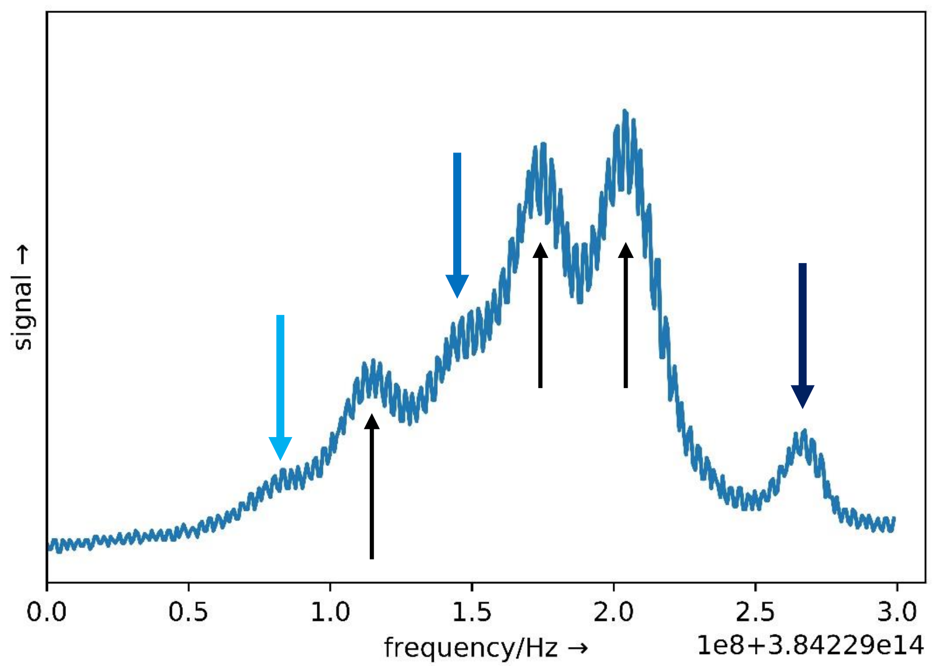


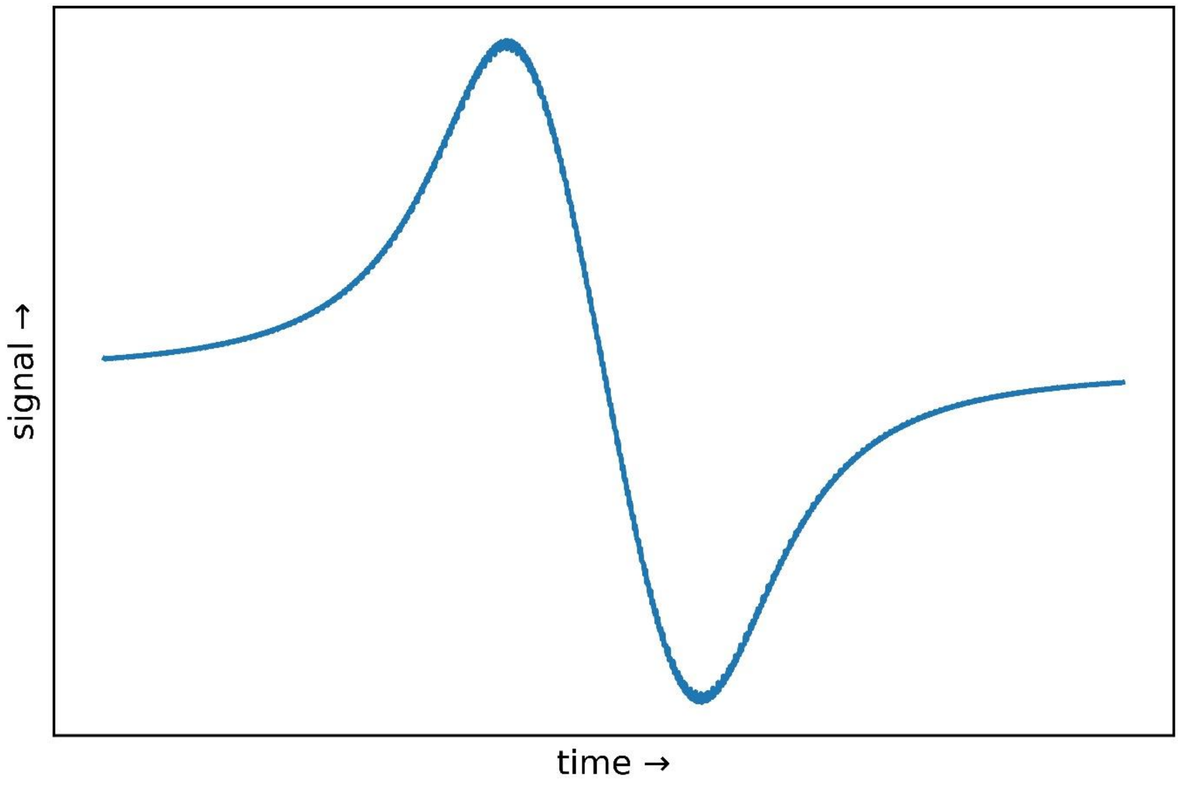
Hyperfine structure transitions



cross-over peaks

Application

- laser frequency stabilisation mechanism using a feedback proportional to the derivative of the obtained absorption signal
- utilizes the fixed frequency of a hyperfine structure transition
- feedback to the laser is zero on the resonance frequency, sign and magnitude for off-resonance frequencies depend on the derivation to the ideal frequency



Summary

- hyperfine structure splitting occurs due to interactions of the electrons with the atomic nucleus
- saturation spectroscopy relies on a pump-probe-setup to overcome thermal Doppler-broadening and can be used to probe hyperfine structure transitions at room temperature
- saturation spectroscopy setup can be used to generate a feedback signal to stabelise a laser on the fixed frequency of a hyperfine structure transition

Thanks to:

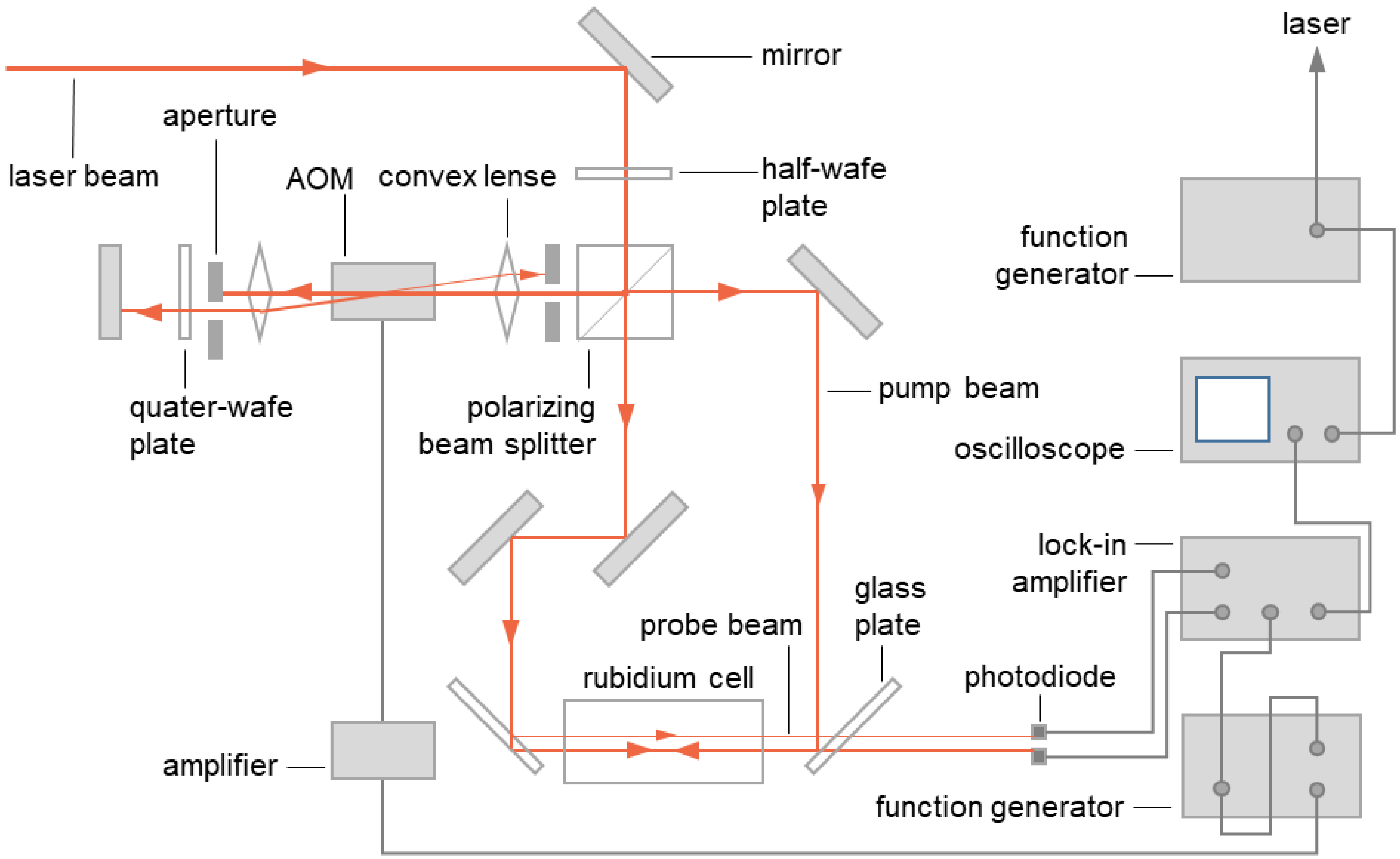
Dr. Pearson

Dr. Teigelhöfer

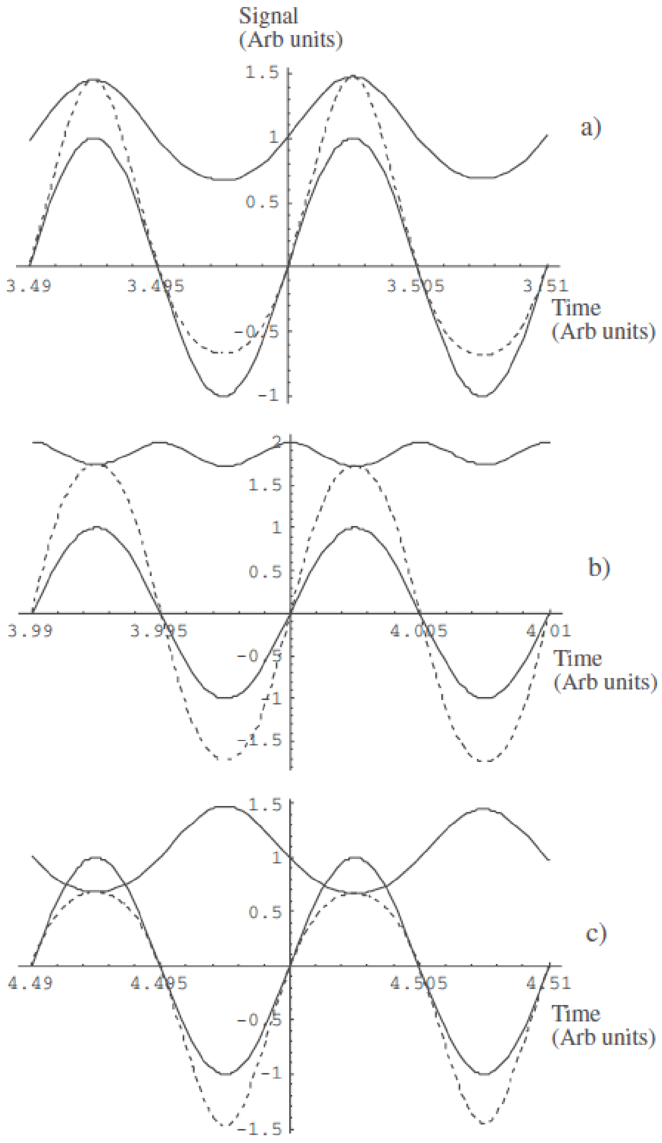
Prof. Buchinger

Prof. Crawford

Laser Stabilisation Set-up



Generation of the feedback signal



Absorption signal with frequency modulation (*a*) below resonance, (*b*) at resonance, and (*c*) above resonance.

In each plot the top curve is the absorption signal, the bottom continuous curve is the modulation, and the broken curve is the product.

Source:

A. Kumarakrishnan, M. Weel. “Laser-frequency stabilization using a lock-in amplifier“. Can. J. Phys. 80: 1449–1458 (2002).