ILP5-Modern methods of laser spectroscopy

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Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

ILP
INSTITUT FÜR LASERPHYSIK

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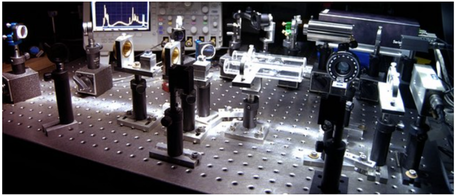
Overview

Experimental implementation of laser spectroscopy on the D2 transition line of rubidium atoms in a vapour cell at room temperature.

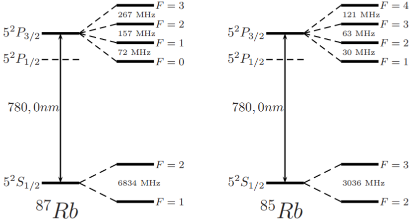
$\Longrightarrow$ first experience on daily work in a atom-optic laboratory



Experimental setup

Goals

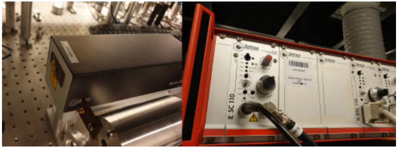
1. probe the Doppler broadened linewidth (identify fine structure of D2-line).
2. resolve the hyperfine structure of D2 line transition of rubidium atoms using saturated absorption setup.
3. observe the effects of power broadening on the natural linewidth.

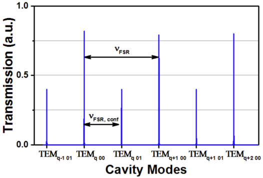


D2-transition line Rb

Day I: External cavity diode laser and cavity Fabry-Perot

- What do they recognise on the experimental breadboard?
- To identify the main light source of the experiment: a commercial external diode laser at $\lambda = 780\,\mathrm{nm}$ wavelength. In this context: Types of external cavity. laser emission, multi-mode?
- FP-cavity as monitor for laser emission. To identity modes-class.
- To determine the beam waist via knife-edge method.

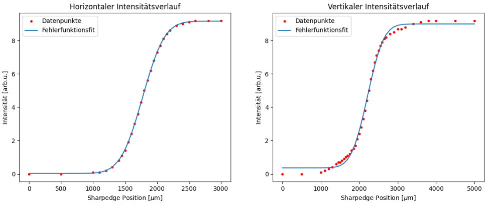




Longitudinal and transversal

schedule

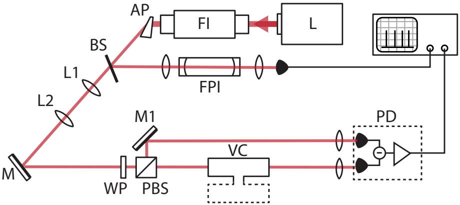
discussion and introduction to the exp.	:	1.5hrs.
visit other laboratory of the building	:	30 min.
implementation and measurements	:	1-3 hrs.
data analysis	:	rest.



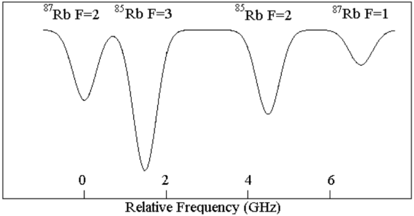
beam waist measurements

Day II: Absorption spectroscopy

- The concepts of linewidth, and Doppler-Power broadening are discussed, followed by the complete implementation of absorption spectroscopy of rubidium atoms.
- To identify the fine and hyperfine structure of Rb atoms. Important: with Doppler broadening, at room temperature it is not possible to resolve the hyperfine structure.
- Scanning through resonance one differentiates four Doppler-broadened profiles.



Experimental setup



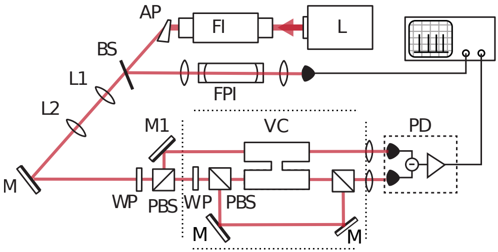
Rb Doppler-broadened profile

schedule

discussion previous results and introduction to the topic	:	1.5hrs.
implementation measurements	:	2-4 hrs.
data analysis	:	rest.

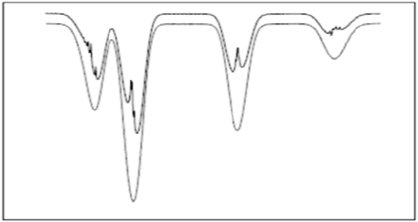
Day III: Doppler-free saturation spectroscopy

- Observing the hyperfine structure of rubidium atoms. In order to resolve this structure, it must be used a pump and probe beam in order to saturate the transition.
- To identify the real and cross-over transitions. crossover peaks originated by two permitted excited states $|E_1\rangle$, and $|E_2\rangle$ sharing the same ground state $|g\rangle$.



Experimental setup

schedule		
discussion previous results	:	1 hr.
implementation	:	30 min.
measurements	:	1-4 hrs.
data analysis	:	rest.

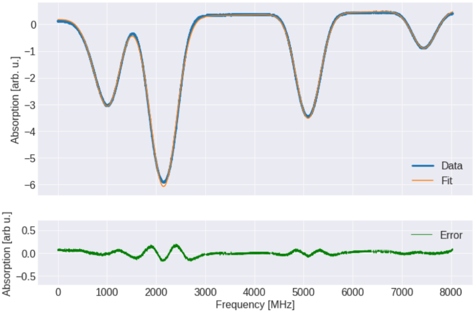


Rb Doppler-broadened profile and Doppler profile with Lamb dips

Day IV-V: Results and data analysis

- A computer is available in the laboratory. Python for data analysis.
- To determine $\Delta\nu_{FWHM}$,

$$
\begin{aligned}
f(\nu) &= \sum_{n}^{3} A_n e^{-\frac{(\nu-\nu_n)^2}{2\sigma_n^2}} \\
g(\nu) &= \sum_{n}^{4} f_n(\nu) + B
\end{aligned}
$$



Exp. results Doppler broadening

$\Delta\nu_{FWHM}$	≈ 500 MHz
Γ	≈ 6 MHz
I_s	$\approx 1.6\,\frac{\mathrm{mW}}{\mathrm{cm}^2}$

Day IV-V: Results and data analysis

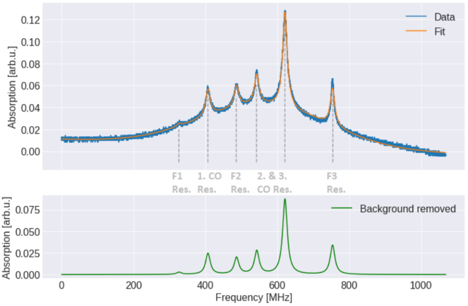
- To determine $s_0 = \Gamma/2$,

$$L(\nu) = \sum_{n}^{6} A_n \frac{s_0}{s_0^2 + (\nu - k\nu_n)^2} + B$$

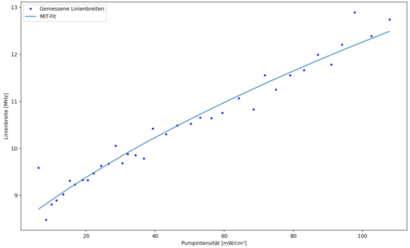
- Finally one gets I_s through

$$\hat{\Gamma} = \Gamma \left(1 + \sqrt{1 + \frac{I}{I_s}}\right)$$

$\Delta\nu_{FWHM}$	≈ 500 MHz
Γ	≈ 6 MHz
I_s	$\approx 1.6 \frac{\mathrm{mW}}{\mathrm{cm}^2}$



Exp. results Doppler broadening



Determination of Intensity saturation

General observations

- It is important to update the instructions book. (English version, it could help)
- Incorrect citations and even not citations at all.
- Problems with properly using fit procedures; hence people ask for more time to hand in their protocols.
- Correct explanation of results plus uncertainties is missing.
- ... sometimes lack of motivation.

Importance of their work

Quantum simulator, and quantum computing machines needs frequency references.