Doppler Free Saturation Spectroscopy

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Abstract

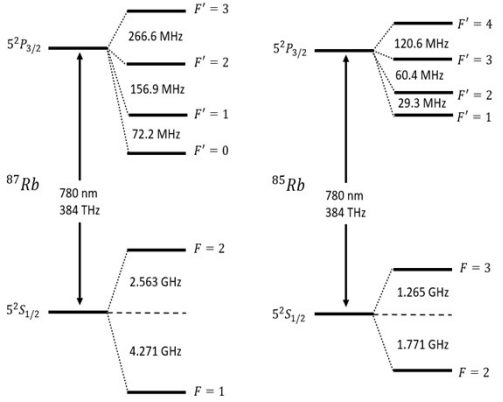
- Using a frequency swept diode laser and employing doppler free saturation spectroscopy techniques; doppler broadening effects and the hyperfine structure of ^{87}Rb's D2 line are investigated.

Introduction

- 27.8% ^{87}Rb, 72.2% ^{85}Rb
- Thermal motion washes out small structure splitting effects and results in doppler broadening of absorption peaks.
- Cooling sample to remove doppler broadening effects not always possible/practical
- Saturation spectroscopy provides a way to measure transition frequencies without doppler broadening/shifts

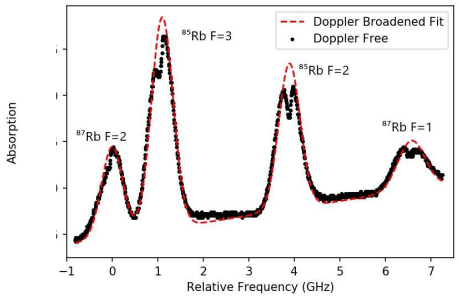
Rb Hyperfine Structure

- Electron angular momentum: $\vec{J} = \vec{L} + \vec{S}$
- Nuclear spin: $\vec{I}$
- Total angular momentum: $\vec{F} = \vec{J} + \vec{I}$
- Optical transition rule: $F' - F = 0, \pm 1$



Physical Effects

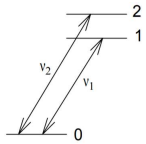
Doppler Broadening

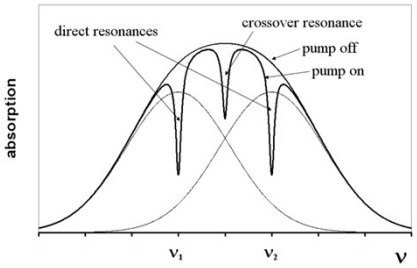


	Separation [GHz]		FWHM [MHz]	
Transition	Accepted	Measured	Theory	Measured
^{87}Rb F=2	–	–	606.7	545.1 ± 38.8
^{85}Rb F=3	1.298	1.099 ± 0.078	541.1	563.8 ± 40.0
^{85}Rb F=2	4.334	3.891 ± 0.276	524.5	554.2 ± 39.4
^{87}Rb F=1	6.834	6.570 ± 0.446	559.1	704.6 ± 50.4

Multilevel Saturated Absorption

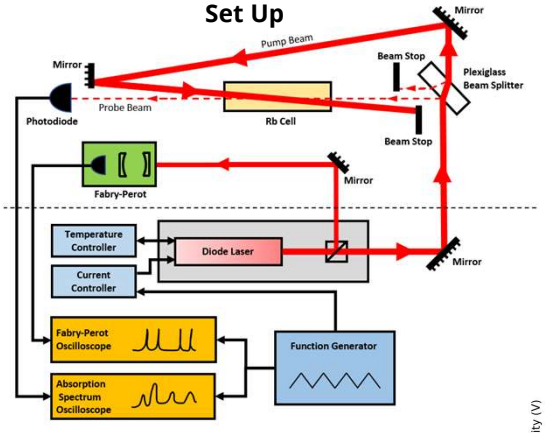
- Pump beam decreases density of atoms in ground state
- Dips in spectrum related to transition frequency
- Crossover arises when the pump and probe beams are resonant with the same two opposite velocity groups





Experimental Details

Set Up

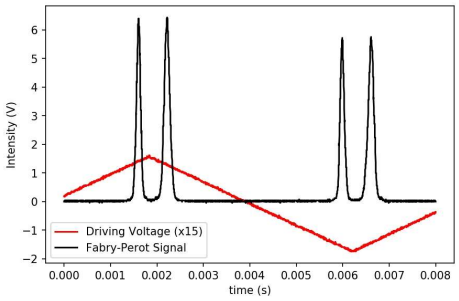


- Diode laser with current modulated by a triangle wave with frequency and amplitude between 90-120 Hz and 10-200 mV

Calibration

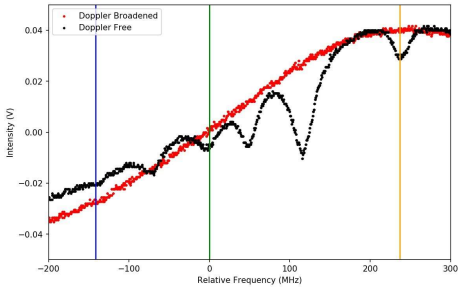
- Fabry-Perot interferometer with 10 GHz free spectral range
- Inconsistent Δt_{FP} measurements on single driving function slope

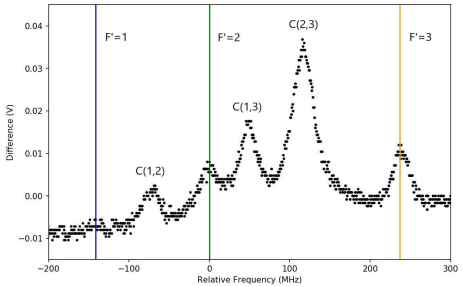
$$f_{calib}(t) = \frac{D_{spec}\,\Delta t_{spec}}{D_{FP}\,\Delta t_{FP}}\, f_{FSR}$$



Doppler Free Measurement

- ^{87}Rb F=2 absorption peak





	Separation [MHz]	
Transition	Accepted	Measured
F'=1	−156.9	-141.4 ± 17.8
F'=2	–	–
F'=3	266.6	237.0 ± 17.5

Conclusions

- Separation measurements seem to 'converge' on accepted values with greater separation
- Fabry-Perot calibration introduced the most significant errors
- Non-linearities in optical frequency sweep and interferometer misalignment most likely culprits for measured and accepted value difference

References:

[1] Daryl W. Preston , "Doppler-free saturated absorption: Laser spectroscopy", American Journal of Physics 64, 1432-1436 (1996) https://doi.org/10.1119/1.18457
[2] Daniel A. Steck, "Rubidium 85 D Line Data," available online at http://steck.us/alkalidata (revision 2.2.2, 29 April 2021).
[3] Daniel A. Steck, "Rubidium 87 D Line Data," available online at http://steck.us/alkalidata (revision 2.2.1, 21 November 2019).
[Multilevel Saturated Absorption Image] https://www.phys.ufl.edu/courses/phy4803L/group_III/sat_absorbtion/SatAbs.pdf