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Comparison of Absorption, Fluorescence, and Polarization Spectroscopy of Atomic Rubidium

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Spectroscopy of Atomic Rubidium

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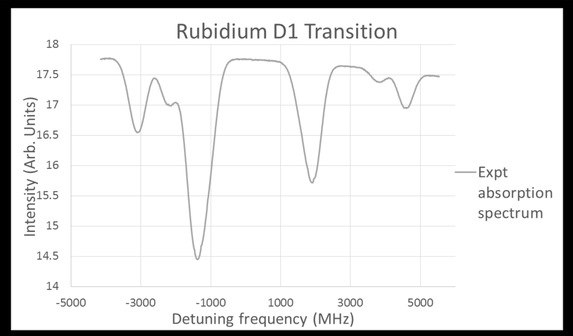
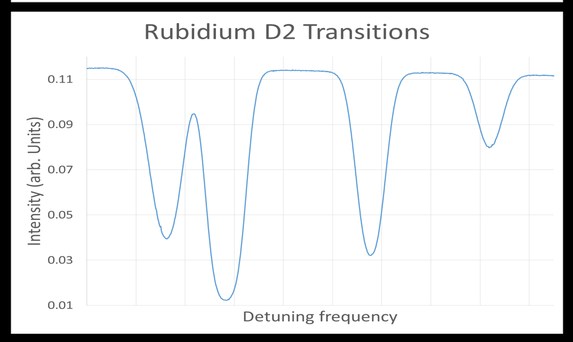
Introduction

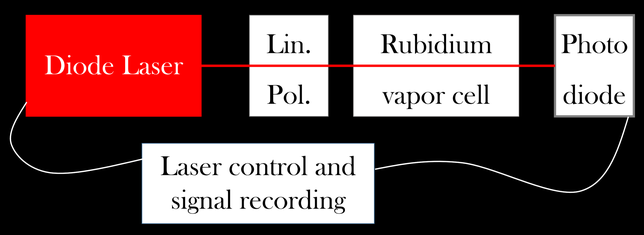
In this undergraduate student led experiment, a high resolution, tunable cw laser is directed through a pyrex cell containing a natural mix of ^{87}Rb (27.8%) and ^{85}Rb (72.2%). A photodiode detects the laser intensity after passing through the rubidium vapor, which is recorded as a function of piezo voltage. The laser frequency can be scanned over several GHz by adjusting the piezo voltage. As the laser scans through a frequency associated with a $5S_{1/2}(F') \rightarrow 5P_{1/2}(F)$ $(D1)$ or $5S_{1/2}(F') \rightarrow 5P_{3/2}(F)$ $(D2)$ transition between hyperfine levels, the rubidium atoms absorb some of the laser intensity. This leads to a decrease in laser intensity detected by the photodiode, indicating an atomic transition.

Absorption Spectra

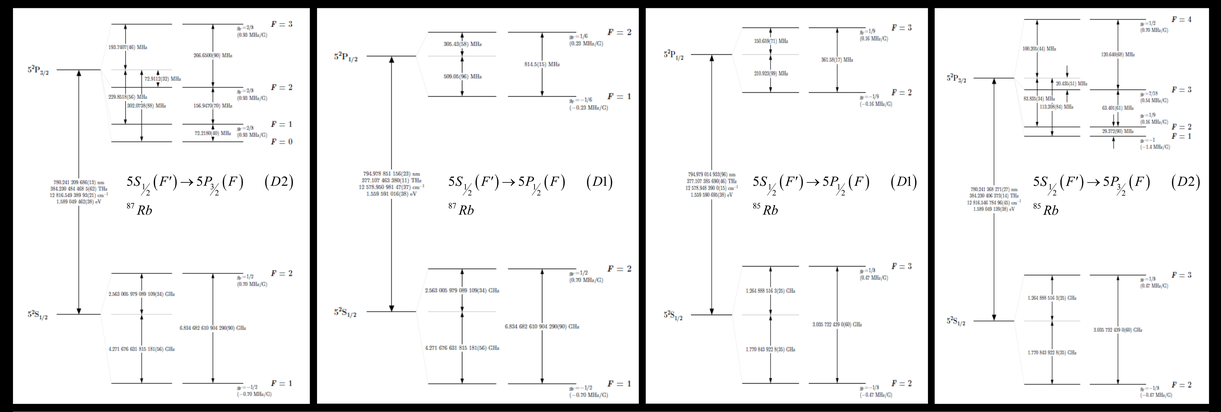




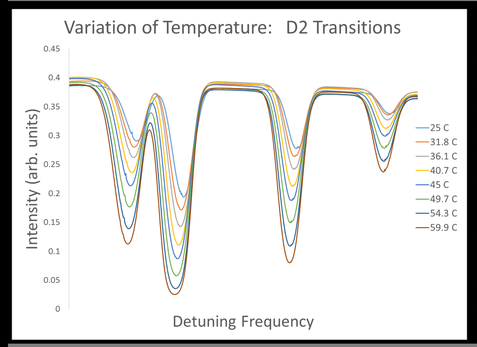
Simplified Absorption Spectroscopy Setup



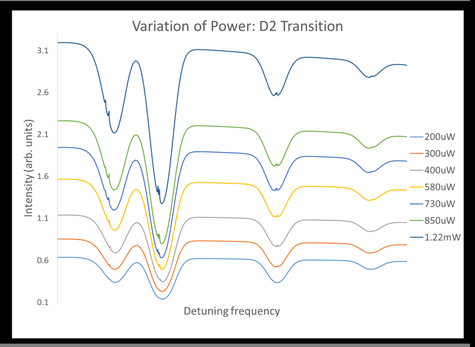
^{87}RB and ^{85}RB Energy Level Diagrams



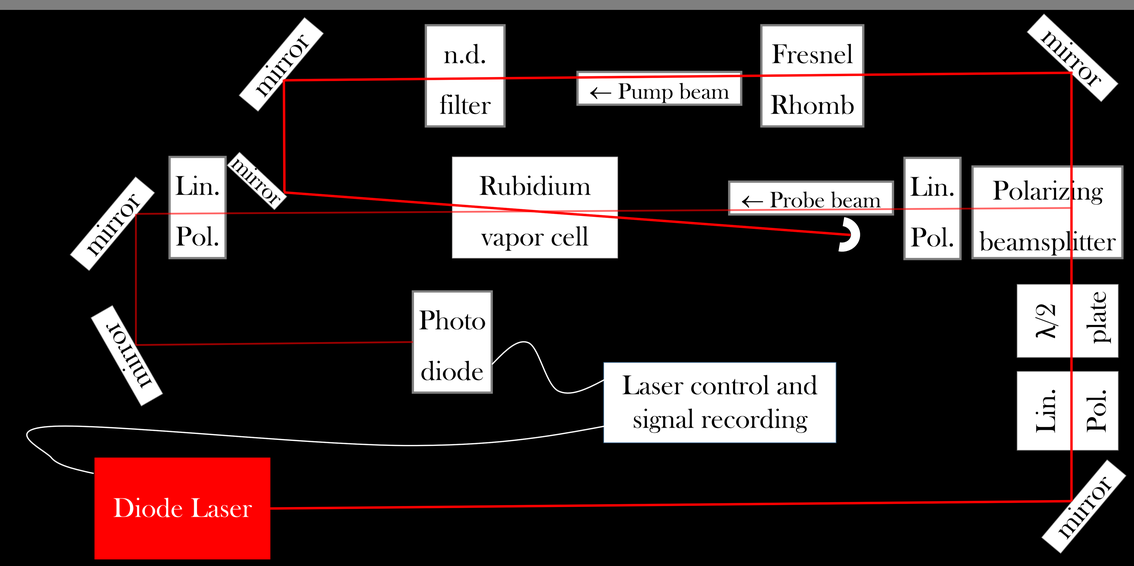
Variation of Rubidium Temperature and Probe Beam Power in One Beam Experiment



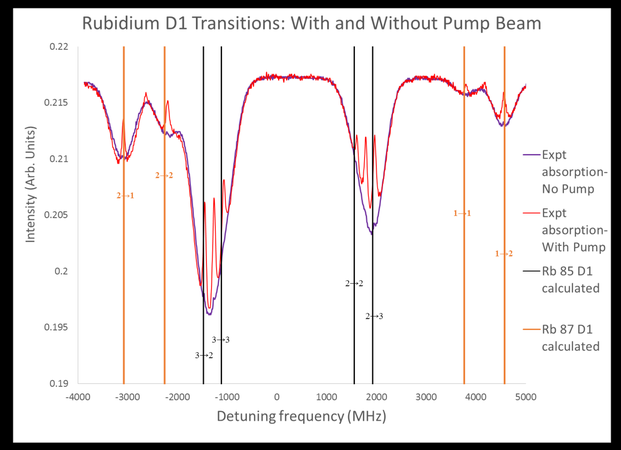
Increasing probe beam power resulted in the probe beam absorption dip broadening and becoming deeper, as more rubidium atoms entered the vapor phase and moved with higher average velocity. Increasing laser power, we observed stronger absorption (up to a point). It can be seen that at higher powers the transitions begin to saturate.



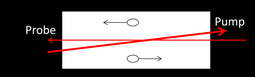
Experimental Setup for Doppler-free Saturated Absorption Spectroscopy and Polarization Spectroscopy



Two-beam Saturated Absorption Spectroscopy



The D1 transitions of rubidium are recorded using the Doppler-free saturated absorption technique (red line). This overlays the purple line which is a simple absorption spectrum. The vertical lines mark the positions of the positions of the transitions between the hyperfine levels of the upper and lower state. Transitions are labeled using the notation $5S_{1/2}(F') \rightarrow 5P_{1/2}(F)$ where just the hyperfine numbers are displayed ($F' \rightarrow F$). An "extra" peak is seen between pairs of labeled hyperfine transitions. This phenomenon is explained below.



As the laser frequency is scanned, the narrow peaks in the saturated absorption spectrum occur when the probe and pump beam interact with the same atoms. The labeled hyperfine transitions occur when both beams interact with the v=0 velocity group. The "extra" line in between each pair of labeled hyperfine transitions occurs when the laser is at a frequency halfway between two hyperfine transitions. For a particular velocity group, the pump and probe beams are each Doppler shifted by an amount equal to half the separation of the hyperfine transitions, and each induces a transition originating from the ground state. So both beams are competing for the same ground state atoms, leaving less available atoms to absorb the probe beam.

Future Work

Next we plan to perform polarization spectroscopy of our rubidium vapor. In our two-beam experimental setup, note we have included a Fresnel rhomb, capable of making our pump beam circularly polarized. This, along with the two linear polarizers in the path of the probe beam, will allow us to investigate using this additional spectroscopic technique.