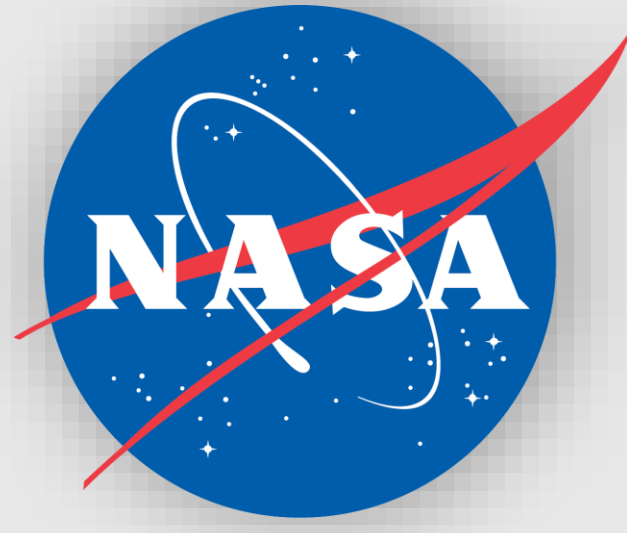
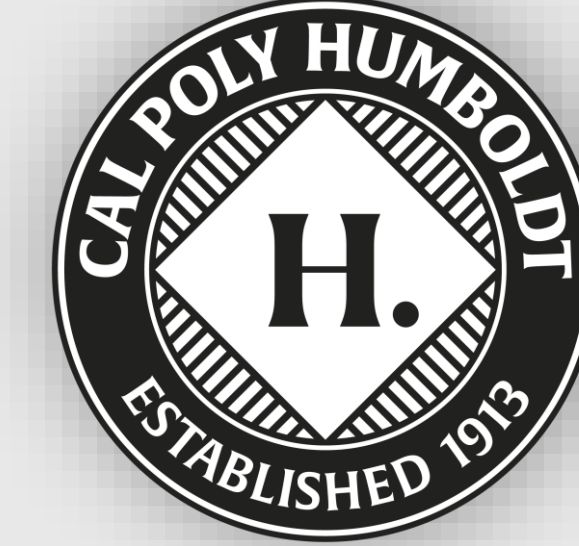


Assembly of a Saturated Absorption Spectroscopy System



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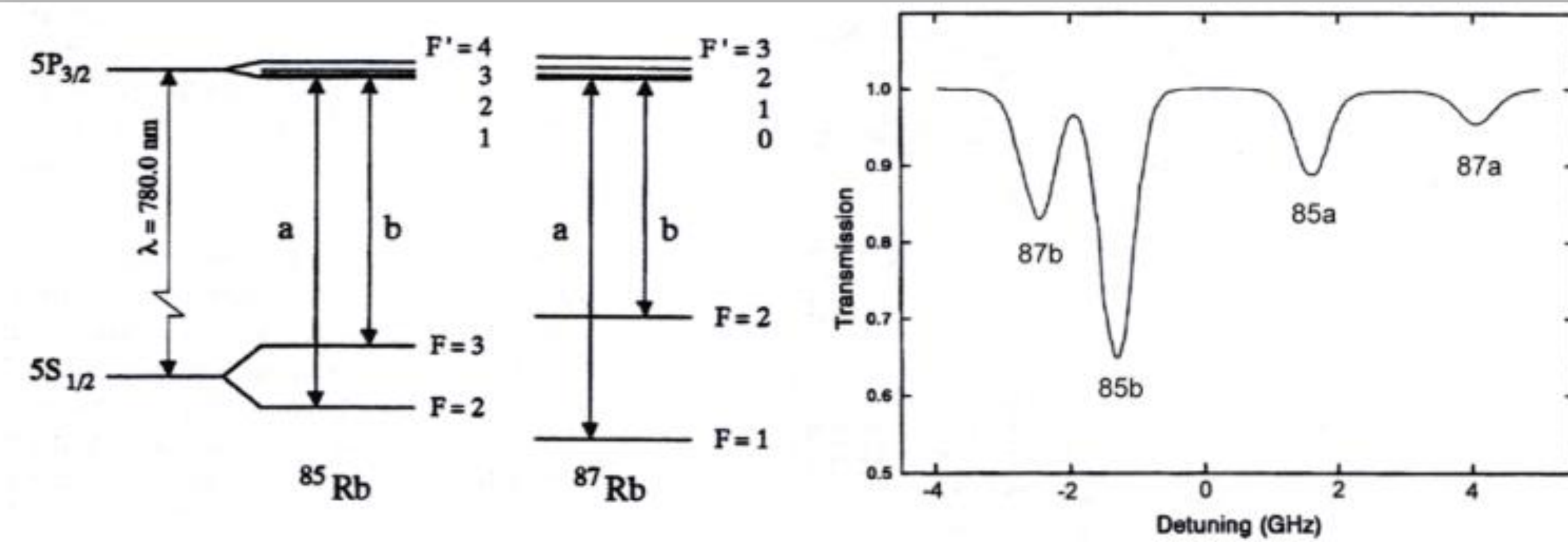


Background and Motivation

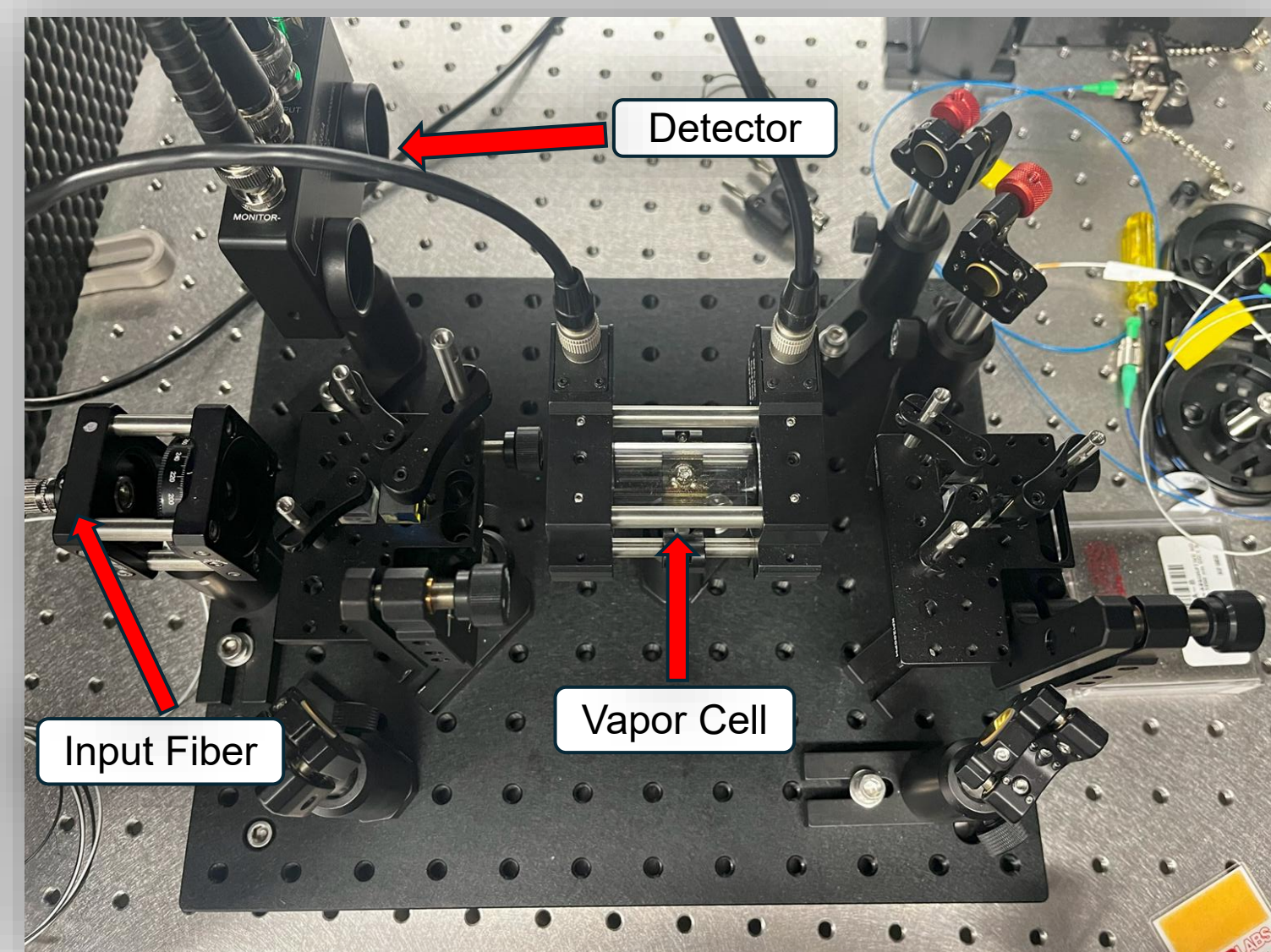
Goal:

Our goal was to demonstrate laser frequency stabilization at a single atomic transition frequency.

- Laser locking is a process by which the output frequency of the laser is stabilized to a high level of precision
- This is a technique that is used in a wide range of physics from development of atomic clocks to the detection of gravitational waves.
- We have paired with NASA Goddard Space Flight Center to give undergraduates an opportunity to learn about laser locking, spectroscopy and optics.



To lock a laser, we first need a frequency to lock to. This is often a transition frequency of an electron in an atom or a molecule. Our system is designed around the D2 transition in a rubidium isotope -- that is 780 nm.



- A transition occurs as an electron moves from one energy level to another.
- To find the transition frequencies we want, we use spectroscopy.
- This works by sending a small portion of our laser through a rubidium cell.
- We then sweep the frequency of the laser by driving a diffraction grating with a piezoelectric actuator.
- We can then measure the absorption of the laser light to determine at what frequencies we see these transitions.
- This looks like a dip in transmission at absorption frequencies.



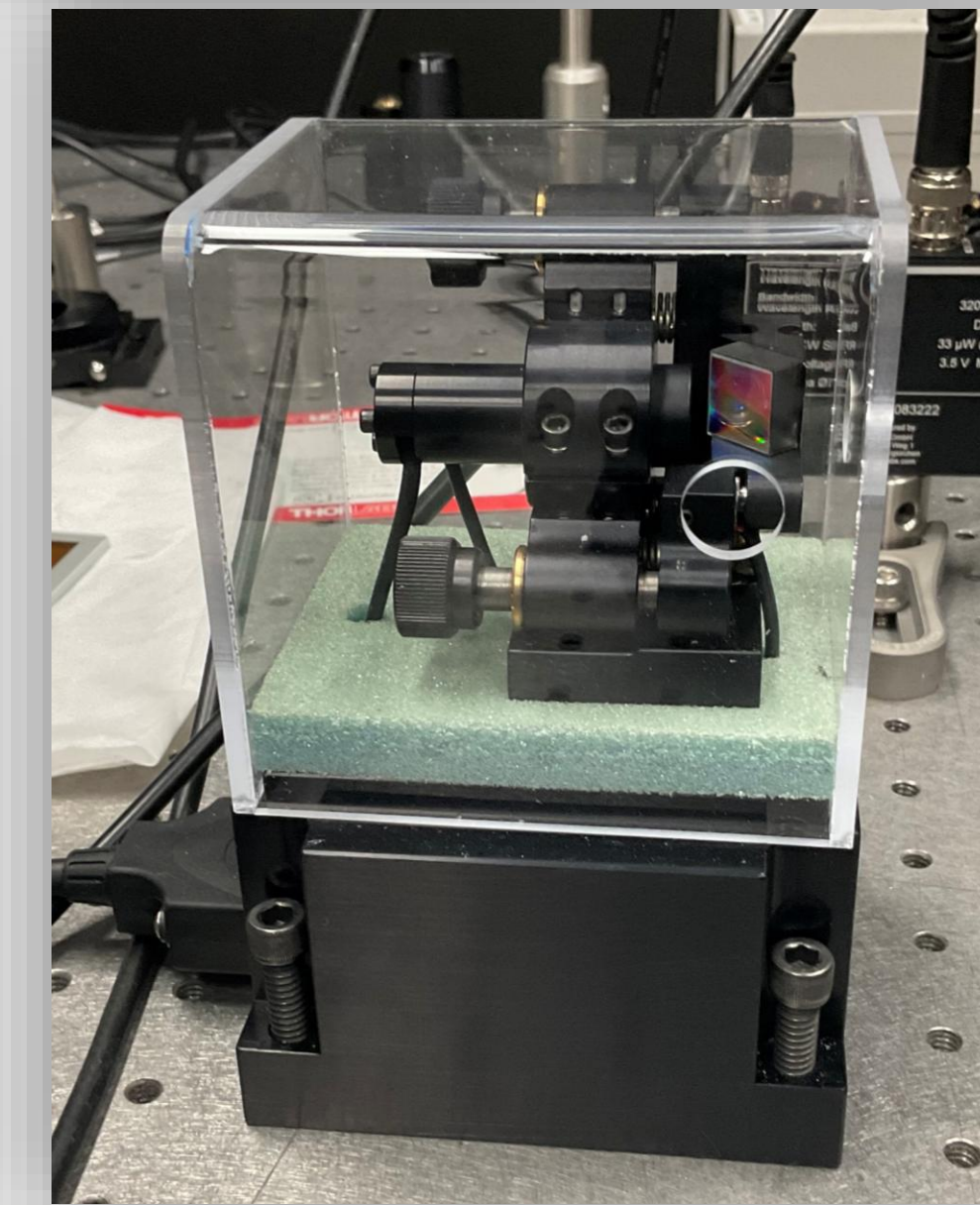
Much like the specific infrared frequency of the Petrova line in Project Hail Mary, we lock on to a specific transition frequency output by our laser.

Work in the Lab

Hardware

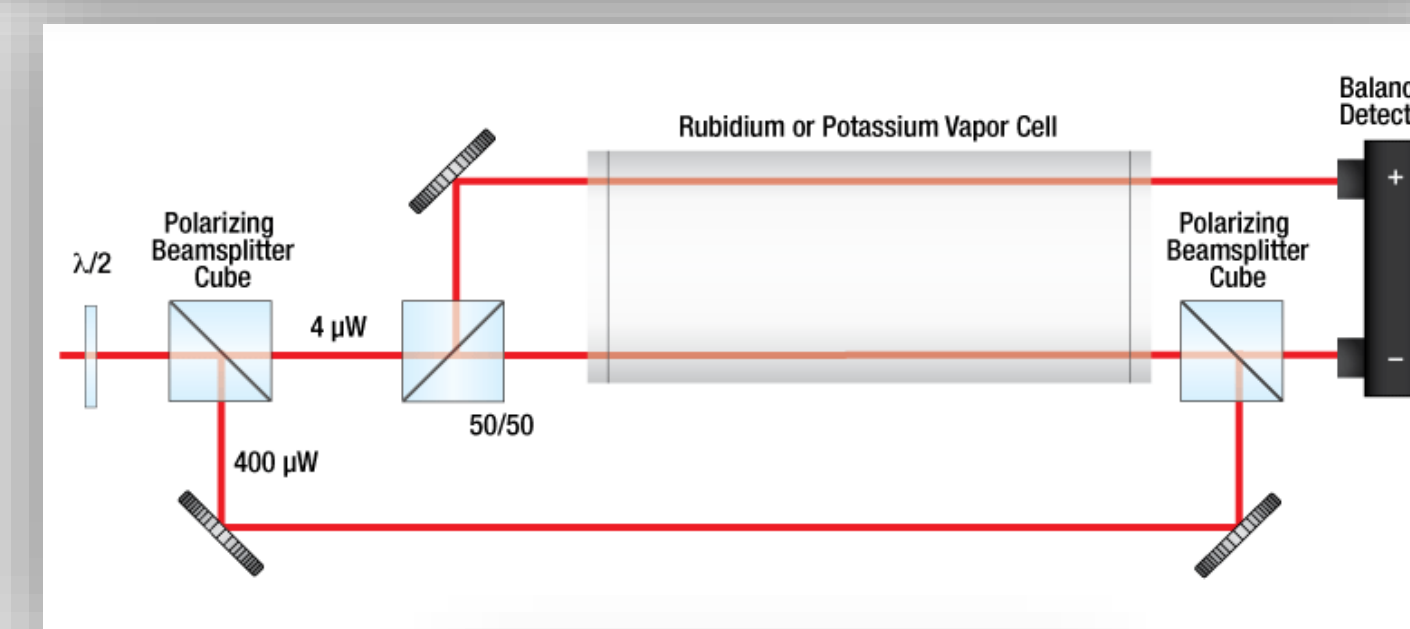
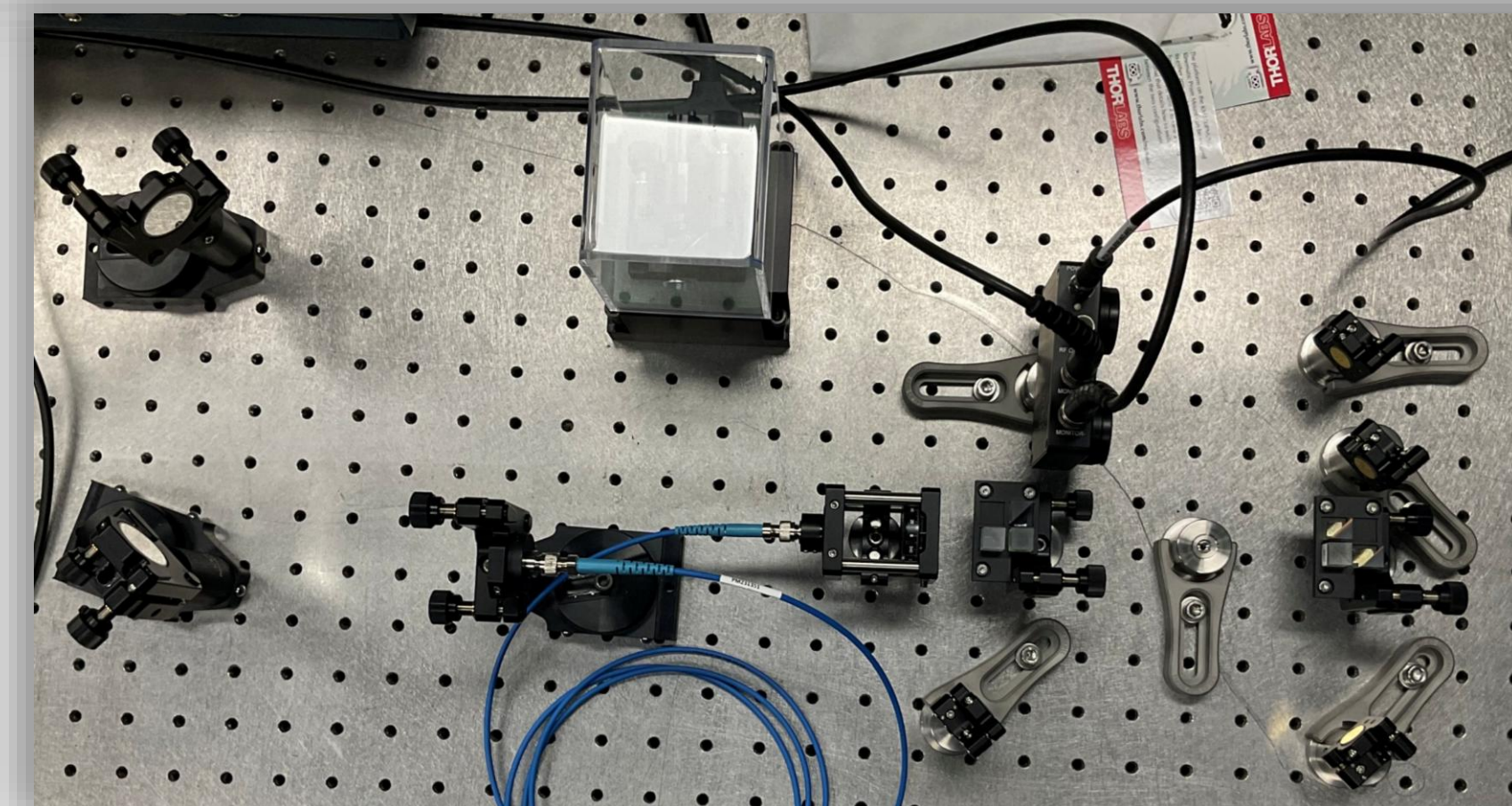
The Laser

We are working with a laser that has a nominal wavelength of 780 nm and a maximum power output of 70 mW. The beam cannot be seen with the naked eye and is powerful enough to do serious damage to your eye. Proper eye protection must be worn when operating the laser.



The Optics

- The optics system consists of a series of mirrors and beam splitters that split the beam into 3 separate beams, the reference beam, the probe beam and the pump beam.
- Currently our system is the process of alignment and attenuation.



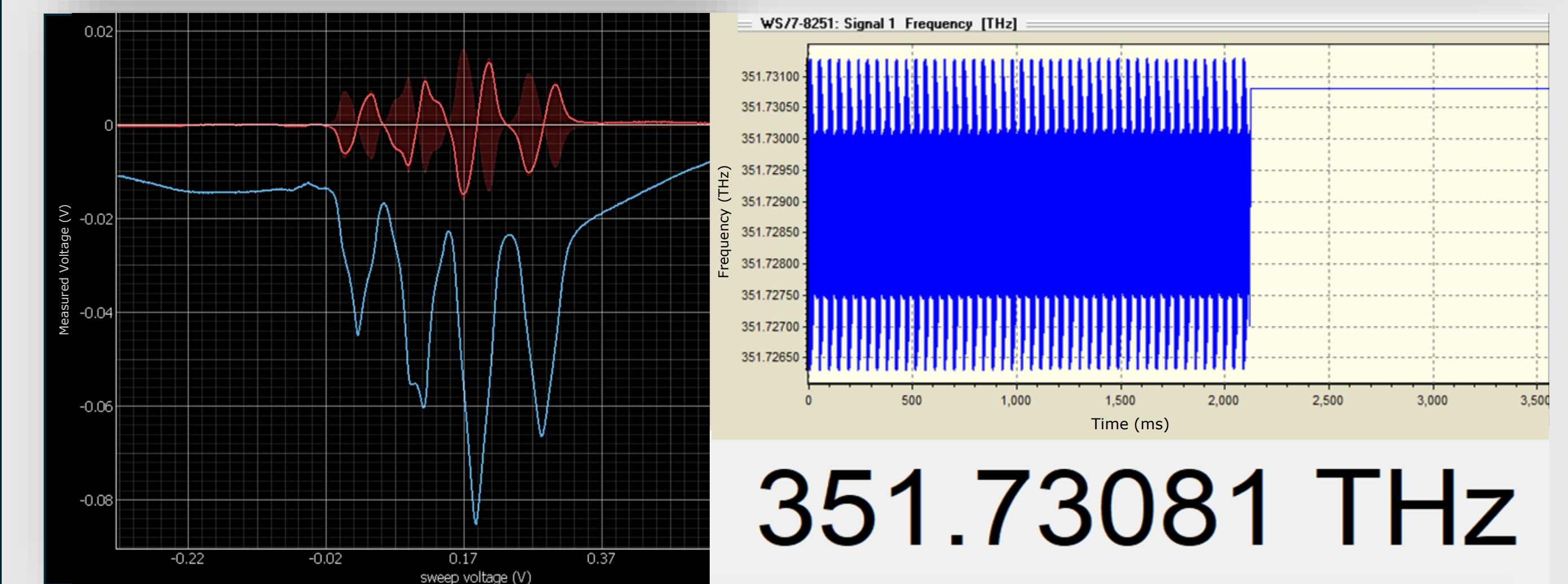
Challenges

One main challenge we have run into is the alignment of the laser beam. We have been using a visible red laser to get a rough alignment of the mirrors, however with alignment with a laser that can't be seen has proven to be challenging. Another challenge has been attenuation, or dimming, of the laser. The reason for attenuation of the laser is to not burn out our detector.

Software

Interfacing

We are using a Red Pitaya to interface with the laser and to collect data. We are using a ramp generator that drives the piezoelectric actuator to sweep through laser frequencies along with controlling laser current; though this may soon be replaced with a script in the Red Pitaya. To collect data and control locking of the laser we use an open-source program called Linien, and analysis in the future will be done in python.



The image above to the left shows Linien interface with an absorption signal with its respective derivative signal. The image above to the right shows frequency vs. time for a laser before and after locking.

Next Steps

The next major milestones for the hardware include aligning, attenuating and coupling the laser with the rest of the spectroscopy system. With this we will be ready to include the rubidium cell in our system. On the software side we are in the process of reading in and retrieving novel data from the sensor to the Red Pitaya and writing python scripts to analyze collected data. Additionally, the Red Pitaya may replace the ramp generator for driving the actuator.

References

Git hub, *Linien - User-friendly locking of lasers using Red Pitaya*, <https://github.com/linien-org/linien>

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Thorlabs, *Saturated Absorption Spectroscopy Systems*, <https://www.thorlabs.com/saturated-absorption-spectroscopy-systems?tabName=SA%20Spectroscopy>

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