Precise Pb Isotope Shift Measurements and Construction of 406nm Laser

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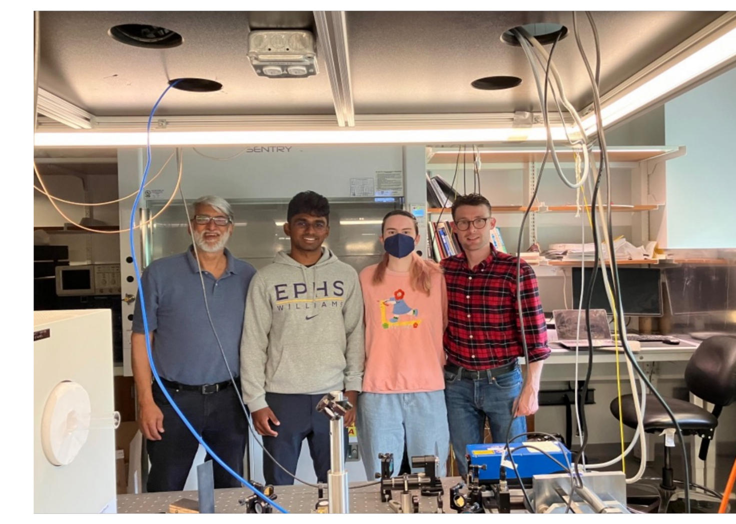
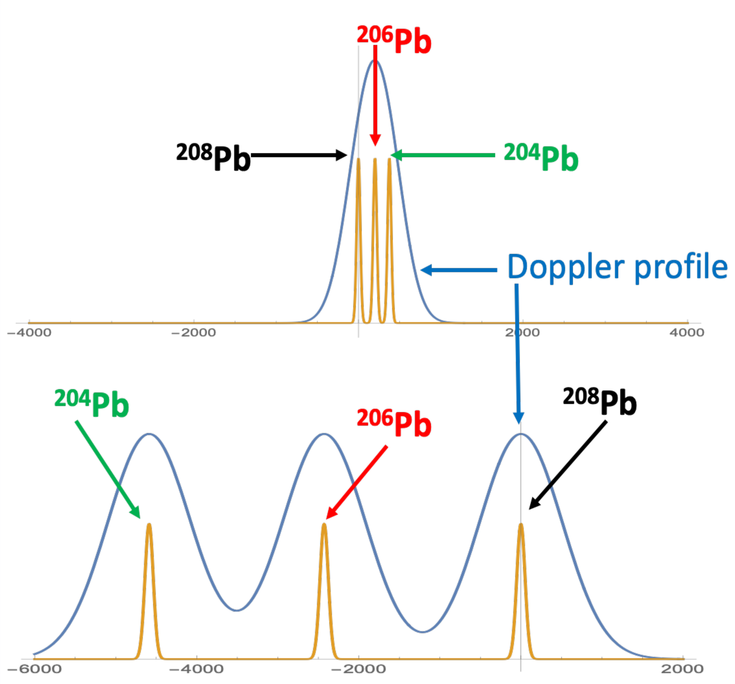
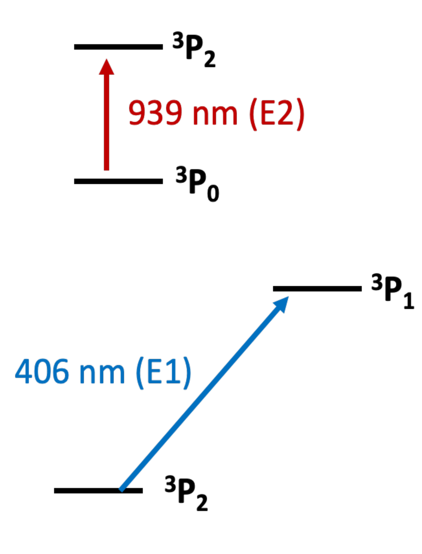


Background

- Heavy, multivalence atoms are good testbeds for probing fundamental particle physics interactions → effects scale as ~Z^3. → BUT Atomic theory is challenging!
- Previous experimental work in our group tests models by our atomic theory collaborators.
- New focus is on Group IV Pb. Improved atomic theory, but very few existing experimental benchmarks.
- Isotope shifts are the changes in energy levels due to differences in the number of neutrons. Measuring these small shifts tests models of wavefunctions near the nucleus.

Isotope shifts for Pb in low-lying transitions:
(Shifts are ~ 1 part in a million of laser frequency)

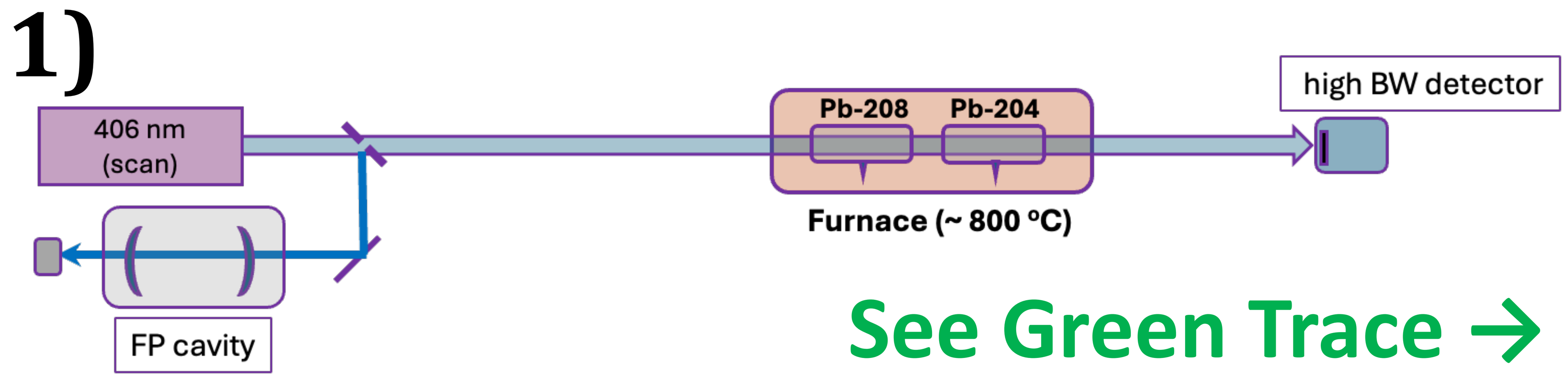




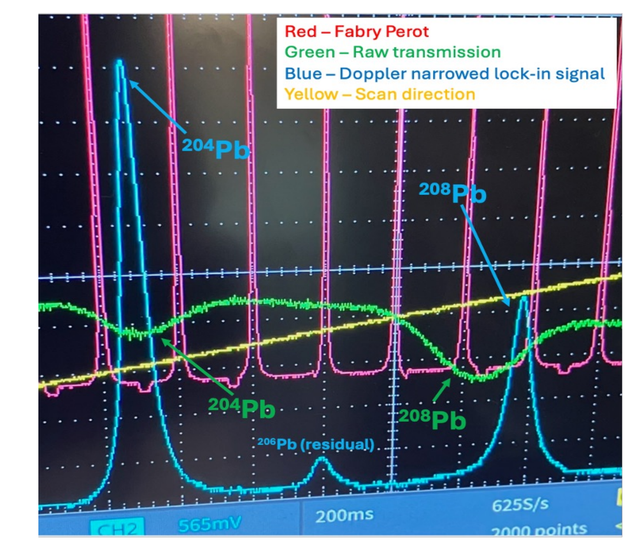
- Doppler broadening makes direct isotopic spectroscopy challenging.

Experimental Setup for Doppler-Free, Two-Step Spectroscopy

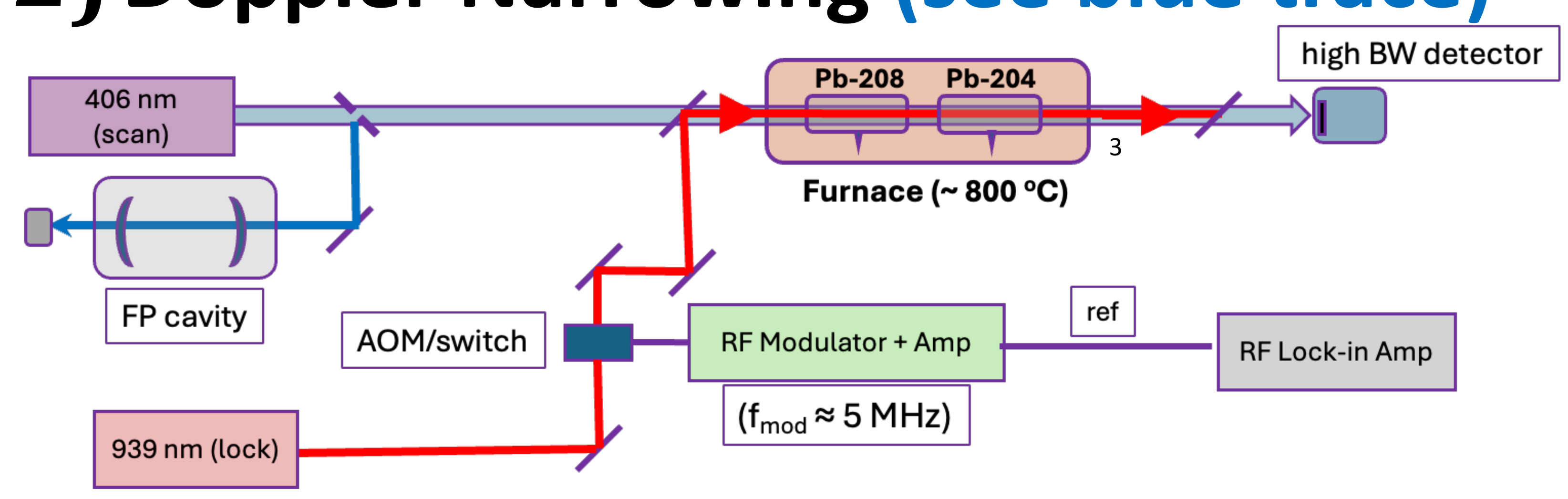
1)

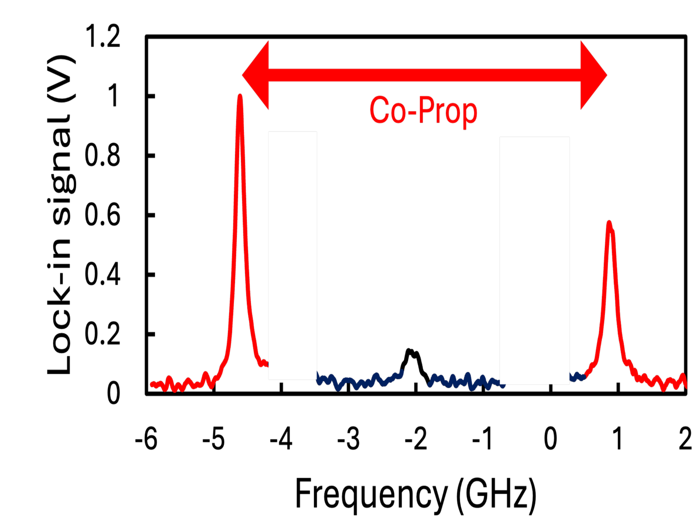


See Green Trace →



2) Doppler Narrowing (see blue trace)





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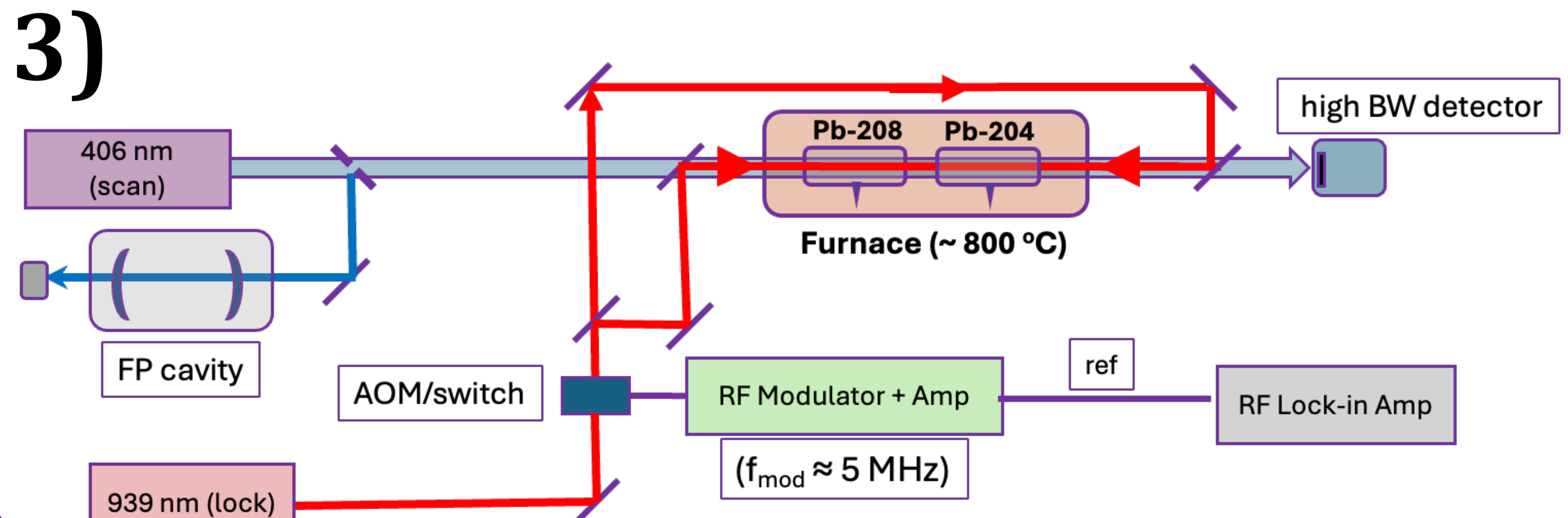
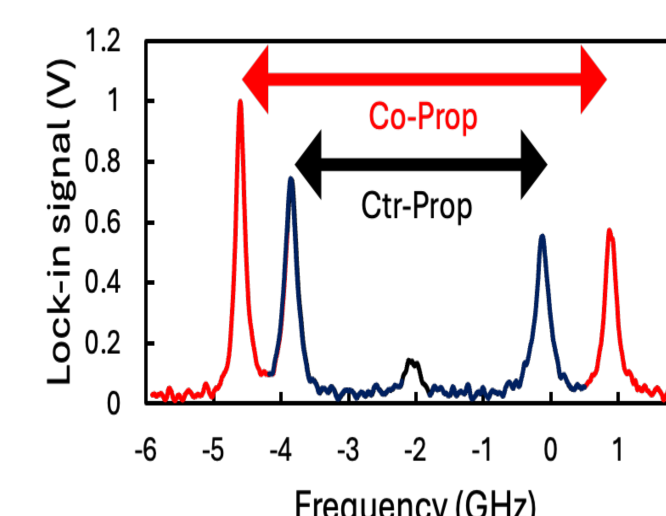
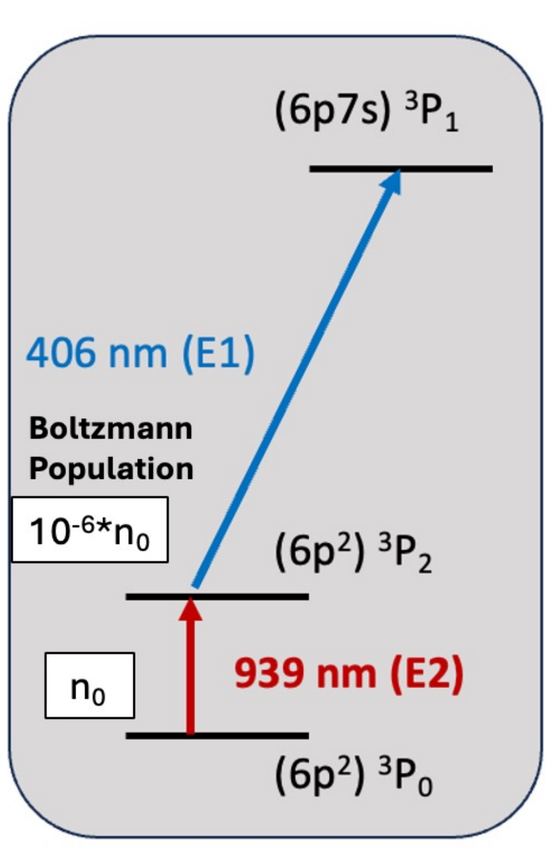
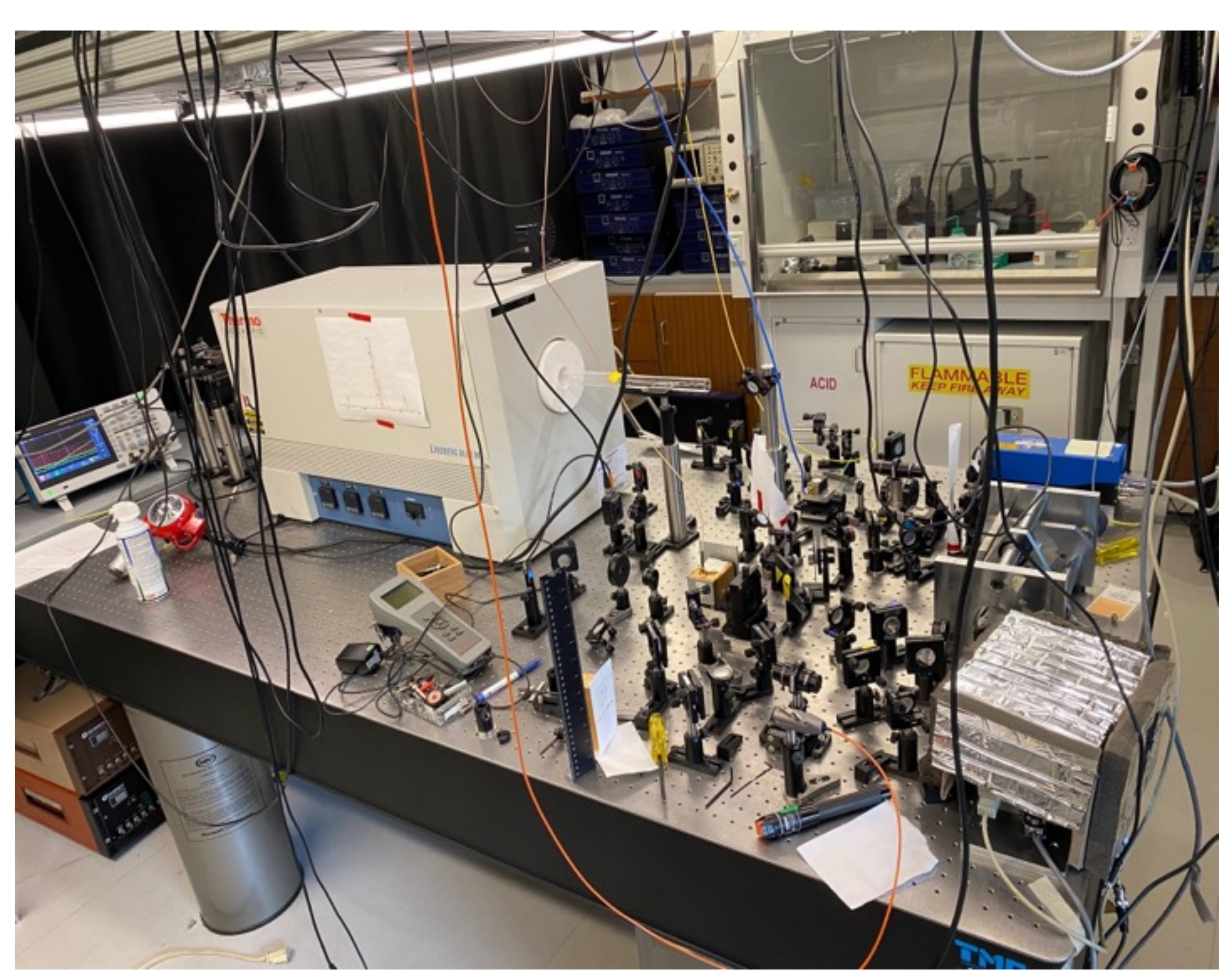




Pb energy levels (group IV)



- Thermal population for $^3P_2$ state is ~ 10^{-6}.
- Pumping E2 transition with 939 diode laser increases this to ~10^{-4}.
- 'Chop' 939 (locked) laser → lock-in detection of 406 transmission signal
- Pb-Pb mean collision time ~ 5 μsec for vapor cell @ 850 °C



Preliminary Results

By taking the sum and differences of the peak positions, we can find the transition isotope shifts:

15 mins of preliminary data:

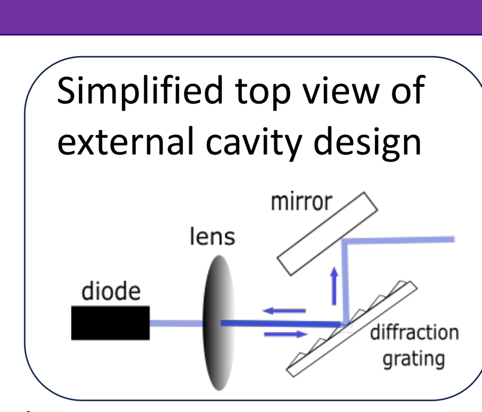
TIS_{406} = 4589(2) MHz

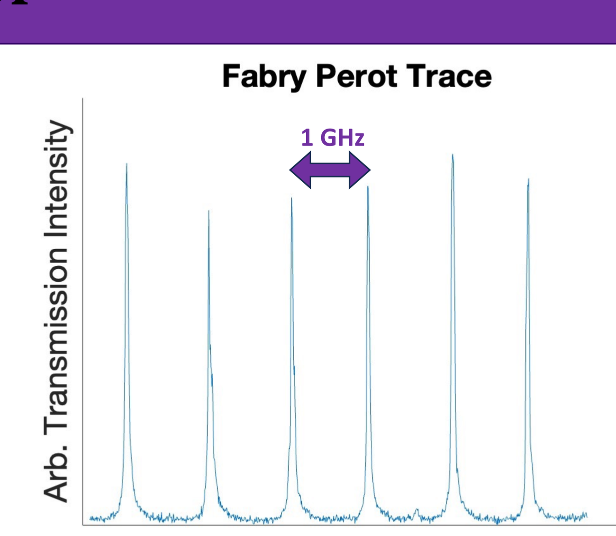
TIS_{939} = 379.5(5) MHz
(first ever direct measurement)

Construction of New 406nm Laser

Desired Characteristics:

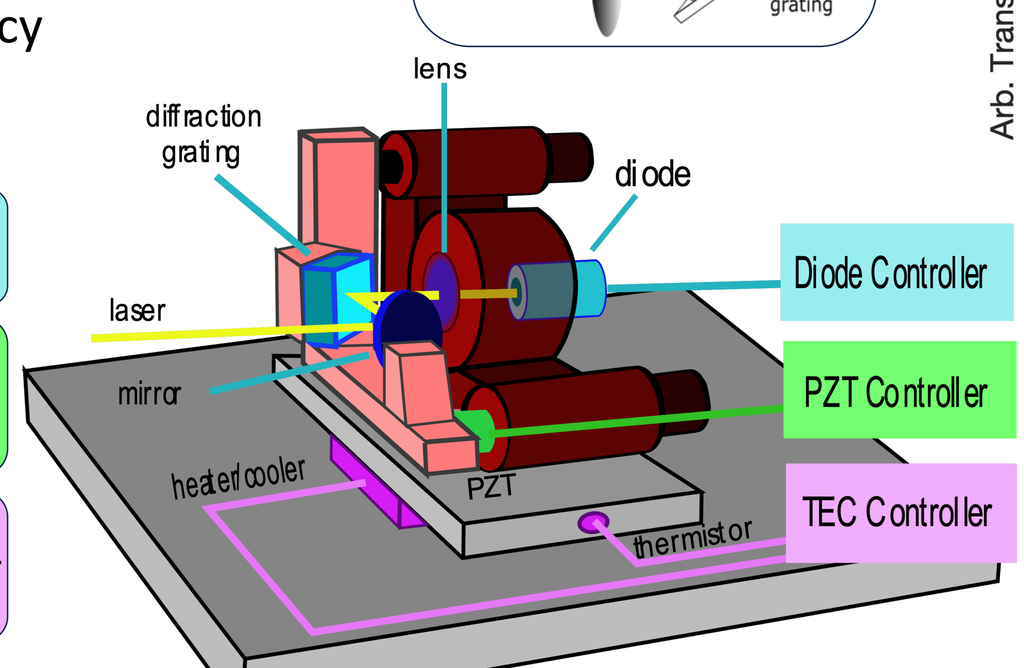
- Produces a very precise frequency/wavelength (738595GHz)
- Consistently lases at one frequency (single mode)
- Able to smoothly tune the frequency

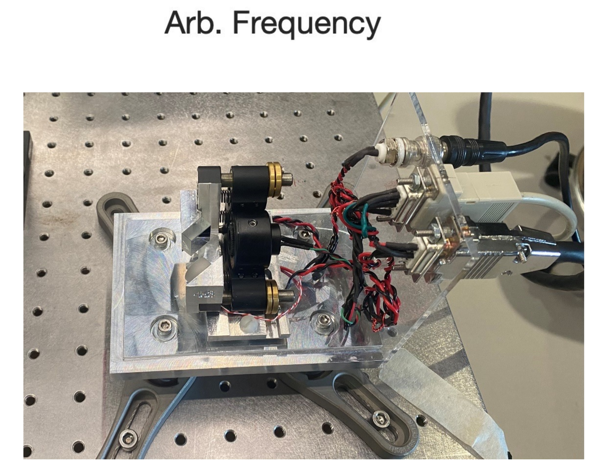




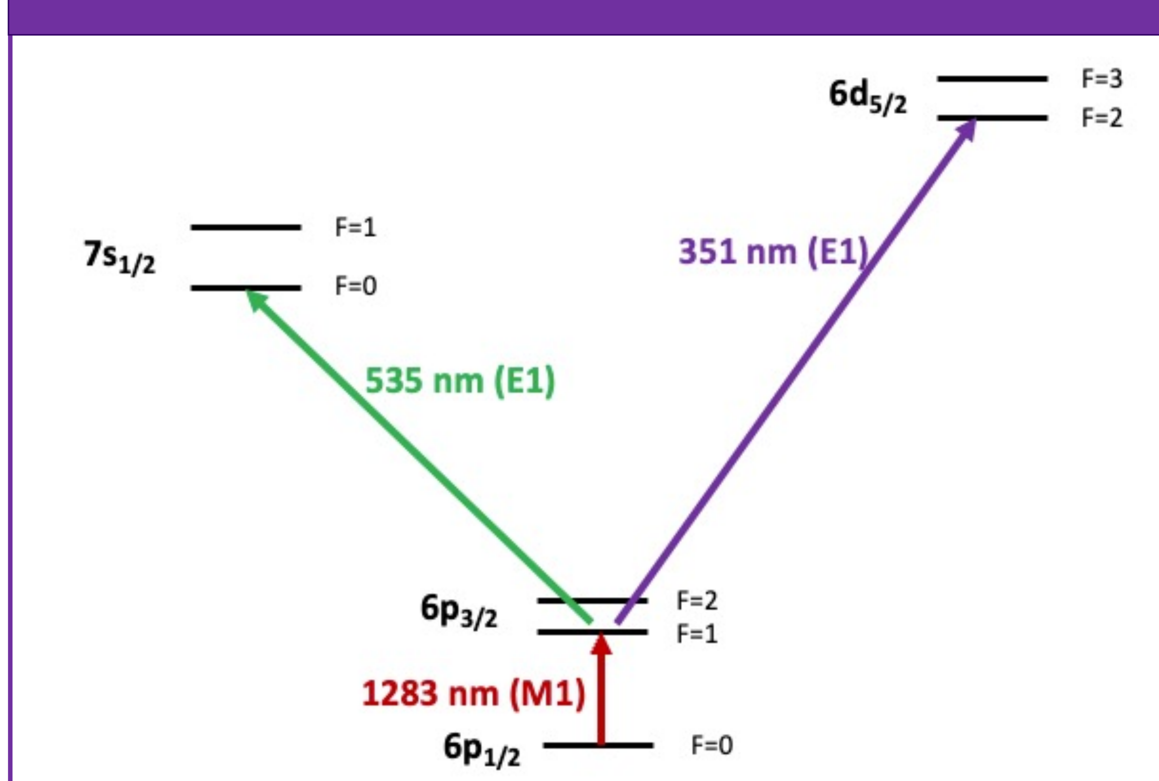
Features:

- "CW" low power laser (~10mW)
- Uses a piezoelectric transducer (PZT) to tune the horizontal angle of the diffraction grating by ~1-10 micrometers
- Heater/cooler and thermistor regulate temperature, with insulated box over laser (not pictured)





Future work in Thallium



Tl-205 (70%), Tl-203 (30%), both I=1/2

- E1/M1 transition amplitude ratios
- 205/203 transition isotope shifts using Doppler free two-step spectroscopy (as above)