Saturated Absorption Spectroscopy of Ytterbium

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Introduction

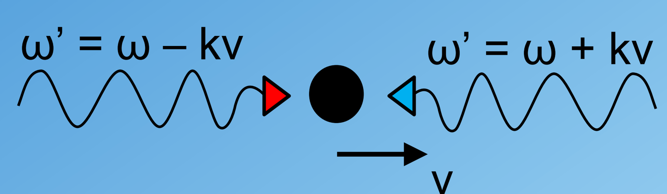
This project involves the development of a saturated absorption laser spectroscopy (SALS) apparatus for stabilizing lasers to optical transitions in the ytterbium atom. SALS is a two beam method which exploits the saturation of atomic transitions due to the absorption of light. The beams are counter propagating and produce a Doppler free signal, which yields a stable reference source. Lasers stabilized by this method will be locked near a resonant transition of the ytterbium atom, and can be used to cool trapped atoms toward degeneracy and the creation of a Bose-Einstein Condensate (BEC).

We use the SALS technique and Ytterbium for several reasons:

- SALS provides us with a Doppler free signal which dramatically simplifies our goal of finding a transition frequency.
- Ytterbium is a simple two level atom, and as such is well suited to be studied by SALS.

Doppler Free Laser Spectroscopy

The Doppler effect alters the relative frequency measured by an observer. An every day example of this effect would be the pitch of police siren as it passes someone on the sidewalk. The person on the street will hear a higher pitch as the car approaches, but a lower pitch as the car drives away. A similar description can be used to describe the frequency of light seen by an atoms as it passes through a laser. An atoms moving toward the laser see a higher frequency light while an atom moving away from the light see a lower frequency.



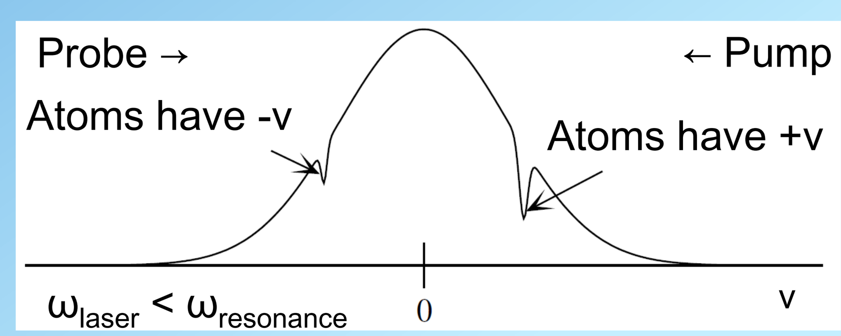
SALS provides a way around Doppler broadening, and is thus a Doppler free method.

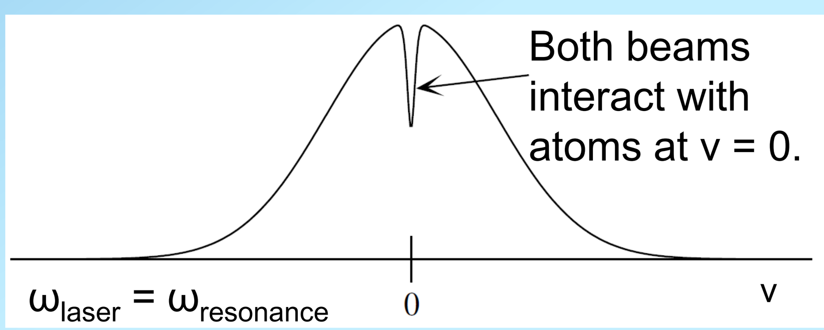
▪Requires two counter propagating beams of differing intensities

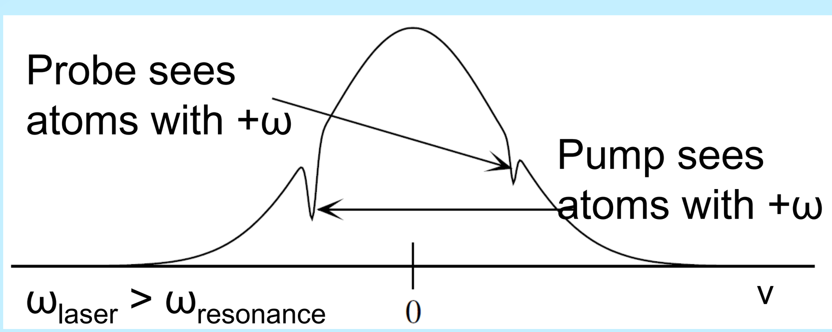
▪Probe beam and Pump beam; $I_{probe} << I_{sat}$ and $I_{pump} \geq I_{sat}$. (I_{sat} = Saturation Intensity)

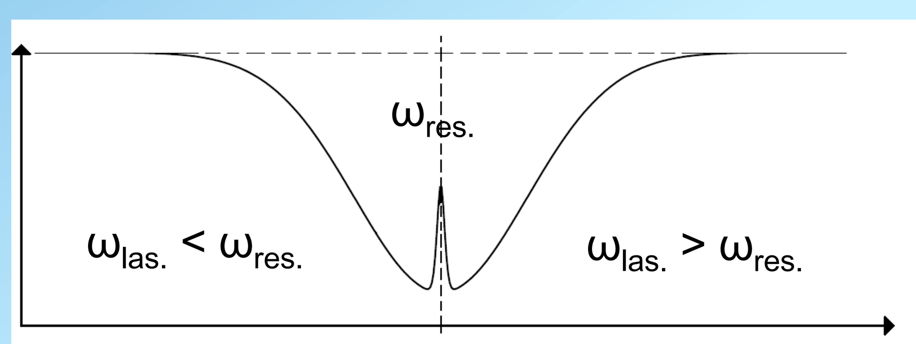
▪Atomic vapor characterized by velocity classes; most atoms are in the class centered at v = 0

▪The beams interact with different atoms depending on the beam frequency

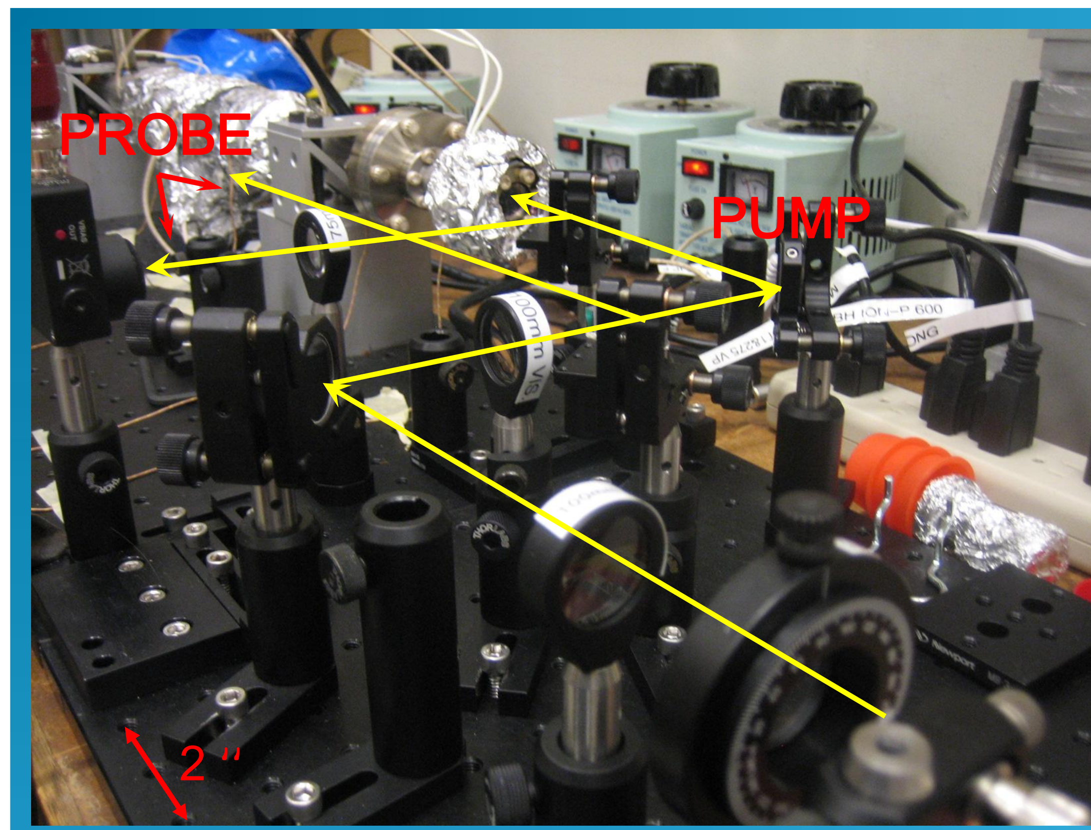


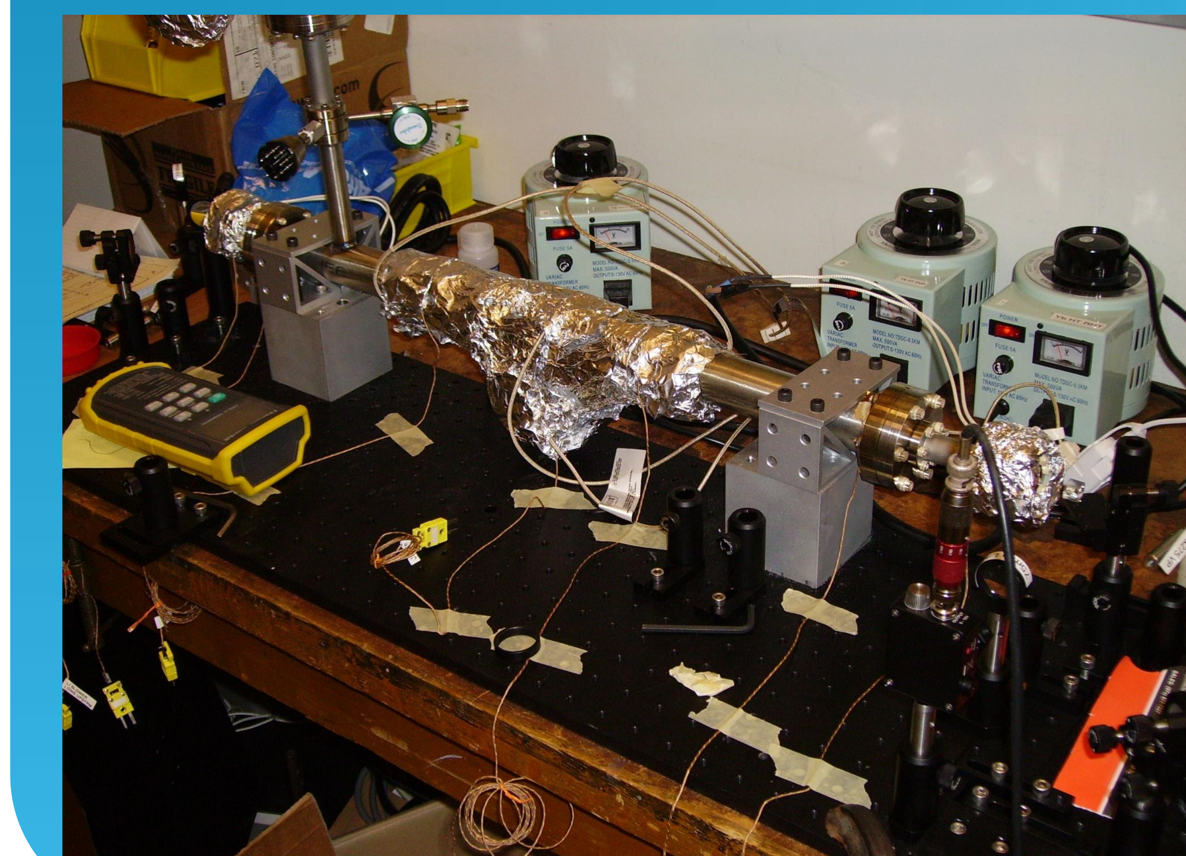






Apparatus





A two and a half foot chamber made of stainless steel provides the housing for our ytterbium sample. At each end of the chamber, there are glass viewports which allow light to pass through the tube. The following actions and considerations were made when preparing the chamber.

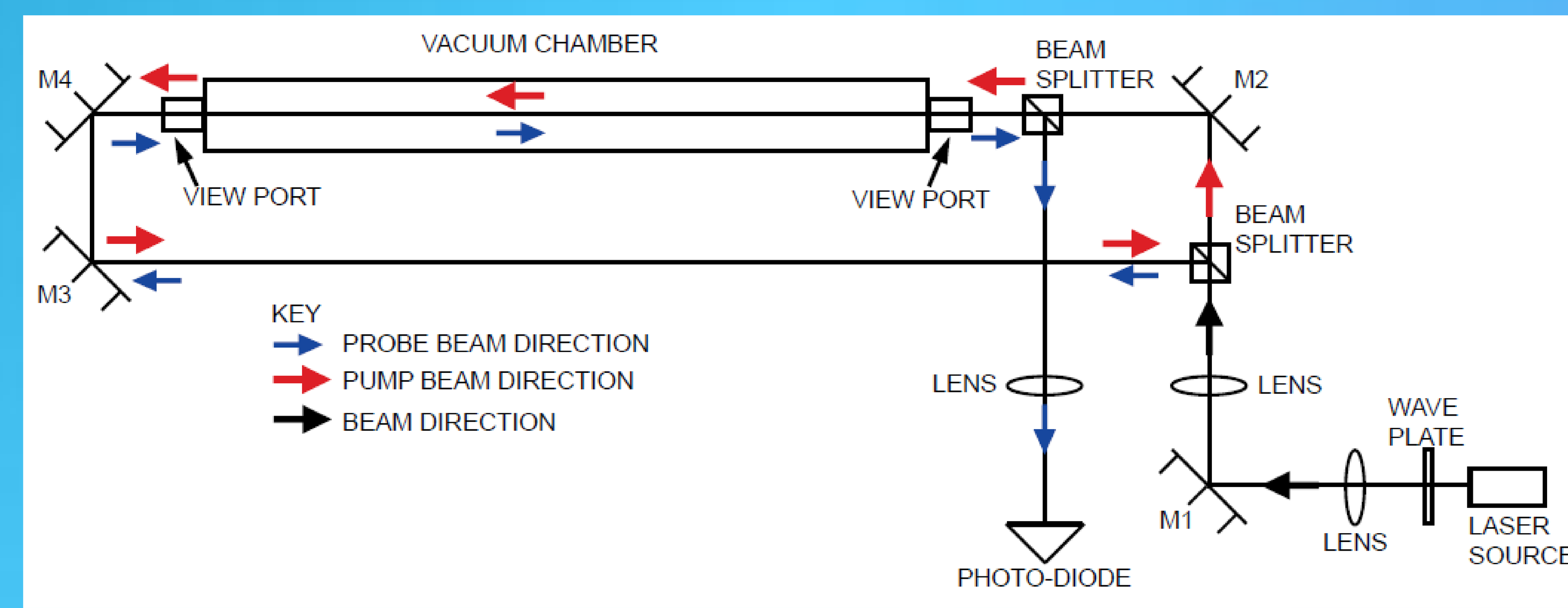
▪The system undergoes a preliminary "bake" to remove impurities, heated to 400°C

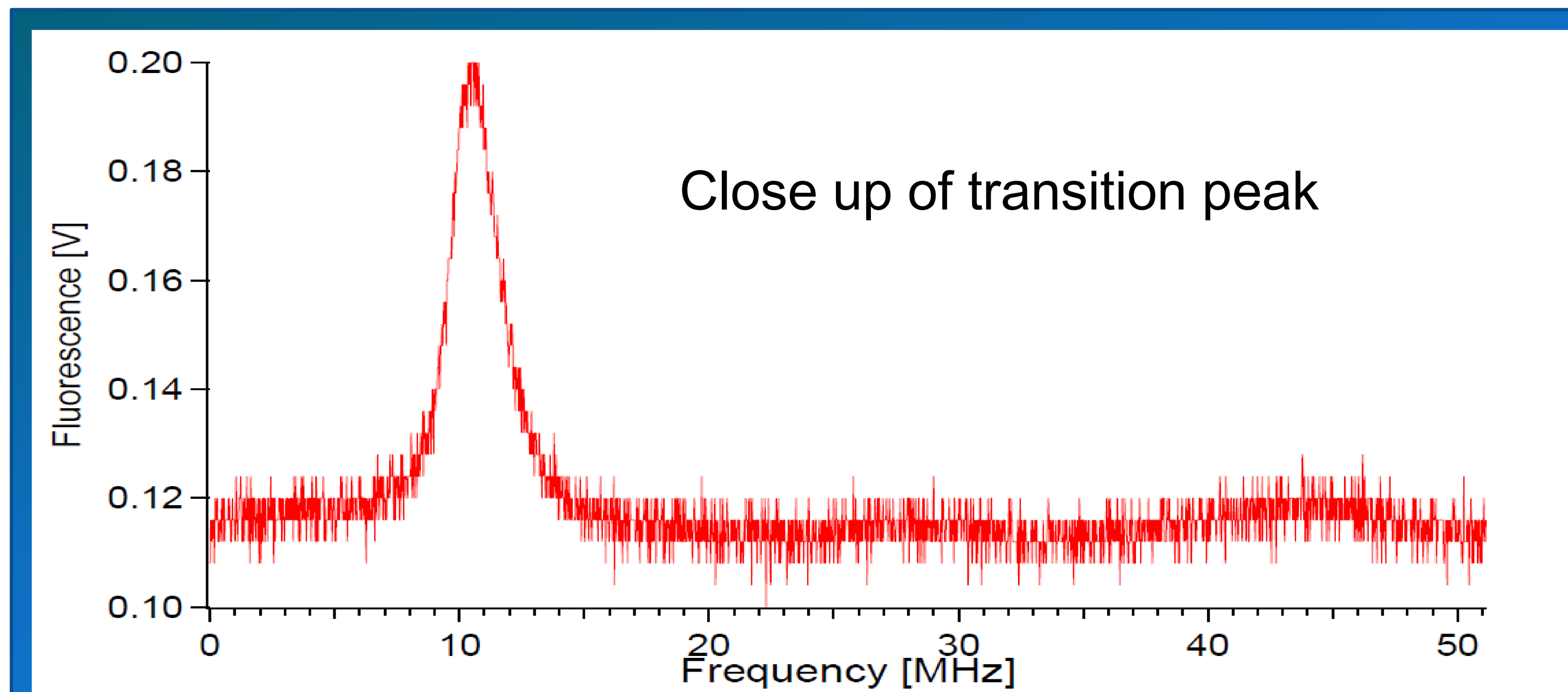
▪Chamber is pumped down to low pressures in order to create vacuum like conditions, helps to keep impurities out of system

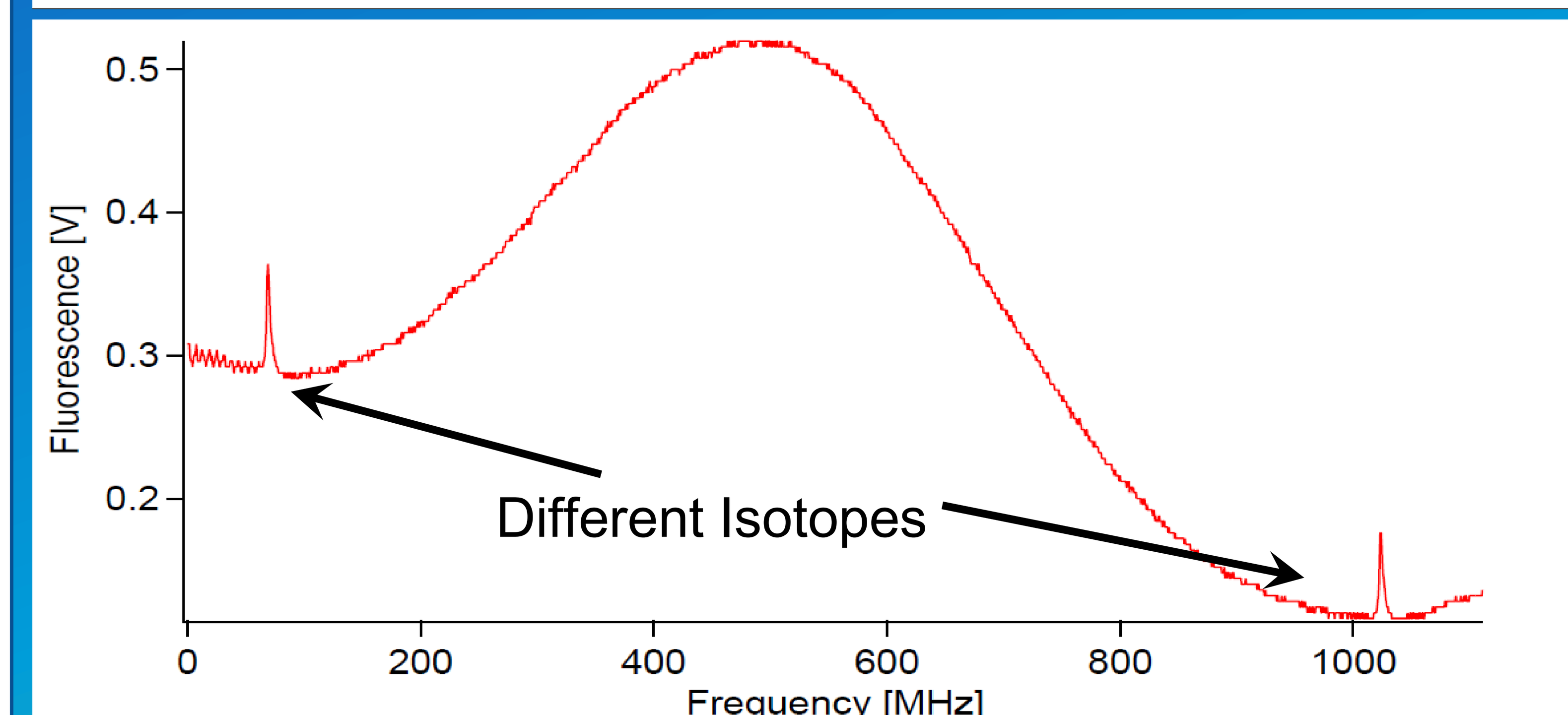
▪Heat only a portion of the chamber in order to reduce likelihood of atoms reaching the viewports

▪Additionally heat the viewports separately in order to reduce the chance of atoms sticking to the surface

▪The chamber size is reduced before reaching the viewports in order to decrease the number of atoms which may strike the viewports







Recent Progress

▪Completed construction of vacuum chamber for prolonged use with minimal maintenance

▪Developed a working optical setup for running SALS experiments

▪Obtained saturated absorption spectrum of ytterbium at various temperature in order to study effects of Doppler broadening as a function of temperature

▪Obtained measurements of Doppler broadening in absorption peaks as a function of probe power in order to better understand the characteristics of this effect

Future Plans

▪Produce an error signal from saturated absorption spectrum, which can be used to lock a laser to a desired frequency

▪Introduce stabilized laser to the greater experiment for use in laser cooling of trapped ytterbium

▪Move the system to a permanent location for prolonged use

▪Determine origin of unwanted noise in our signal and remedy the problem

References

▪C.J. Foot, Atomic Physics, Oxford University Pres, 2005

▪J. Stoltenberg, D. Pengra, and R. Van Dyck, "Lamb Shift in Atomic Hydrogen", University of Washington, Department of Physics, 2008