Laser Frequency Stabilization

REU Summer 2006

Margot Phelps

Layra Reza

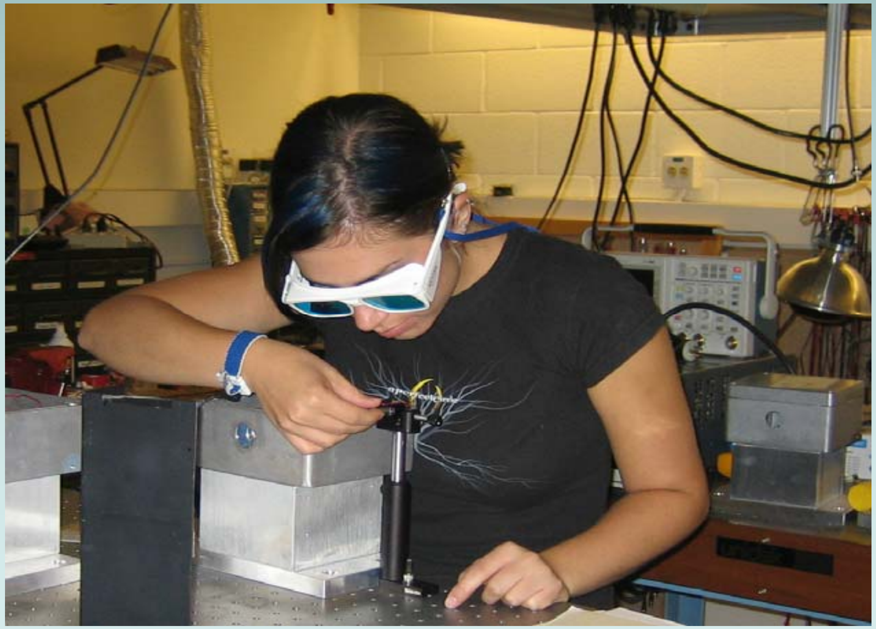
Mentor:Dr. Deborah S. Jin

Outline

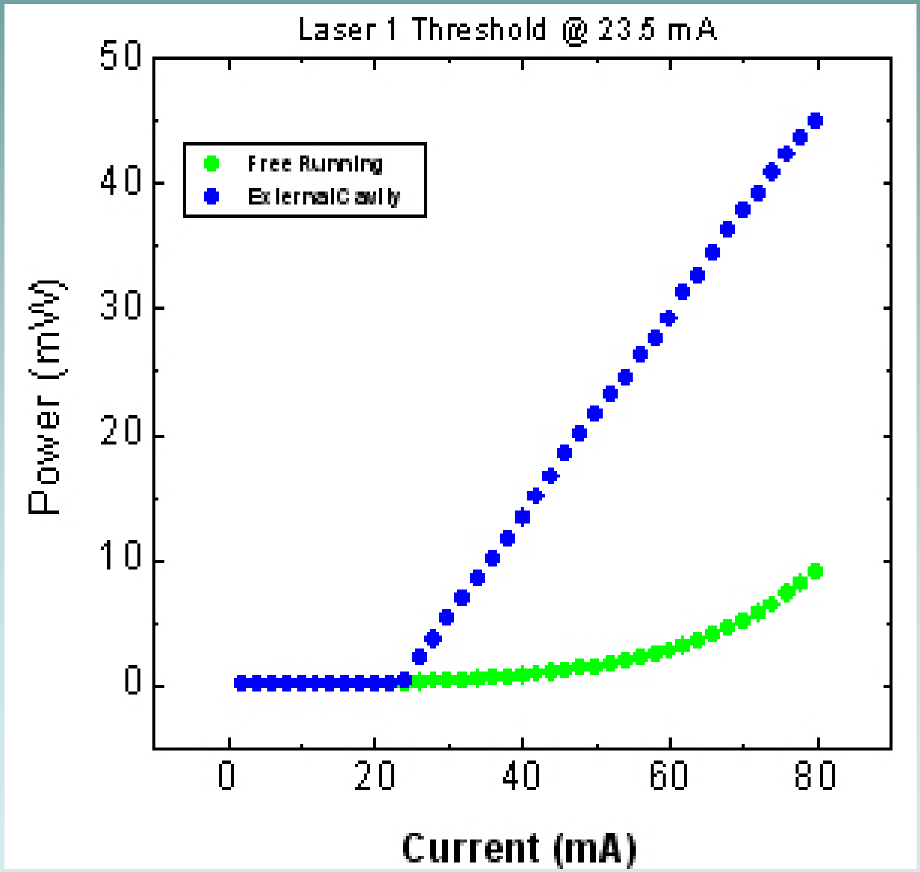
- Using an external cavity diode laser
- stabilizing the frequency of the laser
- How lasers are used in the experiment
- Controlling the laser
- Interpreting error signals

Building the laser

- External cavity diode lasers
- Diode wavelength=767 nm.
- Here we are collimating the beam.



Threshold curves

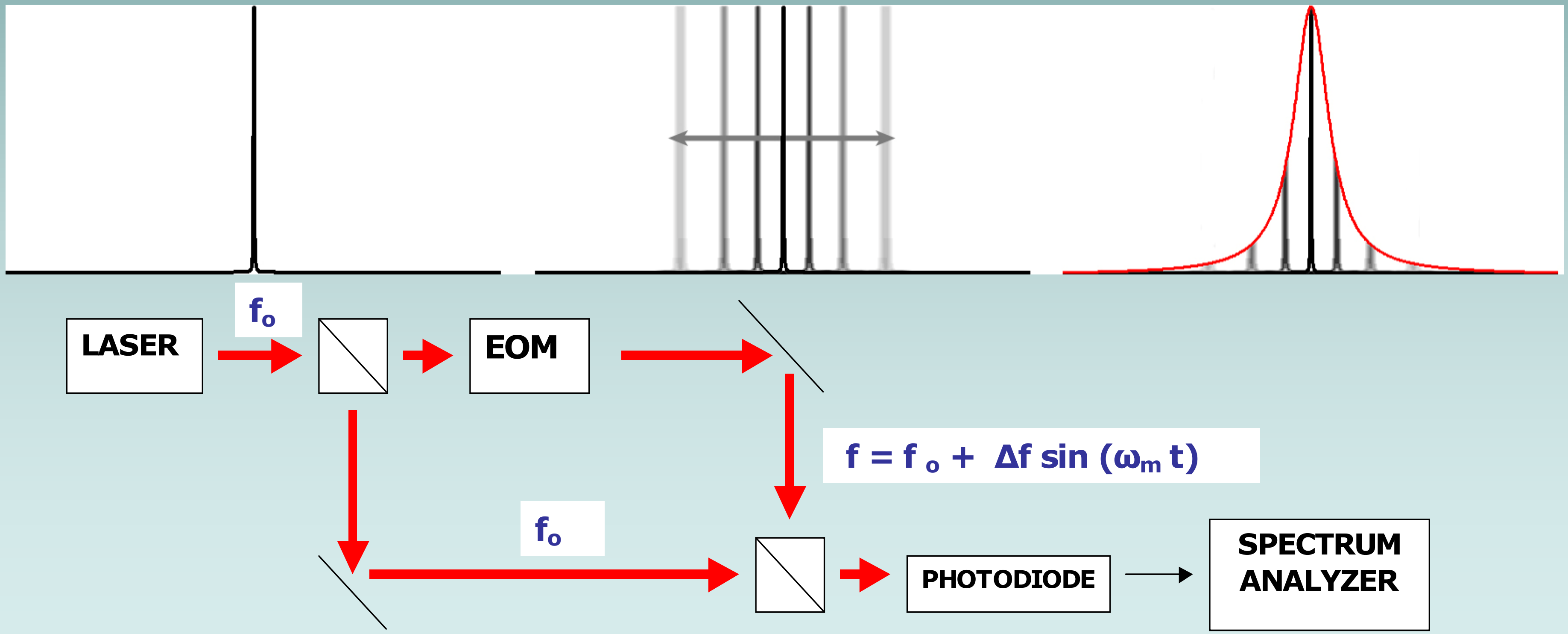


- Helps characterize the behavior of the laser
- The threshold is where the laser begins to lase
- Lasing means that the laser is producing a coherent beam, all its photons are in the same quantum state
- Important in case of suspected laser failure

Beatnotes

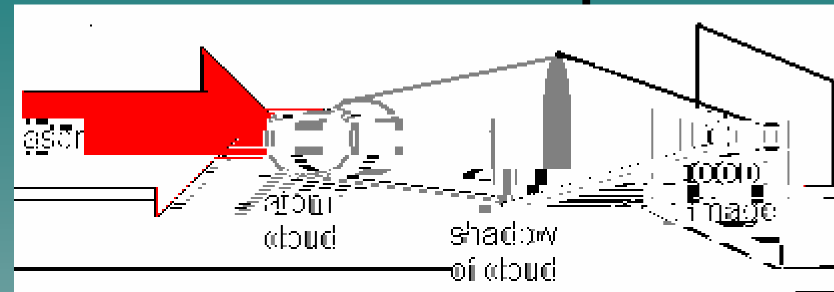
Lasers drift in frequency over time. Instantaneously, they are lasing at one frequency, but a time averaged signal shows something different.

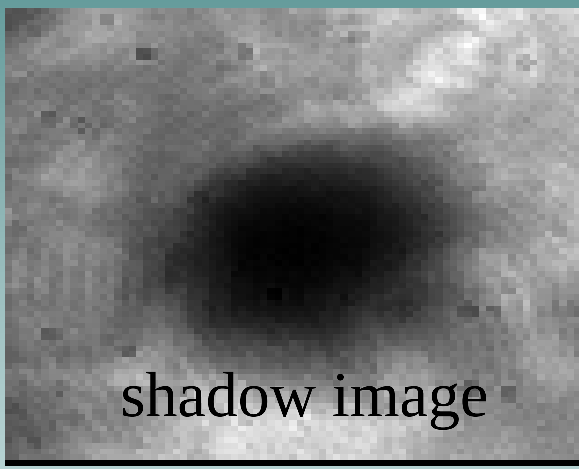
- Reasons for drift: Electronic noise,Temperature drift,Air flow
- Want the laser’s lineshape to be <1MHz

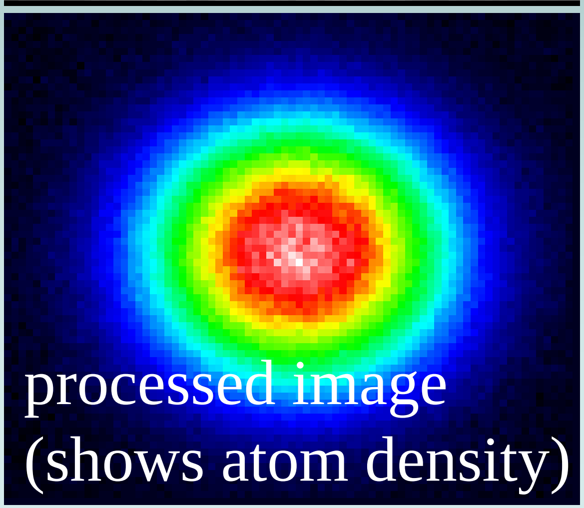


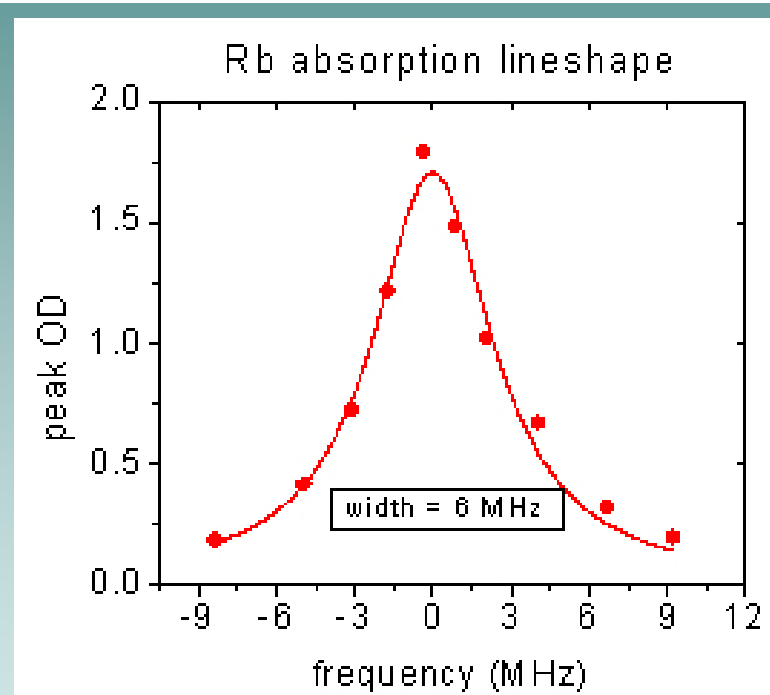
Why is Frequency stabilization important?

- Laser imaging needs the laser to be at the right absorption wavelength for the atoms









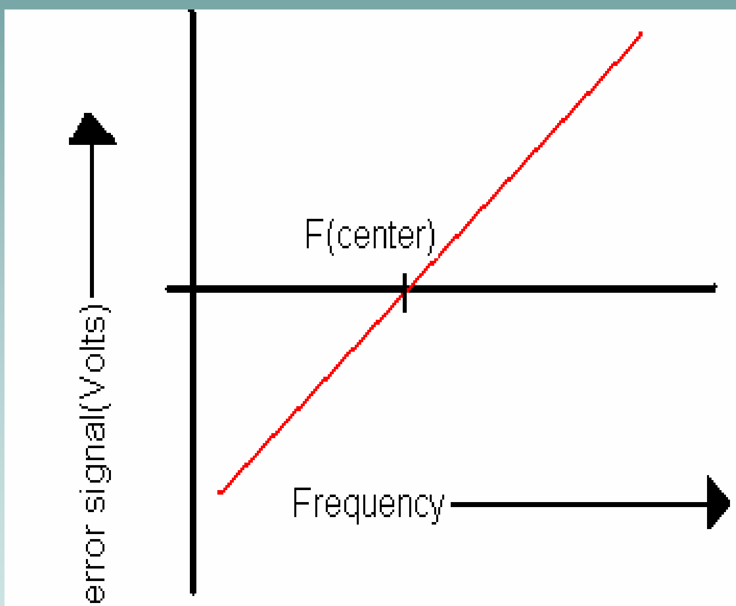
Zero equals resonant frequency

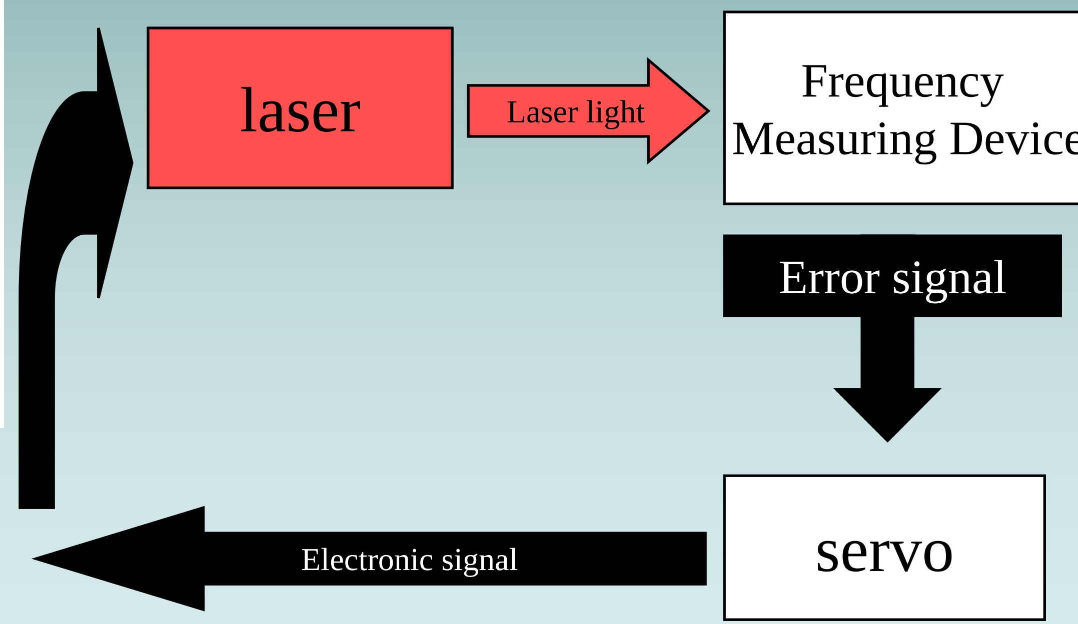
- The lineshape of the laser must be >1MHz

Feedback Loops

Controlling the laser:

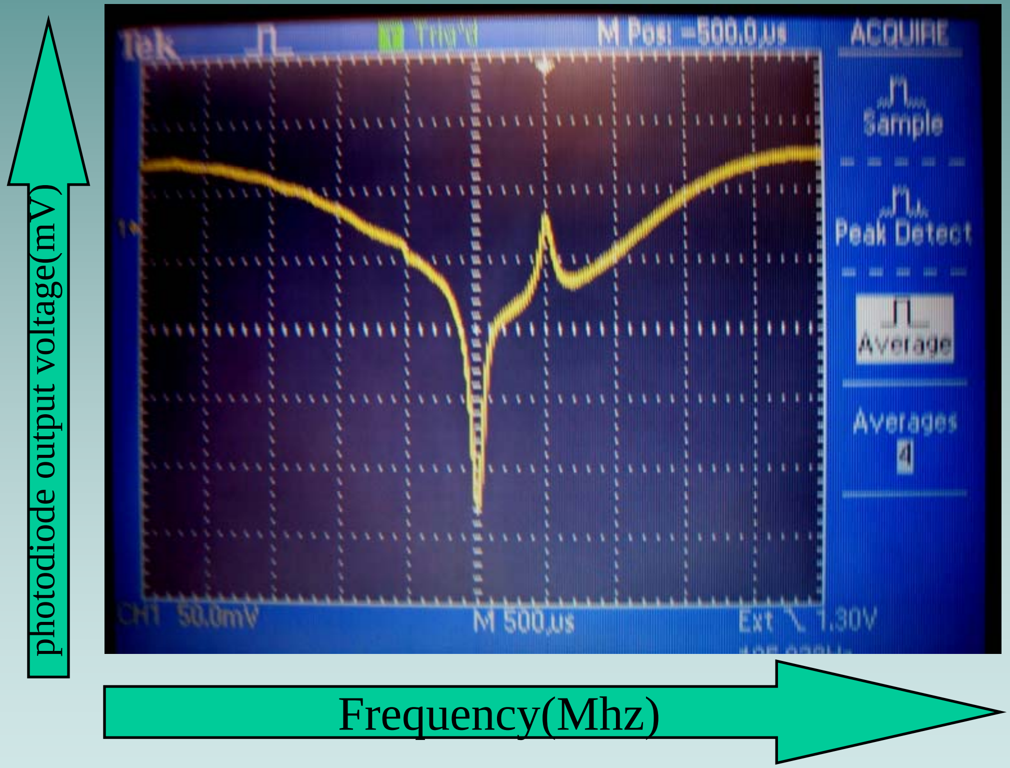
A feedback loop or “servo”

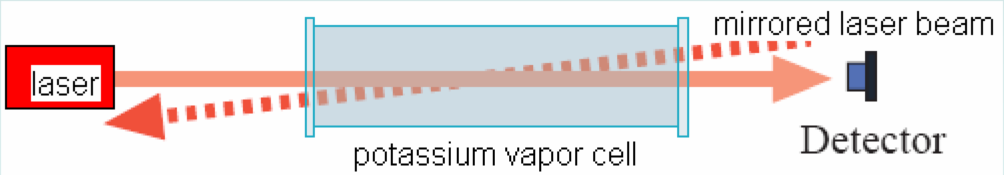




Saturated Absorption

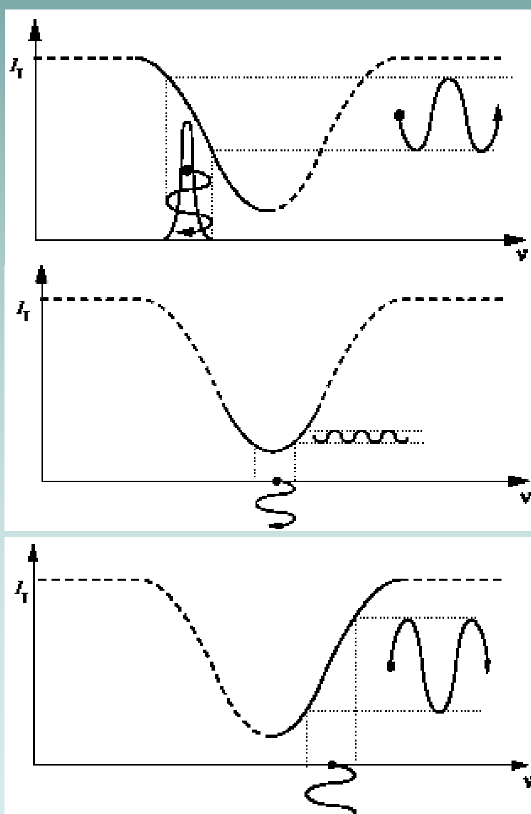
- Widely used setup for laser stabilization
- Wide Doppler dip, with extra peaks
- Scanning laser frequency to find peaks
- saturated absorption peaks at 767 nm for ^{40}K.
- sidelocking to reduce frequency drift

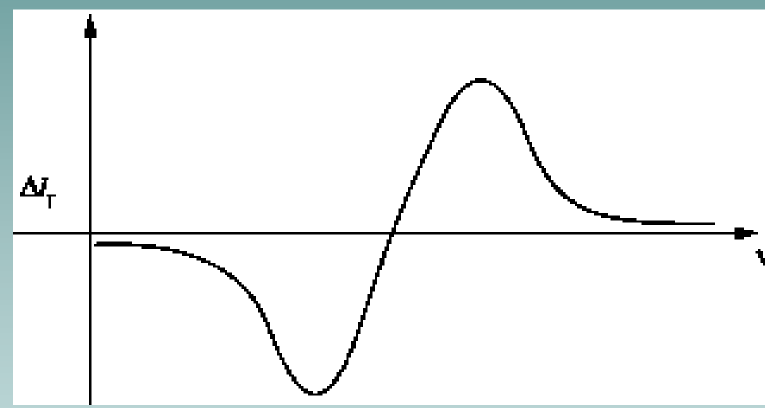




Locking to the Peak

Frequency modulation : the wavelength of the laser is scanned across the atomic transition, and the wavelength modulation is seen as varying amplitude modulation.

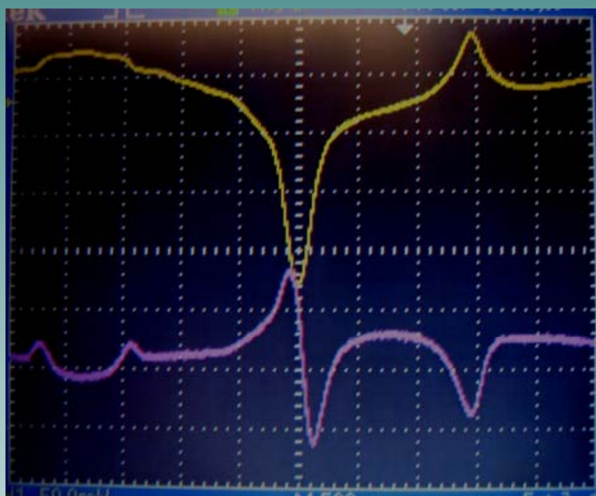




- The ratio of AM to FM versus the laser frequency results in this derivative signal
- This signal is at zero when the laser is on resonance
- Use this as the error signal for peak locking the laser

The Challenge

Saturated absorption lines



Derivative signal

We want:

A way to combine the sidelock and peaklock to eliminate the drawbacks of both methods

Sidelock

- Pros
  - Don’t modulate the frequency of the laser itself
- Cons
  - Might be too far away from the resonant frequency

Peaklock

- Pros
  - Closer to resonance
- Cons
  - Have to modulate laser frequency

Summary

- Importance of laser frequency stabilization
- Some widely used methods
- Room for improvement: other methods could prove to be better than those in use.