

Laser Frequency Stabilization

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Outline

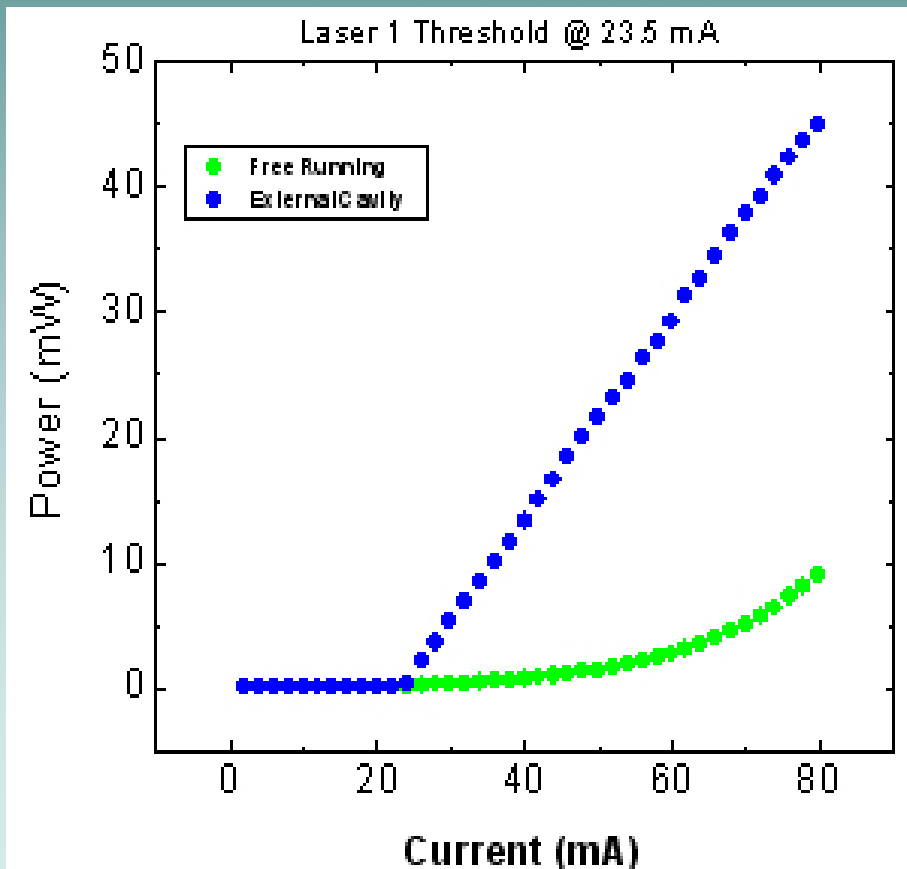
- Using an external cavity diode laser
- stabilizing the frequency of the laser
- How lasers are used in the experiment
- Controlling the laser
- Interpreting error signals

Building the laser

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



Threshold curves

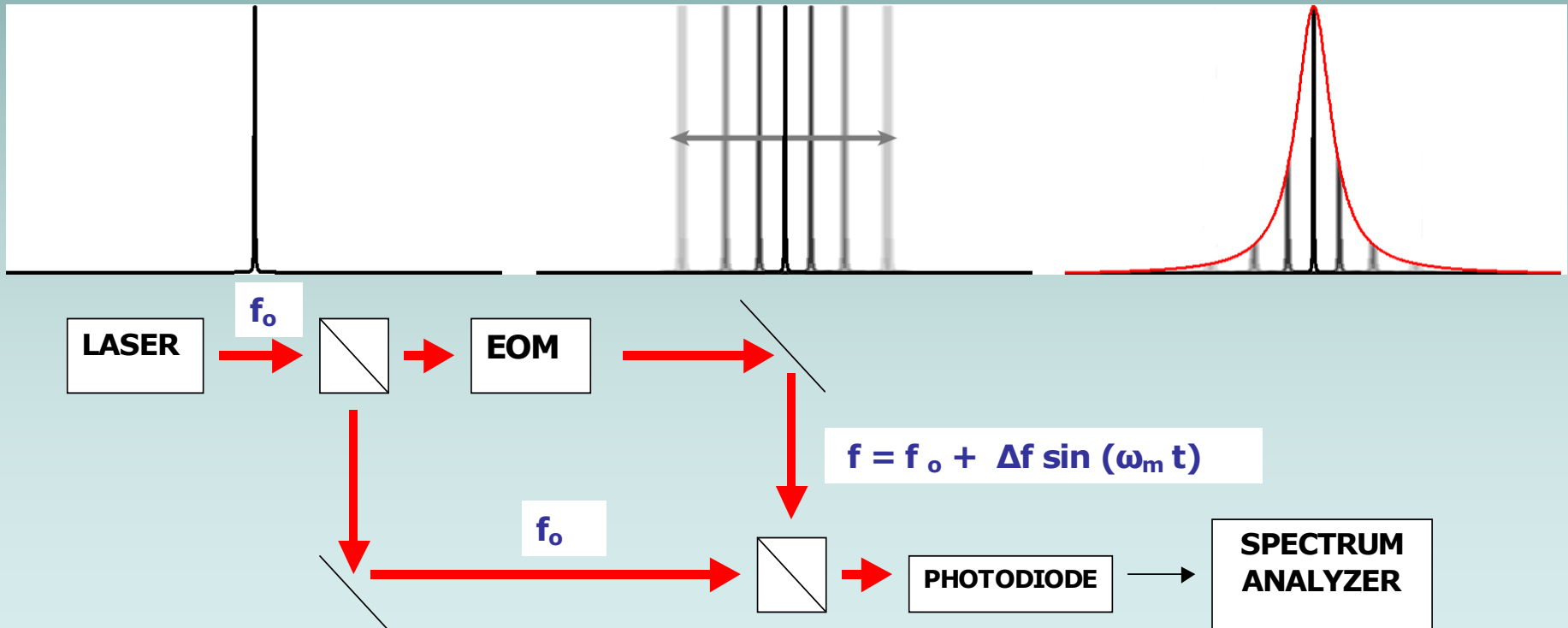


- Helps characterize the behavior of the laser
- The threshold is where the laser begins to lase
- Lasing means that the laser is producing a coherent beam, all its photons are in the same quantum state
- Important in case of suspected laser failure

Beatnotes

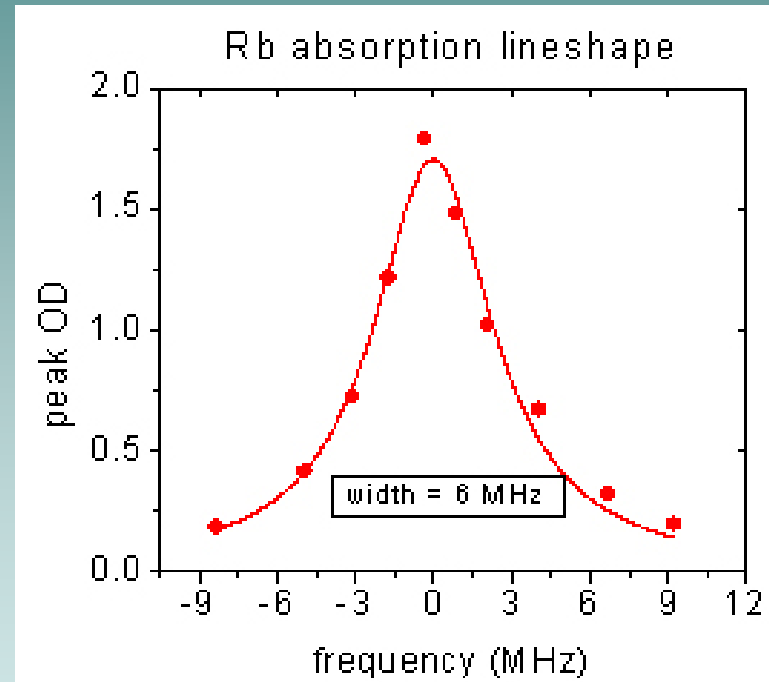
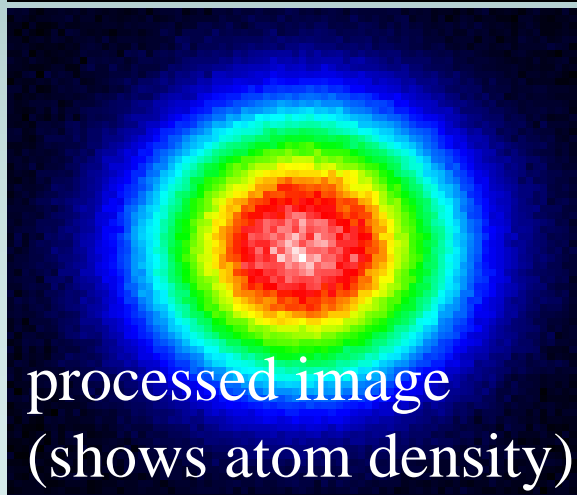
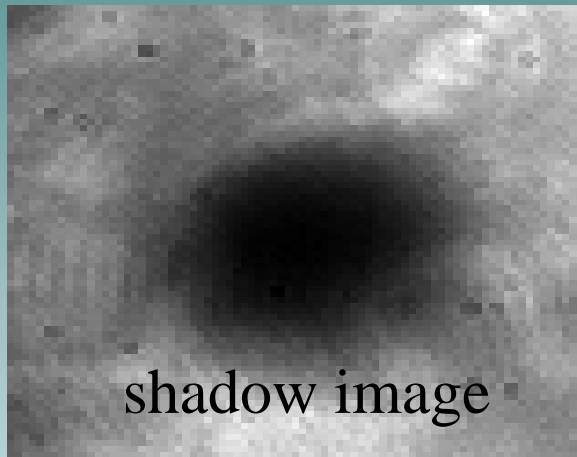
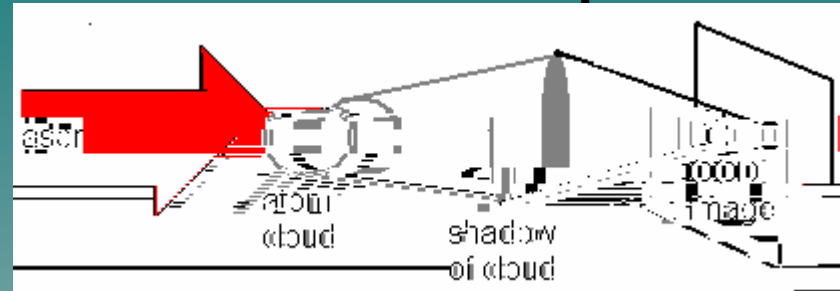
Lasers drift in frequency over time. Instantaneously, they are lasing at one frequency, but a time averaged signal shows something different.

- Reasons for drift: Electronic noise, Temperature drift, Air flow
- Want the laser's lineshape to be $< 1\text{MHz}$



Why is Frequency stabilization important?

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



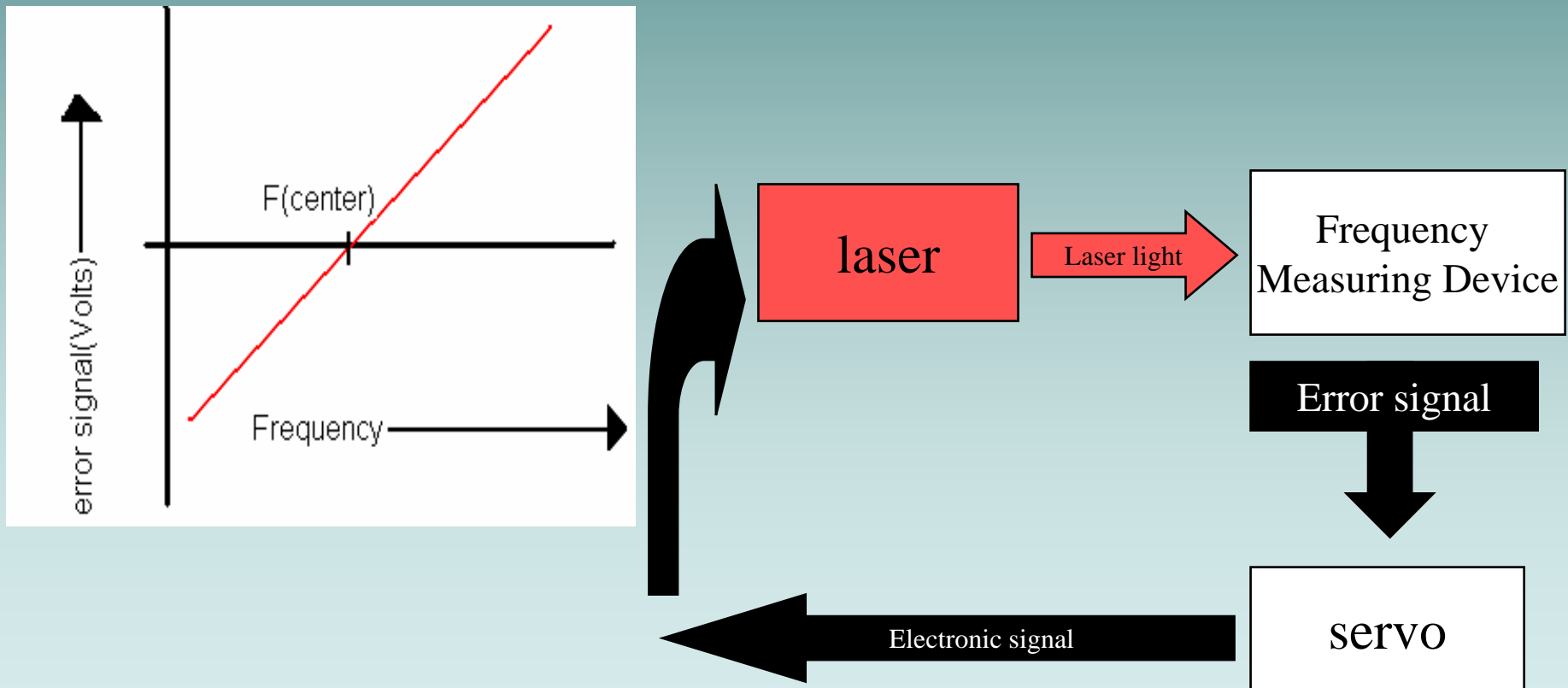
Zero equals resonant frequency

- The lineshape of the laser must be $>1\text{MHz}$

Feedback Loops

Controlling the laser:

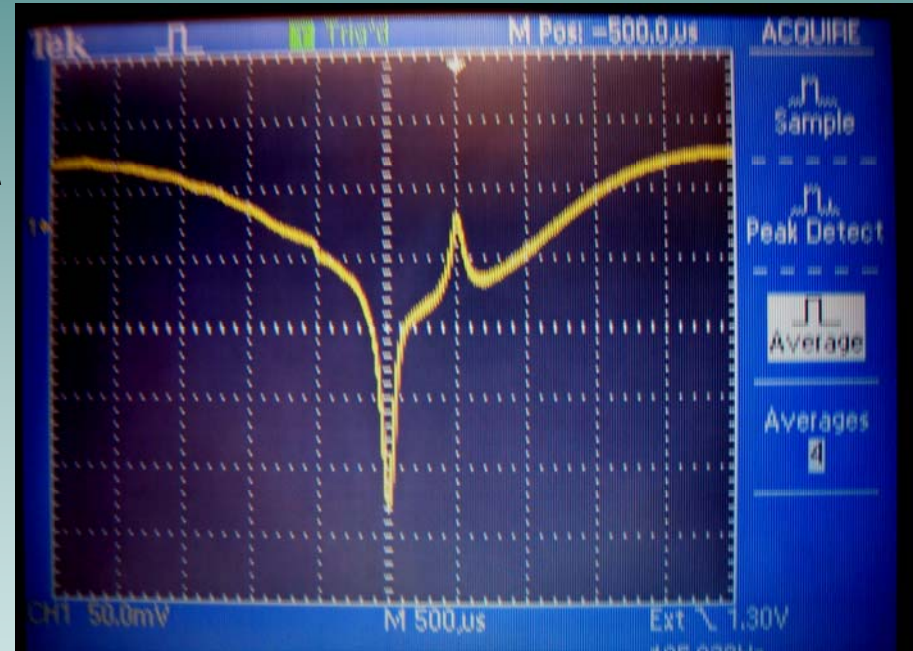
A feedback loop or “servo”



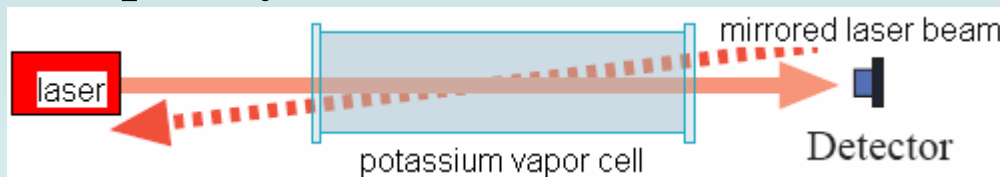
Saturated Absorption

- 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

↑ photodiode output voltage (mV)

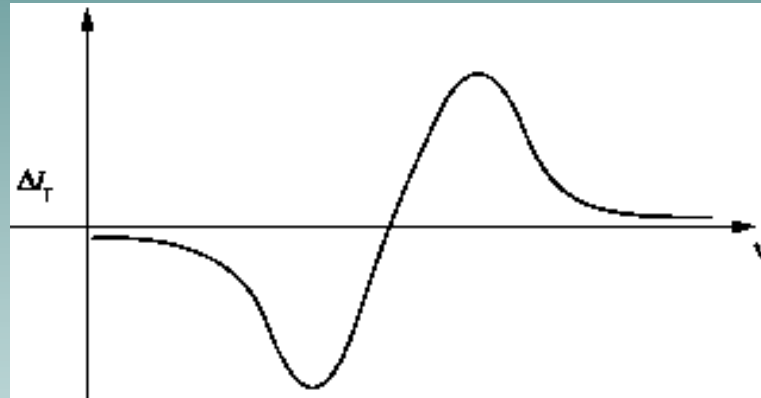
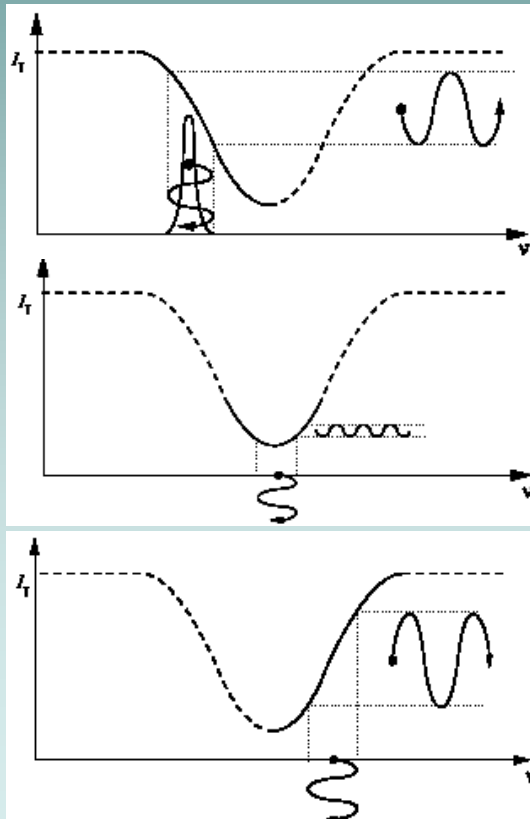


→ Frequency (Mhz)



Locking to the Peak

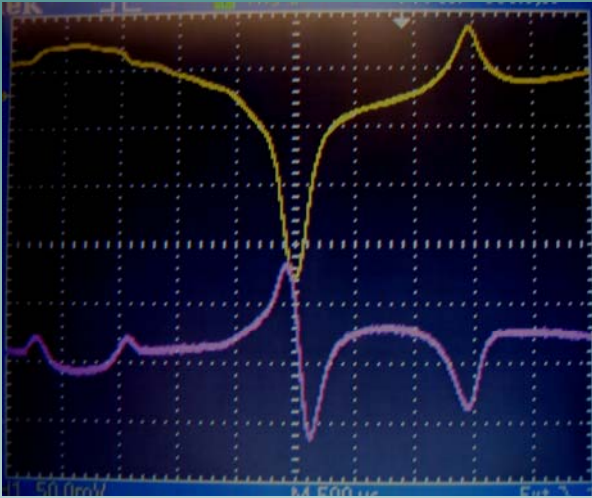
Frequency modulation : the wavelength of the laser is scanned across the atomic transition, and the wavelength modulation is seen as varying amplitude modulation.



- 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.