Laser Locking with Piezo Driven Frequency Modulation

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Saturated Absorption Spectroscopy

• Method of frequency stabilizing laser systems for many experiments in atomic physics, including atomic clocks, laser cooling, and Bose-Einstein condensates.

• There are multiple approaches, but we used a piezo electric transducer to phase modulate the laser light.
Doppler Broadening

\[ \Delta \omega = \omega_0 \left( \frac{v}{c} \right) \]
Doppler Effect and the Absorption Signal

- Doppler-broadened spectral lines
- Difference of the two signals to eliminate Doppler background
- Doppler-broadened spectral lines with hyperfine structures
- Doppler-free saturated absorption spectral lines
What is the error signal?

Expected error signal and absorption signal
Frequency Modulating Laser Beam

\[ E = E_0 \cos(\omega t + \delta \cos \omega_m t) \]
\[ \delta = \frac{2\pi A}{\lambda} \]
\[ E \approx E_0 \left[ \cos \omega t - \frac{\delta}{2} \left[ \sin(\omega + \omega_m)t + \sin(\omega - \omega_m)t \right] \right] \]
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Piezo Movement

Piezo translates in one axis while conserving volume
Initial Set Up
Interferometer Set Up
Interference Signals

Piezo scans up

Piezo scans down

piezo scan distance = 2\Delta L = \frac{\lambda}{2} \sin^{-1} \left(\frac{A}{A_0}\right)
Piezo Movement

Results

Amplitude vs. Frequency

- Frequency (kHz)
- Amplitude (mV)
Piezo Movement
Results

Comparing Scan Distances - Distance vs. Frequency

- Series 1
- Series 2
Unexpected Piezo Effect

Instead of simply translating, mirror was actually flexing as the piezo translated due to low rigidity of the mirror
Without feeding the piezo voltage, this is the interference seen at a DC offset of zero.
Interference
At Different DC Voltages

0 V 10 V 20 V 30 V 40 V
50 V 60 V 70 V 80 V 90 V
100 V 110 V 120 V 130 V 140 V
150
Interference
5,000 Hz

Modulated piezo and synchronized camera to take 10 pictures per cycle at 50 V
Interference
30,000 Hz

Modulated piezo and synchronized camera to take 10 pictures per cycle at 50 V
Current Set Up

Future Work
(Thursday and Friday)

Ring-shaped piezo – new approach which will hopefully fix the problem of the flexing mirror
Conclusion

• Although I wasn’t able to get the error signal and lock the laser successfully, I was able to determine why the set up wasn’t working properly
• Hopefully, I will be able to test the new piezo before I leave and see the dispersive error signal
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Questions?
Resources


• Article: “Doppler-free Saturated Absorption: Laser Spectroscopy” by Daryl W. Preston

• http://instructor.physics.lsa.umich.edu/adv-labs/Experiments_main.html article: “Doppler Free Saturated Absorption Spectroscopy”