Linewidth Measurement of the Model SDL-6702-H1 1083nm Diode Laser

Daniel Stack

Optics Rotation

October 24th 2007

What Is Linewidth?

- The short-term linewidth of a laser is typically defined as the full width at half maximum of the power spectral density of the laser's electric field with respect to frequency.[1]
- This is strongly related to the temporal coherence of the laser.
- A finite linewidth is the result of phase noise if the phase is left to drift unbounded. This may result from changes in the resonance cavity length.
- Mechanical and thermal effects contribute to broadening of the long-term linewidth.

(1) Encyclopedia of Laser Physics and Technology, RP Photonics, 9/23/07. http://www.rp-photonics.com/linewidth.html

Fundamental Limit of Linewidth

- The fundamental origin of phase noise is quantum noise. This results from spontaneous emission of the gain medium into the cavity modes as well as optical losses.
- Schawlow and Townes showed that this leads to a fundamental linewidth:

$$\Delta\nu_{laser} = \frac{\pi h\nu\left(\Delta\nu_c\right)^2}{P_{out}} \qquad (2)$$

$$\Delta\nu_c \equiv \nu_0/Q_c = (\beta/\pi)\Delta\nu_{axial} \qquad (3)$$

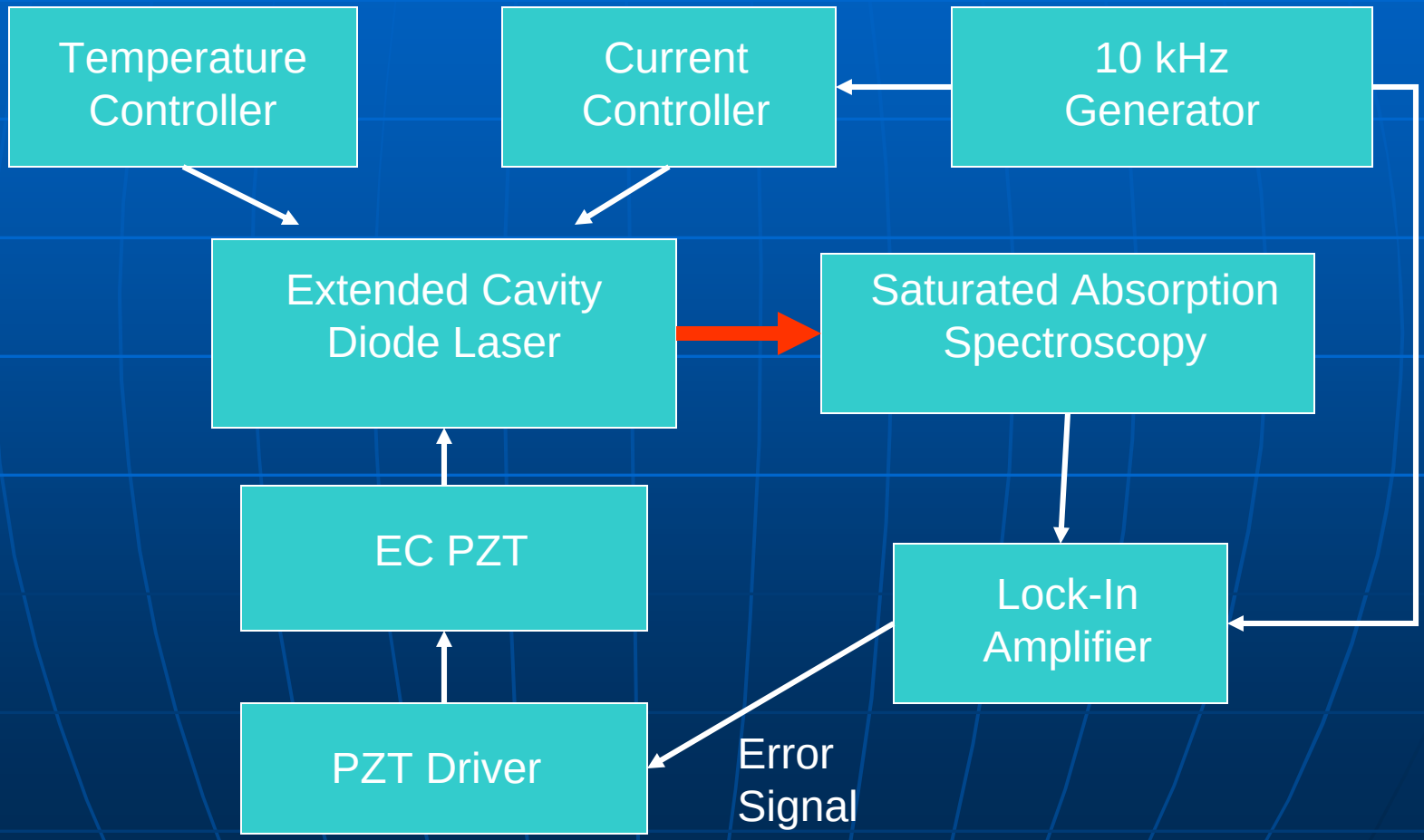
(2) A. L. Schawlow and C. H. Townes, "Infrared and optical masers", Phys. Rev. 112 (6), 1940 (1958)
(3) E. D. Hinkley and C. Freed “Direct Observation of the Lorentzian Line Shape as Limited by Quantum Phase Noise in a Laser above Threshold,” Phys. Rev. Lett. 23 (1969)

Ways to Measure Linewidth

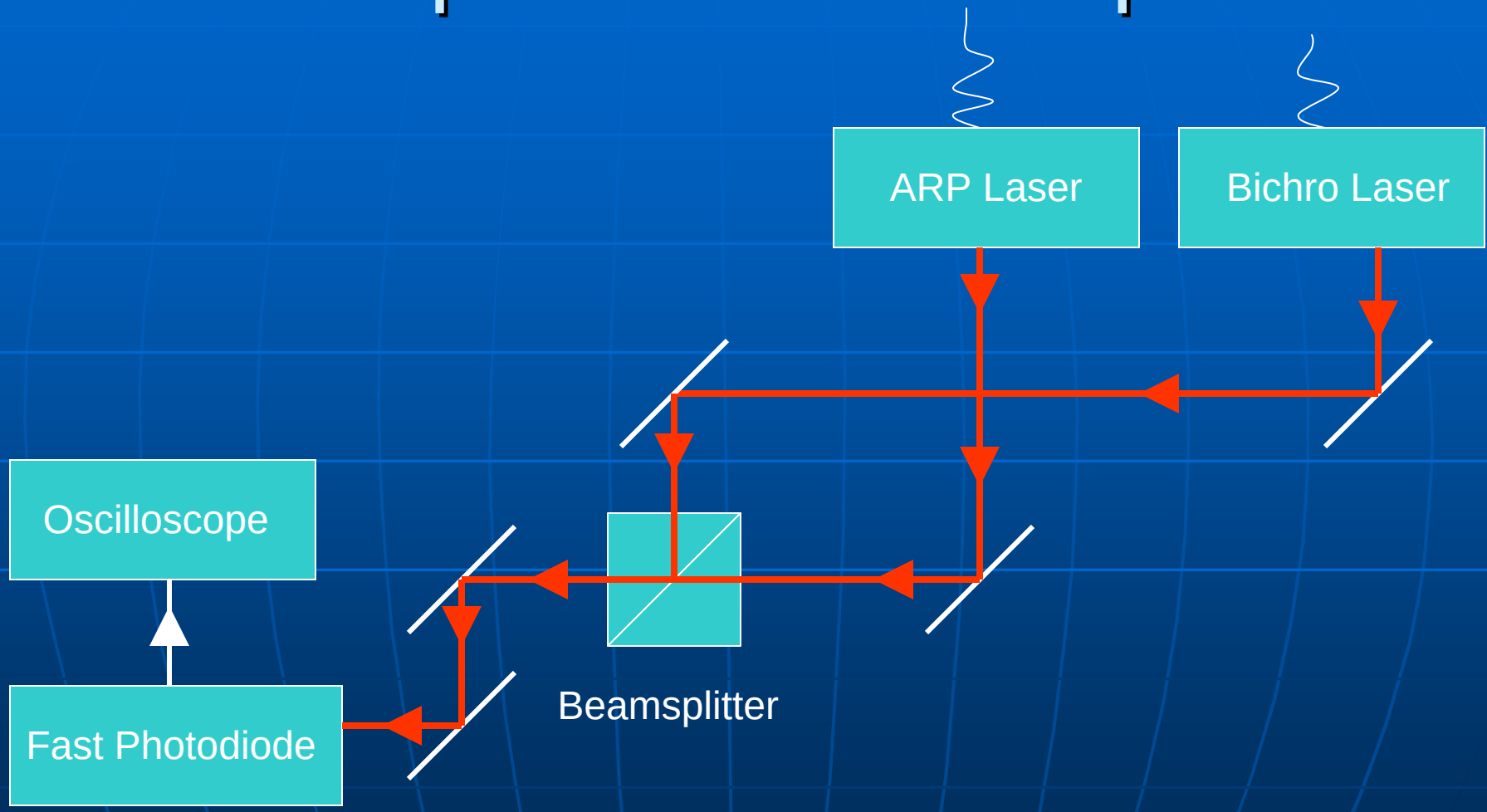
- For a single frequency laser, a self-heterodyne technique may be used. One observes a beat note between the laser and a time-delayed, frequency-shifted version of itself. The time delay must be longer than the temporal coherence of the laser.

- When this is impractical, one may beat a laser with another laser. This laser must either have either a very small linewidth, or the two lasers must have very similar performance.

Stabilization of the Diode Laser



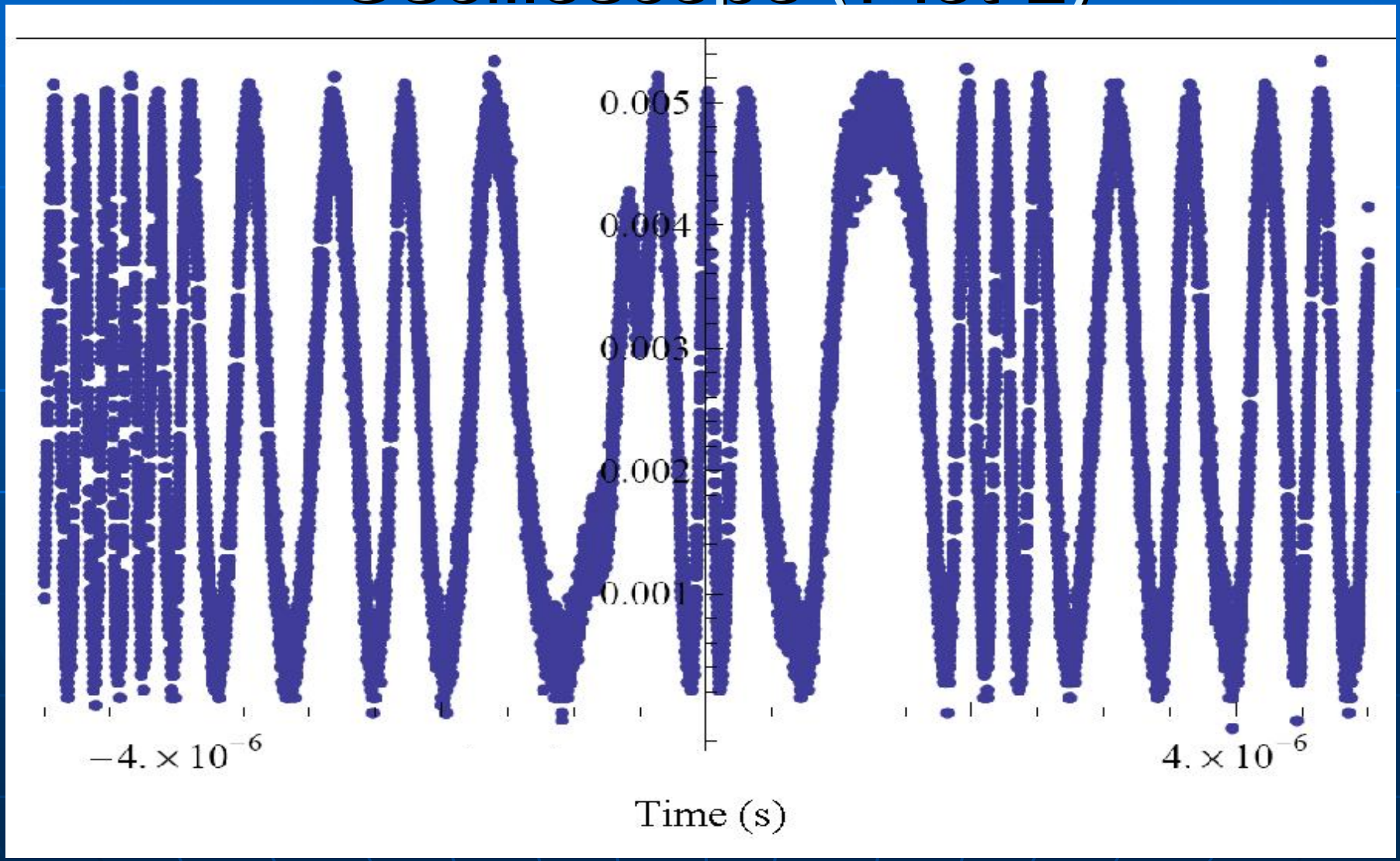
Experimental Setup



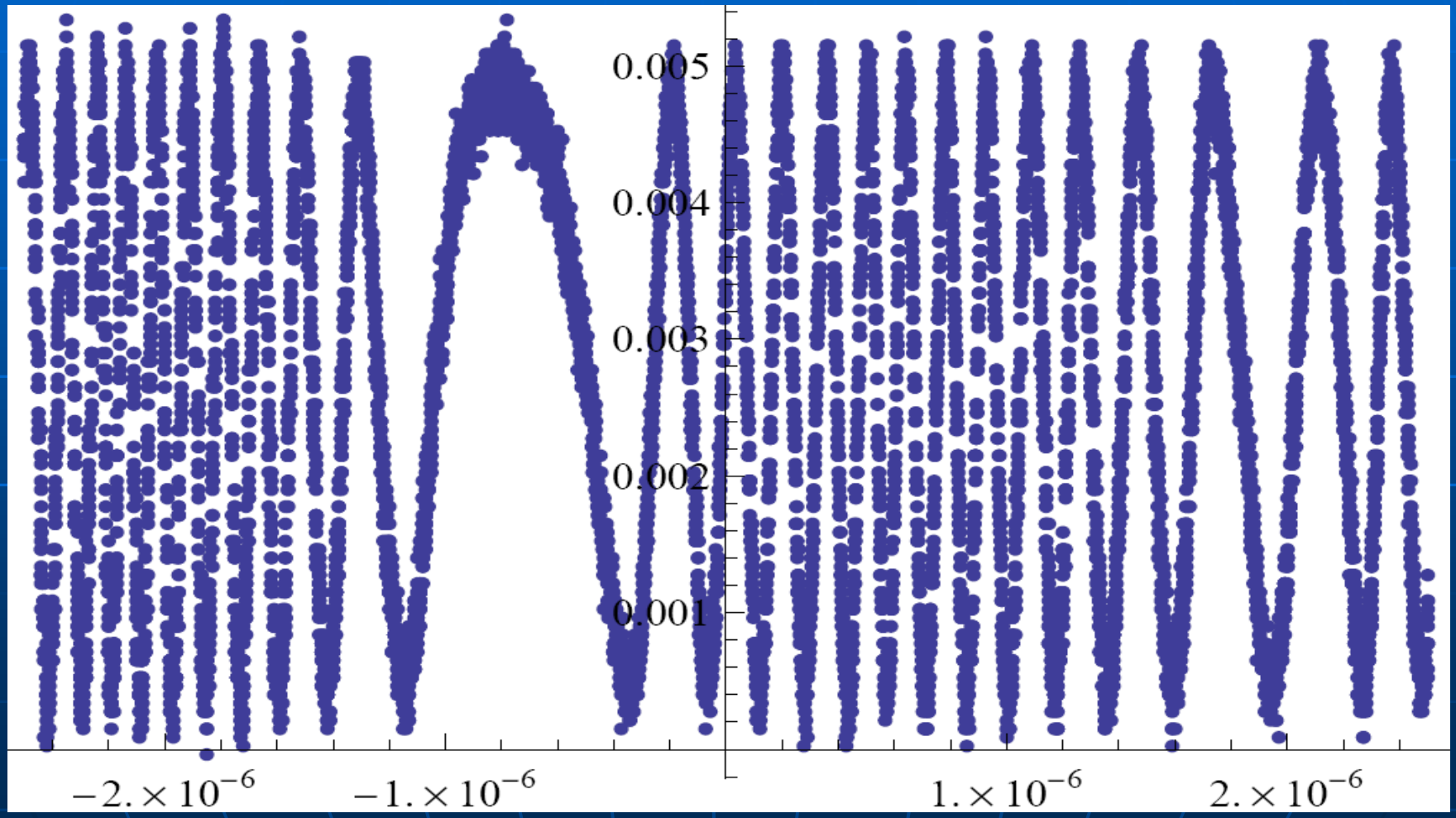
Methods

- Both lasers are locked to the 1083nm transition of helium.
- A ramp signal with frequency 35Hz is applied to one diode lasers so that its frequency changes with respect to time.
- Polarization for each laser is controlled by orientation of optical fibers so they have identical polarizations.
- Lasers are combined onto a fast InGaAs photodetector (ThorLabs D400FC).
- A beat frequency occurs when the optical spectra of the lasers don't overlap. An interference pattern is observed when they do overlap.

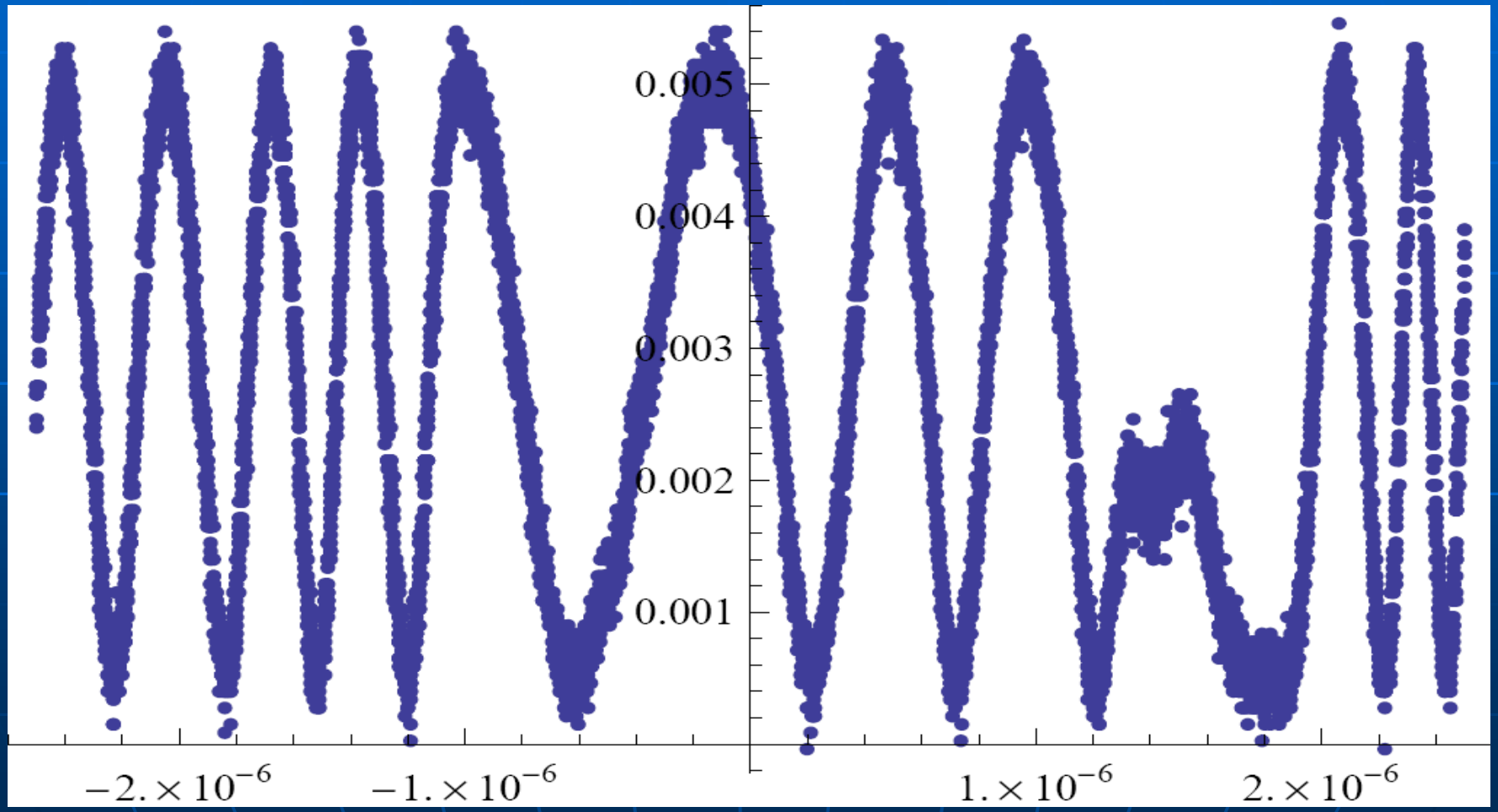
Laser Beat Signal as Seen on Oscilloscope (Plot 1)



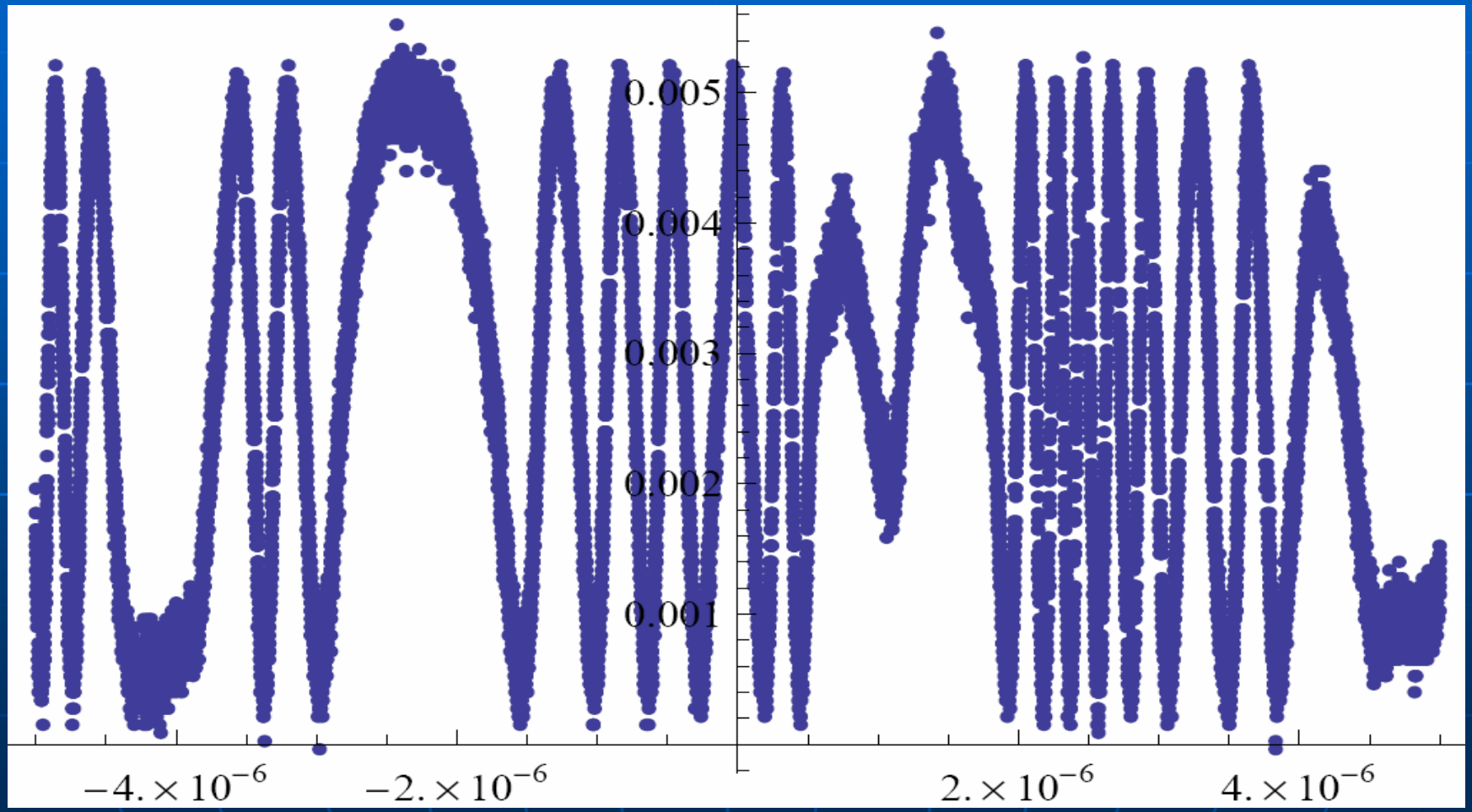
Laser Beat Signal as Seen on Oscilloscope (Plot 2)



Laser Beat Signal as Seen on Oscilloscope (Plot 3)



Laser Beat Signal as Seen on Oscilloscope (Plot 4)



Linewidth of the Diode Laser

- The combined linewidth of the two lasers is roughly given by the lowest measurable beat frequency.
- Since the two lasers have similar configurations and a Lorentzian shape, the linewidth observed should be twice the linewidth of an individual laser.
- In the first plot, the smallest beat frequency was 600KHz. Therefore the approximate linewidth of just one diode laser would be 300KHz.
- This is much smaller than the width of the helium transition in question (1.6MHz).
- However, others plots give conflicting results. There are multiple overlap regions. Also the beat frequency does not always change linearly.

Acknowledgments

- I would like to thank Claire and Jason for all of their hard work and substantial help in making this project a success.

- I would also like to thank Professor Metcalf for allowing me the opportunity to pursue this topic as well as for his insightful advice throughout the course of this project.

References

- A. L. Schawlow and C. H. Townes, "Infrared and optical masers", Phys. Rev. 112 (6), 1940 (1958)
- E. D. Hinkley and C. Freed “Direct Observation of the Lorentzian Line Shape as Limited by Quantum Phase Noise in a Laser above Threshold,” Phys. Rev. Lett. 23 (1969)
- M. Cashen, “Optical Forces on Atoms in Polychromatic Light Fields,” (PHD Thesis, SUNY Stony Brook, 2002).
- Encyclopedia of Laser Physics and Technology, RP Photonics, 9/23/07. http://www.rp-photonics.com/linewidth.html