LASER OPTICS INTERFEROMETRY

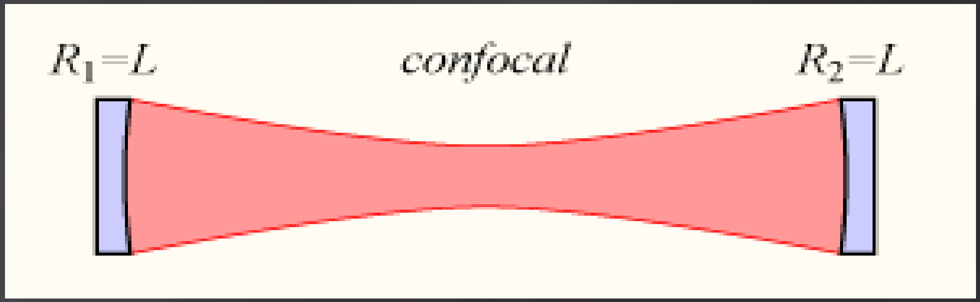
Kristen Brockway
Florida Institute of Technology
Daniel Elliott

The Nature of Light

- Constructive Interference is when waves of the same phase interfere such that their amplitudes add.
- Destructive Interference is when waves of a phase shift of π interfere such that their amplitudes cancel to zero.
- Resonance is the tendency of a system to oscillate with larger amplitude at some frequencies over others.
  - Used in laser cavities to stimulate the gain medium to emit photons
  - Used in interferometers to affect the outgoing transmission out of the cavity

Fabry-Perot Interferometer

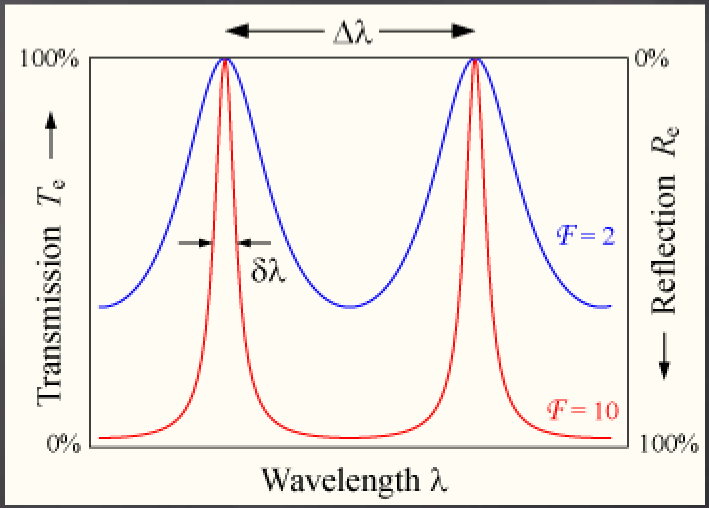
- Is made of a transparent plate of two reflecting surfaces or two parallel highly reflecting mirrors



- This form of cavity is a standing wave cavity

Fabry–Perot Interferometer

- The distance between peaks is known as the Free Spectral Range (FSR).



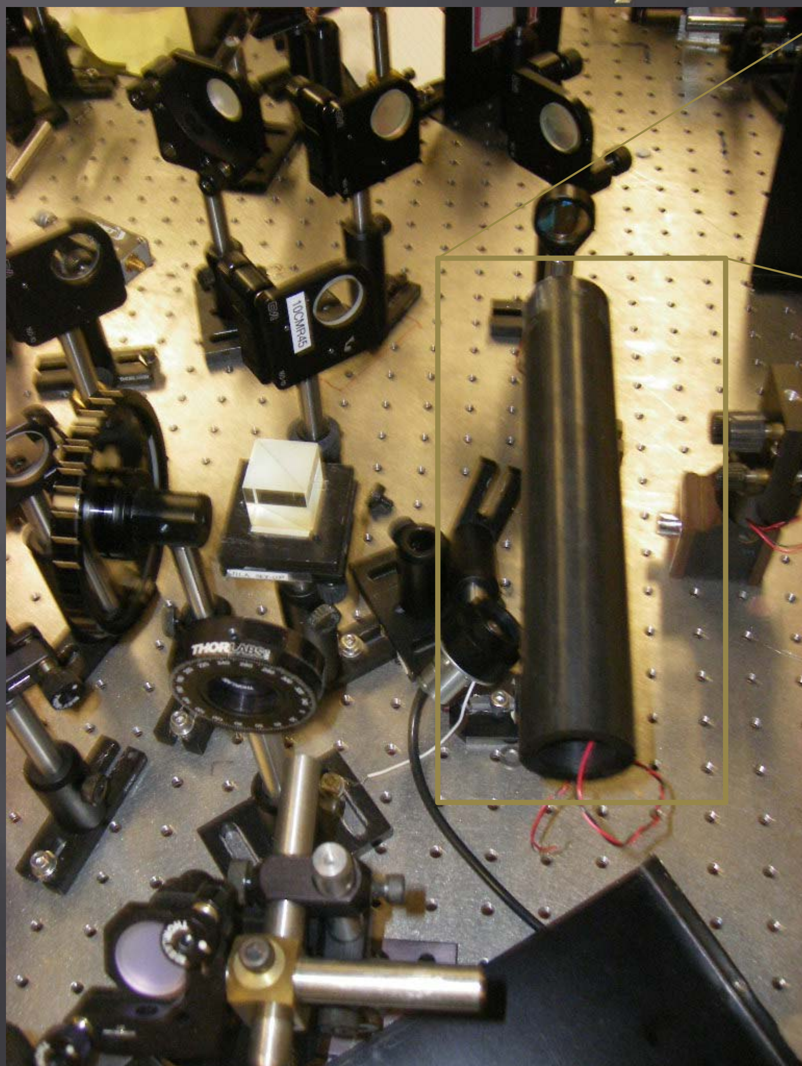
$$FSR = \frac{c}{2nl}$$

Interferometers are categorized by their Finesse.

$$FSR = \Delta\lambda$$

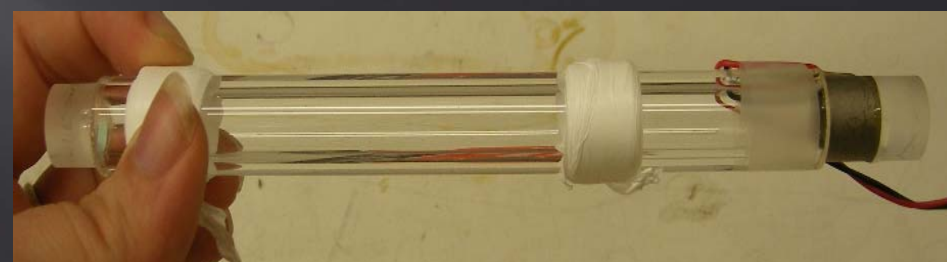
$$\mathcal{F} = \frac{FSR}{\delta\lambda}$$

Fabry-Perot Cavity



The optics setup for the interferometer with Arthur Mill's cavity

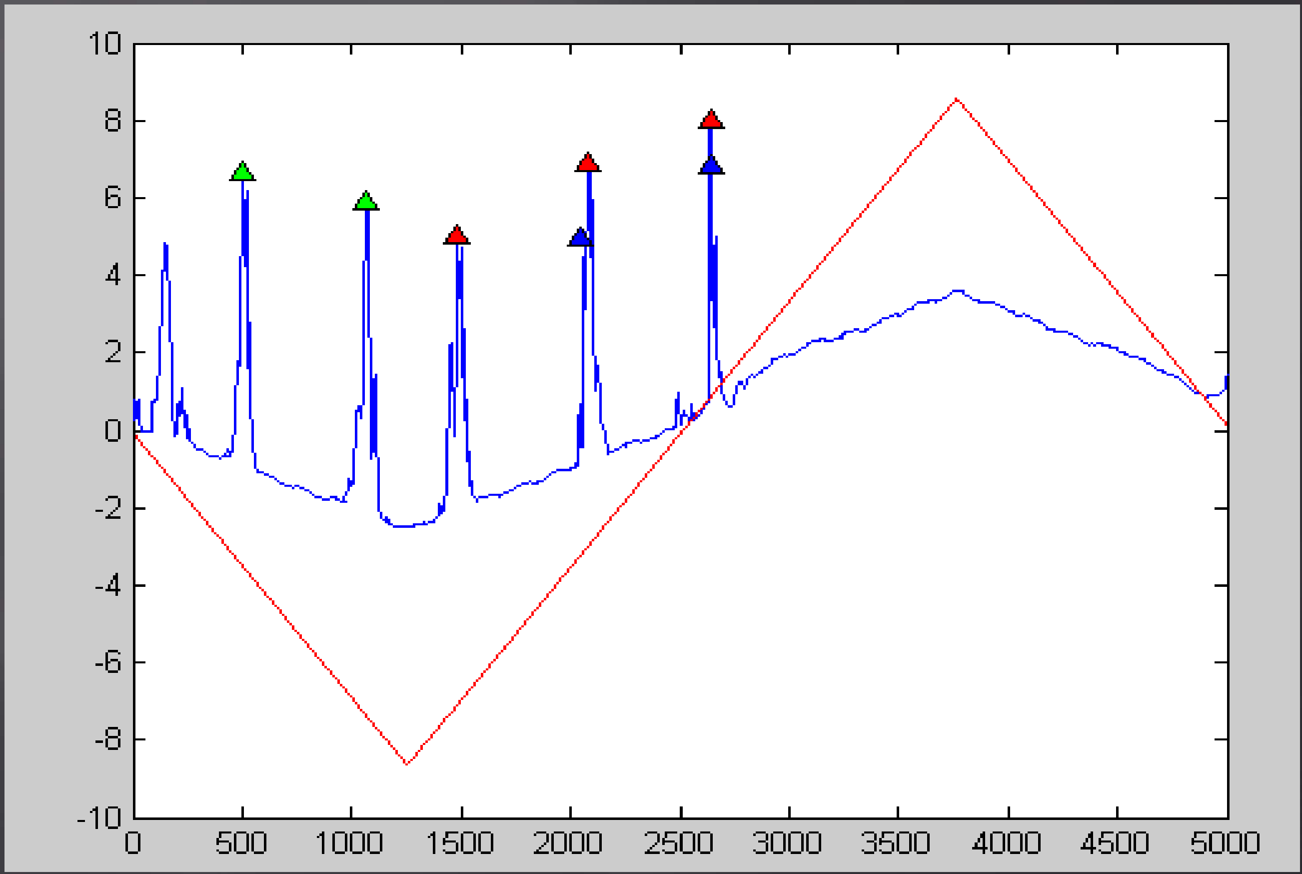
The Fabry-Perot Interferometer Case



The Fabry-Perot Interferometer Cavity

The Source Laser
780nm

Fabry-Perot Data



FSR (in data points)

567 units – Distance between green triangles

Red triangles are peaks of another ramp set (increasing)

Blue triangles are predicted peak locations based on green FSR

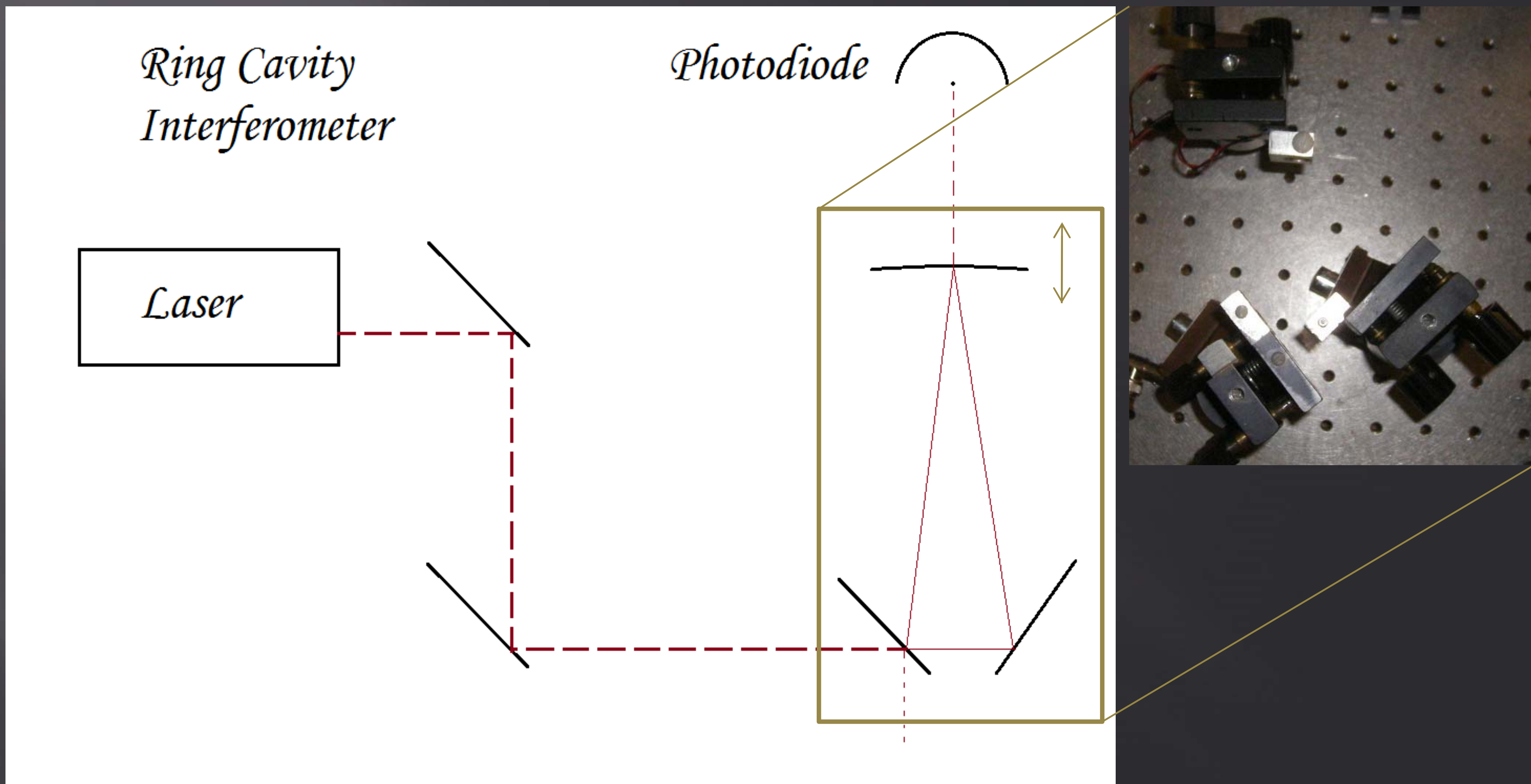
The blue line is the laser output through the cavity

The red line is the ramp output

FSR (red1) = 597 ~ 5.29%

FSR (red2) = 561 ~ -1.06%

Ring Cavity Set-up

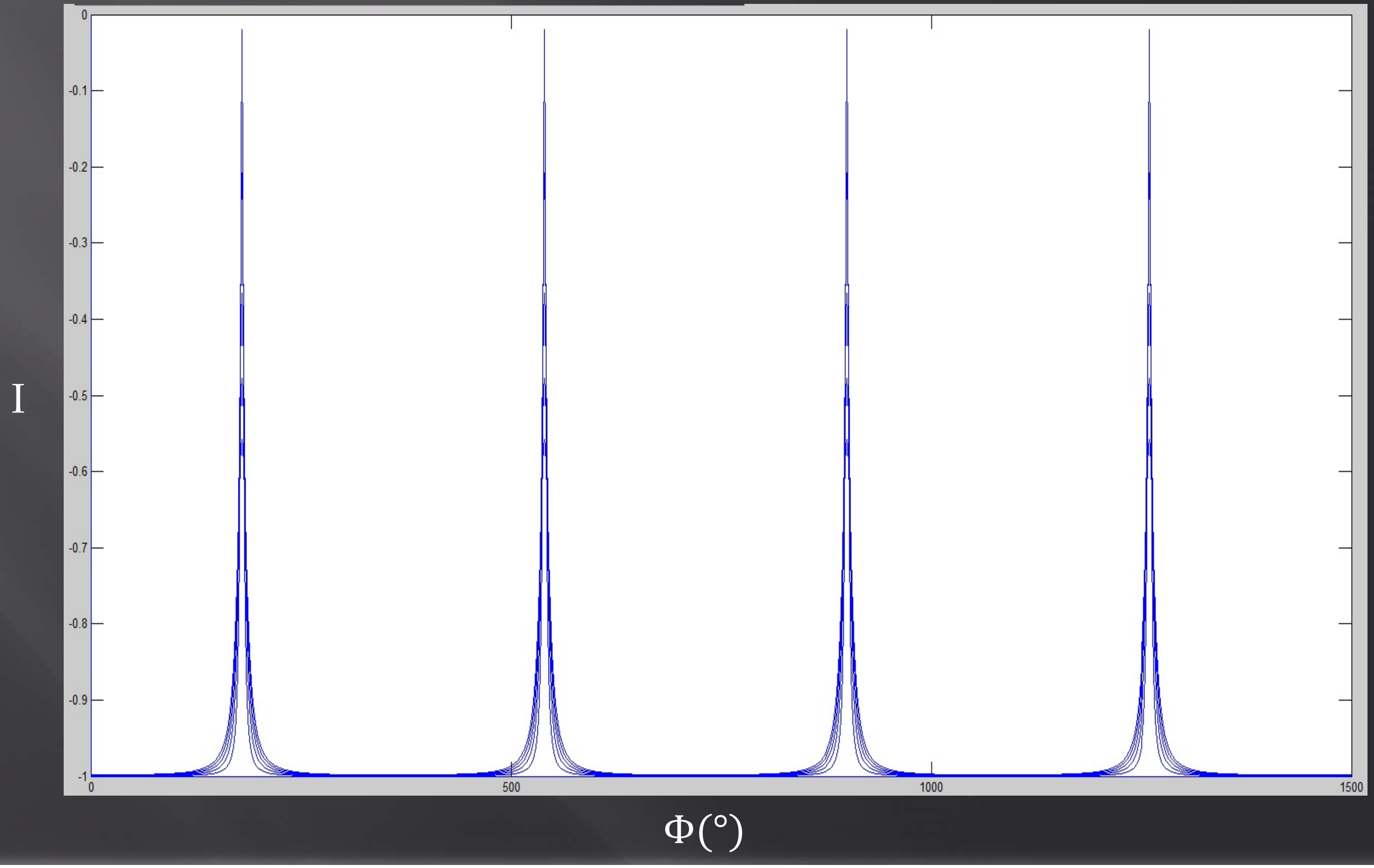


The Ring Cavity Setup (traveling wave)
Diagram (left) and photo (right)

Expected Results

$$I = \frac{r^2 + L^2 + 2rLcos(\varphi)}{1 + L^2r^2 + 2rLcos(\varphi)}$$

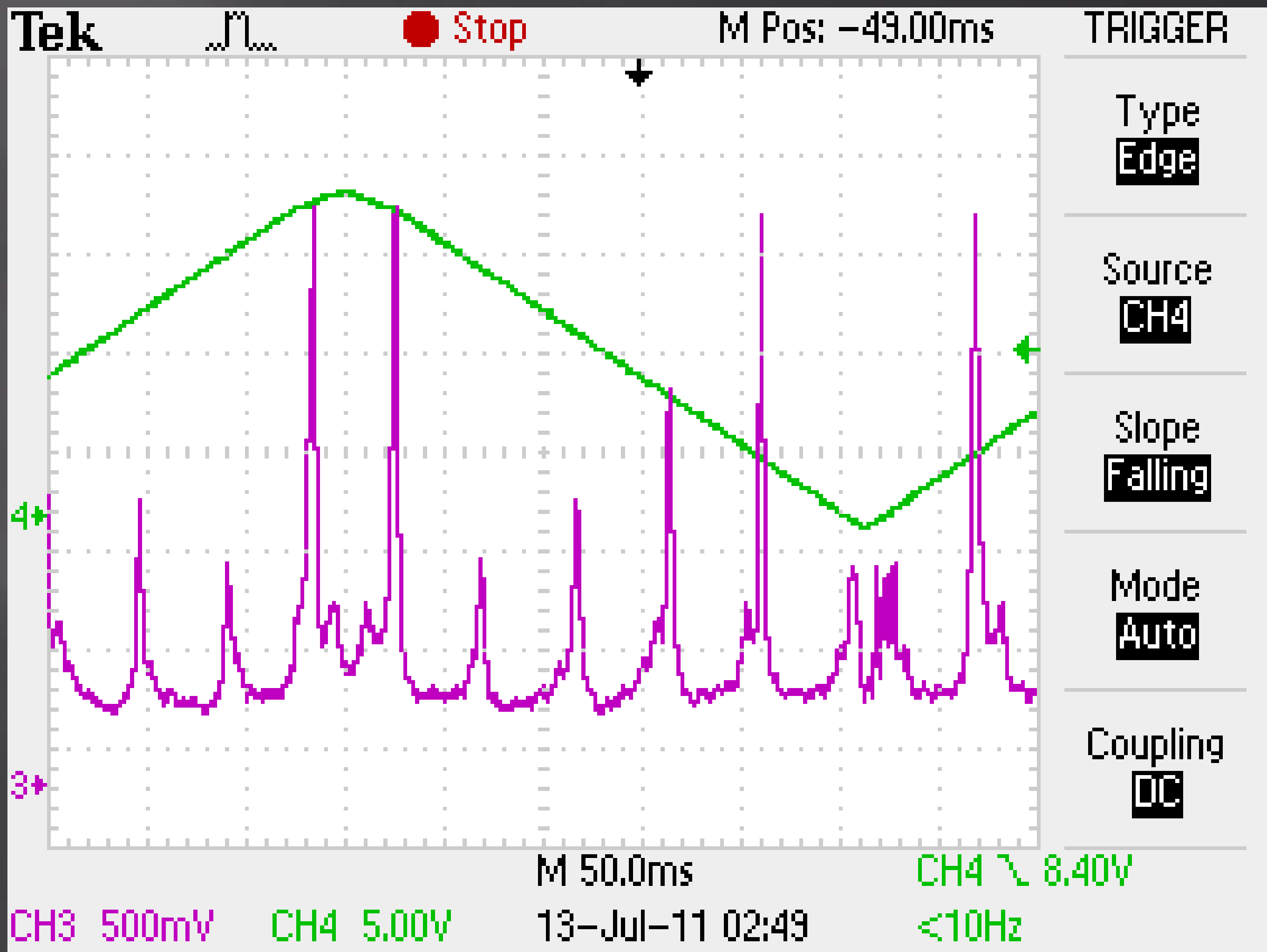
Where,
r = 0.97
L = 0.90 : 0.02 : 1.00



Alignment

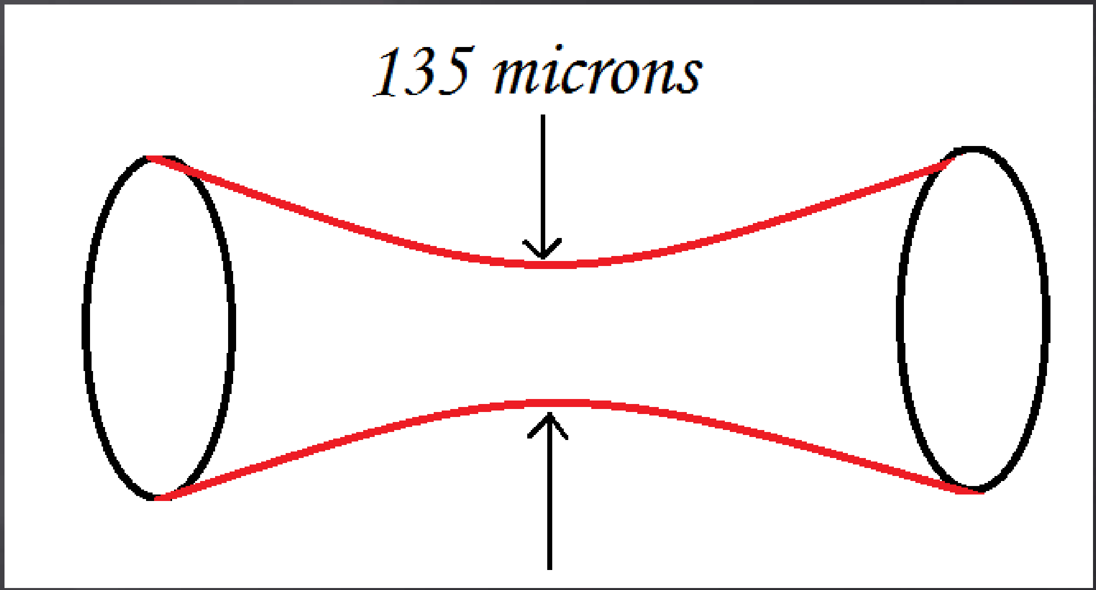
- The hardest part is the first mirror
  - The laser beam has to travel through this mirror, roughly in the middle
  - Beam hits the back side of the mirror off-center and refracts to the center on the other side
- The second mirror has to be placed close to the first mirror and the beam needs to hit close to the center
  - The first and second mirrors are roughly 2 cm apart.
- The third (concave) mirror must be between the two and direct the beam back at the first mirror

The Actual Results



Optimization

- Waist – the smallest point of the focused beam



- In order to achieve the waist diameter best suited to my cavity, it is necessary to optimize the beam and reduce noise

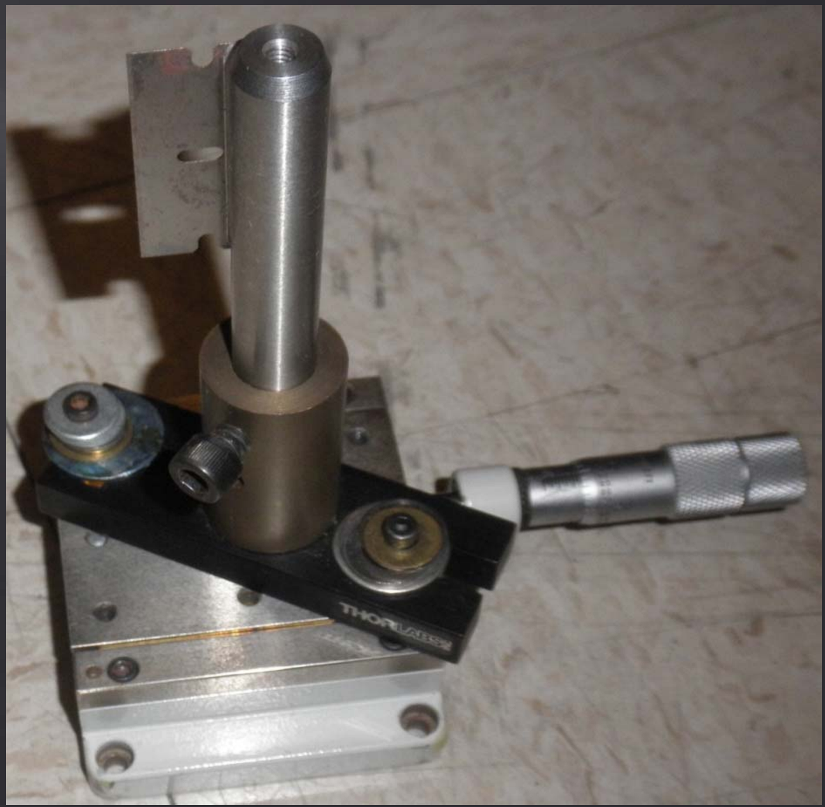
Optimization

- Reduce the size of the original beam with an iris
- This not only reduces the size of the waist but ensures the beam is circular

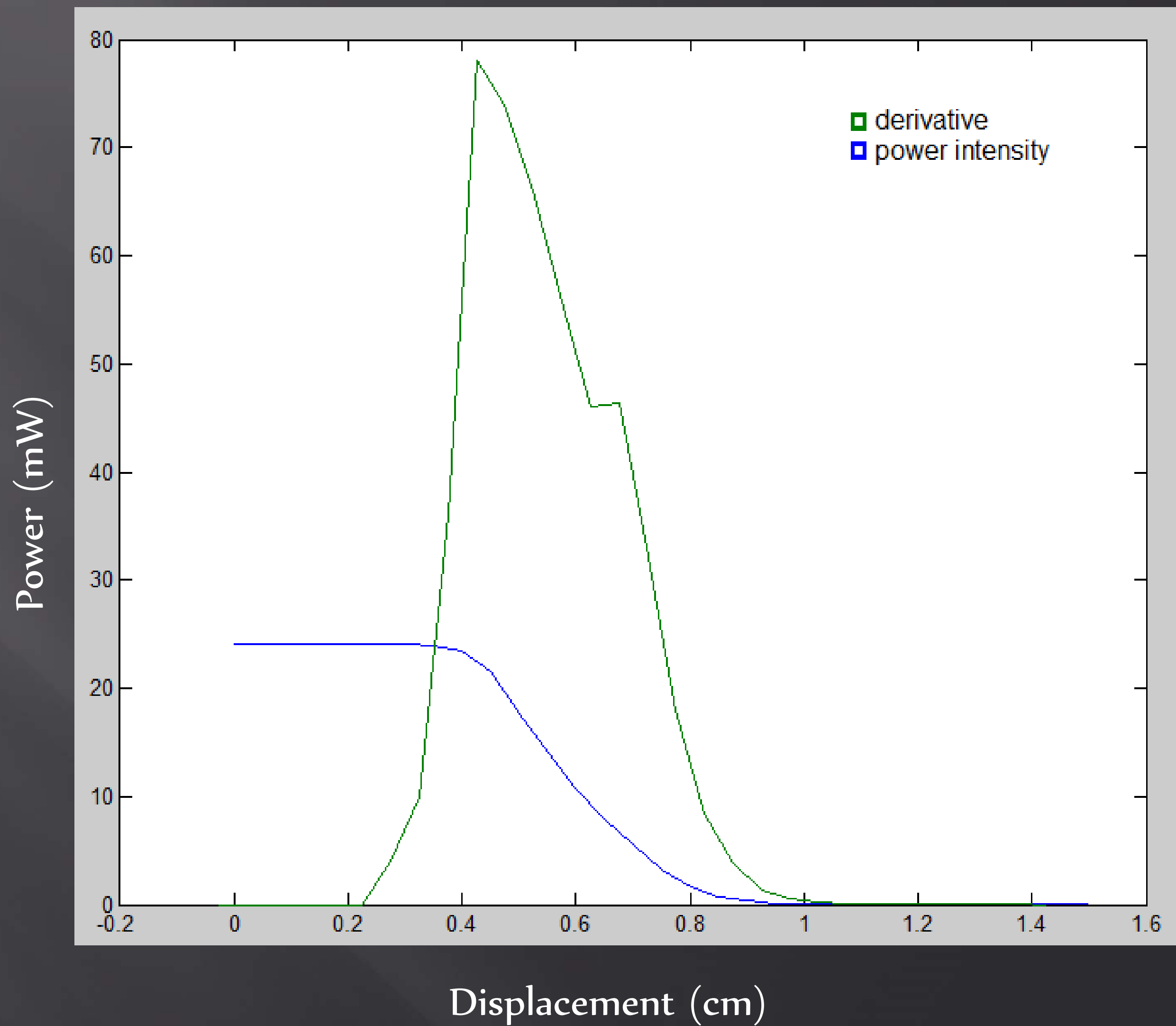
- The iris reduces the beam to a size of 0.6 mm
- The beam needs to be further optimized with a lens
  - But which lens?

Razor Blade Test

- The Razor Blade Test
  - As the razor blade moves in the path of the beam, the power intensity is recorded
  - The displacement and the intensity can be recorded and then plotted
  - The results are then differentiated and given a fit

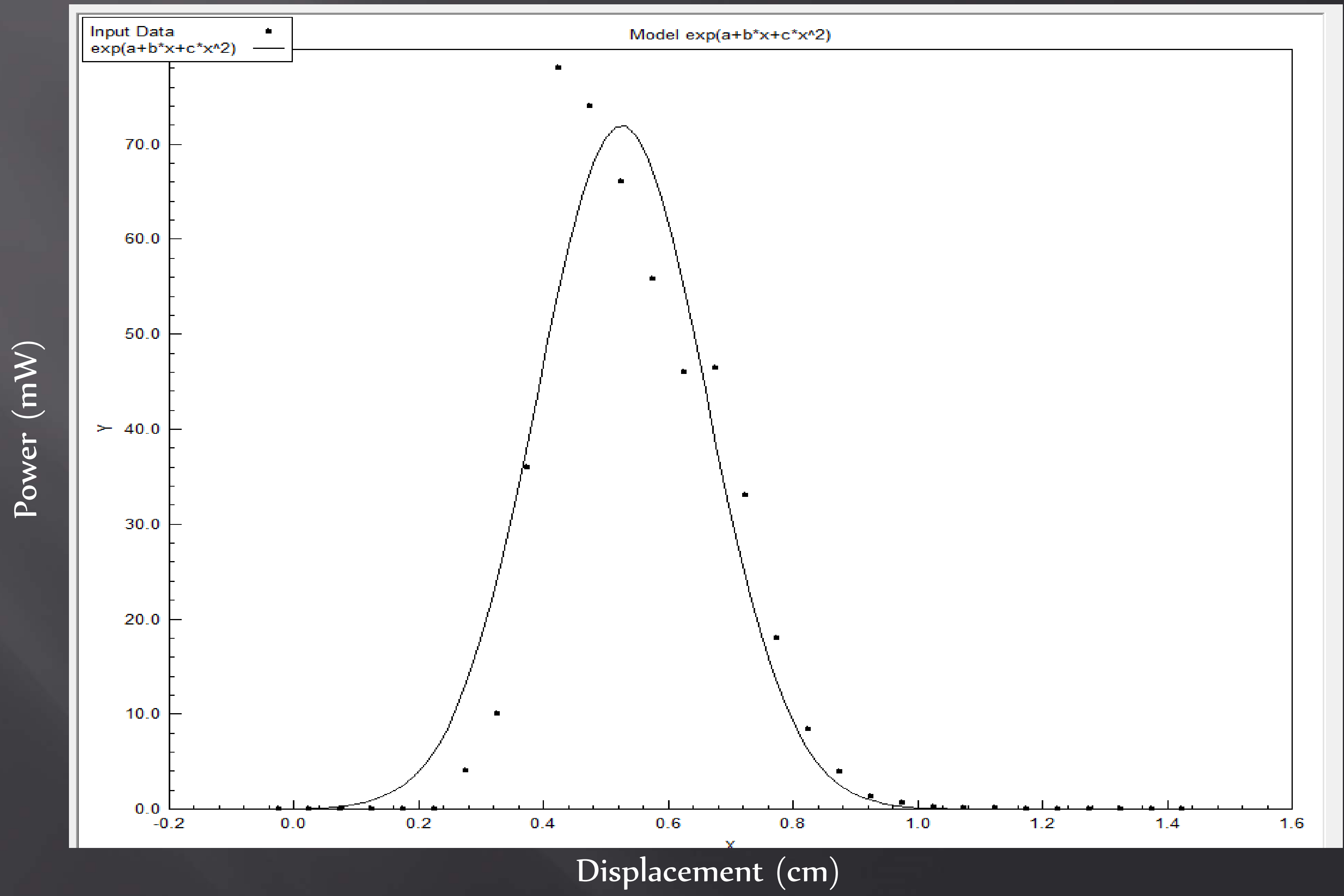


Razor Blade Test

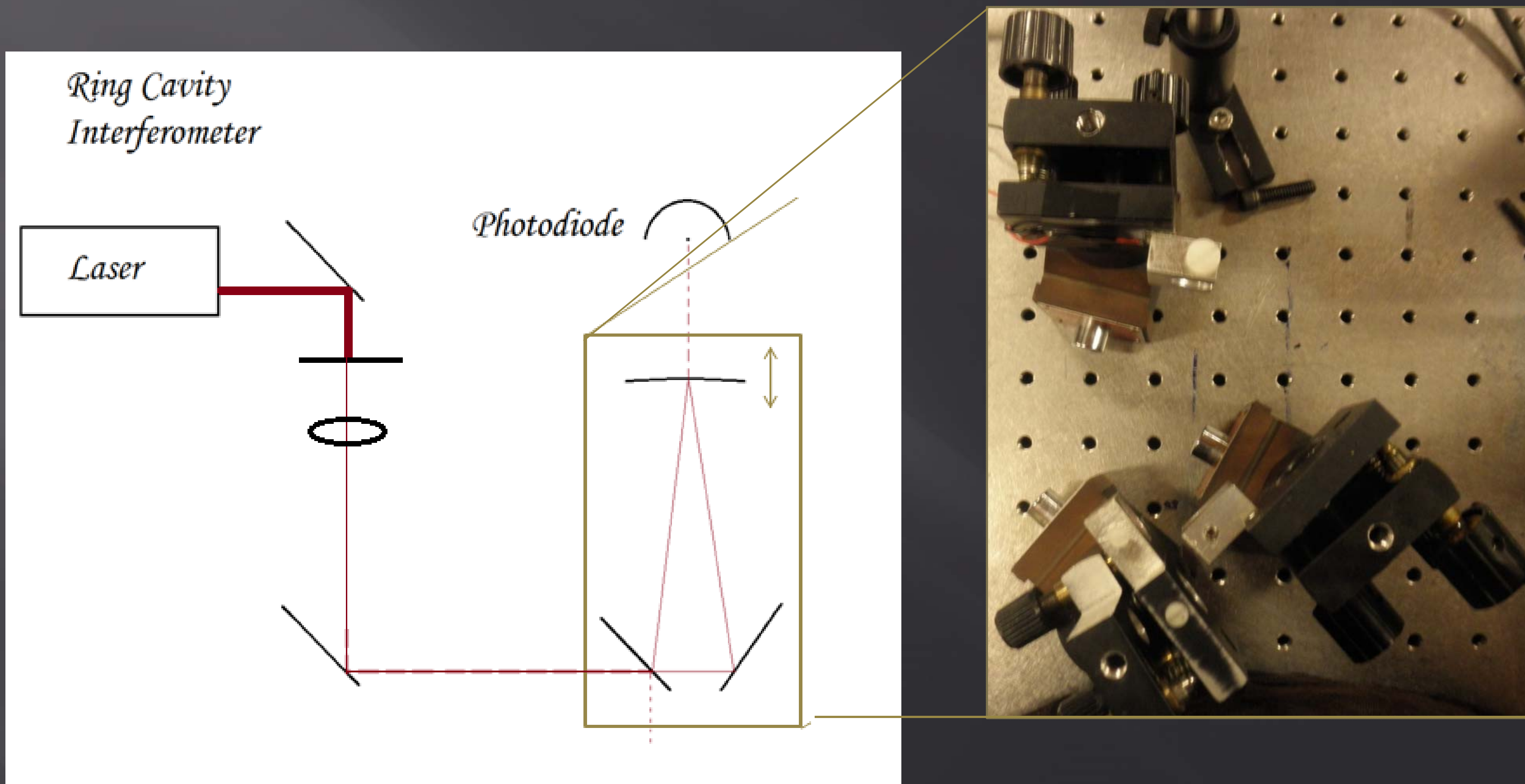


The data then needs to be fit to a Gaussian curve distribution

Razor Blade Test

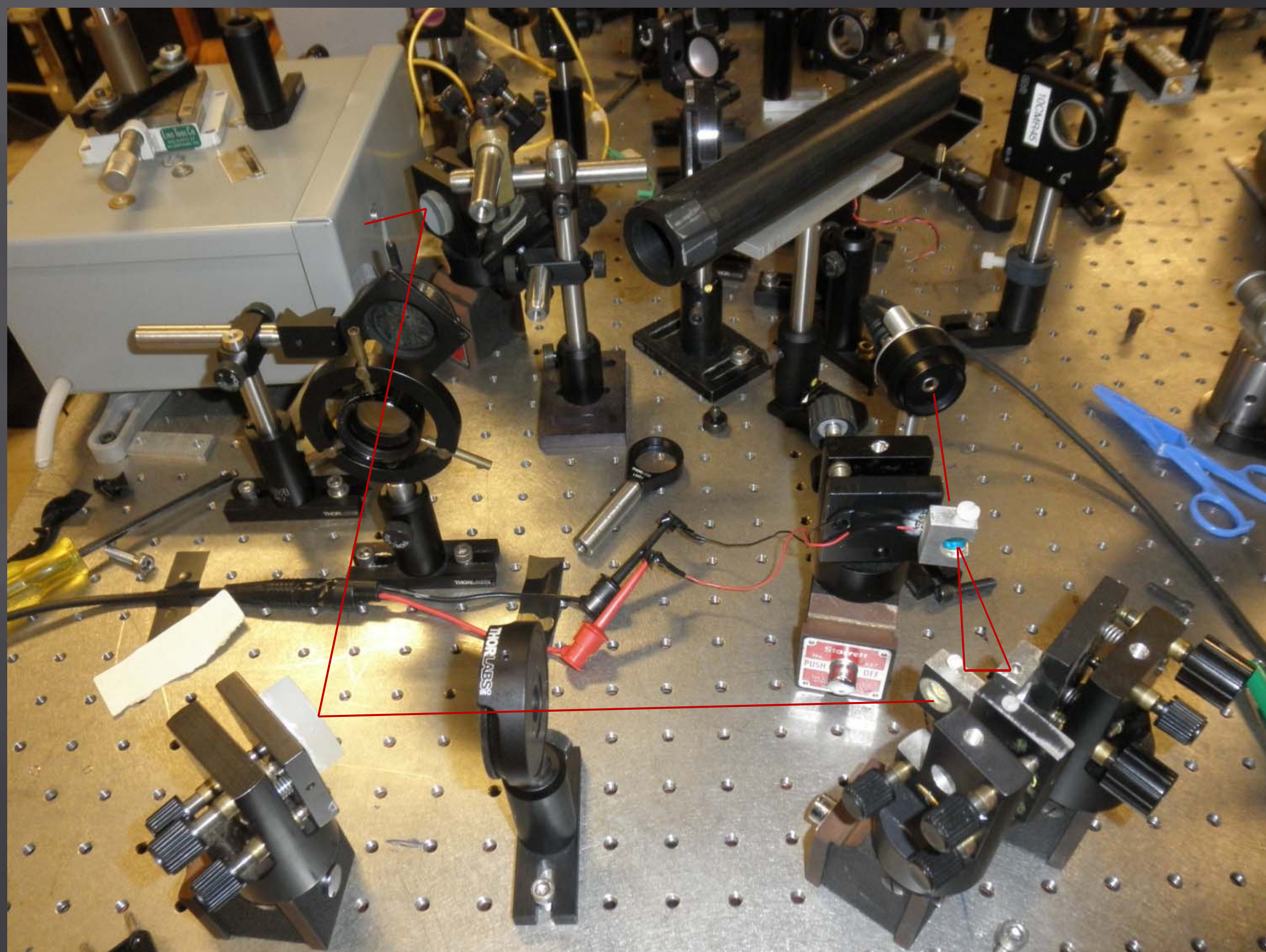


Ring Cavity Setup Revisited



The Ring Cavity Setup (traveling wave)
Diagram (left) and photo (right)

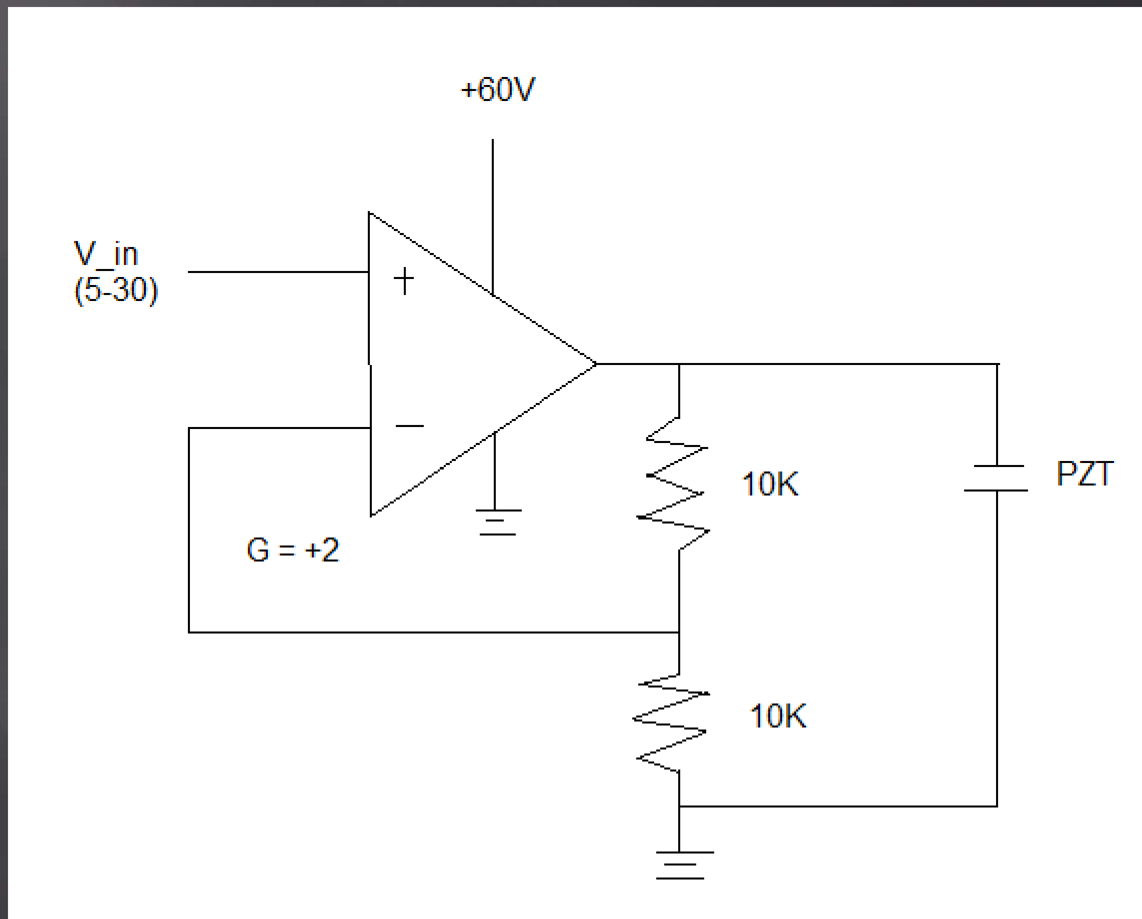
Ring Cavity Setup Revisited



Reaching the FSR

- Now that the beam was optimized and aligned correctly peaks were seen.
- But there was another problem
- The range of voltage going to the piezo was not enough to see an entire Free Spectral Range of the cavity.
- What could be done?
  - Design a circuit to amplify the voltage of the piezo
- What range is needed?
  - 35V

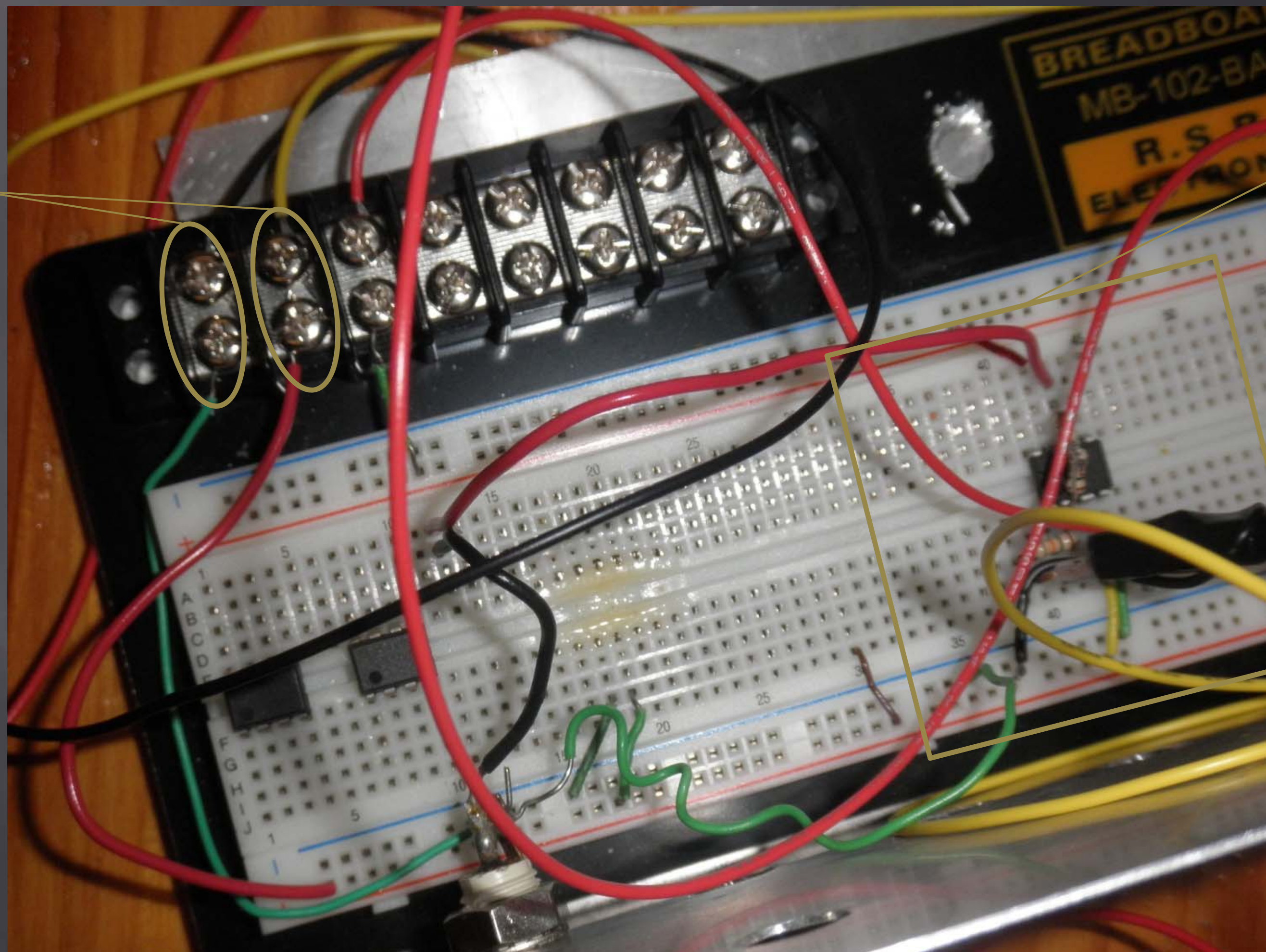
The Circuit Design



The circuit would amplify the ramp voltage going to the piezo by a gain of 2. The piezo would see a voltage of 10 to 60V. This however did not work for multiple reasons

The Circuit

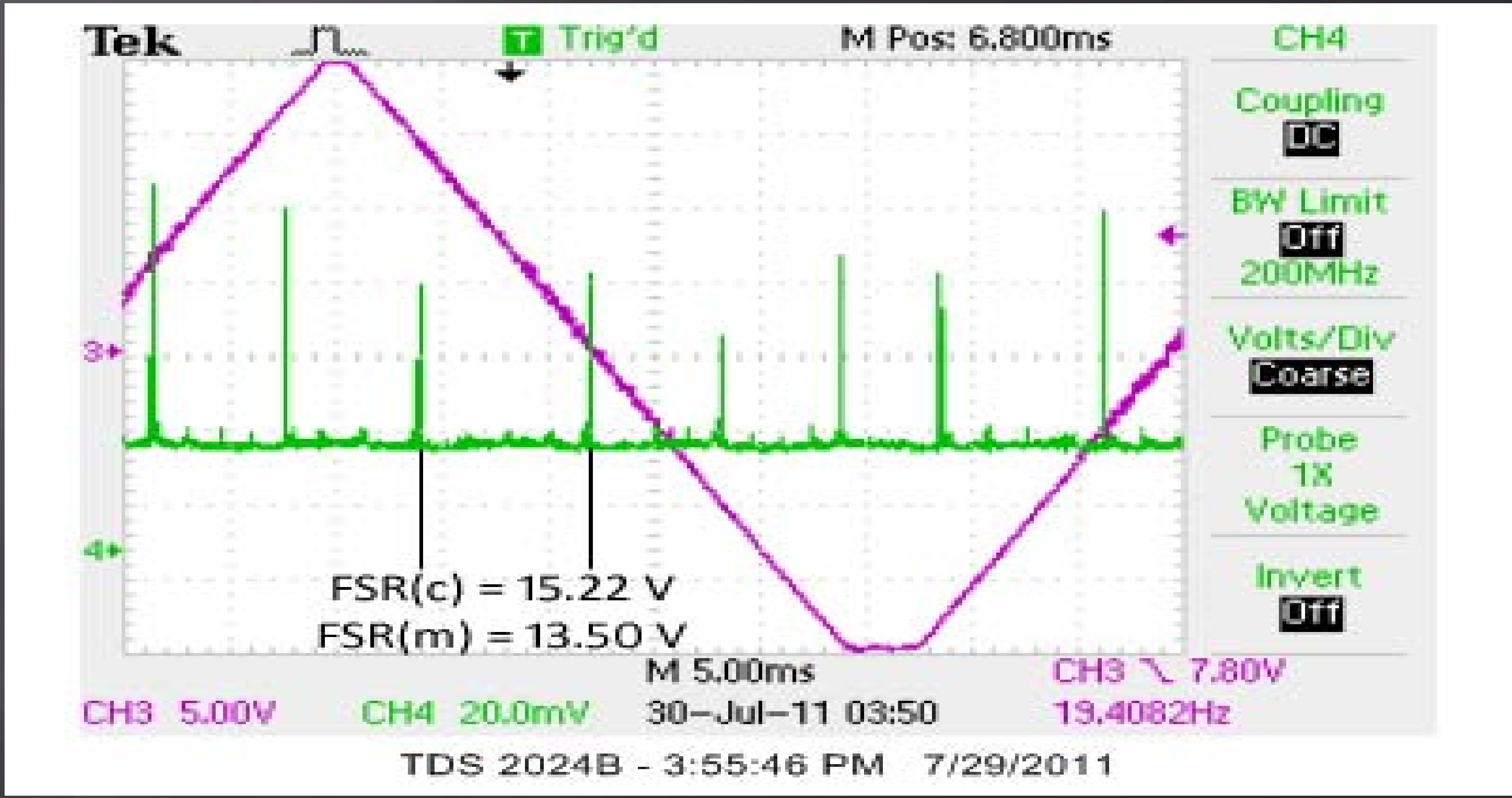
The black wire is ground to the PZT, while the yellow wire is ground to the OPA



The important part of the circuit board

Results

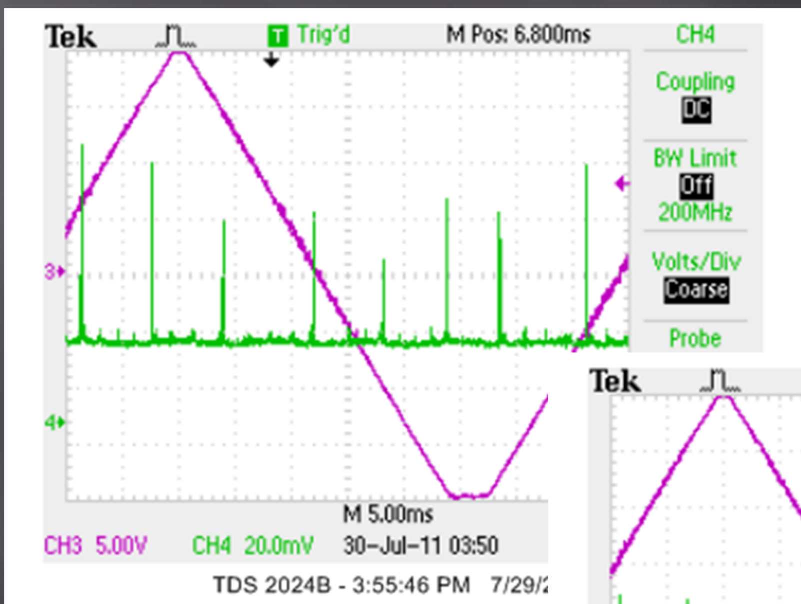
- FSR calculated = 15.2V FSR measured = 13.5V

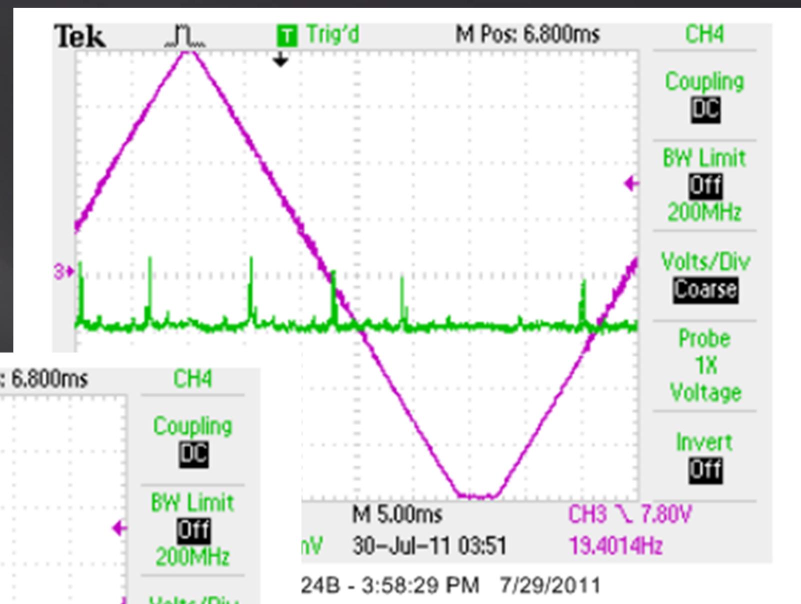


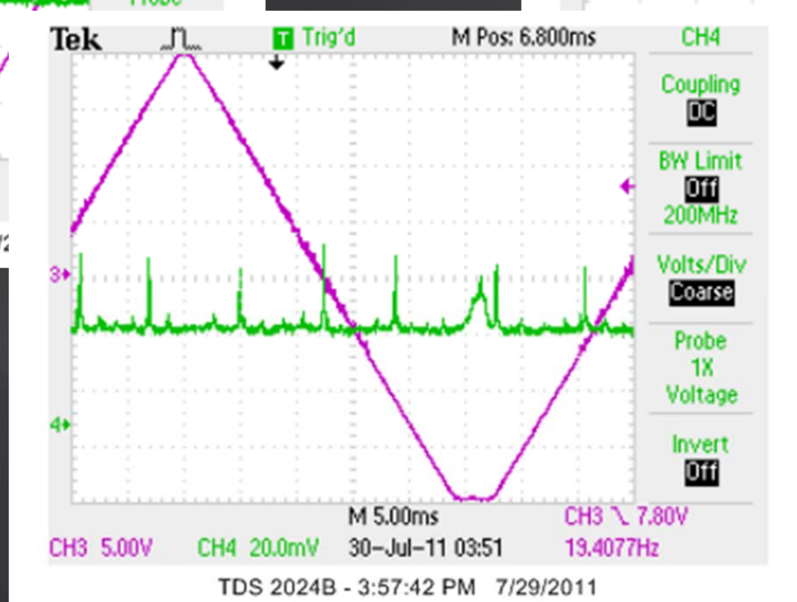
- The percent difference is 12%

Polarization

- The different polarizations of a ½ waveplate changes the peaks shown

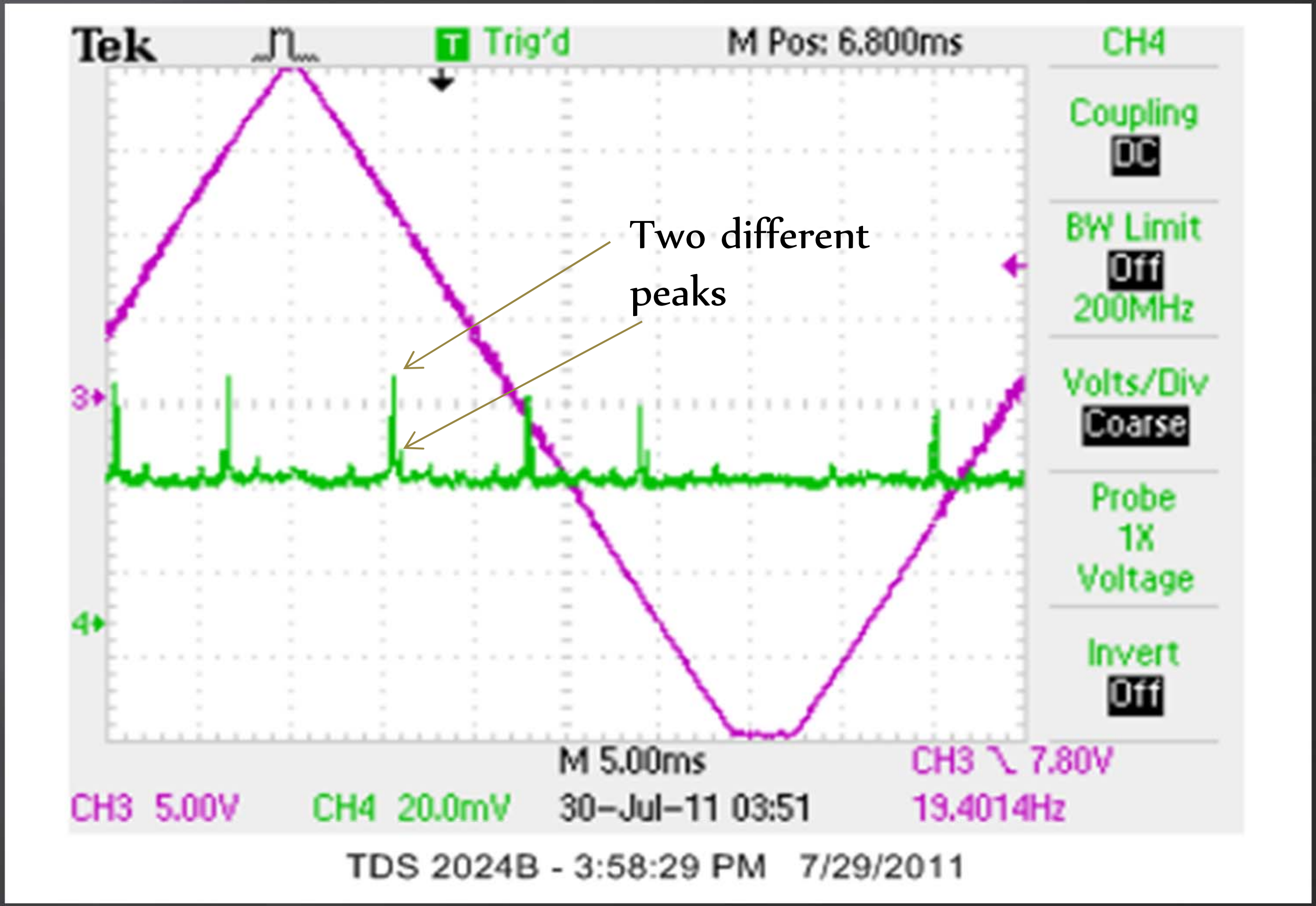






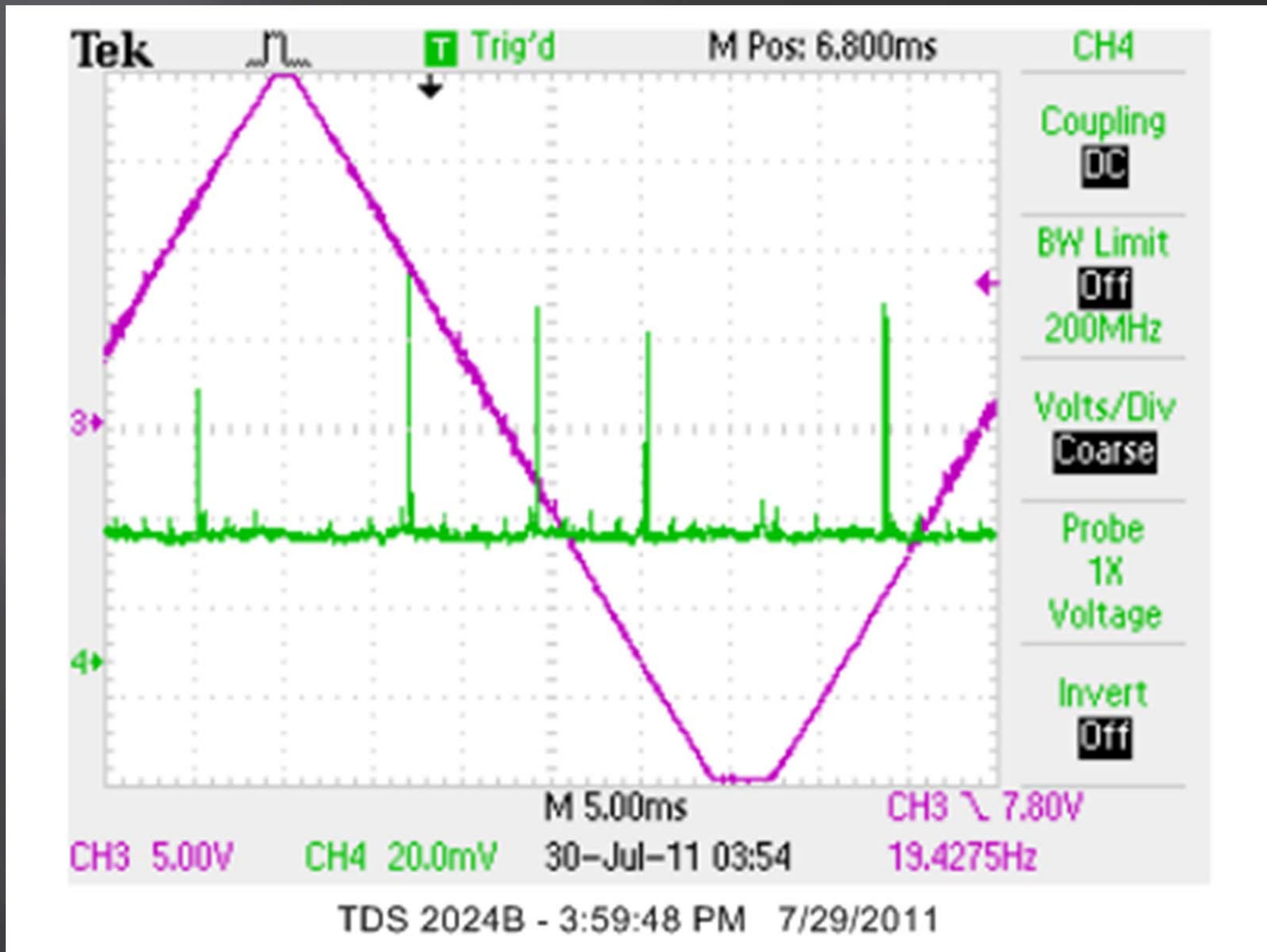
The original (left), 45 deg polarization (bottom), 90 deg polarization (right)

Polarization



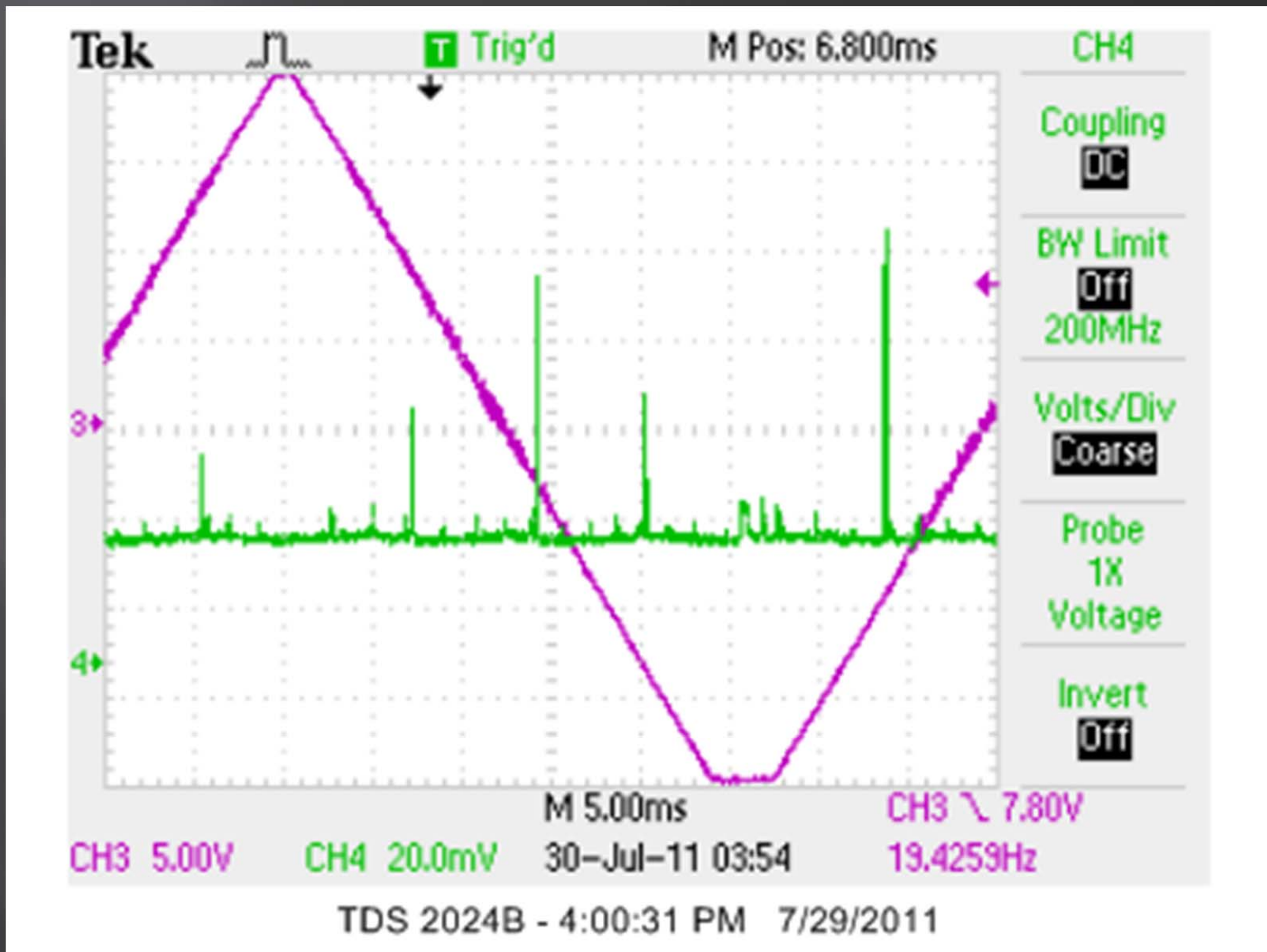
It's possible to see two sets of peaks right next to each other. This is because both the s and p polarizations are traveling through the cavity. One polarization is excited at a higher intensity than the other.

Polarization



Polarization of 135 degrees

Polarization



Polarization of 180 degrees

The Ring Cavity – Uses

- The Fabry-Perot Ring Cavity is used as:
  - A mode cleaner
  - A spacial filter
  - A spectral filter
  - A polarization filter
- This setup will be used on a 540nm beam as a polarization filter
- Used to calibrate and determine the frequency of an unknown beam

Summary

- Aligning the Lasers
  - Aligning in 3D space (x, y, θ)
- Mounting the Optics
  - Cleaning procedures
  - Building a cavity
  - Constructing and modifying mounts
- Analyzing the Data
  - LabView and MatLab code
- Building and debugging OPA circuit
- Optimizing the laser
  - Reducing noise
  - Mode matching