Optical Cavity for Raman Laser

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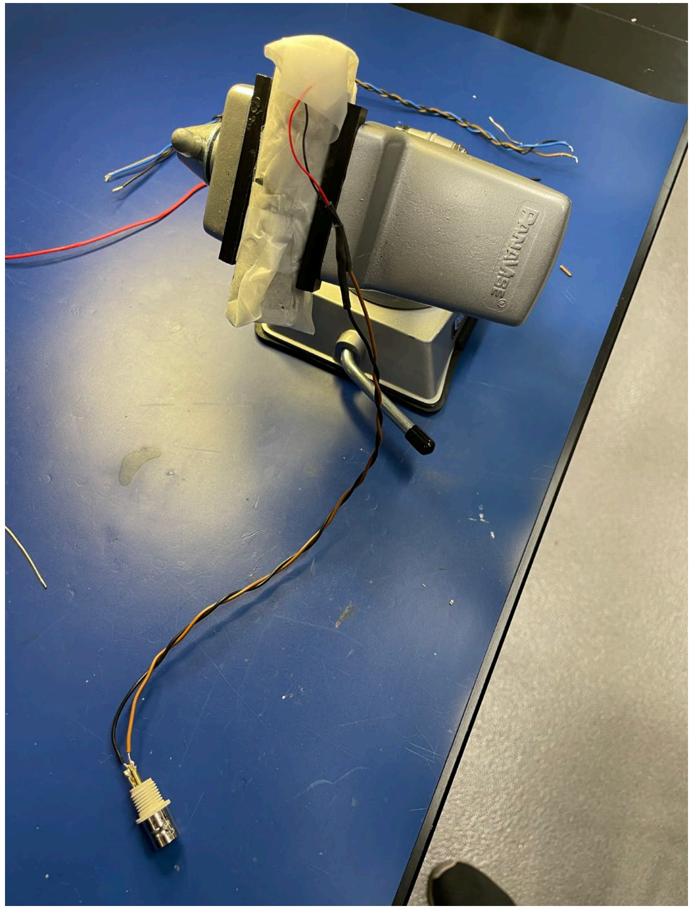
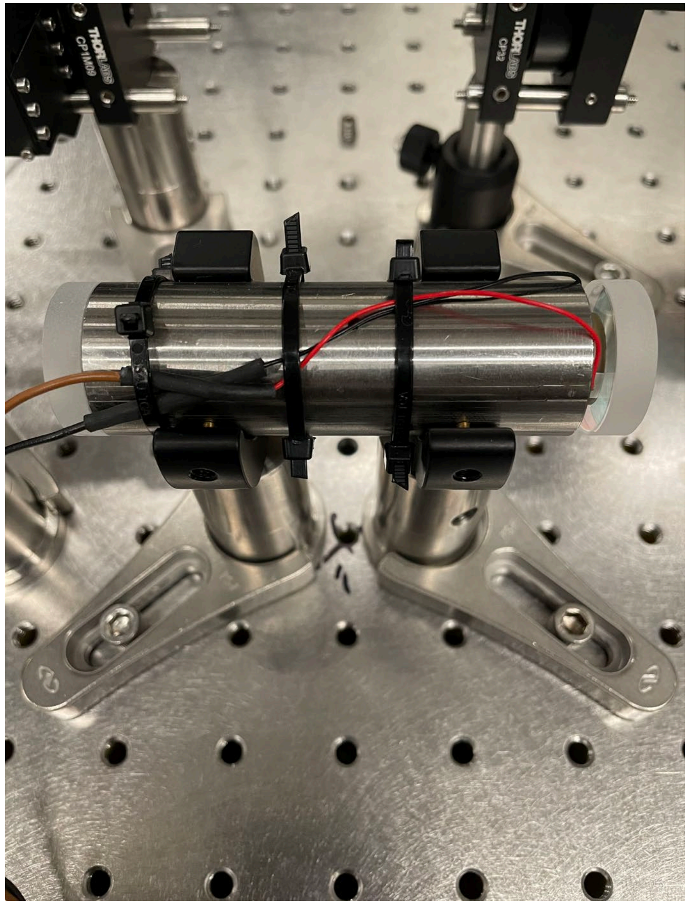
Optical Cavity

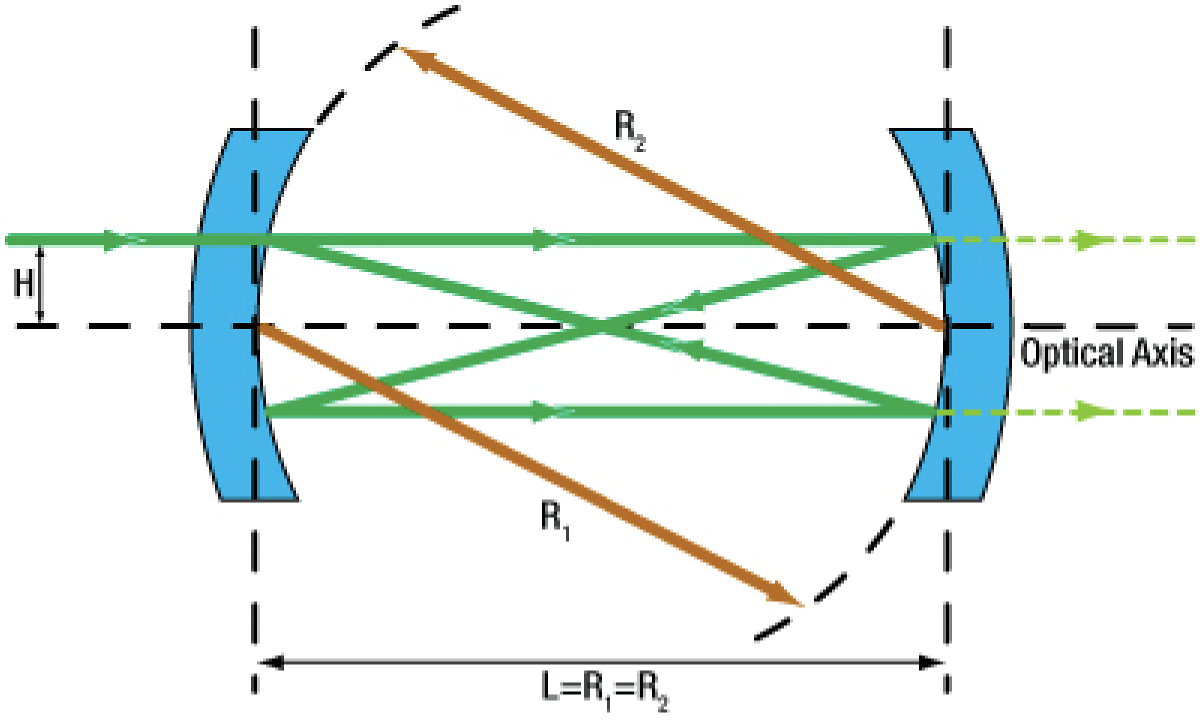
- Arrangement of two mirrors
- Produces standing waves for certain resonance frequencies





Optical Cavity

- Light reflected many times inside cavity, producing standing waves
- Standing waves will either experience constructive or destructive interference



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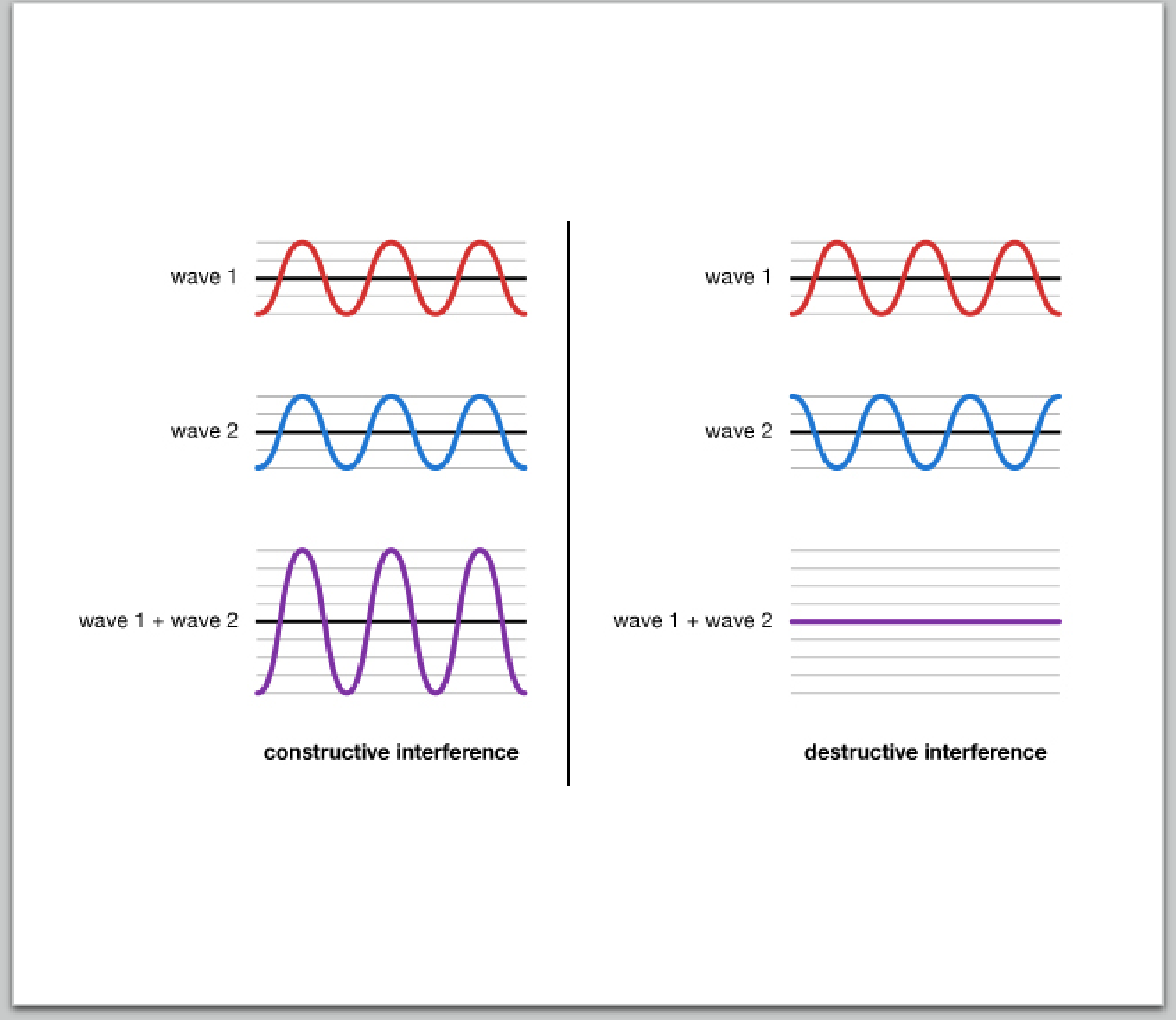
Constructive vs. Destructive

- Constructive interference reinforces the wave, and builds up electric field inside optical cavity
- Constructive or destructive interference depends on length of cavity and wavelength of light
- These standing wave patterns produce modes



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Cavity Modes

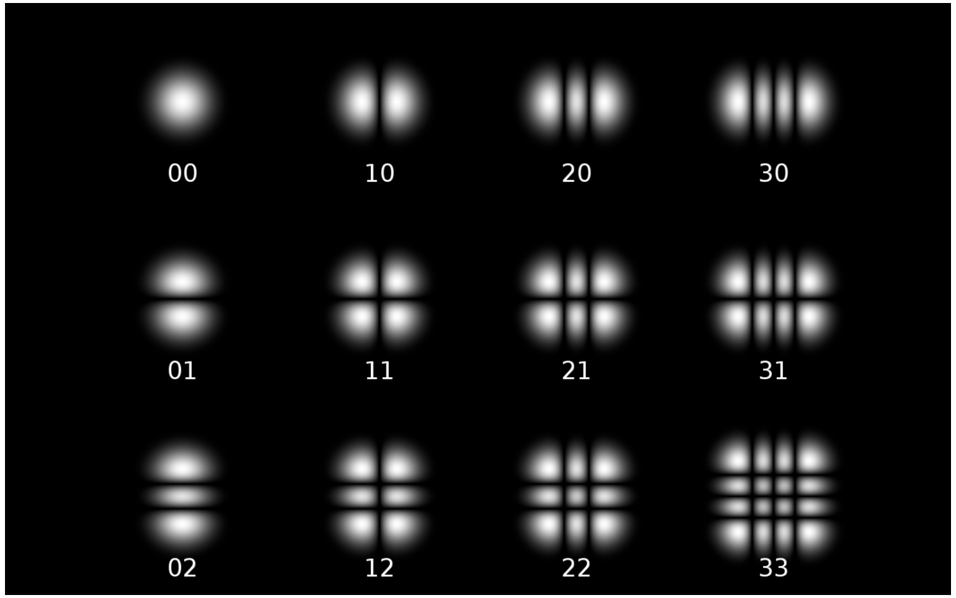
- Standing waves produce modes: Longitudinal and Transverse
- Longitudinal modes differ in frequency from one another
- Transverse modes differ in frequency and intensity pattern

Transverse Modes

- Refers to a type of electromagnetic radiation
- Electromagnetic field pattern of the radiation that is perpendicular to the direction of the radiation propagation
- Describes the shape of the energy distribution in the beam cross section

Transverse Modes

- Referred to as Transverse Electromagnetic Mode (TEM_{mn})
- TEM_{00} is known as the ”fundamental mode”
- Transverse modes with that are not TEM_{00} are referred to as higher order modes



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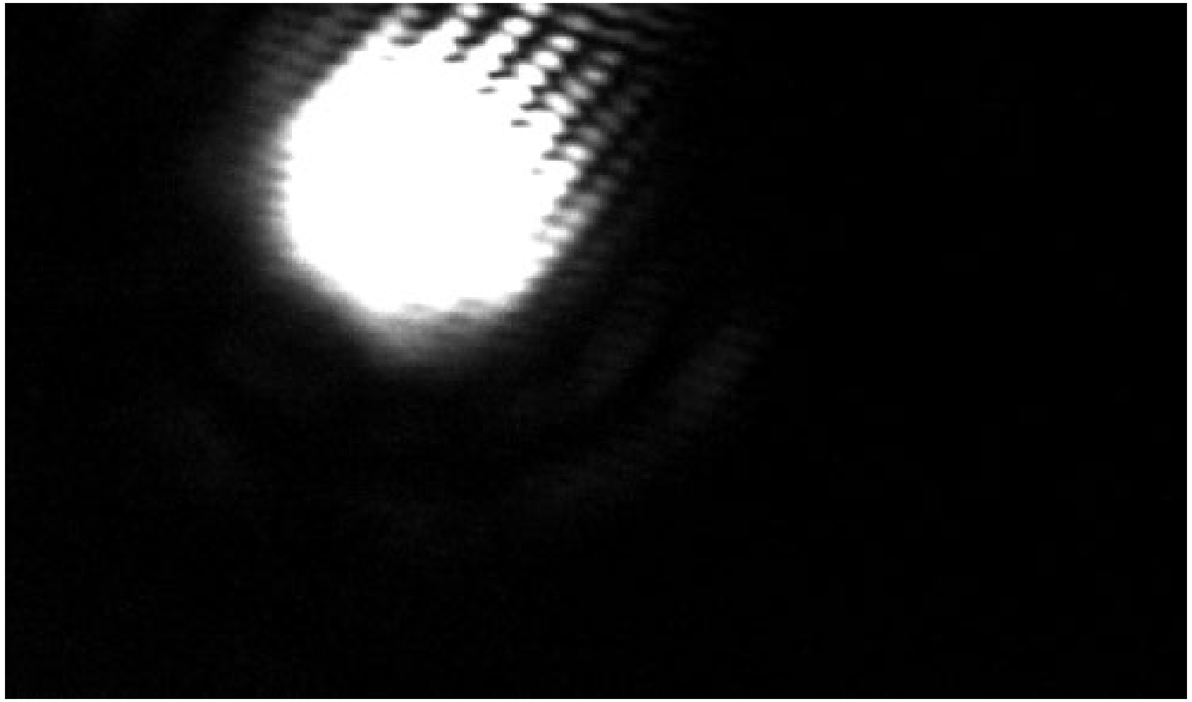


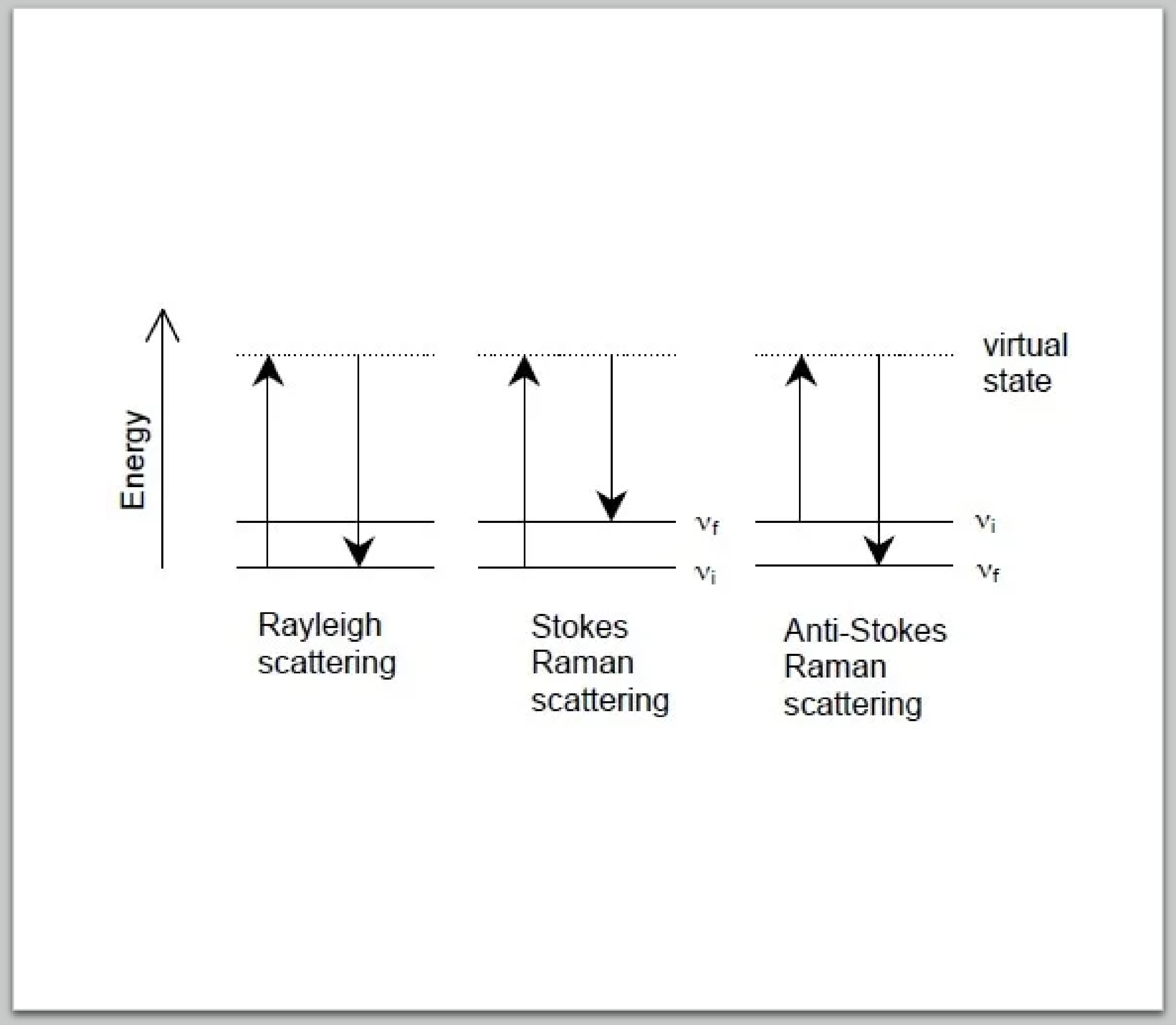
Raman Laser

- A laser suitable for Raman spectroscopy
- Raman spectroscopy- inelastic light scattering
- Also known as Raman scattering

    -inelastic collision of photons

Raman Laser

- Laser light hits gas molecule that is initially in the ground state
- Spontaneous Raman scattering occurs and molecule is excited to a “virtual state”
- Molecule is then de-excited by laser light (Anti-Stokes)



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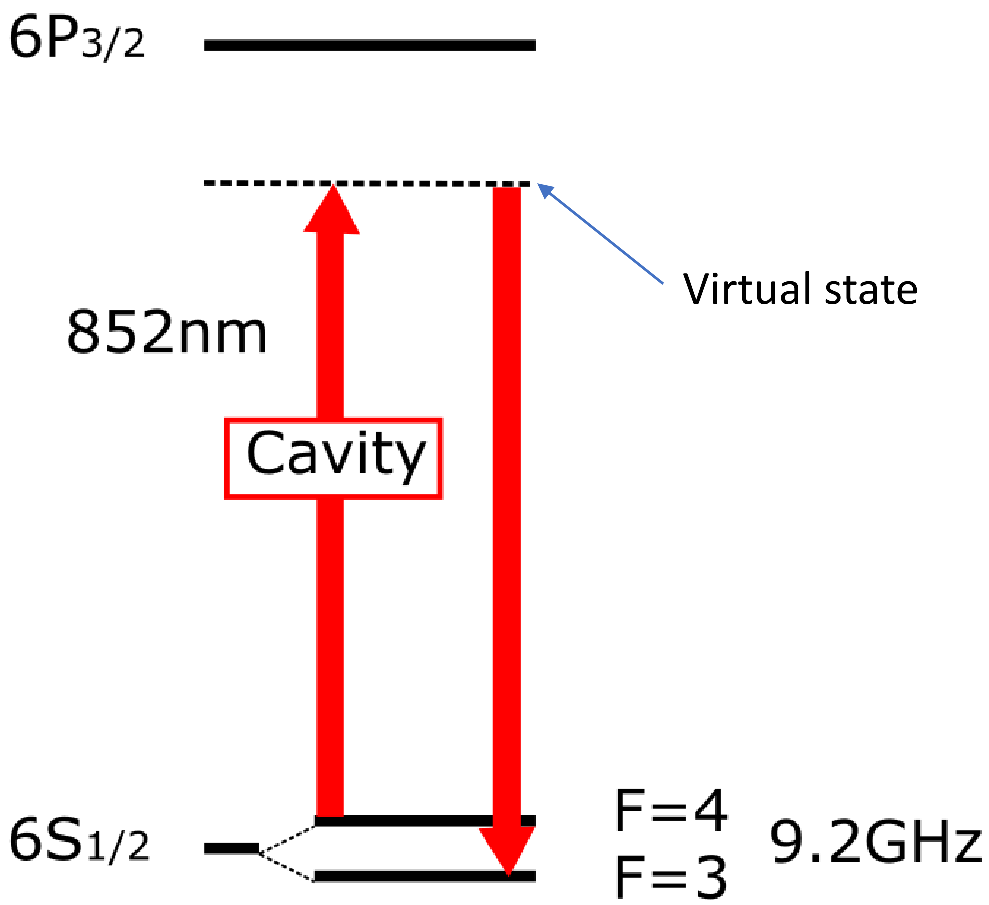
Raman Laser

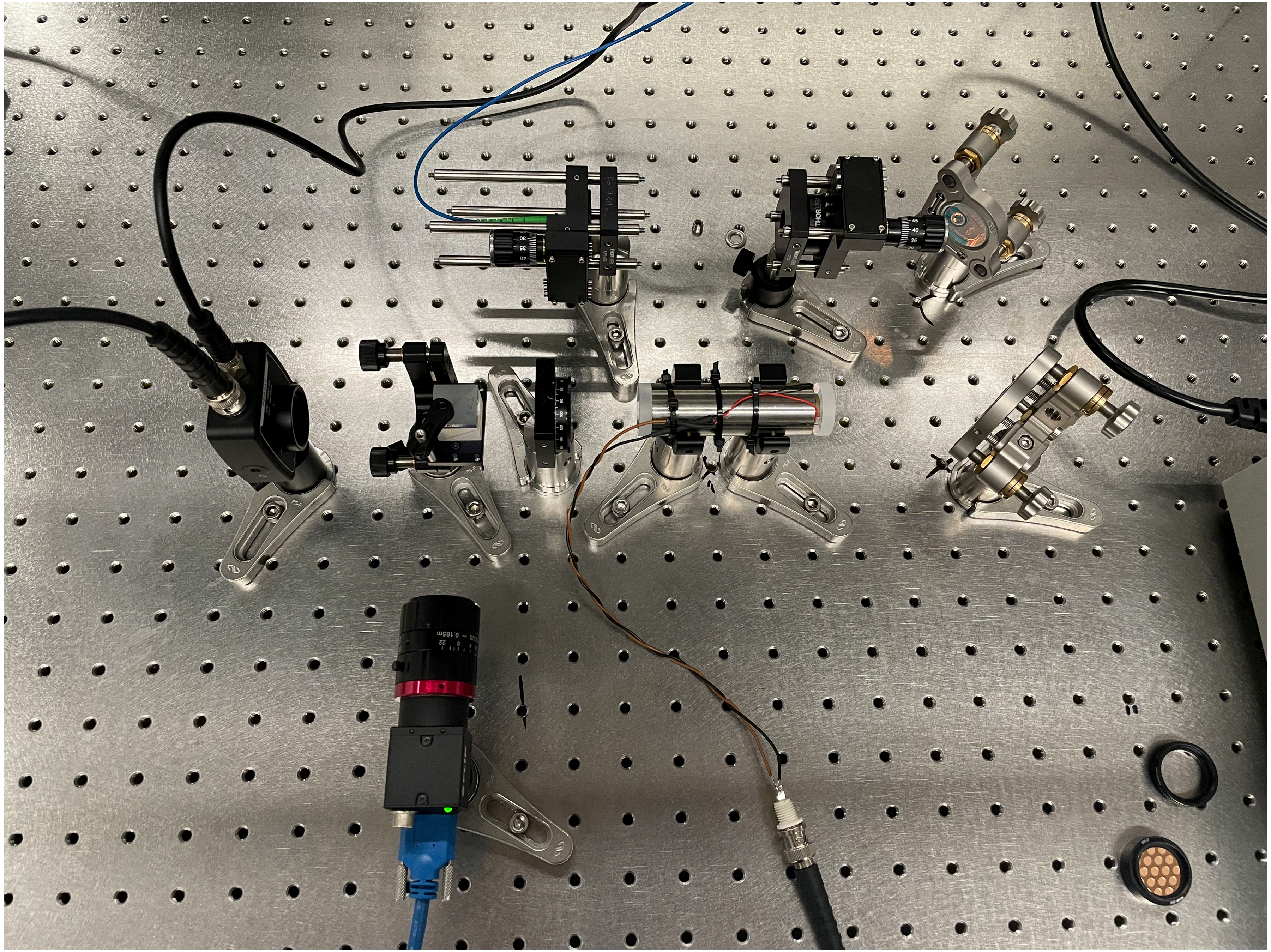
- Cesium atom, using 852 nm wavelength laser

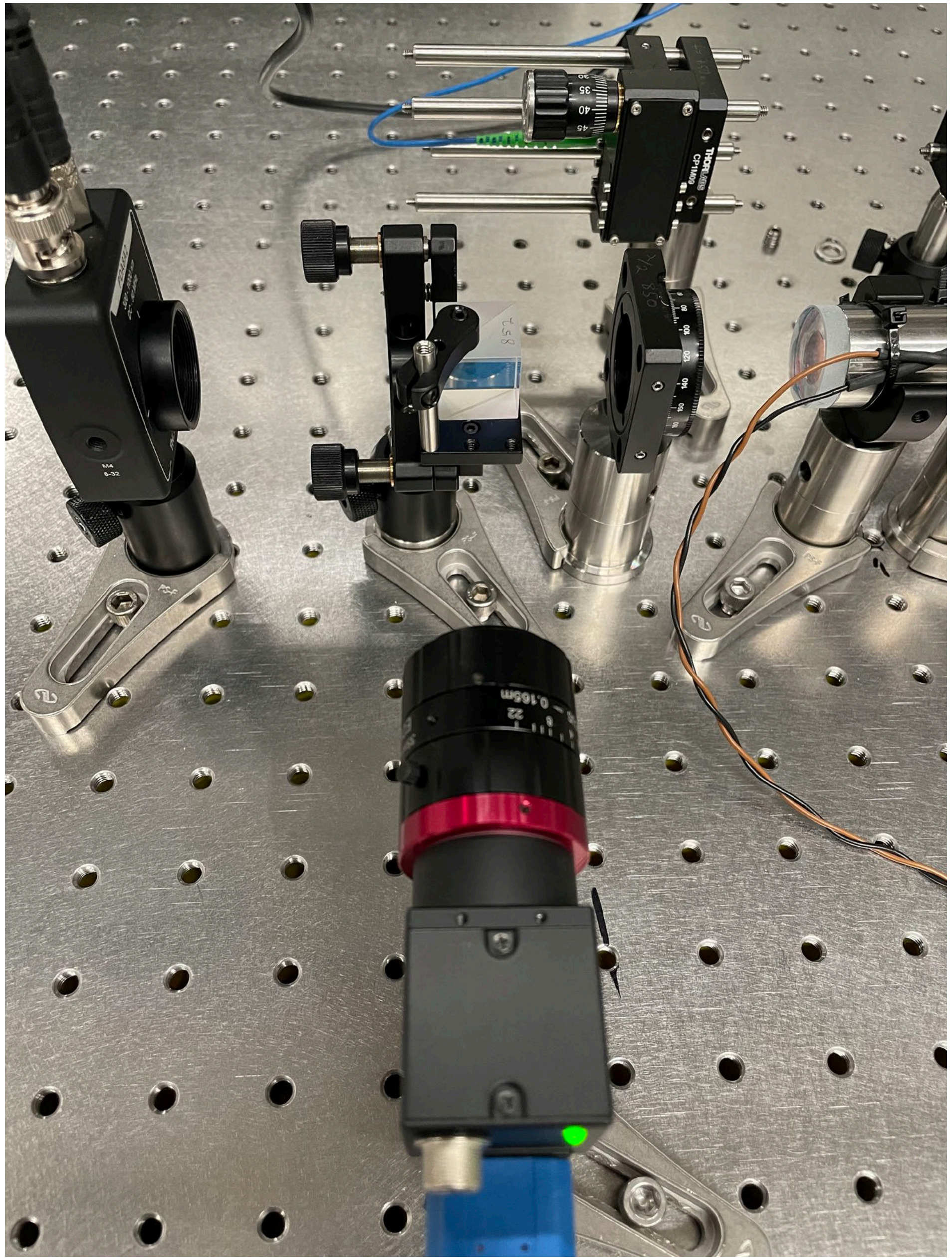


Purpose of Optical Cavity

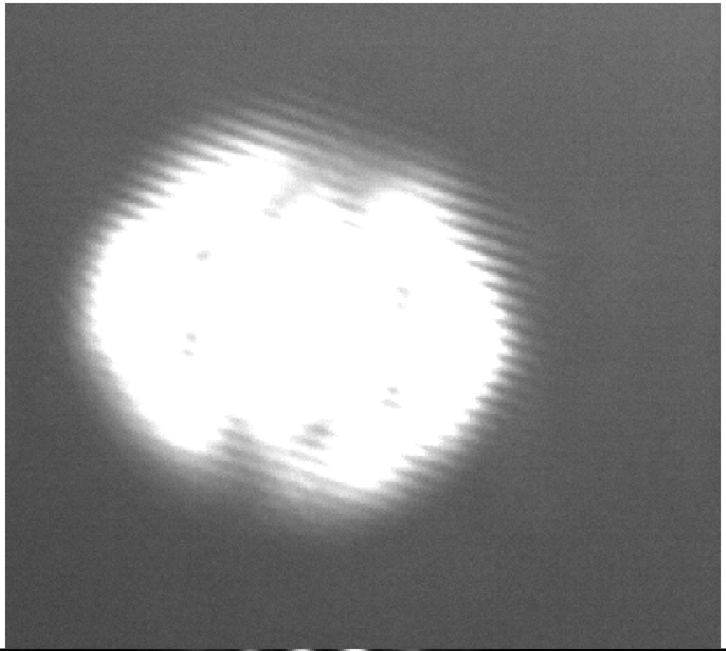
- Calculating and measuring FSR, finesse via the proper alignment

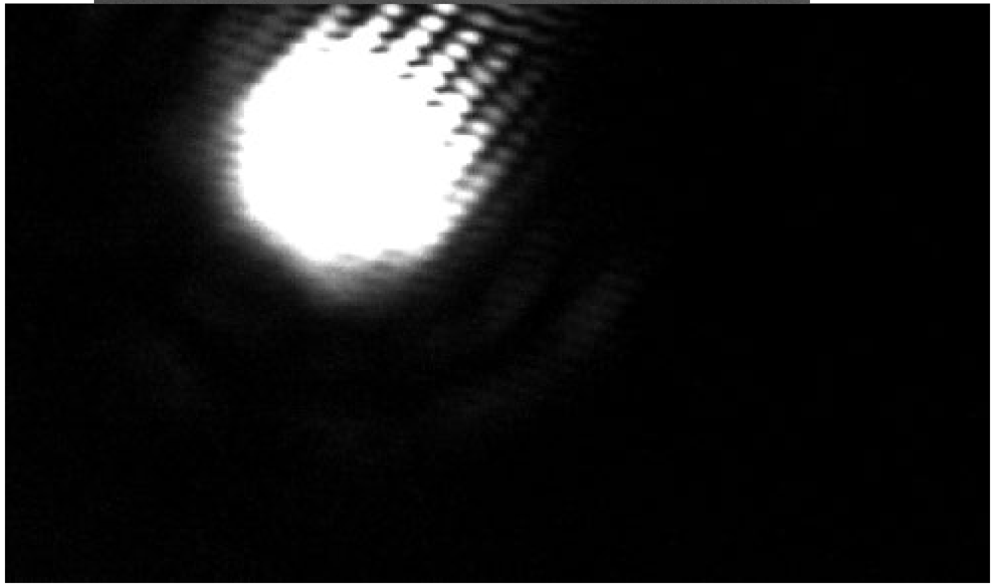
- Laser-locking to stabilize frequency: Pound-Drever-Hall Method

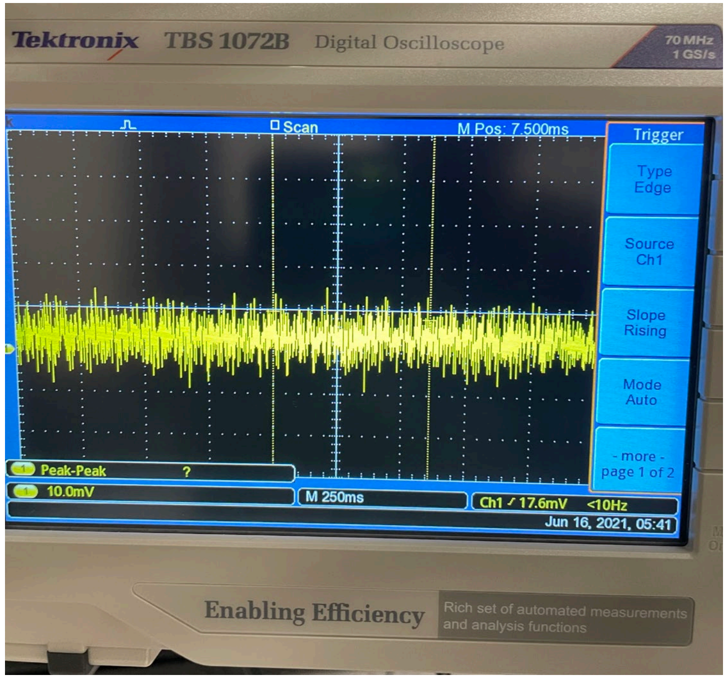


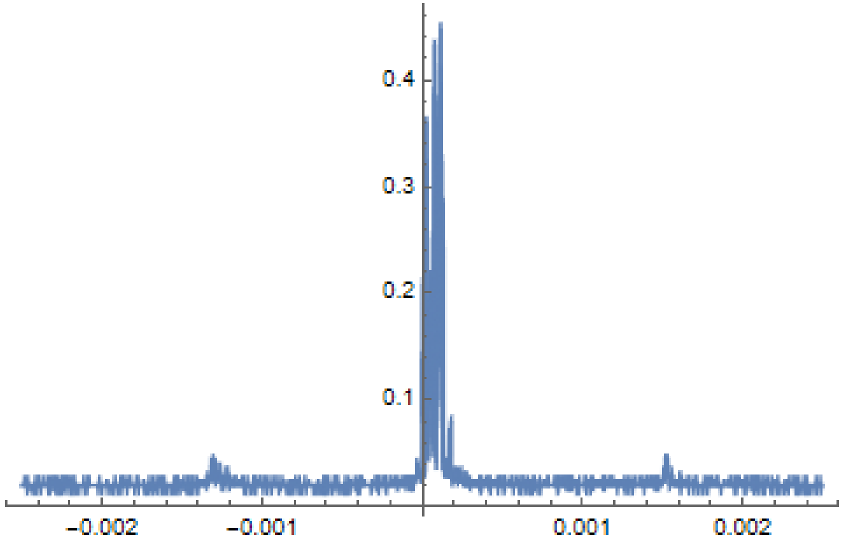


Alignment






Tektronix
TBS 1072B
Digital Oscilloscope
70 MHz
1 GS/s
Scan
M Pos: 7.500ms
Trigger
Type
Edge
Source
Ch1
Slope
Rising
Mode
Auto
- more -
page 1 of 2
Peak-Peak ?
10.0mV
M 250ms
Ch1 ∕ 17.6mV <10Hz
Jun 16, 2021, 05:41
Enabling Efficiency
Rich set of automated measurements and analysis functions


0.4
0.3
0.2
0.1
−0.002
−0.001
0.001
0.002

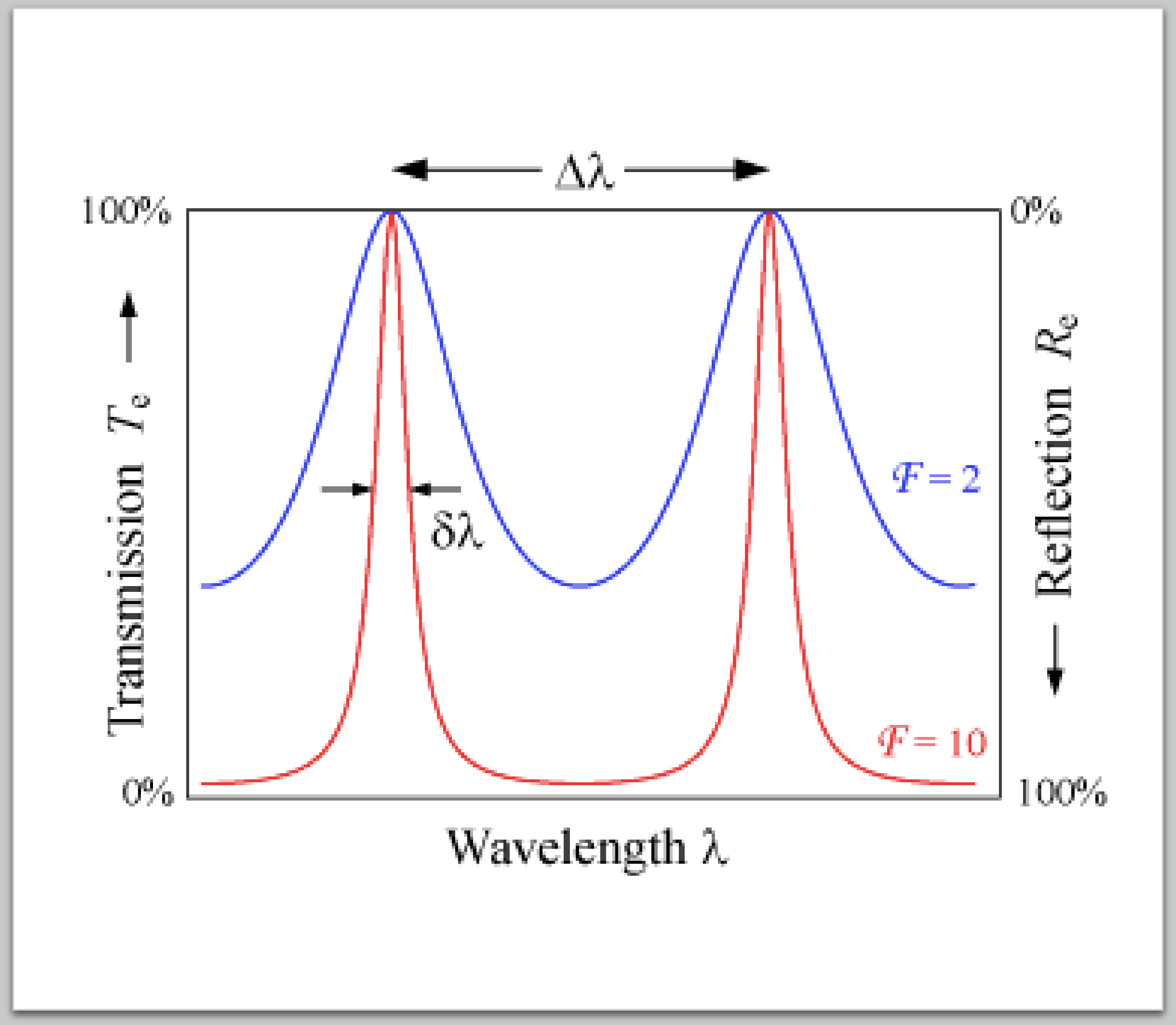
Measuring FSR and FWHM

- **FSR**(Free Spectral Range)- spacing in optical frequency between two maximum peaks

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

- **FWHM**(Full Width at Half Maximum)- width of the peak measured between the points on the vertical axis when the peak is at half of it's amplitude

  -Also known as linewidth



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Finesse

- FSR and FWHM are related by a unitless measurement called "finesse"

$$\mathcal{F} = \frac{FSR}{FWHM}$$

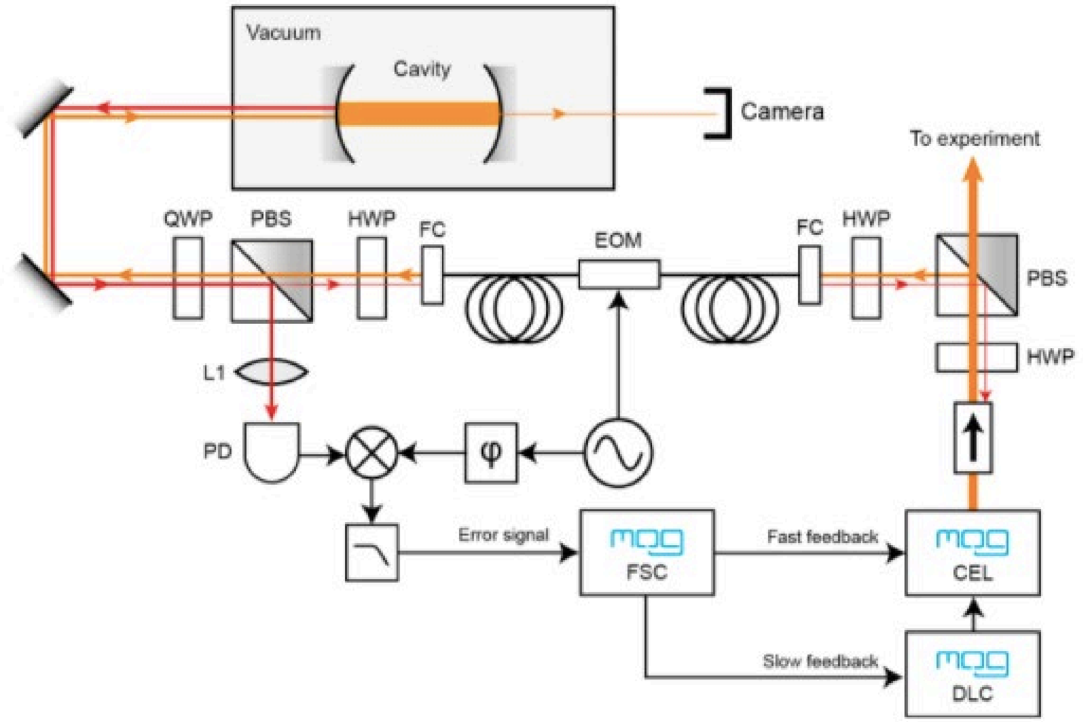
- Linewidth and finesse are inversely related
- Number of times that the beam bounces
- Narrow linewidth/FWHM $\longrightarrow$ high finesse $\longrightarrow$ sharper resonances
- High finesse makes it easier to distinguish closely spaced peaks
- Not common to specify finesse

Pound-Drever-Hall Method

- Pound-Drever-Hall(PDH) Method- used to stabilize the frequency of light emitted by a laser by locking to a cavity
- PDH method can control laser's linewidth/FWHM
- Stabilizing the frequency of a laser is needed to be more precise and reduce frequency fluctuations due to laser instability

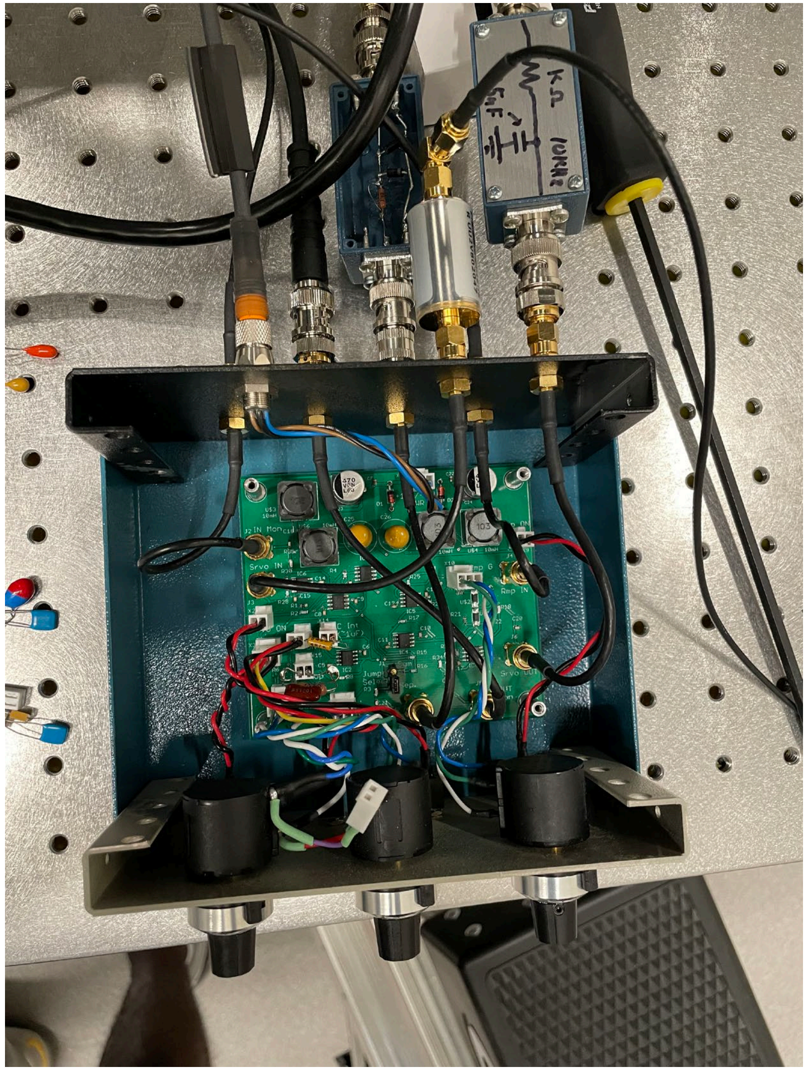
Pound-Drever-Hall Method

- Phase modulated light consisting of the carrier signal and sidebands is sent into the cavity by the process of an EOM and is reflected on the oscilloscope
- Frequency of the signal is mixed down by a mixer that is in phase with the modulated light
- After a phase shift, the signal gives a measure of how far the carrier signal is off resonance with the cavity



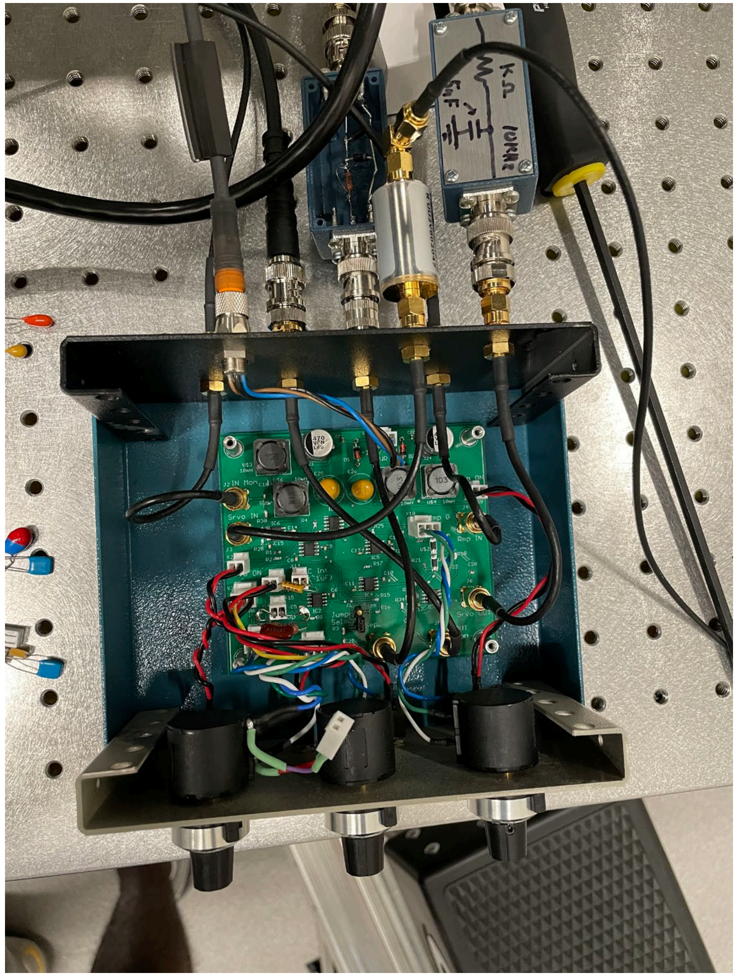
Laser Locking

- Due to the narrow linewidth of the laser, a servo controller is required to lock the laser to the error signal
- Servo controller provides control loops
- A very fast control loop is required for the lock to be stable
- Continuously calculates the error signal



Laser Locking

- Acts as a PI(proportional-integral) controller
- Converts the error signal and converts it into a voltage
- Voltage is then fed back to the laser to keep it on locked on resonance with the cavity



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Questions?