Characterizing a Microwave Cavity

Kellan Brown

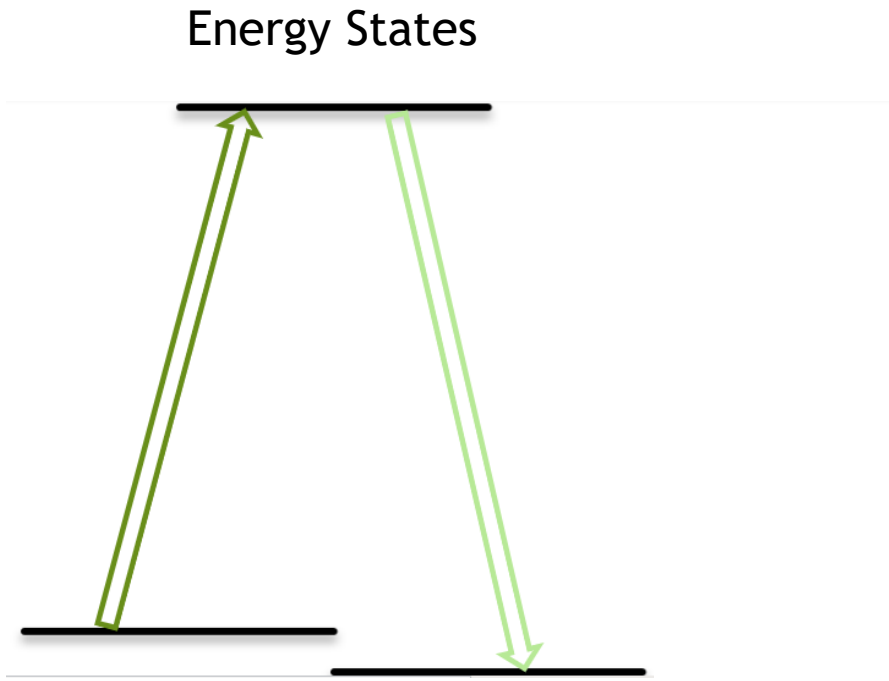
Dr. Marino

Quantum Technology

- New, emerging field
- Many applications
  - Enhanced computing
  - Sensing
  - Privacy
  - Communication

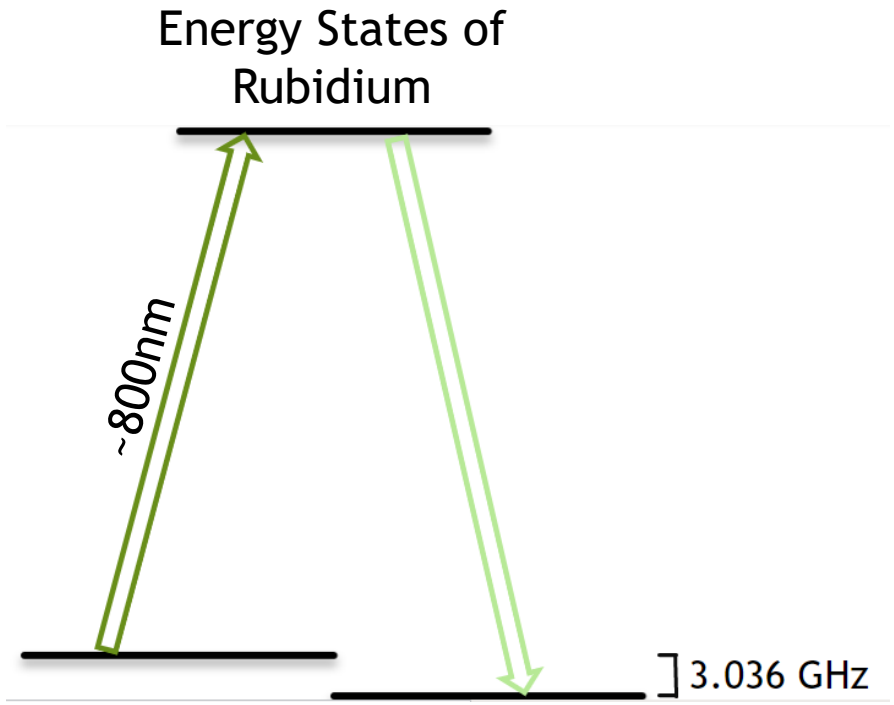
Interaction Between Light and Atoms

- When field is on resonance, electron jumps states
- Photon is absorbed, then photon is emitted
- Optical pumping



Interaction in Rubidium

- Substates are separated by 3.036 GHz
- Looking to couple the two substates together
- A strong field is required for coupling to occur



Cavities

- Optical Cavities
  - A hollow object with two parrallel mirrors
  - Light is bounced between the mirrors, where resonant wavelengths will be amplified
- Microwave cavities have different boundary conditions

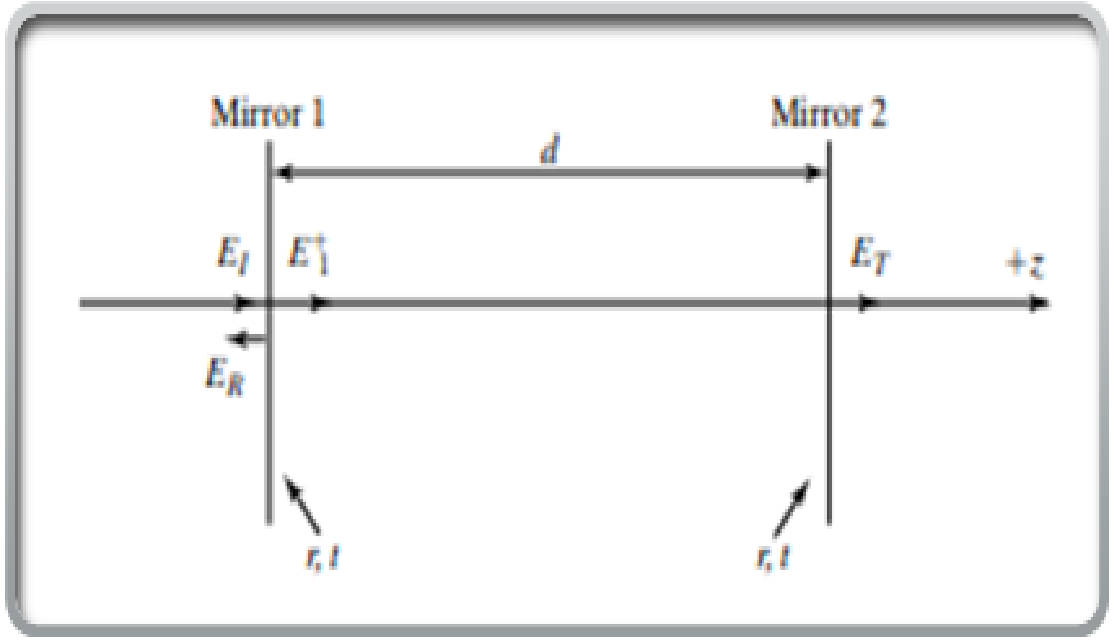


Photo Credit: : Intorduction to Optics: Pedrotti

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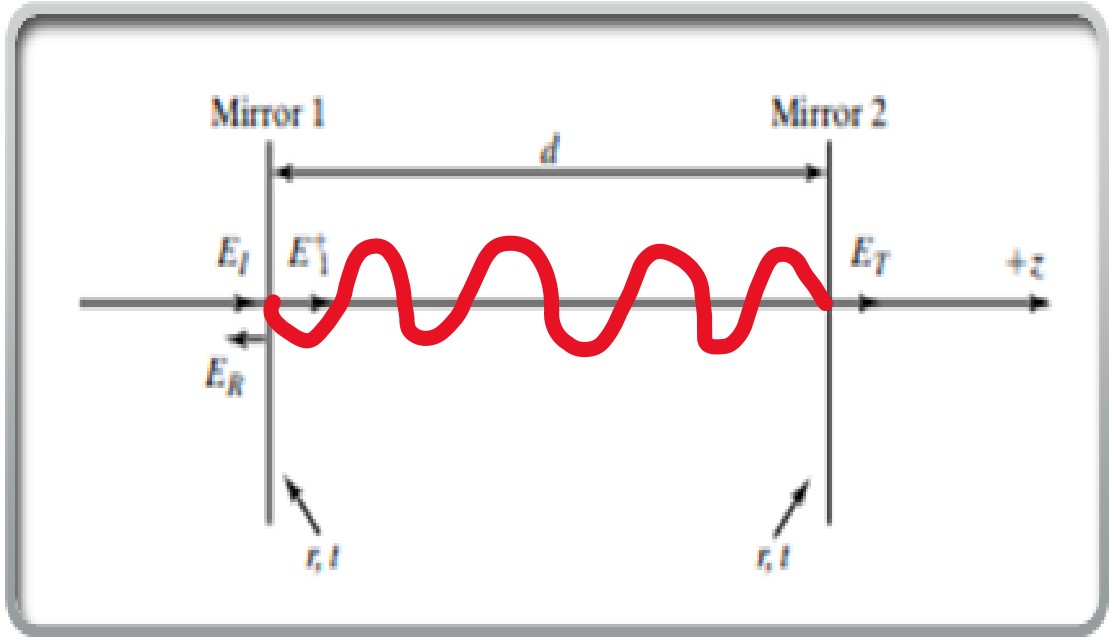

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Microwave Cavity

- Cylindrical Cavity
- Creates an electrical and a magnetic field

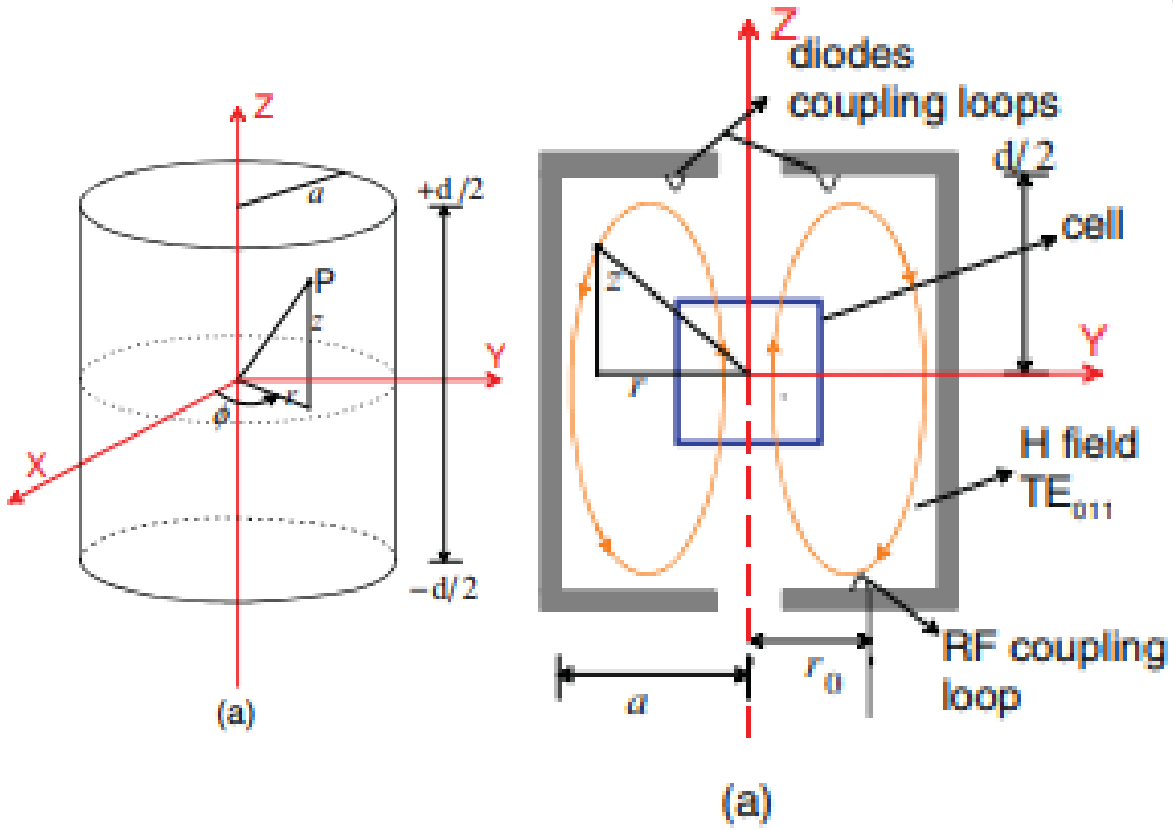
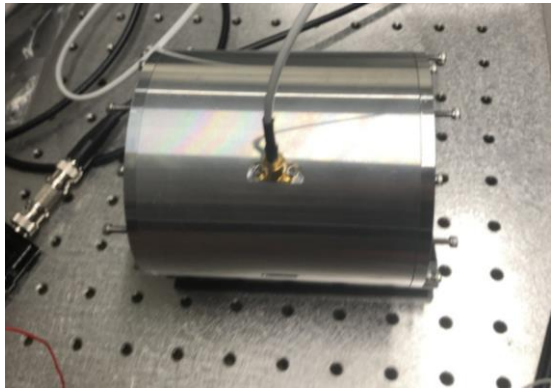
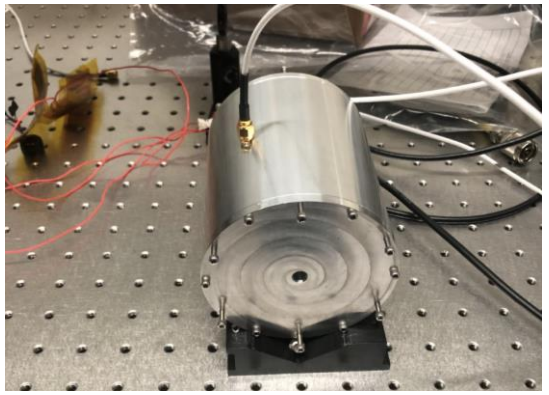


Photo Credit: : Rev. Sci. Instrum. 82, 074703 (2011); https://doi.org/10.1063/1.3606641

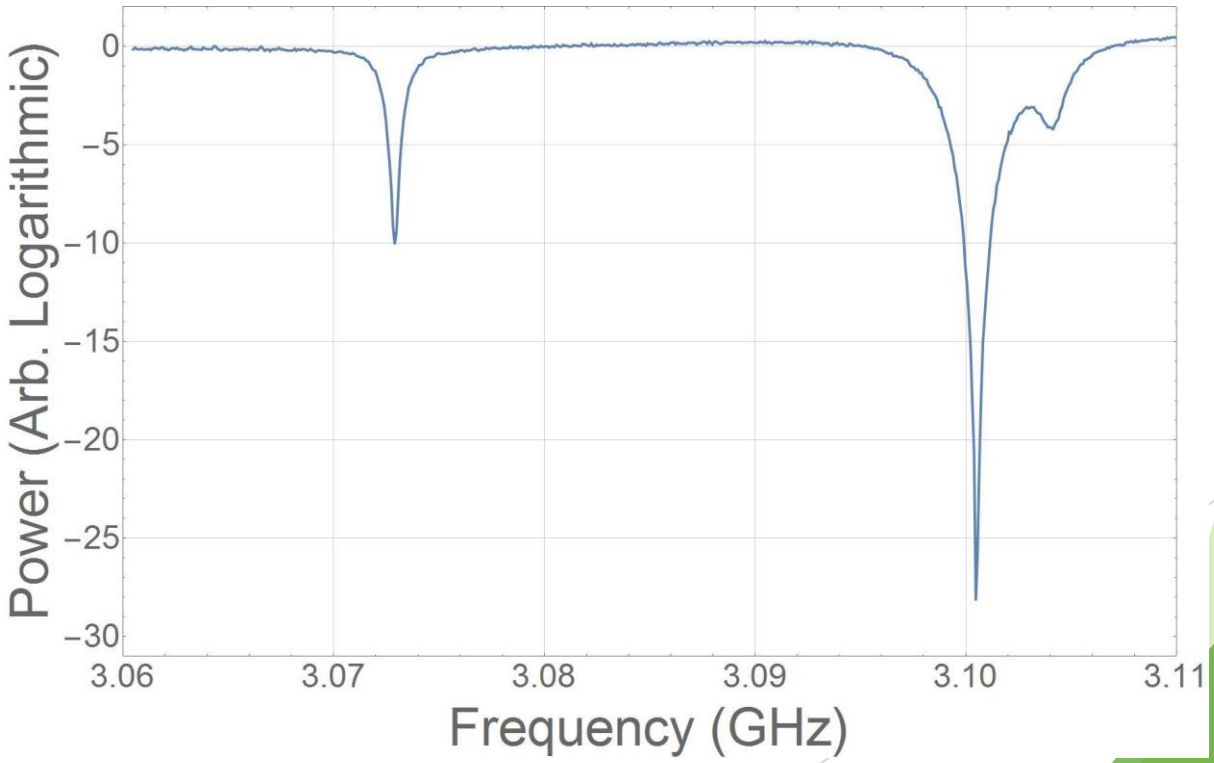
Characterizing the Cavity





- Microwave signal is sent to cavity
- Off resonance are sent back to spectrum analyzer
- On resonance enters the cavity

TM and TE Modes



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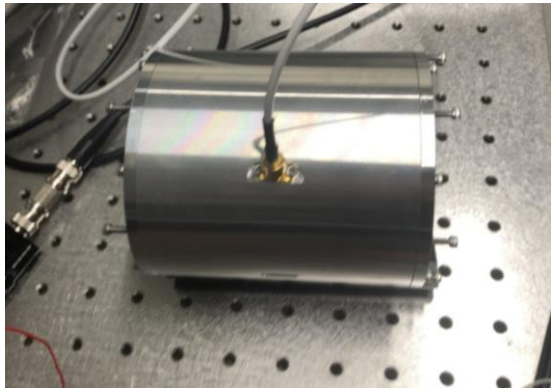

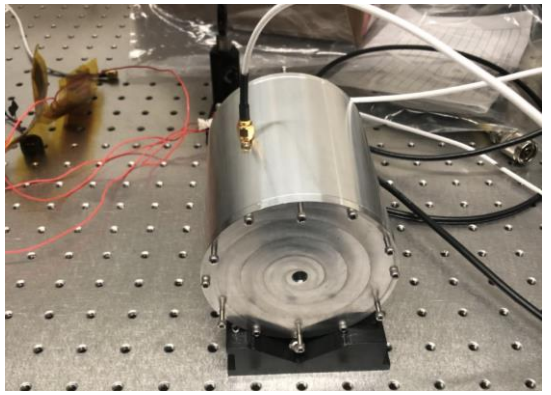

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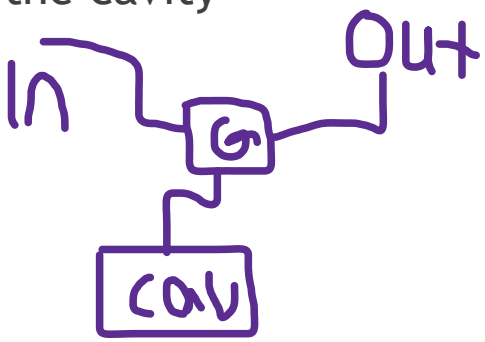

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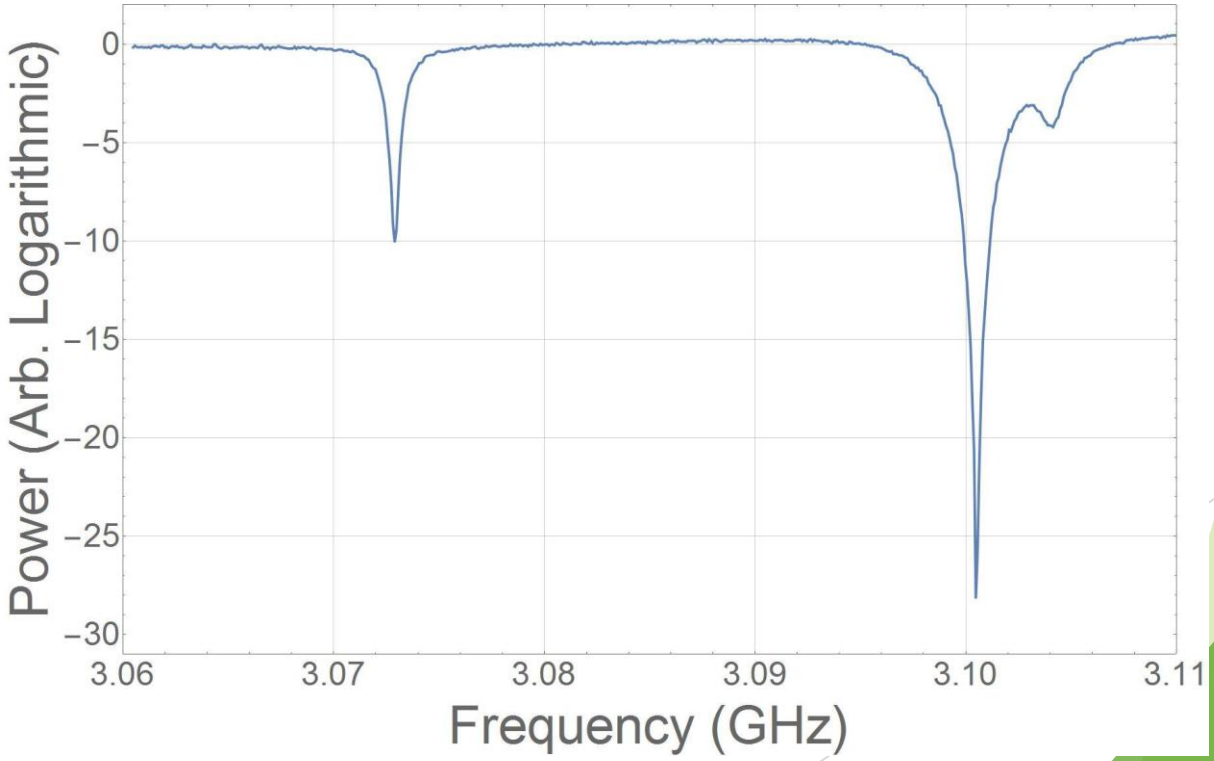

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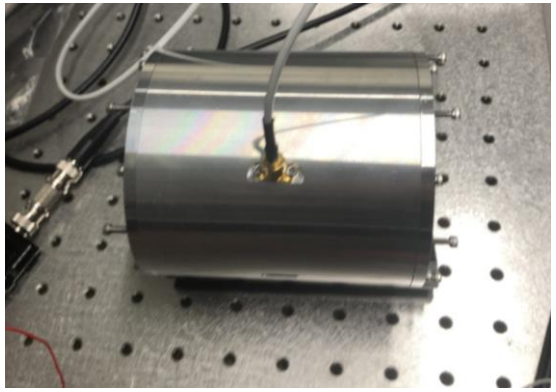

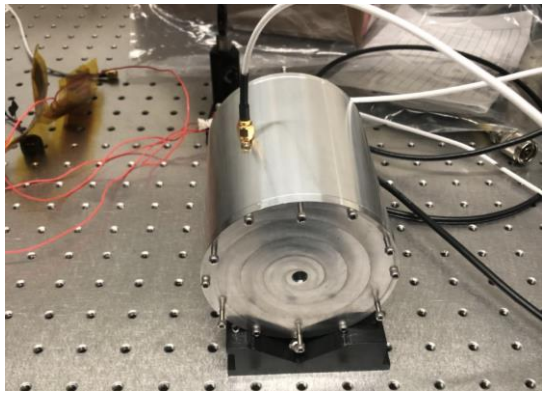

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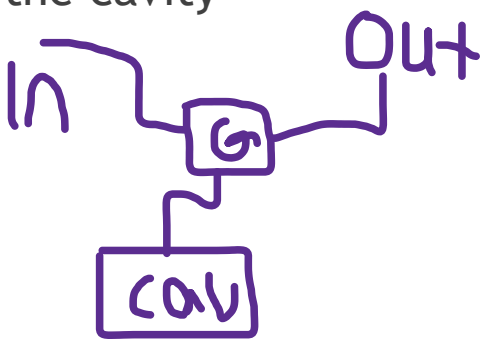

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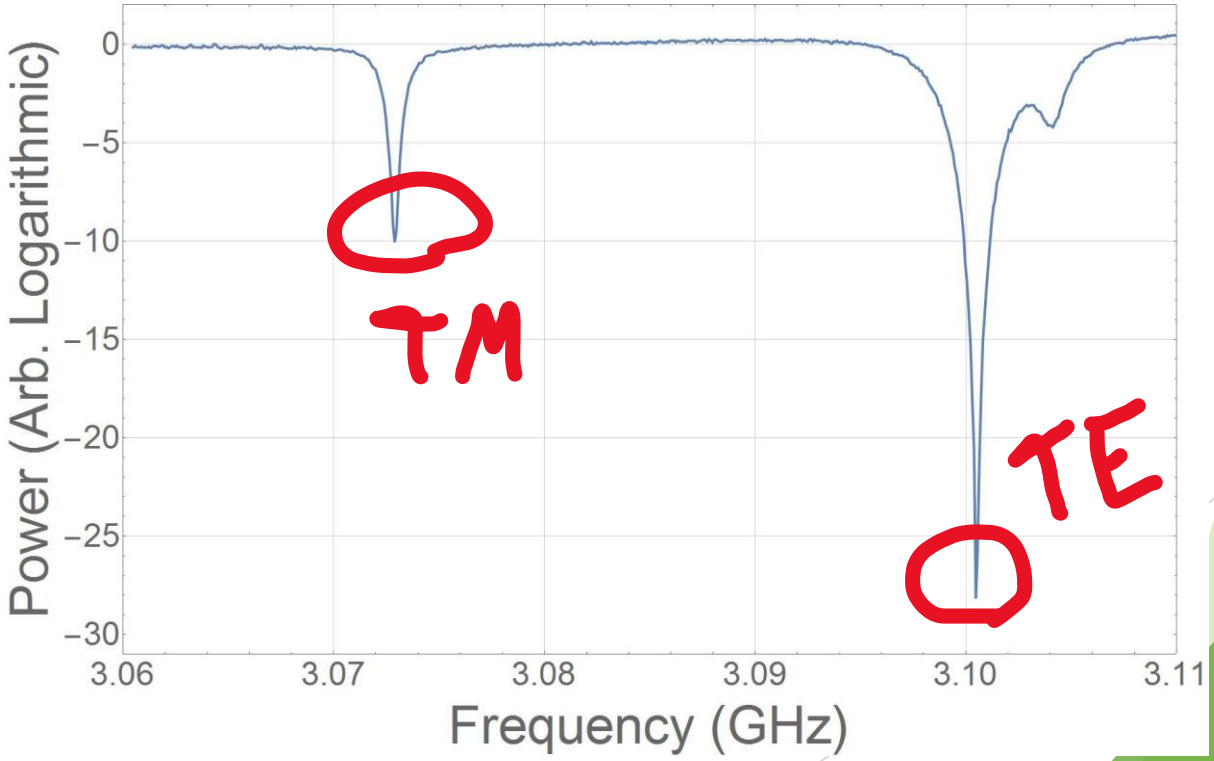
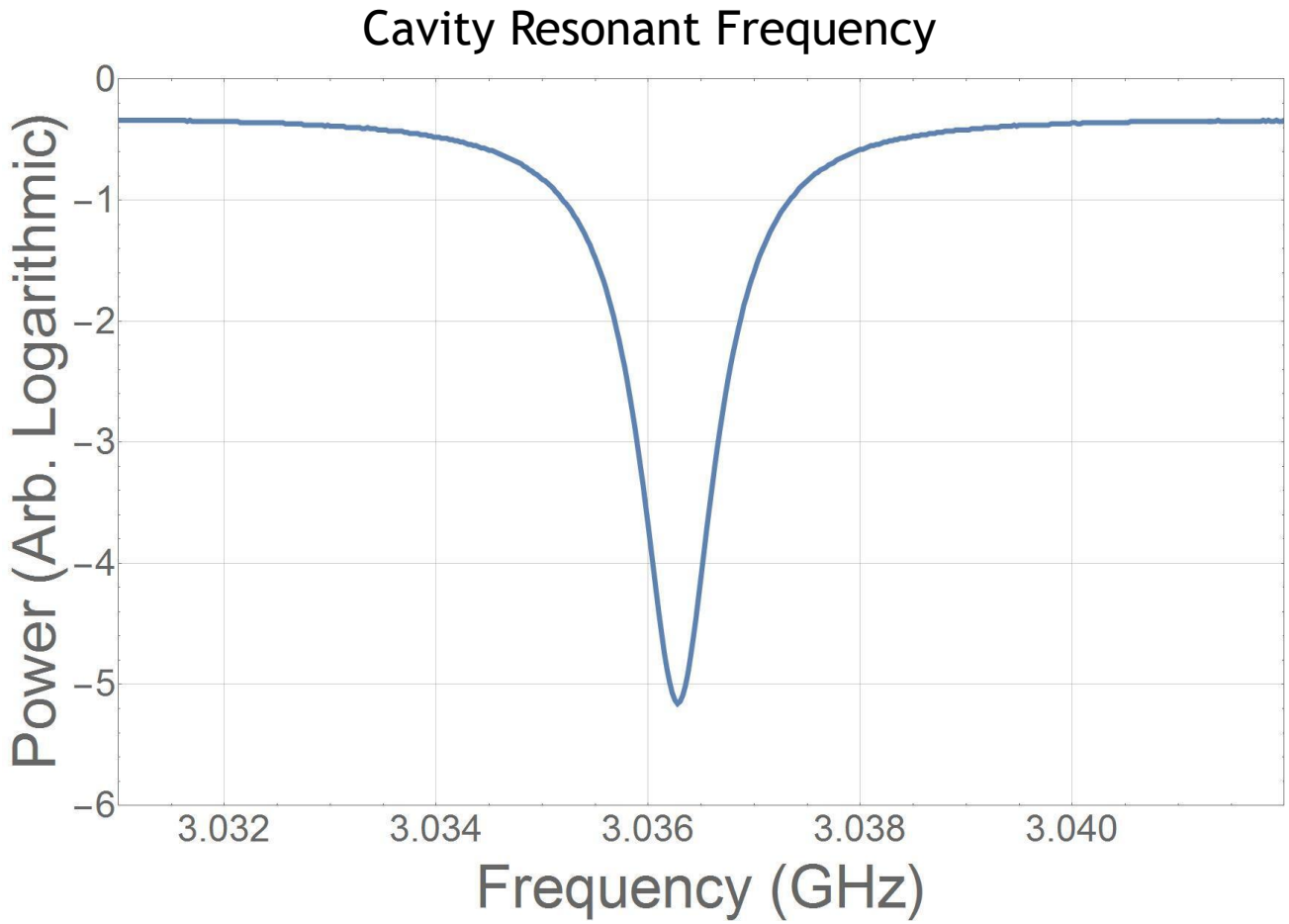
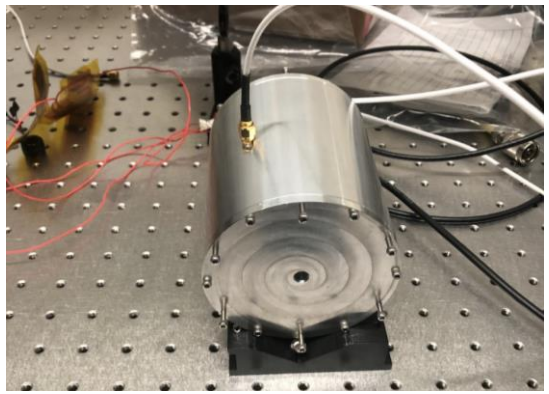


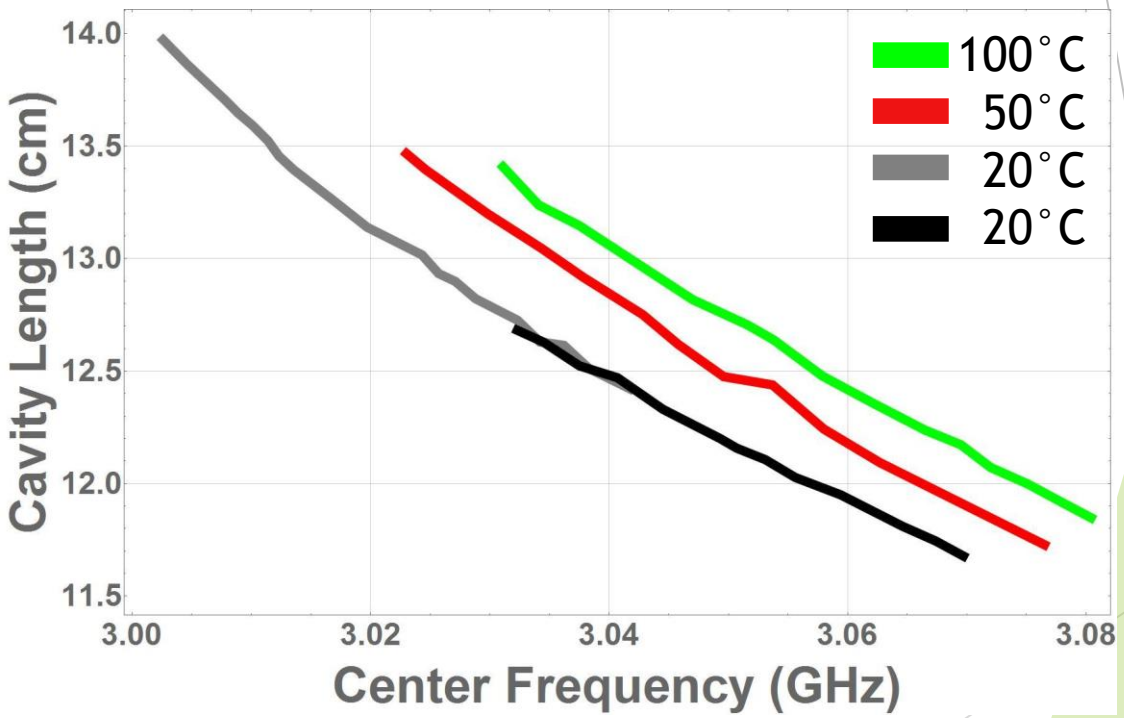
TM Mode


Cavity Resonant Frequency
Power (Arb. Logarithmic)
0
−1
−2
−3
−4
−5
−6
3.032
3.034
3.036
3.038
3.040
Frequency (GHz)

Changing the Resonant Frequency

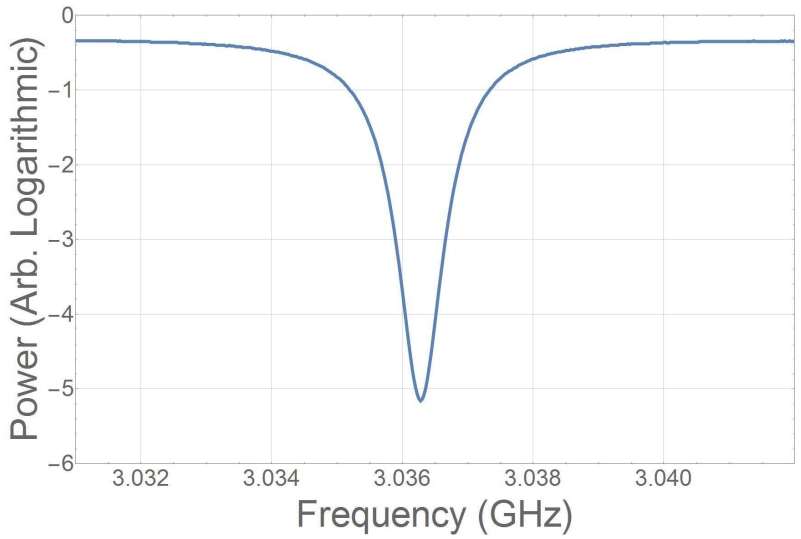


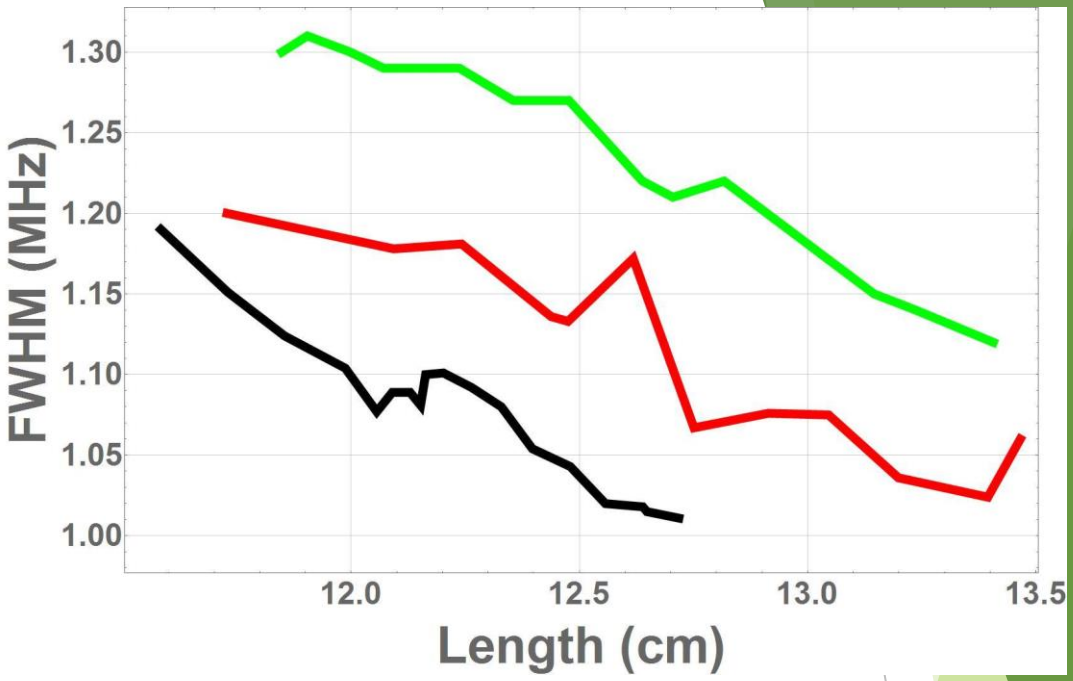
- Cavity length increased in the z-direction
- As Length decreases, frequency increases
- Higher temperature increases resonant frequency

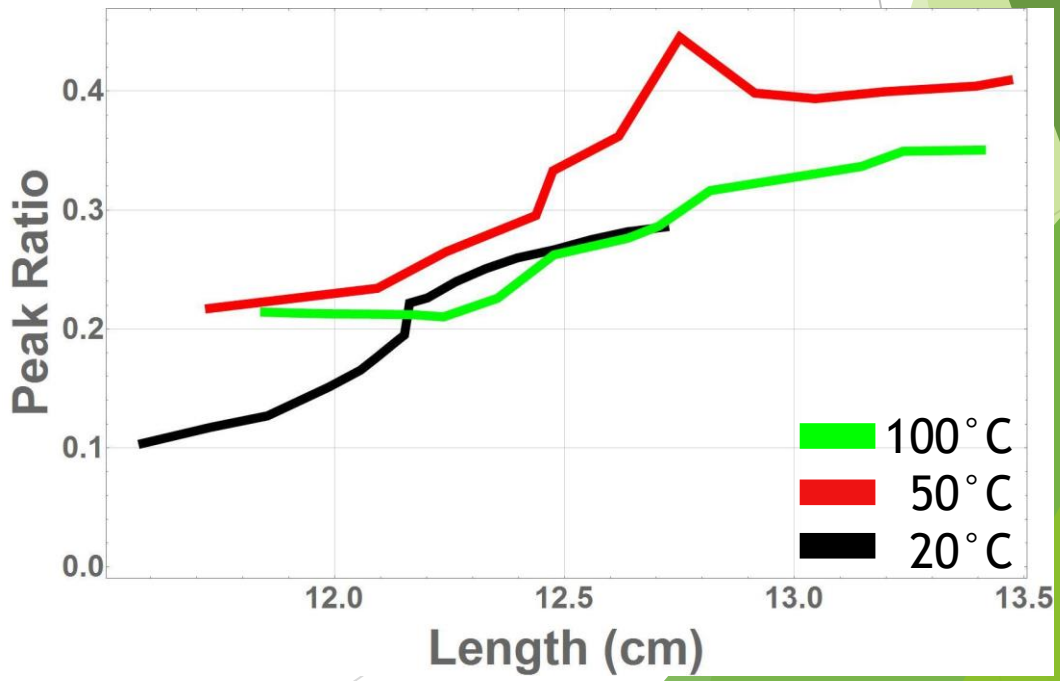


Changing the Resonant Frequency

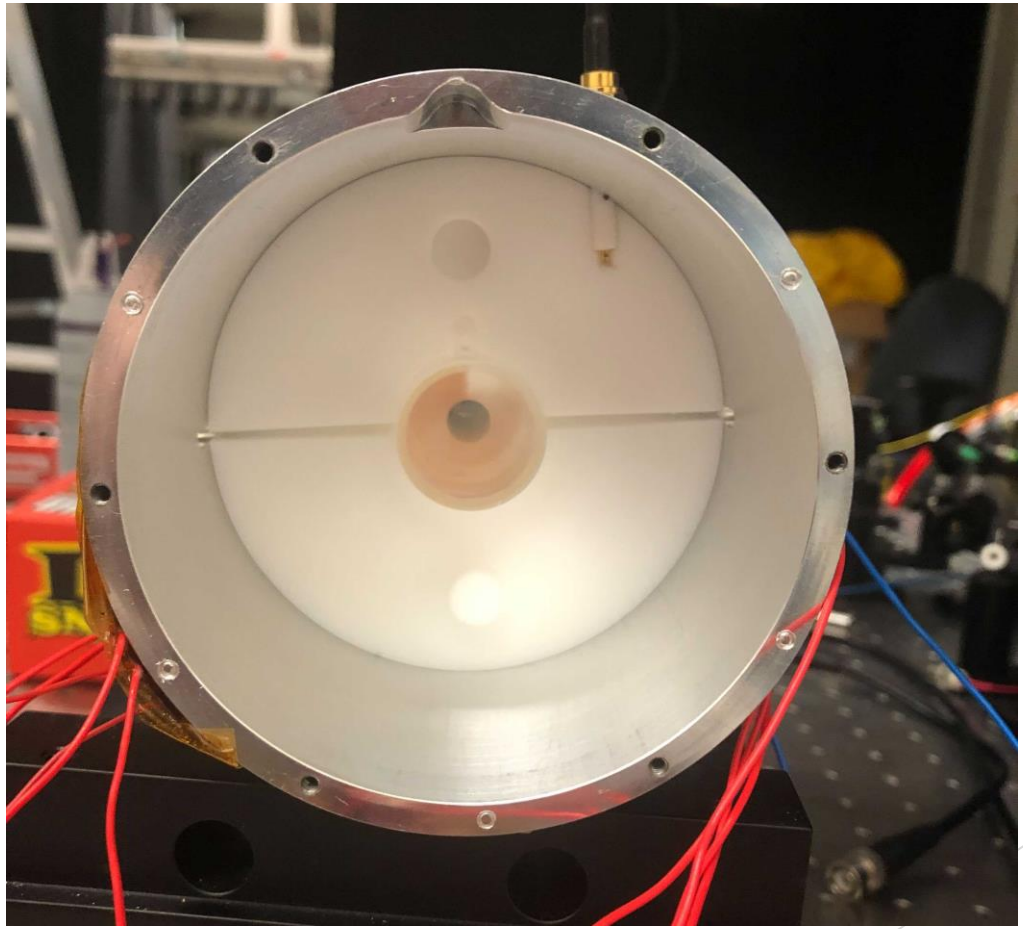
- As Length increases, depth of the peak decreases
- As length increases, the width of the peak decreases







Inside the Microwave Cavity



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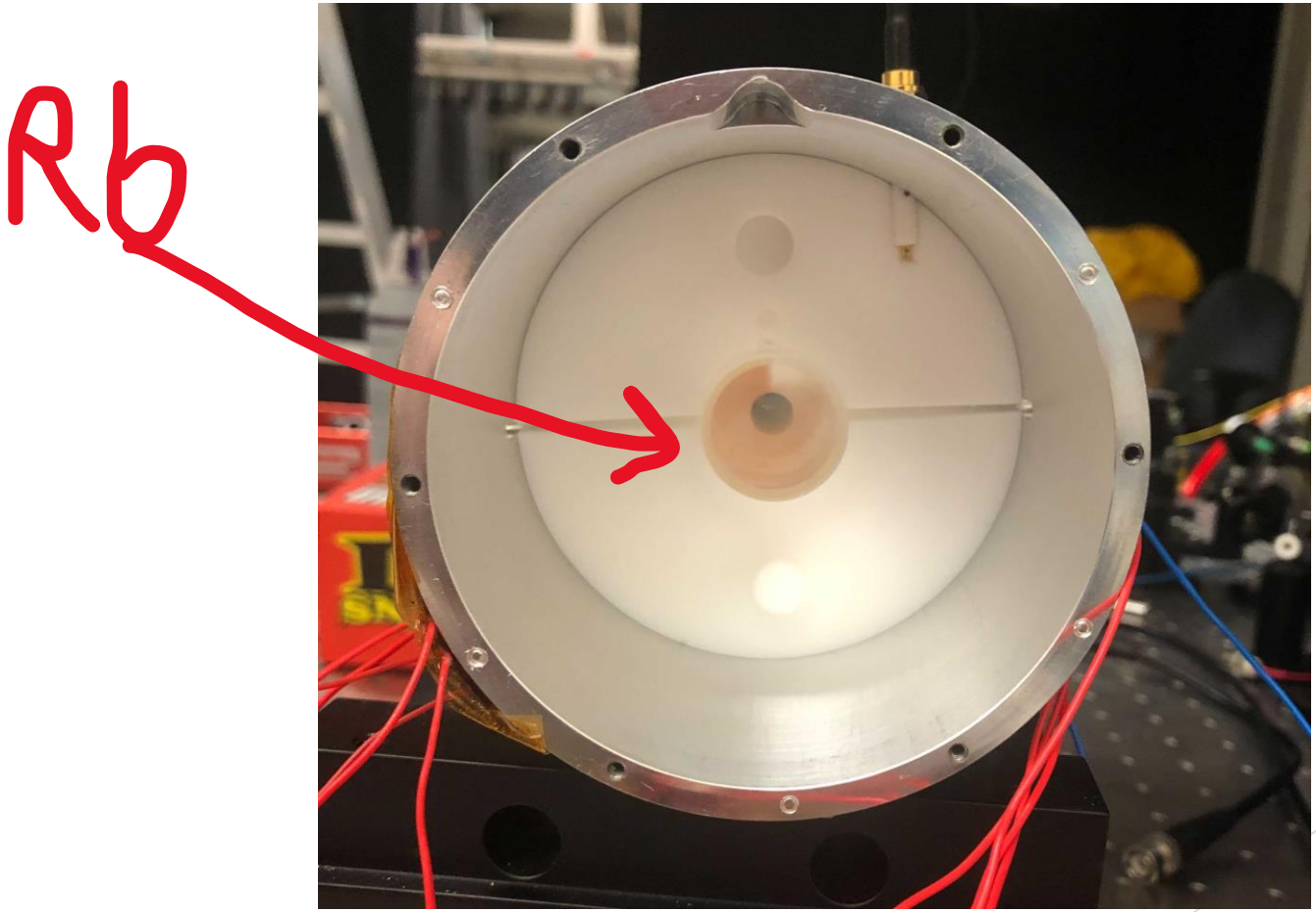

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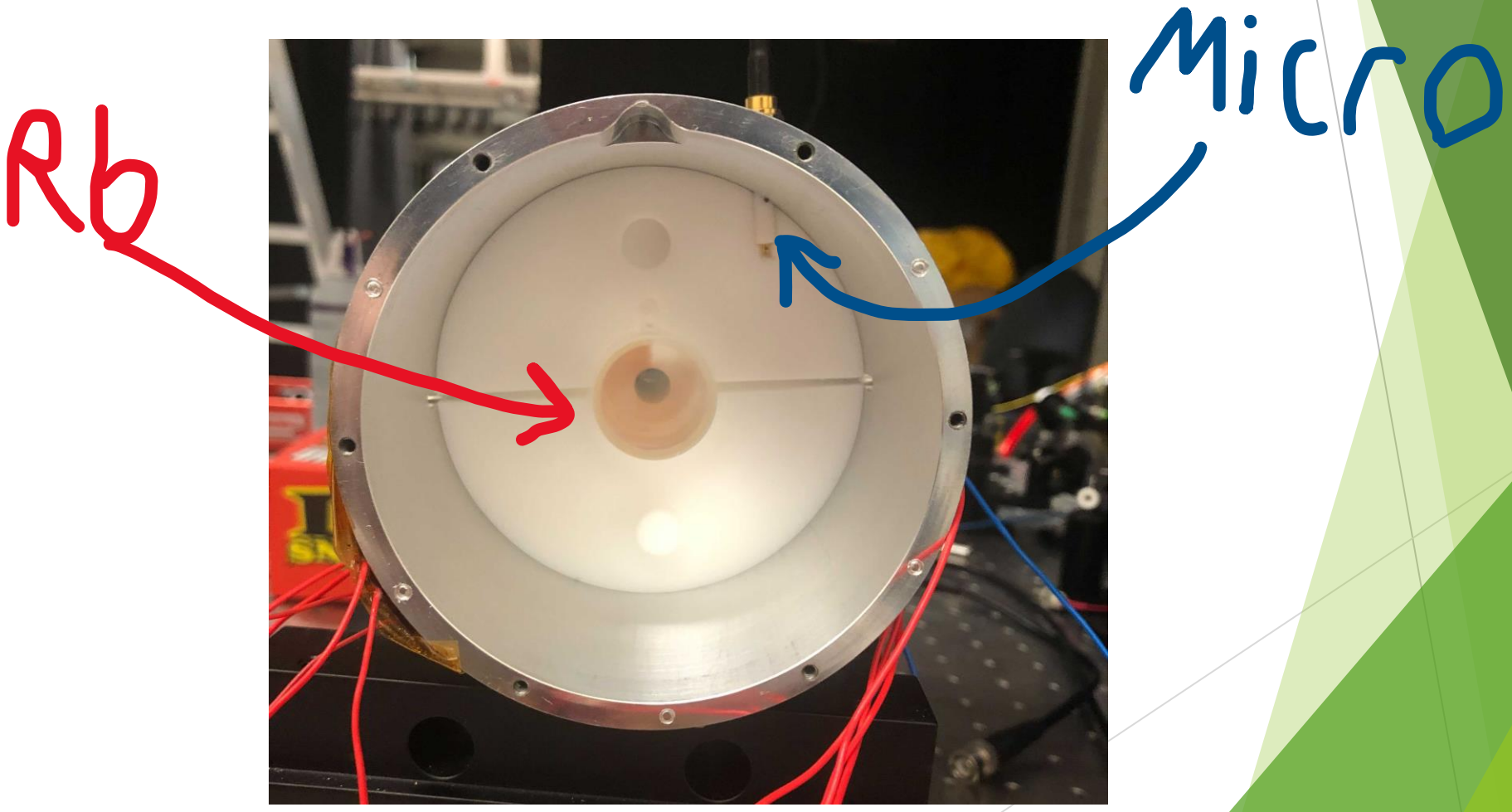
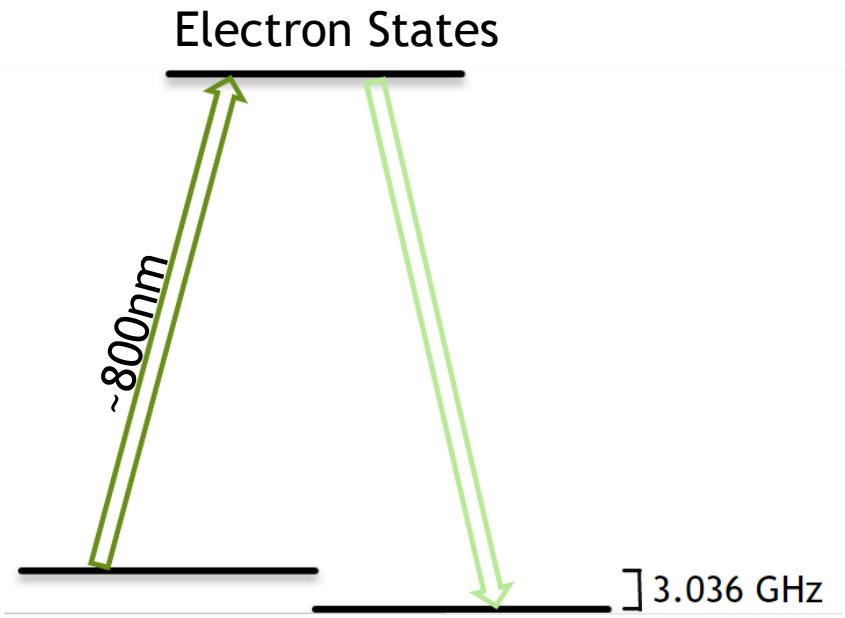
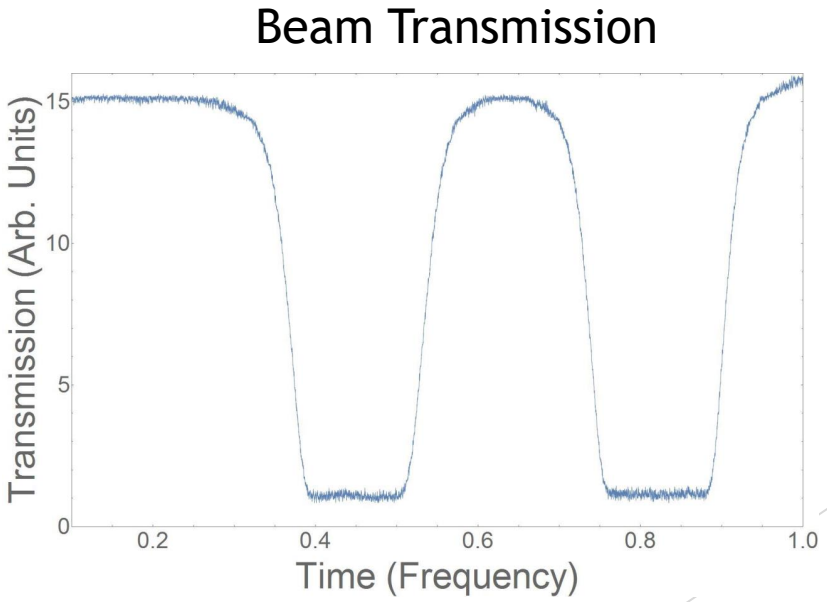


Single Beam

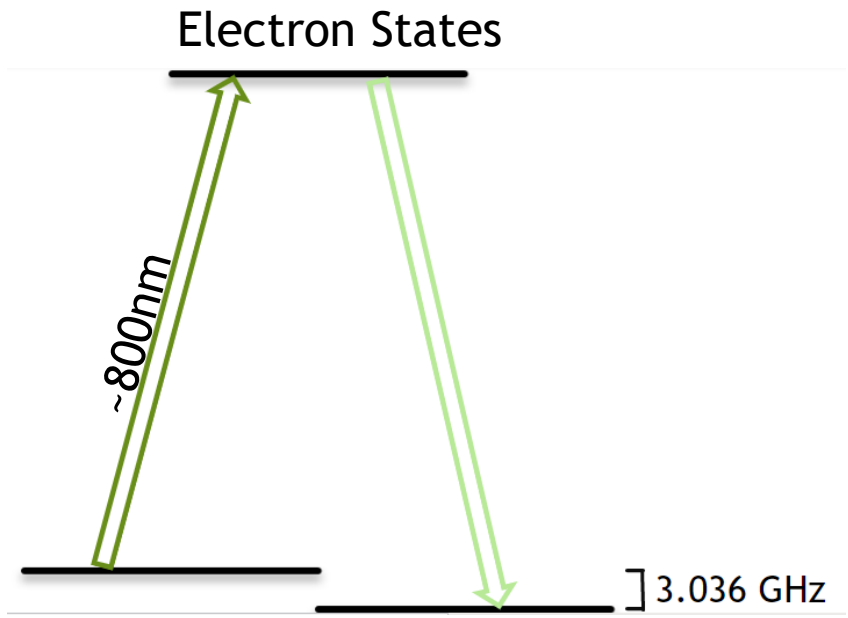
- Absorption spectra of Rubidium
- Dips correspond with transition from one state to another

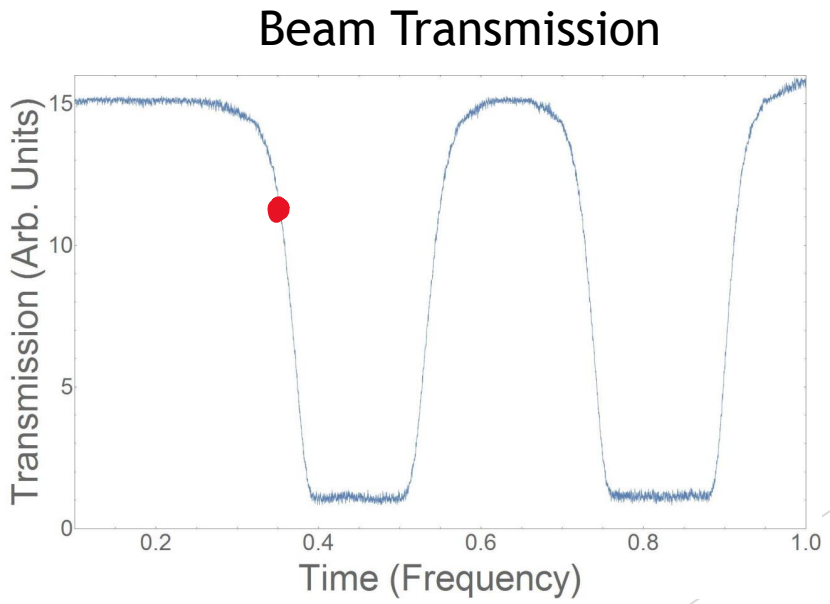




Single Beam

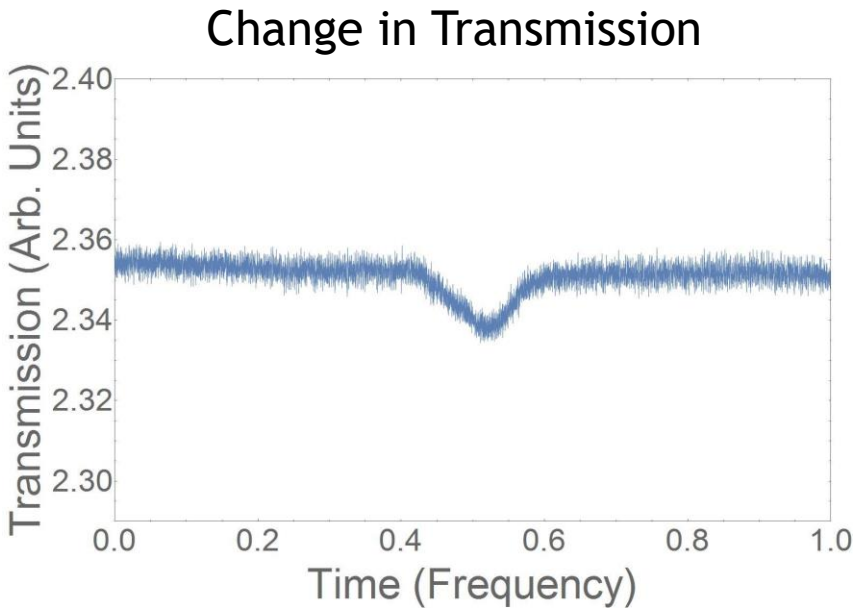
- Absorption spectra of Rubidium
- Dips correspond with transition from one state to another
- We can observe transmission at a single point in the spectra

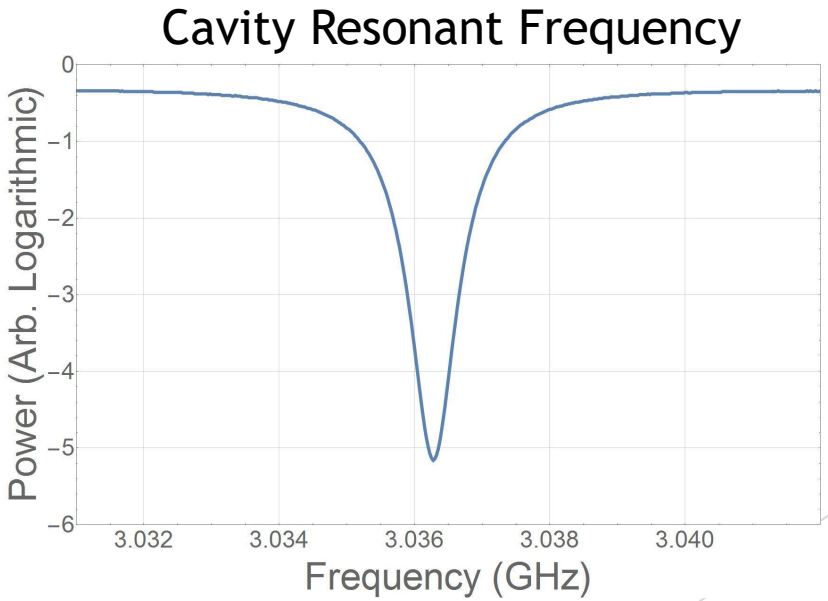




Initial Effects

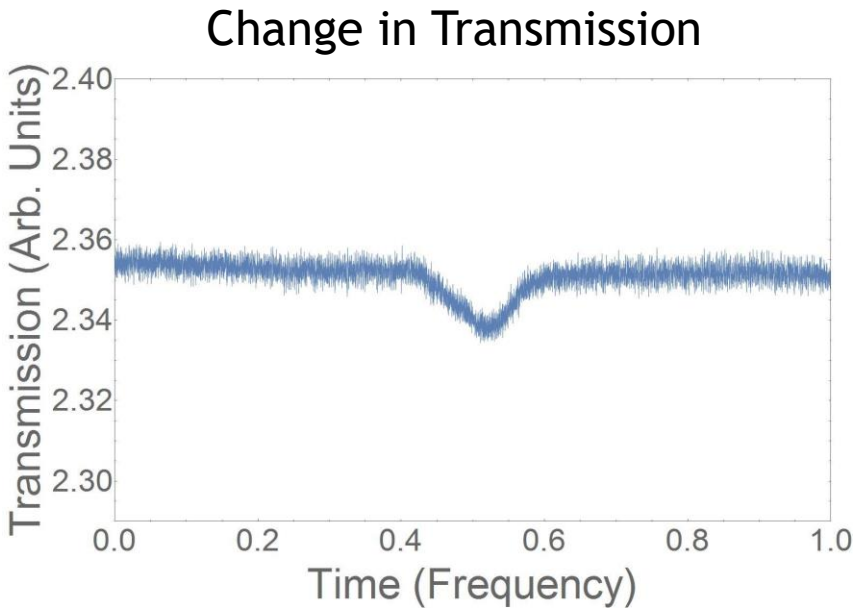
- Each section has a particular amount of absorption
- The cavity creates more absorption

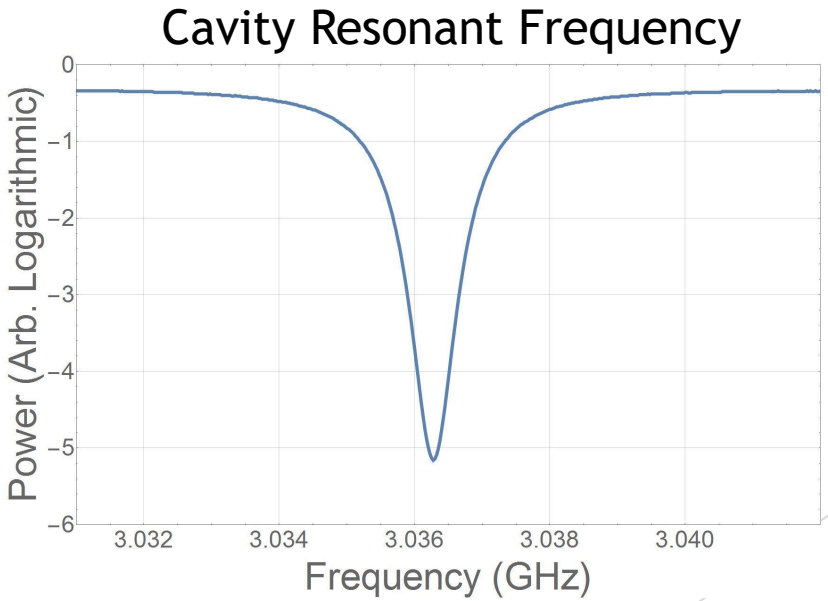




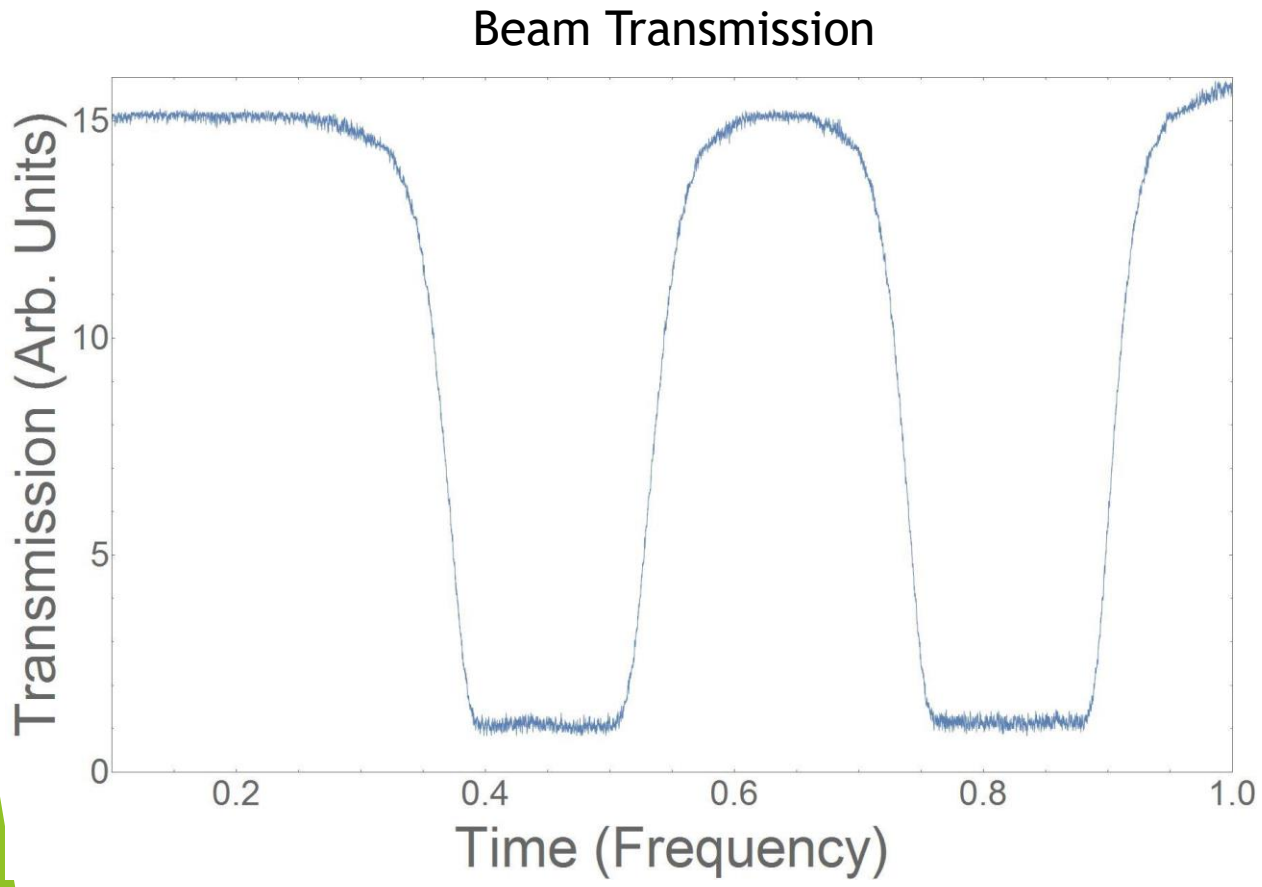
Initial Effects

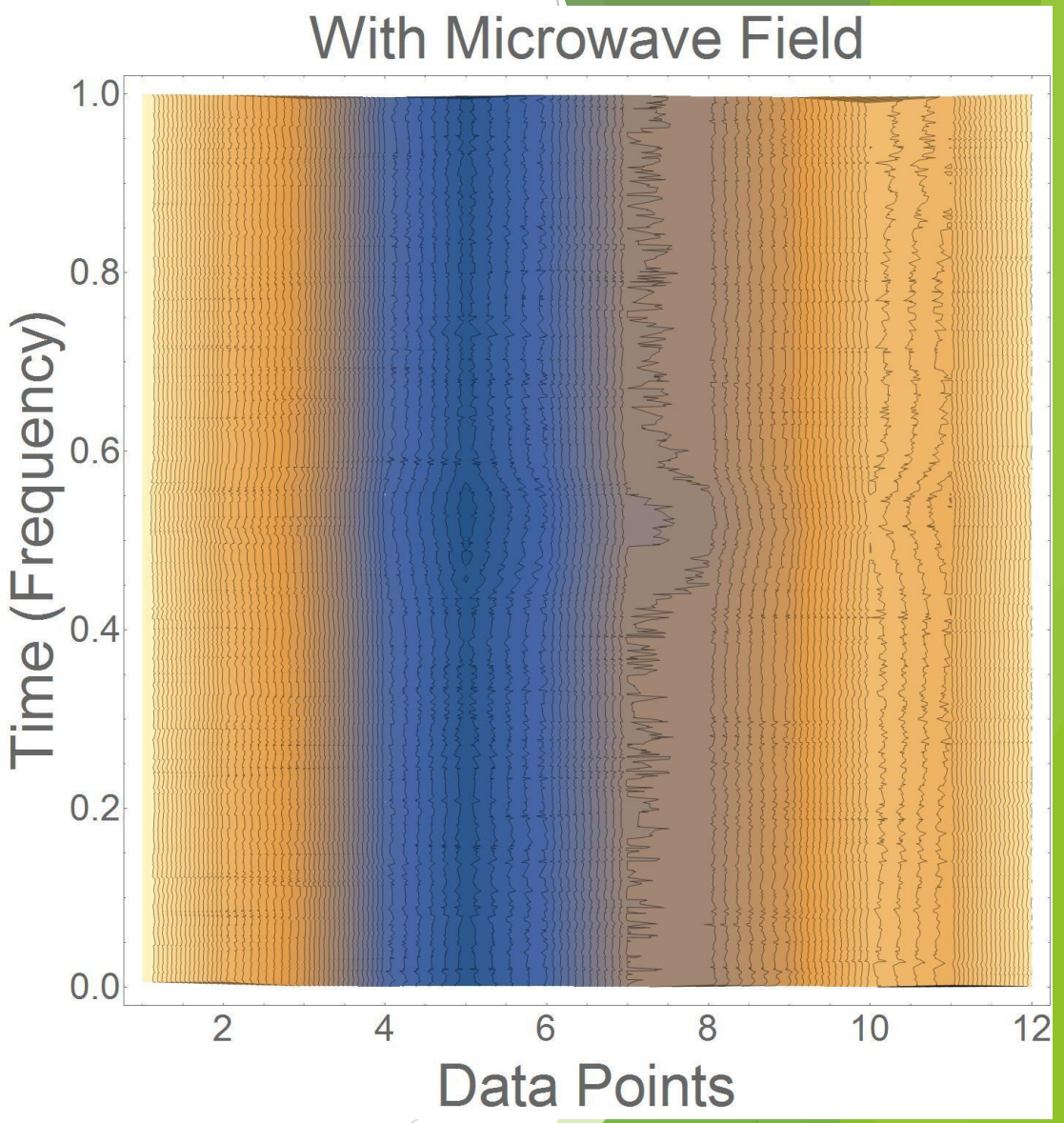
- Each section has a particular amount of absorption
- The cavity creates more absorption
- Now, we put all the transmission data together





Effects Microwave Field has on Beam





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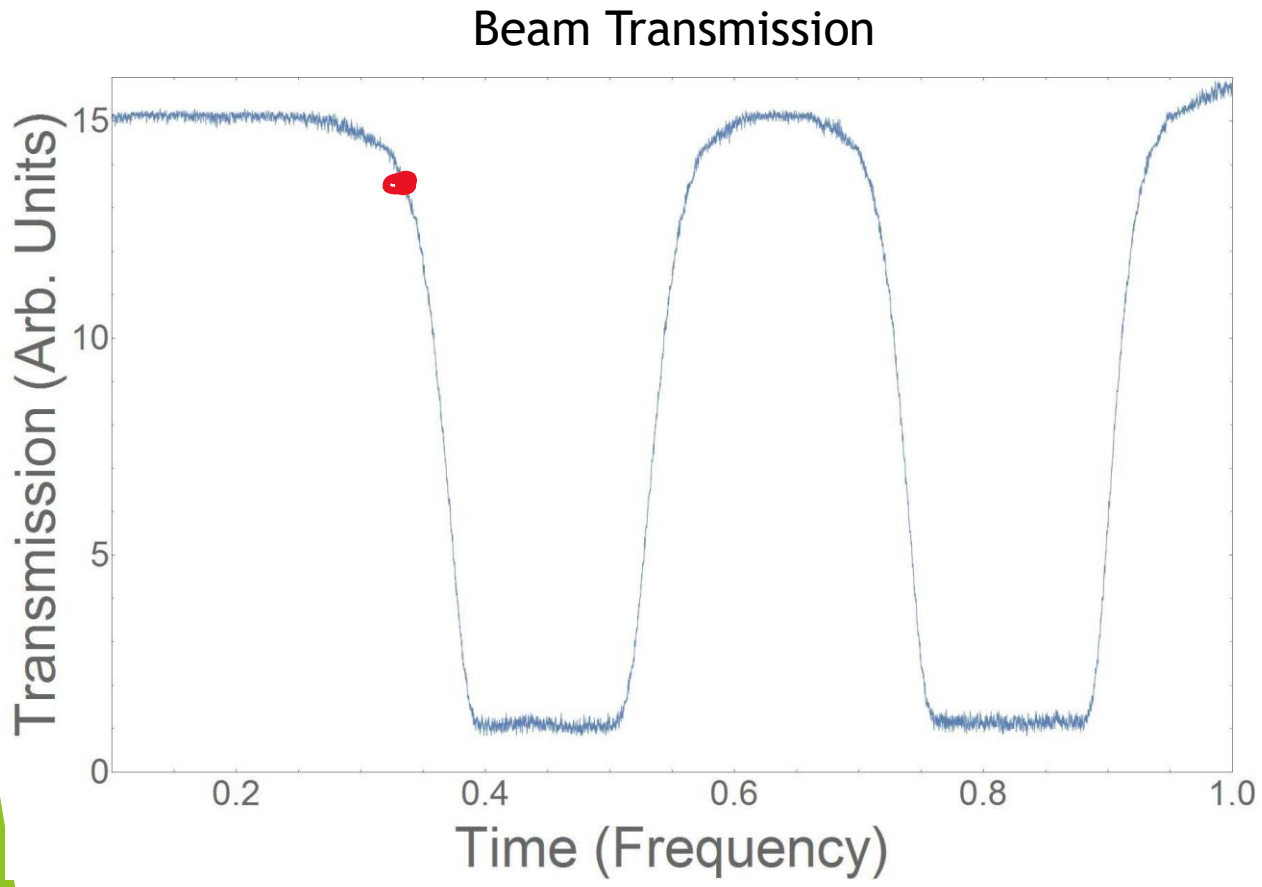

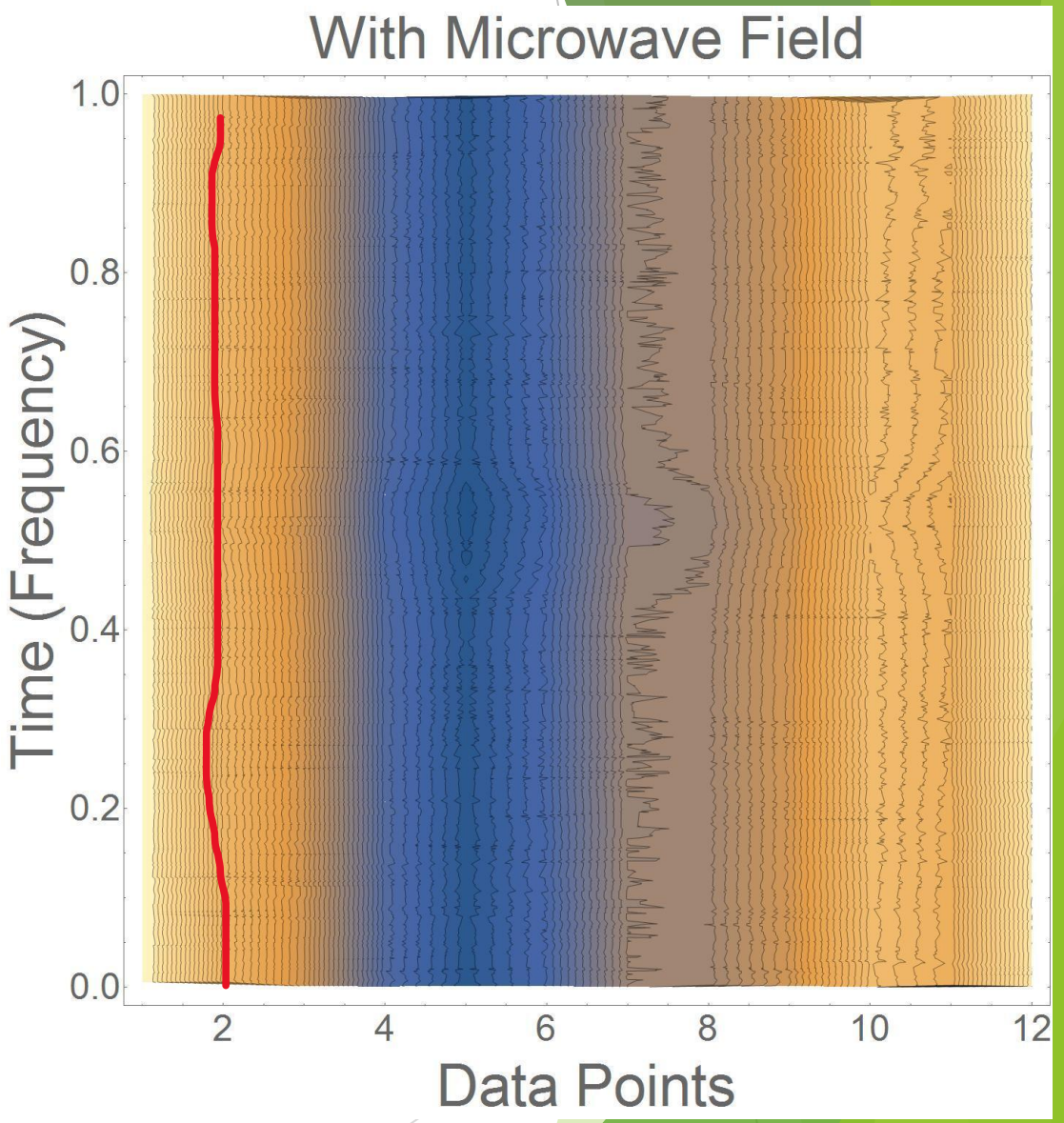

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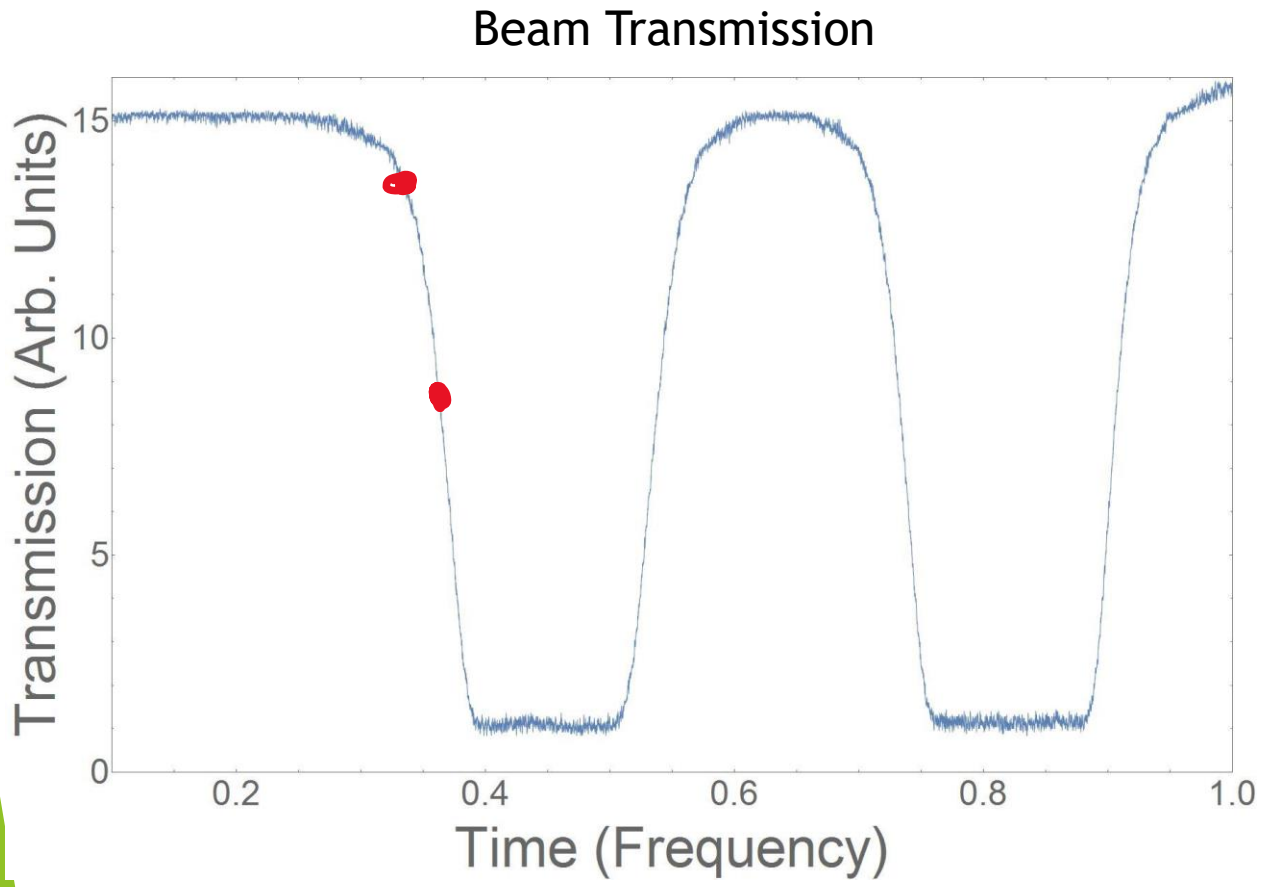

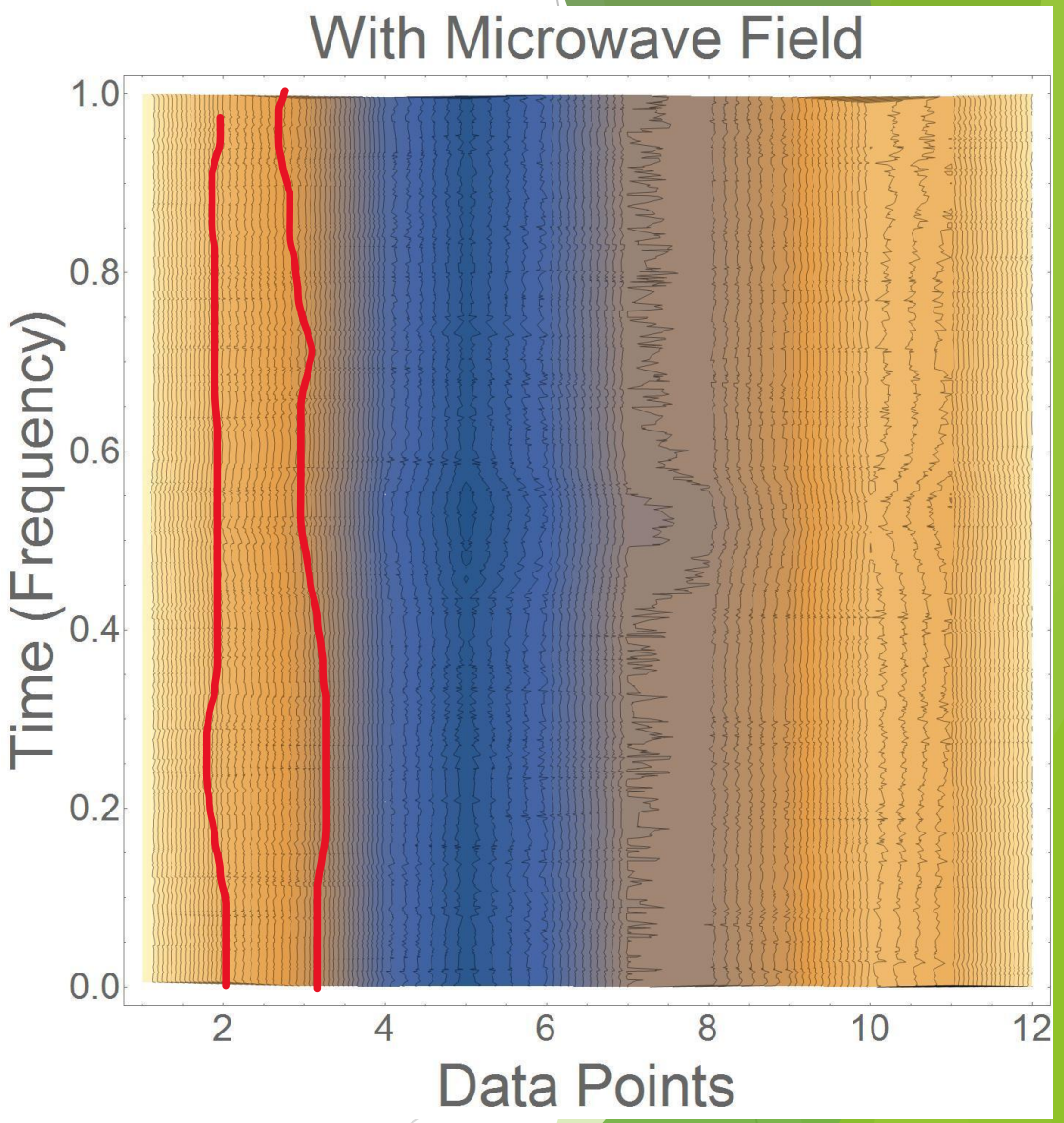

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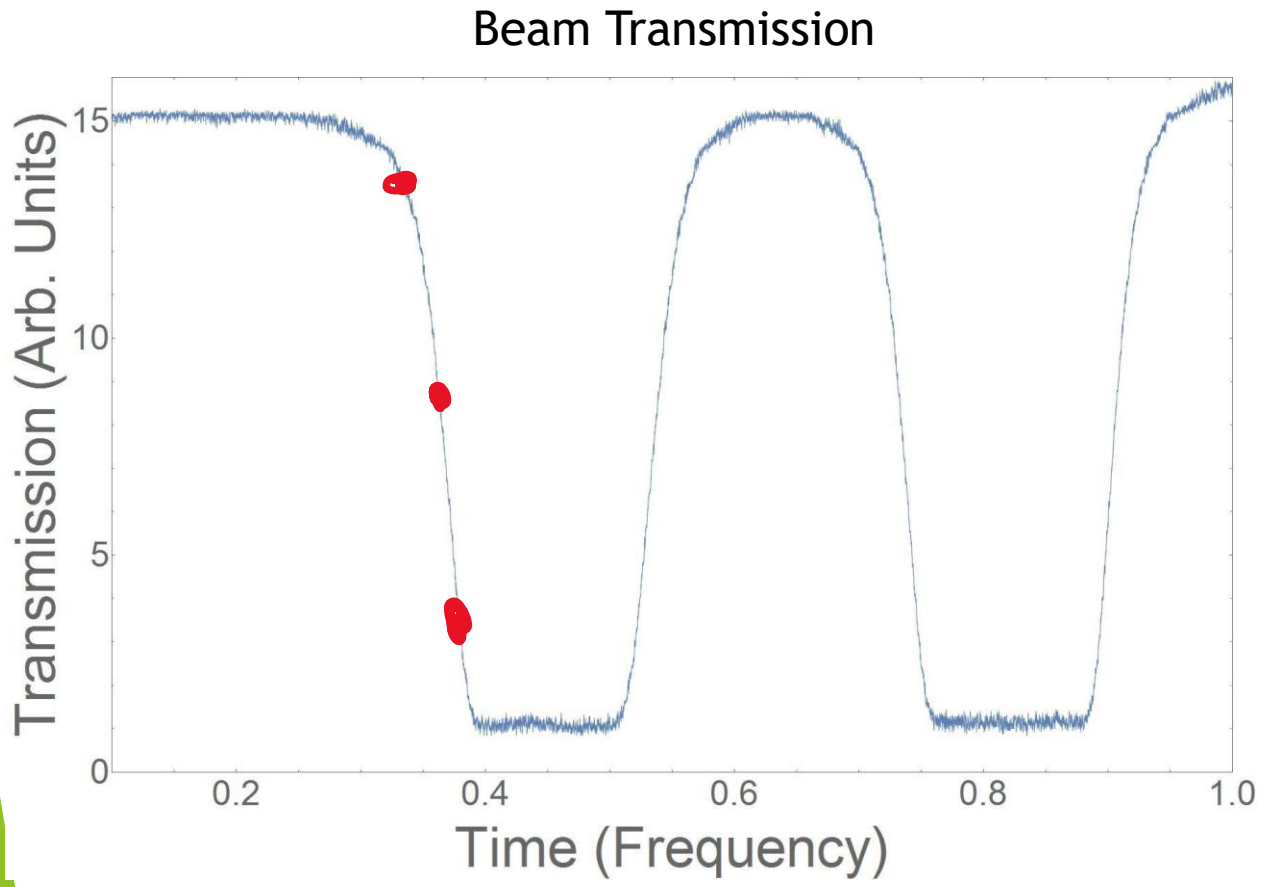

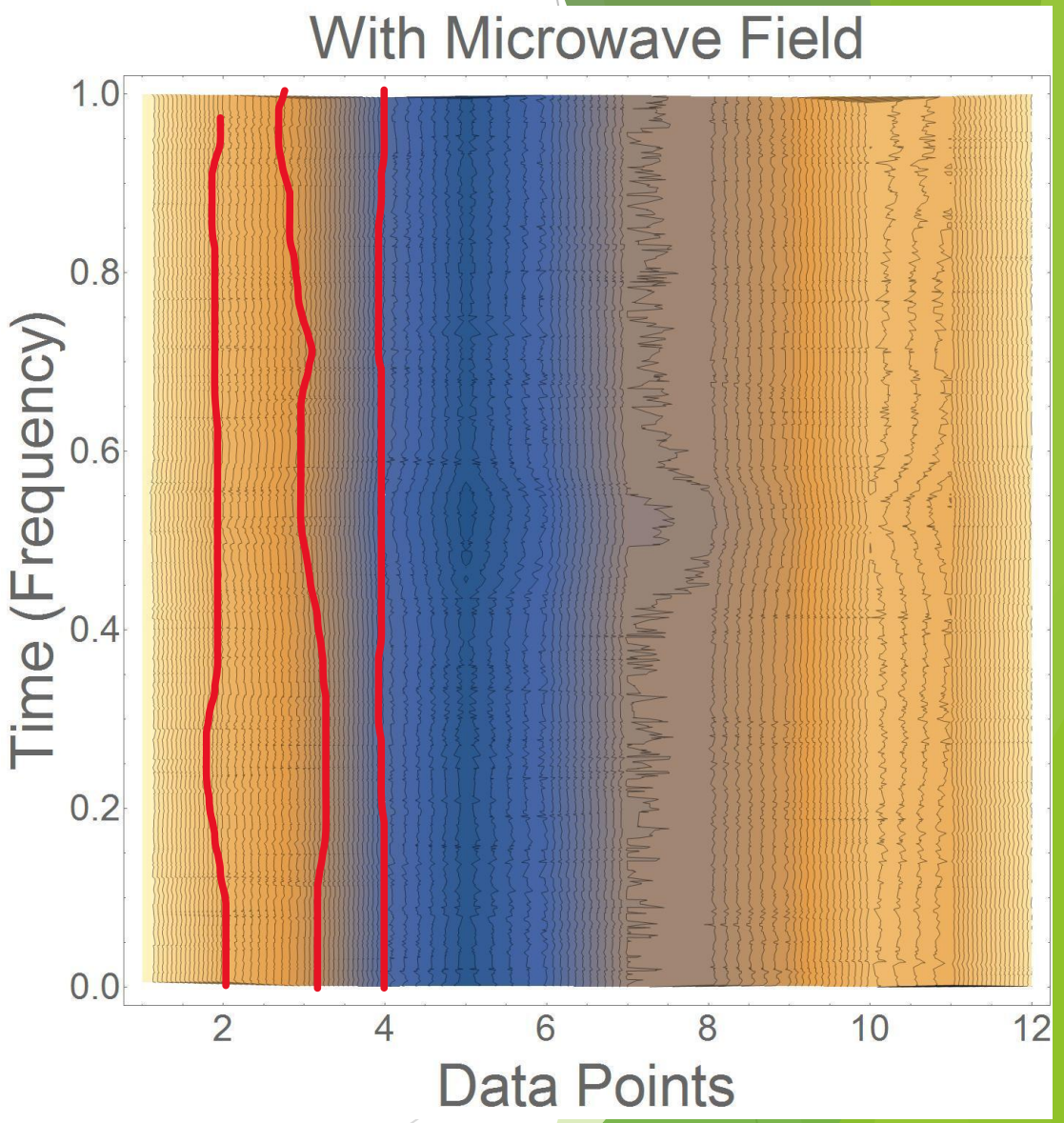

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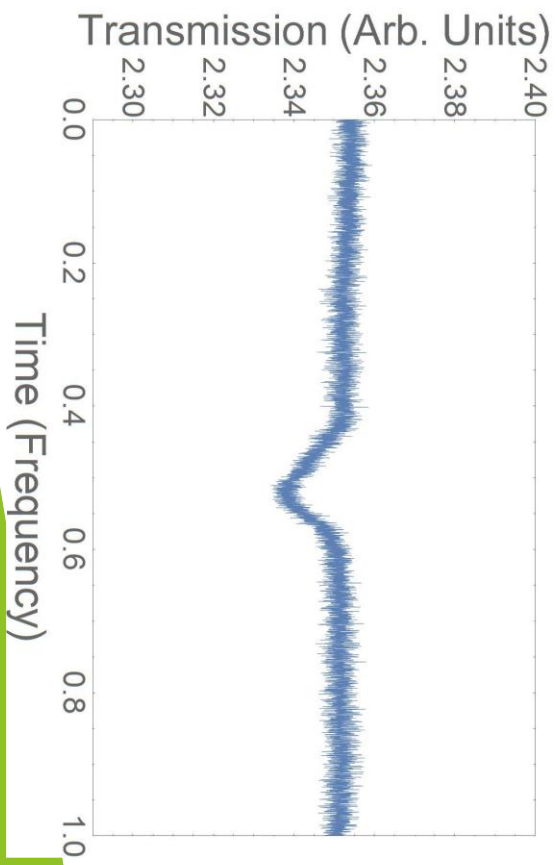

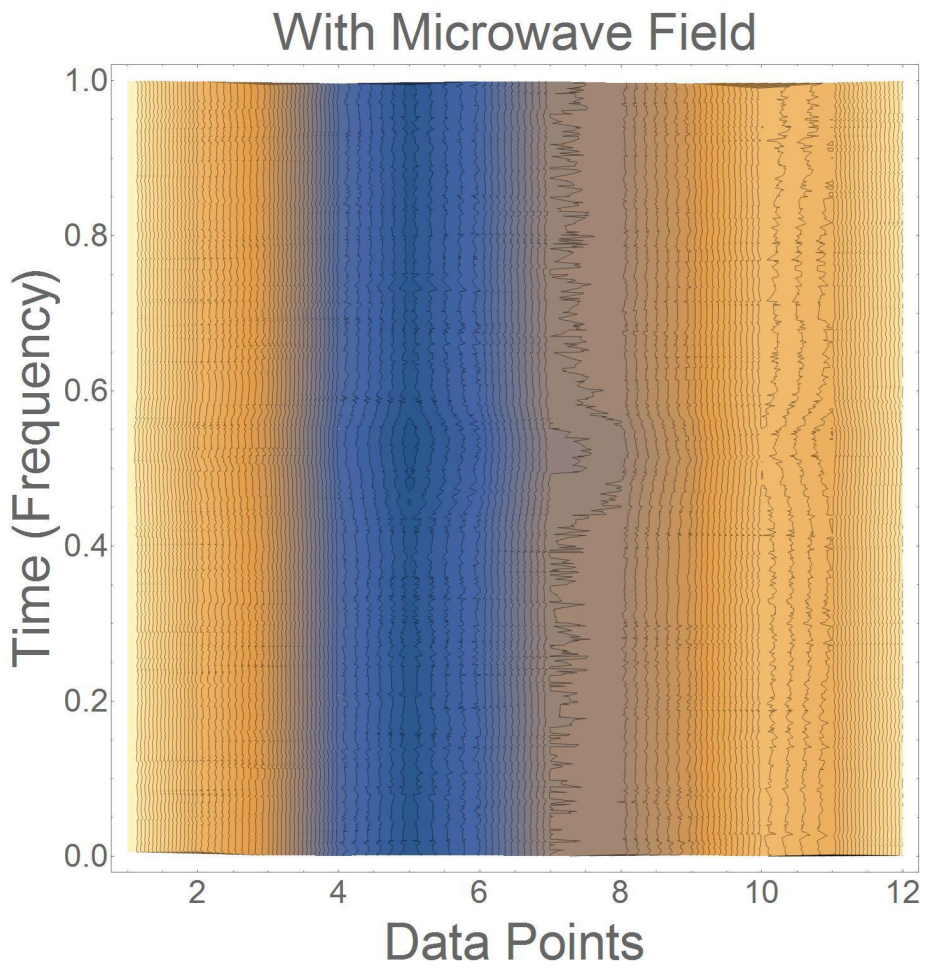

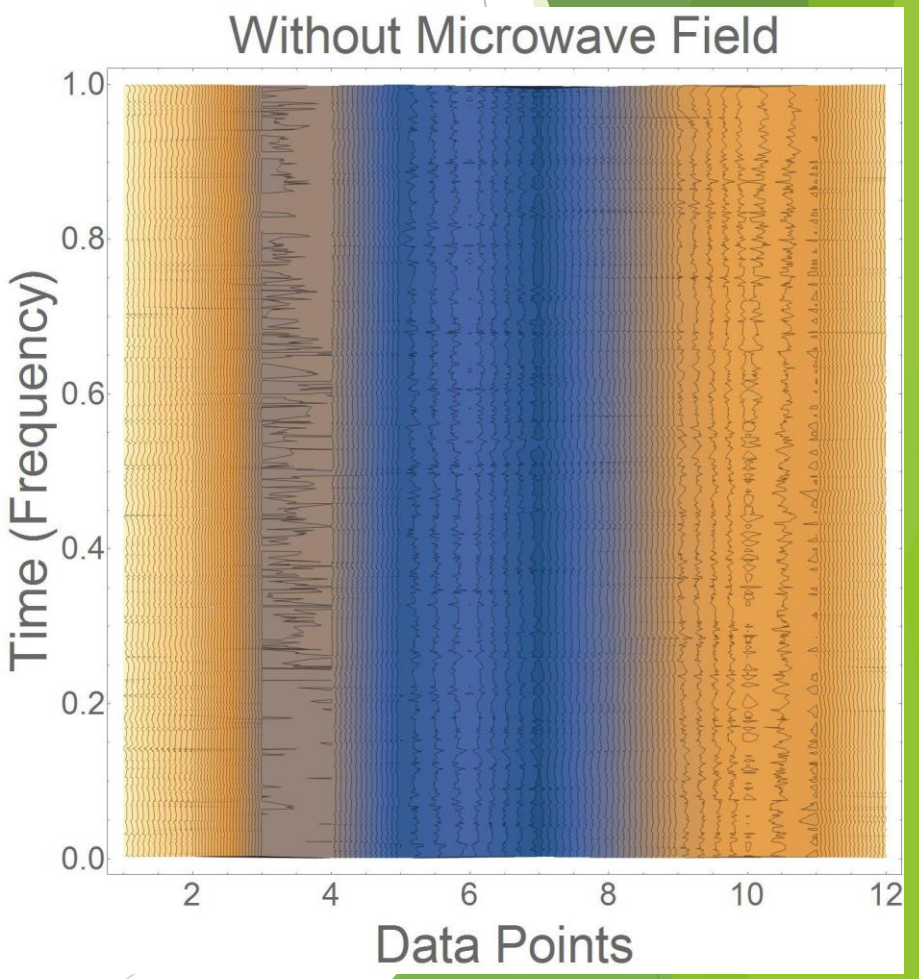

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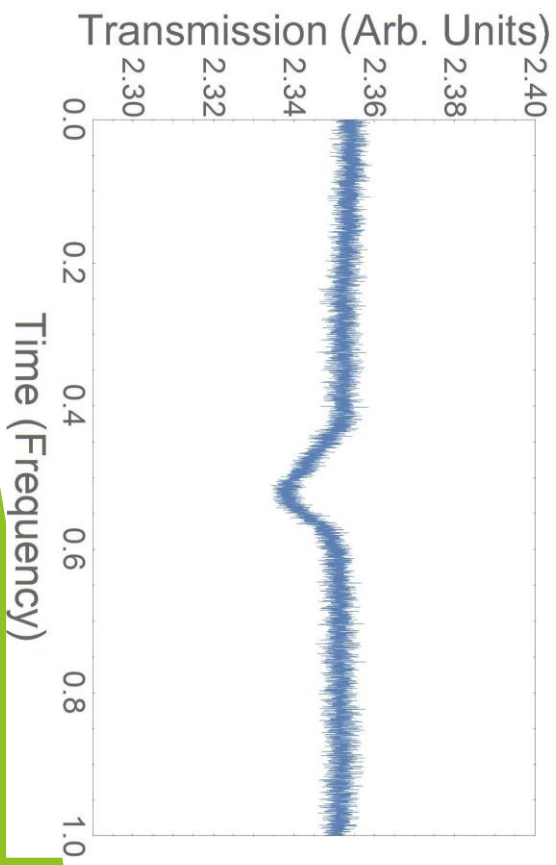
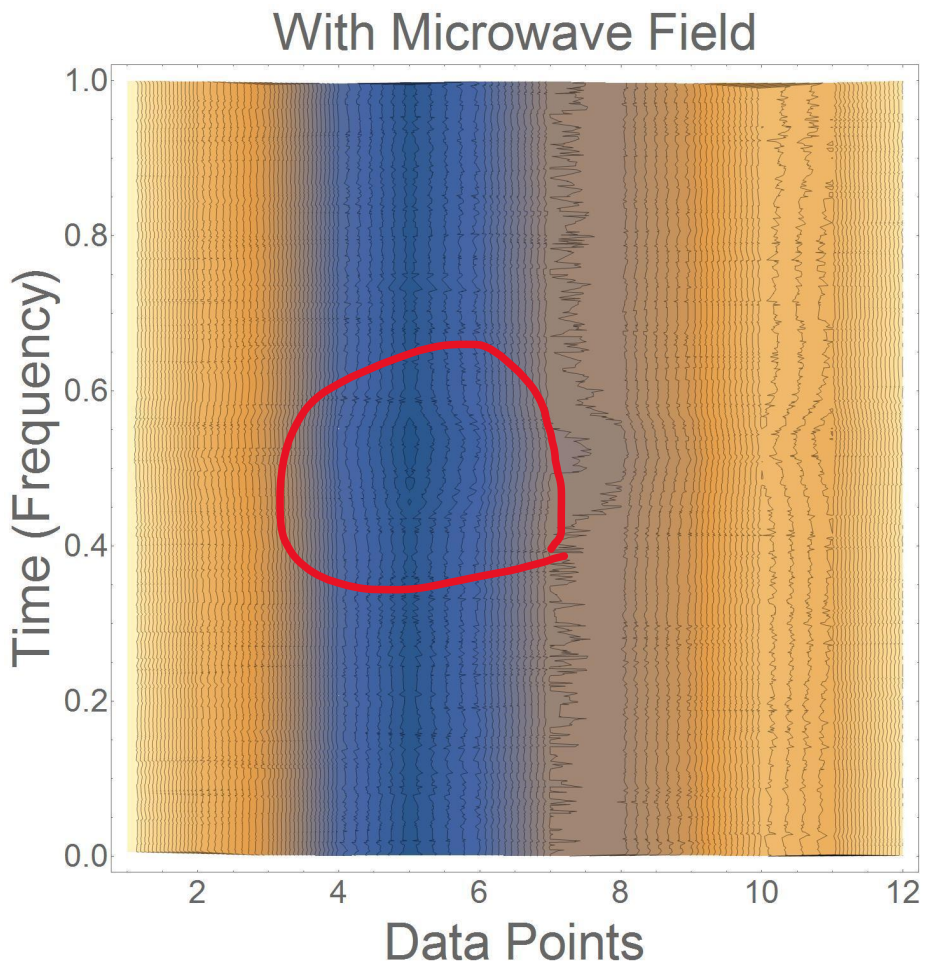
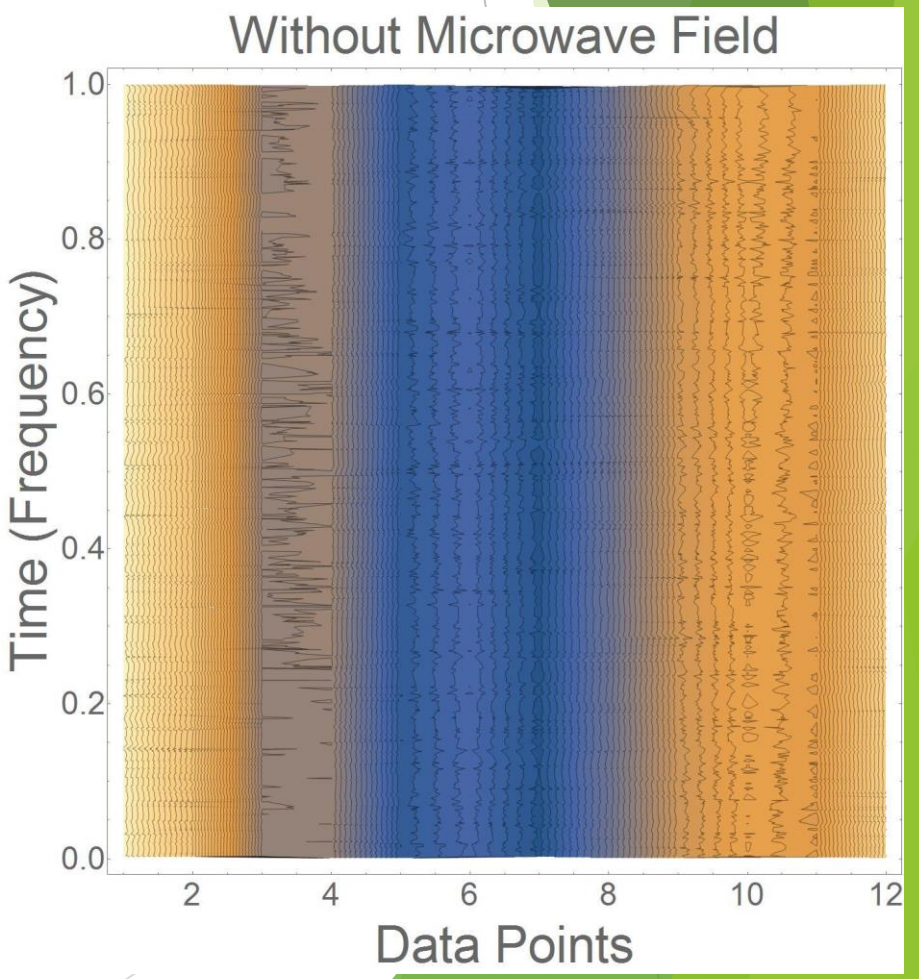
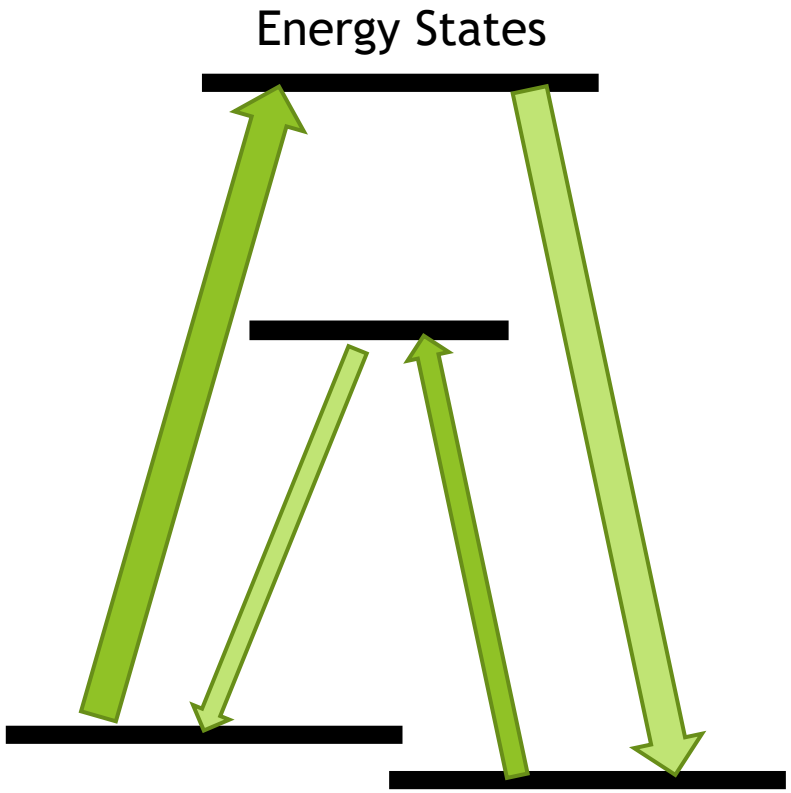






Four-Wave Mixing Process (FWM)

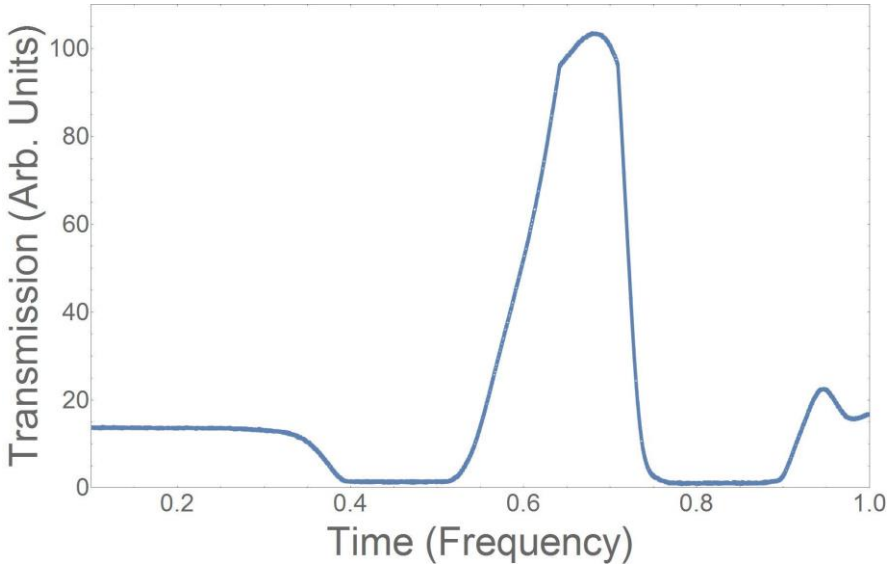
- Two photons are absorbed
- Electron gains then loses energy
- Two photons that are entangled are then emitted



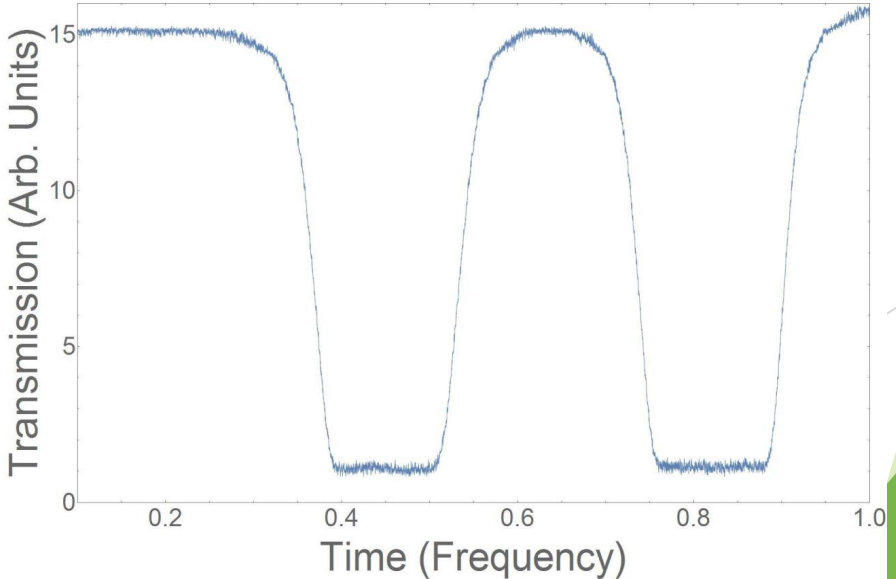
Four-Wave Mixing Process Cont.

- Absorption spectra ascociated with four-wave mixing
- Depending on the temperature, one peak will increase and the other with decrease
- Spectra broken into sections again

Four-Wave Beam Transmission



Single Beam Transmission



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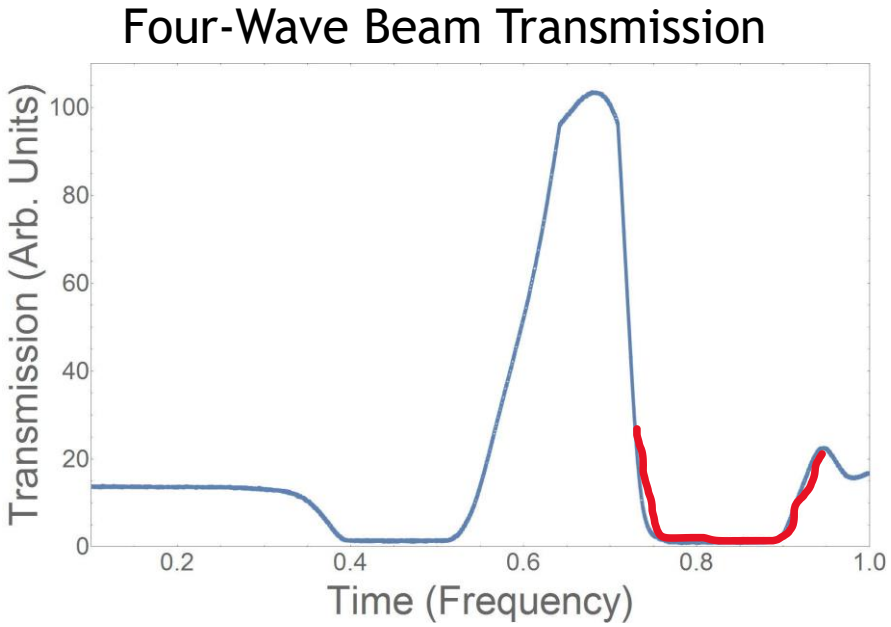
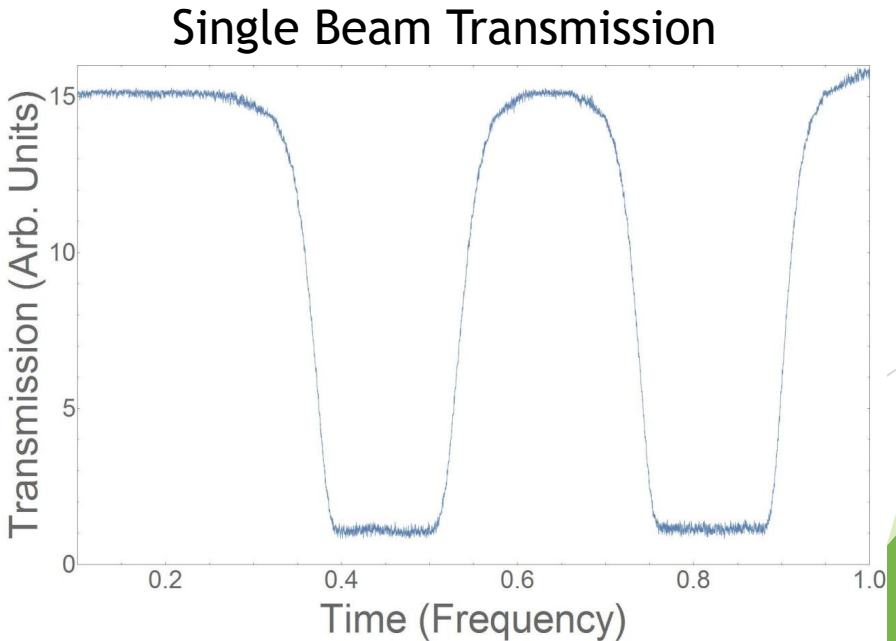
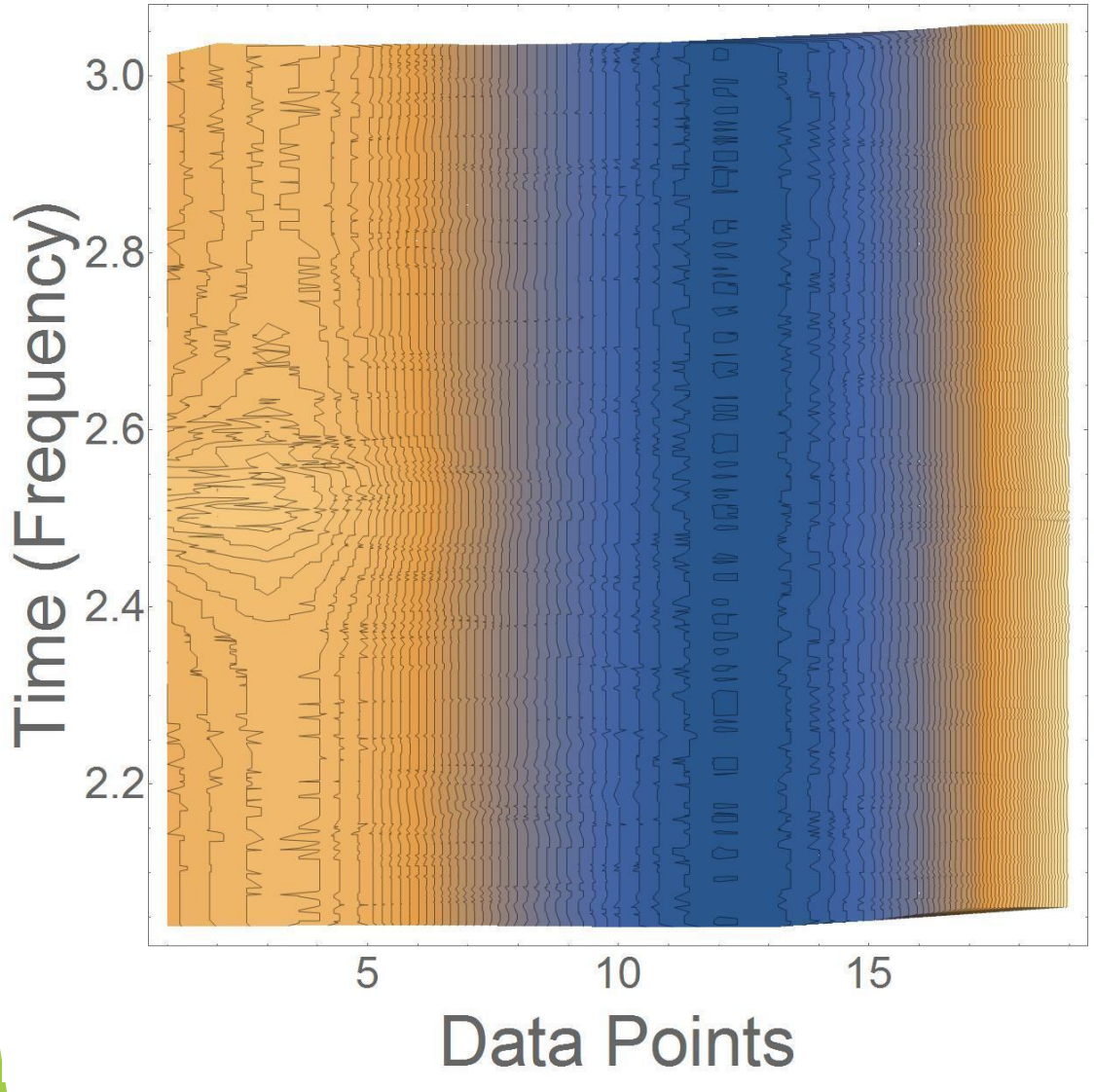


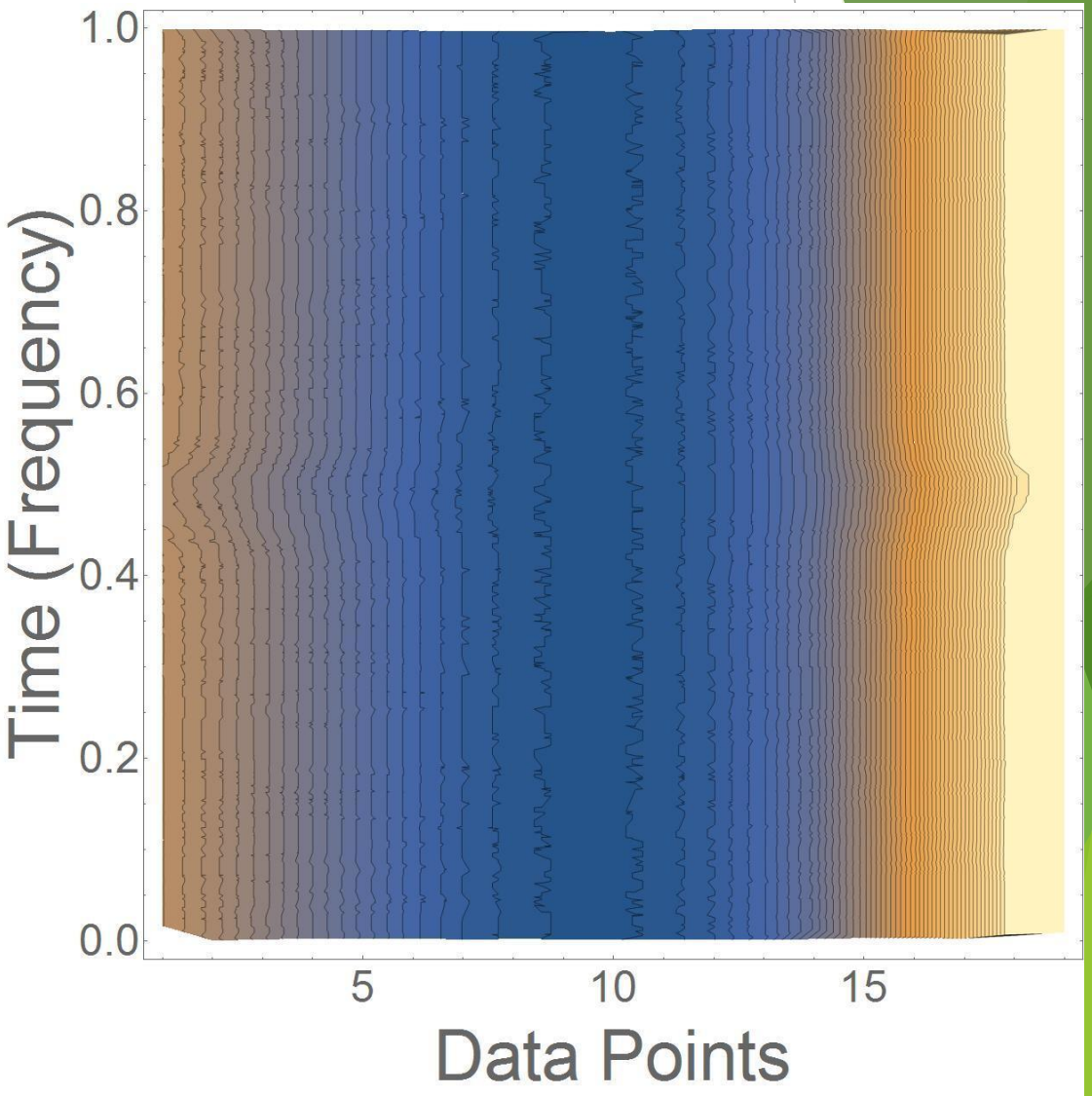


On Resonance

On Resonance



Off Resonance



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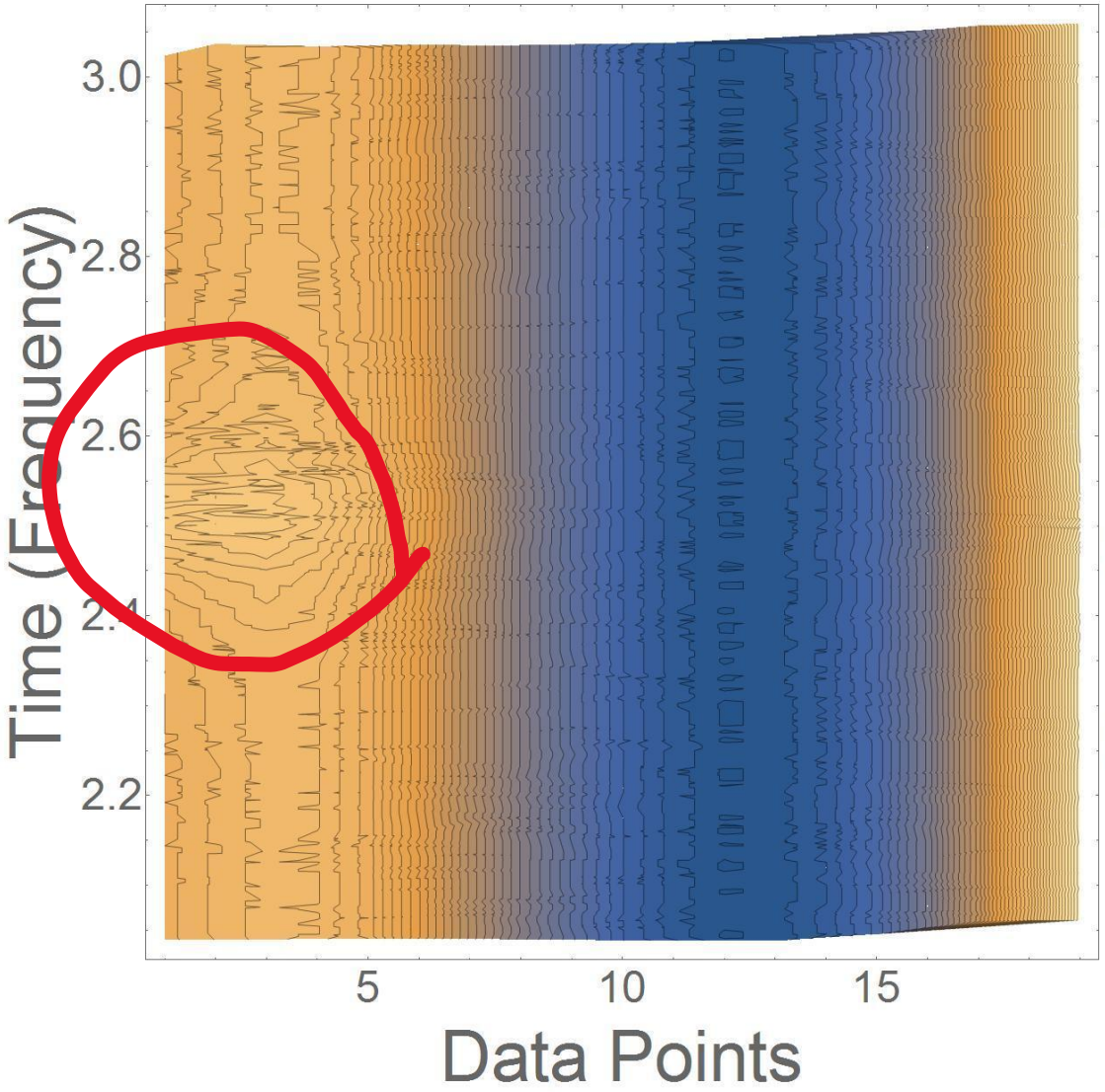
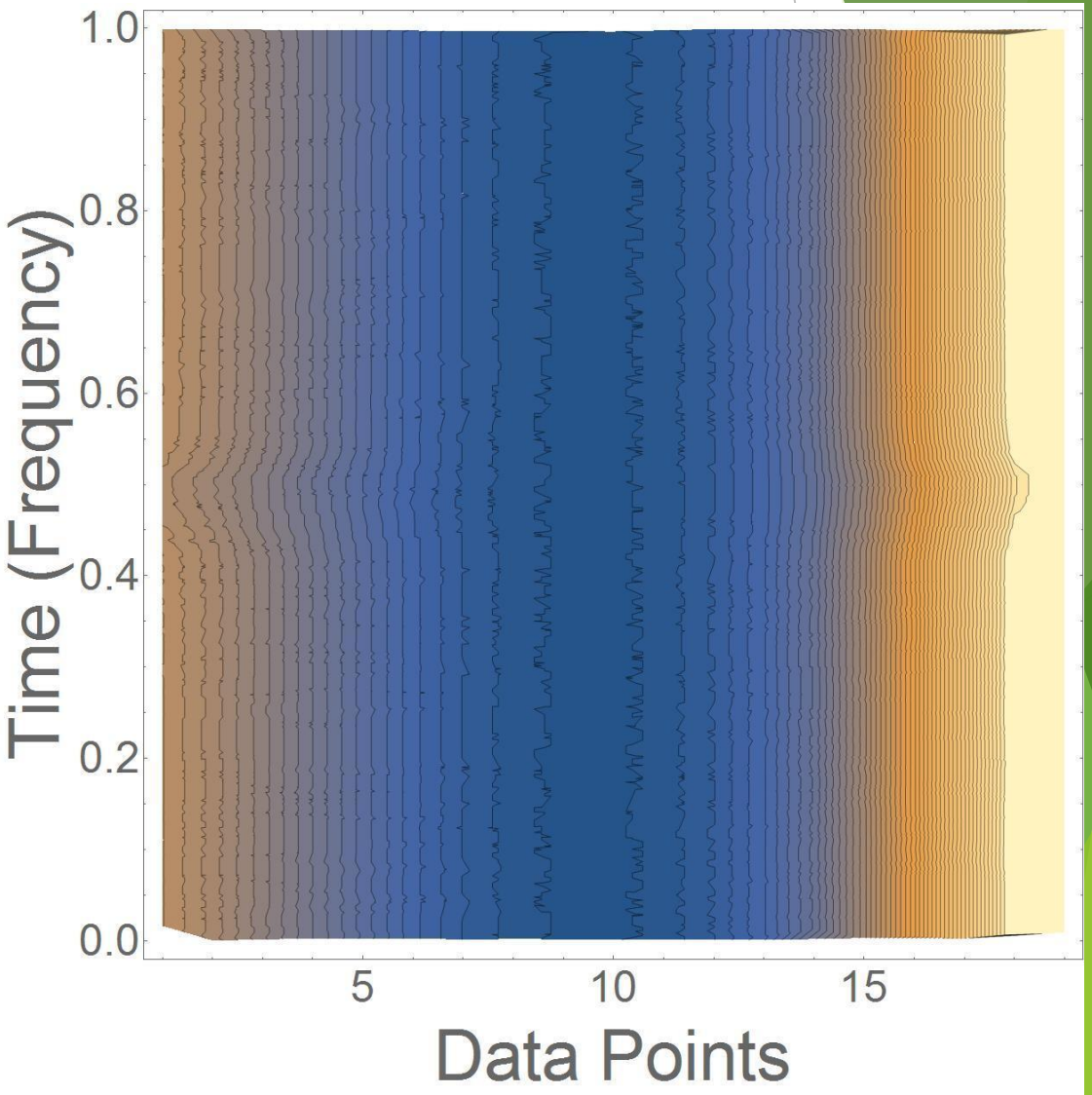


Off Resonance



Conclusion

- Resonant frequency was characterized
  - Position decreased as temperature and length decreased
  - Width and depth decreased as length increased
- Cavity was shown to influence interaction between light and atoms
- Cavity has shown increased gain in FWM