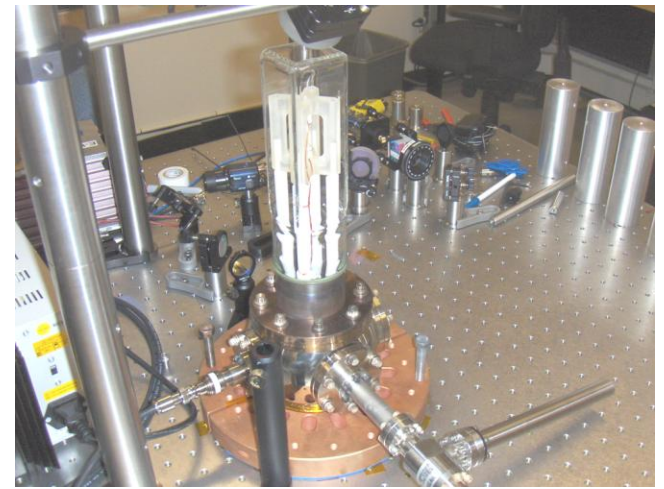
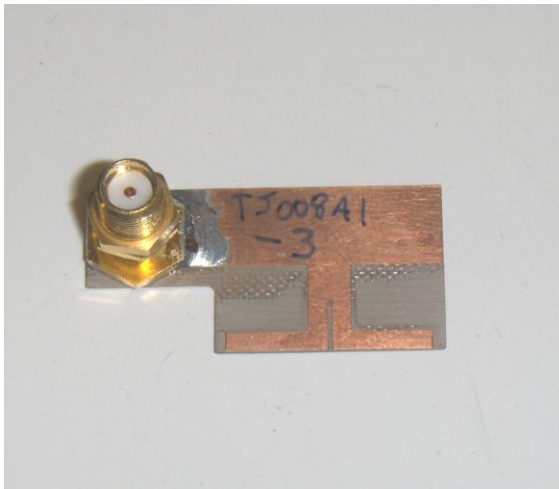


# Building a Microwave Antenna for a Quantum Microscope



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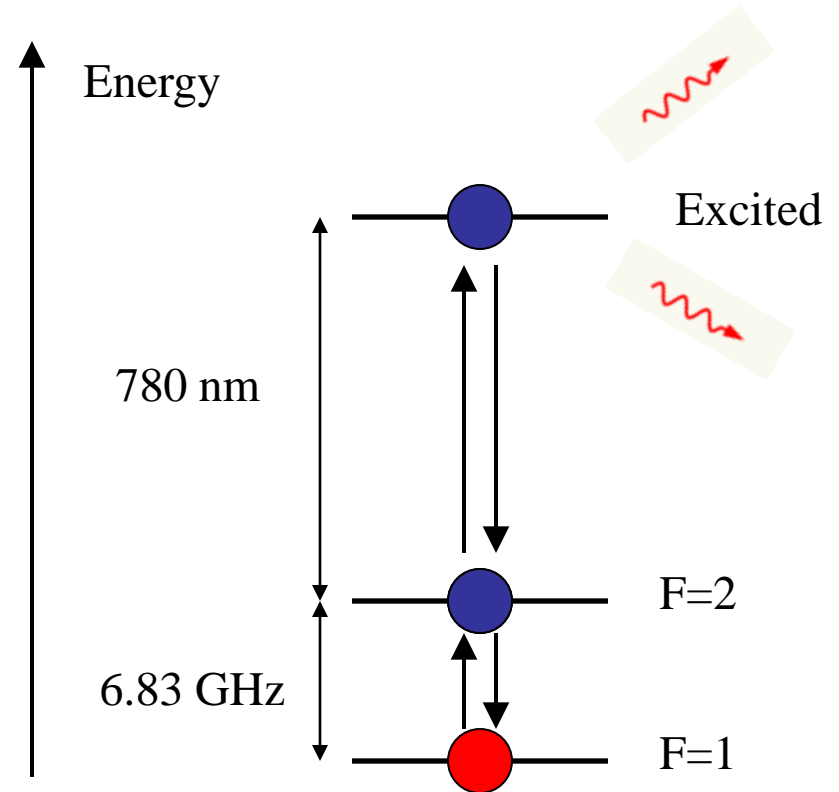
August 7, 2008

# Outline

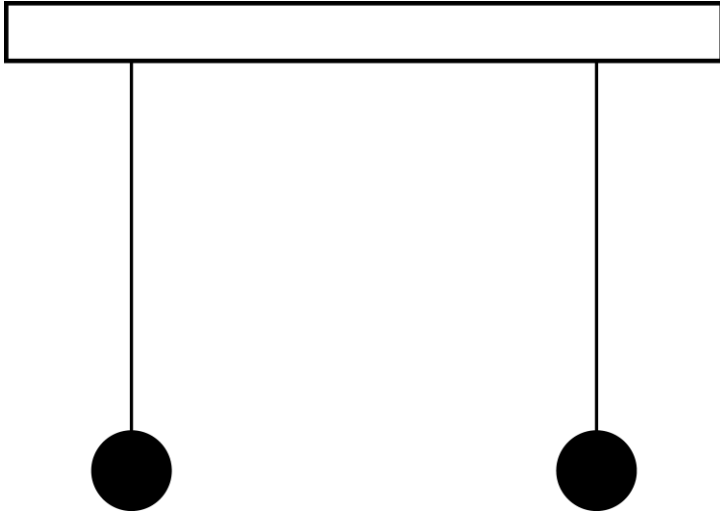
- Brief overview of the experiment
- Rabi flopping
- Microwave antenna setup
- Counting the atoms
- Current status of the experiment
- Summary and conclusions

# Overview of the Experiment

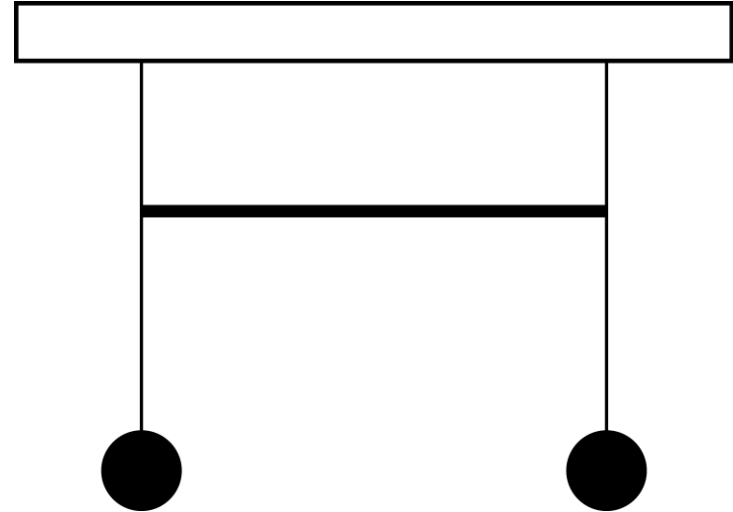
- Use microwaves to excite Rabi flopping between ground states of  $^{87}\text{Rb}$ .
- Measure the relative numbers of atoms in each ground state as a function of time.
- Want to be able to create an arbitrary superposition of the two states.



# Classical Analog of Rabi flopping



The pendulums move independently.

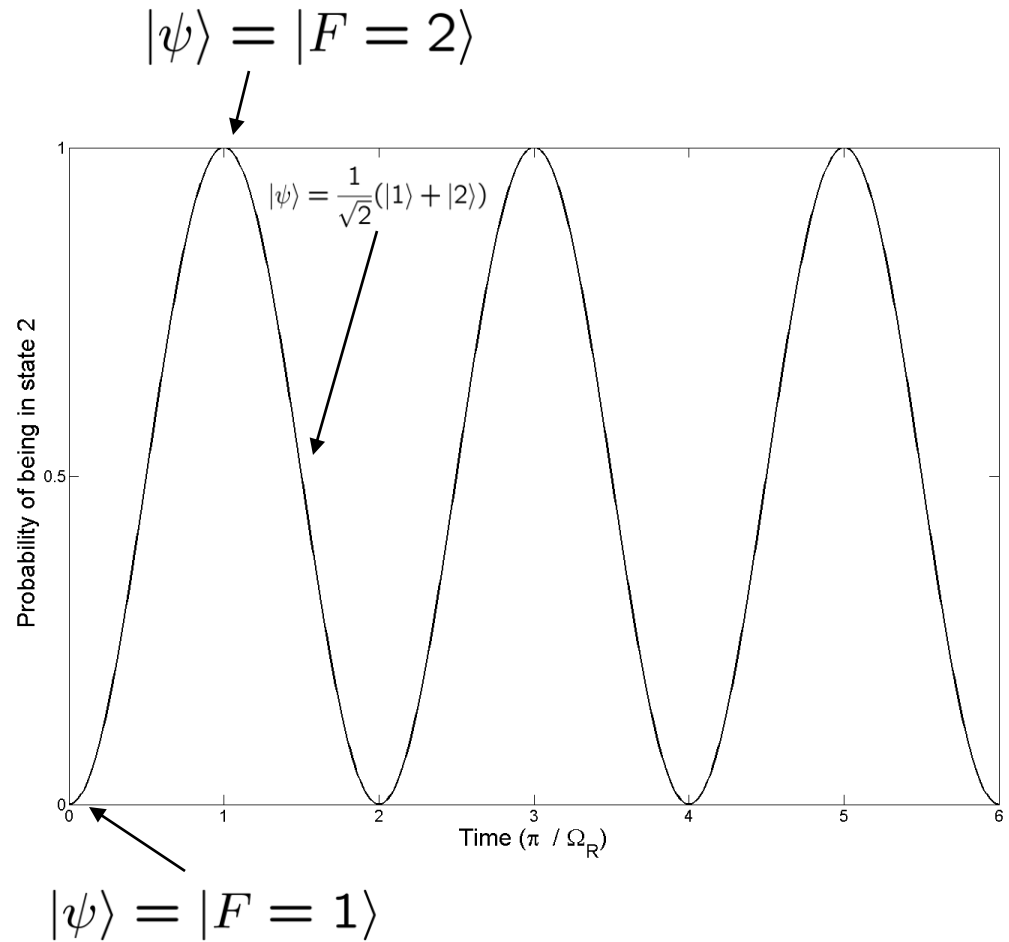


When coupled, the pendulums will transfer energy.

# Rabi Flopping

The cyclic absorption and stimulated emission of photons for atoms in a two-state quantum system.

$$P_{|2\rangle} = \sin^2\left(\frac{\Omega_R t}{2}\right)$$



# The Need for High-Power Microwaves

- We need something to drive the Rabi flopping.
- Energy difference between ground states corresponds to the microwave range.
- We want a high Rabi frequency to beat decoherence rates.

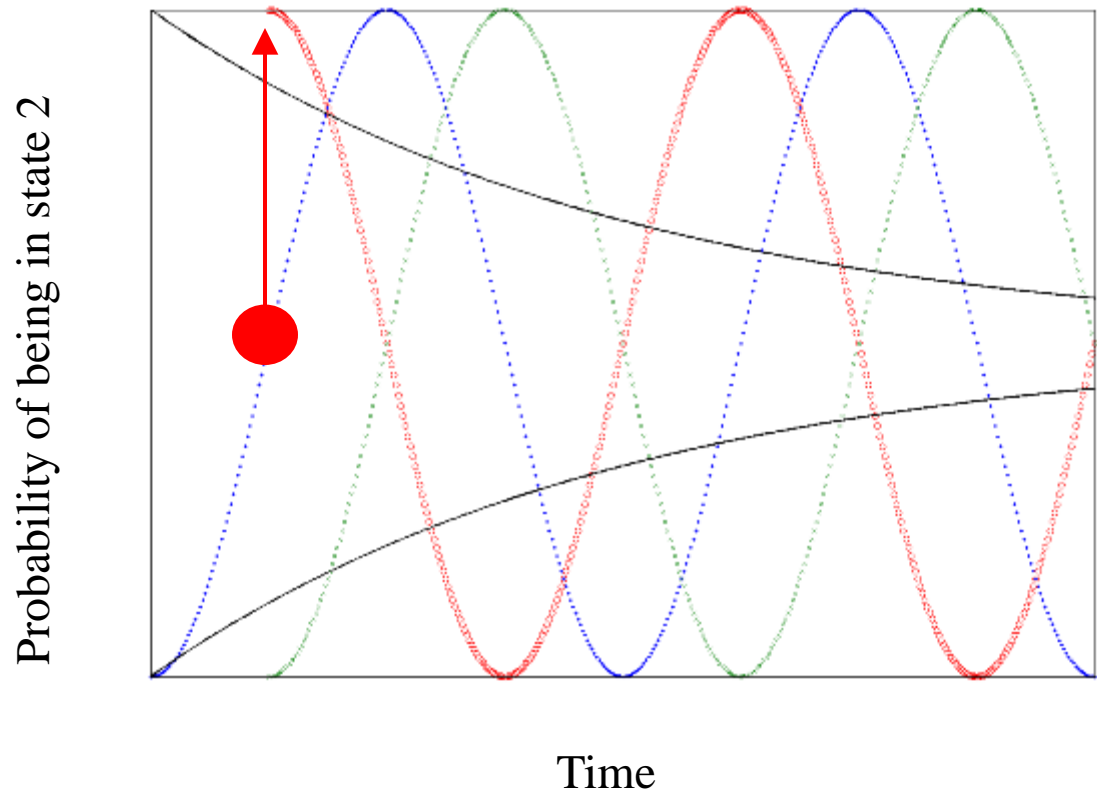
For this transition,

$$|\Omega_R| = \left| \frac{\mu_B B}{\hbar} \right|$$

Conclusion: To make  $\Omega_R$  large, we need a large magnetic field, which means that the microwaves need to have a relatively high power (1-2 W).

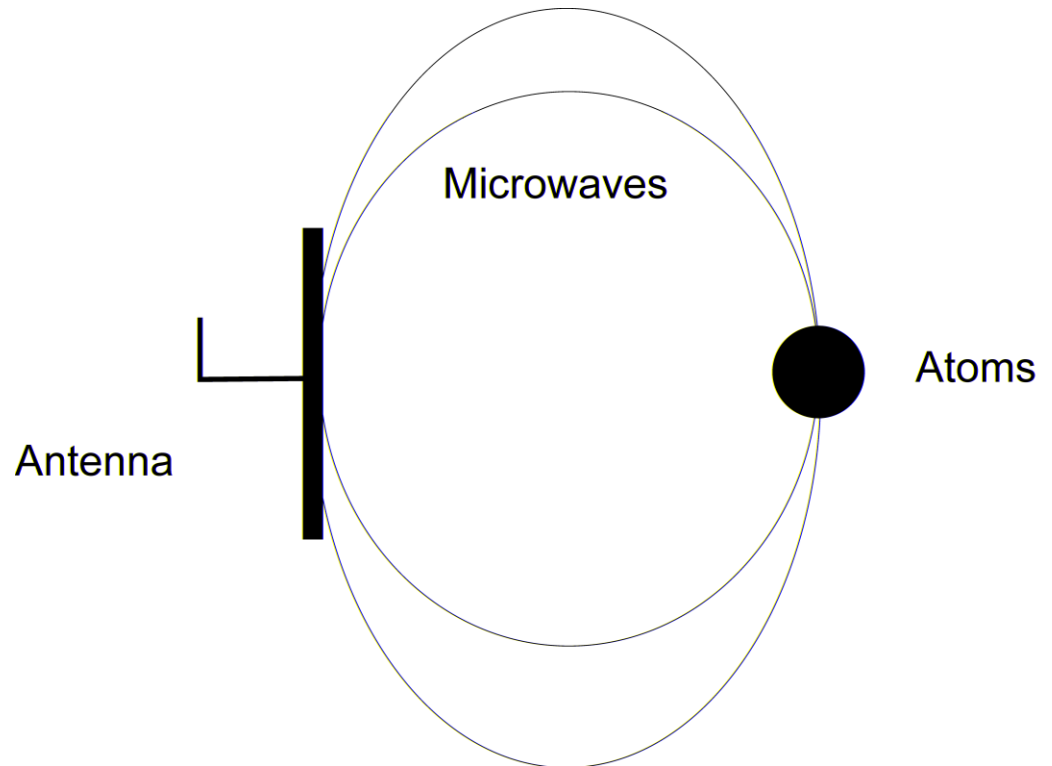
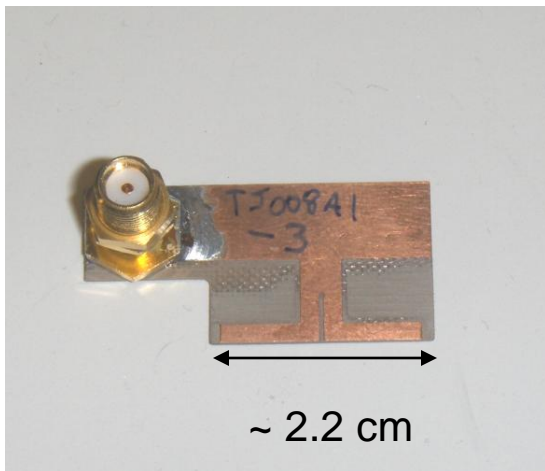
# Decoherence in the system

- Atoms hit wall
- Inhomogeneous magnetic field
- Inhomogeneous trap
- Scattering rate from trap



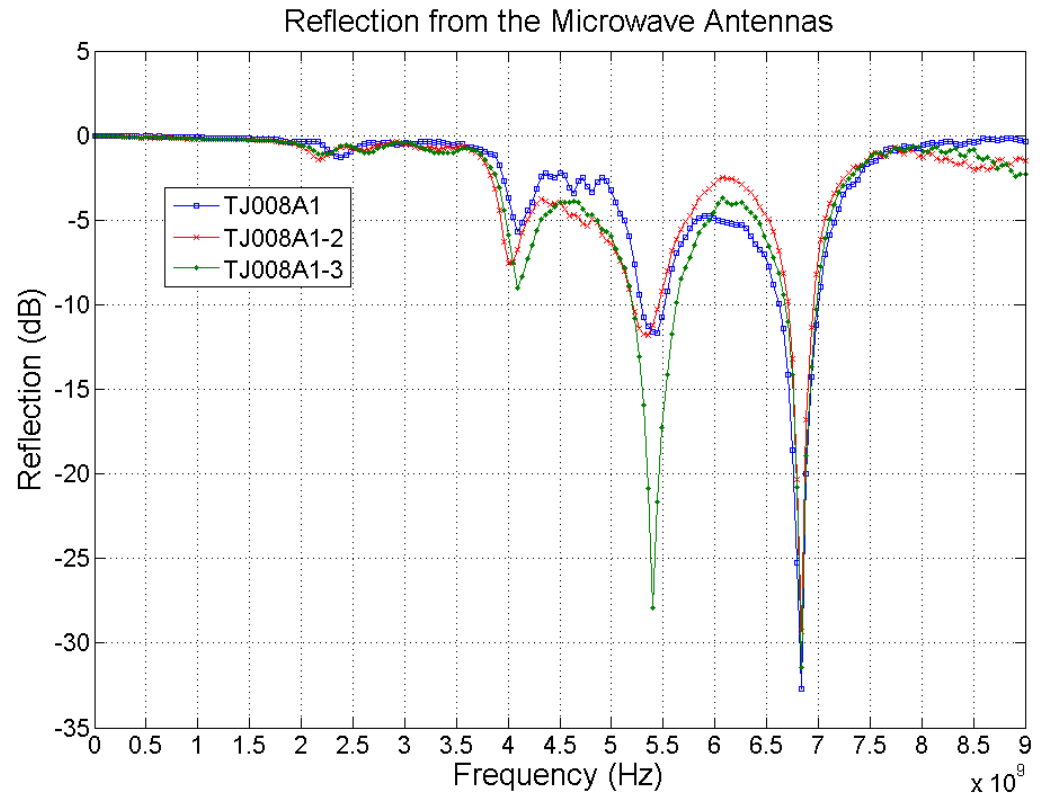
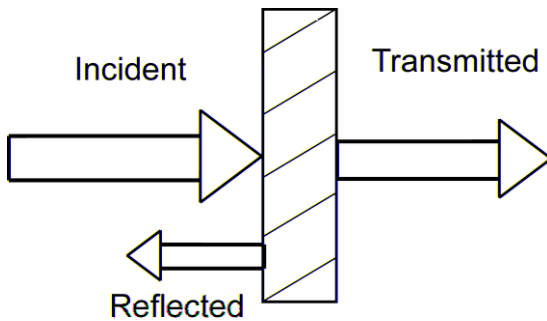
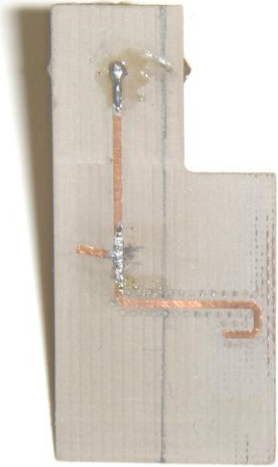
# Microwave Antennas

We will use half-wavelength dipole antennas to produce the microwaves.



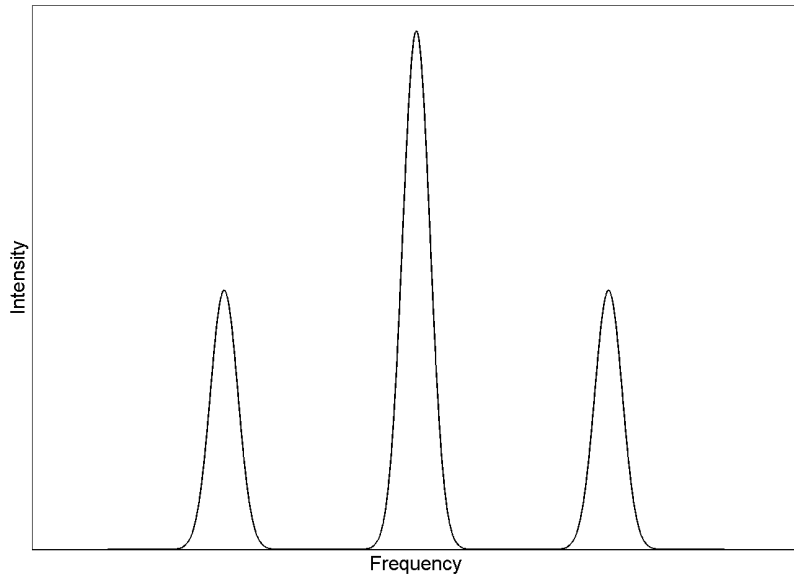
# Impedance Matching

- Eliminate reflections
- Protects the amplifiers
- Accomplished using small wire

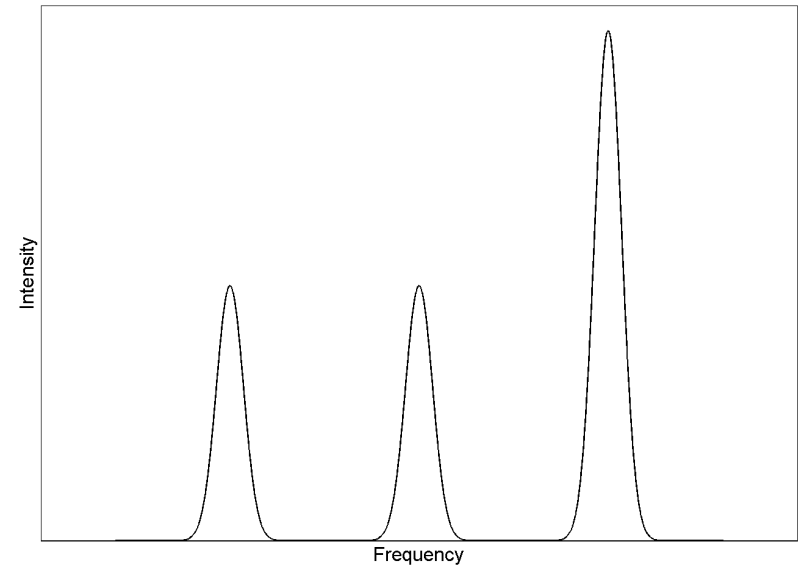


# Image rejection mixer

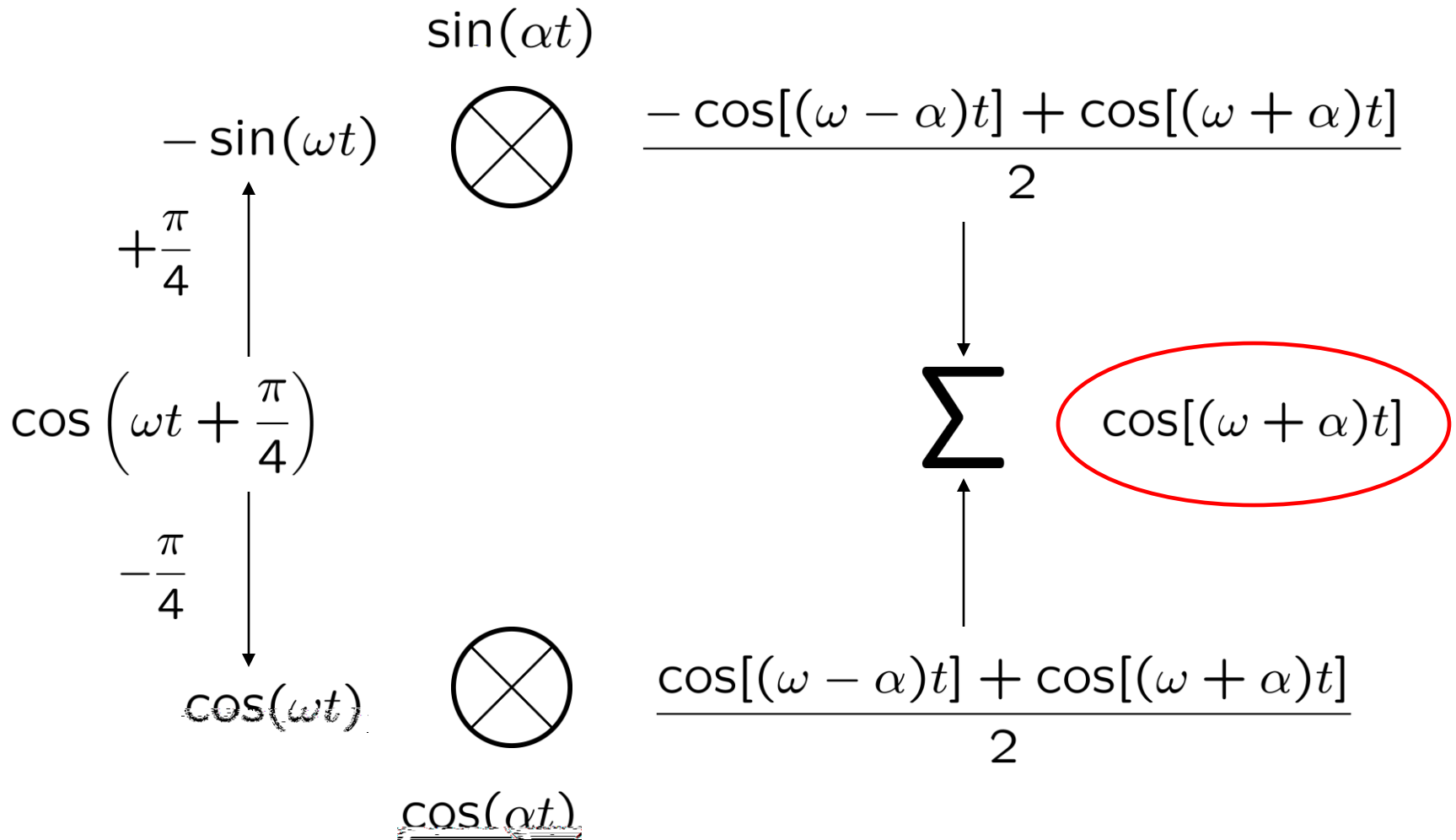
Without



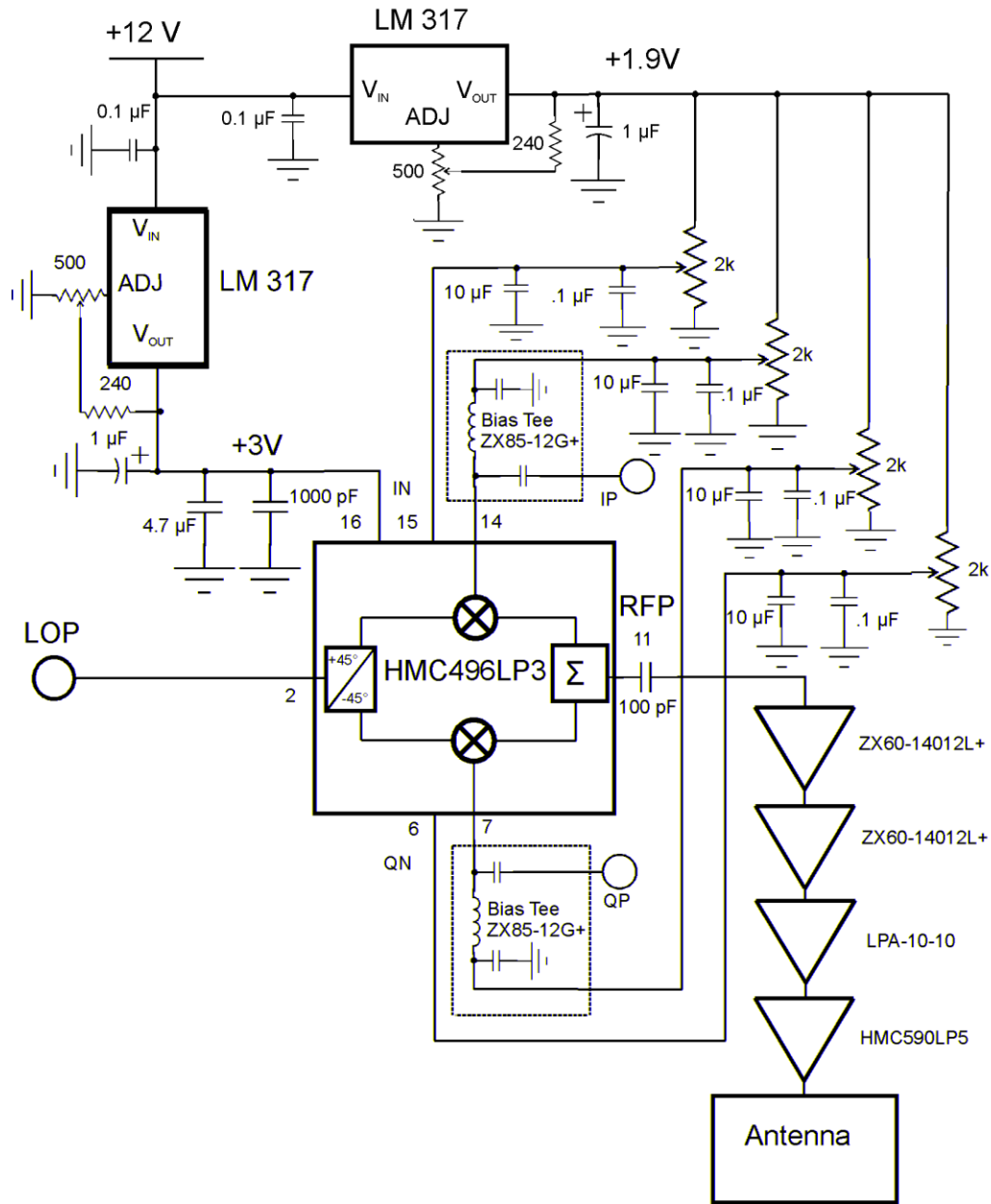
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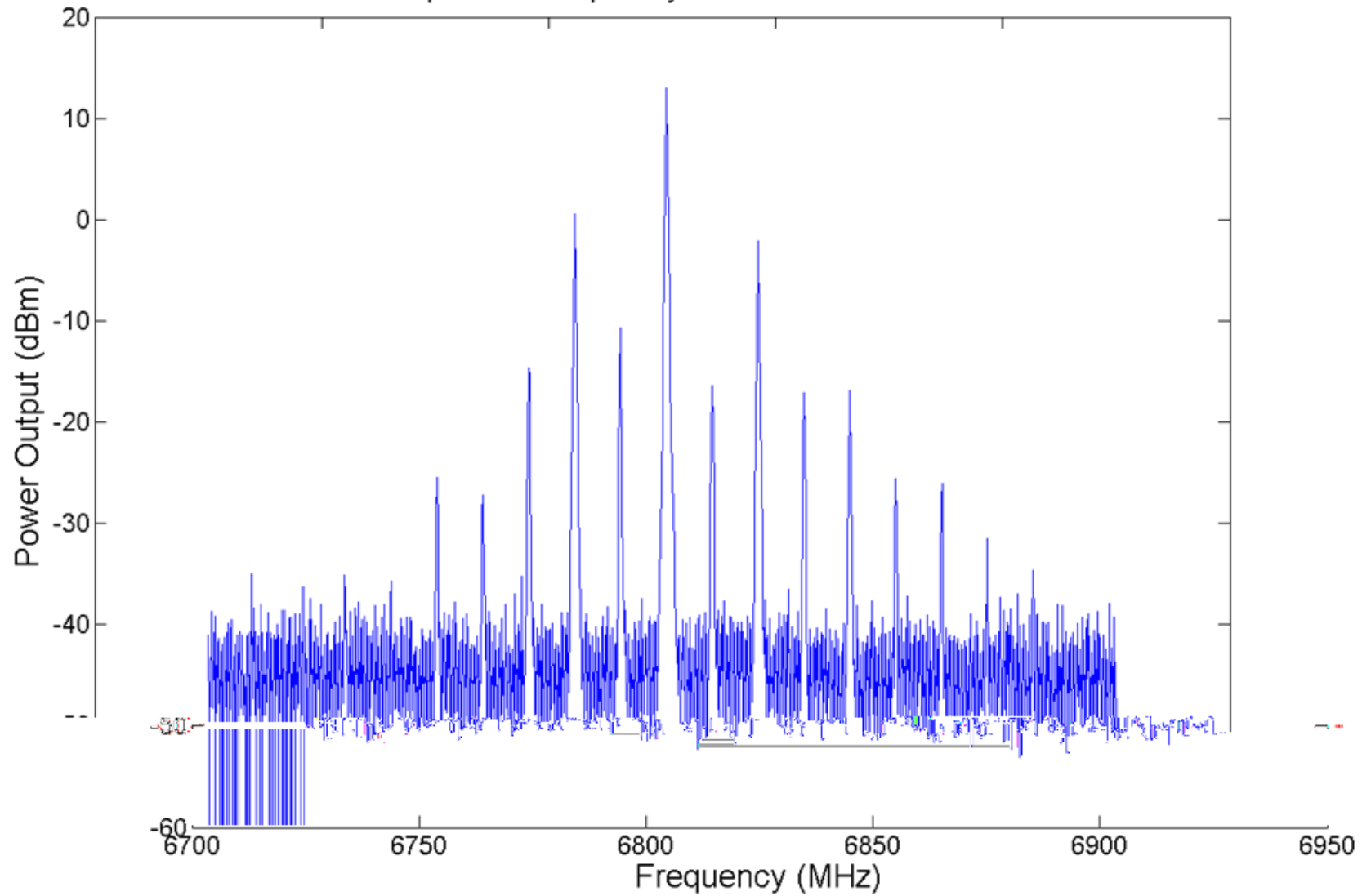
# Image Rejection: How it Works



# Producing the actual microwaves

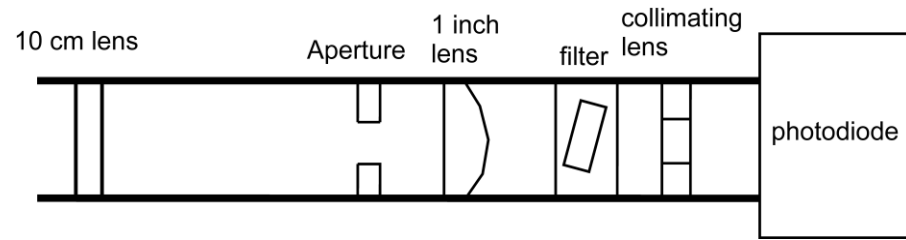


Power Output vs. Frequency for the Microwave Circuit

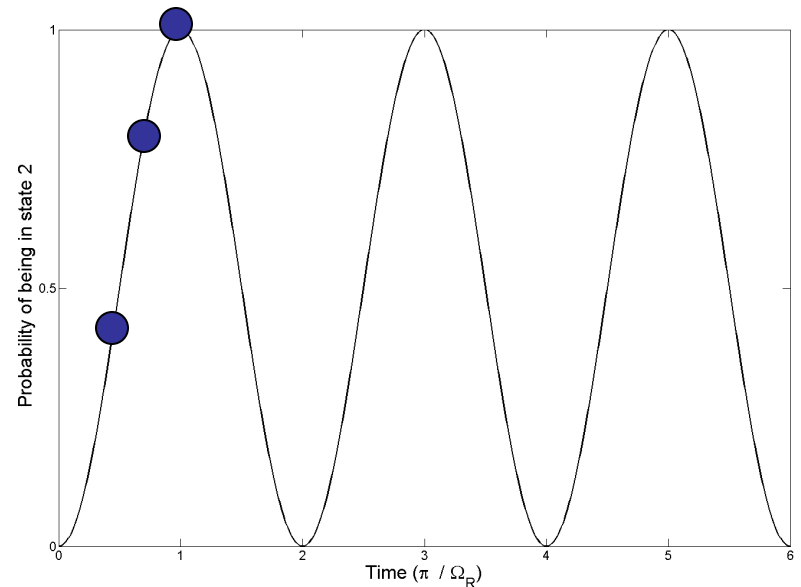


# Counting the atoms

- Atoms in the upper ground state will be pumped to the excited state. They will emit a photon and return to the ground state.
- A photodiode will be used to detect these photons.
- To observe the Rabi flopping, we will run the experiment, measure, reset, and run again.

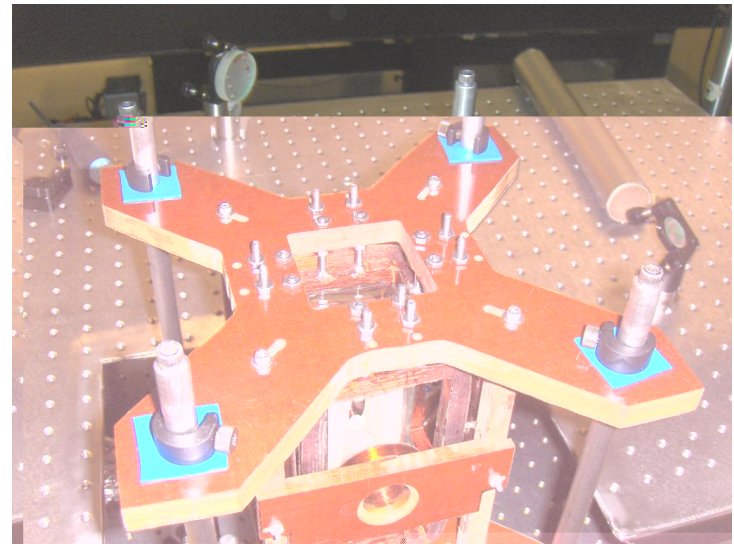
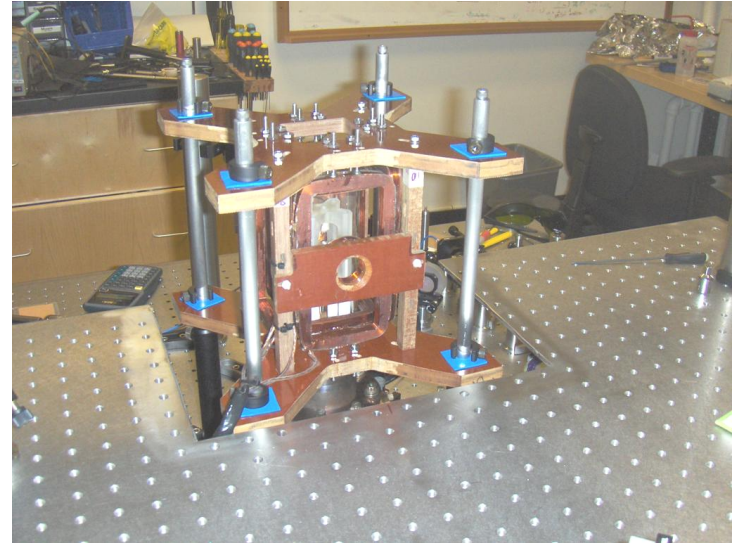


The optics used for the photodiode



# Current Status and Future Work

- We are in the process getting a MOT.
- The antenna will then be installed.



# Summary and Closing Remarks

- We are trying to create a system in which we can observe and manipulate quantum fluctuations.
- Potential applications include better sensors and clocks.
- Could help to create more accurate tests of fundamental physics.

# Acknowledgements

- Prof. James Thompson
- Shannon Sankar, Zilong Chen, and Hsiang-Sheng Ku, the graduate students in my lab.
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- JILA and CU-Boulder