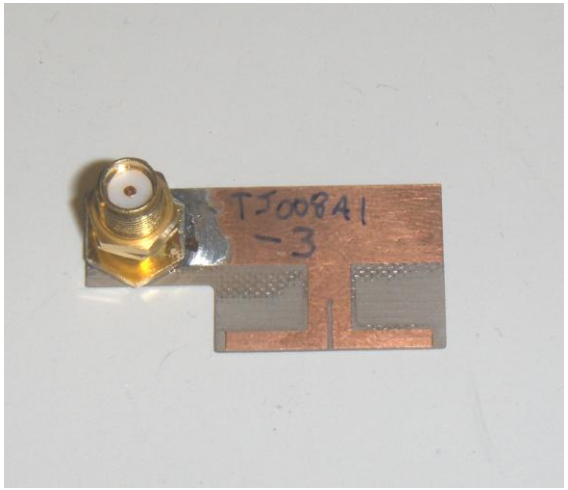
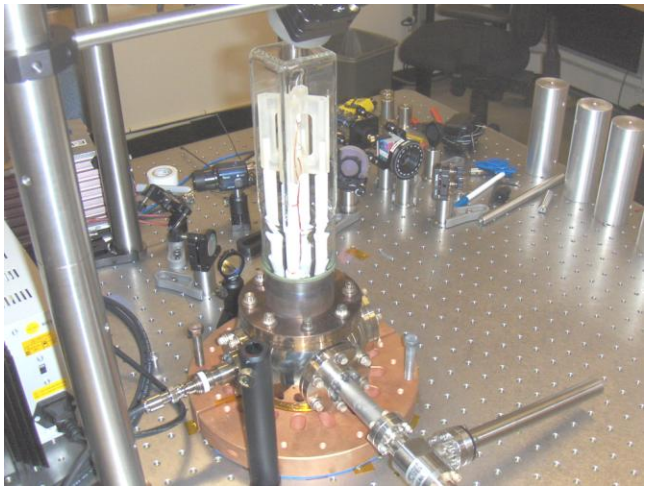
Building a Microwave Antenna for a Quantum Microscope



Steven Moses

University of Colorado/ JILA Physics REU

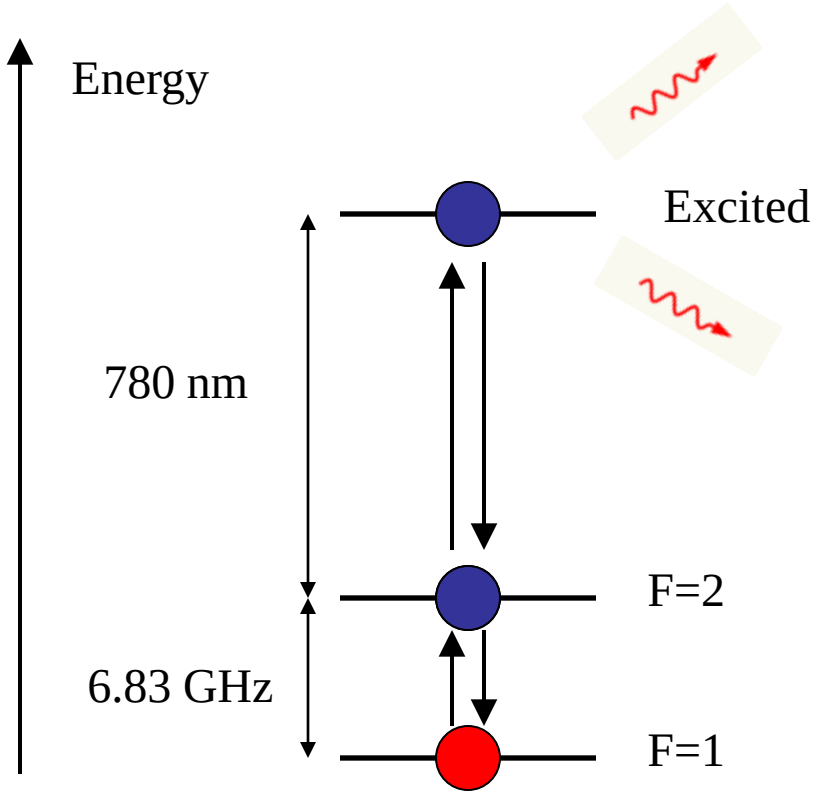
August 7, 2008

Outline

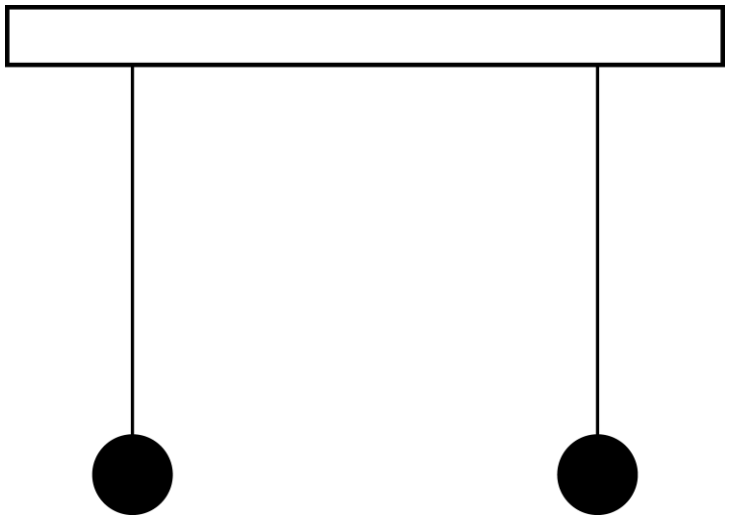
- Brief overview of the experiment
- Rabi flopping
- Microwave antenna setup
- Counting the atoms
- Current status of the experiment
- Summary and conclusions

Overview of the Experiment

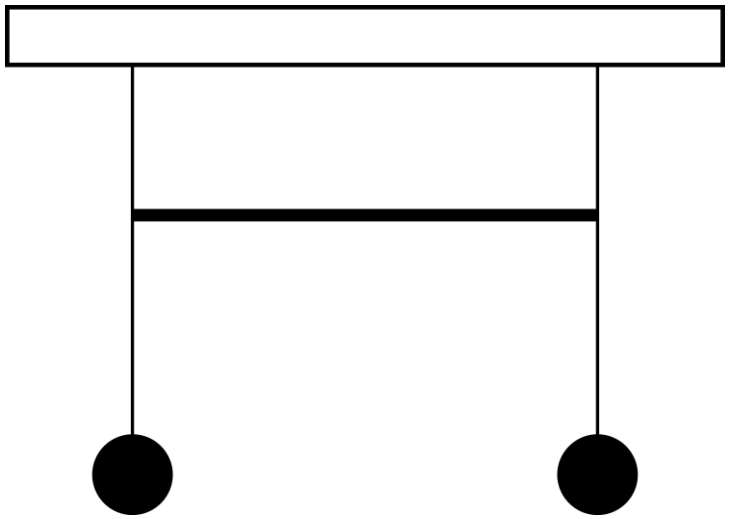
- Use microwaves to excite Rabi flopping between ground states of ^{87}Rb.
- Measure the relative numbers of atoms in each ground state as a function of time.
- Want to be able to create an arbitrary superposition of the two states.



Classical Analog of Rabi flopping



The pendulums move independently.

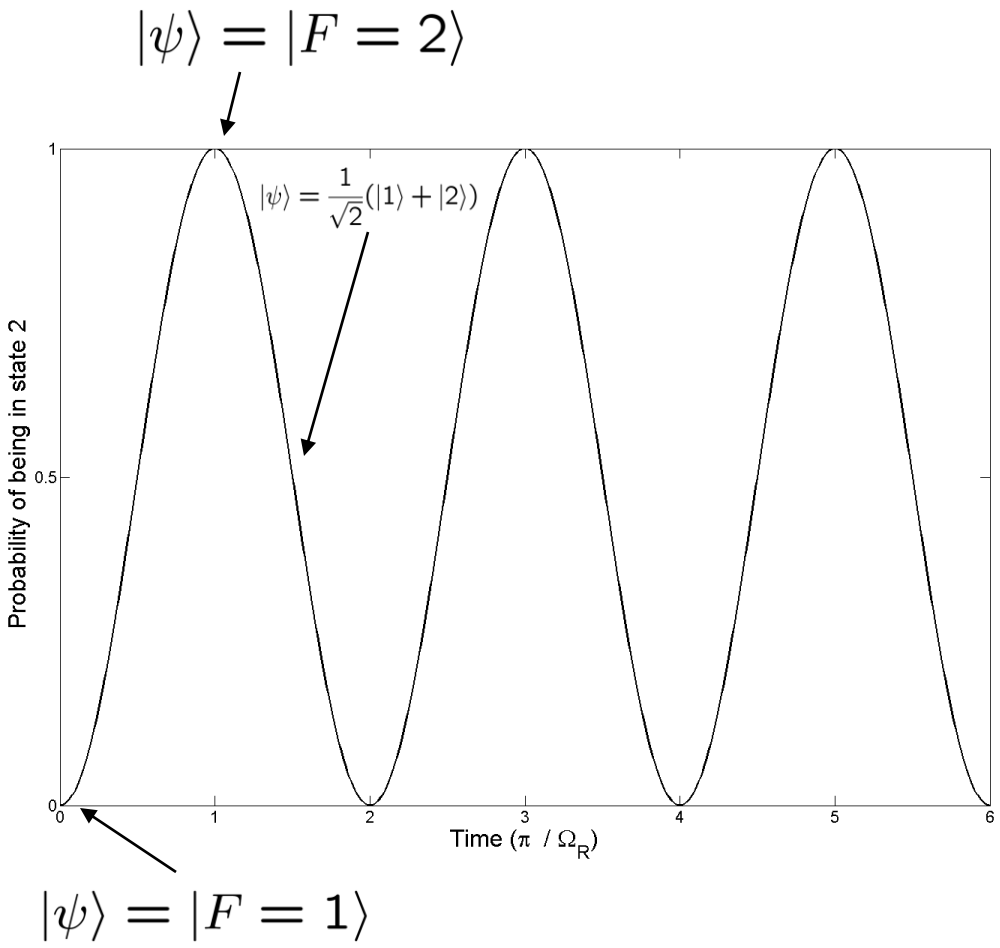


When coupled, the pendulums will transfer energy.

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.

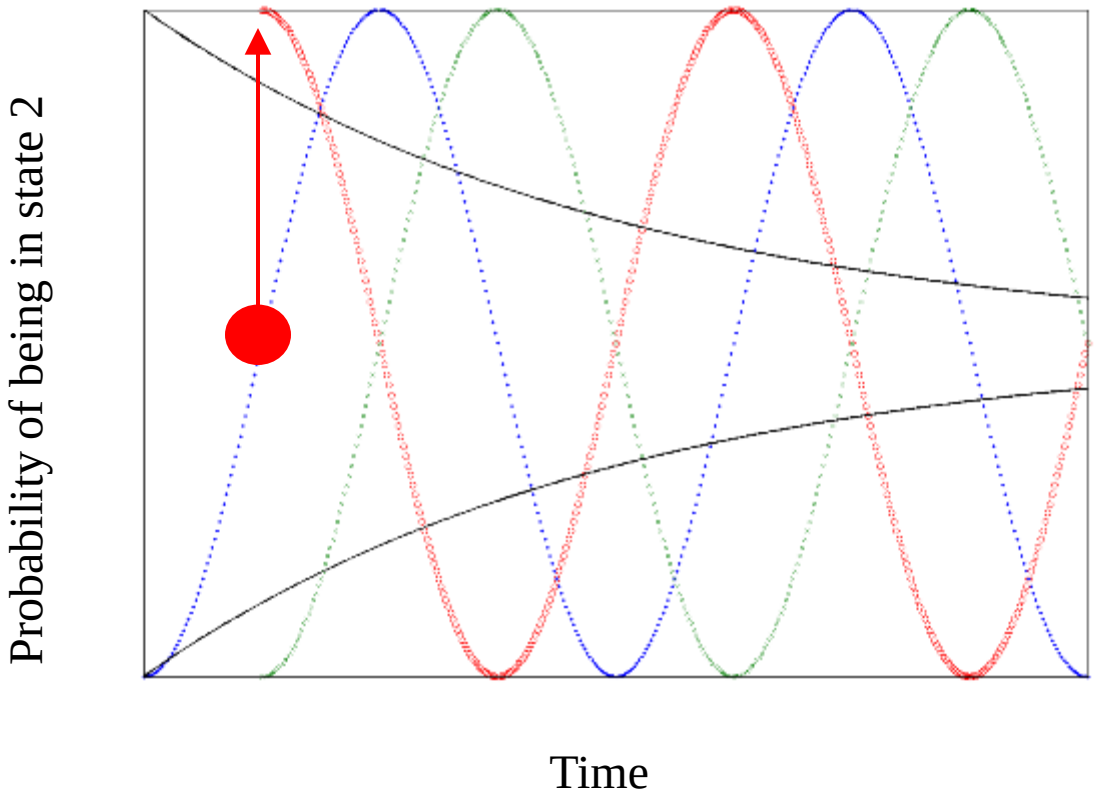
For this transition,

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

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

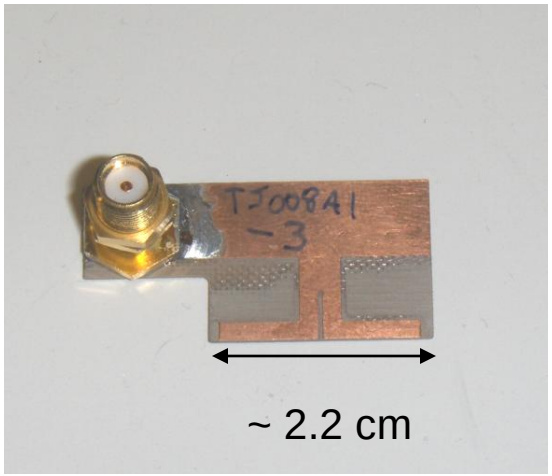
Decoherence in the system

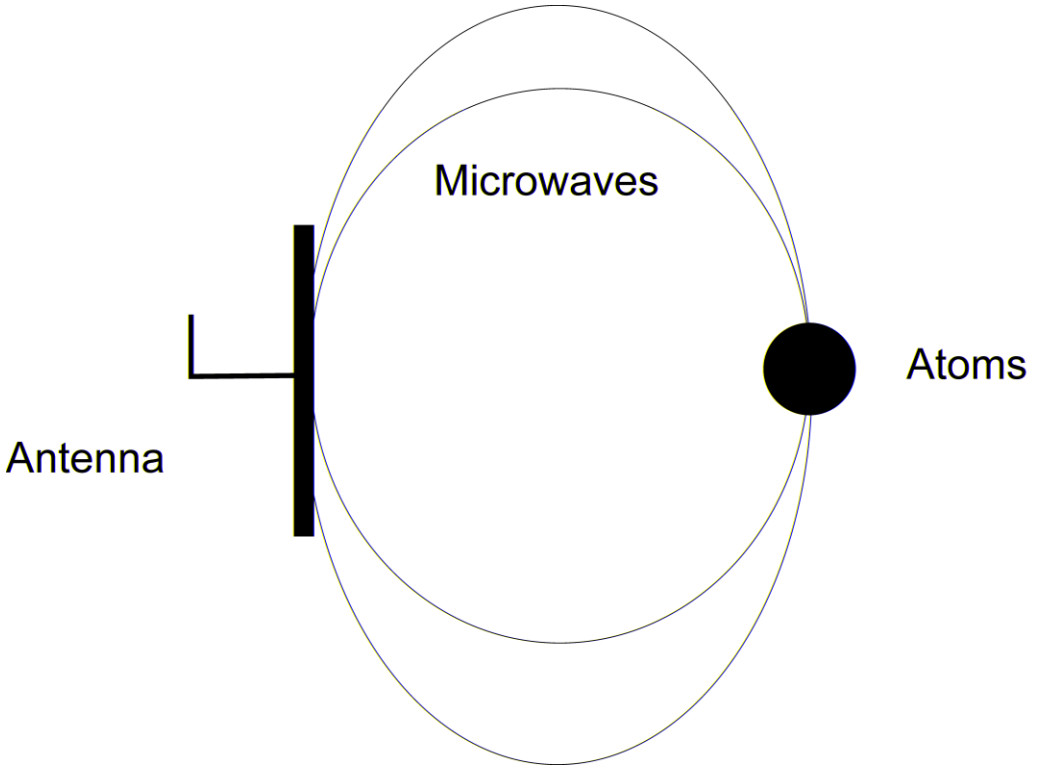
- Atoms hit wall
- Inhomogeneous magnetic field
- Inhomogeneous trap
- Scattering rate from trap



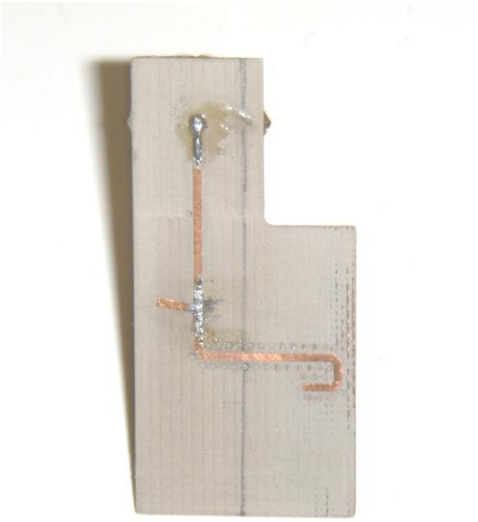
Microwave Antennas

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

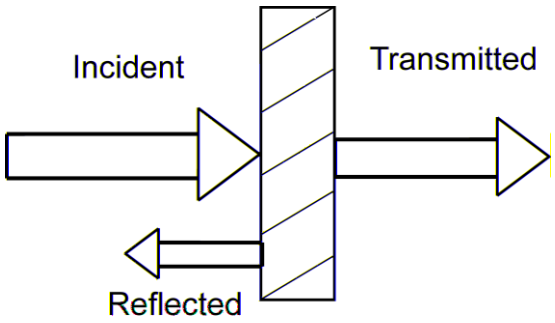




Impedance Matching



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



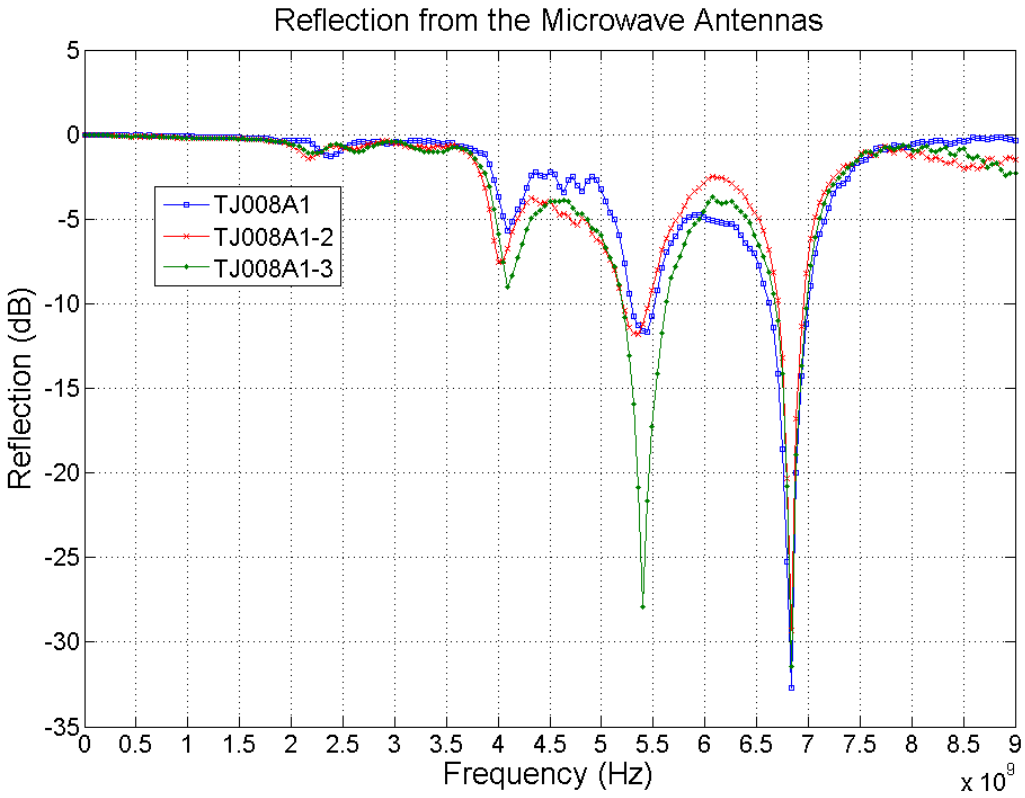
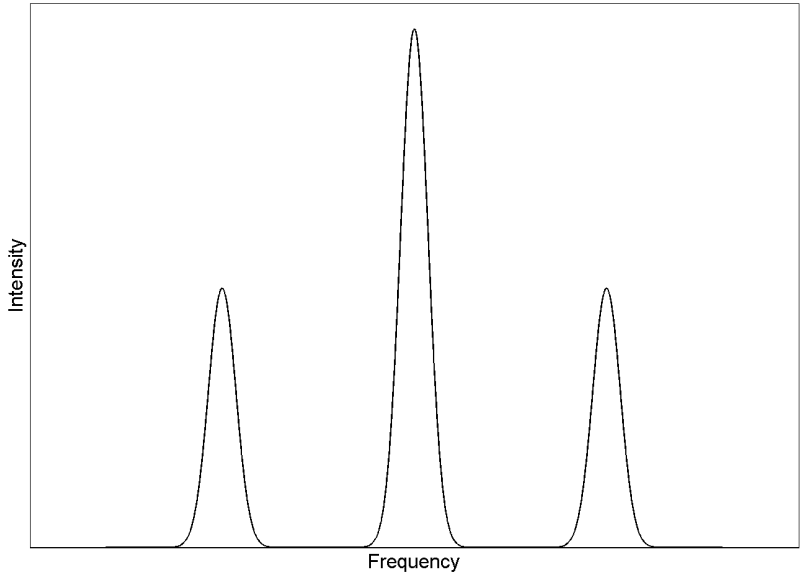


Image rejection mixer

Without



With

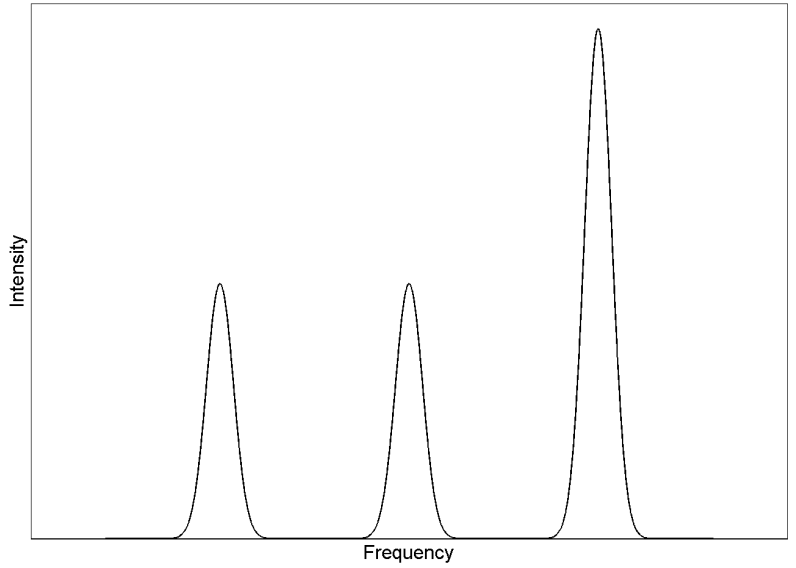
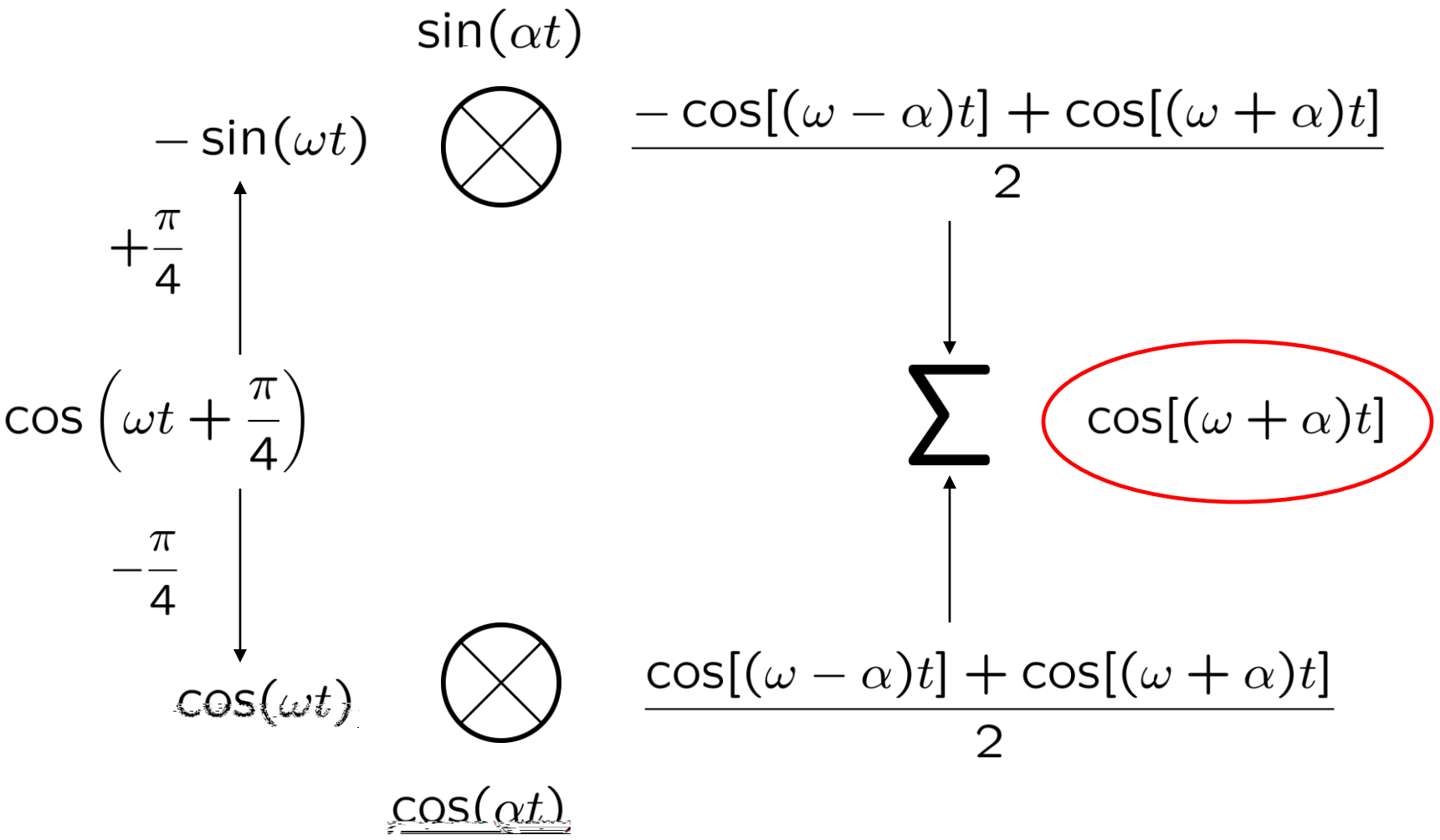
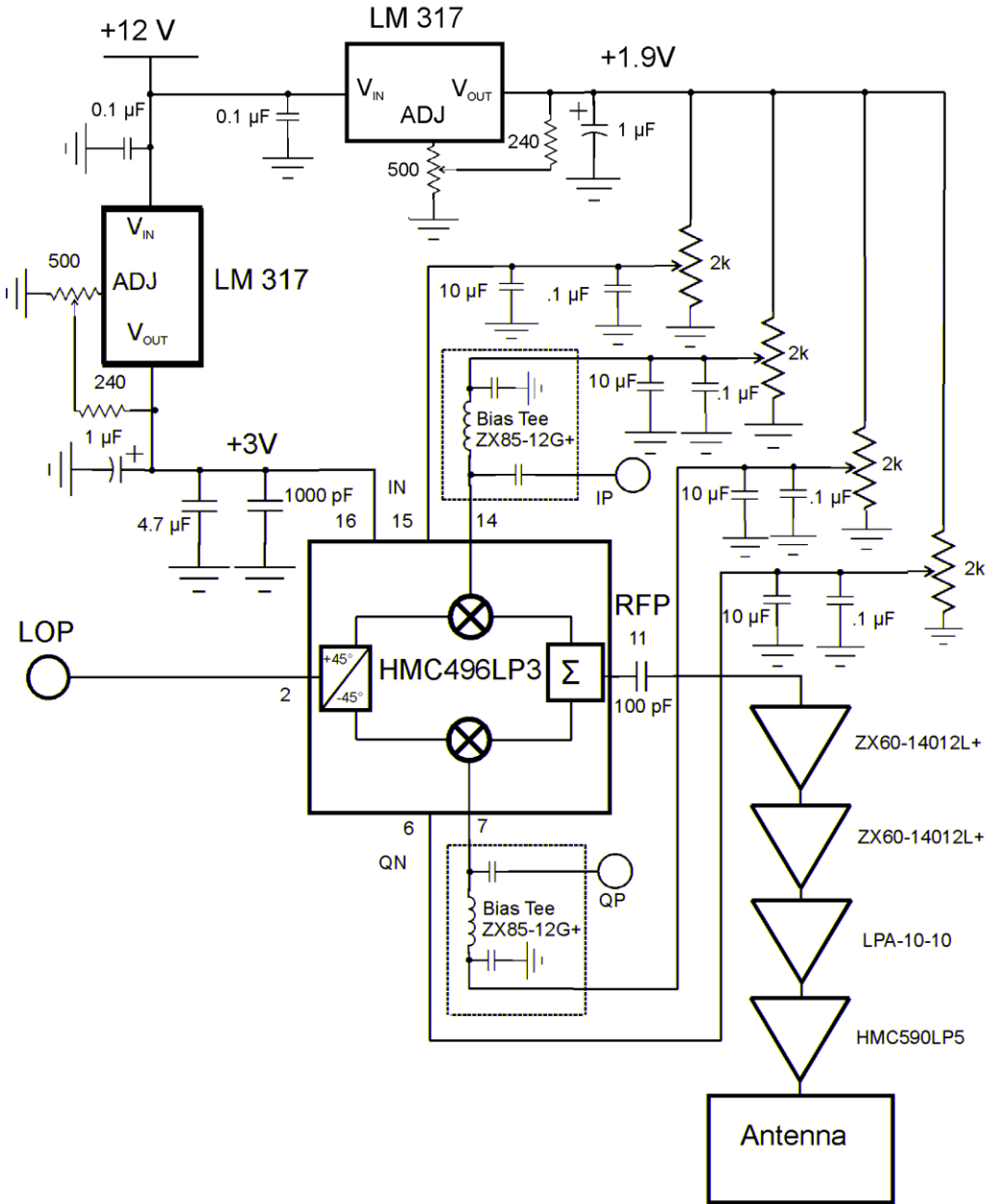
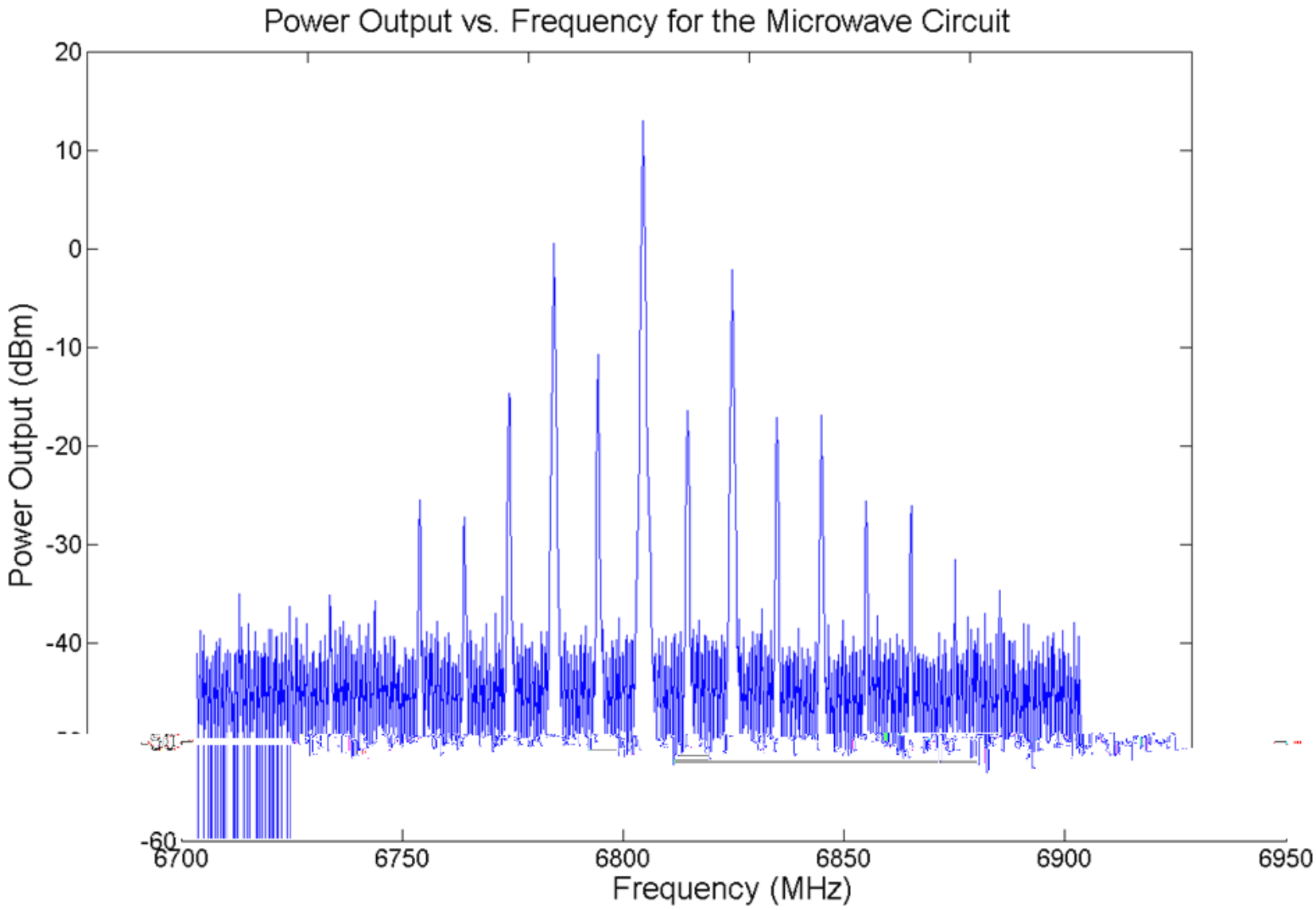


Image Rejection: How it Works



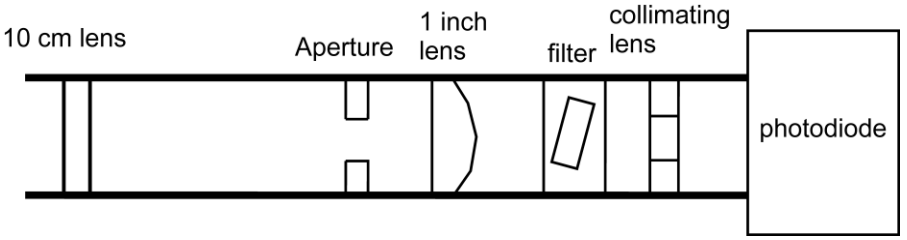
Producing the actual microwaves



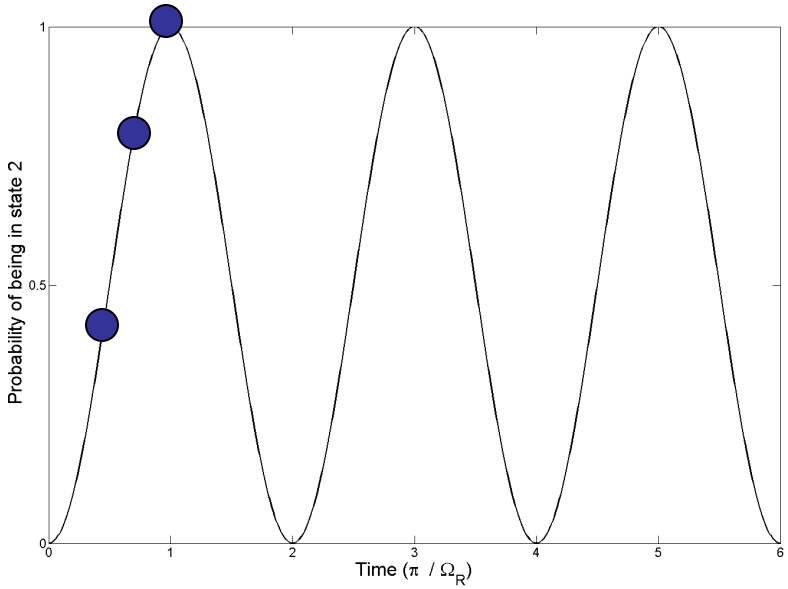

Power Output vs. Frequency for the Microwave Circuit
Power Output (dBm)
20
10
0
-10
-20
-30
-40
-60
6700
6750
6800
6850
6900
6950
Frequency (MHz)

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 be detect these photons.
- To observe the Rabi flopping, we will run the experiment, measure, reset, and run again.

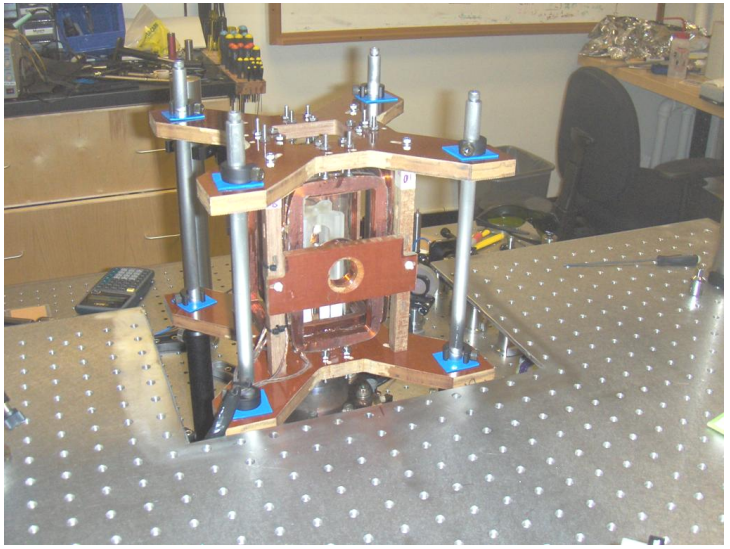


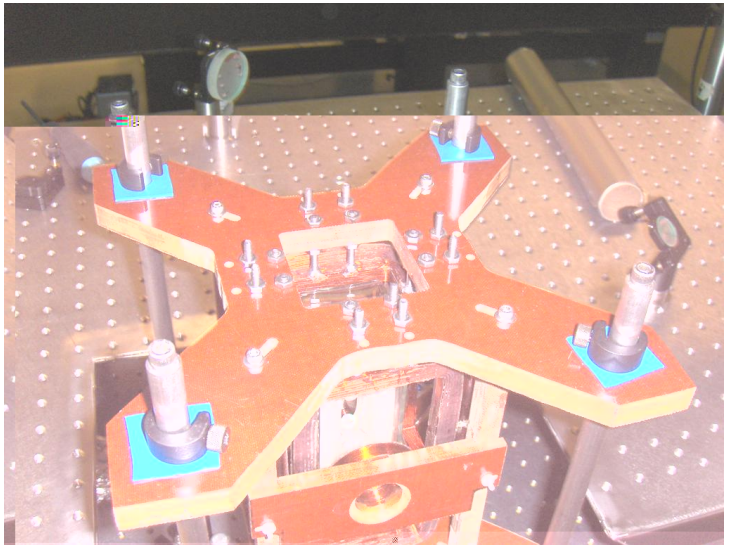
The optics used for the photodiode



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.
- NSF
- JILA and CU-Boulder