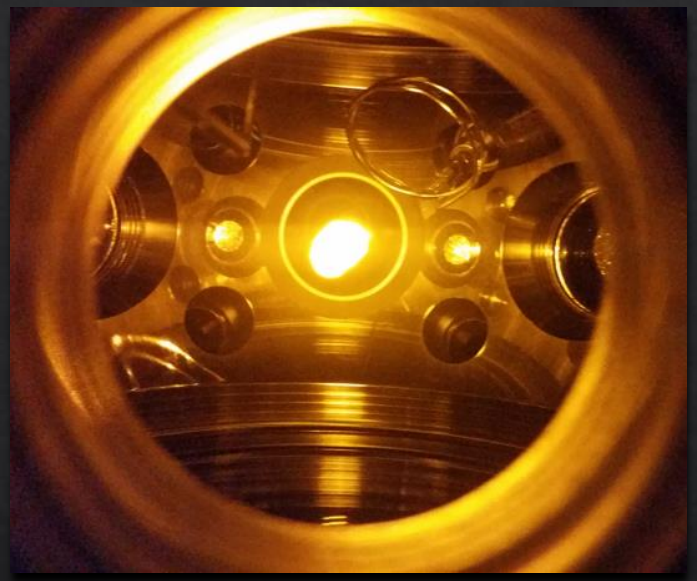
Stabilizing laser and microwave fields for coherent control of spin-exchange collisions in ultracold sodium gases



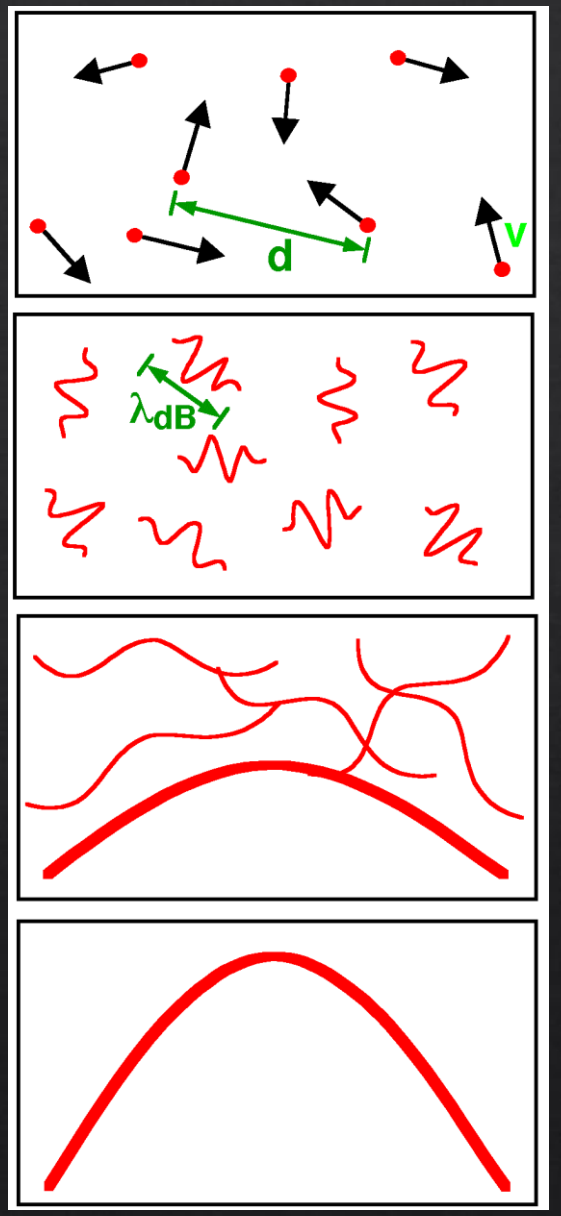
Jeremy Norris

Graduate Student: Shan Zhong

Advisor: Dr. Arne Schwettmann

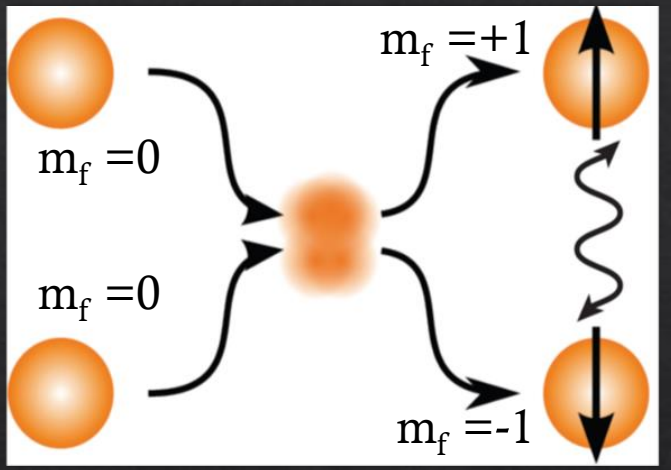
Overview and Motivation

- Cool sodium gas until it becomes Bose-Einstein Condensate (BEC)
  - Critical temperature ~100 nK
  - Use laser cooling and trapping to cool
  - Many atoms occupy ground state, wave packets overlap
  - Can be used for:
    - Precise measurements without thermal noise
    - Studying many-body quantum mechanics
    - Quantum information processing
    - Matter-wave interferometry

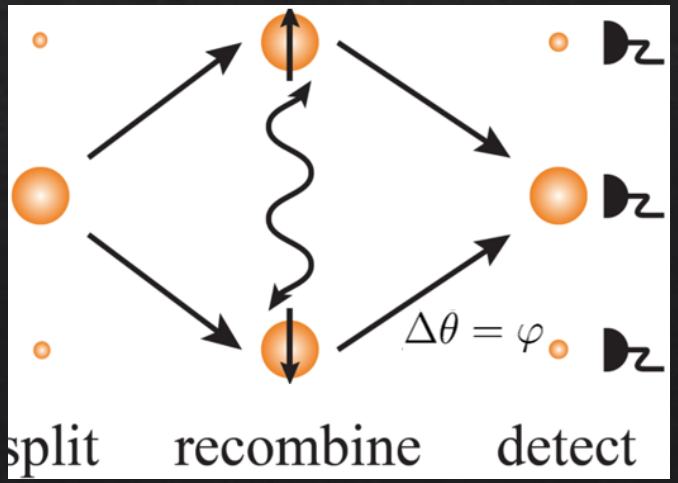


Matter-wave Interferometry

- Spin-exchange collisions create entanglement

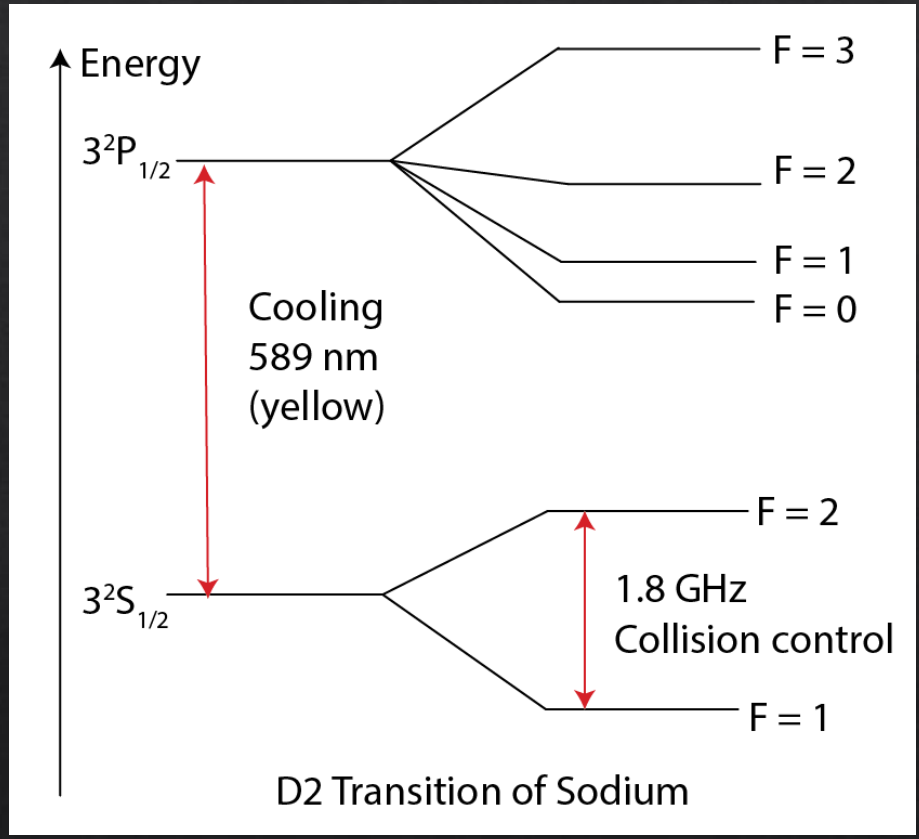


- This can be used to implement an interferometer with reduced noise



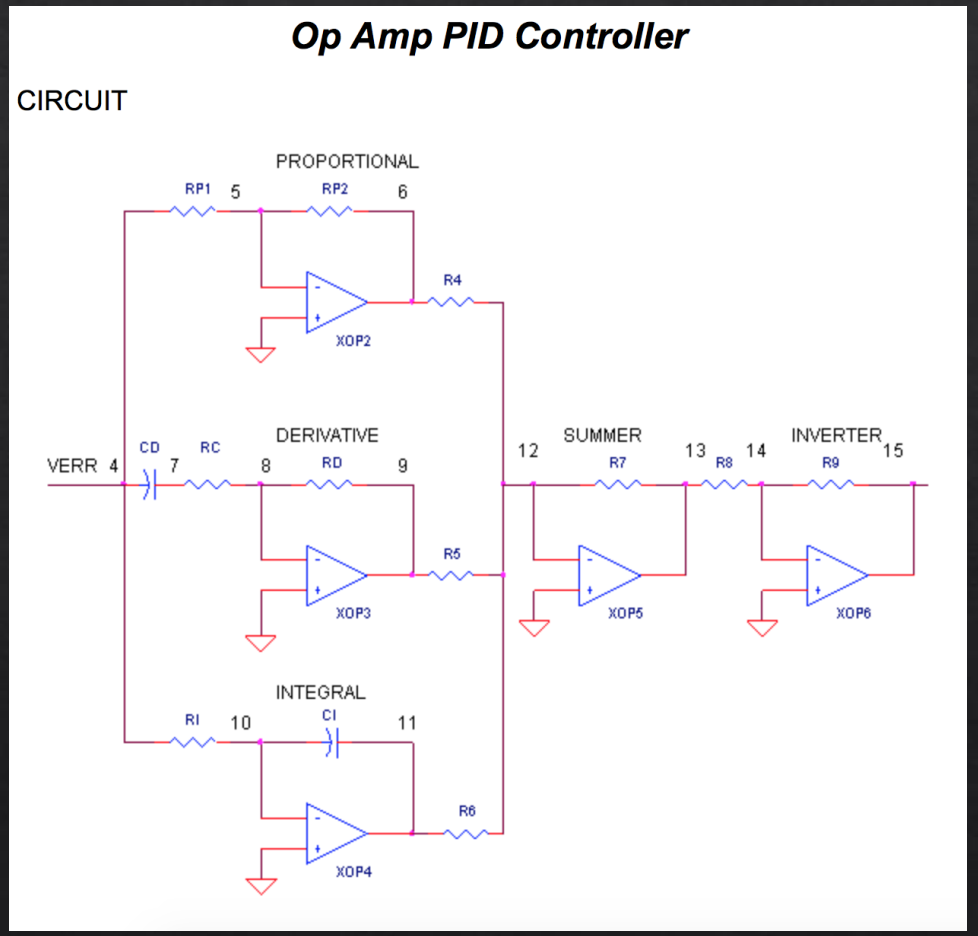
Challenges for Sodium

- The frequency of the laser is stabilized (~1 MHz) via FM saturation absorption spectroscopy
  - Residual amplitude modulation that effects the frequency over time
  - We want to stabilize the amplitude (≤ 5%)
- Controlling spin exchange collisions
  - Precise timing (10 ns) of high, stable power (20 W) microwave pulses



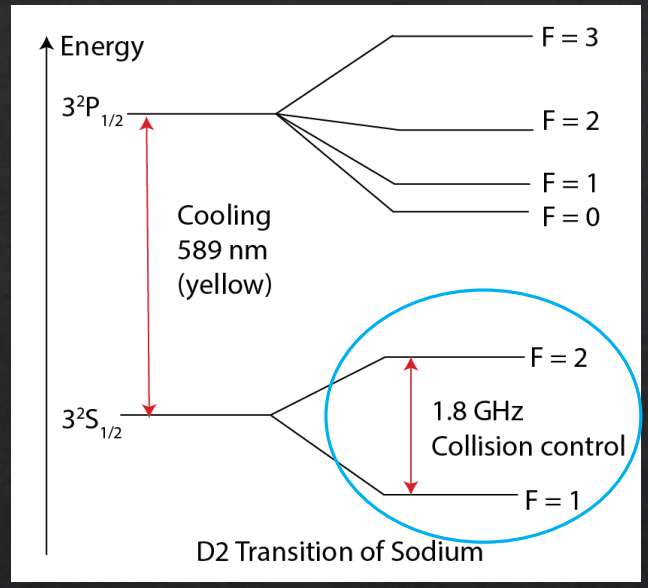
Stabilization of Laser Amplitude

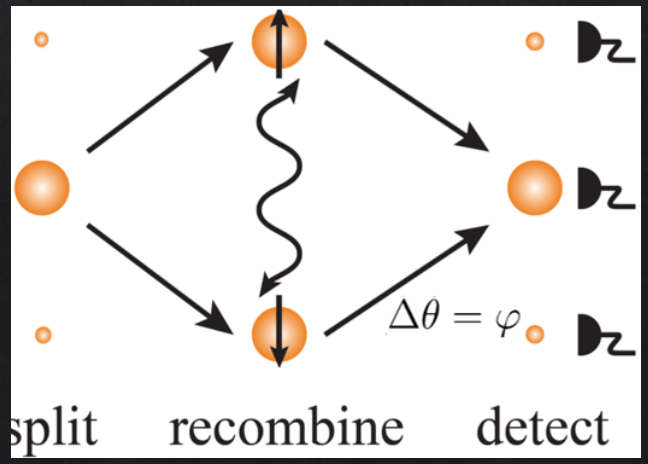
- Amplitude is measured with photodiode, adjusted using Acousto-Optic Modulator (AOM)
- Build PID controller which is a control loop feedback mechanism
- PID controller works like the cruise control in a car
- PID: Proportional, Integral, Derivative
- Replicating existing PID controller used to stabilize laser frequency

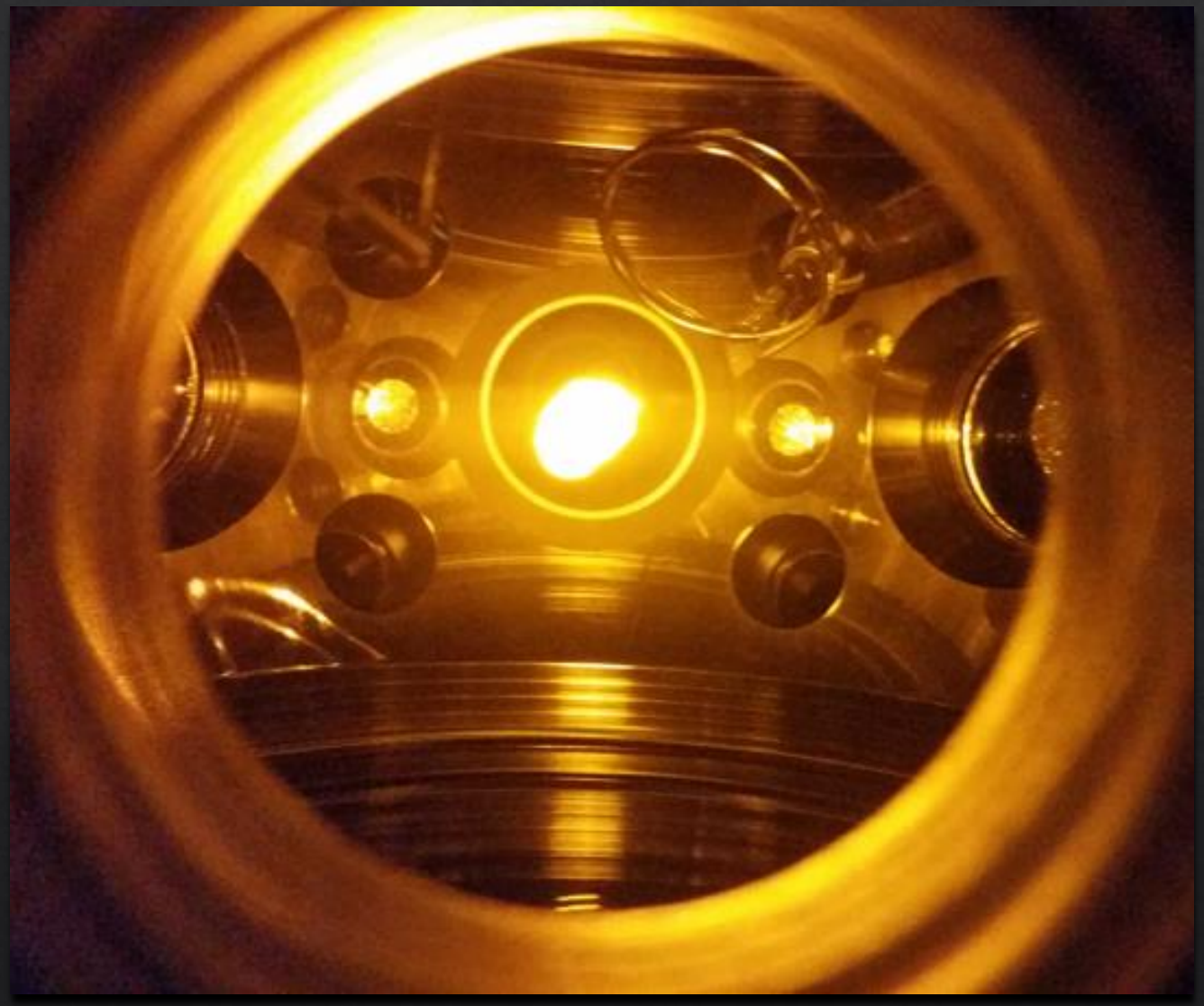


Microwave Control of Collisions

- Produce pulses of controlled microwaves to introduce a phase $\Delta\theta$
- Field Programmable Gate Array (FPGA)
- FPGA controls Direct Digital Synthesizer (DDS)
- DDS produces signal that combines with signal from microwave generator
- Signal is amplified with 20 W amplifier
- Couples to antenna inside vacuum chamber close to the atoms

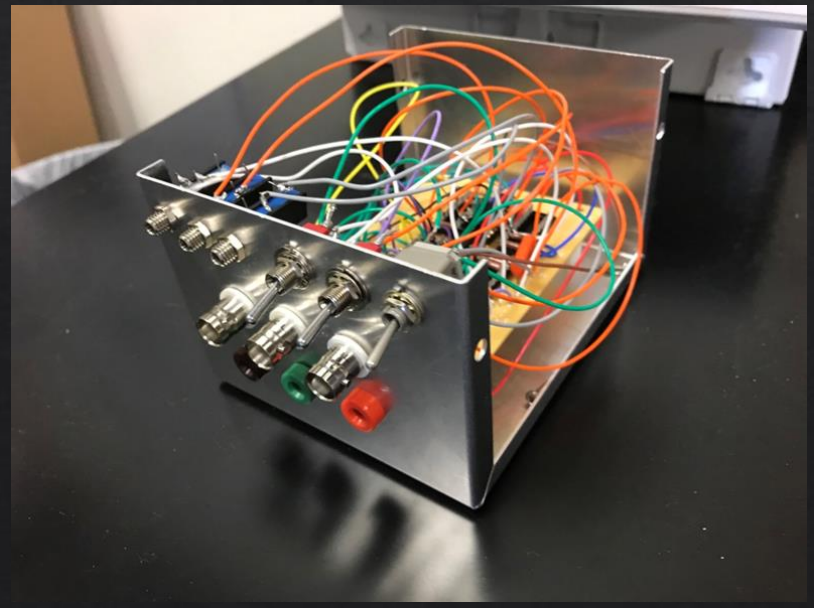






Current Progress

- Finished building PID Controller for laser amplitude stabilization
- Currently testing all components before putting into laser system



Outlook

- Plan to finish testing PID controller this week
- Begin programming FPGA (~2-3 weeks)
- Collect data before the end of summer
  - Measure reduction in amplitude noise
  - Measure the effect of the microwaves on the spin collisions

Thank you.

Questions?