High Current Stabilization Circuit for Ultracold Atom Trap

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Abstract: Bose-Einstein condensates (BECs) are created through laser cooling and magnetic evaporative cooling of a dense group of atoms to temperatures close to 0 K. Our ultracold mixtures group studies the properties and behavior of BECs within magneto-optical and magnetic traps in our lab. Electromagnetic coils in our lab are used to produce magnetic fields to contain and interact with the Rubidium atoms; fluctuations in the current carrying coils results in the production of magnetic field noise that interferes with the experiment. My research focused on creating a configuration of operational amplifiers (op amps) designed to filter and stabilize the current and reduce the noise present in our ultracold atoms traps. In order to withstand current between -30 and 30 amps, we integrated our op amp configuration with a printed circuit board to protect the op amp as well as actively regulate the current to a precision of 0.1mA. Our op amps are attached to aluminum heat sinks and liquid cooling plates and are housed in an aluminum rack. Future work on this system will include tests for increased current and magnetic field stability and precision of current control.

Goal: To help reduce current fluctuations and magnetic field noise and design PID controller for system.

Potential Application: Magnetic field noise is a problem in most of the ultracold mixtures groups in the Joint Quantum Institute. A repeatable method and setup that can reduce the noise can be implemented in other labs here.

BEC's in lab:

- Rubidium atoms travel through Zeeman slower where atoms are slowed by the nearly resonant pump laser (780nm).

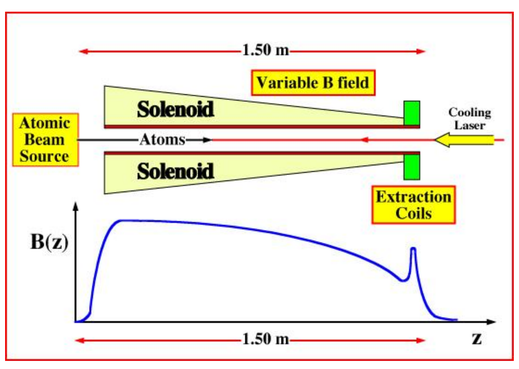


Fig. 1. Andrew Murray. 2007. *Atom Cooling and Trapping Experiments at Manchester.*

- Rb atoms enter the magneto-optical trap (MOT) where lasers in orthogonal direction are used to cool the atoms further and a magnetic field is applied as a restoring force to keep atoms in place.

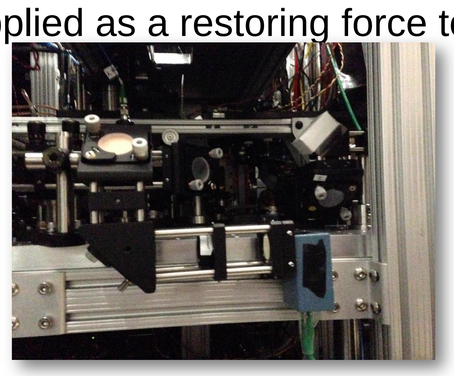


Fig. 2. See reference [2].

- Magnetic trap is used to hold atoms while evaporative cooling reduces temperature of atoms to a few billionths of a degree above 0 K [1, 2] .

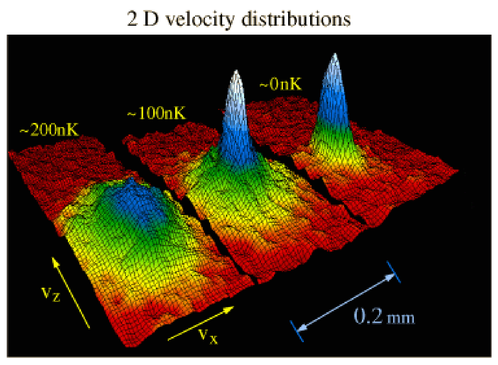
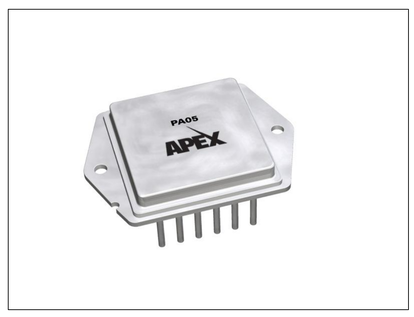


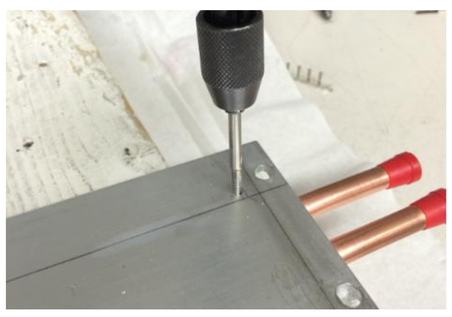
Fig. 3. Mike Matthews et. Al. , JILA. 1995. *Observation of Bose-Einstein Condensation in a Dilute Atomic Vapor.*

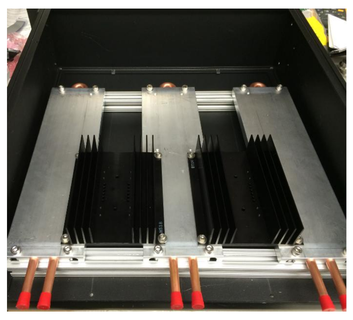
Objective: to design op amp setup to filter and stabilize high current and reduce noise level present in magnetic trap.

Procedure: Operational amplifier required needed to withstand -30 to 30 amps. Most op amps handle magnitudes within a range of milliamps. We found an op amp designed to operate with higher current, the PA05, and an accompanying heat sink.

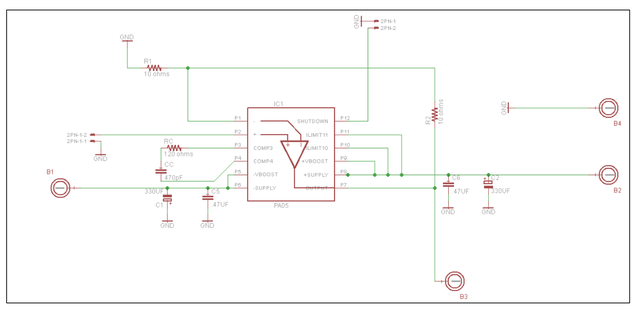


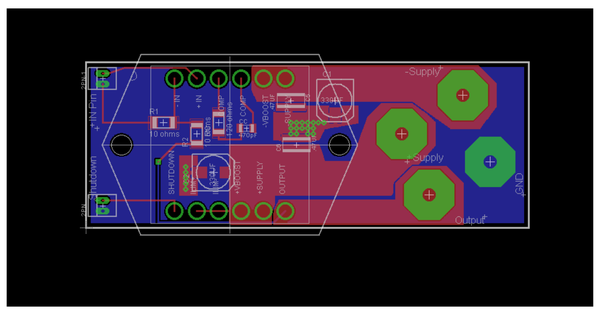
The op amp heats up beyond safe operating ranges when used continuously, so we attached the op amp and heat sink to liquid cooling aluminum plates within our mounting rack. The cold plates had holes marked, drilled, and tapped out to mount 8020 aluminum bars and our op amp set up.





To communicate with and control the op amp, we designed a printed circuit board (pcb) to attach to the op amp pins. The pcb also offers us a way to measure the current directly on the board since there are space constraints within the mounting rack.





Future work: Test system for ability to function properly and continuously and provide more stable current to experiment, examine different methods of current measurement on pcb and on current carrying coils, and design control box for increased precision of control of the current.

References:

[1] Steven Chu, *The Manipulation of Neutral Particles*. 1997.
[2] Ben Cannon, Daniel Stone, Ryan Price, *Light Analysis of Ultra-cold Magneto Optical Trap*

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REU program sponsored by the National Science Foundation
Award Number: PHY1156454