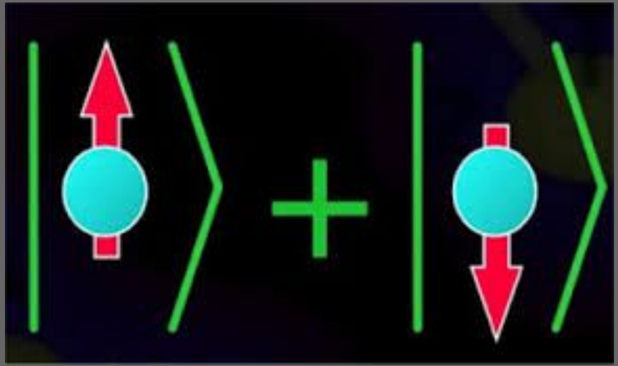
Trapping and Cooling Rubidium Atoms using a Tunable Diode Laser

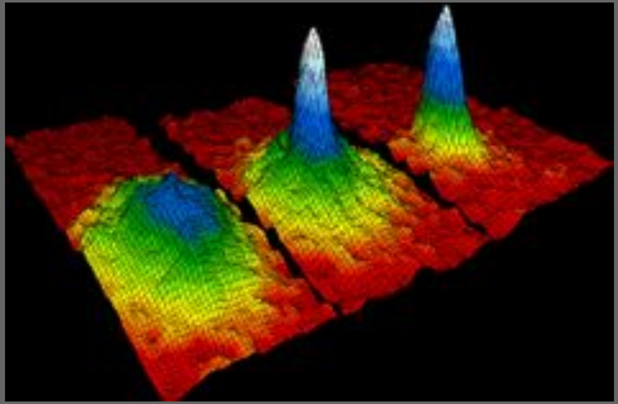
By: Ben Crane and Bjørn Sumner

Motivation

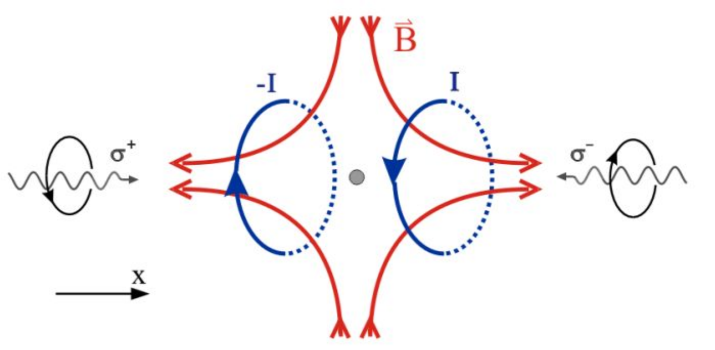
Magneto Optical Traps (MOT)

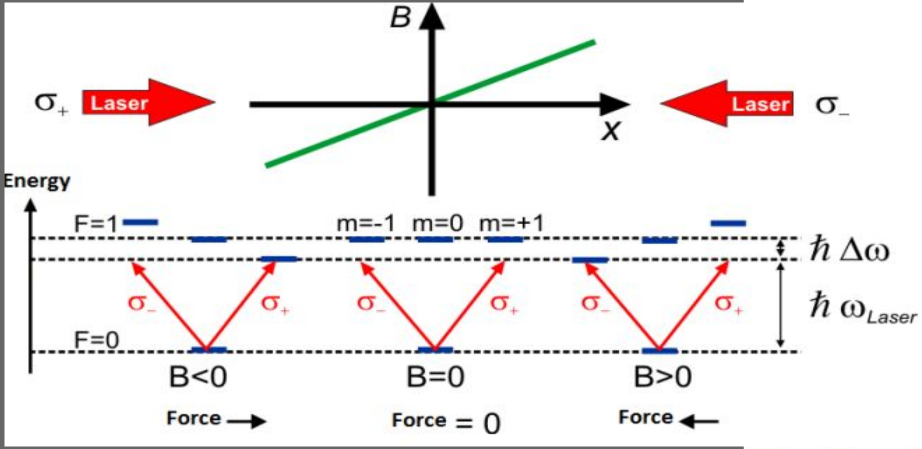
- Quantum Information
- Bose-Einstein Condensate

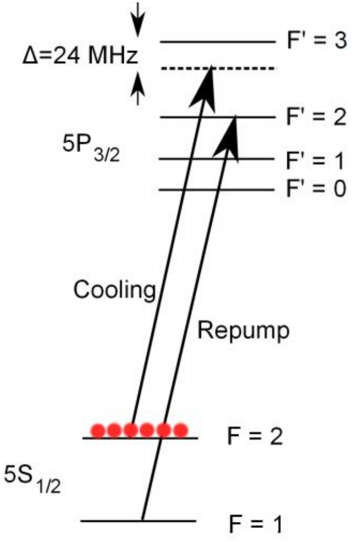




External cavity laser diode provides radiation pressure from all sides to hold the atoms in equilibrium in an optical molasses

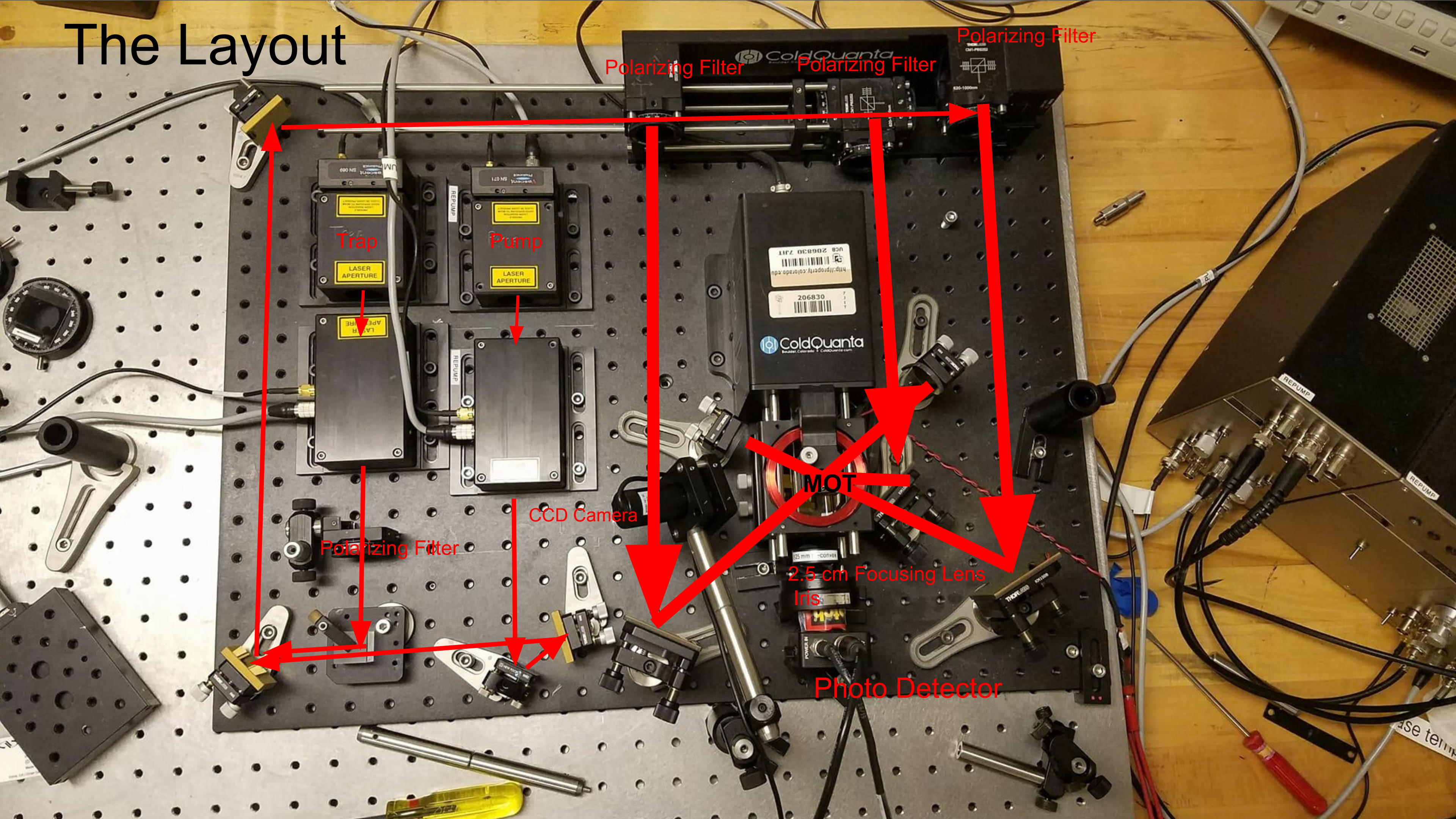






Level-scheme for Rubidium-87 with cooling and repump laser transitions indicated

The Layout


Polarizing Filter
Polarizing Filter
Polarizing Filter
Trap
Pump
LASER APERTURE
LASER APERTURE
ColdQuanta
MOT
CCD Camera
Polarizing Filter
2.5 cm Focusing Lens
Iris
Photo Detector
REPUMP

MOT (Magneto-Optical Trap)

<u>Properties of the MOT:</u>

Refill time
Absolute brightness/intensity (#of Atoms)
Position in the chamber
Magnetic field strength
Optical density,
Cross sectional area/
Volume of atoms being trapped(via absorption)

Refill Time

Trap population: $N(t) = N_0(1-e^{-t/\tau})$

Assume intensity is proportional to population

Fitting the the curves allows for a calculated refill time

By blocking the laser or turning off the

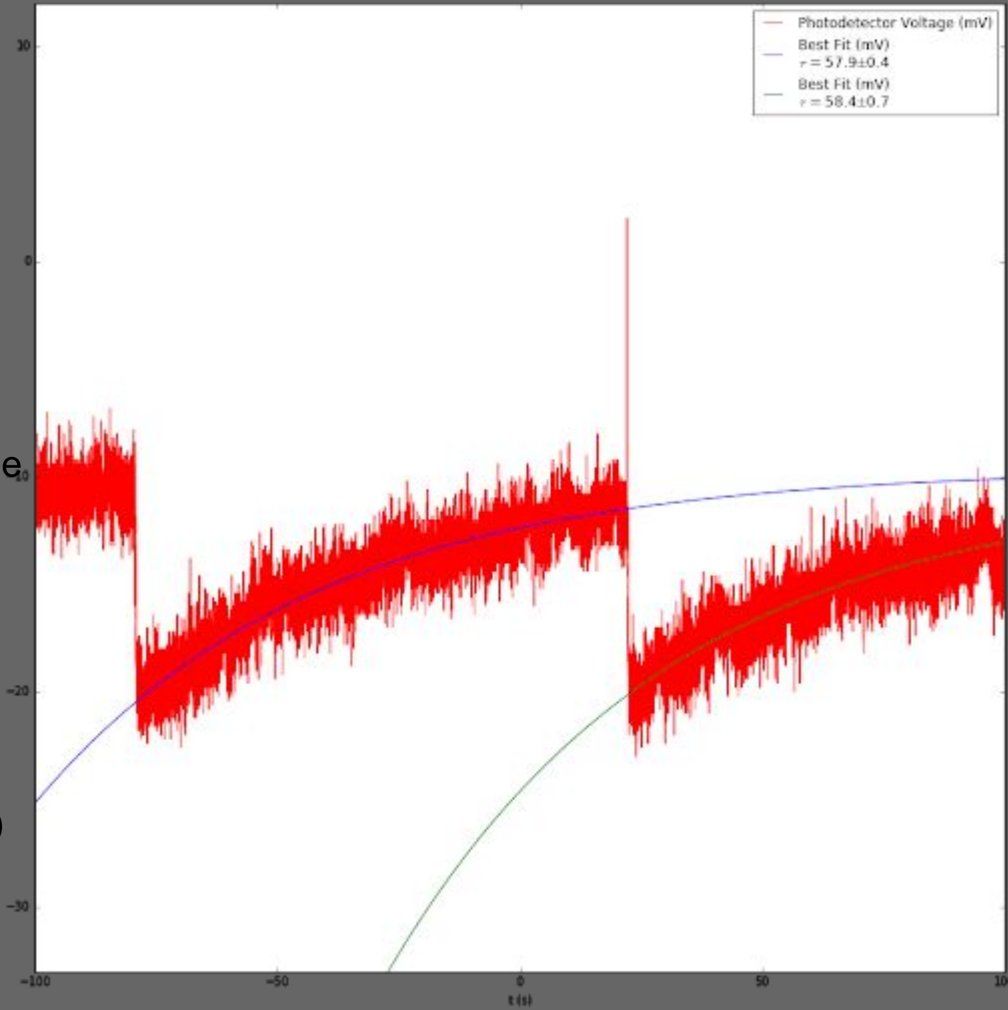
currents in the coils, we can destroy the MOT

As the cluster of atoms forms it glows brighter,

until it stabilizing at a constant intensity. (Refill Time)

We could change the max intensity and refill time by

adding more Rb atoms into the sample



Time Constant

$$\frac{1}{\tau} = n_{Rb}\sigma_{Rb}V_{Rb} + n_{non}\sigma_{non}V_{non}$$

n: Number Density

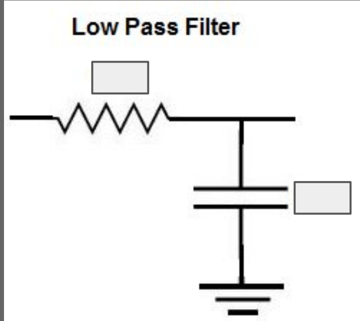
σ: Scattering Cross Section

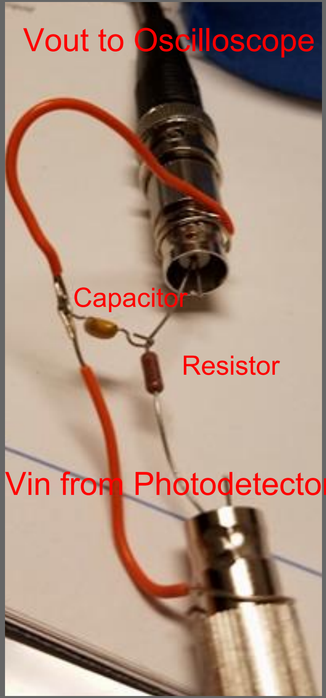
V: Atomic Velocity

Improving our Signal

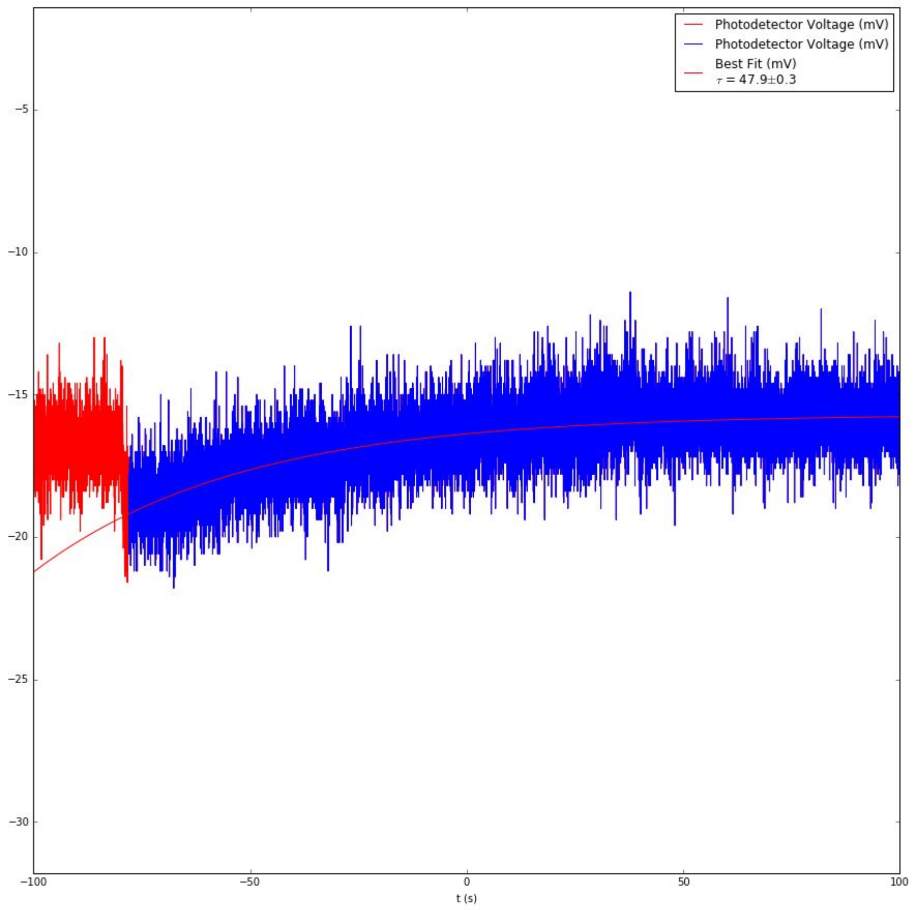
We created an analog low pass filter using a 100k ohm resistor connected to the inner wire, and a 1μF capacitor connected to the grounding sheath.

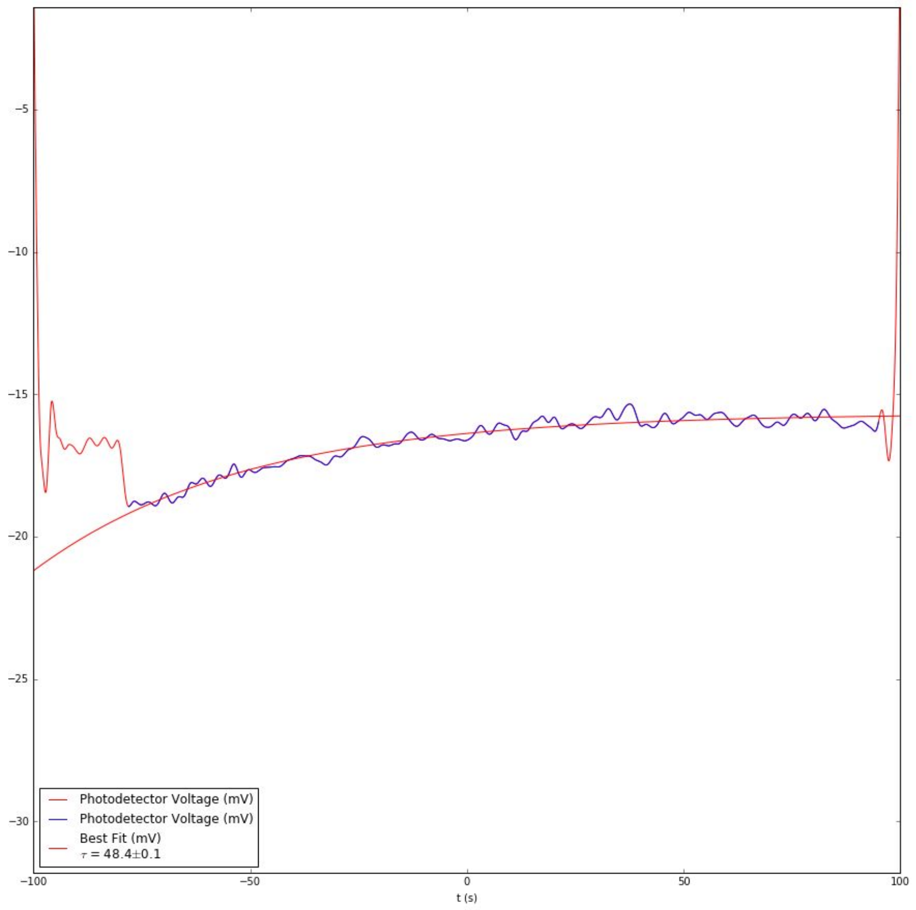
We further improved our data applying a linear filter to further isolate the signal.



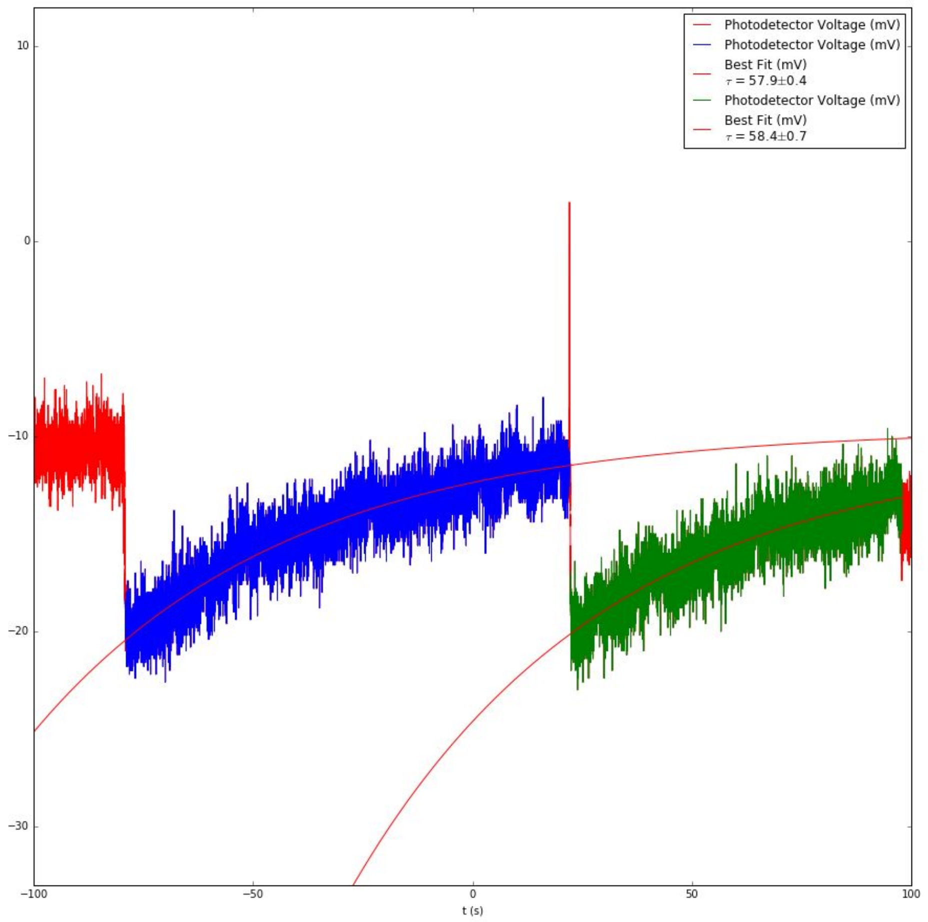


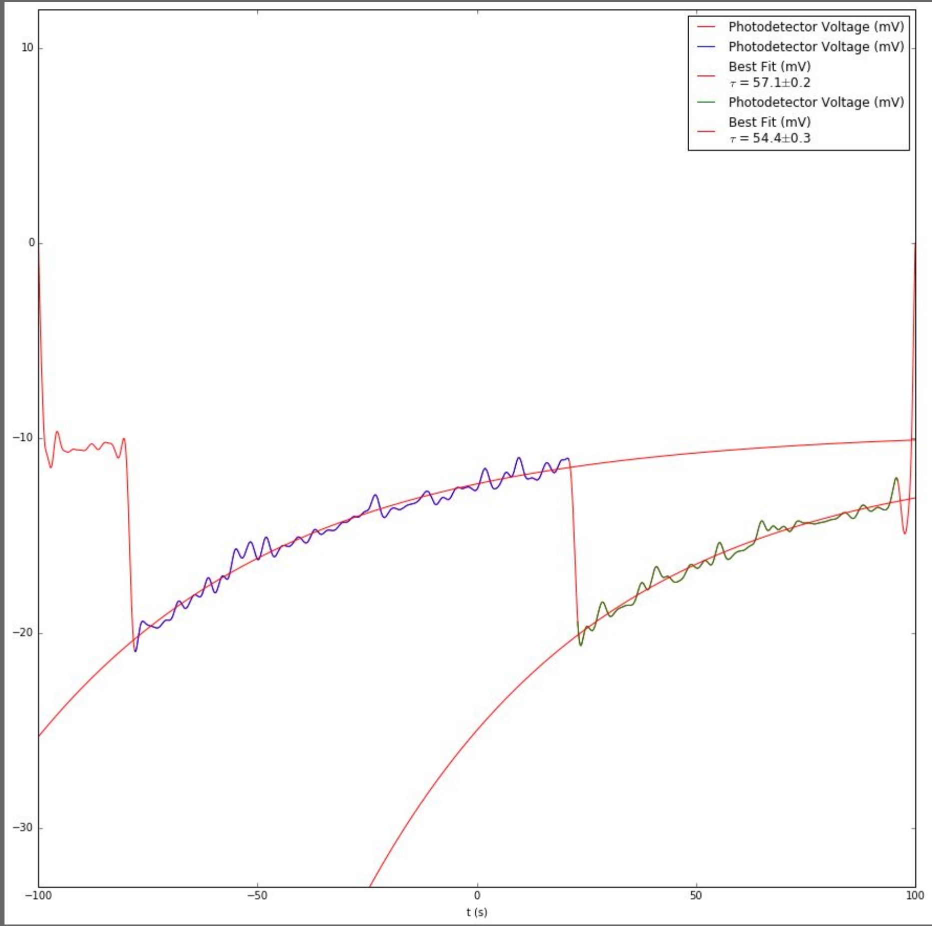
Gustafsson's Method Filter (Pre Pump)



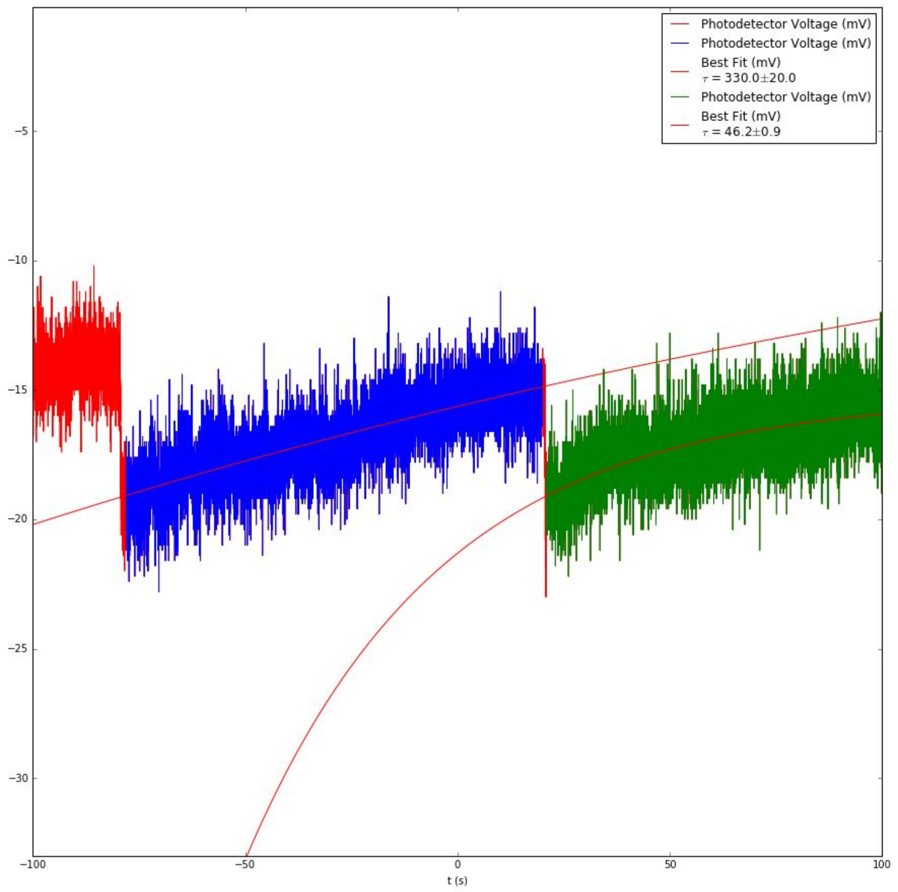


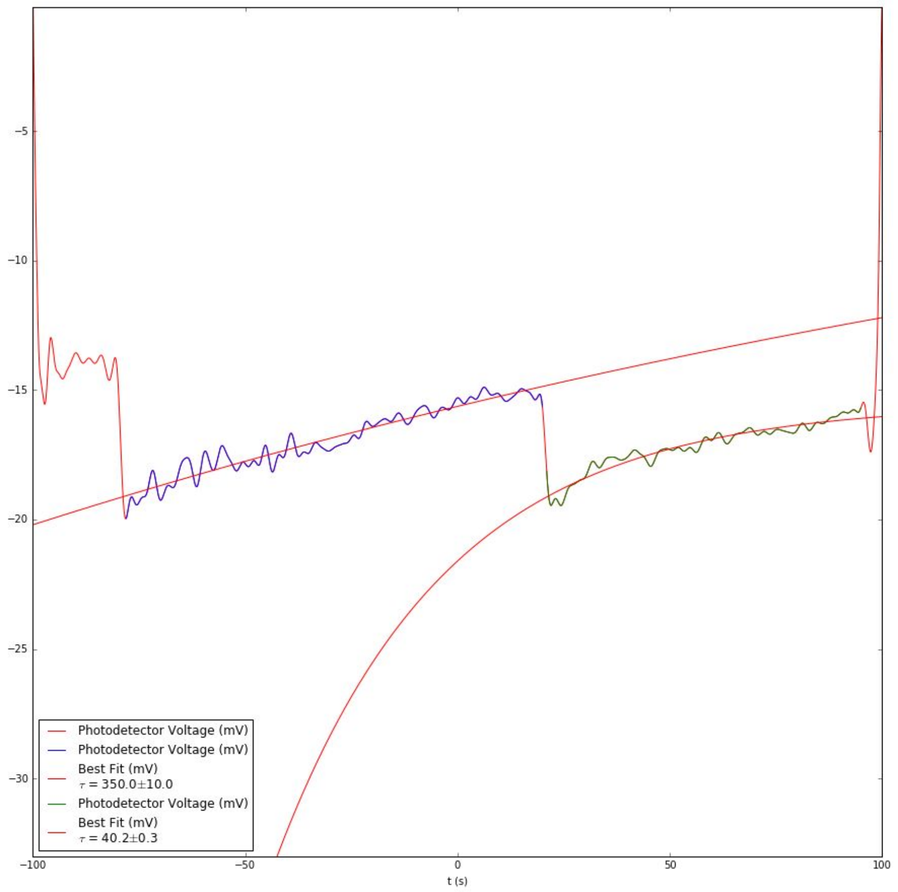
Gustafsson’s Method Filter (Post pump)





Inconsistent MOT formation





Sources of Error

- Difficulty in obtaining image of MOT

- Photodetector not ideal (aiming issues)
  - Imaging scattered/direct laser light
  - Photodetector not centered on MOT

- Cycling B Field

Absolute Brightness as a Measurement for Number of Atoms

Using the solid angle formed by the distance measurement and the diameter of the lens, one could calculate the absolute brightness of the MOT. A lens would focus the light received at that portion of the sphere onto a photodetector.

By knowing the transition that the lasers are locked on to you can calculate the number of photons emitted, thus giving a reasonable estimate for the number of atoms performing such a transition.

The brightness also depends on the number of atoms pumped into the vacuum sealed chamber.

There is a limit on the maximum number of atoms before they repel each other out of the MOT

Adjusting the Position of the MOT Inside the Chamber.

By changing the intensity of the lasers, one could manipulate the position to a different equilibrium position.

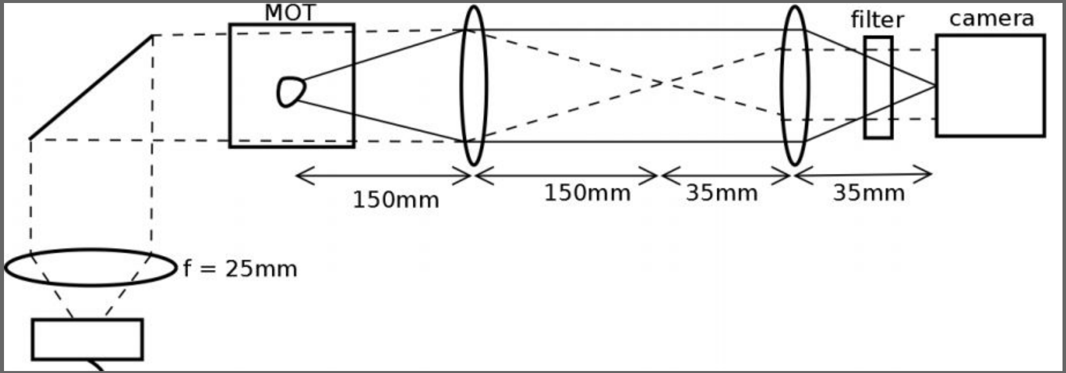
Another way to modify the atoms position is to adjust the magnetic field that the Trap is being placed in.

Changing the current on the top or the bottom coil would alter the origin and thus the position of the MOT.

Bringing an external magnet will push or pull the cluster of atoms depending on magnetic field being introduced.

Imaging the MOT

We could measure the optical density using a collimated probe from a laser, of diameter bigger than that of the MOT, incident upon the MOT. An image of the probe beam with the “shadow” of the MOT (due to absorption of the probe beam) would be taken by a CCD camera.



References

Lab, Advanced Optics. “Laser Cooling and Trapping.” *https://www.colorado.edu/Physics/phys4430/phys4430_sp18/*, www.colorado.edu/physics/phys4430/phys4430_sp18/Labs/Laser%20Cooling_2004.

Luksch, Kathrin. “Measurement of the Number of Atoms in a Magneto-Optical Trap Using Absorption Imaging.” *National University of Singapore*, 2012.