University of Wisconsin-Stevens Point

Design and Construction of a Magnetic Trap

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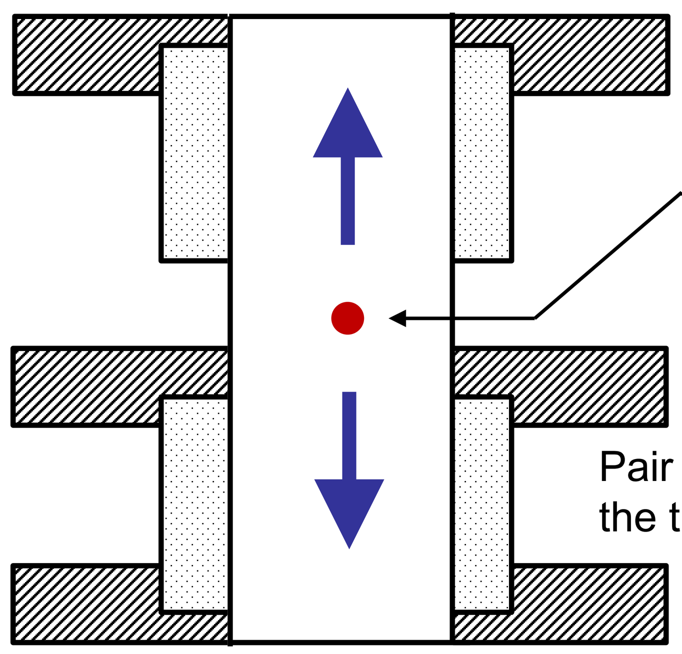
1. Introduction

- The goal of this project is to construct a magnetic trap to study some aspects of atomic physics using everyday objects.
- By trap, we mean: *Is it possible to overcome gravity and suspend an object in space*?



2. Trap design

- Need a field gradient (*dB/dz*) to cancel gravity.
- The field gradient depends on the moment-to-mass ratio (μ/m),

$$\frac{dB}{dz} = \frac{g}{(\mu/m)},$$

and for the object we wish to trap

μ/m is ~ 0.10 Ampere meter^2 per gram.

- Remarkably, this moment-to-mass ratio μ/m is almost the same as for a heavy atom such as cesium or rubidium.
- The physics of the trap only depends on μ/m ! Therefore, our trap can be used to study certain aspects of atomic physics using everyday sized objects.

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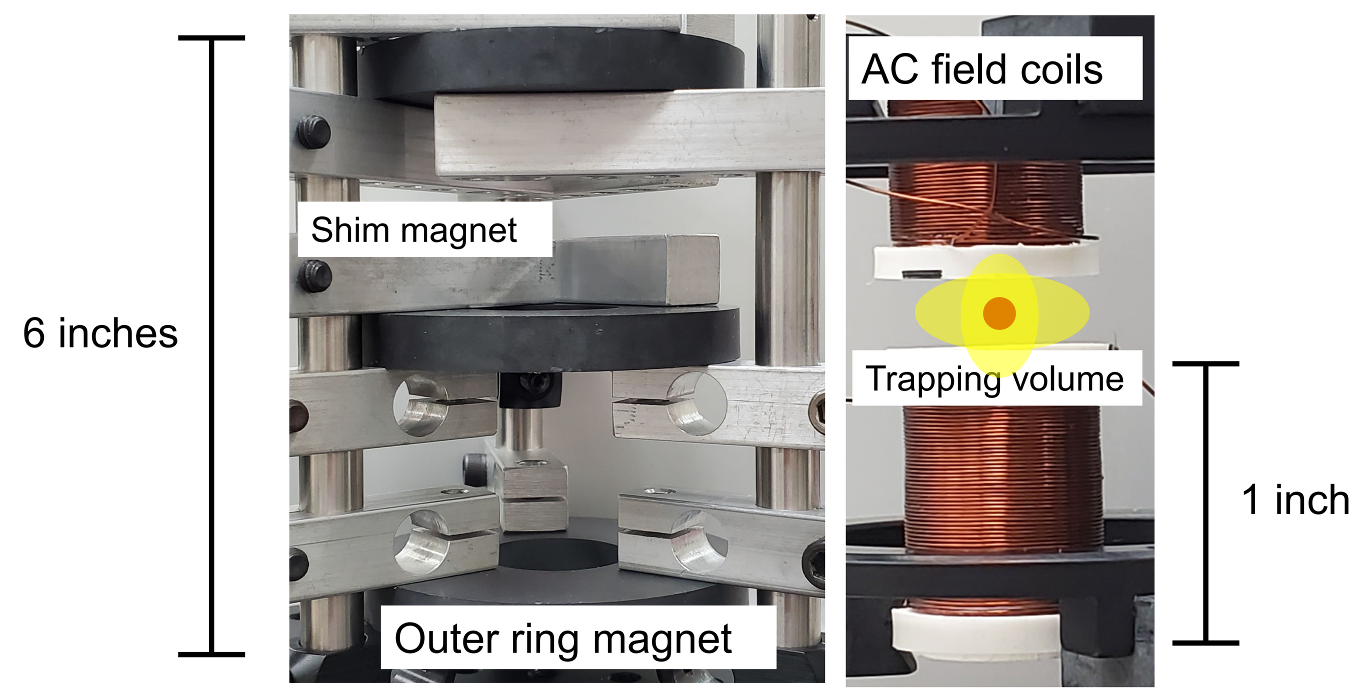
3. Construction

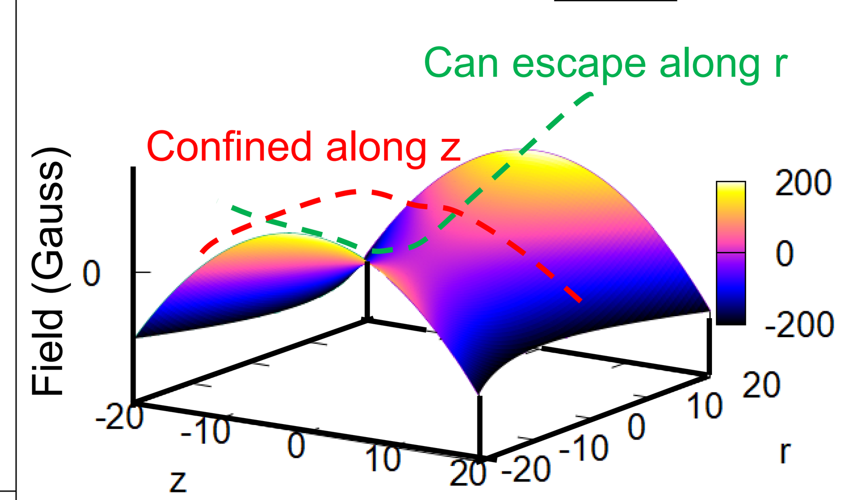
Our trap consists of the following:

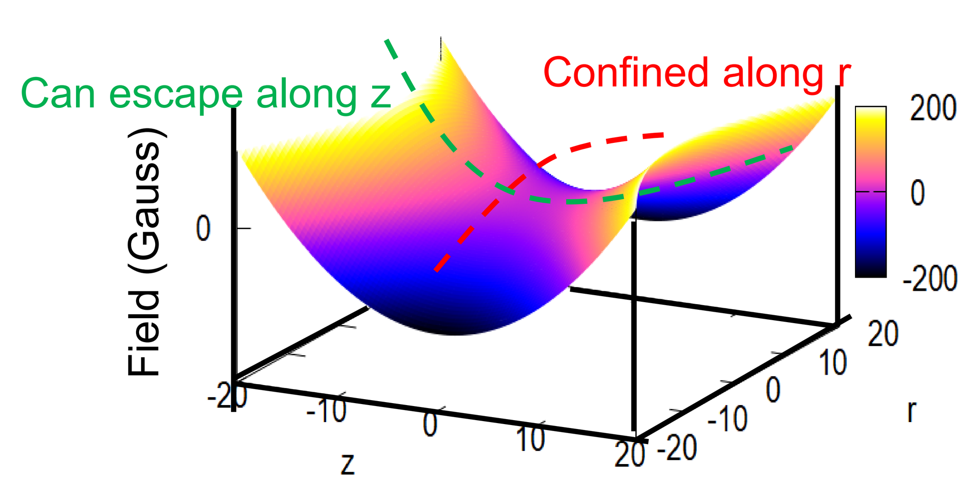
- A pair of ring magnets to generate a uniform bias field along z. In our trap, this uniform field is almost 150 Gauss.
- A shim magnet to generate the gradient (dB/dz) to overcome gravity. In our trap, we get gradients of up to 240 Gauss per cm.
- A pair of AC field coils that are driven with a 4.0 Ampere current at 60 Hz.



4. Field profile within the trap volume

- A field gradient by itself is not sufficient. The gradient provides confinement along axial direction z, but the moment can escape along the radial direction r!
- The radial escape is prevented by an AC field that changes the field curvature faster than the object can respond.

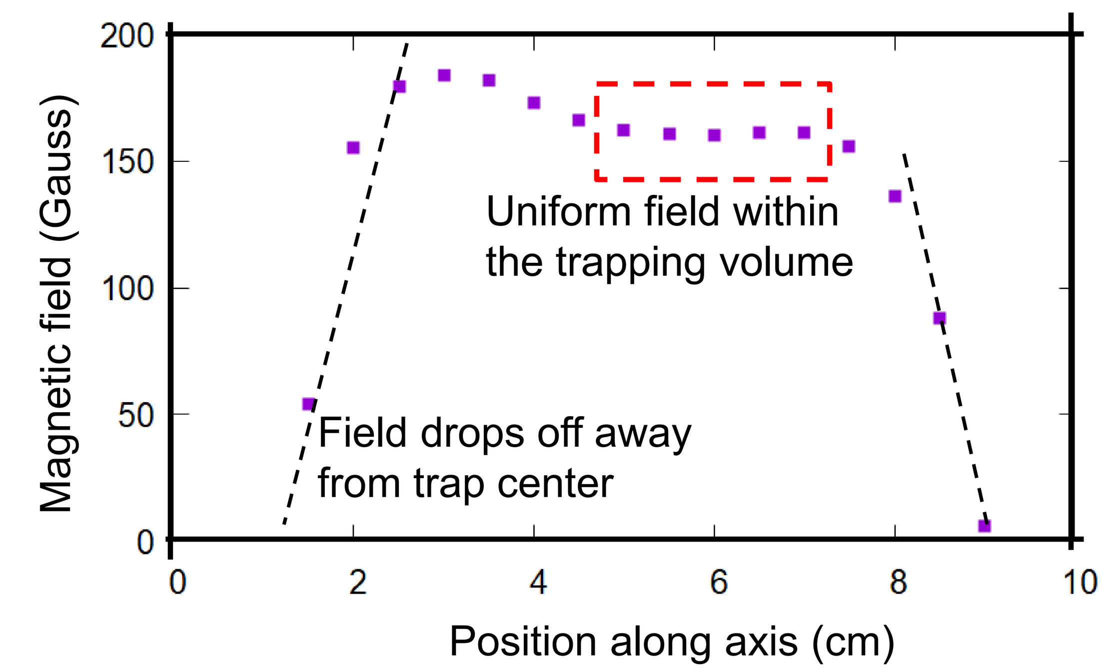




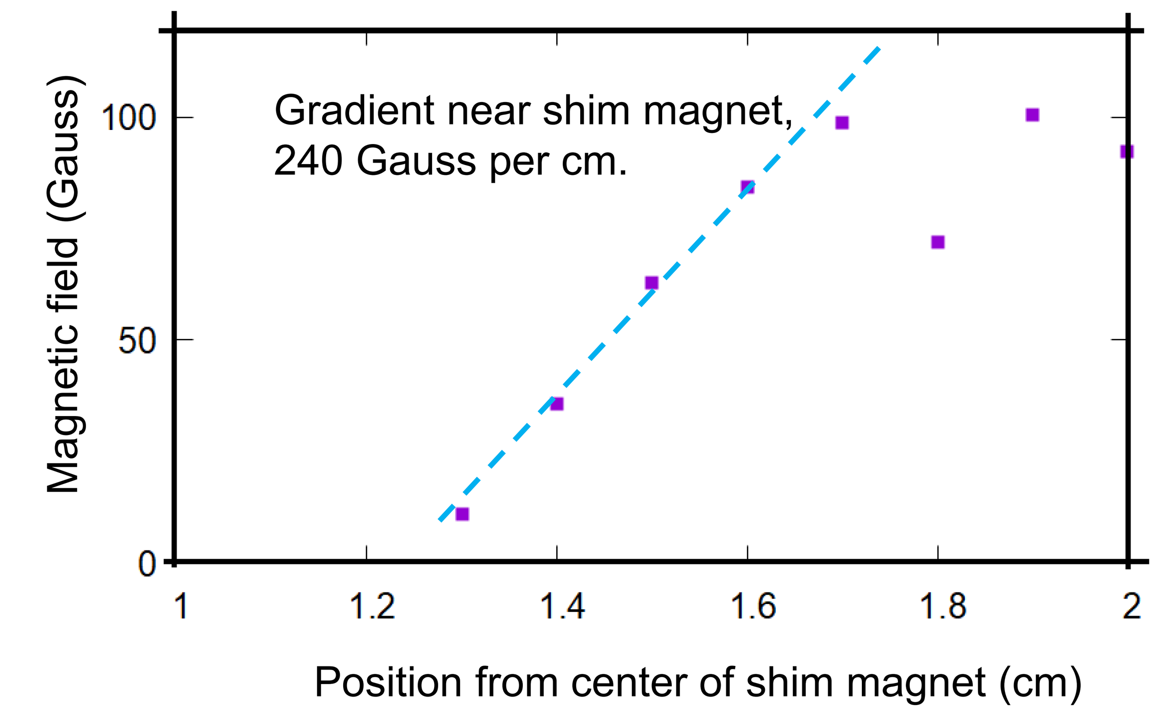
- The ac coil switches the curvature fast enough that the particle is confined along both z and r!

5. Results

- The field profile along the axial direction z was measured for different separations of the two outer ring magnets. We find that an optimum separation of 10 cm gives us a wide enough region of uniform field.



- The gradient profile along the axial direction was also measured near the trap center. We obtain gradients of almost 240 Gauss per cm, far greater than the ~ 12 G/cm gradients we need.



- But is our trap stable? To answer this, we need to know the field profile generated by the ac coils.
- The field profile in the trapping volume is given by

$$B_z(z,r,t) = \underbrace{B_0 + \{B_{dc}}_{\text{Uniform field + small dc curv.}} + \underbrace{B_{ac}\cos(\omega t)\}}_{\text{ac field}} \underbrace{(z^2 - r^2/2)}_{\text{cylindrical symmetry}}$$

- The crucial parameter is B_{ac}. Is the ac field magnitude large enough to provide the curvature necessary to confine along both z and r?
- These are open questions for now, but we hope to answer them during the coming year and demonstrate a working trap.