Tri-Axis Helmholtz Coils For Magnetic Field Control

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Introduction

- If we can control an atom's state, we can utilize it.
- An atom's state is controlled by its energy level.
  - ↳ Its energy level is controlled by a magnetic field's strength.
    - ↳ Fields like Earth's magnetic field influence the state of atoms.
    - ↳ Desired magnetic fields can be created to cancel said fields
- The purpose of this project is to cancel external fields and create a controlled magnetic field with our desired parameters.

The Theory Behind Helmholtz Coils

- The movement of electrical charges (current) form magnetic fields.
- Current flowing through a loop creates a orientable magnetic field.

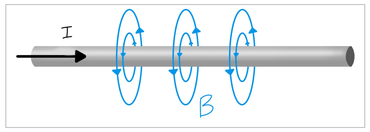


Fig 1. The magnetic field (B) of a wire at a specific current (I)

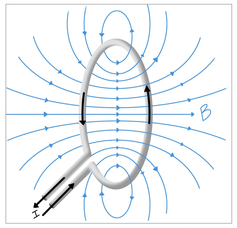


Fig 2. The magnetic field (B) of a coiled wire at a specific current (I)

- Helmholtz coils are when identical coils are placed parallel to each other, running the same current, separated by a distance approximately equal to the common radius.[1]

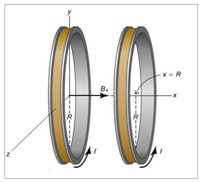


Fig 3. A model of circular helmholtz coils[1]

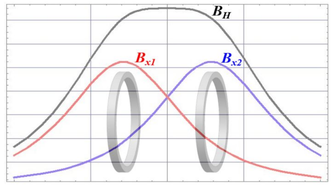


Fig 4. The magnetic field (in the x-axis) of the Helmholtz Coils add perfectly[1]

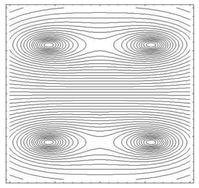


Fig 5. The magnetic field lines of the coils[1]

The Process of Construction

Calculation of coil parameters → Construction of turntable to wind coils → Winding and soldering of wire coils → Formation of coil cage → Measure magnetic field of coil pairs using magnetometer → Measure resistance of coils using multimeter

Results

Coil Pair	Number of Turns	Side Length of Coil (m)	Coil Separation (m)
Outer	82	1.0	0.5445
Middle	77	0.94	0.51183
Inner	73	0.88	0.47916

Table 1. Coil parameters for an approximate magnetic field of 200 microtesla at 1.76 amps, given an expected response of 113 μT / A

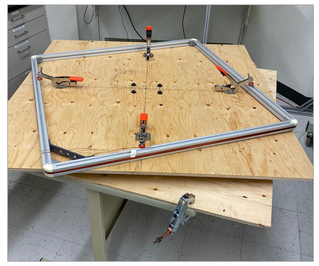


Fig 6. Winding table with coil laying on top

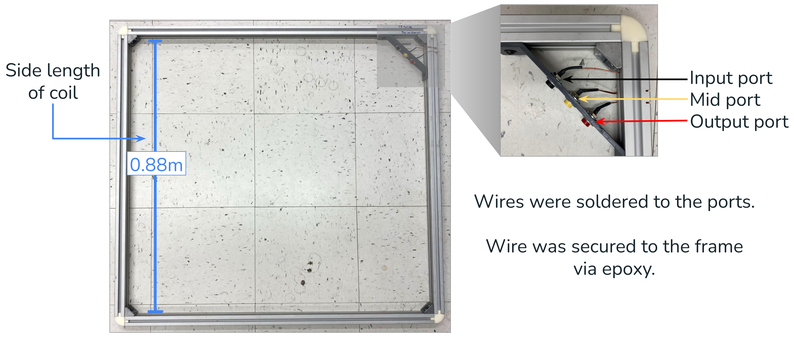


Fig 7. A completed coil

Wires were soldered to the ports.

Wire was secured to the frame via epoxy.

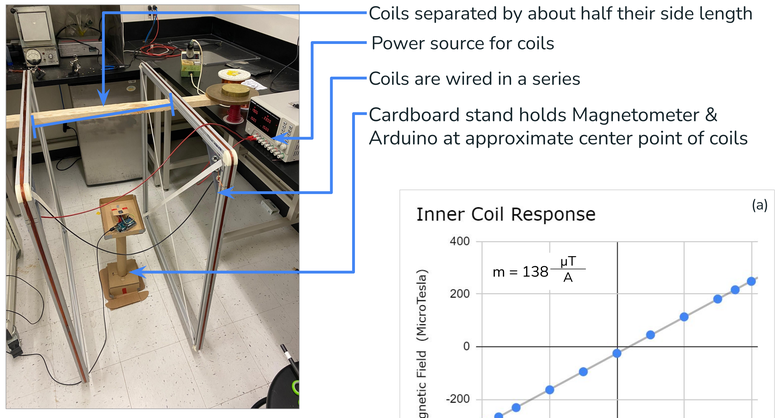
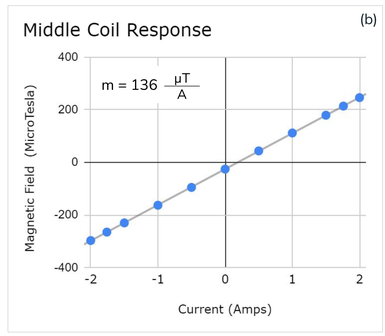


Fig 8. The setup used to measure magnetic fields of coils



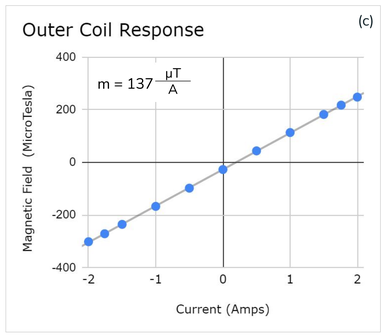


Fig 9 (a)(b)(c). Each point is a mean of 10 readings with an error bar less than 0.2

Results Cont.

Fig 10. Completed cage

Conclusion & Going Forward

- 6 Helmholtz coils were constructed and formed into a cage.
- The coils' responses are within 2μT of each other.
- The coils' responses (~ 137 μT / A) are within 30μT of the expected response (113 μT / A).
- The near uniform magnetic field created by the coils allows us to control the atom's state.
- Going forward, we can utilize this behavior in technology like:
  - ↳ Atom magnetometry
  - ↳ Quantum memory
  - ↳ Atom based Quantum computing

References

[1]A. del C. Fontanet Valls, "Design and construction of a 3D Helmholtz coil system for the ALBA magnetic measurements laboratory," Bachelor Thesis, universitat de politecnica de catalunya, 2019. Accessed: Jul. 31, 2023. [Online]. Available: https://upcommons.upc.edu/bitstream/handle/2117/168009/Memoria_TFG-Andrea%20Fontanet.pdf?sequence=4&isAllowed=y

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[3]"Not Black Magic: Helmholtz Coil," notblackmagic.com. https://notblackmagic.com/bitsnpieces/helmholtz-coil/ (accessed Aug. 08, 2023).

Acknowledgements

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