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Research Advisor: Eric Cornell
Research Field: Physics
Expected Semester of Graduation: Spring 2018

Stabilization and digitization of an ultracold Bose gas apparatus

Prospectus:
Recently ultracold Bose gases have attracted a lot of attention due to their magnetically tunable Feshbach resonances. This has made resonantly interacting Bose gases a subject of great interest [1-5]. In our experiment we seek to create a K39 Bose-Einstein Condensate (BEC) and study it near resonance. We create this BEC via a 3-stage cooling process, with two Magneto-optical traps (MOTS) and an optical dipole trap in which the BEC is finally created via evaporative cooling. Because tuning the magnetic field in this trap is what allows us to tune the interactions of the BEC and study the resonances, knowing and controlling this magnetic field is of vital importance to the experiment.

For this project, I will stabilize and digitize the current apparatus in order to provide greater monitoring capabilities, stability, and control of the magnetic field in the optical dipole trap. I will create systems to measure various sources of magnetic field noise. I will also design and construct a set of servomechanisms to remove magnetic field noise using feedback loops to measure and correct noise sources. The goal is to record these noise sources as well as control the magnetic field to a precision of five milli-Gauss on fields that can range up to around one hundred and sixty-two Gauss.

Bibliography:

[1] B. S. Rem, A. T. Grier, I. Ferrier-Barbut, U. Eismann, T. Lan- gen, N. Navon, L. Khaykovich, F. Werner, D. S. Petrov, F. Chevy, et al. Lifetime of the Bose gas with resonant inter- actions. *Phys. Rev. Lett.*, 110(16):163202, 2013.

[2] R. J. Fletcher, A. L. Gaunt, N. Navon, R. P. Smith, and Z. Hadz- ibabic. Stability of a unitary Bose gas. *Phys. Rev. Lett.*, 111(12):125303, 2013.

[3] P. Makotyn, C. E. Klauss, D. L. Goldberger, E. A. Cornell, and D. S. Jin. Universal dynamics of a degenerate unitary Bose gas. *Nat. Phys.*, 10(2):116–119, 2014.

[4] U. Eismann, L. Khaykovich, S. Laurent, I. Ferrier-Barbut, B. S. Rem, A. T. Grier, M. Delehaye, F. Chevy, C. Salomon, L.-C. Ha, et al. Universal loss dynamics in a unitary Bose gas. *Phys. Rev. X*, 6(2):021025, 2016.

[5] R. J. Fletcher, R. Lopes, J. Man, N. Navon, R. P. Smith, M. W. Zwierlein, and Z. Hadzibabic. Two- and three-body contacts in the unitary Bose gas. *Science*, 355(6323):377–380, 2017.

Timeline:

By Oct. 23:

- Correct miscellaneous sources of DC noise (elevators, etc..)
- Have objective list of measurable noise sources
- Begin setup for correcting noise from 60Hz lines

By Nov. 6:

- Finish correcting 60Hz noise
- Progress down list building logging systems for error sources
- Put together necessary digitalization components (ADCs, etc…)

By Nov. 20:

- Complete necessary digitalization to allow for multiple servoing mechanisms
- More progress through list of error sources

By Dec. 18:

- Control of magnetic field within desired five milli-Gauss

By Jan.:

- Begin writing intro and structure for thesis

By Feb:

- Complete additional desired upgrades to apparatus
- Full draft of thesis for advisor feedback

By Mar.:

- Final revisions of thesis with advisor
- Finished thesis ready to present