FINAL REPORT

Laser Cooling and Trapping Apparatus for Undergraduate Study

SPS Undergraduate Research Award
Old Dominion University

Introduction

The SPS Chapter at Old Dominion University undertook a research project to create a magneto-optical trap (MOT) to produce and confine ultracold ($T < 1$ mK) rubidium atoms using light forces. The purpose of this project was to provide students with an opportunity to learn about ultracold physics and the associated instrumentation and to create an apparatus for later use in the undergraduate teaching lab and for independent study. As described below, we were successful in constructing the MOT and we demonstrated the confinement of ultracold rubidium atoms.

SPS Team

Most of the work was done by the original team members: Rodney Beckner, Peter Bradshaw, Rebecca Clark, Patricia Hoeft, Michael Klann, Amber Mitchell, Christine Thomas, Tammie Wallace, and Jonathan Wood. In addition, in the latter stages of the effort, Robert Horne and Gambhir Ranjit also worked on the project. Professor Sukenik served as the research advisor.

Vacuum System

Initially, several designs for the vacuum system were considered. A principal consideration was minimizing complexity and cost, while still allowing for the objectives of the project to be met. Although our apparatus closely follows the work of the Wieman, et al. paper[1] we decided to make some modifications which simplified the apparatus. In particular, we decided to use a glass cell with a circular cross-section as opposed to the cube mentioned in the article. A photo of the apparatus is shown in figure 1.

Laser system

The laser source used for the MOT was a diode laser operating at 780 nm. We used an external cavity diode laser (master) to inject a second diode laser (slave). The master laser frequency was monitored on a saturated absorption spectrometer setup. The output of the slave laser was sent via fiber optic cable to the MOT chamber. In order to derive the second laser frequency needed for MOT operation (the hyperfine repumper laser), we applied a 3 GHz microwave modulation to the slave laser current, thereby putting a sideband on the laser at the appropriate frequency.

Rubidium Source

The rubidium for the MOT was obtained by running a current of ~3A through a rubidium dispenser (SAES Getters).

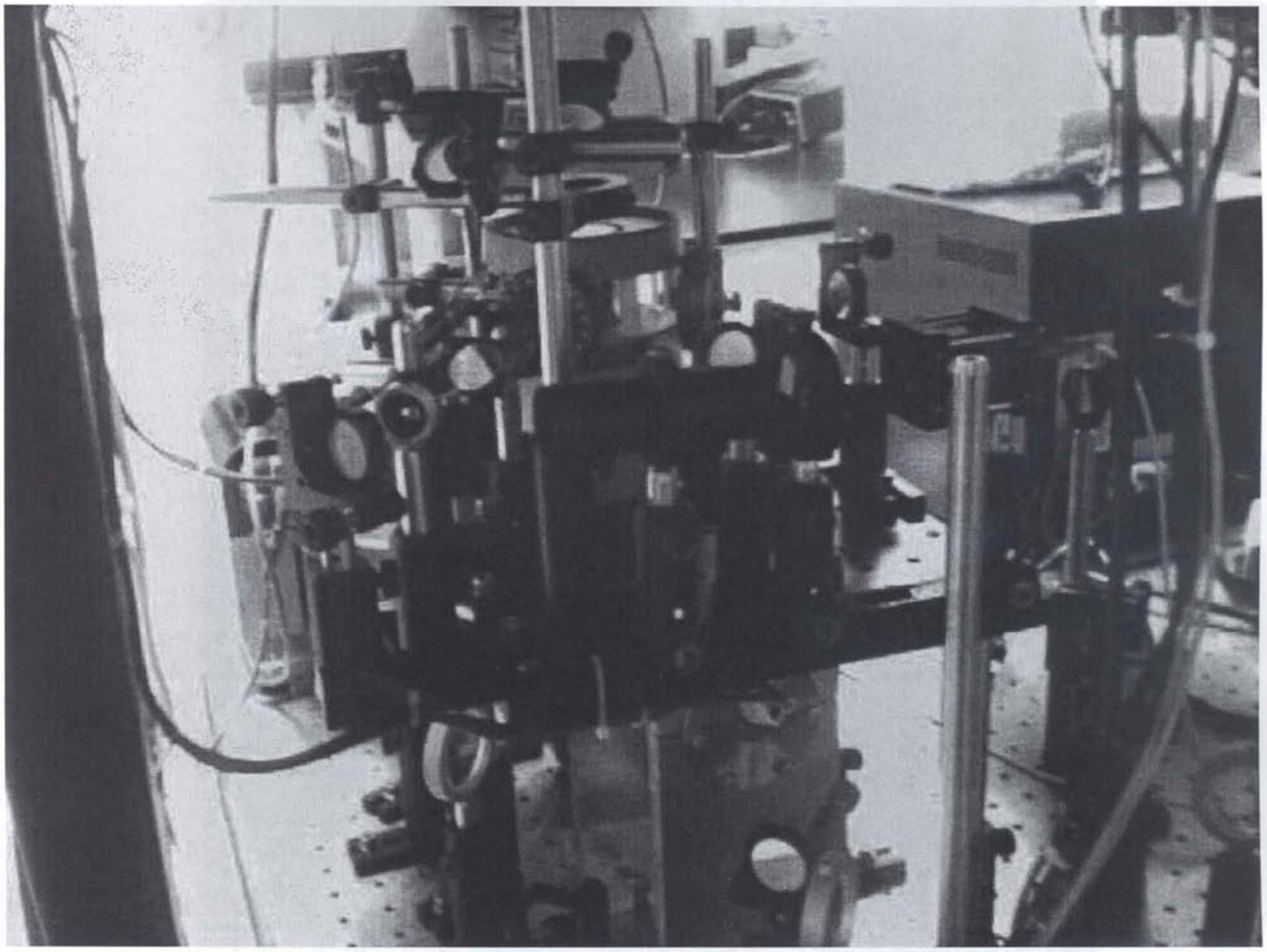

Figure 1: Photo of the SPS Magneto-Optical Trap

Budget

In addition to the items listed below, we also used many components already in the Undergraduate Research and Teaching Lab, such as mirror mounts and post holders, power supplies, and some components needed for the laser system. We also incorporated a used ion pump and controller which had been purchased on eBay.

With help from Walt Hooks, operations manager in the Department of Physics, orders were placed for all the remaining items we needed to build our apparatus and complete our project. A summary of the purchases made with the Award funds can be found in the table below:

Company	Items	Cost
Edmund Optics	optics	$ 276.70
Kurt J. Lesker	vacuum hardware	308.26
New Focus, Inc.	optics/mounts	190.28
Duniway Stockroom	vacuum hardware	769.64
Triad	Rb cell	275.00
Jameco	cables, electronics	199.00
total		$2018.88

Project Tasks

Different project tasks were divided among the team members. These tasks included 1) assembly and testing of the vacuum system, 2) alignment of the diode laser system, 3) design and construction of the anti-Helmholtz coils, and 4) alignment of the light at the MOT chamber.

Results

After many months of work, the above tasks were all completed and it was time to search for evidence of ultracold atoms in the MOT. Using both a CCD camera with monitor and an infra-red viewer, we searched for MOT fluorescence as the final optics alignment (setting the quarter wave plate orientation) was done. When the optics were properly set, the MOT appeared! Although we have not done a quantitative measurement yet, we estimate that we were able to trap several hundred thousand ultracold rubidium atoms in the MOT.

Conclusion

We undertook a research project to construct a magneto-optical trap (MOT) to confine ultracold rubidium atoms. Working as a team, we were able to successfully design and construct a MOT in which ultracold rubidium atoms were observed. Our apparatus is now available for students to use in advanced laboratory classes or for independent study projects.

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[1] C. Wieman, G. Flowers, S. Gilbert, "Inexpensive laser cooling and trapping experiment for undergraduate laboratories," Am. J. Phys. 63, 317 (1995).