Characterization of the Magneto-Optical Trap for Rb Atoms

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INTRODUCTION

A magneto-optical trap (MOT) for rubidium (Rb) atoms has been in operation at the University of San Carlos Optoelectronics Research Laboratory in Cebu City since 1998. The experimental design for this MOT is based on the system described by Wieman et al. (1995). This system formed the backbone of the research which resulted in the first observation of Bose-Einstein condensation (BEC) by the same group in 1995. An essential step for realizing this remarkable result was the accuracy in the timing mechanism of the experiment. To obtain an MOT in which we can switch the laser and magnetic fields with sub-millisecond accuracy, we have put considerable efforts to realize a computer-controlled system.

Previous measurements have been used to validate our new results. The realization of a fast switch for the trapping laser creates the opportunity to measure time-of-flight (TOF) signals. These ballistic measurements can be used to infer the temperature of the cloud of trapped atoms.

We hope to continue working on this automated system of the MOT towards BEC as a long-term goal of our research group.

METHODOLOGY

Our experimental setup consists of a Rb reservoir which is heated to load Rb atoms into a glass cell, maintained at a low pressure by means of an ion pump. Two frequency-stabilized lasers are used, the trapping laser and the repumping laser, which are locked to the $5S_{1/2}F=2 \rightarrow 5P_{3/2}F'=3$ and $5S_{1/2}F=1 \rightarrow 5P_{3/2}F'=2$ transitions of the ^{87}Rb isotope, respectively. Helmholtz coils, with currents in opposite directions, are set up such that the center of both coils coincides with the center of the glass cell and the center of the six trapping beams, thus completing the MOT configuration. A more detailed description of the system is given elsewhere (Liwag, 1999).

We developed LabVIEW routines to switch the current through the Helmholtz coils on or off, to start the image acquisition of our CCD camera, as well as to block or unblock the trapping laser beam through an electronically controlled relay switch.

To determine the number of trapped atoms, the total amount of light scattered by the atomic cloud was determined using a calibrated power meter which sends a voltage signal to the DAQ card for further computations in LabVIEW. The experimental setup is shown in Fig. 1.

Part of the emitted light from the atomic cloud was made to converge on the head of a power meter using a plano-convex lens of focal length 50 mm placed at a

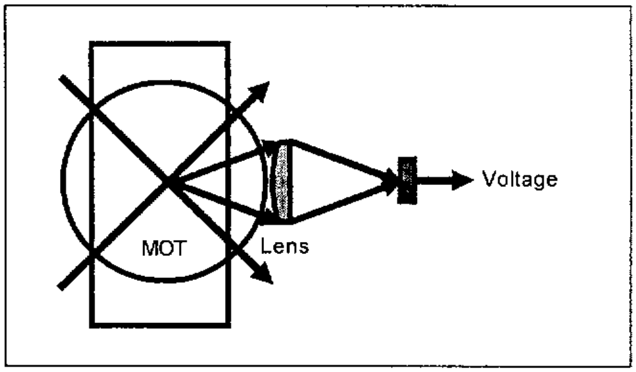

Fig 1. Diagram of the setup for determining the number of trapped ^{87}Rb atoms. Only one Helmholtz coil and two laser beams are shown with the trapping cell

distance of 53 mm from the center of the MOT. This distance is slightly larger than the focal length of 50 mm in order for the light to be properly converged on the power meter. The light that reaches the power meter is a fraction of all the light emitted by the cloud. The fraction is given by the area of the lens of diameter 2.54 cm, divided by the surface area of the sphere with radius 53 mm which encloses the cloud. Therefore, the total amount of light emitted by the cloud is roughly 70 times the power meter reading.

To account for the background fluorescence, the difference in the voltage readings when the magnetic field is on and off is recorded. A LabVIEW routine transforms this voltage to a corresponding intensity, which is used to compute the number of trapped atoms.

Different detunings were used to investigate the dependence of the number of trapped atoms on the detuning frequency D. The current through the Helmholtz coils was varied to investigate the dependence of the number of trapped atoms on the magnetic field B.

The lifetime of the trap was determined using the setup shown in Fig. 2.

A CCD camera connected to an IMAQ card captured images of the atomic cloud when the magnetic field was switched on by the computer. For each trial, 75 images were recorded at a 150-ms time interval. These images clearly show an increase in intensity, from which the lifetime was obtained by fitting the intensity data to an exponential growth curve.

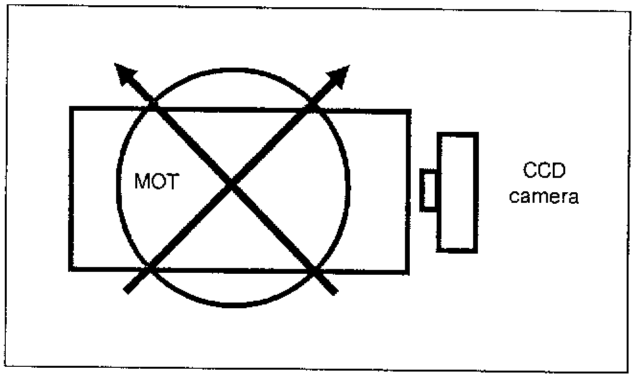

Fig 2. Diagram of the setup for determining the lifetime of the MOT

For the temperature measurement, a probe laser beam was sent through the trapping cell at a distance of 1 cm below the atomic cloud. The probe beam entered a photodiode connected by an IMAQ card to the computer. A fast relay switch with a razor blade was set up to block the trapping laser electronically via the computer. We measured switching times of less than 0.5 ms. A LabVIEW routine switches off the Helmholtz current and the trapping laser beams simultaneously. So far, attempts to capture a TOF signal on the computer screen in this manner were not completely successful. The TOF signals were too fast to be captured on the computer screen. In any case, we expect a temperature of the order of 1 mK for our atomic cloud, which corresponds to a most probable velocity of 43 cm/s for the trapped atoms.

RESULTS, DISCUSSION, AND CONCLUSION

In this paper, we report trapping of as many as 6 x 10^{8} ^{87}Rb atoms, and trap lifetimes of as long as 3.0 ± 0.2 seconds. Comparison with previous results (Liwag, 1999) showed that the lifetime has increased by a factor of 3, which we attribute to the decrease in pressure. These measurements were carried out at a pressure of less than 10^{-7} mbar. The refined methods make us believe that earlier estimates of the number of trapped atoms were rather conservative.

Table 1 shows the data of the number of trapped atoms for different detunings of the trapping laser below the atomic resonance frequency.

Fig. 3 shows the cloud of trapped atoms for different values of the magnetic field. We observe the increase

Table 1. The number of trapped atoms for different detunings. The current through the Helmholtz coils is set at 3.0 A. Here G = 6 MHz is the natural linewidth of the ^{87}Rb cooling transition

Detuning D of Trapping Laser (*MHz*)	**Number of Trapped Atoms**
-2.5Γ	(7 ± 3) ˙ 10^{7}
-3.5Γ	(3 ± 2) ˙ 10^{8}
-4.5Γ	(6 ± 4) ˙ 10^{8}

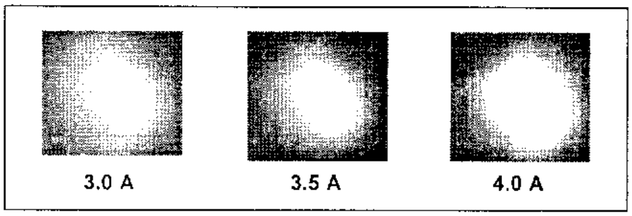

Fig 3. Images of the cloud of trapped ^{87}Rb atoms in steady-state for different currents applied to the Helmholtz coils. The detuning D of the trapping laser here is set at -3.5G.

in intensity of the cloud, and hence, an increase in the number of trapped atoms, for increasing magnetic field. This is due to the fact that an increase in the magnetic field increases the restoring force in the MOT.

As mentioned before, our attempts to measure the temperature have not yet been successful. Instead of measuring the TOF signals after switching off the MOT, we now monitor the expansion of the cloud in optical molasses. In molasses the velocities of the atoms are much smaller, which makes it possible to use a video camera for our measurement. In molasses we have observed an upward expansion of the atomic cloud, which we attribute to the presence of a residual magnetic field. Presently we are trying to compensate for this magnetic field by placing extra Helmholtz coils around the MOT. During the conference, we hope to show a video of this expansion of the cloud in optical molasses.

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