Studies of cooled and trapped magnesium atoms

D. N. Madsen, C. V. Nielsen, F. Y. Loo, A. Brusch, N. Andersen and J. W. Thomsen

Niels Bohr Institute, Ørsted Laboratory, University of Copenhagen
Universitetsparken 5, DK-2100 Copenhagen, Denmark
Tel +45-35320476, Fax +45-35320460
E-mail: vandel@fys.ku.dk

During recent years, laser cooling of neutral atoms has become a powerful and versatile tool in physics. Advances in sophisticated optical techniques have now made it possible to laser cool two-electron atoms such as magnesium. These systems, though, present a serious experimental challenge since their resonant wavelengths are typically in the UV range inaccessible to standard photon sources [1]. Previous work has thus concentrated on symmetric alkali (Na, Rb, Cs) and rare gas (He, Ne, Kr, Xe) systems, all with easily accessible resonance transitions available from well-established light sources. All these systems, however, have inherent complications, namely the presence of fine or hyperfine structure splitting of atomic energy levels. This prevents quantitative experimental interpretation as well as detailed theoretical studies [2]. Atoms with a simpler internal structure, such as magnesium, are therefore highly desirable.

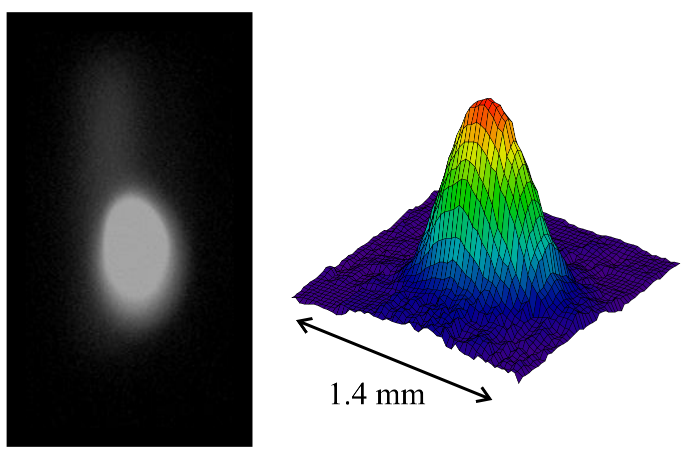

Figure 1: CCD camera image of 10^6 ^{24}Mg atoms at a temperature of 2 mK.

We capture about 10^6 Mg atoms in a volume of 0.1 mm^3 at a minimum temperature of 2 mK set by the Doppler limit[3]. The 285 nm light required for the MOT is produced by frequency doubling of a 570 nm dye ring laser in an external four mirror cavity using a BBO crystal. Our cavity is tuned to high output power for optimal atom trapping. The setup has the flexible possibility of being able to trap any of the three stable magnesium isotopes ^{24}Mg (boson), ^{25}Mg (fermion) and ^{26}Mg (boson) independently.

Cold atoms interacting are usually revealed in form of energetic atoms leaving the trap. By studying the MOT fluorescence we have seen clear evidence of cold atoms interacting. These results now form basis for more detailed theoretical models. Another trap loss mechanism present for the Mg MOT is photo-ionization of the trapped atoms 3s3p $^1P_1$. In a systematic study of the MOT lifetime as a function of laser intensity we determined the absolute photo-ionization cross section[4].

We are now improving the setup for photoassociation spectroscopy where it is possible to probe the rotational and vibrational structure of a quasimolecule formed by two cold atoms interacting. This will provide valuable information on the Mg_2 potential curves as well as determination of the ground state scattering length.

A positive scattering length is important in order to push the magnesium sample into the BEC regime. First theoretical estimate shows a positive value for ^{24}Mg and ^{26}Mg in favor of BEC, but this needs to be confirmed experimentally.

Recently, we succeeded in performing high resolution spectroscopy on the MOT using the 457 nm intercombination line. The 457 nm transition is an ideal atomic clock candidate with a very narrow transition (30 Hz)[1] and a high Q-value of 10^{15}. In addition, the intercombination line transition offers the possibility of cooling the atoms to very low temperatures of less than 1 μK.

This work is performed in collaboration with the Danish Institute of Fundamental Metrology. See also presentation by V. Ruseva at this conference.

Results on absolute photo-ionization measurements, high resolution spectroscopy using the intercombination line and cold collisions based on the Mg MOT will be presented at the conference.

This work is supported by CAUAC and the Carlsberg Foundation

[1] K. Sengstock et al., *Appl. Phys.*, **59** 99 (1994).
[2] M. Machholm et al., *Phys. Rev. A*, **59** R4113 (1999).
[3] D. N. Madsen et al., Manuscript in press.
[4] D. N. Madsen et al., Manuscript in press.