NEW COOLING SCHEMES OF ALKALINE EARTH ATOMS

F. C. Cruz[1], N. Malossi, S. Damkjær, P.L. Hansen, L.B. Jacobsen, L. Kindt, S. Sauge, M. Allegrini[2], E. Arimondo[2], E. van Ooijen, A. Brusch and **J. W. Thomsen**

The Niels Bohr Institute, Universitetsparken 5, 2100 Copenhagen, Denmark
1 Instituto de Fisica Gleb Wataghin, UNICAMP, Campinas, 13083-970, Brazil
2 Dipartimento di Fisica E. Fermi, Università di Pisa, L. Pontecorvo 3, I-56127 Pisa, Italy

The interest in laser cooling of alkaline-Earth atoms has increased significantly over the past years. One of the reasons is the use of those elements for new improved frequency standards, optical clocks and precision measurements. For these applications low atom sample temperatures are crucial. In case of Bosonic systems temperatures are limited to a few milikelvin due to a non degenerate ground state. While intercombinationline cooling has proven efficient for Sr, for magnesium and calcium the photon scattering rate is too slow.

We have analyzed a new two photon cooling mechanism for cooling Alkaline Earth atoms below the Doppler temperature [1]. Originally two photon cooling of atoms were considered by Cruz et al [2], however, the coherences between the two extreme states and were not considered. In the case of magnesium, we consider the magnesium ladder system $(3s^2)\ ^1S_0 \rightarrow (3s3p)\ ^1P_1$ at 285.2 nm followed by the $(3s3p)\ ^1P_1 \rightarrow (3s3d)\ ^1D_2$ transition at 880.7 nm. The life time of the $(3s3p)\ ^1P_1$ state is 2 ns and the $(3s3d)\ ^1D_2$ state 71 ns. For the ladder system quantum coherence effects become important. Two-photon excitation allows for production of atomic coherences which lead to a broad frequency region over which cooling takes place. This happens mainly through a modification of the apparent lifetime of the intermediate state.

Combined with the basic two-level Doppler cooling process this allows for reduction of the atomic sample temperature by more than a factor of 10 over a broad frequency range. We present experimental evidence for the two photon cooling process and compared to model calculations [1,3]. Agreement between theory and experiment is excellent. In addition, by properly choosing the Rabi frequencies of the two optical transitions a velocity independent atomic dark state is observed.

Two photon cooling of the calcium system is progressing as well, see talk number 6 Tuesday by Flavio Cruz.

A more sophisticated models based on a full quantum treatment of the atom momentum has been developed by J. Dunn and C. Greene, please see talk number 2 in Wednesday's session.

[1] N. Malossi et, Phys. Rev. A Rapid communication **72** (2005) 051403(R)
[2] W. C. Magno, et al., Phys. Rev. A 67, 043407 (2003)
[3] K. Moldenhauer et al ICAP 2006 Book of abstracts, p.153