COOLING AND TRAPPING LIGHTER ALKALINE-EARTH ELEMENTS AND SPECTROSCOPY IN CALCIUM

Luciano S. Cruz, Silvania A. Carvalho, Giovana T. Nogueira, Luis E. E. de Araujo, Armando Mirage*, Daniel Pereira, and **Flavio C. Cruz**

Instituto de Física Gleb Wataghin, Universidade Estadual de Campinas, CP.6165, Campinas, SP, 13083-970, Brazil

We have been exploring the possibility of further cooling, e.g. beyond the Doppler limit of the $^1S_0$-$^1P_1$ transition of alkaline-Earth atoms (834 μK for Ca), by using bichromatic excitation of 3-level transitions. This is motivated by the need of alternative cooling methods for lighter atoms such as calcium and magnesium, for which cooling with their too narrow intercombination transition is difficult. It has been explored previously, both theoretically [1], [2] and experimentally [3], [4]. A quantum analysis of this cooling mechanism is also presented at this workshop [2]. The dynamics can be interpreted as Doppler cooling in the new dressed state basis. For ladder systems the decoherence of the upper state limits the amount of cooling, but for systems available in alkaline-earth atoms, in which the upper state decay rate γ_2 is smaller than the intermediate state rate γ_1, a temperature reduction by ~ γ_1/γ_2 is possible and can facilitate trapping in optical dipole traps. As a second approach for cooling and trapping, we describe a setup for a deep optical trap/lattice for atoms at miliKelvin temperatures. The two main motivations are: 1) the possibility to trap atoms which have undergone only regular Doppler cooling to a few miliKelvin, such as Ca and Mg, and 2) perform sideband cooling efficiently in a deep potential, using for example the intercombination $^1S_0$-$^3P_1$ transition.

We discuss some spectroscopic results in 3-level ladder systems in calcium. Electromagnetically induced transparency (EIT) has been investigated on the $(4s^2)$ $^1S_0$ - $(4s4p)$ $^1P_1$ - $(4p^2)$ $^1D_2$ (423 nm and 586 nm) calcium ladder system in a homemade hollow-cathode lamp [5]. Transparencies of the probe laser (423 nm) as high as 70% have been obtained either for counter propagating or copropagating beams. We believe that the residual Doppler effect which usually reduces EIT in Doppler broadened media has been greatly reduced by velocity-changing collisions. We have detected the probe laser transmission, fluorescence and in particular the optogalvanic signal. We observed that the optogalvanic signal has opposite polarities for the probe and coupling transitions, and for both transitions it increases under EIT, while fluorescence from the intermediate $^1P_1$ state also decreases.

Finally we mention two implementations of optical frequency combs for use in optical clock research and spectroscopy. One of them uses a homemade Ti:sapphire 750 Mhz femtosecond laser with a spectrum broadened in a microstructure fiber. The other one is a 1 to 2 Ghz Ti:sapphire laser which produces a broadband spectrum from 585 to 1200 nm [6]. Using this laser we are now investigating the possibility of doing broadband direct frequency comb spectroscopy [7] of a plasma containing calcium and krypton, using the high sensitivity optogalvanic detection.

* Instituto de Pesquisas Energeticas e Nucleares – IPEN - São Paulo, Brazil

We acknowledge financial support from the AFOSR and the Brazilian agencies FAPESP, CEPOF, CNPq and CAPES.

References

[1] W. C. Magno, R. L. Cavasso-Filho, and F. C. Cruz, Phys. Rev. A **67**, 043407, (2003).
[2] J. Dunn, talk at this workshop.
[3] N. Malossi, S. Damkjaer, P.L.Hansen, L.B.Jacobsen, L. Kindt, S. Sauge, J. W. Thomsen, F. C. Cruz, M. Allegrini, and E. Arimondo, Phys. Rev. A, **72**, 051403(R) (2005)
[4] J. Thomsen, talk at this workshop.
[5] L. E. E. de Araujo, S. A. de Carvalho, L. S. Cruz, A. Mirage, D. Pereira, F. C. Cruz, to be published.
[6] G. T. Nogueira and F. C. Cruz, Opt. Lett. 31 (2006) 2069-2071.
[7] A. Marian, M. C. Stowe, J. R. Lawall, D. Felinto, and Jun Ye, Science, 306, (2004) 2063.