Loading of an ion trap using resonance-enhanced photo-ionization

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Resonance-enhanced two-photon ionization of atomic beams has been demonstrated to provide an effective tool for loading ions into a trap [1]. The common loading method using electron bombardment is connected with ionization of residual gas atoms and unwanted isotopes in the atomic beam. Furthermore, the atomic element of interest is typically ionized to several charge states. In these respects the resonance-enhanced photo-ionization loading is superior, since it leads to singly charged, nearly isotope pure samples. We have demonstrated the feasibility in the cases of Mg and Ca, but the method should easily be extended to other elements such as, e.g., Sr, Ba, and In.

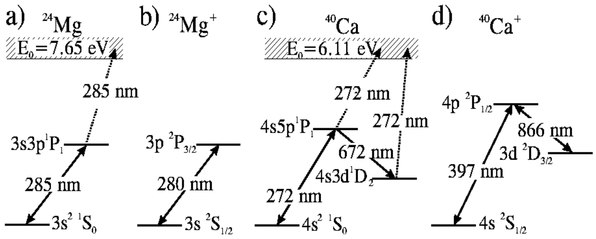

Figure 1: Schematic level schemes for (a) ^{24}Mg, (b) ^{24}Mg$^+$, (c) ^{40}Ca, and (d) ^{40}Ca$^+$ identifying the transitions involved for laser ionization and cooling.

To photo-ionize Mg and Ca we have employed a tunable, narrow-bandwidth continuous wave laser system. The two-photon ionizations proceed from the ground states as shown in Fig. 1a,c. In our experiments, ions are laser cooled during production and confined in a linear Paul trap. Fig. 1b,d show the optical transitions which are driven to cool ^{24}Mg$^+$ and ^{40}Ca$^+$. The laser cooled ions form Coulomb crystals and these are imaged using the induced fluorescence from the cooling lasers. In Fig. 2 we show such an image of a large ^{40}Ca$^+$ crystal. The crystal is very

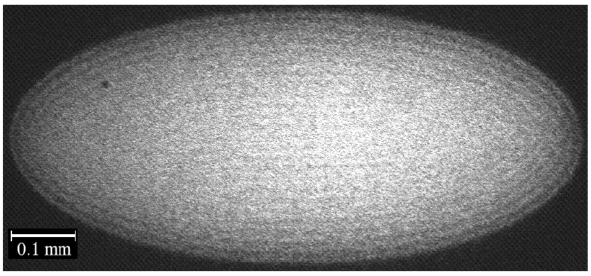

Figure 2: Large ^{40}Ca$^+$ crystal produced by photo-ionization.

isotope-pure since the isotope shift for the resonant transition in the ionization process is much larger than the natural linewidth of the transition and the bandwidth of the ionizing laser. This fact can also be exploited to load isotopes of low natural abundance. In Fig. 3a we show the result of loading with the ionization laser detuned to the transition resonance-enhanced photo-ionization of ^{26}Mg. Loading of the ^{26}Mg$^+$ isotope (natural abundance $\sim$ 10 %) is seen to be far more favorable than in the case of the ^{24}Mg$^+$ isotope (natural abundance $\sim$ 80 %).

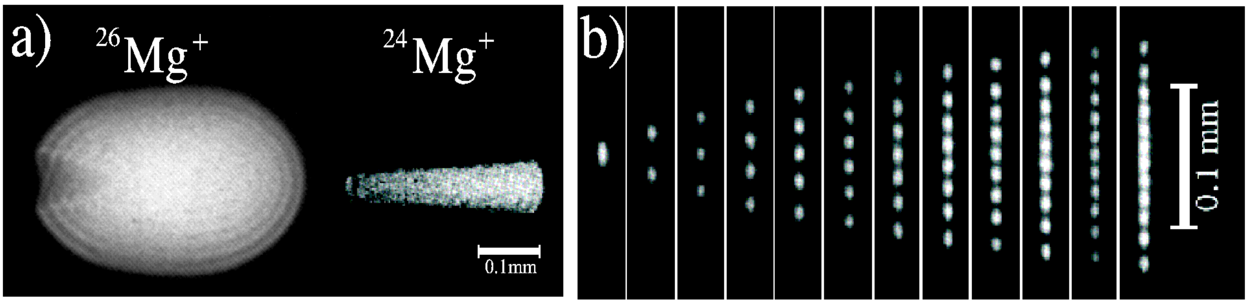

Figure 3: (a) Loading with the ionization laser close to resonance of ^{26}Mg. Left: cooling laser resonant with ^{26}Mg$^+$. Right: cooling laser resonant with^{24}Mg$^+$. (b) Strings of ^{24}Mg$^+$ produced by photo-ionization.

Resonance-enhanced two-photon ionization provides a very controlled way of loading a trap and has played an important role in recent results on the formation of multi-species Coulomb crystals (see the contribution to this conference by M. Drewsen *et al.*). In these experiments one ion species is loaded into a Coulomb crystal of another species, and purity is of highest concern. Furthermore, controllable parameters viz. laser detuning, laser intensity and atomic beam flux opens up the possibility of loading a specific number of a few ions (see Fig. 3b): the production rate is simply kept low and the ionizing beam blocked when the desired number of ions has been trapped. This is of interest in quantum optics experiments (e.g., quantum computation), where the creation of strings containing a specific number of ions is often of special interest [2, 3, 4].

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[1] N. Kjærgaard, L. Hornekær, A.M. Thommesen, Z. Videsen, and M. Drewsen, *Appl. Phys. B*, Accepted for publication.

[2] H.C. Nägerl, W Bechter, J. Eschner, F. Schmidt-Kaler, and R. Blatt *Appl. Phys. B* **66**, 603 (1998).

[3] E. Peik, J. Abel, Th. Becker, J. von Zanthier, H. Walther, Phys. Rev. A **60**, 439 (1999)

[4] C. A. Sackett, D. Kielpinski, B. E. King, C. Langer, V. Meyer, C. J. Myatt, M. Rowe, Q. A. Turchette, W. M. Itano, D. J. Wineland, C. Monroe, *Nature* **404**, 256 (2000).