Electron impact ionization of calcium atoms inside quadrupole trap

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Synopsis We present experimental method for electron impact ionization cross sections of calcium. The technique involves a Paul trap equipped with low energy electron gun. The general assumptions of the method are discussed.

Loading a Paul trap with ions requires application of ionization process of any type. In the case of calcium ions, two photoionization schemes [1, 2] are commonly used. High-energy (keV) electron impact technique was also used before development of the optical methods.

Our experimental results confirmed that the electronic ionization can be relatively easily achieved for energies below 100 eV. The proposed technique provides ion production rate at the level of hundreds of new ions per second.

An efficiency of ionization strictly depends on experimental conditions such as energy and density of the electron beam, atomic beam density and trapping potential parameters. Thus, analysis of the cloud of trapped ions for given conditions delivers information about integral cross sections for electron impact ionization processes.

The ion production rate is given by equation:

$$\dot{N} = \sigma \cdot l \cdot \frac{I}{e} \cdot n, \qquad (1)$$

where σ is integral ionization cross section, l is geometrical parameter (approximately diameter of the trap), I is the effective current of electron beam, n is number density of neutral atoms and e is elementary charge. Thus, by determining number of ions trapped in certain time in well known conditions, ionization cross section can be found. The method can provide experimental data complementing existing data sets obtained with different experimental methods (time of flight [3]), (crossed beam experiment [4, 5]) and theoretical models [6, 7, 8].

In the experiment [9] cross-fired electronic and atomic beams were used. The interaction region was situated in central part of a linear, segmented Paul trap. The ions produced in collisions were captured by the trap's potential and subsequently cooled with Doppler red-shifted optical laser beams of 397 and 866 nm. The presence of the ions was detected by observation of 397 nm fluorescence with a CCD camera. Number of ions in cooled ensemble can be determined by analysis of the image. Geometry of the experiment is presented in Fig. 1.

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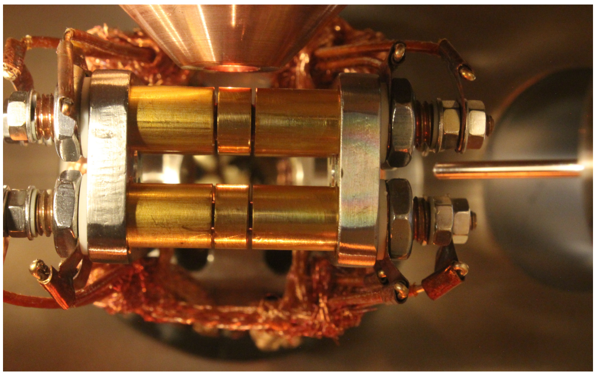

Figure 1. Photograph of the main part of the experimental setup. The linear segmented trap of 30 mm in length and 4 mm gap between electrodes is accompanied by electron gun (top) and the source of atomic beam (on the right, aligned at 45° to the image plane). The laser beams propagate along the trap main axis. The imaging system is aligned perpendicular to the plane of the picture.

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