Observation of String Ion Cloud in a Linear RF Trap

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RF ion trap (Paul trap) is a device which confines charged particles using an rf electric field. The ion cloud confined in the ion trap is characterized by isolation from surrounding environment, very long confinement time, controllability of the number of particles, etc. These features make it possible to cool the confined ions to less than 1 K by applying the laser-cooling technique. The formation of large Coulomb crystals, which contain more than 10^5 laser-cooled Mg^+ ions in a linear rf trap, has been reported [1]. The dynamics of a small number of ions such as the chaos and order transition have been observed using a photon correlation method [2]. Recently, the deformation of the velocity distribution functions of the strongly-correlated system is studied in the field of Tsallis statistics or large-deviation statistics. We are aiming to study the statistical characteristics of strongly-correlated systems by using cooled ions confined in a linear RF trap. For this purpose, we need to know the information of ions in the phase space (v, r). We developed a linear RF trap, a cooling diode-laser and an optical-diagnostic systems. We report here device performances and the preliminary results of cooling experiments.

The linear rf trap is composed of four cylindrical rf electrodes and two dc end-electrodes. The diagonal distance of the surface of the rf electrodes was 8.8 mm, and the diameter of the rf electrodes was 4 mm. Here, we prefer optical accessibility of ion clouds to the ideal quadrupole electric field. Small numbers (< 20) of Ca^+ ions were laser-cooled by using labo-made diode-laser systems. Since the temperature of laser-cooled ions is sensitive to the wavelength of the cooling laser in the vicinity of the resonance wavelength, the stabilization of the laser system is necessary to perform systematic experiments. Here, the short-term fluctuation of the laser wavelength was stabilized by the optical feedback from an external cavity. On the other hand, the long-term drift of the laser wavelength was decreased to several mega hertz or less per 10 minutes by stabilizing the position of fringe of a Fabry-Perot interferometer. The laser-induced fluorescence (LIF) of ion clouds is observed using a photomultiplier tube (PMT) and an intensified charge coupled device (ICCD) camera with an optimized imaging-lens system. In addition to the devices, we are developing a probe-laser system to perform non-destructive Doppler-LIF measurements. The results of the traditional LIF measurements and the probe-laser measurements will be presented at the workshop.

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