Trapping of Multiply Charged Ions

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1. Introduction

Ion traps can confine ions of very low-energy in a small space, and they are useful tools for making precise spectroscopy of ions. A lot of works by storing singly charged ions in ion traps have already been reported[1,2]. In our project spectroscopic investigation of the trapped MCI (multiply charged ions) and a study on one-component cold plasma were undertaken.

Production of the cold MCI is one of the very important factors for efficient trapping. In order to produce very cold MCI, the use of inner-shell photoionization by X-ray followed by multi-Auger processes is known to be the best method[3]. Though the transition wavelength becomes shorter in general as the charge becomes higher, wavelengths of the fine or hyperfine structures of some MCI lie in the accessible region with conventional lasers.

2. Experimental

We constructed an ion trap of rf-type. It was connected to the beamlines of UVSOR of the Institute of Molecular Science and PF of KEK to produce and trap MCI of Xe. In both cases no monochromator was used. The photons passed through the center point of the trap. The ions stored for certain time were pushed down by the pulse voltage applied to the upper endcap of the trap electrodes, and then analyzed through the TOF spectroscopy.

3. Results and Discussions

The results obtained by supplying lower energy photons at UVSOR is shown in Fig.1[4]. Ions up to triply charged state were observed. Figure 2 shows the intensities of Xe^{2+} and Xe^{3+} ions as a function of storage time. Photons were continuously supplied, and ions were extracted after each storage time. That is, the abscissa corresponds to the interval between the

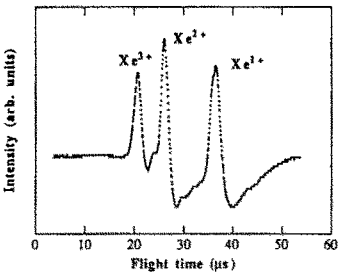

Fig. 1. Time-of-flight spectrum of multiply charged Xe ions extracted from the rf ion trap by using the undulator radiation from BL3A1 of UVSOR

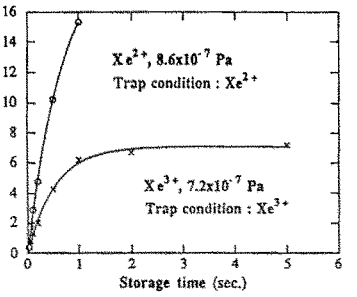

Fig. 2. Time dependence of the storage of Xe^{2+} and Xe^{3+} ions.

application of the extraction pulses. The figure indicates that loss rate for 3+ ions are much larger than 2+ ions, and an equilibrium state is quickly reached for 3+ ions. It means also that 2+ ion has much smaller cross section for charge changing collisions with background gas.

The spectra in Figs. 3 and 4 were obtained at PF. As seen in Fig. 3, we could store only ions with specific charges up to Xe^{7+} by changing the dc voltage applied to the ring electrode of the trap. Depending on the time interval of the extractions, the spectra changed as shown in Fig. 4, where the trapping condition was well tuned for 3+ ion. The signal intensity was determined by the production rate and loss rate. In this case SR photons were continuously supplied. The intensity was observed as a function of time after the turning off of the SR beam as shown in Fig. 5 for Xe^{6+} and Xe^{7+} ions.

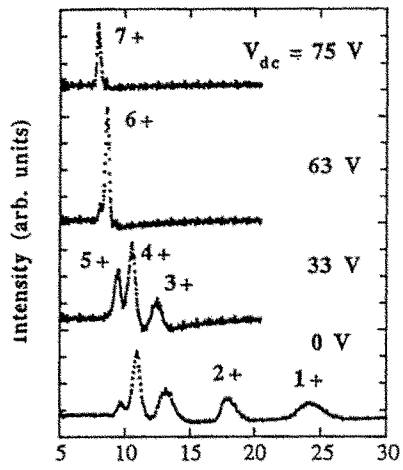

Fig. 3. Time-of-flight spectra of multiply charged Xe ions extracted from the ion trap. By changing the dc voltage applied to the ring electrode, only ions with specific mass-to-charge ratio are selectively stored.

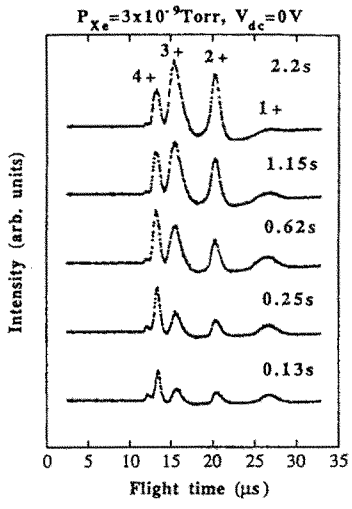

Fig. 4. Time-of-flight spectra of multiply charged Xe ions extracted from the ion trap. Dependence of the quantity of several species of ions on storage time. SR photons were continuously supplied.

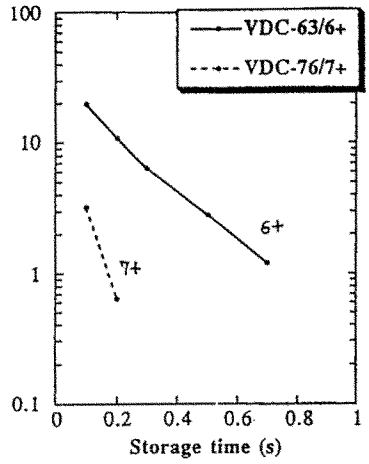

Fig. 5. Decay of Xe^{6+} and Xe^{7+} ions. Ions were extracted after SR beam was turned off

Since very high vacuum is essential for getting long storage time, pulsed gas supply is strongly desirable. At present, however, the pulse performance of target-gas supply was not satisfactory. In the present work, the storage time of ions was not long enough to perform spectroscopic investigations of the MCI. We found that the higher vacuum and improvement of pulsed gas handling were indispensable to increase the storage time.

References

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