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Experiments on ion leakage from BX-U linear trap during potential barrier closure

K. Akaike and H. Himura
Department of Electronics, Kyoto Institute of Technology
e-mail (speaker): akaike16@nuclear.es.kit.ac.jp

A Penning trap have been used for many studies such as quantum computations [1, 2], a measurement of the magnetic moment of the proton [3], and confinements of antimatter particles [4]. In conventional Penning traps, charged particles are radially confined by a uniform magnetic field and axially done by a pair of potential barriers that is set at the both ends of the potential well.

Figure 1 shows a schematic diagram of our experimental setup in the BX-U linear trap [5]. To trap lithium (Li^+) ions in the positive potential well, the upstream potential barrier (ϕ_{iu}) must be reduced down to a finite voltage lower than the acceleration voltage for the Li^+ ions that are launched from the most left-hand side of Fig. 1. Then, ϕ_{iu} quickly restores its original voltage. At this moment, a part of Li^+ ions in the ϕ_{iu} region are accelerated there, and then result in overcoming the downstream potential barrier [6-10]. We clarified the physical mechanism for the observed leakage not only experimentally but also numerically [5].

In our recent paper [5], we revealed the existence of two control parameters that are sensitively related to the amount of the leakage ions. One of those is the voltage increment ($\Delta\phi_{iu}$) when the value of ϕ_{iu} is reduced. The second one is the rise time of ϕ_{iu} (Δt_r). These values play a role also in exciting an axial oscillation of the trapped ions, which causes the intermittent leakage after the first leakage [5]. In this paper, dependences of those parameters on the observed ion leakage are investigated systematically.

In presented experiments, the total amount of leakage ions (N_{leak}) was measured by varying $\Delta\phi_{iu}$ and Δt_r independently. Values of N_{leak} decrease with decreasing $\Delta\phi_{iu}$ and increasing Δt_r. Changes of negative charge induced on two segmented electrodes are measured using current amplifiers, from which f_{aof} can be obtained. Plotted data in Fig. 2 clearly show that f_{aof} of axial oscillation of the trapped ions widely correlates with f_{mlf} that is obtained from the time interval of the intermittent leakage. Figure 2 also shows the dependence of f_{aof} and f_{mlf} on ϕ_{iu}. The solid curve is a theoretical prediction of f_{aof} [11], which strongly indicates that the intermittent leakage is owing to the axial mode excited by increasing ϕ_{iu}, when the positive potential well is completed.

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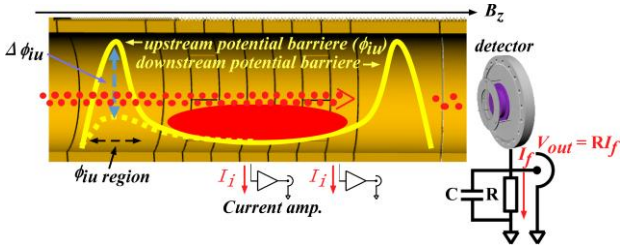

FIG. 1. A schematic of experimental setup.

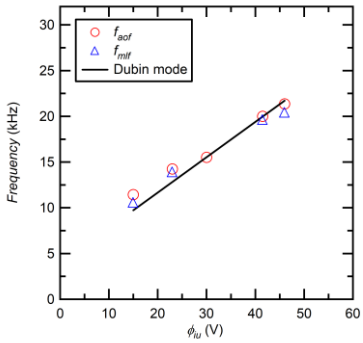

FIG. 2. Dependences of f_{aof} and f_{mlf} on ϕ_{iu}. The solid curve shows the Dubin mode.