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Experimental Study of Two-Fluid Plasma Equilibria Using Nonneutral Plasmas

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Although many macroscopic motions have been explained using the single fluid MHD model, the MHD does not include any characteristic length scale. Thus, such a plasma phenomenon that occurs in a short scale length has been explained by extended MHD models. The two-fluid plasma model is one of them. It includes a characteristic length and permits electrical non-neutrality. However, there is no clear-cut experiment if such a two-fluid plasma state exists. To experimentally investigate that, we produce a two-fluid plasma by superimposing positive and negative non-neutral plasmas in a nested Penning trap of the BX-U linear trap [1].

In experiments, a Li^+ plasma is confined in an outer well of the nested Penning trap, while an e^- plasma is confined in an inner well of it. Figure 1 shows dependences of the number of Li^+ particles on the superimposition time. When the density ratio $f = n_i/n_e$ [2] is less than 0.1 (blue square points in Fig.1), the number of Li^+ dissipates faster. Figure 2 shows end-on images of the superimposed Li^+ and e^- plasmas. The shape of the Li^+ plasma is not circular, while the e^- plasma keeps circular. On the other hand, for the case of $f \approx 0.2$ (yellow triangle points in Fig.1), the Li^+ plasma lasts longer. The confinement time, which is defined as the $1/e$ folding time, is approximately 300 us. Meanwhile, the e^- plasma is robust. Although data taken from different values of f are analyzed now, they suggest the existence of some equilibrium state despite of the charge non-neutrality. Such a state is not clearly observed for the case where the rotation axes of the e^- and the Li^+ plasmas are not coincided each other. As recognized from Fig. 2(c), the confinement time of the Li^+ plasma is the order of 10 us even in the case of $f \approx 0.1$.

Other experiments in which the e^- plasma is placed in the outer well of the nested Penning trap show that both e^- and Li^+ plasmas' confinement time is longer than 10 ms in the case of $0.1 < f < 100$.

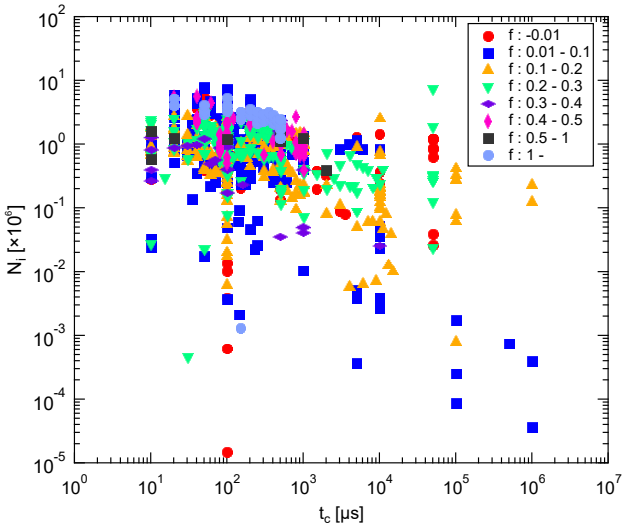

Figure 1. Dependences of the number of Li^+ ions on the superimposition time together with e^- plasmas. Symbols of each plot correspond to the value of f.

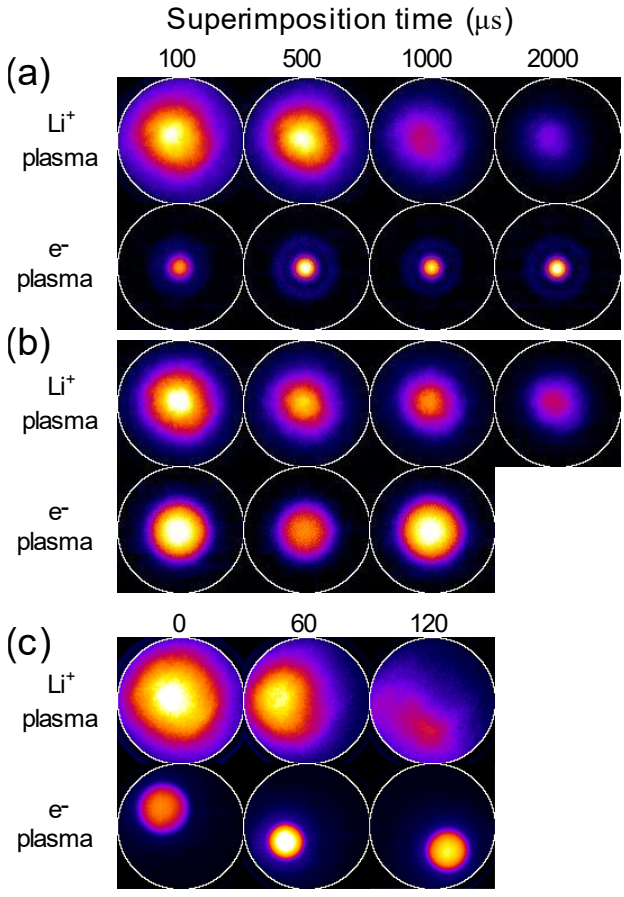

Figure 2. End-on images of superimposed e^- and Li^+ plasmas when f is (a) 0.009, (b) 0.2. In both cases, two nonneutral plasmas are coaxial. Images of (c) show the case where two nonneutral plasmas are not coaxial. White circles indicate the boundaries of the observation area.

References

[1] H. Himura, *Nucl. Instrum. Methods Phys. Res., Sect. A* 811, 100 (2016).
[2] R. C. Davidson (2001). *Physics of nonneutral plasmas.*