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Experimental exploration of two-fluid plasmas by use of non-neutral plasmas

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The extended magnetohydrodynamics (MHD) model, especially the two-fluid plasma state, is a challenging subject in experimental plasma physics. Unlike an MHD plasma, two- fluid plasma allows ion and electron (e^-) fluids to move independently. This plasma model has been proposed in both theoretical and computational plasma physics to explain observations such as high-β equilibrium and magnetic reconnections. However, no direct experiments focusing on the two-fluid plasma state have been conducted, although some researchers have discussed it. This lack of study is mainly due to the experimental difficulty of probing the short-scale length of the ion skin depth λ_i where the two-fluid plasma state or the two-fluid effect is expected to appear. However, λ_i can be far longer in non-neutral plasmas, because of the relatively low ion density. Because of this and other benefits of using non-neutral plasmas, we proposed a new experiment and developed a linear machine called the BX-U.

The BX-U linear trap that is a modified version of the Penning-Malmberg trap was recently completed wherein both positive and negative harmonic potential wells were created by using a set of multi ring electrodes. In the BX-U machine, pure lithium (Li^+) and e^- plasmas are not only produced independently but also trapped simultaneously. Confinement properties of those non-neutral plasmas were investigated experimentally. In particular, weakly magnetized Li^+ plasmas were extensively studied also numerically. Regarding diagnostic tools, we investigated, for the first time, the applicability of a micro-channel plate (MCP) followed by a phosphor screen to charged particles along with a calibration method for estimating the acceptable limit of input particle flux and appropriate operation parameters of a particular MCP. To capture of images of Li^+ and e^- plasmas in one attempt, we developed a new innovative method of changing the axial potential applied to the MCP using a high-voltage vacuum relay. This method allows consecutive images of Li^+ and e^- plasmas to be successfully captured.

Then, using the high-voltage vacuum relay, we are now capturing the two images of Li^+ ion and e^- fluids before and after the superimposition. The scale length of the Li^+ plasma is set to be the ion skin depth. Figure 1 shows a preliminary result. When an e^- plasma is superimposed on a Li^+ plasma and then, only the Li^+ plasma is ejected from the trap, there appears a sharp peak of ion density at the plasma center. Perhaps this result may be due to some two-fluid effect, although more data are required to conclude it confidently.

In this meeting, we present our recent efforts along with detailed description of the BX-U for experimentally exploring two-fluid plasmas, for the first time, by using non-neutral plasmas.

References

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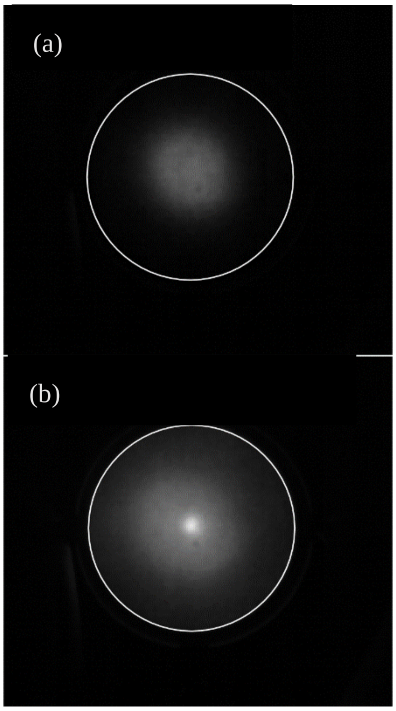

Figure 1 A typical images of Li^+ ion fluids (a) before and (b) after superimposition of Li^+ ion and e^- plasmas.