Investigation of counter-differential rigid-rotation equilibria of electrically non-neutral two-fluid plasma

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In current and enthusiastic efforts to verify two-fluid effects in plasmas or to create electron–positron pair plasma, the quasi-neutrality is not necessarily required, since they separately produce the electron (e^-) and ion (i^+) plasmas initially. Previously we predicted the counter-differential rigid-rotation equilibria[1] of electrically non-neutral two-fluid plasma with finite pressure. Theoretically, i^+ and e^- plasmas, which are confined in a single trap with a uniform magnetic field $\boldsymbol{B}$, exhibit corresponding rigid-rotations around the machine axis with different angular velocities ω_i and ω_e. If the ion and e^- plasma is cold, the pressures are negligible, and so the rotation is simply $\boldsymbol{E}\times\boldsymbol{B}$ drift driven by the $\boldsymbol{B}$ and the self-electronic field $\boldsymbol{E}$ produced by the difference between the uniform density $n_{i,e}$ of i^+ and e^- plasmas. Considering the $\boldsymbol{E}\times\boldsymbol{B}$ drift, it is consistent that the i^+ and e^- plasma rotate in same direction. With finite pressure, in contrast to the cold plasma, the diamagnetic drifts become dominant and the e^- and i^+ plasmas rotate in counter directions to each other. However, the stability of the equilibrium has not been examined, and also experimentally, the existence of such equilibria have not been demonstrated.

In my presentation, typical results of PIC simulation with the counter-differential rigid-rotation equilibria as the initial condition and a scheme of its experimental verification in the BX-U liner trap are presented. Figure 1 shows one of the results of the time evolution of particle profiles of lithium ion (Li^+) and e^- plasma. According to the results, most of the instabilities are m=4 instabilities, while results that seems to be stable in some parameter ranges are obtained.

To experimentally investigate the equilibria, we started to measure rotations of i^+ and e^- plasmas by using a wire that makes a kerf in the plasma that arrives at a micro-channel plate (MCP) with a phosphor screen along the magnetic field lines[2]. At this moment, the rotation angle of the kerf is measured (see Figure 2). Preliminary data show that the rotation angle agrees with the estimated value based on the theory of the two-dimensional equilibria of non-neutral two-fluid plasmas, rather than the magnetron motion of a single ion confined in a Penning trap.

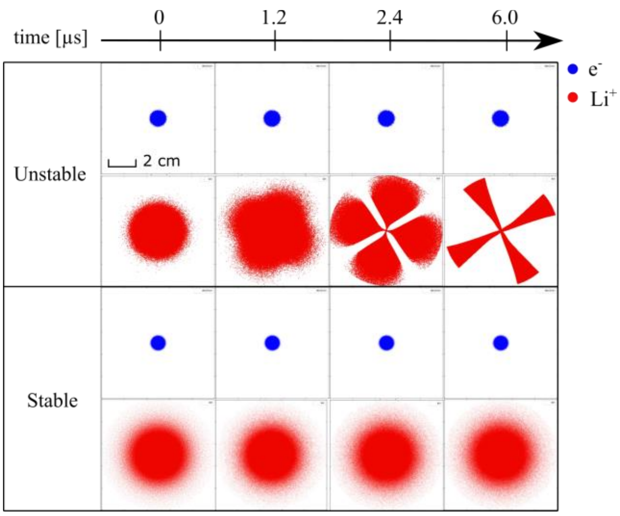

Figure 1. Time evolution of particle profiles of Li^+ and e^- plasma calculated by the PIC code with the counter-differential rigid-rotation equilibria as the initial condition.

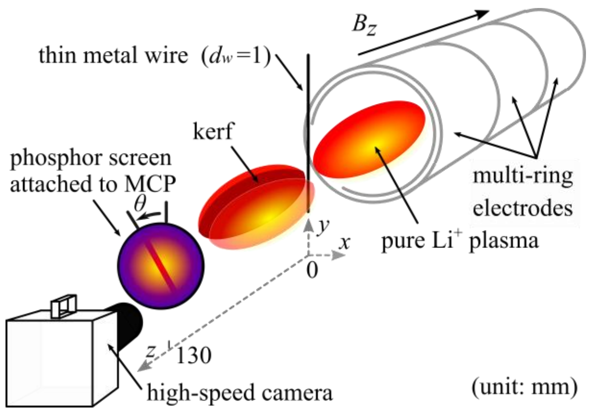

Figure 2. Schematic of the experimental setup using the BX-U linear trap[2]. The wire makes a kerf in the plasma. Then, the rotation angle of the kerf is measured by the MCP plate with a phosphor screen.

References
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[2] Y. Nakajima, H. Himura, T. Okada, AIP Advances **12** (4), 045015 (2022)