Effect of ion mass on ExB Electron Drift Instability by 2D PIC simulation

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Operating a Hall thruster at Very Low Earth Orbit (VLEO) with Air-Breathing Propulsion system requires the light-mass ion propellant to achieve the long-duration missions. However, the thruster model and the operation range reliability due to the anomalous transport have not yet been established and understood. One of the important plasma instability phenomena that plays the major role to develop the anomalous transport of the electron is ExB electron drift instability (ExB EDI). The EDI is the wavy plasma correlations formed in the azimuthal direction and is said to be developed from the Bernstein mode which is the high order of electron cyclotron rotation. It has been studied for several decades to reveal the detail mechanism of the instability growth and to establish the model of the effect of this azimuthal correlated instability on the electron anomalous transport.

Boeuf et al. proposed a computational benchmark model to reproduce the azimuthal ExB EDI plasmas for xenon [1]. Several groups took the verification of this benchmark code developed individually and shows the high accuracy [2]. From our previous research, the difference of the 2D wave structure between xenon and atomic oxygen. In this study, we focus on the effect of the in the wave structure of ExB EDI with atomic oxygen propellant, which is lighter-mass ion than xenon, and investigate its effect on the axial transport by performing collisionless 2D3V full-Particle-In-Cell (PIC) simulations.

The computational model was adopted from the benchmark 2D (axial-azimuthal) PIC model. The radial magnetic density distribution and particle generation function due to the ionization were given mathematically in the axial direction. The maximum radial magnetic field is 10 mT at the channel exit (x=0.75 cm). To reduce the time required to reach a quasi-steady state and maintain the neutralization, electron injects from the cathode line at the downstream. The number of electron injected was determined by the current density converged to 400 A/m^2 for xenon and 1061 A/m^2 for atomic oxygen.

Fig. 1 shows the 2D distribution of the azimuthal electric field the wave dispersion relationships at x=0.75 cm and 2.0 cm for xenon and atomic oxygen. It can be seen that the wavy structure is significantly different for atomic oxygen and xenon. By observing the propagation of the wave, we can see that the azimuthal wave with a wavelength of 800 μm was observed, as in previous studies with xenon. On the other hand, a wavelength of 1000 μm was observed in the same propagation direction for atomic oxygen.

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References

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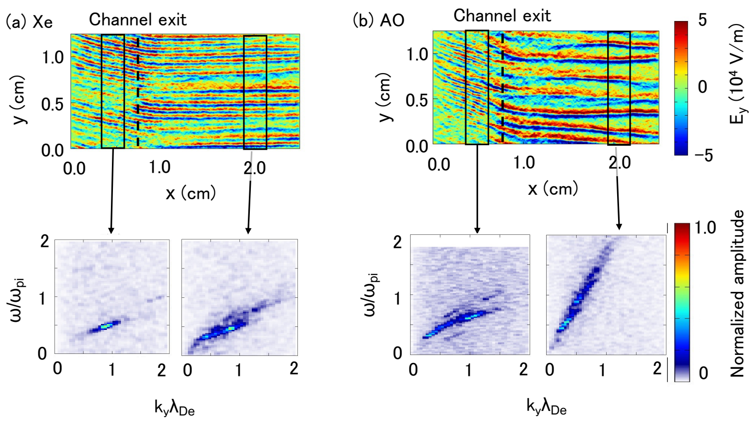

Fig. 1 2D azimuthal electric field distribution and wave dispersion relationships at x = 0.75 cm and x = 2.0 cm at 17.5 μs.