GEC18-2018-000513

Abstract for an Invited Paper
for the GEC18 Meeting of
the American Physical Society

Quasineutral plasma modeling of low-frequency oscillations in cross-field discharge plasmas: breathing mode and rotating spokes

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Two types of low-frequency plasma oscillations that occur in cross-field discharge plasmas are presented. One is the breathing mode that is a discharge oscillation in the 10-30 kHz due to the interplay between ion acceleration and ionization. The other is azimuthally rotating spokes, self-organizing coherent structures that occur in the direction of the ExB drift of a cross-field discharge, such as Hall effect thrusters (HETs) and magnetron discharges. As much as a high-fidelity kinetic model is needed to understand the physics of such cross-field plasmas, a fluid type solver, particularly for electrons, is computationally inexpensive and useful for validation, namely, modeling low-frequency plasma oscillations that can be directly compared with experimental data. Fluid and hybrid fluid-kinetic models of cross-field discharge plasmas, assuming a quasineutral plasma and a drift-diffusion flux for electrons, are developed. First, numerical noise induced by nonlinear coupling due to the quasineutral assumption is reviewed and the development of an electron-pressure coupling method is discussed. Next, 1D axial simulations and perturbation theory of the HET discharge plasma are shown. The results indicate that electron transport and electron heat transfer play an important role in the excitation and damping of the ionization oscillations. Finally, stably propagating rotating spokes are simulated using a 2D axial-azimuthal hybrid simulation. It is suggested from the numerical results that the gradient drift instability downstream initiates an azimuthal nonuniformity, leading to low-frequency ionization oscillations in the azimuthal direction.