Models for modulated rotation of a Penning-trapped magnetized electron vortex in a variable-charge regime

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We routinely confine and study electron plasmas in a Penning-Malmberg trap generated by means of a quite unconventional production scheme, i.e. using a low-amplitude radio-frequency (RF) drive on one of the trap electrodes [1, 2]. This weak RF drive can effectively heat up the few free electrons in the residual gas - at pressures in the high to ultra-high vacuum regime - and initiate a discharge and accumulation of an electron plasma. Interesting stationary states are reached within some seconds. A peculiar example is the creation of a single column (vortex) of electrons displaying a radial displacement with respect to the longitudinal symmetry axis and thus rotating around it. Total charge and density profile show very robust stability to perturbations and usual instabilities, e.g., ion-induced instability and the relevant loss of confinement, as long as the ionizing drive is maintained. Even more peculiar is the occurrence of stable low-frequency ($\sim$ 1 Hz) oscillations of both charge and radial offset in these rotating vortices [3, 4]. In this contribution, we discuss the interpretation of these oscillations. We start from a simple predator-prey scheme for the electron charge and displacement, where we plug in realistic parameters extracted from experiments, and address the complicated roles of the ionizing RF drive and of the other species present in the trap during the formation process. We notice that an oscillating behaviour of the system variables is observed in a number of other multispecies plasma environments, such as the breathing oscillations seen in Hall thrusters. We show that, although the complete dynamics is highly complicated and spans a range of time scales from microseconds to seconds, we can reproduce to a quantitative level the main features observed in the experiments.

References

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