Experimental and Theoretical Studies of Electrostatic Confinement on the INS-e Device

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Abstract

Theoretical studies[1,2] have suggested that a tiny oscillating ion cloud immersed in a uniform electron background may undergo a self-similar collapse that can result in the periodic and simultaneous attainment of ultra-high densities and temperatures. The oscillating ion cloud (referred to as the Periodically Oscillating Plasma Sphere or POPS) is in local thermodynamic equilibrium at all times independent of the collisionality of the plasma (i.e. these self-similar solutions are exact solutions of the Vlasov equation). POPS is stable to multidimensional perturbations, while its self-similar solutions appear to be attractors.[3] Theoretical projections have indicated that such a system may have net fusion gain even for an advanced fuel such as D-D. In addition, these systems have very favorable reactor attributes in that the total power scales inversely with the size, leading naturally to a modular, high mass power density device.

However, there are several issues that need to be resolved in order to determine the efficacy of this scheme. In particular, POPS requires a quiet virtual cathode with a harmonic potential well, which calls for control of the plasma density profile and its stability. A deep, steady-state potential well has been created in our electrostatic device without any apparent sign of instability.[4] It has also been shown that the radial electron density profile can be varied to produce a desired near-uniform density by adjusting the bias voltages of the grids. Virtual cathode well depths as deep as 60% of the applied voltage have been achieved experimentally, exceeding the theoretically predicted stability limits[5] by a factor of 4. In order to understand this discrepancy, new theoretical work has been undertaken using the ENNF code, a 1-D gridless PIC simulation code. Results indicate that in spherical geometry the two-stream stability limit allows virtual cathodes with well depths close to 100% of the applied voltage.

We are also using the code to do fully kinetic (ions and electrons) studies of POPS in order to study space charge effects during the ion collapse phase. An analytic formalism has shown that it is possible to program the distribution function of the injected electrons to completely mitigate space charge effects during the ion cloud collapse. If this can be achieved, the required compression rations for POPS can be drastically reduced. These results are presently being tested with the simulations.

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Oral talk requested