Multi-modal oscillations in a spherical positive polarity inertial-electrostatic confinement device

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A pulsed, positive-polarity gridded inertial electrostatic confinement device is being investigated experimentally, primarily using a single Langmuir probe and some preliminary optical diagnostics. Large amplitude oscillations are observed in the anode voltage and current, as well as the probe current. An emergent tri-modality in the character of the oscillations has been observed, which is highly sensitive to chamber pressure and peak anode voltage. The canonical oscillatory mode as observed by Tuft (Physics of Plasmas, 17, 2010) is most sensitive and is stochastically subject to minor fluctuations in seemingly invariant experimental parameters, as localised discharges or arc spots induce the more dominant oscillatory modes. This mode features a prominent potential well, which is observed as a sharp, radially dependent fluctuation in the floating potential.

It has been found that the induction of this oscillatory mode is sensitive to the value of a series ballast resistor, whose function is to facilitate the initial application of a high voltage to induce breakdown, and to dynamically limit the current supplied to the plasma by allowing the anode voltage to sag during the low impedance regime of the discharge transient.

A preliminary analysis yields the hypothesis that the canonical oscillatory mode is the result of coherent ion oscillations within a harmonic potential well formed by a region of uniform negative space charge within the centre of the device.

The induction of the second and third oscillatory modes is likely to involve an asymmetric point convergence of electrons and subsequent ion oscillations. This hypothesis is confirmed by the inference of the formation of a stronger virtual cathode (as observed by a higher oscillatory frequency), an inability to measure any strong potential well within the anode area, a non uniform spatially resolved optical intensity profile, a weaker susceptibility to a perturbing magnetic field, and most importantly, the presence of these oscillatory modes when a solid spherical anode is used in place of the gridded anode. We propose that these oscillatory modes are those associated with the discharge phenomenon commonly referred to as the "fireball" (R. Stenzel, Plasma Sci & Tech, 2008)

A thorough study of these oscillatory phenomena is pending the development of an accurate transient Langmuir probe theory and subsequent data analysis, as well as the implementation of fast optical instruments to collect spatially resolved intensity and wavelength data to infer time resolved ion energies and rough density distributions. The influence of an electron gun facilitating the formation of a non neutral plasma is also being investigated, as it is expected that this line of research will yield some convergence with the POPS project. (J. Park, Phys Rev Letters, 95, 2005)