Abstract

Well-confined non-neutral plasma equilibria have been observed in cylindrical traps. These equilibria are believed to be connected to in-variants that exist for such systems. Toroidal traps lack such in-variants and their equilibrium, stability and confinement properties are unknown and therefore of considerable interest.

To this end, a trap to confine electron plasmas has been created in a low aspect-ratio (≈ 1.6) toroidal device. It employs electrostatic fields to trap the electrons along the toroidal direction while a pulsed toroidal magnetic field achieves the radial confinement. The trap therefore is similar to a cylindrical trap but retains the toroidal features, namely the single particle drifts. Electrons after being injected from a thermionic source are seen to remain confined over several hundred rotations of the plasma. The lifetime increased from $100\mu s$ to over $1ms$ as pressures were brought below $< 10^{-8}$ torr. This further improved to ~ 4 ms on removing various asymmetries in the system. These confinement periods are longer than the single-particle drifts and also longer than any reported observation so far in a tight aspect ratio trap in the absence of any feedback or external fields.

Also observed for the first time is an unstable flute mode, hitherto observed in cylindrical devices (diocotron modes). The mode is seen to have strong toroidal signatures with two alternating cycles in a single poloidal drift. A change in aspect ratio is seen to reduce the toroidal effects on the mode. The frequency, initially around 100KHz (at 200G) has a strong shear; it reduces as the mode evolves, but later increases before it falls off as the mode dies. The mode is extremely nonlinear with highly phase coherent harmonics. Absence of any power-law tail suggest absence of any turbulence. Analysis of the mode structure suggests the, presence of a coherent, convective, toroidal vortex, drifting $E \times B$.

The evolution of this vortex has been investigated in great detail, including the role of ions, resistive wall etc. The birth of the vortex is sensitive to initial conditions such as the Pressure, Magnetic field etc. Mode born at different initial conditions evolve to attain the same saturation amplitude per unit magnetic field; this corresponds to a critical charge content of the vortex (per unit magnetic field (Q/B)). Thereafter, the mode clamps itself to the magnetic field and decay is regulated only by dB/dt. Finally, at a certain point of time in its evolution it detaches itself from the magnetic field and decays self-consistently, in a collisional manner. In the absence of any theoretical model for such a trapped plasma in a tight-aspect -ratio toroidal geometry, exhaustive experimental studies were undertaken by varying different parameters in a controlled manner. All of these results merge to suggest a very consistent set of scaling laws.

All of the above investigations were aided by developing several diagnostics and/or models for their interpretation, consistent with the complexities of the trap and the plasma. Charge collectors and capacitive probes have been the mainstay of our experiments. The charge collector was redesigned to deal with several problems intrinsic to charge measurements in such plasmas in low-aspect ratio traps. It is particularly designed to carry out charge estimations of few nanocoulombs in

the presence of a strong displacement current. A model has also been proposed to appropriately interpret the wall probe measurements and compute charge out of it.

All of these results have been presented and discussed in detail in the thesis.