THEORETICAL STUDIES OF
PURE ELECTRON PLASMAS
IN ASYMMETRIC TRAPS

by

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ABSTRACT

Pure electron plasmas are routinely confined within cylindrically symmetric Penning traps by static electric and magnetic fields. However, the azimuthal symmetry can be broken by applied perturbations. In this thesis, the static and dynamic properties of plasmas confined in traps with such applied electric field asymmetries are investigated. The shapes of the non-circular plasma equilibria are studied both analytically and numerically. A simple analytic model for the boundary of a uniform density asymmetric plasma is derived, and it agrees well with vortex-in-cell simulations. Both the analytical results and numerical simulations agree with the shapes observed in experiments. Furthermore, an energy principle is used to prove that these asymmetric plasmas are stable to $E \times B$ drift perturbations, when the asymmetries are small. For an $\ell = 1$ diocotron mode in a cylindrically symmetric trap, the plasma rotates as a rigid column in a circular orbit. In contrast, plasmas in systems with electric field asymmetries are shown to have an analog to the $\ell = 1$ mode in which the shape of the plasma changes as it rotates in a non-circular orbit. These bulk plasma features are studied with a Hamiltonian model, in which elliptical plasma shapes are
assumed. Equations for the motion of the center of the plasma, its ellipticity, and its orientation are derived. It is seen that, for a small plasma, the evolution of the plasma shape and orientation has little effect on the center of charge motion, and the area enclosed by the center of charge orbit is an invariant when electric field perturbations are applied adiabatically. This invariant has been observed experimentally. Detailed studies are made of the breaking of the invariant when perturbations are rapidly applied. The dynamic Hamiltonian model is also used to predict the shape and frequency of the large amplitude $\ell = 1$ and $\ell = 2$ diocotron modes in symmetric traps, and good agreement with experimental results is obtained.

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