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Experimental Realization of Nearly Steady-State Toroidal Electron Plasmas[1]

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Non-neutral plasmas are routinely confined in the uniform magnetic field of a Penning-Malmberg trap for arbitrarily long times and approach thermal equilibrium. Theory predicts that dynamically stable and therefore long-lived equilibria exist for non-neutral plasmas confined in the curved, non-uniform field of a *toroidal* trap, but that ultimately thermal equilibrium states do not exist. On long timescales, the poloidal $\mathbf{E}\times\mathbf{B}$ rotation through the non-uniform toroidal magnetic field leads to magnetic pumping transport. A new experiment has, for the first time, demonstrated the existence of a stable, long-lived (*i.e.* nearly steady-state) toroidal equilibrium for pure electron plasmas and is poised to observe the magnetic pumping transport mechanism.[2] Electron plasmas with densities of order 10^6 cm^{-3} are trapped in the Lawrence Non-neutral Torus II for several seconds. LNT II is a high aspect ratio ($R_o/a \approx 10$), partially toroidal trap (a 270° arc with $B_o = 670$ G). The $m = 1$ diocotron mode is launched and detected using isolated segments of a fully-sectored conducting boundary and its frequency is used to determine the total trapped charge as a function of time. The observed confinement time (≈ 3 s) approaches the theoretical limit (≈ 6 s) set by the magnetic pumping transport mechanism of Crooks and O'Neil.[3] We also present equilibrium modeling and numerical simulation of the toroidal $m = 1$ mode constrained by experimental data. Future work includes the identification of the dominant transport mechanisms via confinement scaling experiments and measurement of the $m = 2$ mode frequency, and development of a strategy for making a transition to fully toroidal confinement.

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[2]J.P. Marler and M.R. Stoneking, Phys. Rev. Lett. **100**, 155001 (2008).
[3]S.M. Crooks and T.M. O'Neil, Phys Plamas **3**, 2533 (1996).