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New Results for Understanding Confined Plasma using the Laboratory Magnetosphere

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During the past decade, experiments and simulations have characterized a new regime of high-beta toroidal plasma confinement using unique facilities, called laboratory magnetospheres [1]. In a laboratory magnetosphere, a large plasma is confined by a relatively small, magnetically levitated, superconducting current ring. Complex nonlinear processes, including the inverse cascade of turbulent fluctuations and turbulent self-organization, are studied and controlled in near steady-state conditions. Because a dipole's magnetic field lines resemble the inner regions of planetary magnetospheres, these studies link laboratory and space plasma physics. However, unlike planetary magnetospheres, the magnetic field lines from a levitated dipole are axisymmetric and closed, imparting unique properties to the laboratory magnetosphere. A levitated dipole confines high-pressure plasma without field-aligned or neoclassical currents, even when plasma pressure exceeds the local magnetic pressure ($\beta > 1$). Particle drifts are omnigeneous, and the dynamics of passing and trapped particles are similar. Because parallel currents can be a source for instability, many well-known low-frequency instabilities found in other toroidal configurations, like kink, tearing, ballooning, and drift modes, are not found in a dipole plasma torus. Instead, interchange and entropy modes, which resonate with bounce-averaged toroidal particle drifts, dominate plasma dynamics.

This talk focuses on new measurements of the turbulent evolution of the plasma density profile following the fast injection of lithium pellets into the Levitated Dipole Experiment (LDX) [2]. As the pellet passes through the plasma, it provides a significant internal particle source and allows investigation of density profile evolution, turbulent relaxation, and turbulent fluctuations. The total electron number within the dipole plasma torus increases by more than a factor of three, and the central density increases by more than a factor of five. During these large changes in density, the shape of density profile is nearly "stationary" such that the gradient of the particle number within tubes of equal magnetic flux vanishes. In comparison to the usual case, when the particle source is neutral gas at the plasma edge, the internal source from the pellet causes the toroidal phase velocity of the fluctuations to reverse and changes the average particle flux at the plasma edge. An edge particle source creates an inward turbulent pinch, but an internal particle source increases the outward turbulent particle flux. Statistical properties of the turbulence are measured by multiple microwave interferometers and by an array of probes at the edge. The spatial structures of the largest amplitude modes have long radial and toroidal wavelengths. Estimates of the local and toroidally averaged turbulent particle flux show intermittency and a non-Gaussian probability distribution function. The measured fluctuations, both before and during pellet injection, have frequency and wavenumber dispersion consistent with theoretical expectations for interchange and entropy modes excited within a dipole plasma torus having warm electrons and cool ions.

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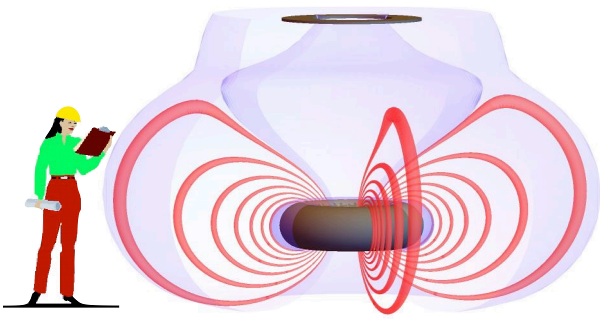

Figure 1. Illustration of the magnetic geometry of the Levitated Dipole Experiment (LDX) used to explore high-temperature plasma confinement by the magnetic field of a superconducting ring.