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Laboratory Dipole Plasma Physics[1]

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Modern laboratory studies of plasma confined by a strong dipole magnet originated twenty years ago when it was learned that planetary magnetospheres have centrally-peaked plasma pressure profiles that form naturally when solar wind drives plasma circulation and heating. Unlike other internal rings devices, like spherators and octupoles, the magnetic flux tubes of the dipole field expand rapidly with radius. Unlike plasma confinement devices that obtain stability from magnetic shear and average good curvature, like tokamaks and levitrons, the dipole-confined plasma obtains stability from plasma compressibility. These two geometric characteristics of the dipole field have profound consequences: (i) plasma can be stable with local beta exceeding unity, (ii) fluctuations can drive either heat or particles inward to create stationary profiles that are strongly peaked, and (iii) the confinement of particles and energy can decouple. During the past decade, several laboratory dipole experiments and modeling efforts have lead to new understanding of interchange, centrifugal and entropy modes, nonlinear gyrokinetics, and plasma transport. Two devices, the LDX experiment at MIT and RT-1 at the University of Tokyo, operate with levitated superconducting dipole magnets. With a levitated dipole, not only is very high-beta plasma confined in steady state but, also, levitation produces high-temperature at low input power and demonstrates that toroidal magnetic confinement of plasma does not require a toroidal field. Modeling has explained many of the processes operative in these experiments, including the observation of a strong inward particle pinch. Turbulent low-frequency fluctuations in dipole confined plasma cause adiabatic transport and form a fundamental linkage between the radial variation of flux-tube volume and the centrally peaked density and pressure profiles.

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