We report the first production of high beta plasma confined in a fully levitated laboratory dipole using neutral gas fueling and electron cyclotron resonance heating. The pressure results primarily from a population of energetic trapped electrons that is sustained for many seconds of microwave heating provided sufficient neutral gas is supplied to the plasma. As compared to previous studies in which the internal coil was supported, levitation results in improved particle confinement that allows higher-density, high-beta discharges to be maintained at significantly reduced gas fueling. Elimination of parallel losses coupled with reduced gas fueling to improved energy confinement and a dramatic change in the density profile. Improved particle confinement assures stability of the hot electron component at reduced pressure. By eliminating supports used in previous studies, cross-field transport becomes the main loss channel for both supported and levitated discharges.

**Abstract**

**Levitated Dipole Experiment (LDX)**

- **1.5 MA Floating dipole coil**
  - Nb3Sn superconductor
  - Inductively charged by 16 kV charging cord
  - Up to 4 hour levitation using active feedback on upper levitator coil
- Two component plasma created by multiple frequency (ECRH): 2.5 kV, 2.4 GHz
  - 150 MW, 6.4 GHz
  - 165 MW, 10.5 GHz

**Plasma Diagnostic Set**

- Magnetic equilibrium
  - Balloons, Dp coils, Hall effect sensors, levitation system tracings
- Fast electrons
  - 4 Channel LPHX, x-ray detector, 137 GHz radiometer
- Core parameters
  - Interferometer, visible camera, visible data, and array, survey spectrometer
- Fluctuations
  - Edge Lp, Lp, x, probes, Mirnov coils, visible dipole arrays, interferometer, fast visible camera, floating probe array
- Edge parameters
  - swept and MHz probes

**Typical Supported Mode Shot**

**Uncommon Plasma Topology**

- No magnetic shear
- Cold connection lines are possible
- Non-linear evolution of interchange may lead to
- Oscillations exist of interchange line instabilities
- Near marginal stability
  - connection lines do not necessarily transport energy

**Possible Fusion Power Application**

- **Internal ring**
- **Steady state**
- **Non-interlocking coils**
- **Good field utilization**
- **Possibility for r > r**
- **Advanced fuel cycle**

**Levitation System**

- 450 A / 10 V power supply
- Resistor coil allows for rapid shutdown
- Digital logic control computer
- Four independent control methods
  - Elher-Becker D-8101
  - Tore Supra model
  - Programmable logic controller
  - Interchange system
- Double-acting fast shutdown
  - 0.02 s
  - Full fast control under development
- Laser interferometer
  - Interchange system

**Hot Electron Interchange (HEI)**

- With supports, high fueling needed for scalable HEI, increase density, and increase beta
- Once discharges were shown needed to maintain stability
- ECRH power required per flux tube
- Consistently with theory showing background density stabilizing lower m=1, n=1

**Linear Diamagnetic Flux**

- Neutral pressure for different beta
- Steady state central chordal diamagnetic flux density measured versus neutral pressure for different conditions.
- The effect of levitation for maximum pressures with 5 kW of input ECRH is shown as increased density by a factor of 4x. Also depicted are significant power and species dependencies at high neutral pressure.

**Investigating Radial Transport and Turbulence**

- With levitation, observed density profile is dominated by radial transport
- Interchange mixing likely cause of profiles with near constant density per flux tube
- We observe low frequency oscillations, both broadband and quasi-
  - coherent that may be representative of interchange mixing
- Ongoing examination of relationship of observed turbulence with changes in plasma profiles as well as the effect of plasma turbulence on the plasma profiles.

**Confinement Improves with Levitation**

- Similar shots
  - With (solid) and without (dashed) levitation
  - Similar gas fueling
  - 3 x density
  - much more peaked profile with levitation
  - 2 x stored energy

**Comparison of the density profile for supported and levitated plasma under similar**

- **Conditions with 15 kW of ECRH**
- The levitated case has a single peaked profile with near constant number of particles per flux tube.

**Deviation parameter (A) from constant number of particles per flux tube profile**

- Levitated plasmas with multi-source ECRH and sufficient neutral fueling exhibit density profiles close to the interchange stationary profile.

**Plots of edge floating probe arrays, showing quasi-coherent structure of edge turbulence.**

- Diamagnetic flux density measured versus radial probe locations, rotating in the edge diamagnetic 4 GHz drive.

- Correlation weighted histograms of phase relationship between floating probe arrays during steady phase of edge radial scrape-off layer at edge radial scrape-off layer.

- Same quasi-coherent 4 GHz mode is observed.