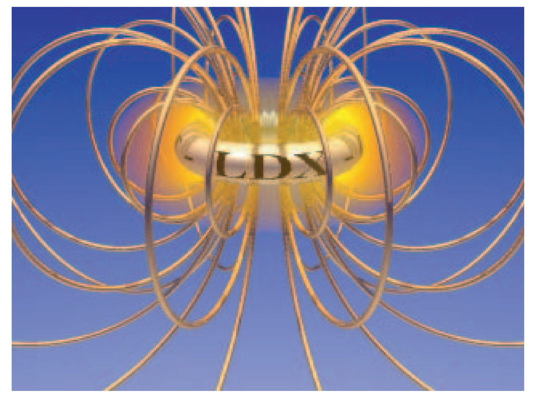
Employment of Multiple Frequencies of Electron Cyclotron Resonance Heating on the Levitated Dipole Experiment



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ABSTRACT

During the initial plasma experiments in the Levitated Dipole Experiment (LDX), the dipole field coil is to be supported within the vacuum chamber rather than levitated. In this configuration some of the magnetic field lines intersect the supports, which is expected to set the particle loss rate. Such plasmas provide benchmarks against which those formed with a levitated dipole field coil (i.e. no end losses) may be compared.

We have already tested out the glow discharge system, which will be used to clean up the vacuum chamber for magnetized plasma operation. As part of the glow testing, we ran several different working gases, and the same gas system will be used for magnetized plasma operation.

The initial plasmas in LDX will be formed and heated using electron cyclotron resonance heating (ECRH). The sources that are currently operational, 2.45 GHz and 6.4 GHz, can each apply up to 3 kW to generate the base-case hot-electron plasmas. By changing the amount of power in each source, we will be able to perform some crude profile studies. In addition, we have the capacity to do transient experiments by forming a plasma with one source and applying a pulse on the other. We can also chop the sources rather than applying CW power.

In addition to varying the heating power, we can vary the equilbrium magnetic field structure via a pair of Helmholtz coils. These coils can be fed as a true Helmholtz set or with a different current in each coil. These coils should be able to affect the plasma compressibility (volume) quite dramatically.

We will employ the base-case diagnostics for these studies. The initial edge magnetic diagnostics set will be employed for fluctuation measurements as well as for equilibrium reconstruction, and includes flux loops, Hall probes, and Mirnov coils. The energy of the energetic electrons will be assessed with a multichannel X-ray pulse-height analyzer. A microwave interferometer will be used to measure the electron density. Electrostatic probes, including Langmuir probes and an emissive probe, will measure the equilibrium potential as well as its fluctuations.

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What's New?

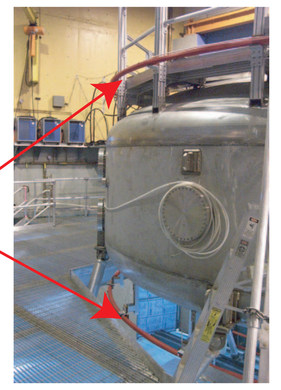
First plasma is just weeks away!

OPERATIONS

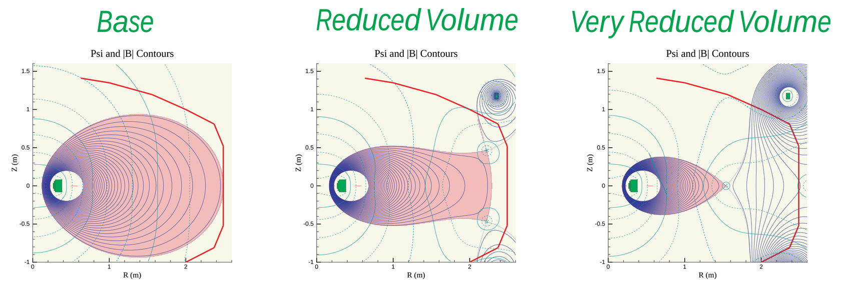
Shaping the Plasma can Change the Peak Pressure

- The dipole equilbrium at marginal MHD stability satisfies: $\frac{P_{core}}{P_{edge}} \leq \left(\frac{V_{edge}}{V_{core}}\right)^{\gamma}$, where $V \equiv \oint \frac{d\ell}{B}$ and $\gamma = \frac{5}{3}$.
- By changing the plasma volume $(\sim V_{edge}/V_{core})$we can dramatically affect the pressure gradient $(\sim P_{core}/P_{edge})$.
- We will accomplish this via a set of Helmholtz coils mounted outside the vacuum chamber. These will be operated with:
  - The same current in both coils, i.e. a true Helmholtz configuration.
  - Different currents in each coil.

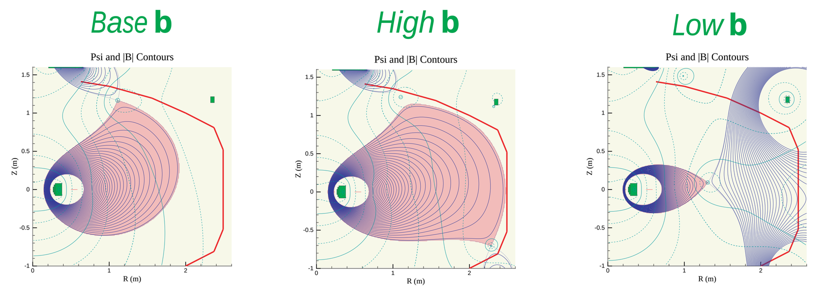
Coils on the Vacuum Vessel



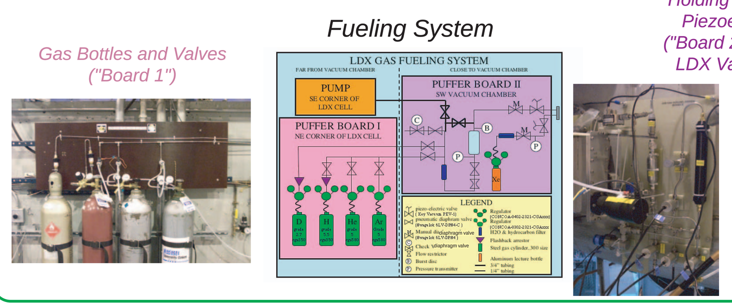
Reference Equilibria for Different Coil Currents (Same P_{edge})



By turning on the levitation coil, we can investigate equilibria in supported mode that are similar to those that will be seen in levitated operation:

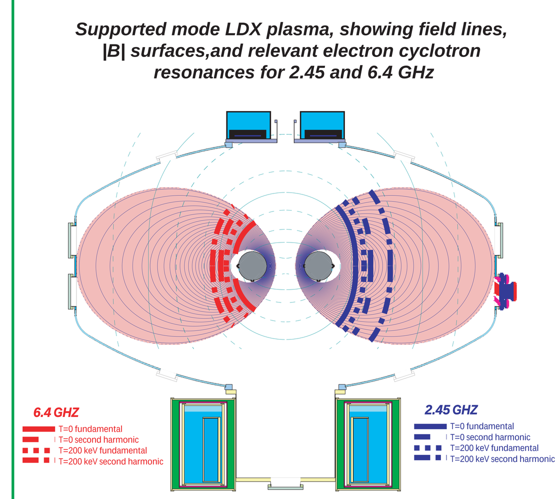


Glow Discharge Cleaning Has Been Tested

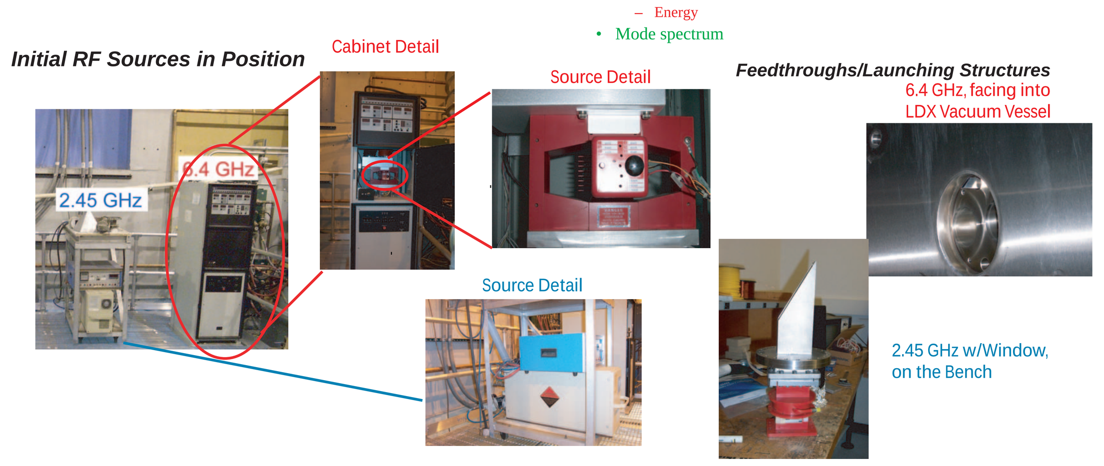


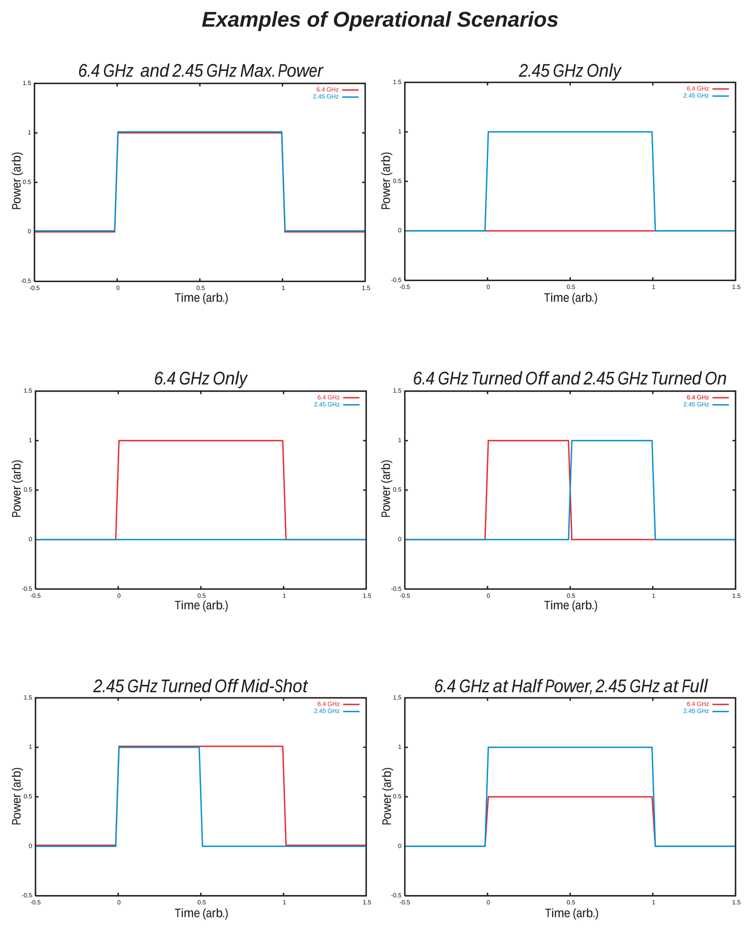
- The glow discharge system has been tested.
  - We studied the performance based on the rates of:
    - Fueling
    - Pumping
  - Several gases were used.
    - H_2
    - He
    - Ar
- Some further optimizations will be added.

The Initial Plasmas Will be Heated with Two Frequencies of ECRH



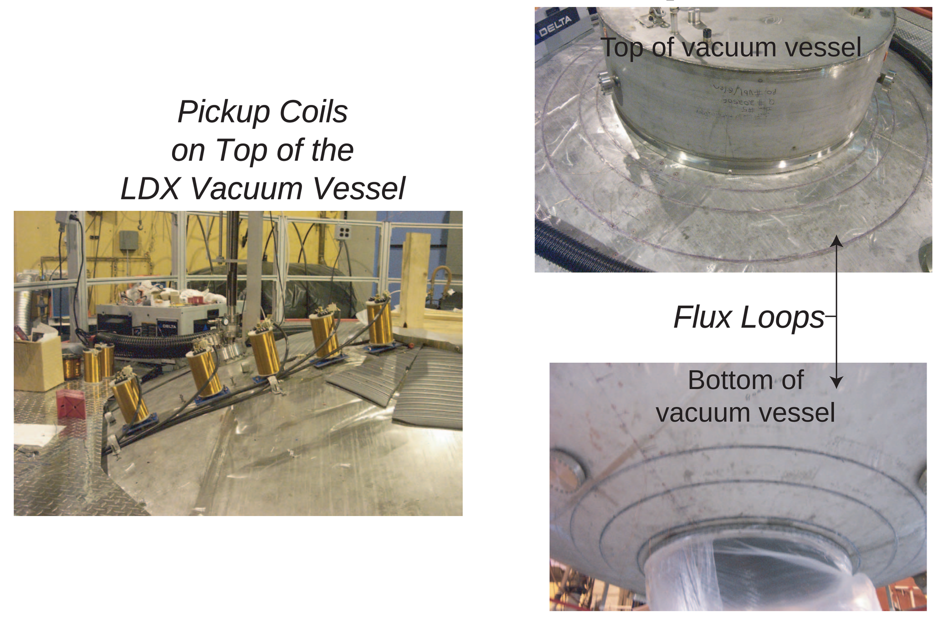
- ECRH is an effective way to create a high **b** hot electron population.
- Initial plans:
  - We will have 3 kW of microwave power at 2.45 and 6 GHz for the first plasmas.
  - We will assess the the response of the plasma to single frequencies, primarily via X-ray diagnostics:
    - X-ray pulse-height analyzer.
    - X-ray camera (collaboration with S. Zweben, PPPL).
  - Even with only two sources there are a variety of scenarios available.
- Ultimate goals:
  - Apply power at 10.5 GHz and higher frequencies in order to heat the bulk electrons across the whole plasma.
  - Tailor multi-frequency heating power in order to attempt to produce ideal (stable) pressure profile with maximum peak **b**.
  - Attempt to drive instabilities by driving the pressure gradient above marginality.
    - Find the saturation amplitudes.
    - Assess the transport.
      - Particle
      - Energy
    - Mode spectrum



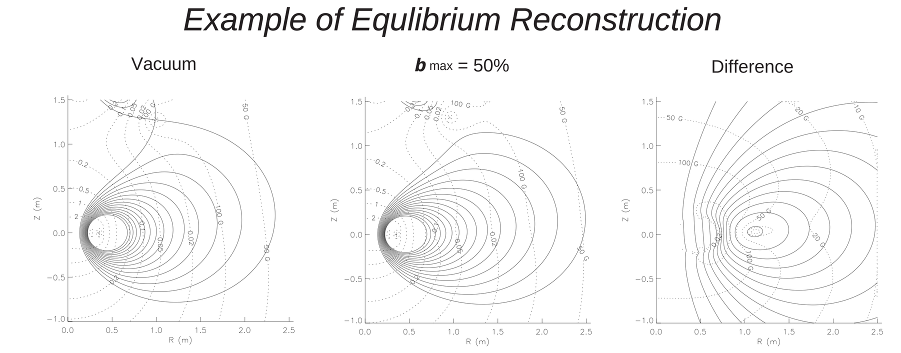


DIAGNOSTICS

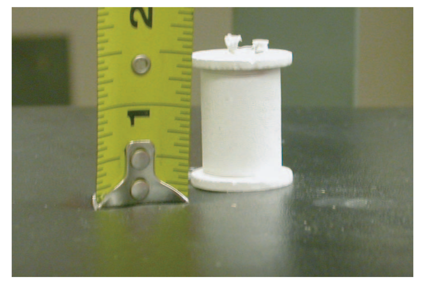
We will have Magnetic Measurements for Both Equilibrium and Fluctuations



- Equilibrium Magnetics
  - Flux loops (9)
  - Pickup coils
    - 9 tangential
    - 9 normal
    - Forms also have Hall probes attached.
  - Mounted outside the vacuum vessel.
- Fluctuation Magnetics
  - Pickup (aka Mirnov) coils (8).
  - Installed inside the vacuum vessel.
  - Sensitive to fluctuations in the microsecond range.

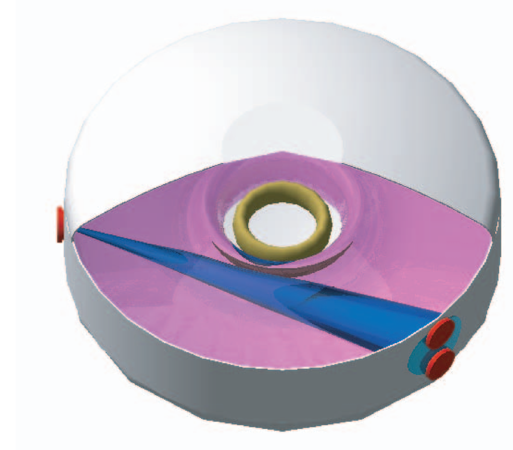


Mirnov Coil

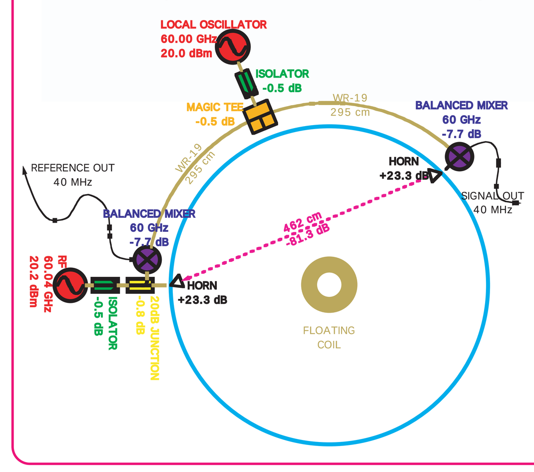


A Microwave Interferometer will Measure the Electron Density

Cutaway View of LDX, Showing Lines of Sight for the Microwave Interferometer

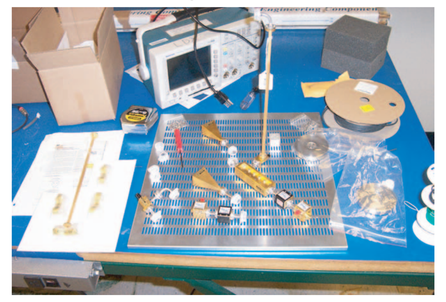


Block Diagram of Interferometer Setup



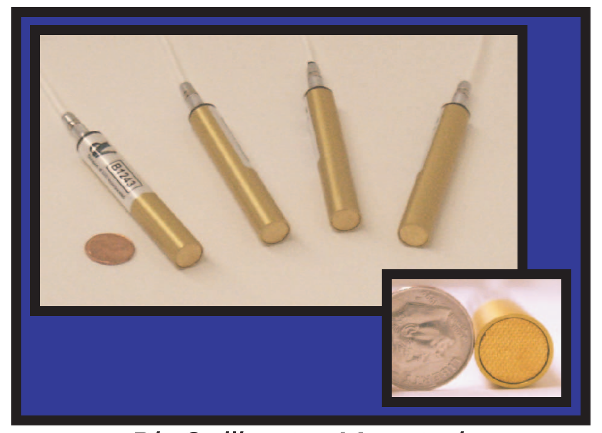
- A density profile measurement is important for LDX.
  - The density can vary by orders of magnitude between its peak value and the plasma edge.
  - Knowledge of the density profile is necessary to understand the stability of low frequency drift modes.
    - This also requires knowing the temperature or pressure profile.
- We are constructing a multichannel microwave interferometer.
  - center frequency of 60GHz
  - Initially we will use a one-channel superheterodyne interferometer, with two free-running Gunn oscillators.
    - Once it works, we will add channels

Waveguide Parts



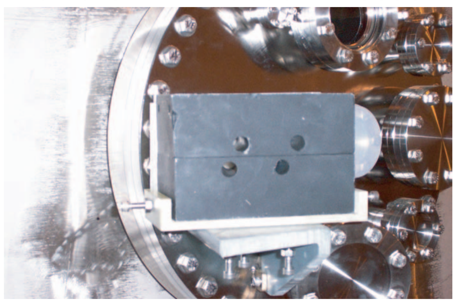
An X-ray Pulse Height Analyzer Will Assess the Energy of the Hot Electrons

CZT Detectors

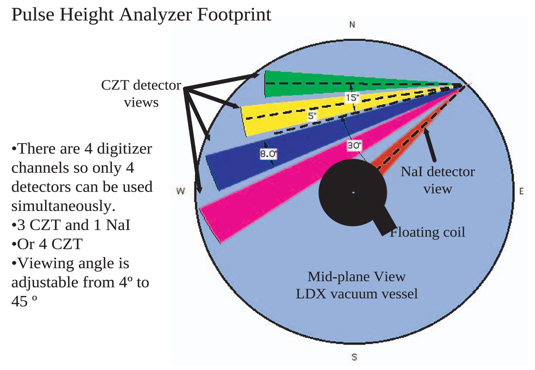


- The pulse height analyzer will look at the Bremsstrahlung X-ray energy spectrum in four radially separate views.
  - Useful for assessing the ECRH power deposition.

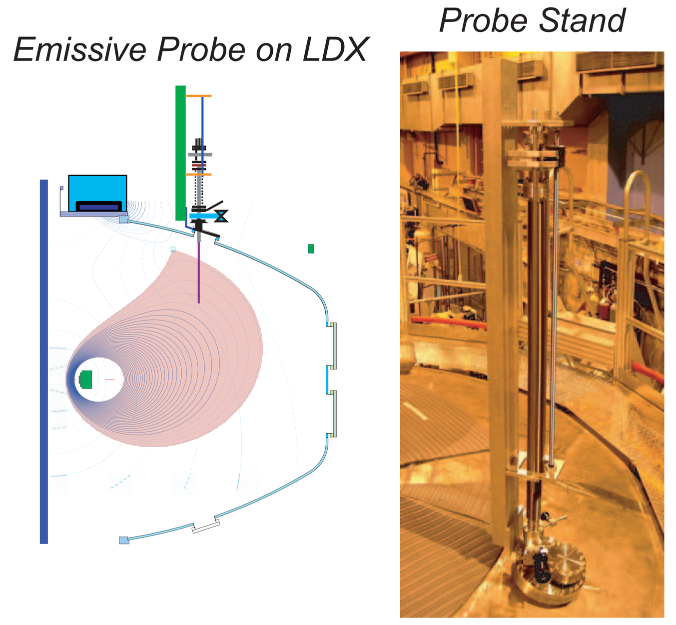
Pb Collimator Mounted on the LDX Vacuum Vessel



Views

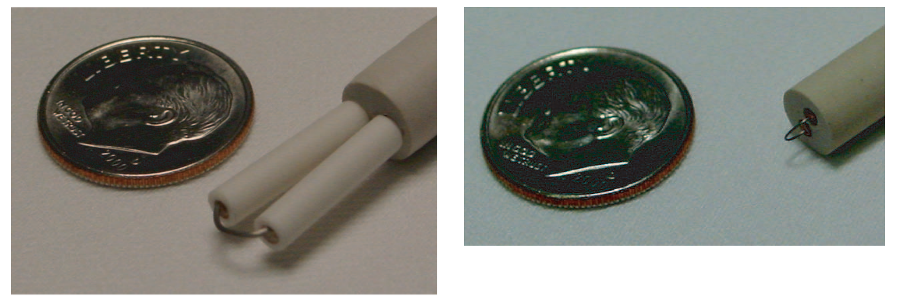


Electrostatic Diagnostics will Probe Instabilities.

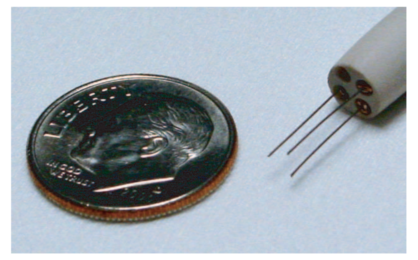


- Emissive probe:
  - Radially movable.
  - Measure plasma potential.
  - Biasing
    - Toroidally localized due to absence of rotational transform.
    - Drive instabilities, e.g. convective cells.
- Triple probe
  - Density
  - Temperature
  - Potential

Emissive probe heads



Triple probe head



For reprints of this or other LDX posters, visit our website: http://www.psfc.mit.edu/LDX

Summary

- Operations systems and diagnostics are being installed.
- Preparations for first plasma are proceeding at a feverish pace!