Triple probe measurements of mode transitions in an inductively coupled plasma

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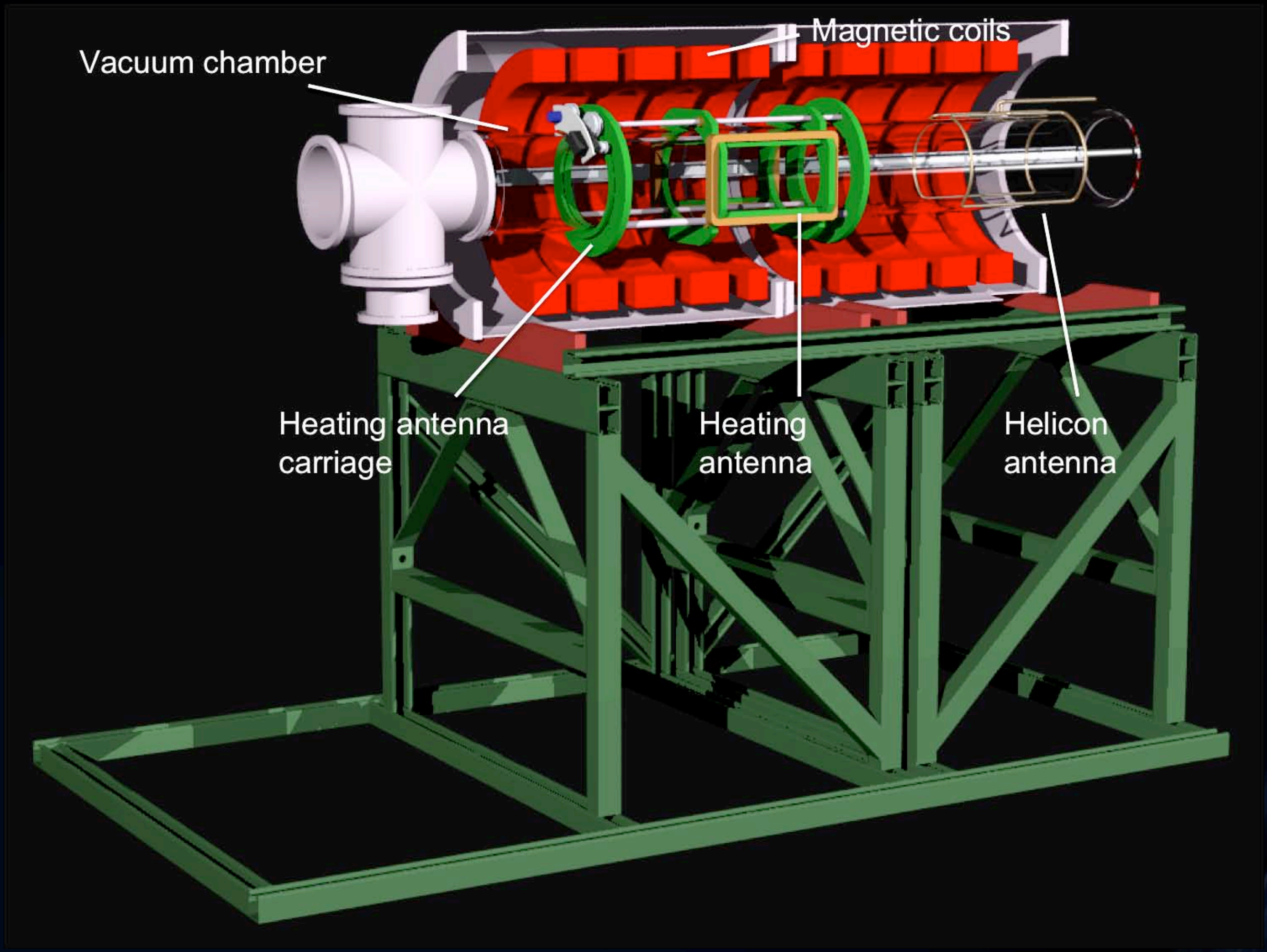
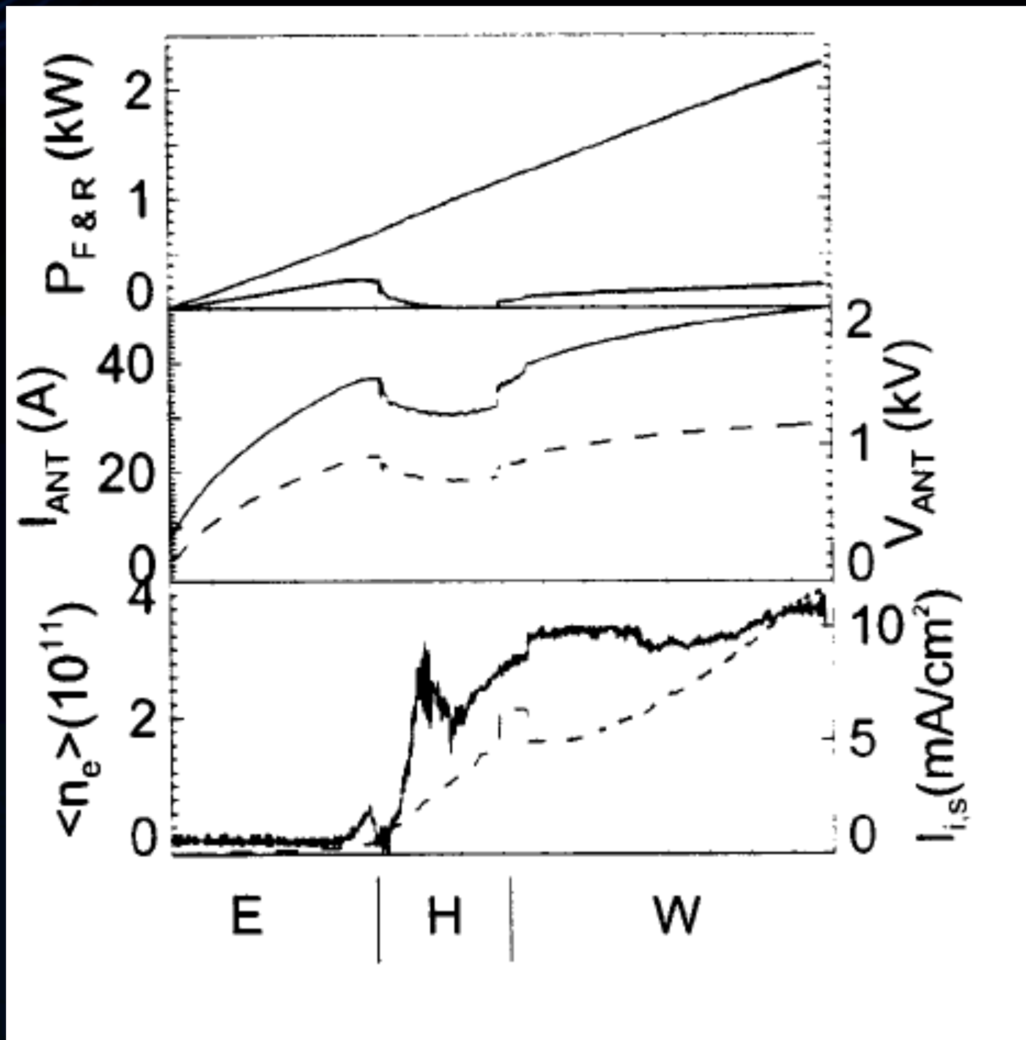
Outline

- Plasma setup
- Modes and characteristics
- Methods of measuring plasma parameters
  - Microwave interferometry
  - Langmuir probes
  - Thomson scattering
- Triple probe setup and operation
- Data presentation

Experimental setup



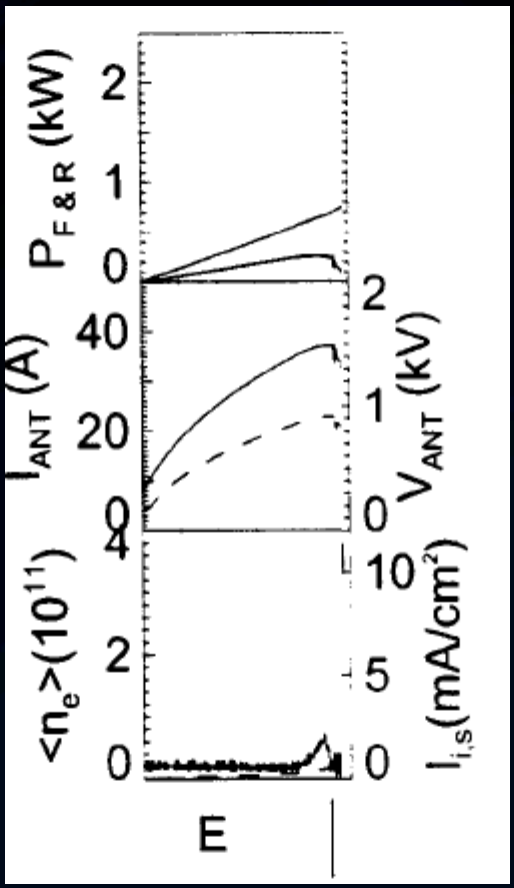
Modes of Operation



- Capacitive (E-mode)
- Inductive (H-mode)
- Helicon (W-mode)

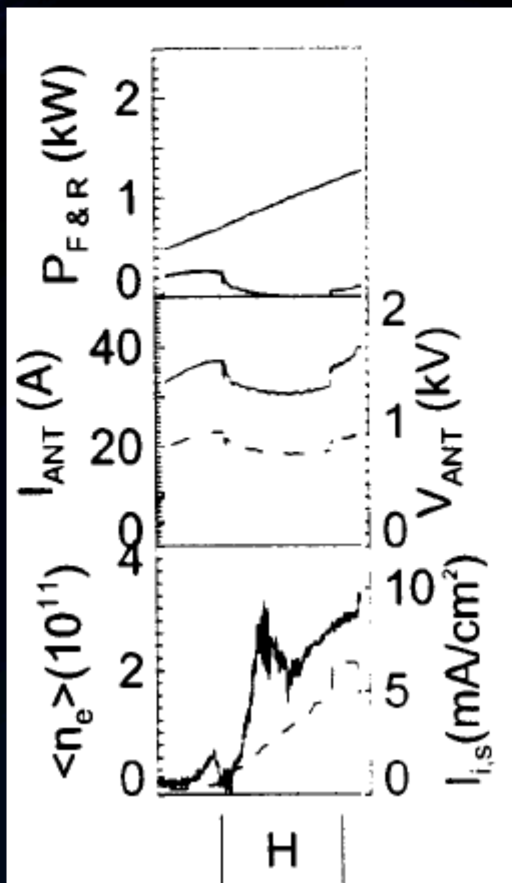
Boswell, R. W., and E. R. Wellington. "Capacitive, Inductive and Helicon-wave Modes of Operation of a Helicon Plasma Source." *Physics of Plasmas* 3.7 (1996). *Physics of Plasmas*. 16 Apr. 1996. Web. 10 Aug. 2010.

Capacitive Mode



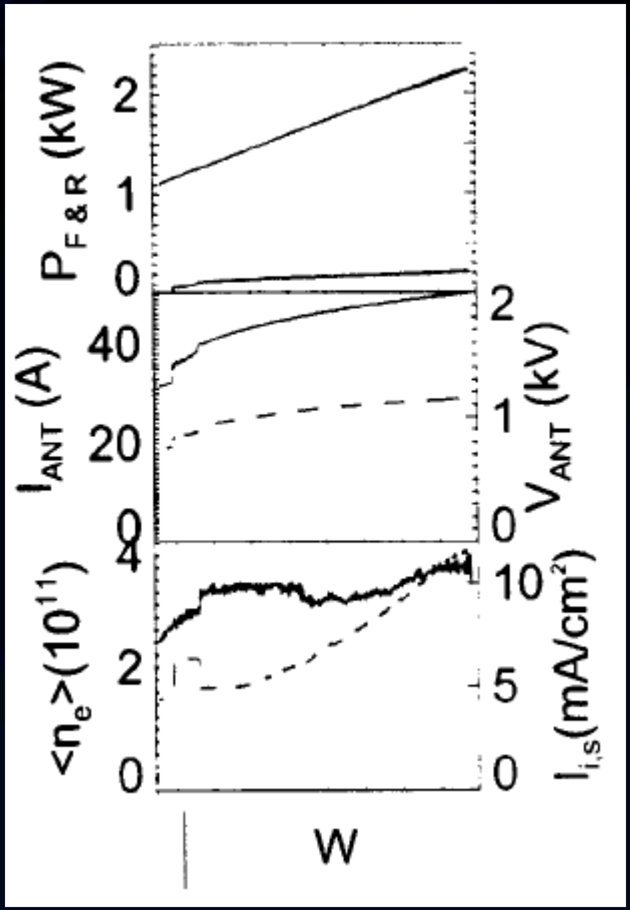
- Usually low density, low power
- Gas is ionized and plasma sustained by E-field from antenna
- Low coupling efficiency

inductive Mode

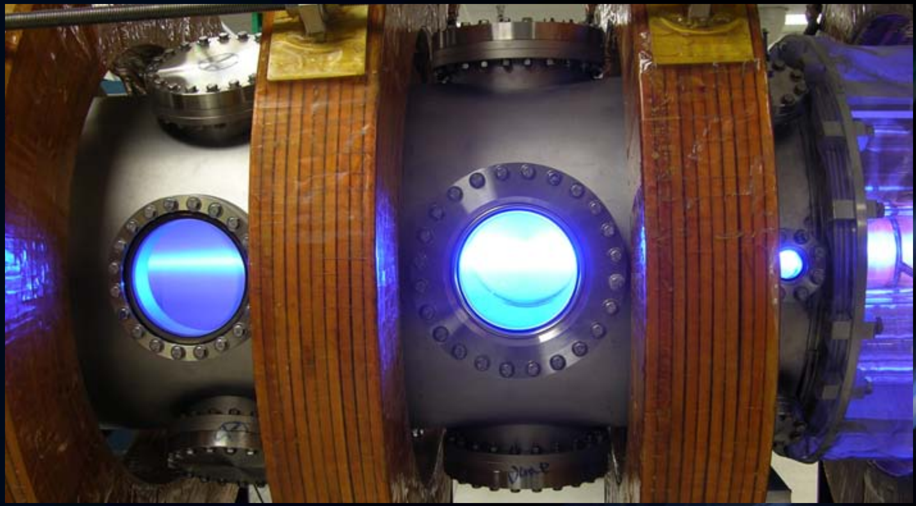


- ➢Plasma mainly driven by magnetic field
- ➢Plasma generates currents, shielding out imposed RF magnetic field
- ➢Reflected power drops
- ➢Density jumps by factor of ~10

Helicon Mode



- Center of plasma ohmically heated
- Axial magnetic fields
- Density increases more
- Reflect power increases, but efficiency also vastly increases

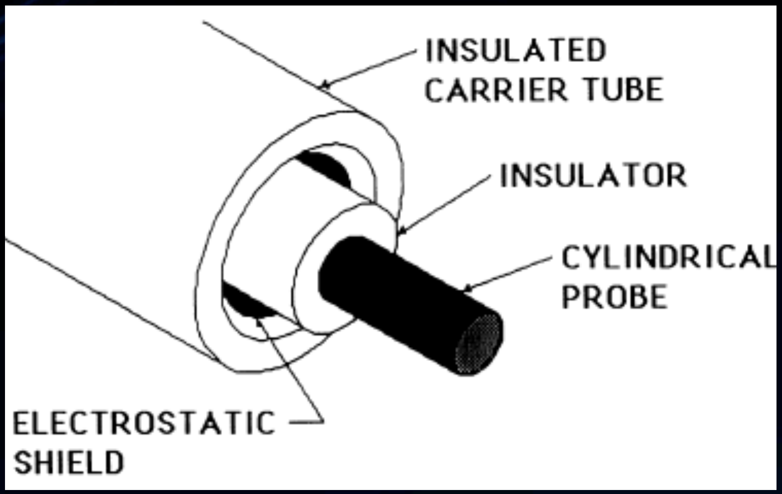


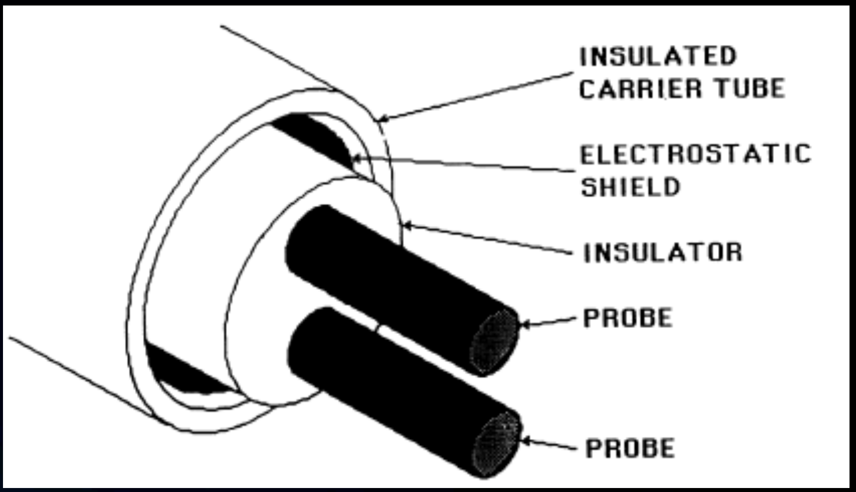
UNM Plasma and Fusion Science Lab HELCAT Plasma Device Photo Gallery. http://www.eece.unm.edu/~gilmore/DSCN2373.JPG

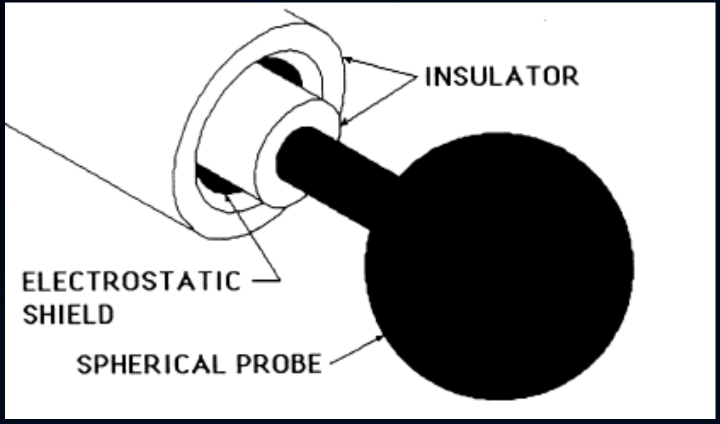
Methods for measuring plasma parameters

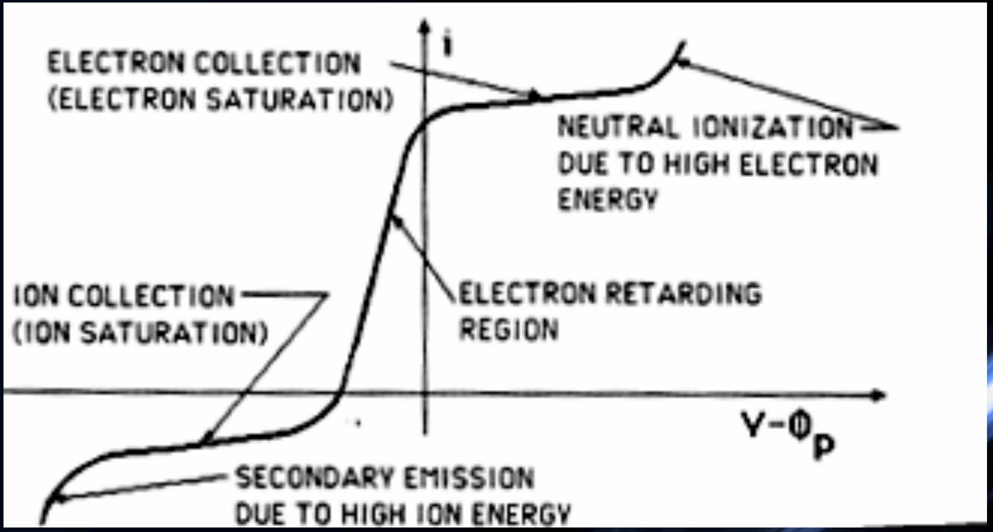
- Microwave interferometry
- Thomson scattering
- Langmuir probes

Langmuir probes









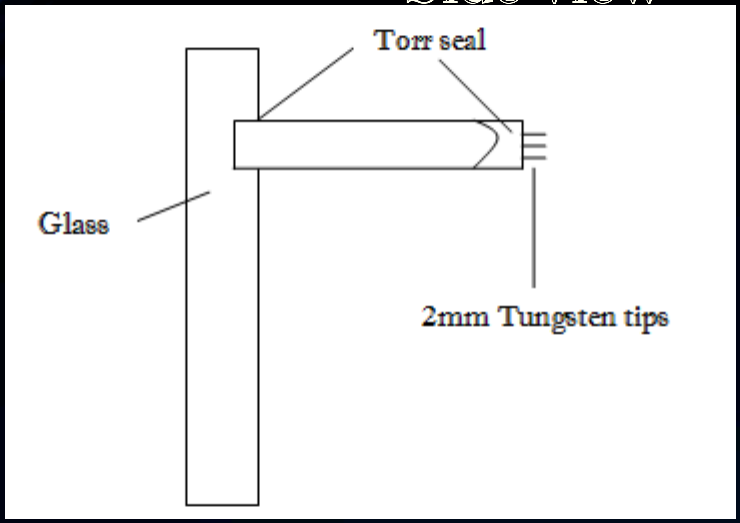
Owens, D.K. “Lecture IV: Langmuir Probes”.

Triple Langmuir Probe advantages

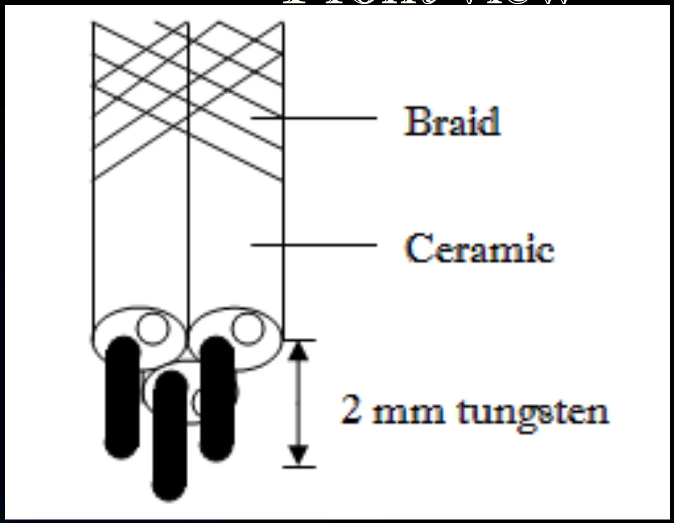
- No voltage sweep needed
  - Direct display possible
  - Good time resolution
- Floating reference → filters out RF noise
- Error due to magnetic field is small

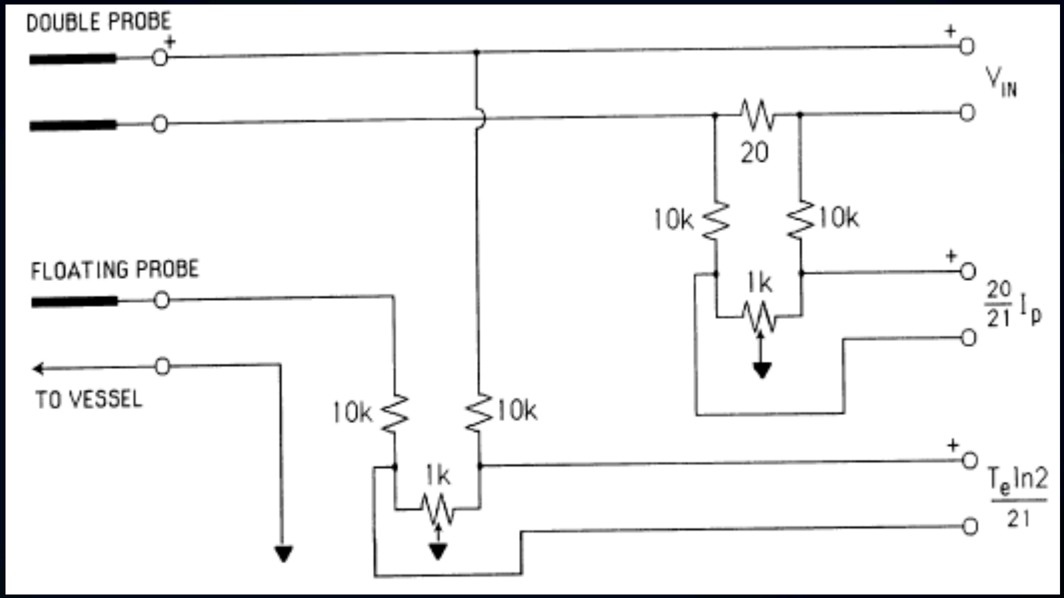
Triple Langmuir Probe setup

Side view



Front view





Driver circuit

Triple Langmuir Probe Equations

Electron Temperature:

$$e^{eV_1/kT_e} = \frac{2e^{eV_f/kT_e}}{1 + e^{-eV/kT_e}}$$

$$\approx \quad eV_1/(kT_e) = eV_f/(kT_e) + \ln 2 \quad = \quad kT_e/e = (V_1 - V_f)/\ln 2$$

Electron Density:

$$j_+ = en_e(Z_i kT_e/M)^{1/2} e^{-1/2}$$

$$\Rightarrow \quad i_+ = .61 en_e A(Z_i kT_e/M)^{1/2}.$$

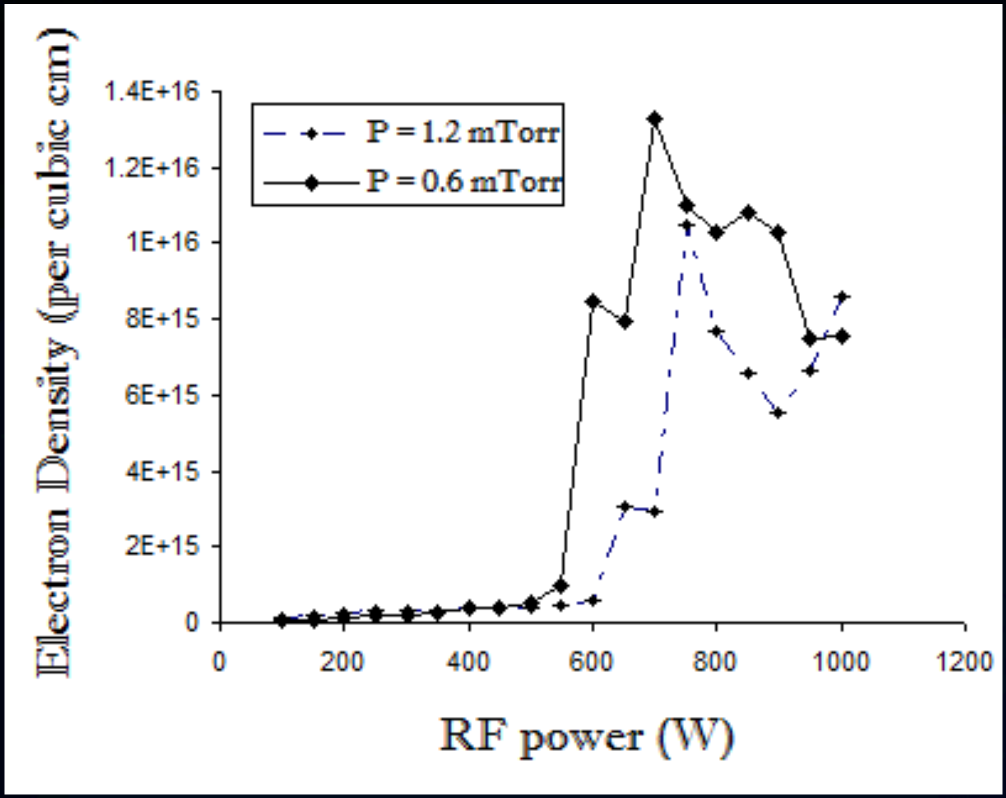
e = electron charge ; k = Boltzmann's constant ; T_e = electron temperature

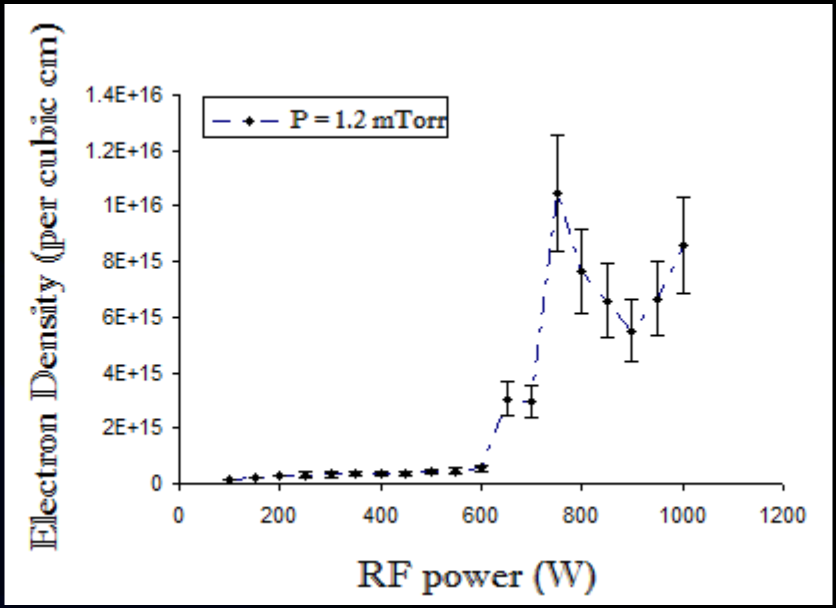
V_1 = positive bias voltage ; V_f = floating voltage ; V = applied voltage

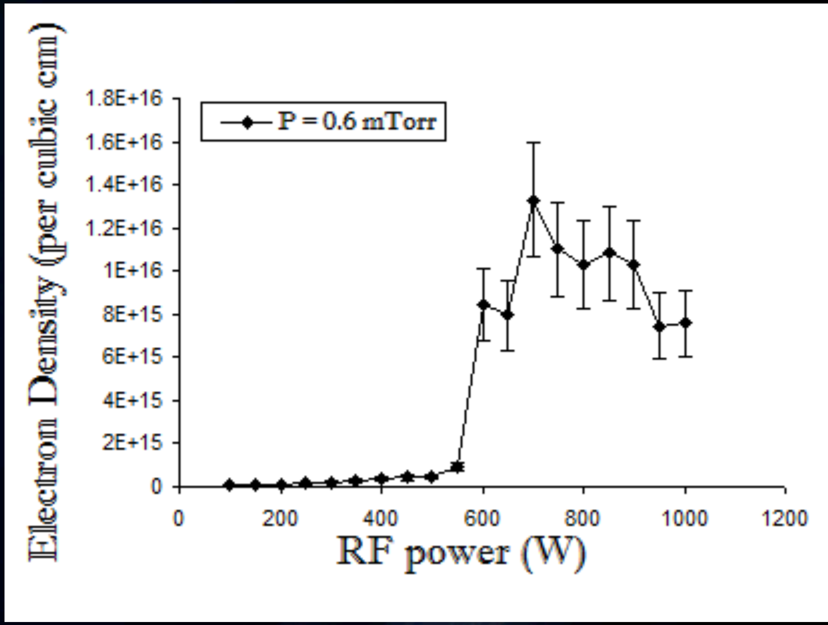
$j+$ = ion current density ; $i+$ = ion current ; Zi = ion charge state = 1; M = ion mass

A = probe surface area

Density Data







Data discussion

- Significant density jump at about 600-700 RF power

- Power required to mode-change increases with increasing background pressure

Conclusion

- Plasma created by coupling with RF waves

- There are three modes of operation seen during an RF power ramp

- The mode transition power level depends on magnetic field and background pressure

- Triple Langmuir probes allow us to directly display plasma parameters, along with other advantages

The end!