Emissive Probe Measurements with ICRF Waves in LAPD

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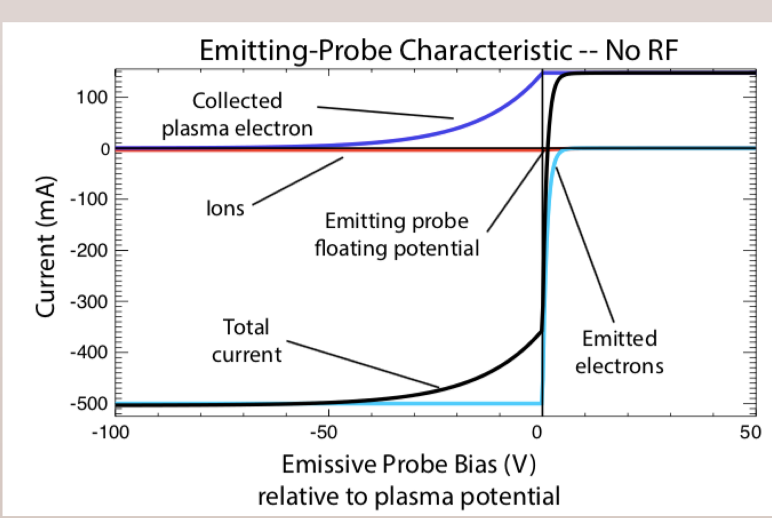
MOTIVATION

- **Ion cyclotron range of frequencies(ICRF) waves are a promising option for heating fusion plasmas, but can raise the plasma voltage through rectification effects in the sheath. This can lead to undesirable sputtering and impurity generation.**
- **Physicists often rely on plasma voltage measurements from emissive probes, but these probes are also affected by plasma waves, which calls their accuracy into question.**
- **Data from the Large Plasma Device(LAPD) is analyzed to discern differences between actual variations in plasma voltage and false probe readings.**

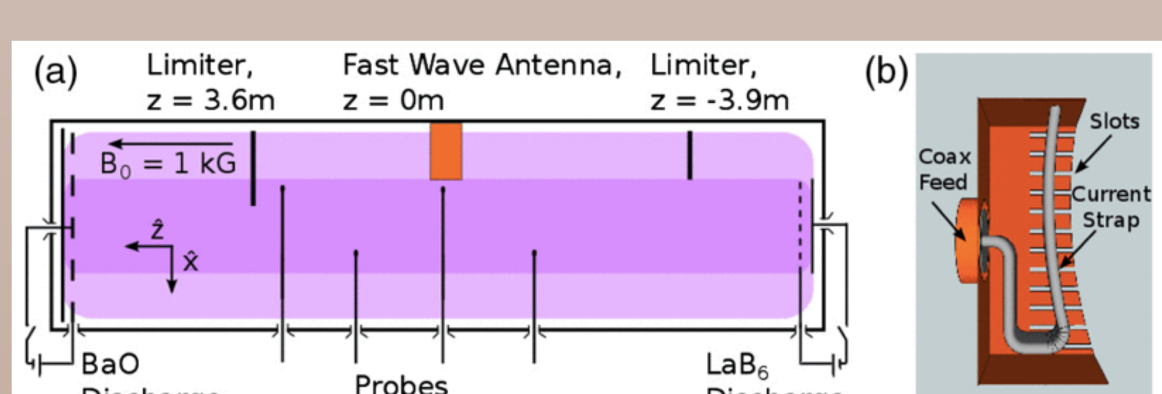
BACKGROUND: EMISSIVE PROBES

- Langmuir probes are particularly susceptible to RF rectification, which causes the probe to yield a false measurement of V_{plasma}.
- An emissive probe is a metal filament heated to the point of thermionic electron emission. Since emissive probes undergo a sharp transition to strong emission when $V_{probe} < V_{plasma}$, they tend to yield a closer measurement to the actual value.

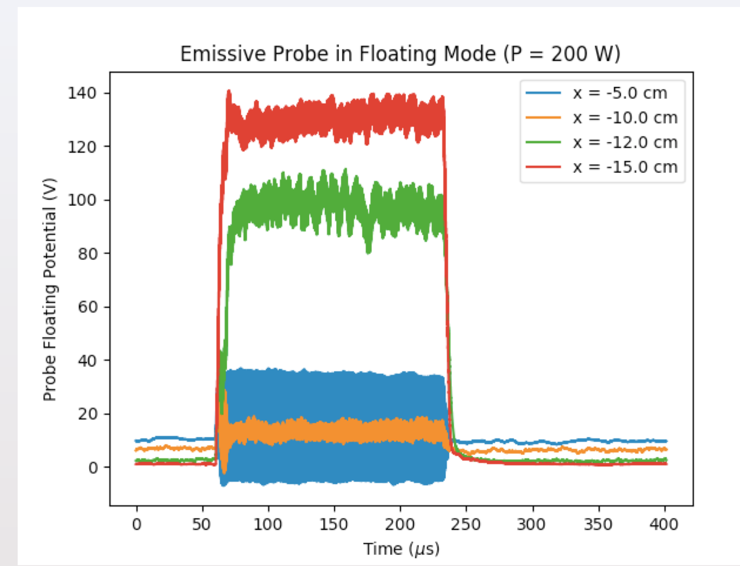


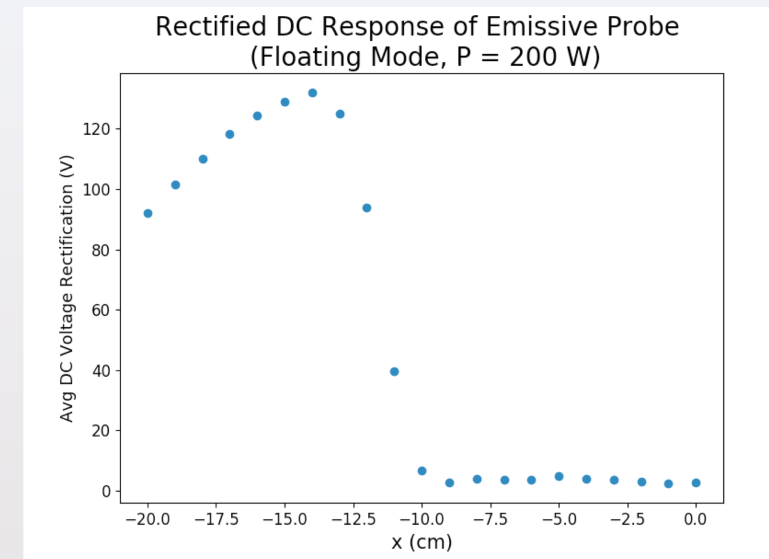
LARGE PLASMA DEVICE (LAPD)

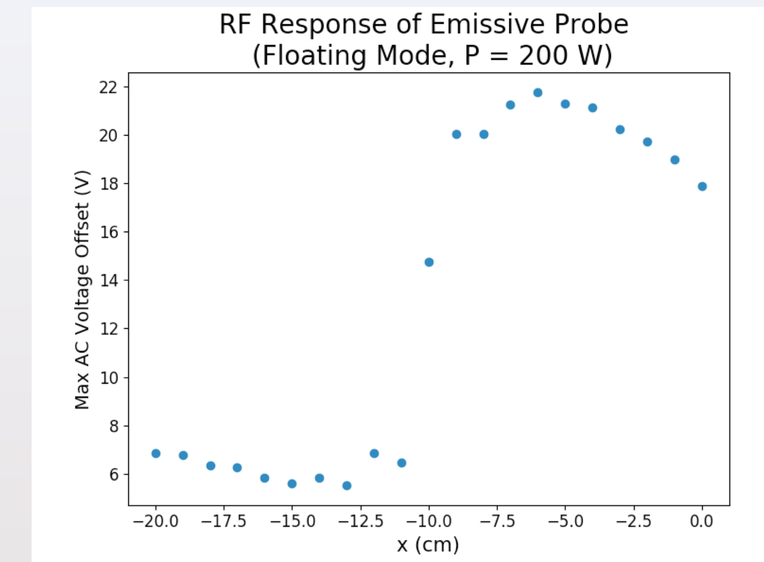
- LAPD is a user facility at UCLA that is focused on studying basic plasma science. It is a 20-m long (1-m diameter) vacuum chamber that can support plasma discharges from both LaB_6 and BaO anodes.
- A recent installation included an ICRF antenna along with several emissive probes.
- LAPD data offers a chance to study emissive probe behavior in detail, including operation in both swept and floating mode, with and without RF waves present, and in both the core and edge of the plasma column.



EXPERIMENTAL EMISSIVE PROBE READINGS





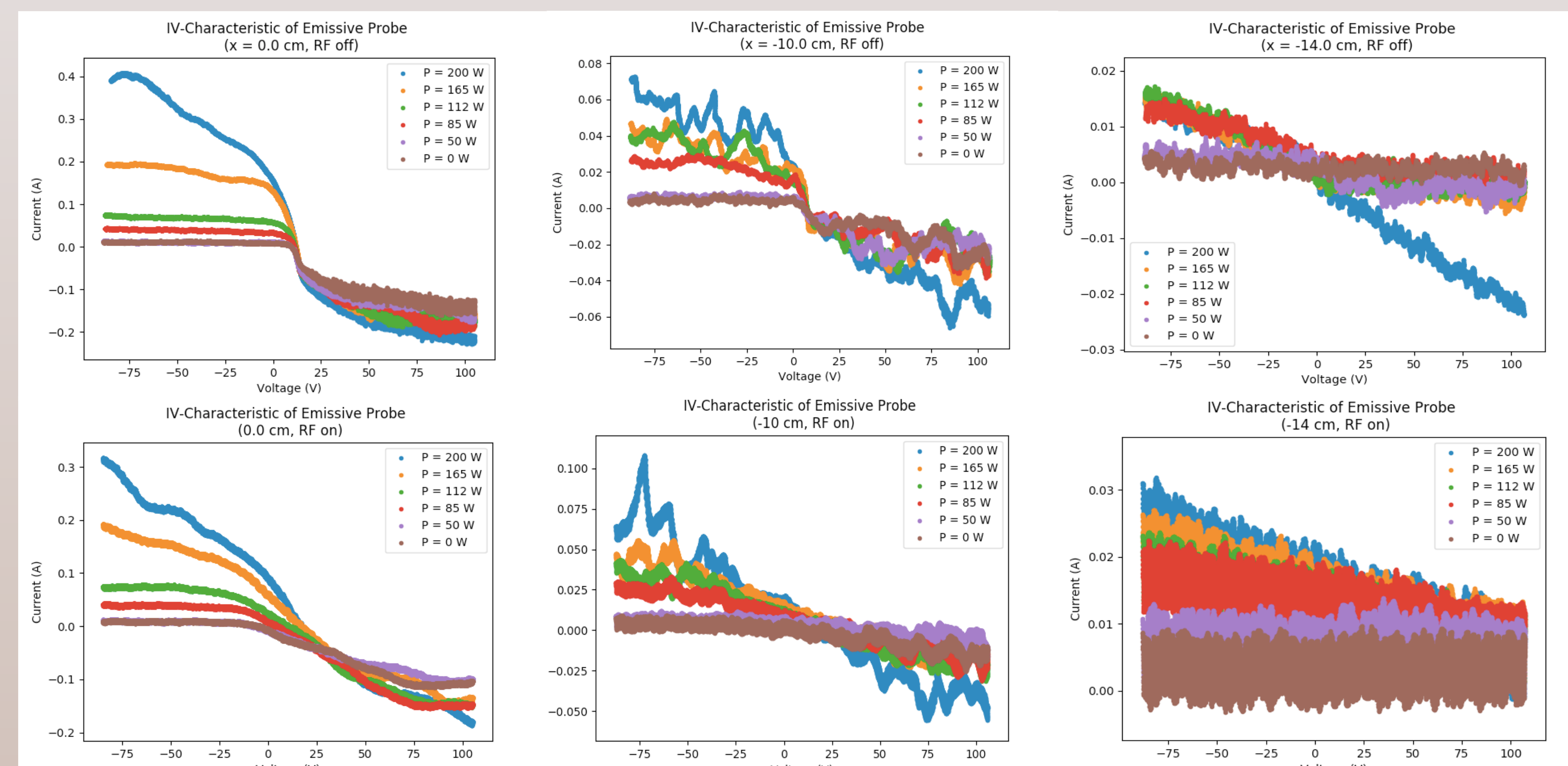


- Probe bias voltage can be in swept or floating mode, where ideally the probe will float to the plasma potential.
- Higher emission rates are associated with a steadier behavior during the pulse - with zero probe power, a long transient is induced.
- Rectification effects are strongest in the edge, as expected. The RF amplitude is dramatically larger in the core.

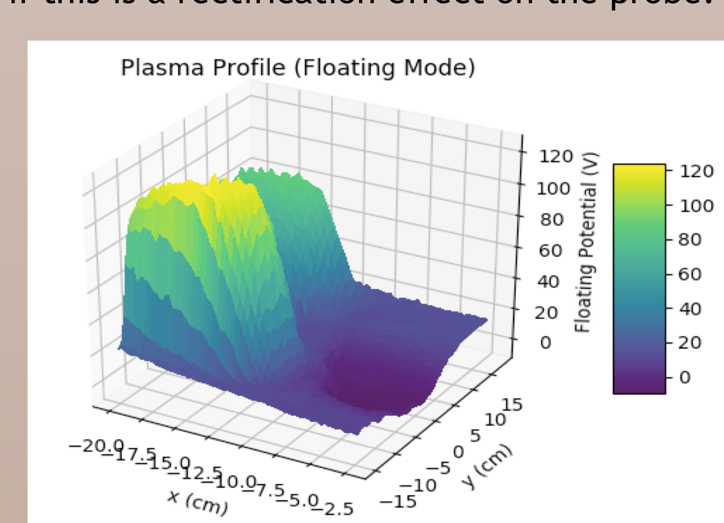
EFFECT OF RF ON I-V CHARACTERISTIC

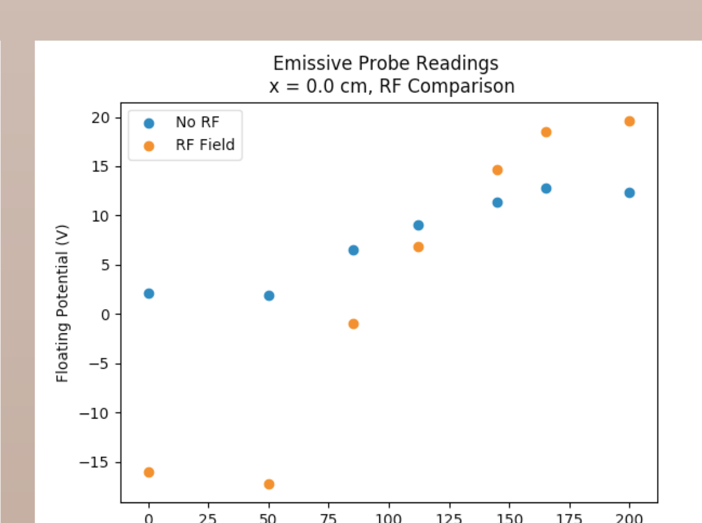
CORE | **EDGE** | **SHEATH**

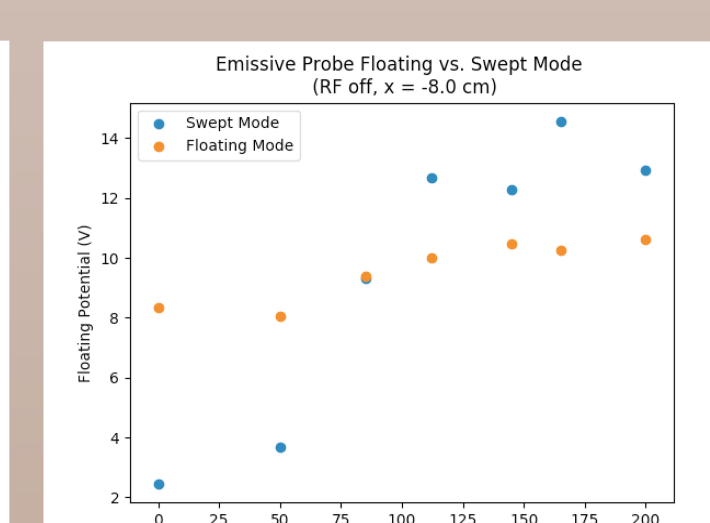
RF OFF / **RF ON**



- The RF wave averages the current over each cycle, leading to a much less abrupt transition from collecting to emitting electrons. This increases the uncertainty in V_{plasma} from the order of T_e to the order of V_{RF}.
- Near the edge of the plasma, the characteristic becomes far more noisy and does not have a clear floating potential measurement. This may be due to the sweep not having a large enough range.
- With the RF present, the floating potential becomes highly dependent on probe power. It is not clear if the plasma voltage is actually increasing or if this is a rectification effect on the probe.



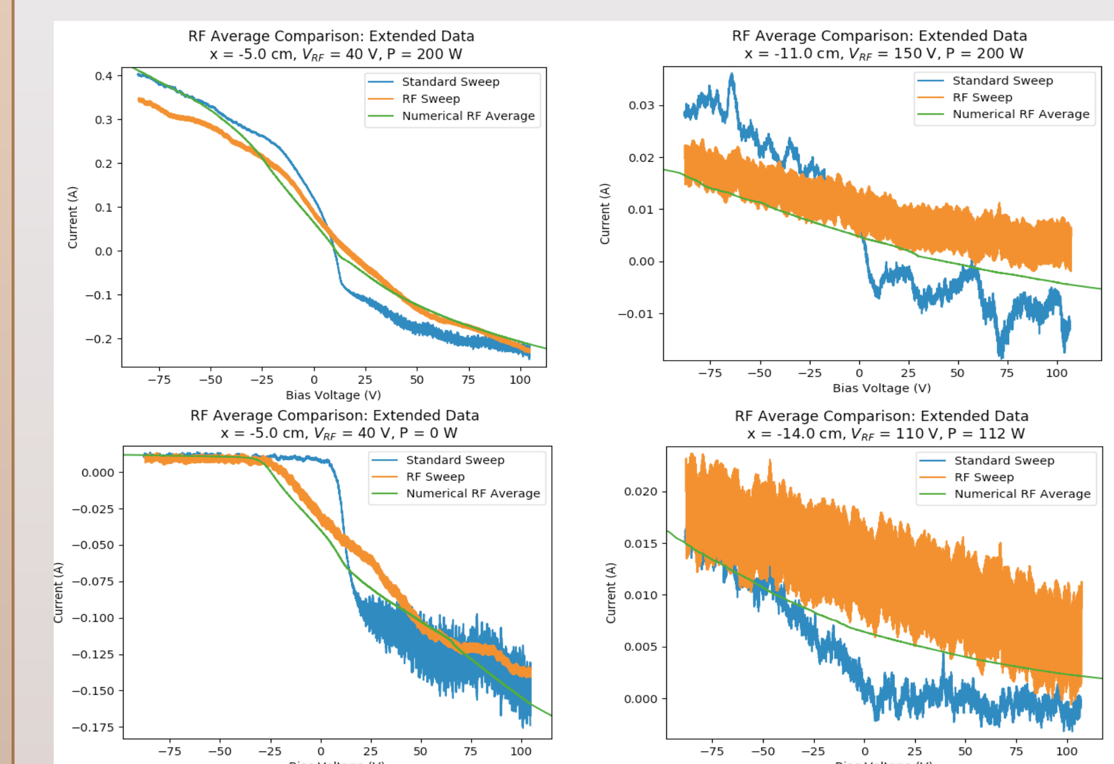




NUMERICAL RF AVERAGING

- Characteristic for a non-RF sweep is averaged over each RF cycle using numerical integration, and can be compared to sweeps with RF present.
- This method leads to anomalies related to boundary effects, so the data is extended with a linear fit.
- For certain probe configurations and V_{RF} values, the numerically averaged curve matches the RF curve well.

$$\langle I \rangle = \int I(V_0 + V_{RF}\cos\omega t)dt$$



CONCLUSION/FUTURE WORK

- **RF seems to change the measured floating potential without necessarily affecting the plasma potential, especially by averaging the I-V characteristic.**
- **Effects are magnified at low plasma density / near antenna, to the point where the characteristic is too noisy to interpret clearly.**
- **In order to isolate actual changes in V_{plasma} from false probe readings, the next step is to compare theoretical models for time-dependent probe behavior at the experimental conditions.**

REFERENCES

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- Martin, M., Gekelman, W., Compernolle, B. V., Pribyl, P., & Carter, T. (2017). Experimental Observation of Convective Cell Formation due to a Fast Wave Antenna in the Large Plasma Device. *Physical Review Letters, 119*(20). doi:10.1103/physrevlett.119.205002

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