The Use of Divertor End Plates as Diagnostics in the PFRC-2

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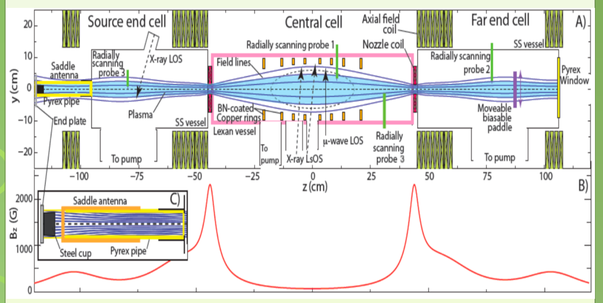
Introduction: PFRC 2

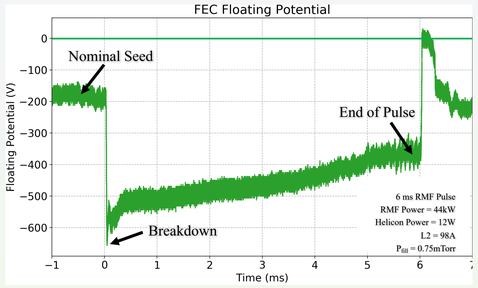
- The PFRC is a compact toroid that utilizes odd-parity rotating magnetic fields to form and heat a Field Reversed Configuration.
- Currently being developed to burn D-^{3}He fuel as a small clean fusion reactor, ideal for spacecraft power and direct propulsion.
- Significant device attributes include:
  1. High Temperature Superconducting Magnets for passive flux conservation, which enable >250 ms stable pulses.
  2. High β, with axial magnetic fields > 1,000G.
  3. RF power input of 70kW via RMF_o coupled to seed plasma.

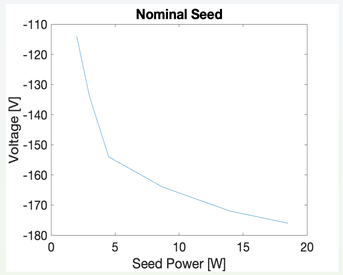
Divertor Regions

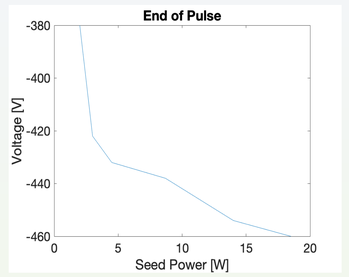


- The goal of this research was to use the divertor end plates of the PFRC-2 as probes to characterize plasma within the end cell regions. This information can then be used to understand particle and energy flow from the center cell of the device.
- By allowing the divertors to remain at floating potential or connected to ground, time dependent behavior of electron energy, density, and FRC stability during RMF discharge can be obtained.
- The divertor regions are terminated by a Tantalum disk of 54mm diameter in the Far End Cell (FEC), and a Steel cup of 38mm diameter in the Source End Cell (SEC).

Varying Seed Plasma Power Experiment







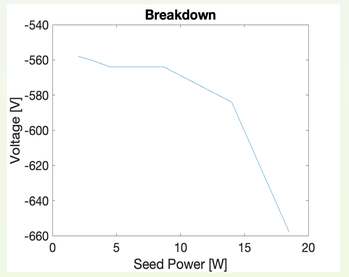
Assuming $T_e > T_i$ and a Maxwellian distribution, the Floating Potential can be converted to an equivalent electron energy.

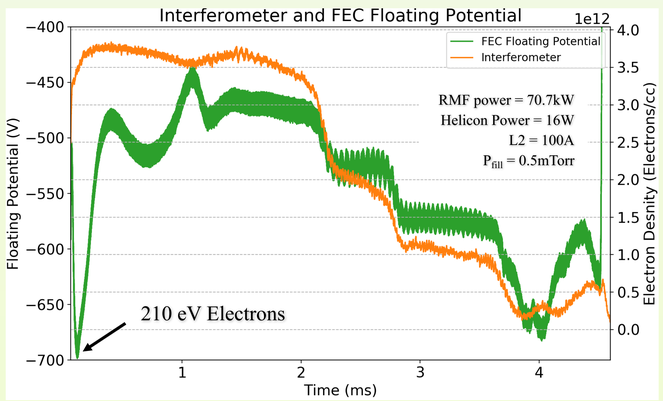
$$\bar{v} = 2\left(\frac{2T}{\pi m}\right)^{\frac{1}{2}} \qquad \frac{A_{sheath}}{A_{probe}} \approx 1$$

$$I_{total} = n_\infty e A_{probe}\left(\frac{T_e}{m_i}\right)^{\frac{1}{2}}\left[\frac{1}{2}\left(\frac{2m_i}{\pi m_e}\right)^{\frac{1}{2}} exp\left(\frac{eV_0}{T_e}\right) - \frac{A_{sheath}}{A_{probe}}\exp\left(-\frac{1}{2}\right)\right] = 0$$

$$\frac{eV_f}{T_e} = \frac{1}{2}\left[ln\left(2\pi\frac{m_e}{m_i}\right) - 1\right]$$

	Nominal Seed	Breakdown	End of Pulse
Highest Electron Energy Recorded	53.3 eV	197 eV	138 eV





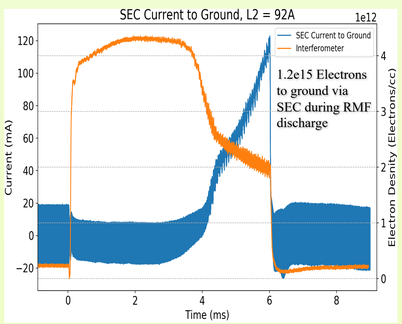
- At higher RMF and Seed Power, and lower fill pressure, the floating potential in the FEC began to step more negative.
- This behavior was closely related to the electron density decay in the center cell, as seen by the interferometer.
- It was clear that as electron density decreased in the center cell, the end cell's measured higher energy electrons. The same oscillation frequency is also present in both signals.

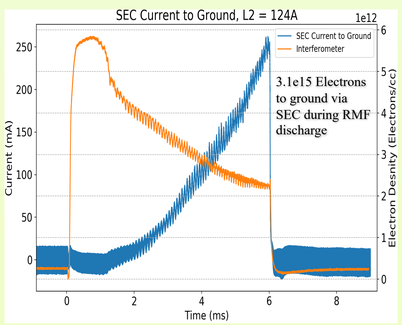
Grounded SEC End Cup

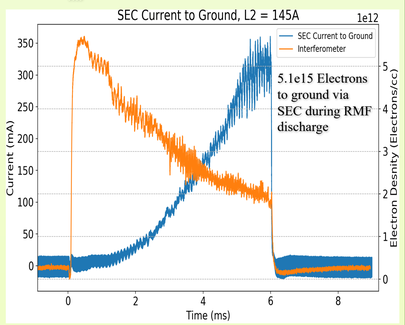
Positive current on graph's indicate electron current

RMF Power = 49kW

P_{fill} = 0.51mTorr



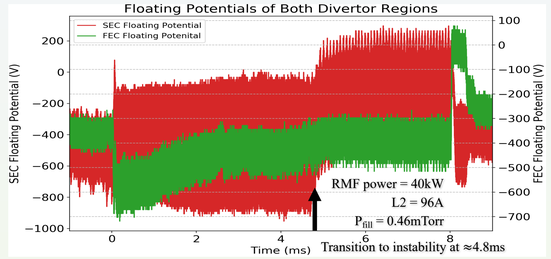


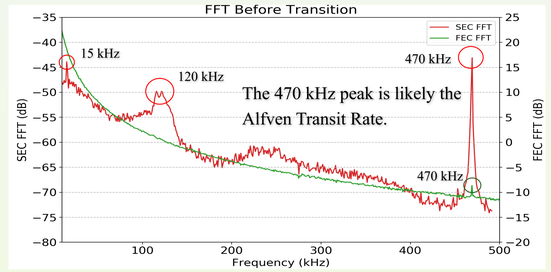


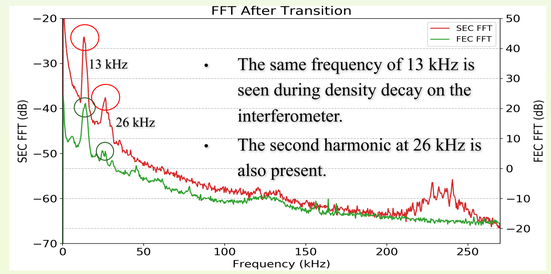
- Density decay is very strongly correlated to the rise in current to ground in the divertor region.
- The same oscillation frequency (≈13 kHz) present in the density decay is seen on the current.

Oscillation in Floating Potential

Applying a Fast Fourier Transform Analysis







Conclusion and Future Work

- Successfully utilized the divertors in the PFRC-2 as diagnostics to measure both the floating potential's and current to ground.
- Gained quantitative insight on electron energy and densities in the end cells of the device over a range of operating conditions.
- Directly observed the density decay in the center cell translate to particle and energy gain in the end cells.
- Future work should aim to better understand the plasma instability, a likely candidate is the MHD Flute instability. A future experiment should apply a sweeping voltage bias to the divertors, to more accurately measure electron energies and densities.

Acknowledgements

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References

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