Measurement, Characterization, and Suppression of Low-Frequency Instabilities in the PFRC-2

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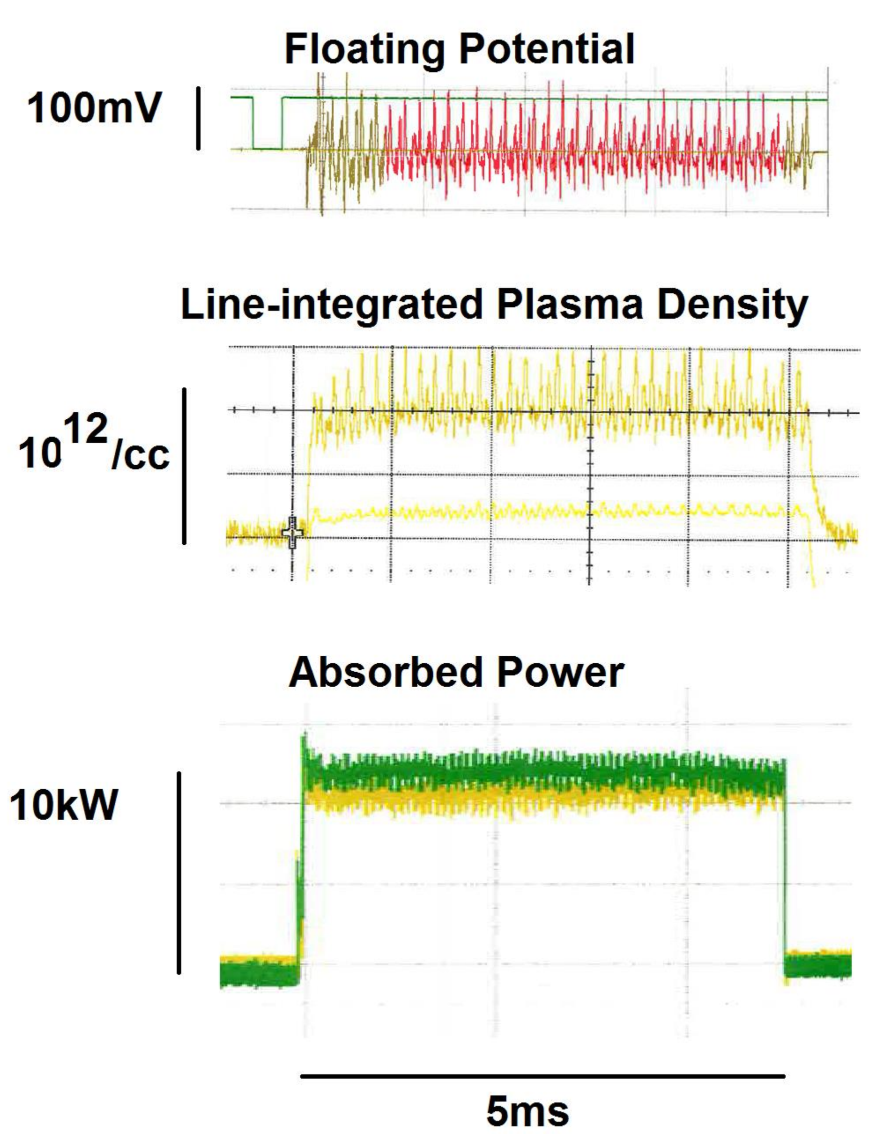
Motivation

The Princeton Field-Reversed Configuration-2 (PFRC-2) device[1] investigates aspects of FRC reactor design. When exploring modes of operation, we observe oscillations in plasma parameters measured by interferometry, Langmuir probes, high-speed visible light photography, and RF power coupling. These oscillations might have serious implications for transport and stability, and understanding their causes and mitigation is a priority.

Detection

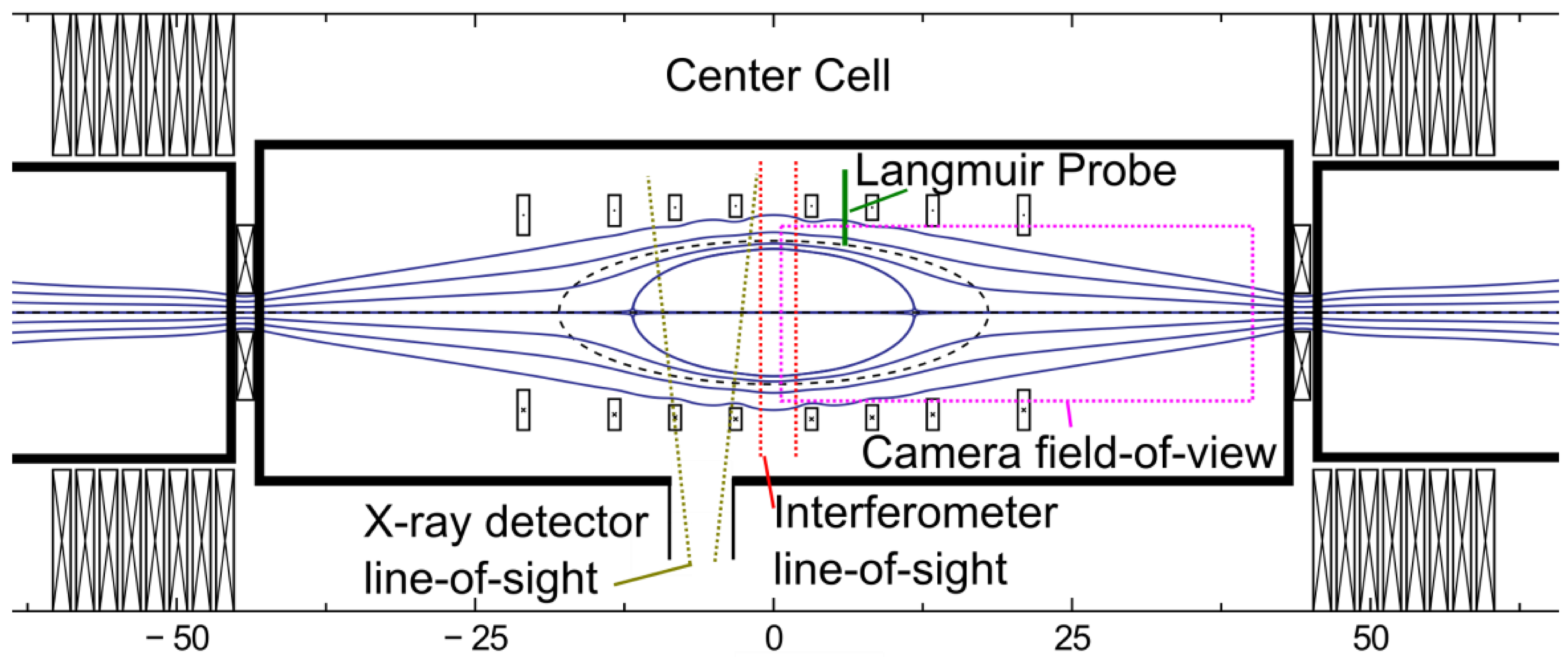


Case Study

The fast camera trace below was taken under conditions of:

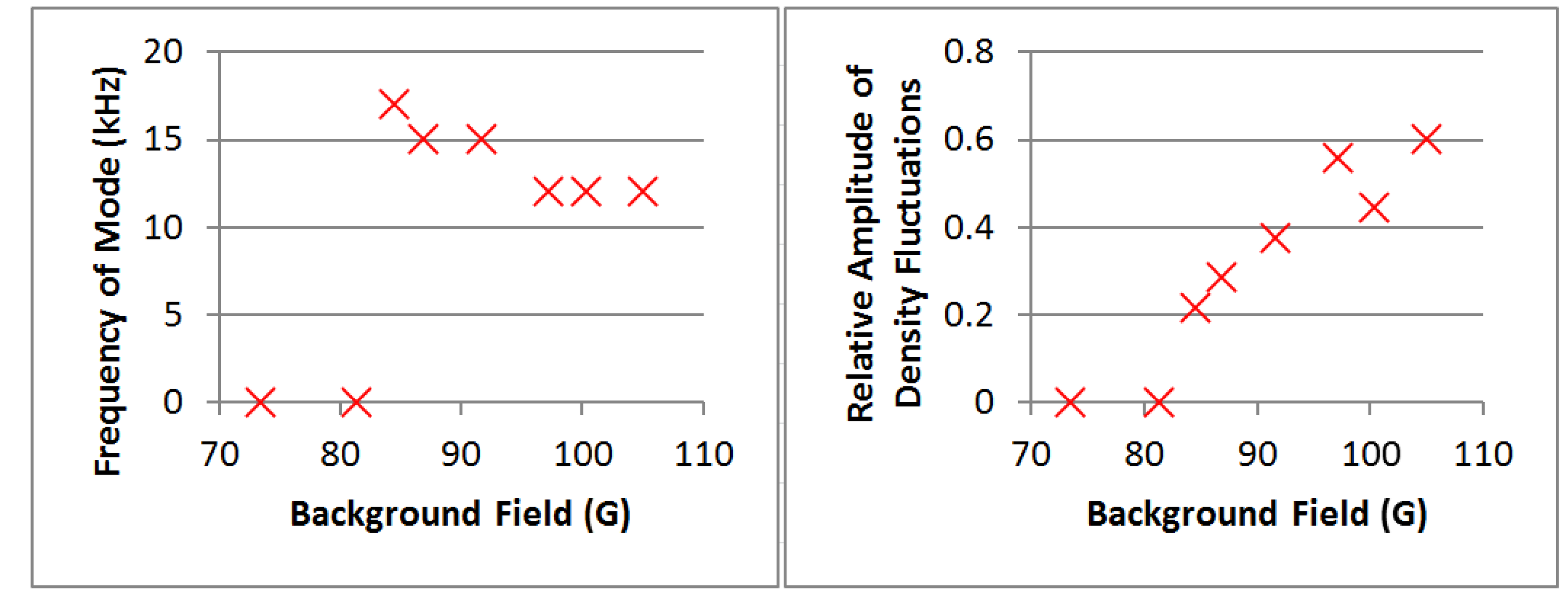
- 73Gauss background magnetic field
- 0.447mTorr of neutral Hydrogen pressure
- Superconducting flux conservers
- 75ms of RMF power starting at 20kW and decreasing to 13kW
- A gas puff of Hydrogen into the center cell 45ms after pulse start
- 95,000 frames per second

PFRC-2 Device



Magnetically, the machine is a tandem mirror configuration. RF antennae form a field-reversed configuration (FRC) in the Center Cell, where it is confined for study. Depicted here are the areas of interest for the diagnostics named in this poster.

Magnetic Behavior



Mode is quiescent at background magnetic field values below ~85G and increases roughly linearly in relative amplitude of the density fluctuation as background field strength increases above this value.
Mode oscillation frequency decreases as background field increases above this value.

Fast Camera

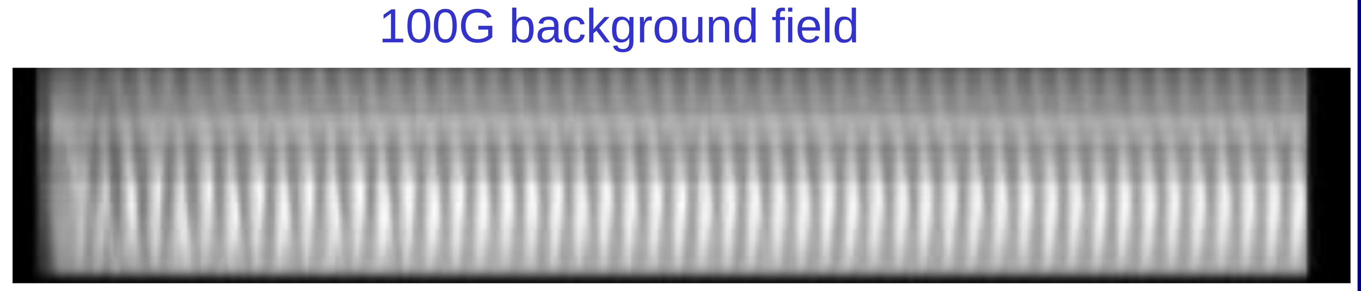
We use a Phantom 7.3 high frame-rate visible-light camera to film the instability. No filter is used.

Phantom field of view (center cell)

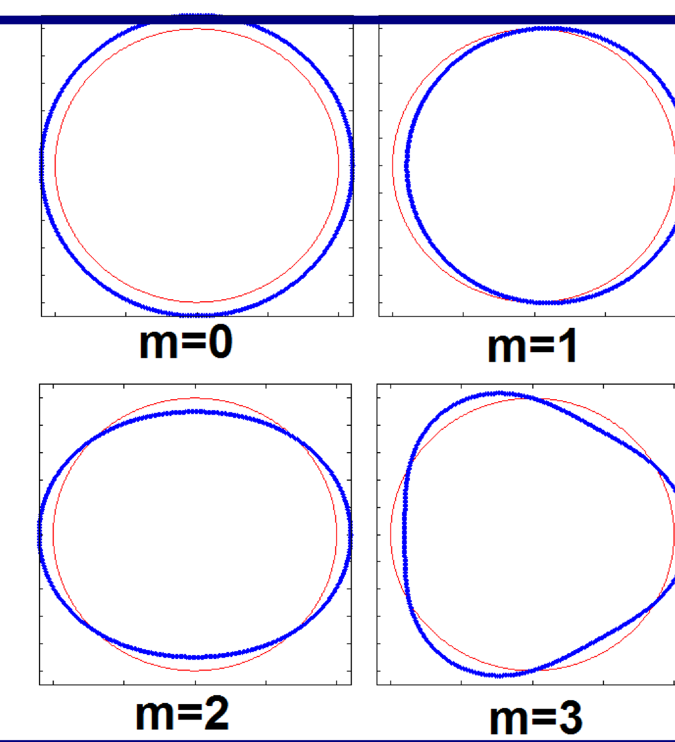
Mode appears to have $k_{||} = 0$. Here, we average over the axial direction and arrange frames in time (x=time).

83G background field

100G background field

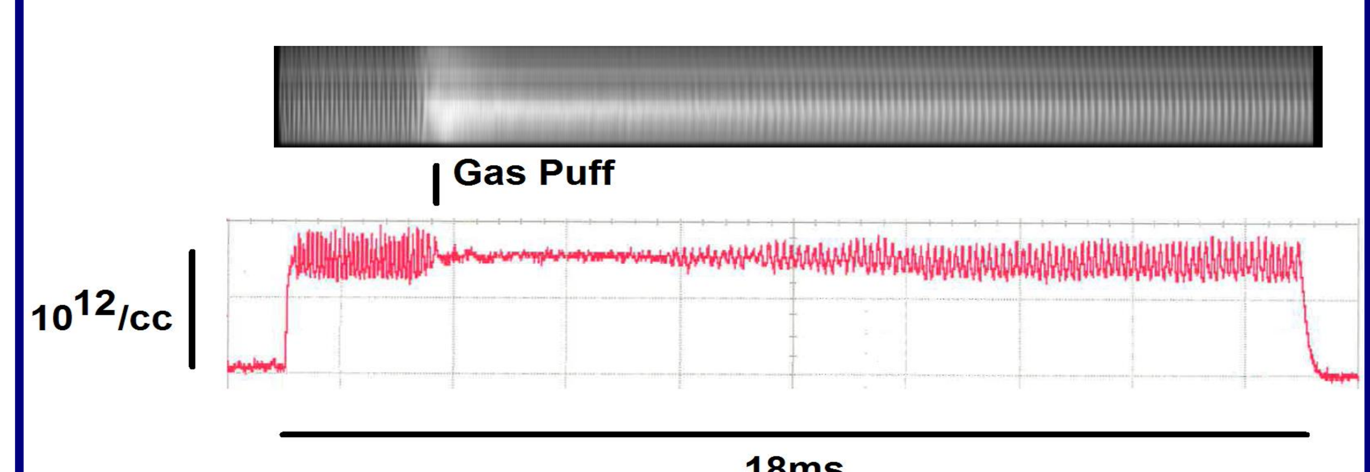


Speculation



The mode is certainly low azimuthal mode number, m=1 or m=2.
Fluting modes are a consequence of a pressure gradient and unfavorable magnetic curvature. Flute modes are observed and predicted to occur in high-β mirror configurations.
Rotational instabilities with m=2 are predicted[2] to occur in FRC devices in the parameter regimes of interest to this experiment. The driving force is the centrifugal potential of the spontaneous rotation of the plasma.
We speculate that the inverse $|\vec{B}|$ dependence on the frequency is due to the $\vec{E}X\vec{B}$ drift of the plasma, $V \propto B^{-1}$.
We speculate that the gas puff suppression is due to ion slowing down on neutral atoms.

Gas Puff



Hydrogen gas is introduced at different times. Above, 3ms into the pulse. Oscillations are suppressed for ~5ms

Future Work

Multiple azimuthal capacitive probes and fast camera tomography:

- Azimuthal mode number. m=1? m=2? Both?
- Direction of rotation. Ion diamagnetic? Electron diamagnetic?

Time-resolved X-ray spectra and gas puff time scan:

- Gas puff suppression mechanism
- Effect of oscillation on temperature and therefore confinement.

References

[1] S. Cohen et al., **AIP Conference Proceedings** 1406, 273 (2011); doi: 10.1063/1.3664976

[2] S. Harned, **Physics of Fluids** 26, 1320 (1983); doi: 10.1063/1.864254