Azimuthal Kinetic Ion Oscillations in a Magnetized Hollow Cathode Discharge

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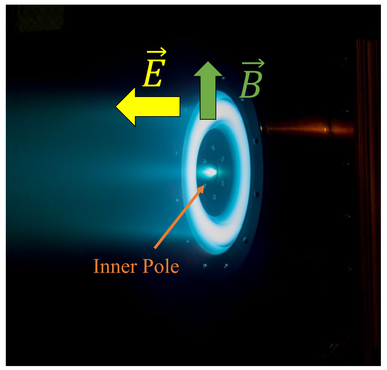
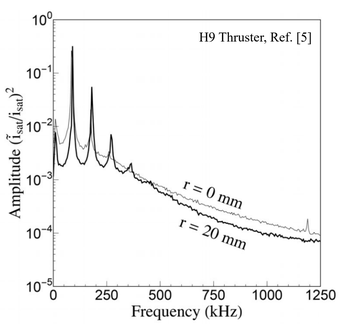
Motivation: Pole Erosion

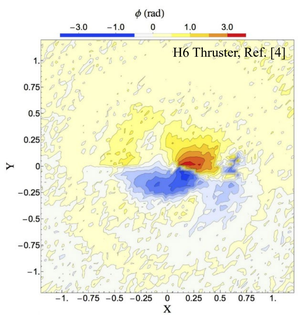


- Hall Thrusters with magnetic shielding exhibit erosion of their inner front pole, potentially limiting device lifetime [1].
- This pole erosion has been tied to anomalously large ion temperatures near the pole [2].

- Lower-hybrid plasma waves have been proposed as a mechanism for this anomalous ion heating [3].
- However, it is possible that other lower-frequency plasma waves also contribute to ion heating near the magnetic poles.

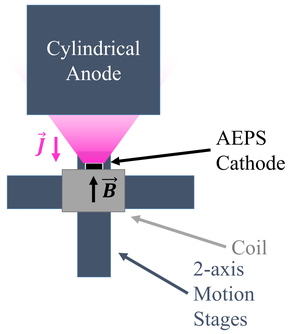
Azimuthal Cathode Waves

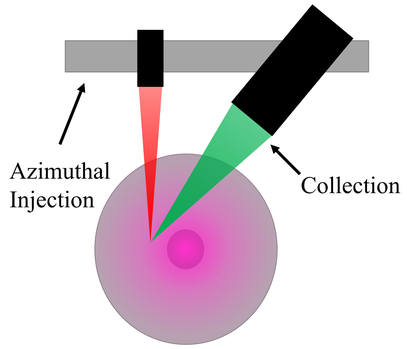




- Prior studies have demonstrated azimuthal waves (~100 kHz) in magnetized Hall thruster cathodes [4,5].
- These waves were identified with a gradient-driven fluid instability which sources energy from diamagnetic electron drift.
- Such waves could accelerate and heat ions.

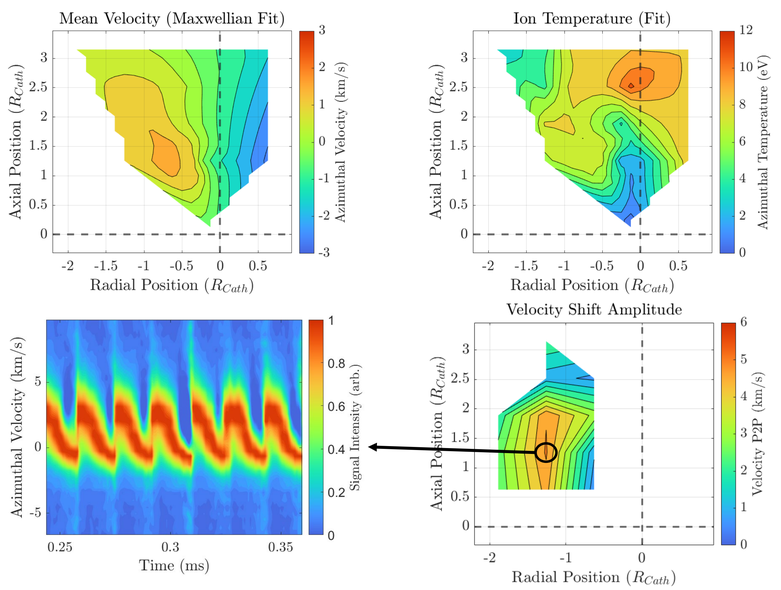
Time-Resolved LIF





- We measured the gradient-driven cathode mode in the Advanced Electric Propulsion System (AEPS) hollow cathode with a magnetic field to mimic Hall thruster operation at the Jet Propulsion Laboratory.
- We used laser-induced fluorescence (LIF) velocimetry with a transfer-function averaging approach [6] to measure the time-resolved azimuthal ion velocity distribution.

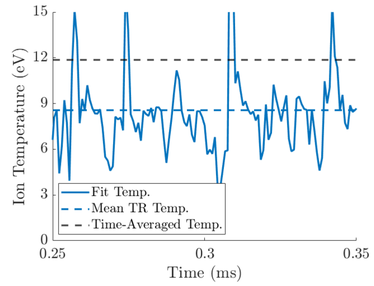
Results



(Dimensions normalized to cathode keeper radius)

Discussion

- Ions are accelerated to a time-averaged swirl velocity of 1-2 km/s, with time-averaged ion temperature of ~8-10 eV.
- Time-resolved LIF reveals large coherent waves (60 kHz) which shift the mean velocity of the ion distribution.
- The amplitude of these ion oscillations are localized off-centerline near the cathode exit.
- The time-averaged ion temperature appears larger than the instantaneous temperature by ~3 eV due to the wave effect.



Conclusions

- In a standalone cathode, gradient-driven waves contribute to moderate ion acceleration and heating, but the energies involved are not large enough to fully explain pole erosion.
- Future studies will repeat similar measurements in a full Hall thruster discharge to characterize the impact of this azimuthal ion heating on sputtering yield models.

References

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