Measurements of Dispersion and Growth Rate of Plasma Waves in a Hollow Cathode

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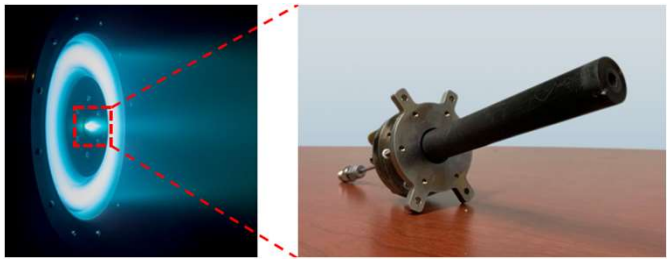
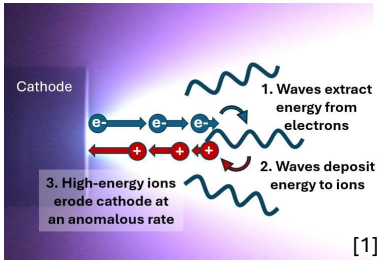
Background



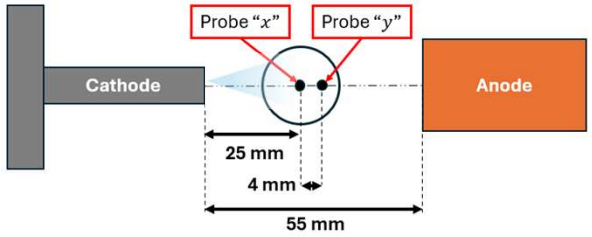


[1]

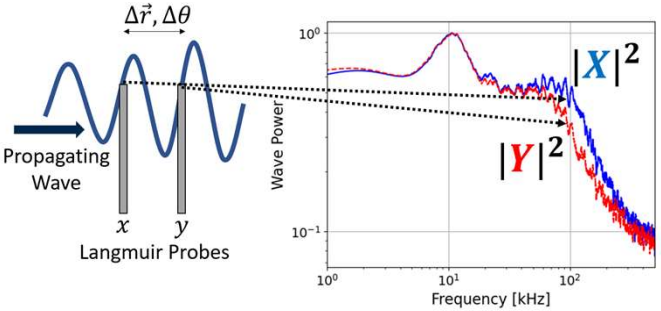
- Hollow cathodes are commonly employed as plasma sources
- Ion acoustic (IA) waves have been identified as dominant instability mode influencing ion and electron dynamics [2]
- IA waves linked to non-classical resistivity for electrons and anomalous heating of ions [2]
- Direct relationship between waves, electron resistivity, ion heating no well understood

- **There have been no direct experimental measurement of the frequency-resolved growth rate of ion acoustics waves to date**
- Current methodologies to evaluate wave-induced effects assume a *theoretical* linear growth rate in lieu of experimental measurements
- The need is apparent to **directly measure growth rate of IA waves** to validate current approach and to shed more light on cathode plasma dynamics

Experimental Methodology

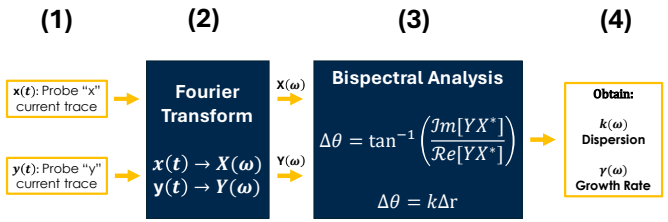


Experimental apparatus showing cathode, probes, and anode



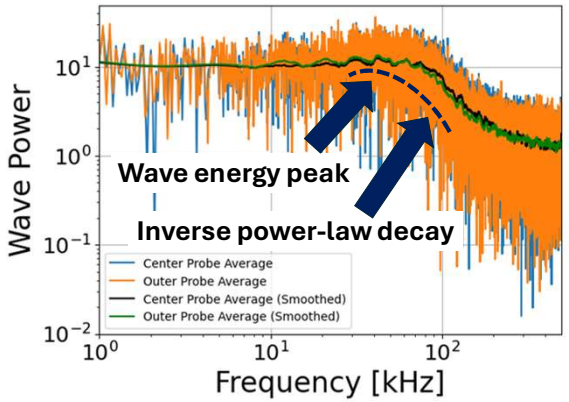
Wave properties are inferred through 2-probe correlation

Analysis Technique



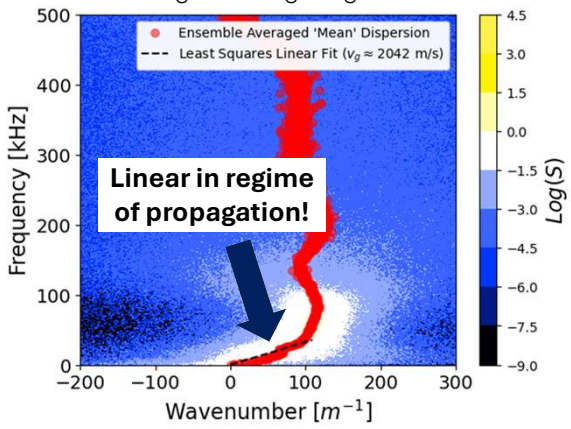
Results

The power spectra is used to confirm the dominant frequencies of waves, i.e. **confirm the regime of wave propagation**



PS shows a peak in the regime of wave propagation followed by inverse power decay, **commensurate with IA turbulence**

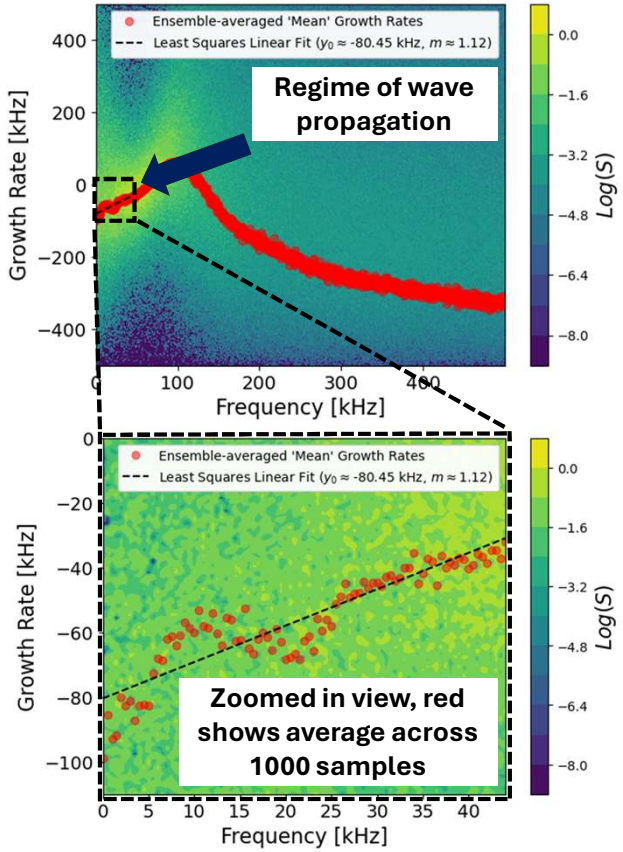
Measuring the dispersion allows us to **confirm the type of wave**. Ion acoustic waves theoretically exhibit linear dispersion in the long wavelength regime



Measured dispersion confirms presence of ion acoustic waves

Results (continued)

The growth rate represents how fast the wave extracts momentum from electrons. **Ion acoustic waves theoretically exhibit linear growth rates at long wavelengths.**



Measured growth rates largely linear in regime of propagation

Conclusions

- Confirmed presence of IAT from power spectra and dispersion plot
- **Obtained the first experimental measurements of frequency-resolved ion acoustic wave growth rate**
- Measured growth rate appear largely linear, validating current methodology of assuming theoretical linear growth rate
- Inferred plasma parameters commensurate with previous experimental measurements

$T_e = 1 - 3.6$ [eV] $\quad M_e = 0.27 - 0.55 \quad \nu_{i-n} \approx 128\ kHz$

Acknowledgements

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References

[1] M. P. Georgin, "Ionization Instability of the Hollow Cathode Plume," thesis, 2020
[2] Goebel, D. M., Katz, I., & Mikellides, I. G. (2024). *Fundamentals of electric propulsion*. Wiley.