National Aeronautics and Space Administration

Near Field Probe Measurements in the Plume of a NEXT Ion Thruster

Neil Arthur

Vantage Partners LLC, Brook Park, OH, 44142

George Williams

NASA Glenn Research Center, Cleveland, OH, 44135

International Electric Propulsion Conference

9/19/2019

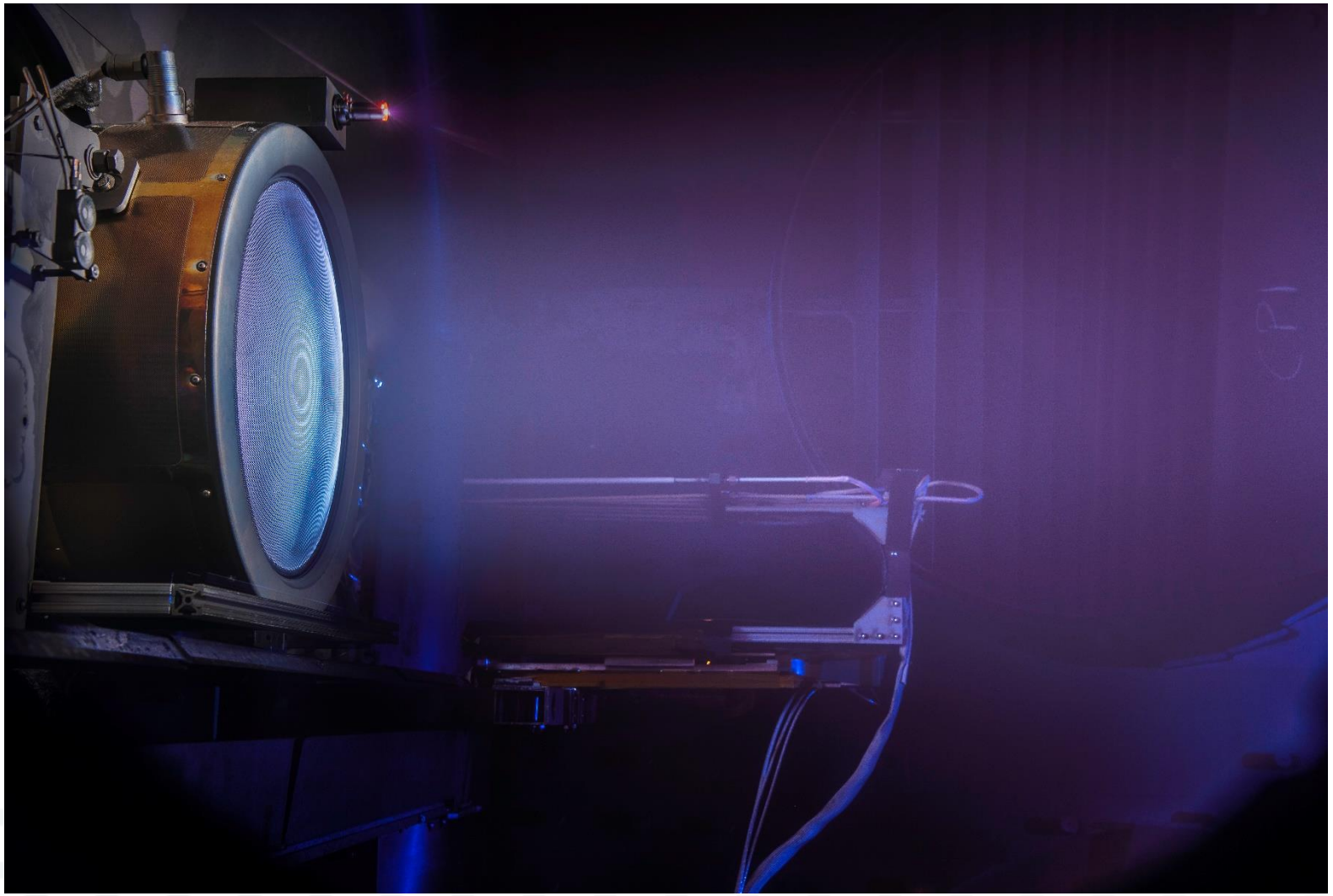
Vienna, Austria

NEXT-C

NASA'S EVOLUTIONARY XENON THRUSTER–COMMERCIAL

Outline

- Introduction
- Test Setup
- Electron Temperature
- Plasma Potential
- Conclusion

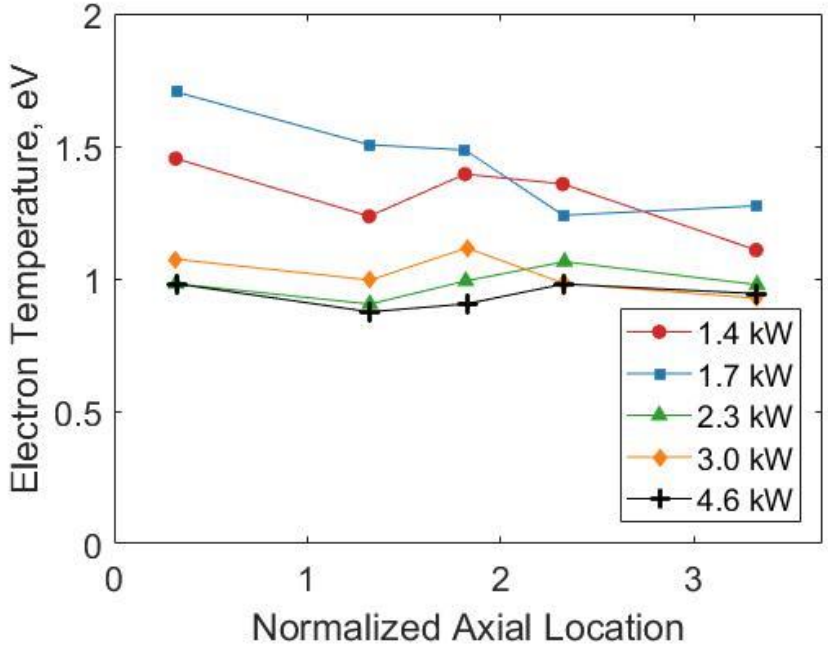


Introduction

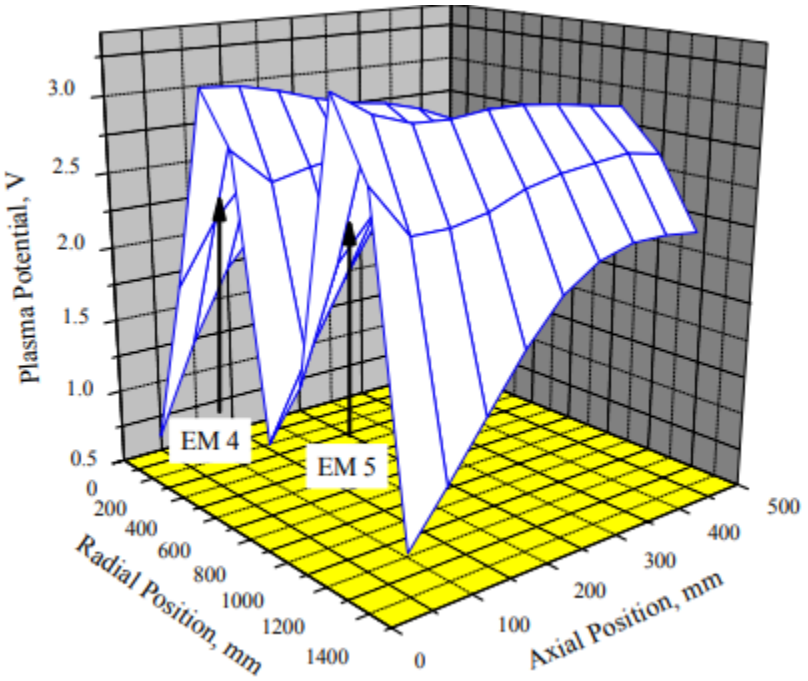
- NEXT has a broad throttle range and a demonstrated lifetime in excess of 50,000 h
- NASA's effort to commercialize through the NEXT-C contract requires application specific lifetime predictions
  - Testing specific throttle profiles over the course of years for each application is not feasible
  - The NEXT-C program has chosen to apply lifetime models that are anchored to ion thruster testing data
- Both NASA GRC and JPL are developing NEXT lifetime models

Introduction

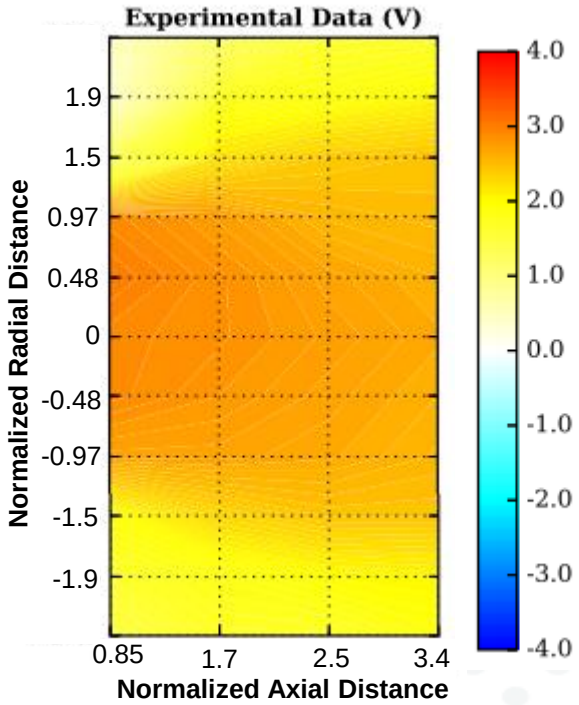
- Past measurements in the beam of an ion thruster have been made at > 0.1 thruster radii



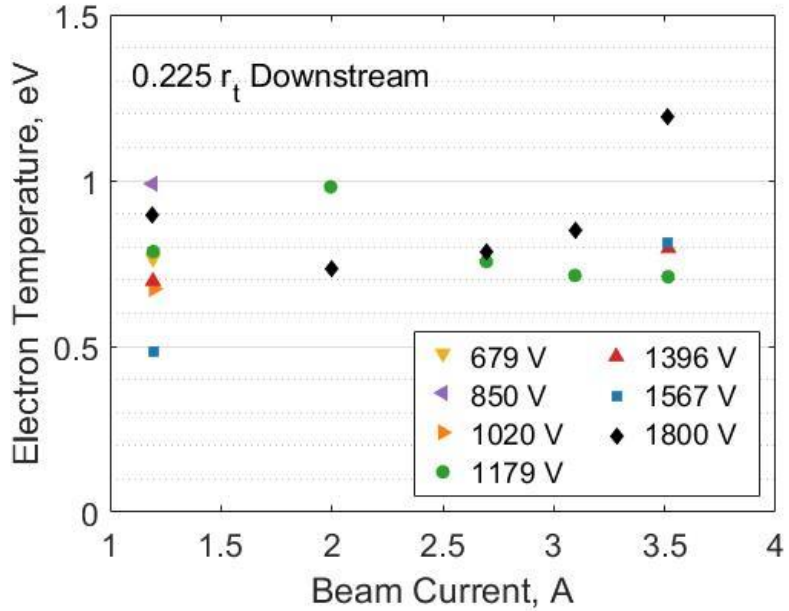
Foster, et al. AIAA-2000-3812



Foster, et al. AIAA-2006-5181



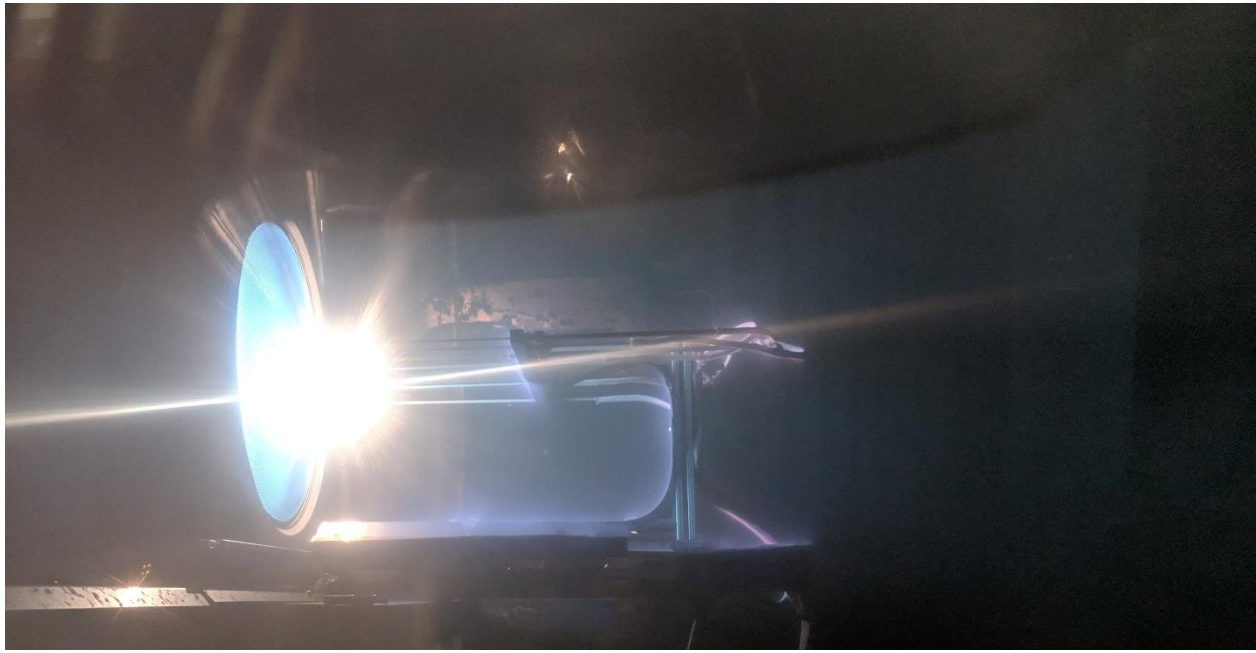
Bermudez and Jermakian, IEPC-2017-281

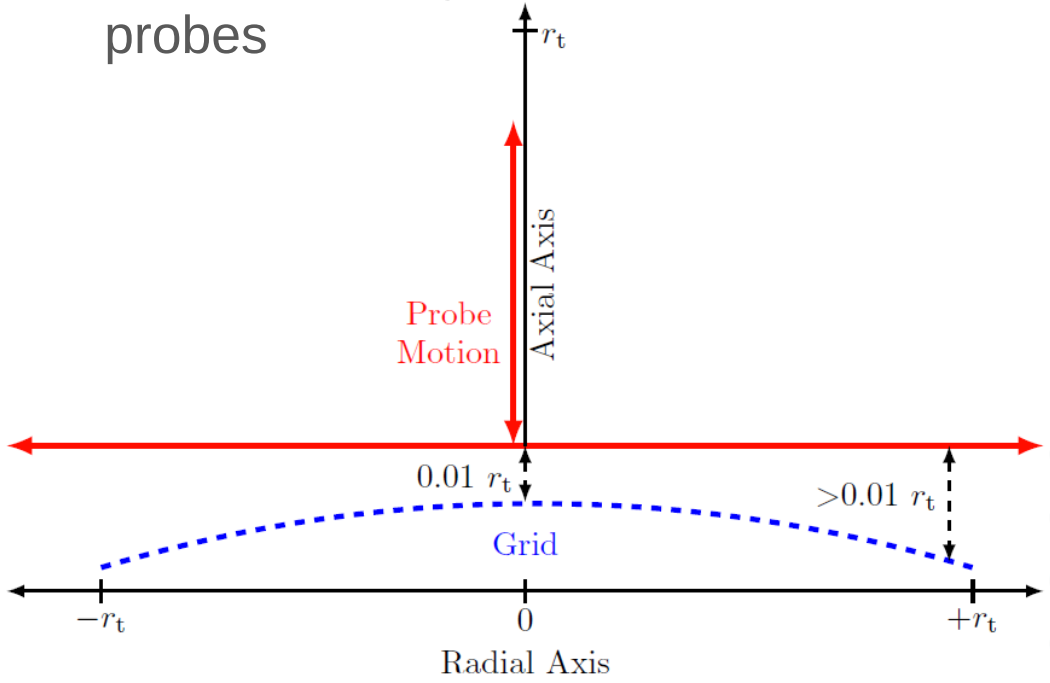


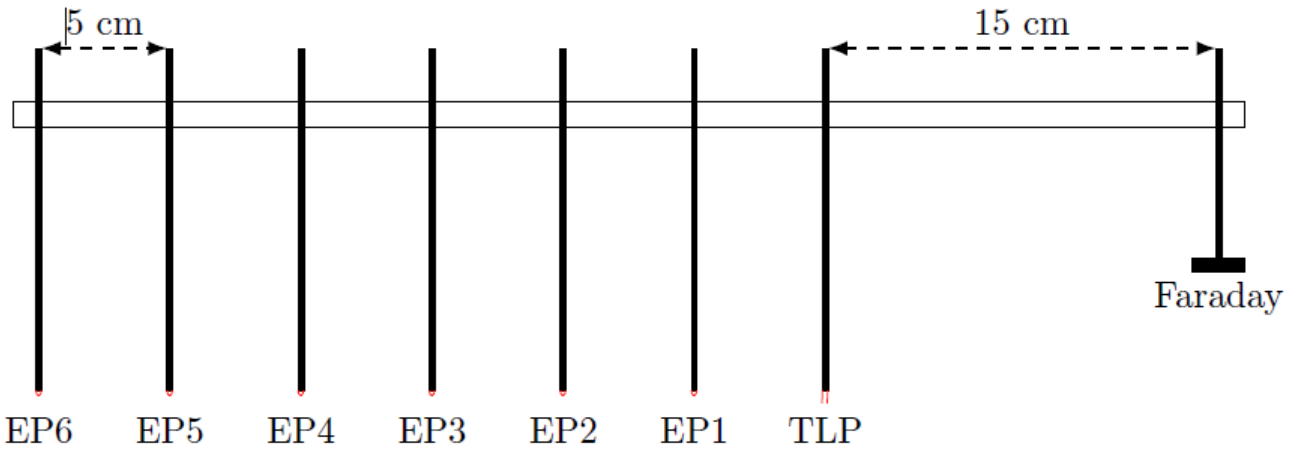
Kamhawi, et al. AIAA-2004-3792

Test Setup

- Testing at NASA GRC in VF-16
  - 2.75 m diameter x 4.5 m long vaccum chamber
- Engineering model NEXT thruster
- A probe rake consisting of a Faraday probe, triple Langmuir Probe, and 6 emissive probes was swept in front of the thruster
- Two linear stages were used to move the probes

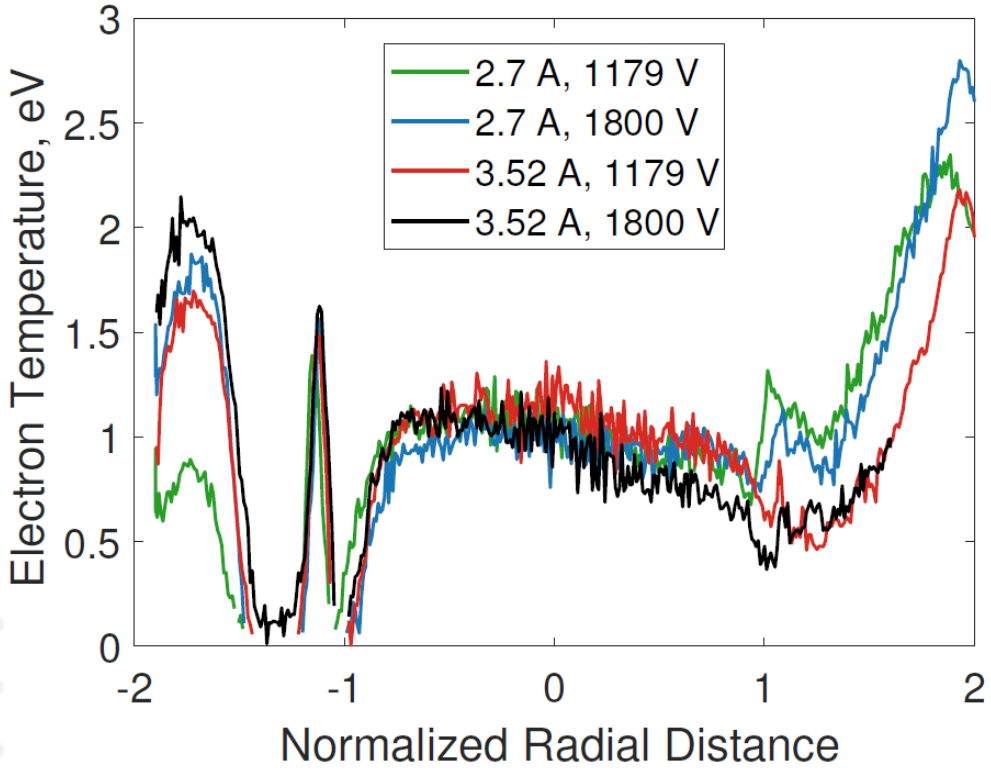


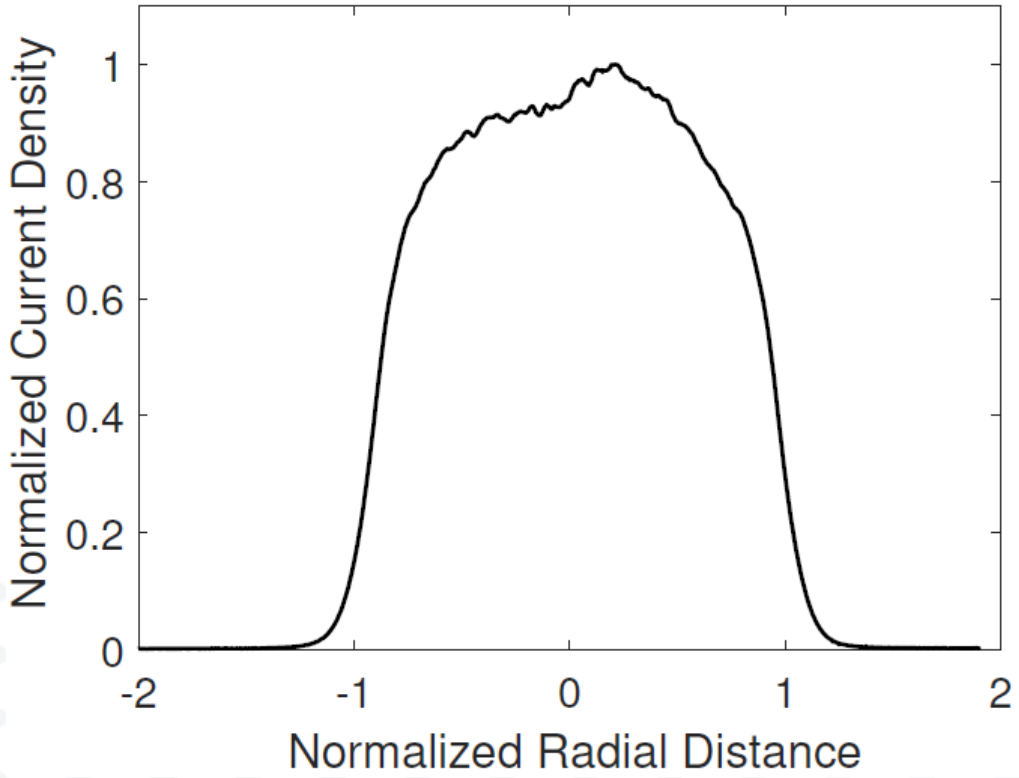




Electron Temperature

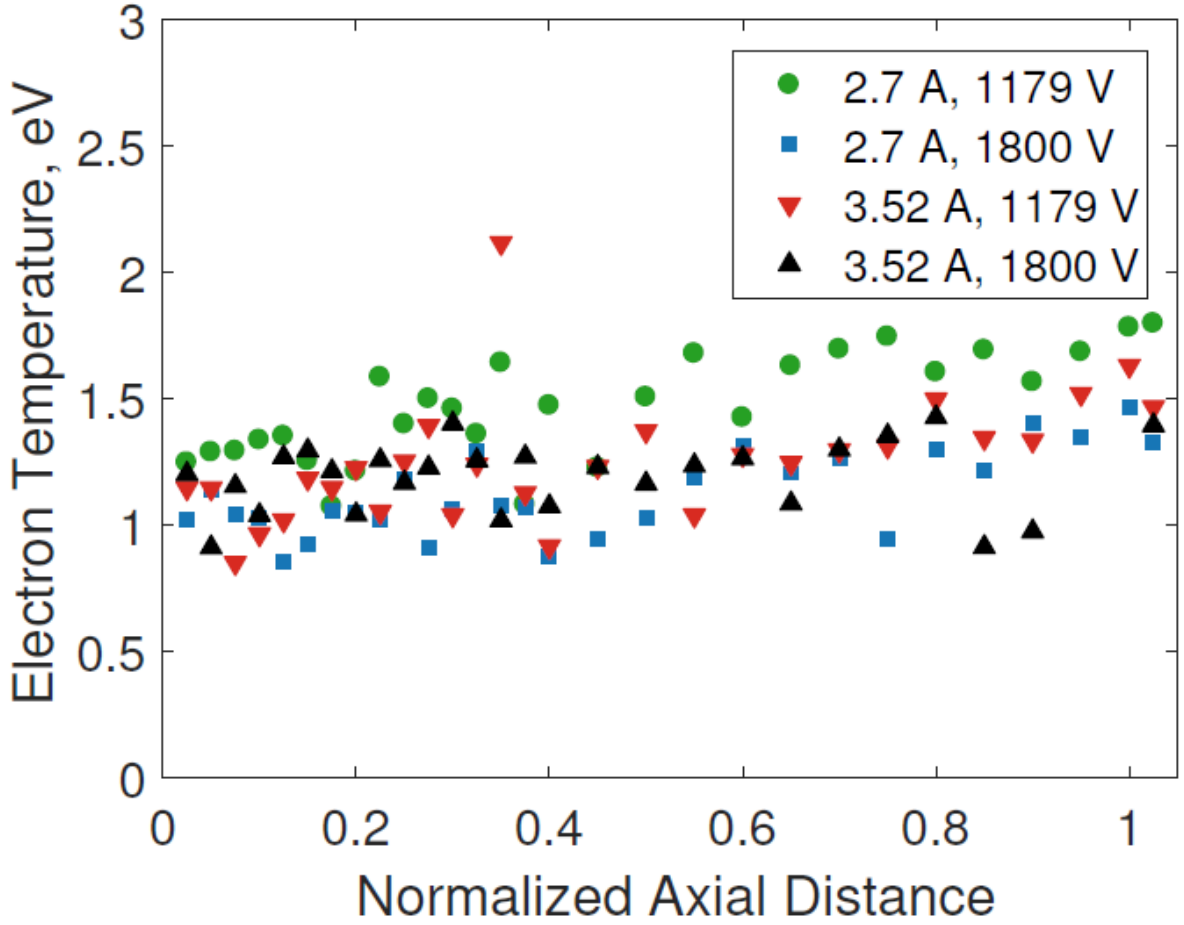
- Radial electron temperature at various power levels shows little trend
- Slight downward trend towards the right side of the thruster may be due to asymmetries in the beam current density profile





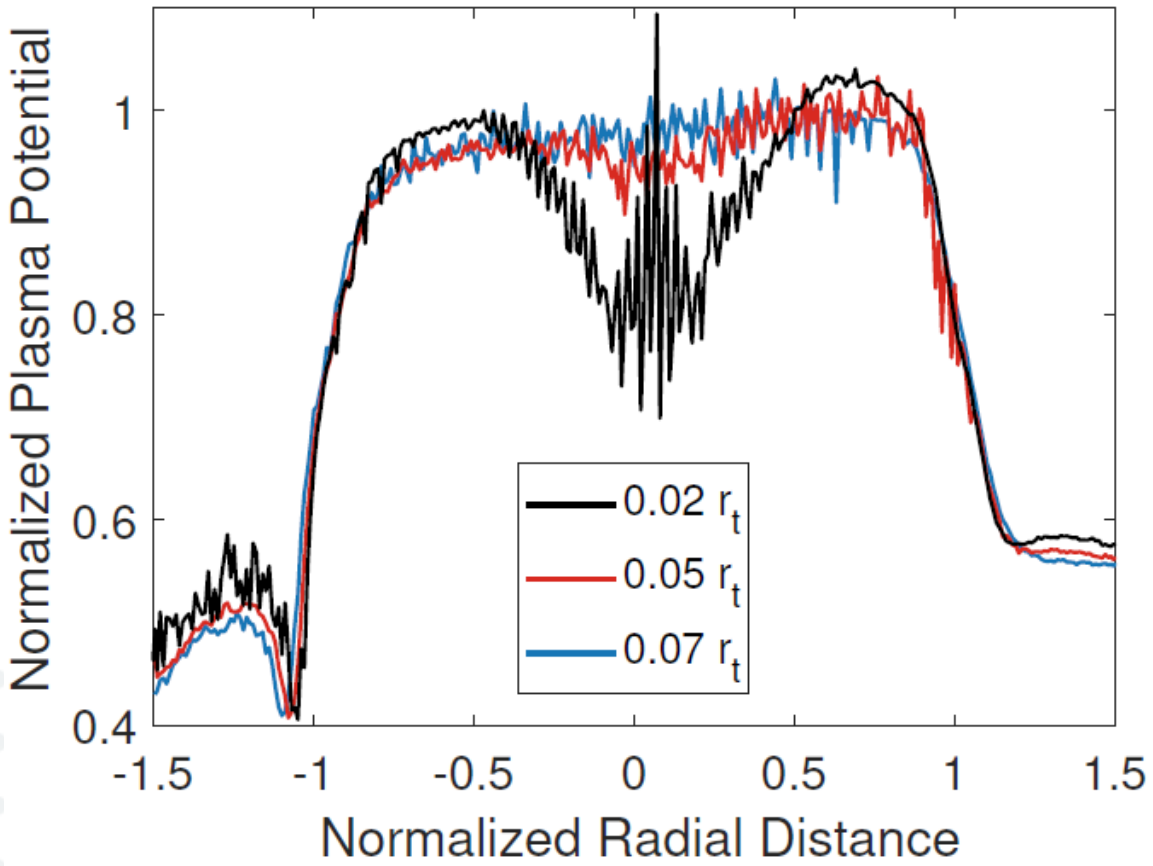
Electron Temperature

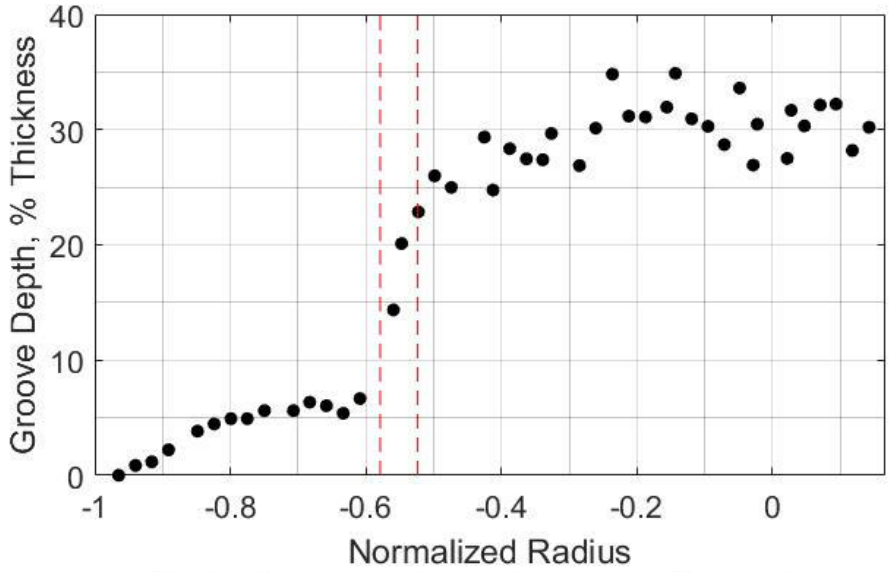
- Axial profile shows no trend with power level
- Past ion thruster studies have attributed changes in T_e with power level to changes in coupling and neutralizer keeper voltage
  - $\Delta V_g = 0.2$ V
  - $\Delta V_{nk} = 0.7$ V
- NEXT's throttle table (v11) features relatively constant V_g and V_{nk} for $J_b > 2.7$ A



Plasma Potential

- Radial profile nearest to the grid shows the plasma potential dips towards the centerline

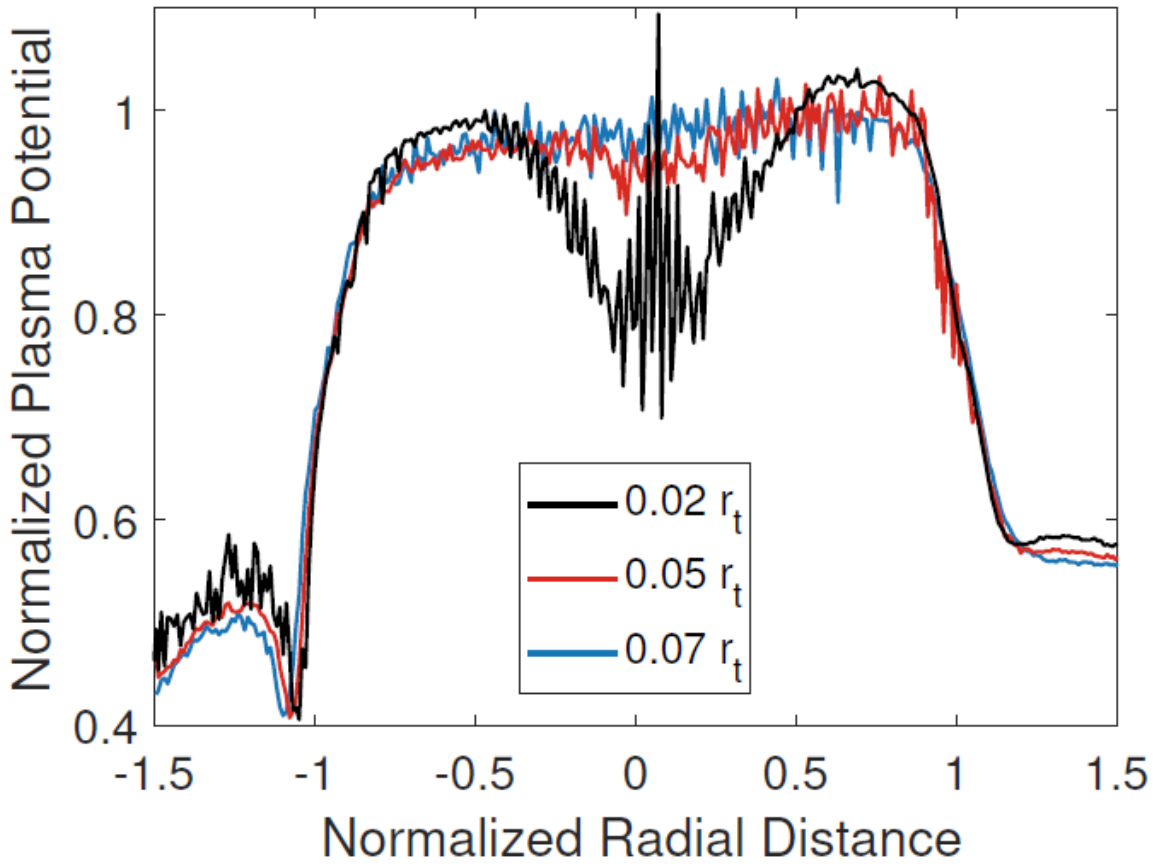


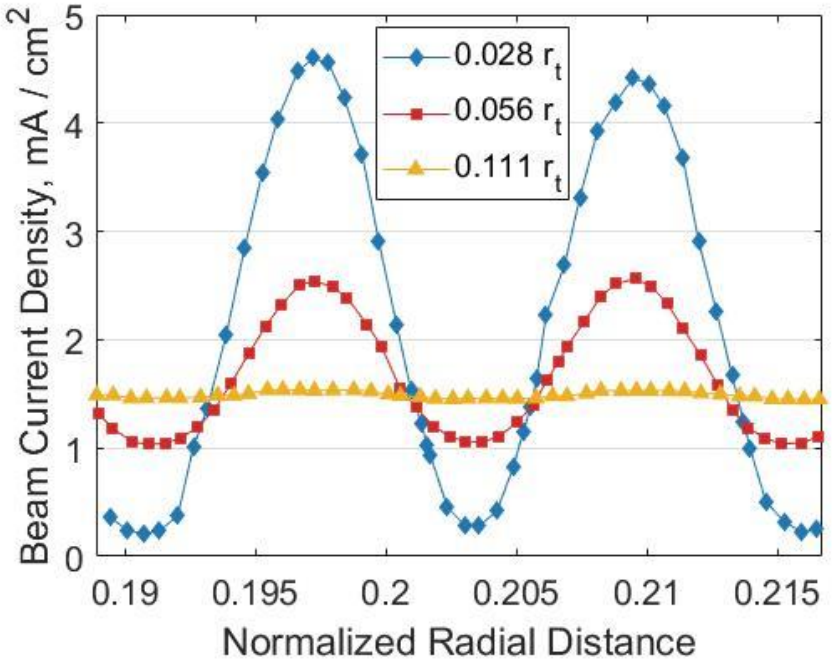


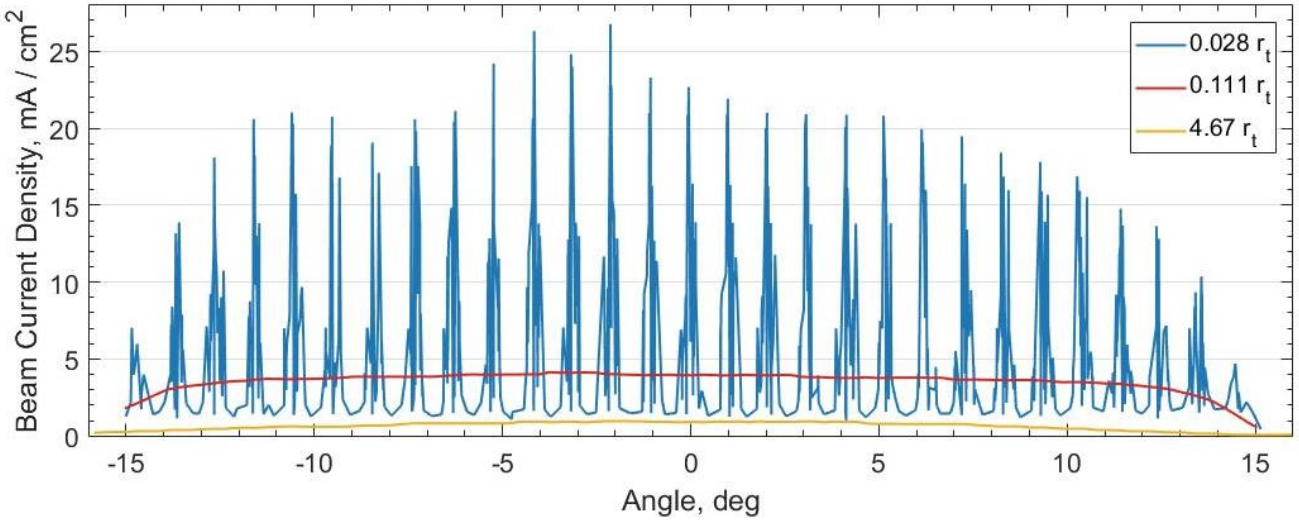
Soulas and Shastry, AIAA-2016-4632

Plasma Potential

- At the closest approach individual beamlets are visible
- Probe diameter ≃ Aperture diameter



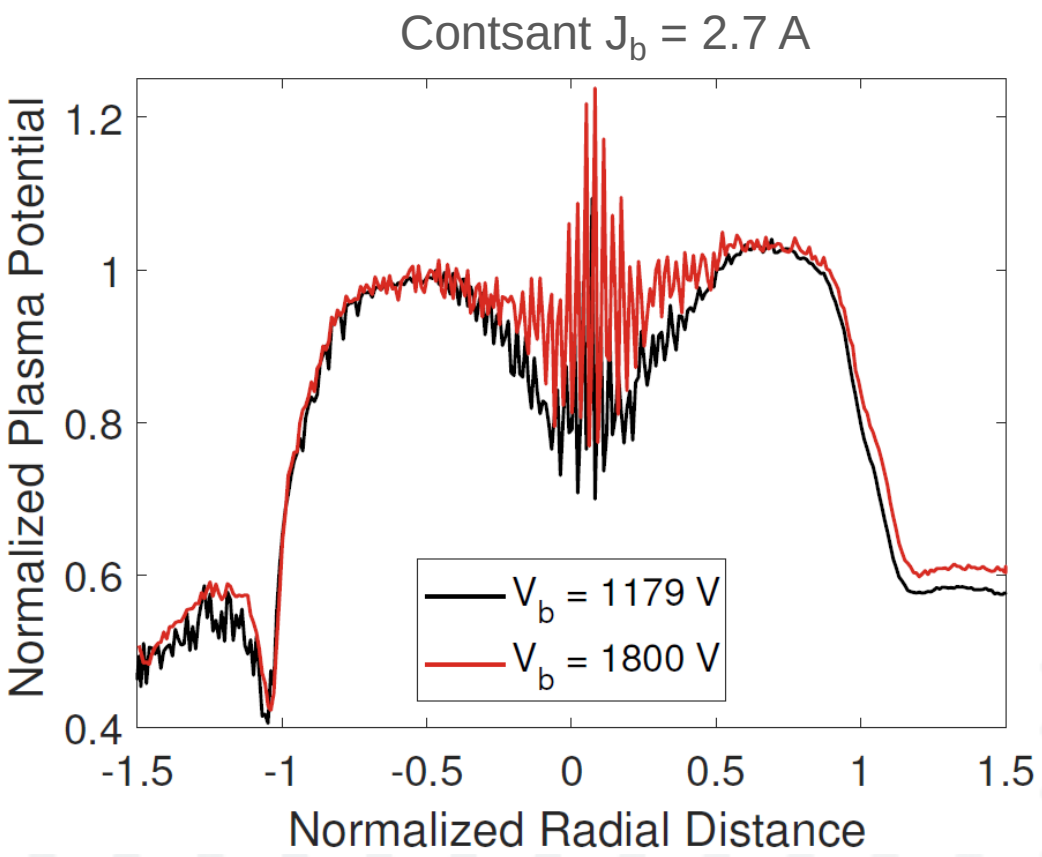


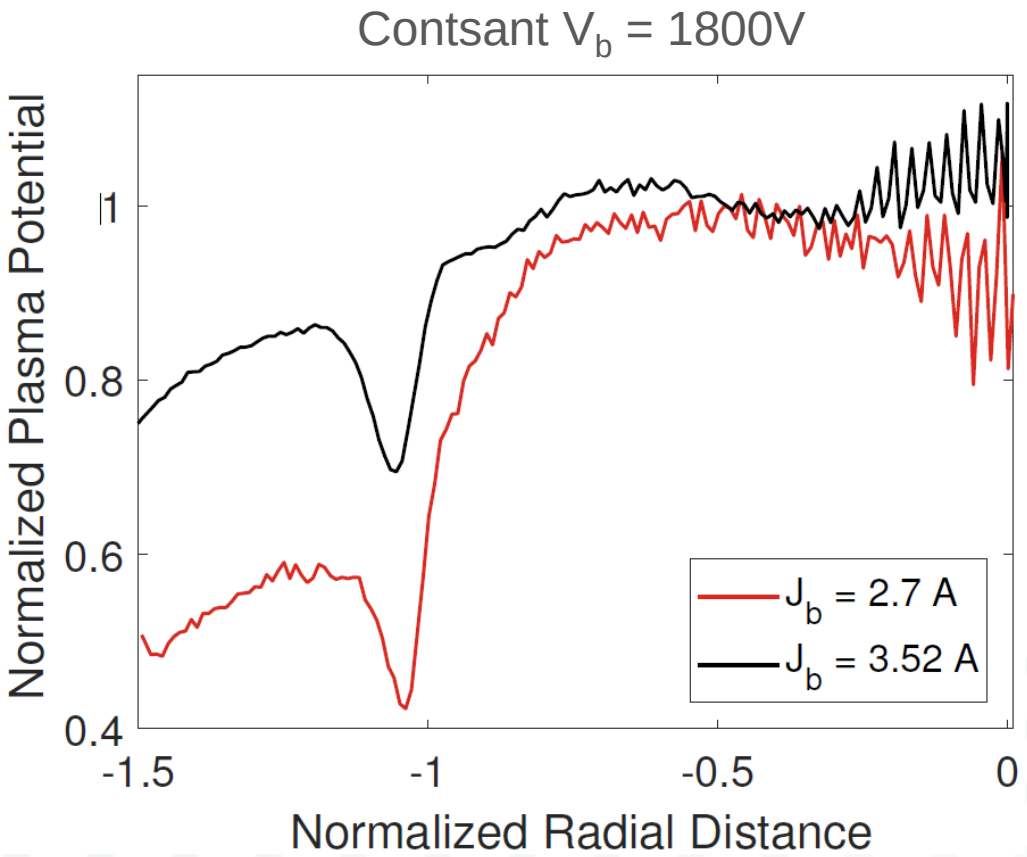


Pollard, et al., AIAA-2010-6779

Plasma Potential

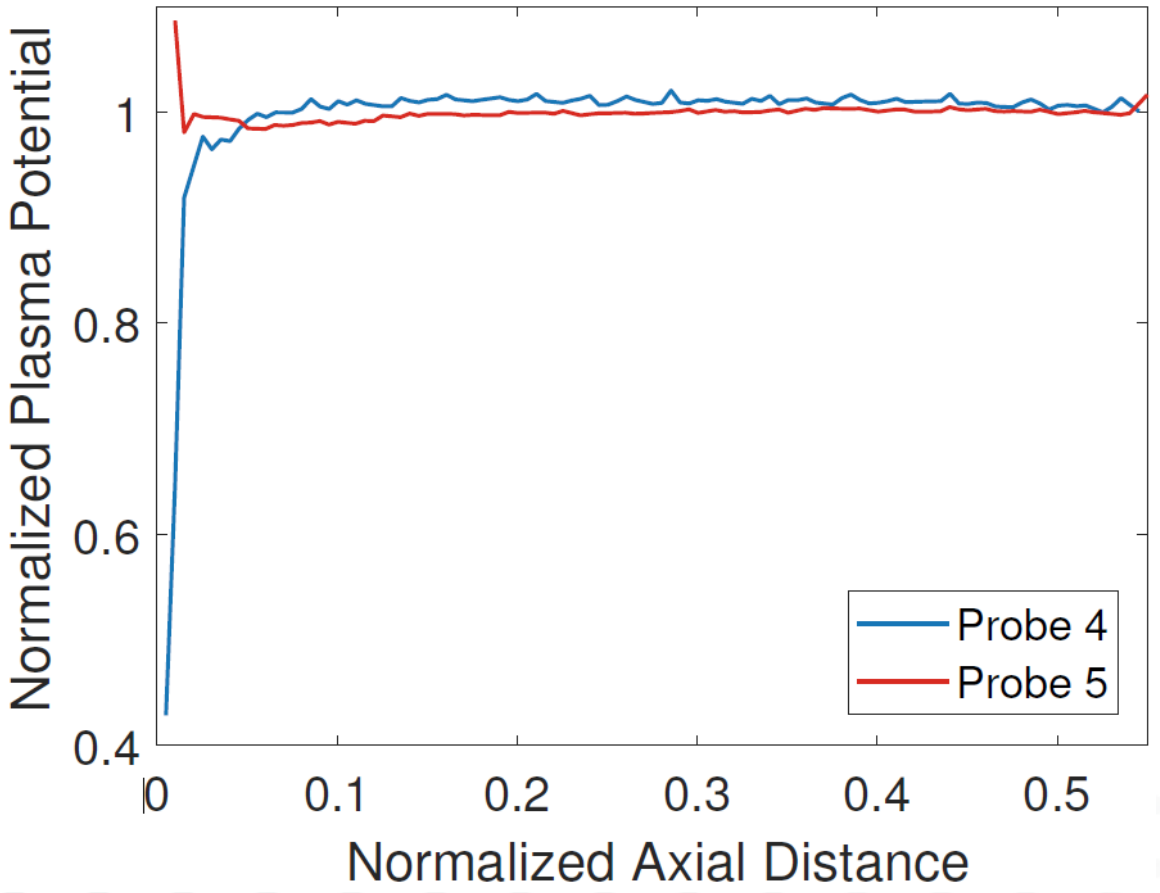
- At both constant J_b and V_b, the centerline potential increases with increasing power





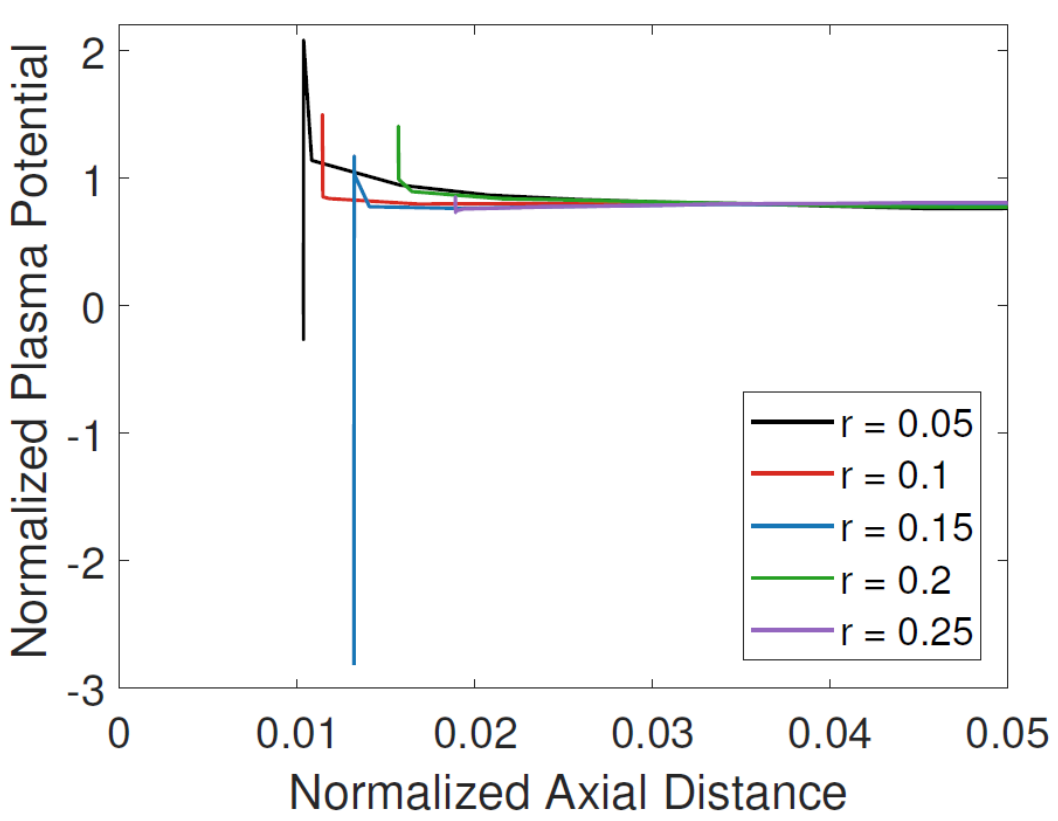
Plasma Potential

- The axial plasma potential profile should fall off as the probe approaches the accel grid at -200 V
- Due to the uncertainty and error in the probe alignment process, some probes show a potential spike near the grids
  - It is possible to discern individual beamlets near the grid, and these beamlets appear as increases in plasma potential
  - As probe 4 approaches it is between beamlets
  - As probe 5 approaches it is within a beamlet

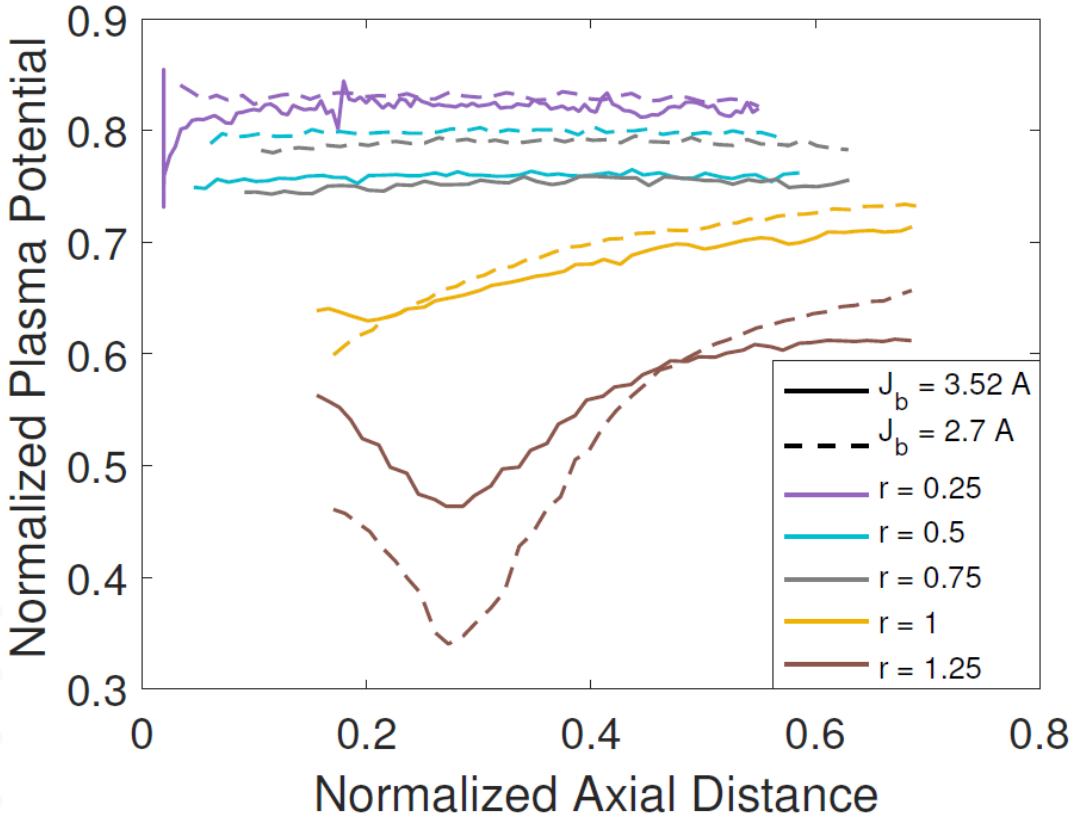


Plasma Potential

- Axial profile off centerline at various radial distances
- Near to the thruster centerline the plasma potential increases and then decreases



- Near mid-radius the profile is very flat
- Towards the edge the plasma potential decreases
- Outside the beam, there is a small potential well

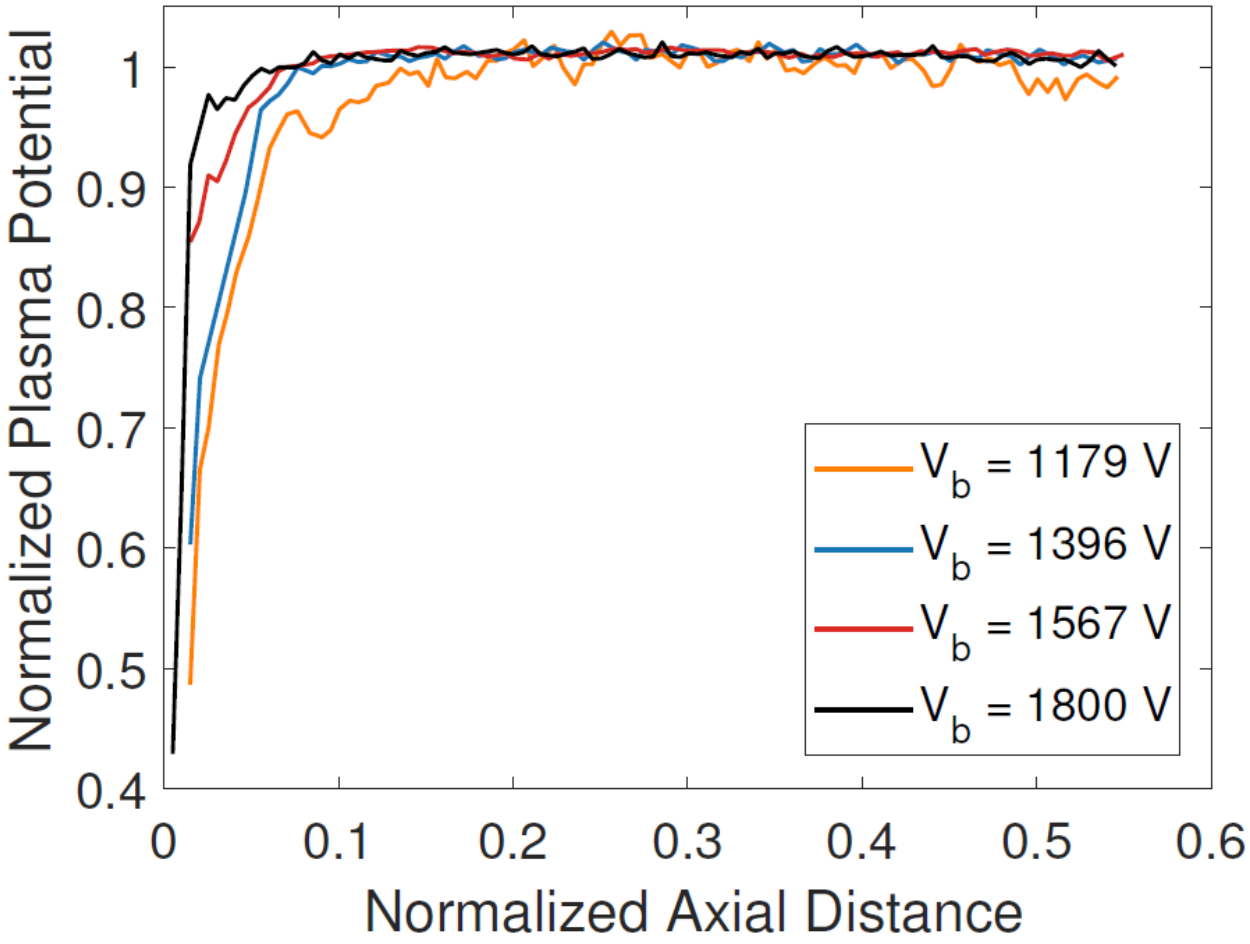


Plasma Potential

- For constant J_b, as V_b increases the drop in plasma potential occurs closer to the grid
  - V_a is ~constant
- Kaufman's decel length is the distance from the accelerator grid to the neutralization plane
  - Extent of the accel sheath

$$\ell_{\mathrm{d}} = \ell_{\mathrm{a}} \sqrt{\frac{1 + 3\sqrt{R} - 4R\sqrt{R}}{F_{\mathrm{s}}} \frac{j_{\mathrm{b}}}{j_{\mathrm{CL}}}}$$

$$R = \frac{V_{\mathrm{N}}}{V_{\mathrm{T}}}$$



- Plasma potential fall off distance agrees with expected trend of R-ratio changes

Conclusion

- The plasma properties downstream of a NEXT ion thruster were measured using emissive and triple Langmuir probes
- In front of the thruster the electron temperature remained fairly constant
  - There was also no noticeable trend with power
  - Attributed to the relatively constant V_g and V_{nk}
- Radially, the plasma potential showed a decrease on thruster centerline
  - The magnitude of this decrease was reduced as power was increased
- Axially, the plasma potential was flat up until 0.2 thruster radii
  - Some probes measured the decreasing potential of the accel sheath
  - Other probes measured the increases potential which may be individual beamlets
- At constant J_b, as V_b was increased the extent of the accel sheath was reduced
  - This trend agrees with the decel length theorized by Kaufman, which varies with R-ratio

This work was completed as part of the NEXT-C project, which is supported by the Planetary Science Division of the Science Mission Directorate, NASA Headquarters and awarded to Aerojet Rocketdyne and ZIN Technologies.