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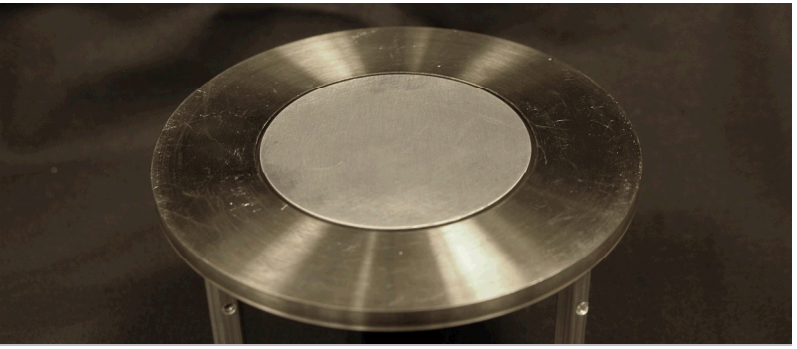
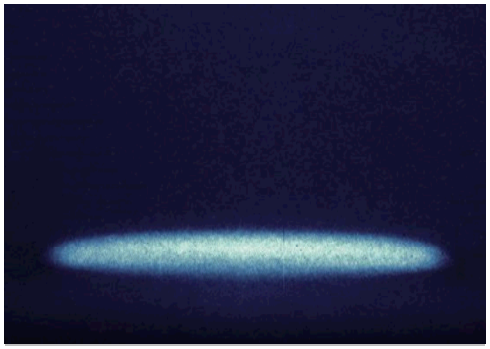


Bulk plasma effects of the electron sheath

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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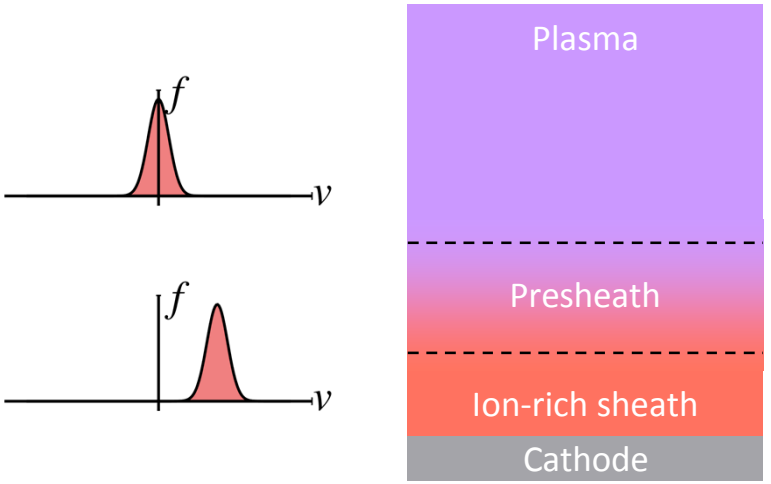
Outline

- Conventional sheath structures
- Experimental evidence for bulk effects
- Kinetic simulations of electron sheaths
- Dynamic electron sheath behavior
- Summary

see also NR3.00005 in this session for further detail

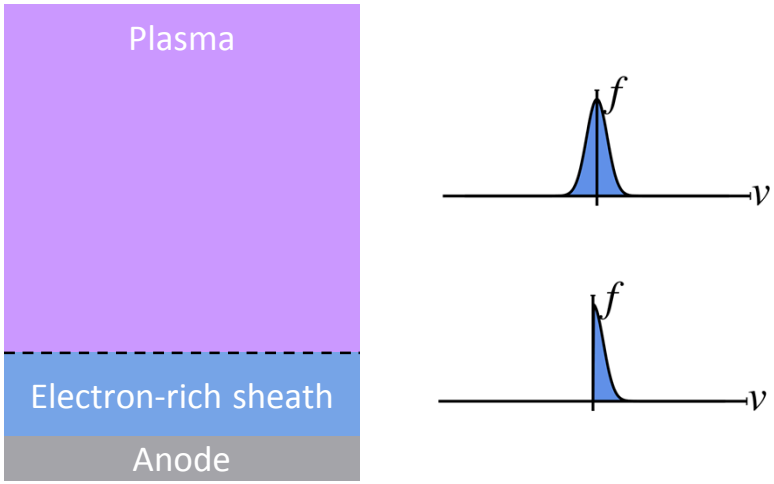
Conventional sheath structures

Ion Sheath



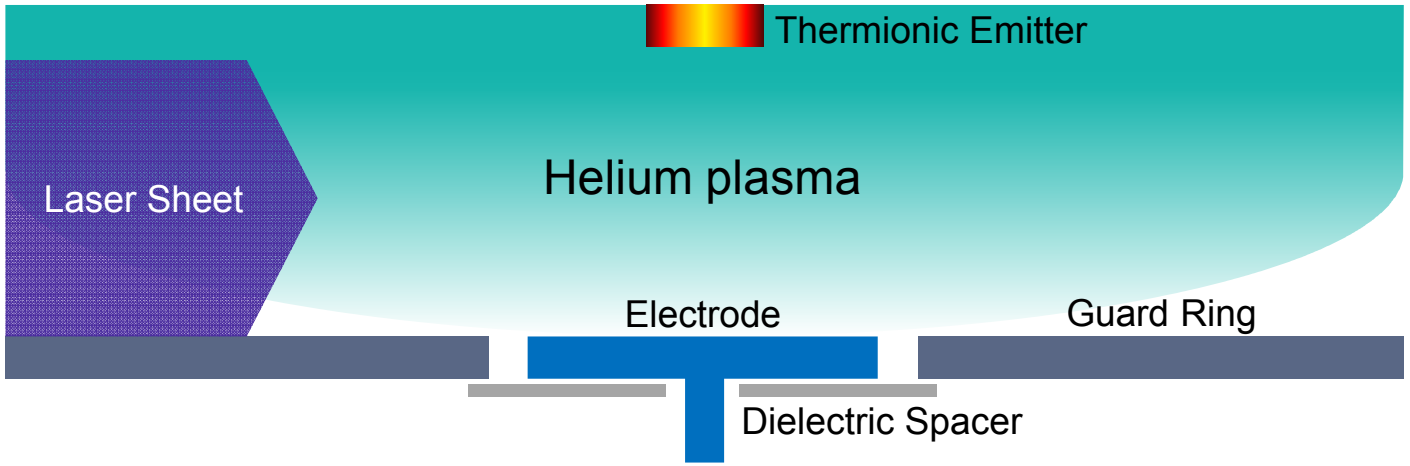
- Boundary *below* plasma potential
- Presheath accelerates ions to Bohm velocity [1]
- Accelerating presheath, length scale determined by collisions

Traditional Electron Sheath

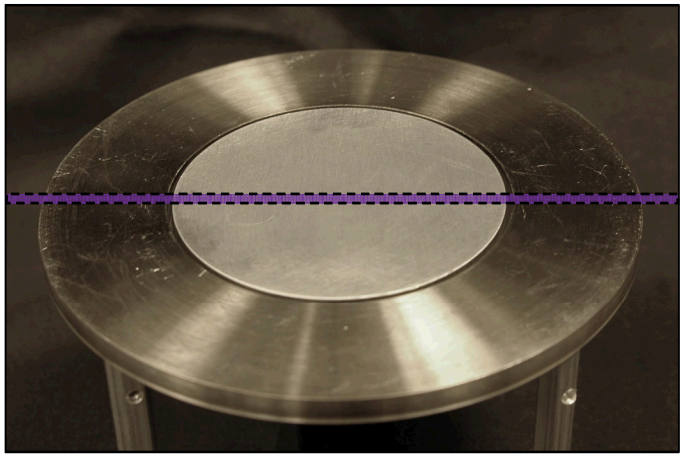


- Boundary *above* plasma potential
- Only thermal flux collected; VDF truncation [2-4]
- No presheath or region of acceleration

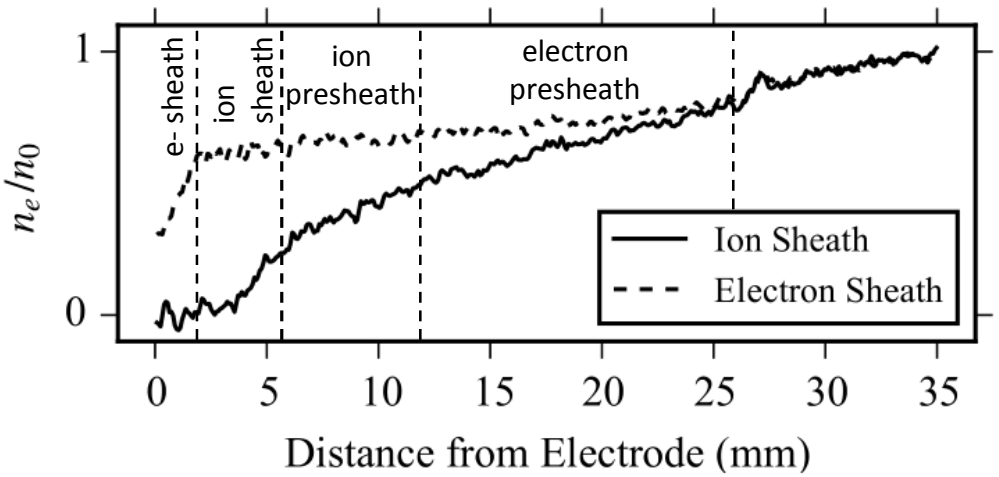
Experimental Setup



- GEC cell (cylindrical volume)
- Sufficiently small (19 mm dia.) [5] embedded electrode
- 20 mTorr He plasma
  - $n_e \sim 3 \times 10^9\ cm^{-3}$
  - $T_e \sim 4$ eV
- 2D electron densities from LCIF [6]



On-axis electron densities



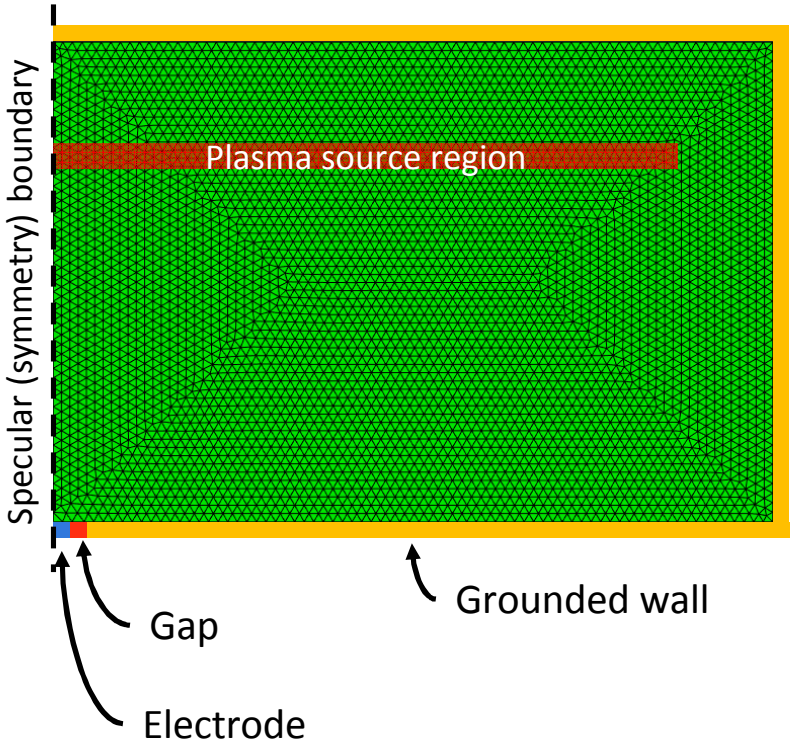
- Ion sheath (-50 V) represents nominal density profile
  - Sheath: 0 – 6 mm
  - Presheath: 6 – 12 mm

- Electron sheath (+15 V) deviates over 25 mm from electrode
  - Sheath: 0 – 2 mm
  - Presheath (?): 2 – 27 mm

[7]

Simulation setup

- Electrostatic PIC-DSMC
- 20 mTorr neutral He
- Plasma sourced to obtain bulk density of 10^9 cm^{-3}
- 2D, 5.0 x 7.5 cm domain
  - Electrode-wall area ratio comparable to experiment
- Neutral-ion elastic collisions
- 50 µs simulation time
  - 20 µs to reach equilibrium
  - 30 µs of averaging



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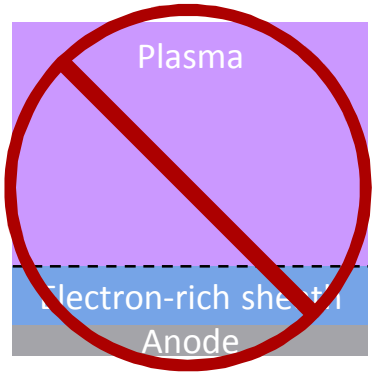
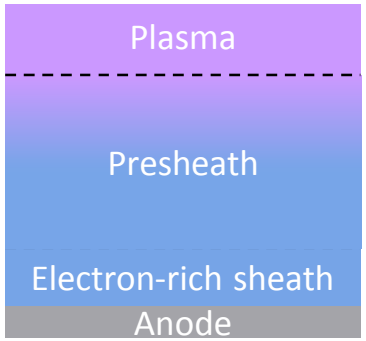
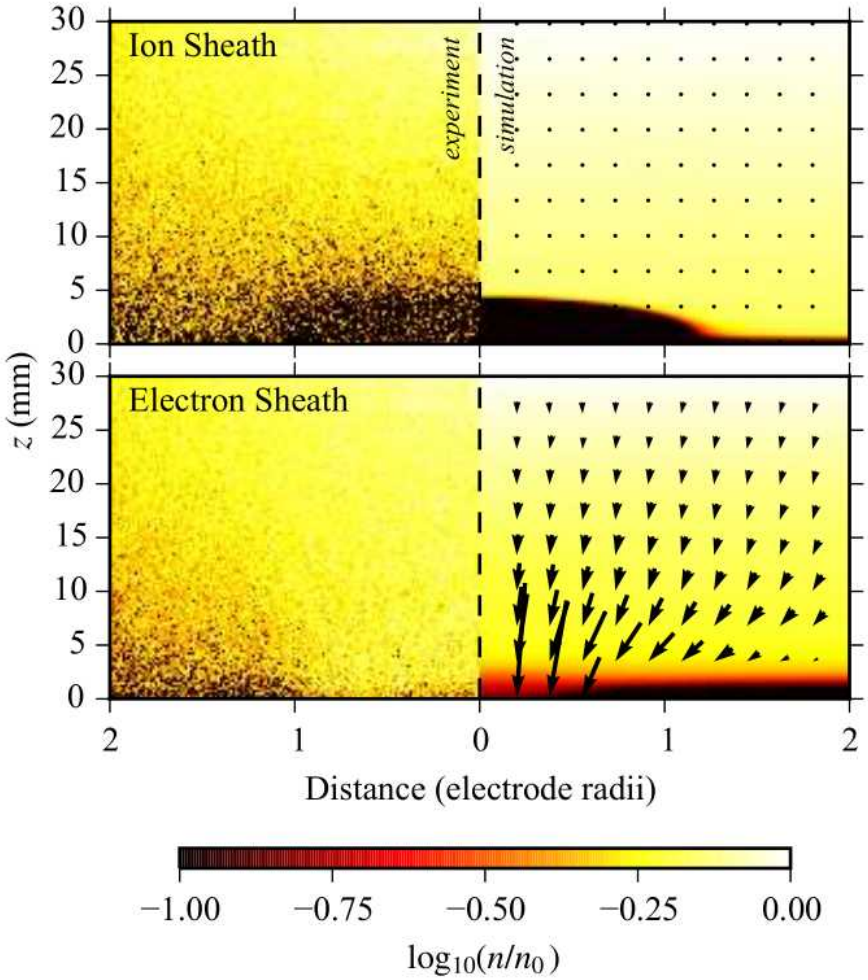
Detailed sheath structure

- Ion sheath as expected
  - Strong depletion of electrons in sheath
  - Confined bulk electrons
- Electron sheath
  - Directed electron fluid flow (from > 60 λ_d away)
  - Funneling/convergence effects







See NR3.00005 for further detail on flow mechanisms

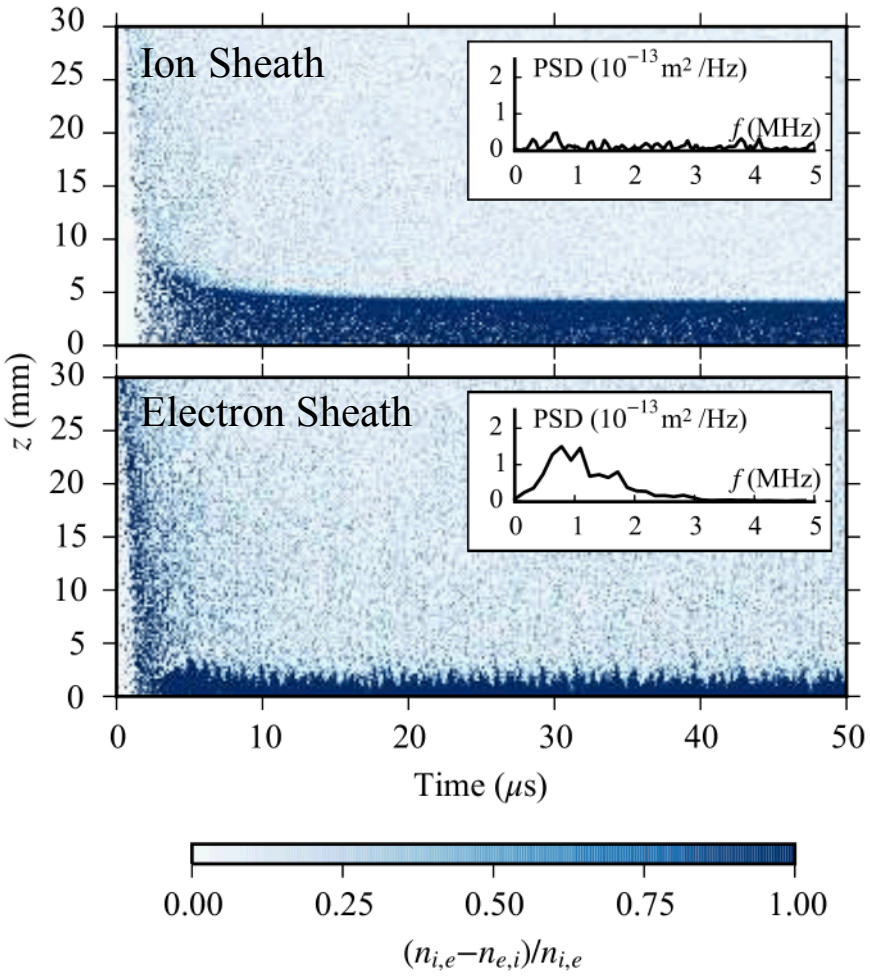
Sheath Dynamics

Electron Sheath

Ion Sheath

Instabilities and sheath edge

- Ion sheath edge stable in time
- Electron sheath edge highly oscillatory
  - Mean location is 2 mm, similar to experiment
  - Power spectrum peaks at 1 MHz
  - Likely a result of ion-acoustic instability
  - Explains previous measurements of noisy current collection by positive probes [8, 9]



[7]

Summary

- Electron sheath forms a distinct presheath analagous to the ion presheath
  - Electron flux collected by positively biased electrode is *not* the random thermal flux crossing the sheath edge
  - Length scale appears much larger (25+ mm vs. 6 mm)
- Strong electron fluid flow drives instabilities far from electrode
  - Frequency analysis is consistent with the ion acoustic instability

Electron sheaths affect electron fluid flow and plasma stability many Debye lengths from the electrode.

Citations

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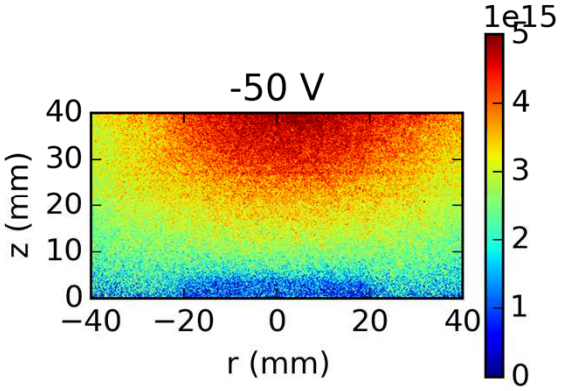
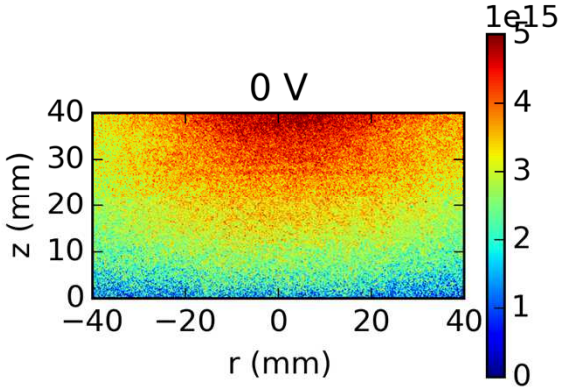
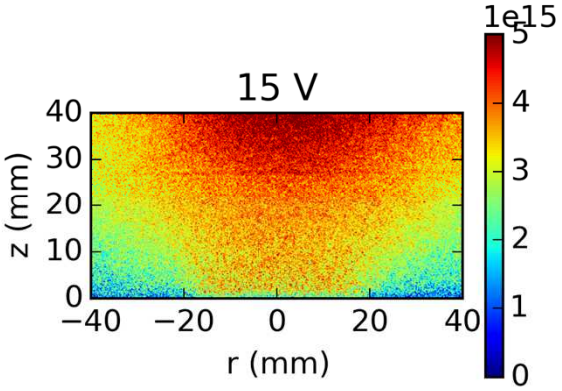
BACKUP SLIDES

LCIF results, linear scale







40 mTorr on-axis comparison

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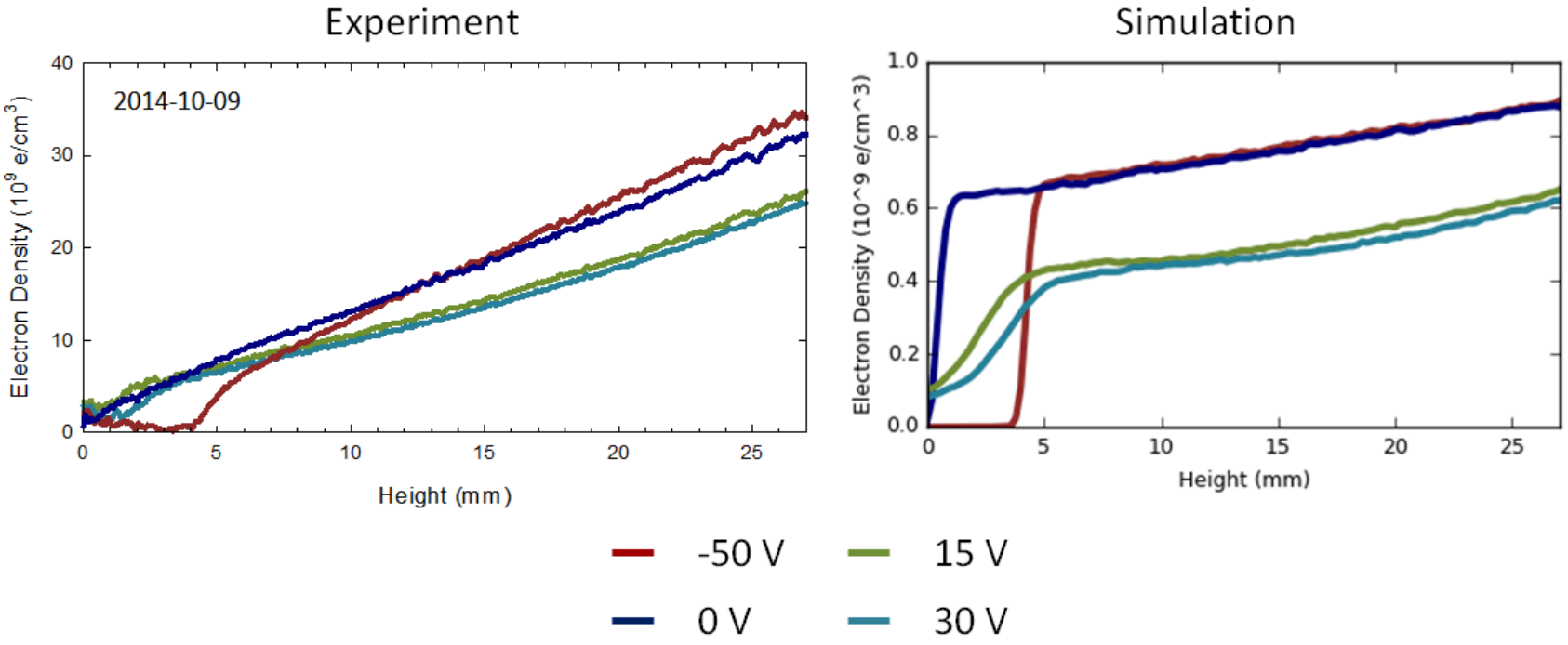
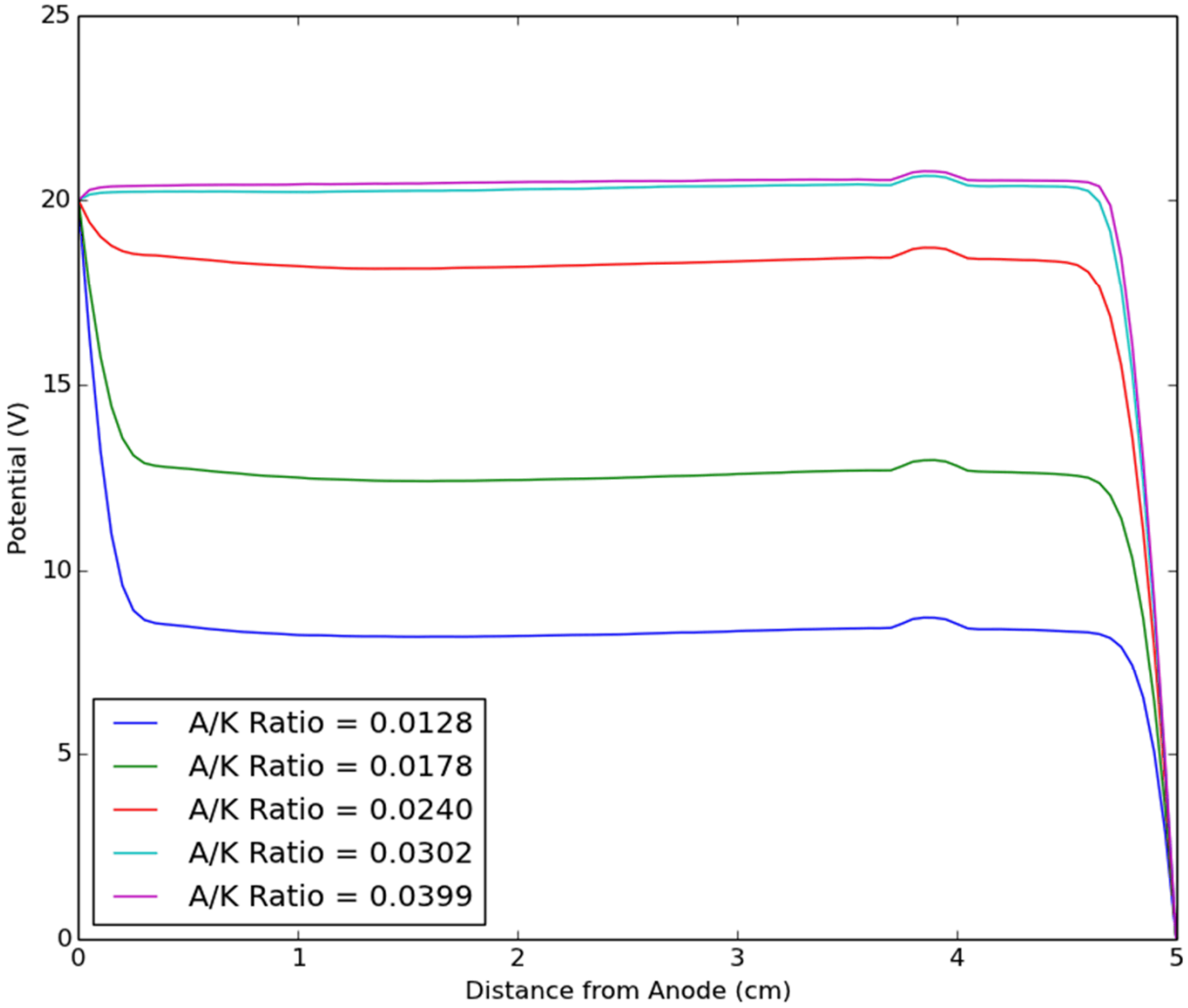


On-axis sheath potentials



Electron sheath results