27th IEEE International Conference on Plasma Science

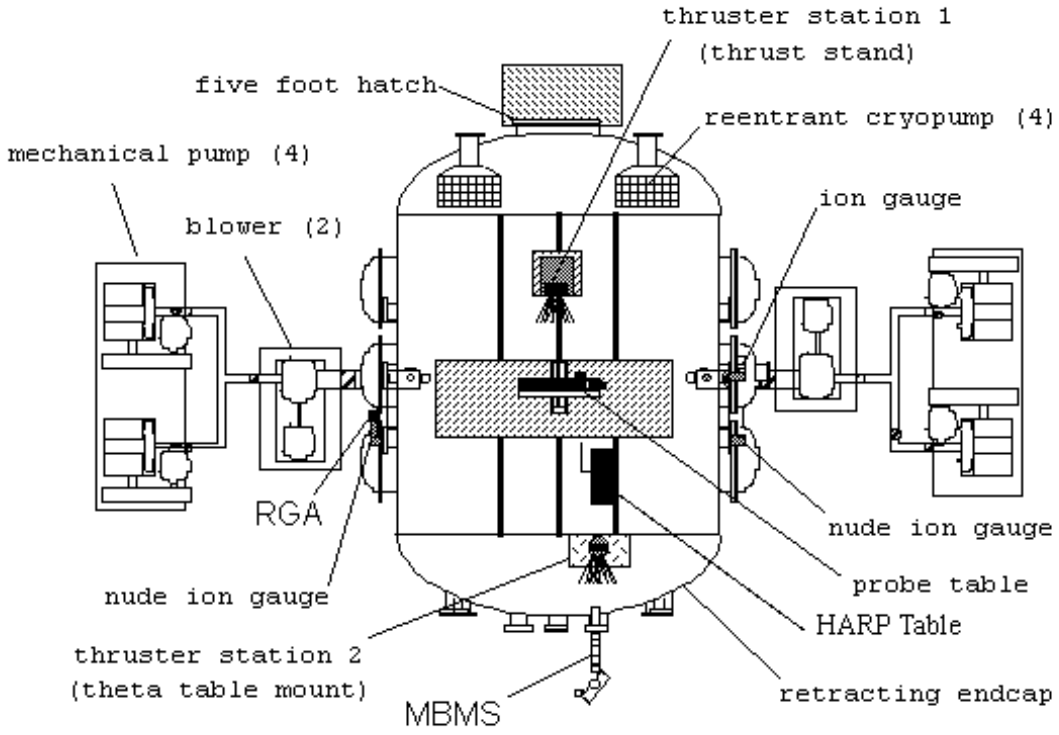
Experimental Investigation of Hall Thruster Magnetic Field Topography

ICOPS 2000-4A06

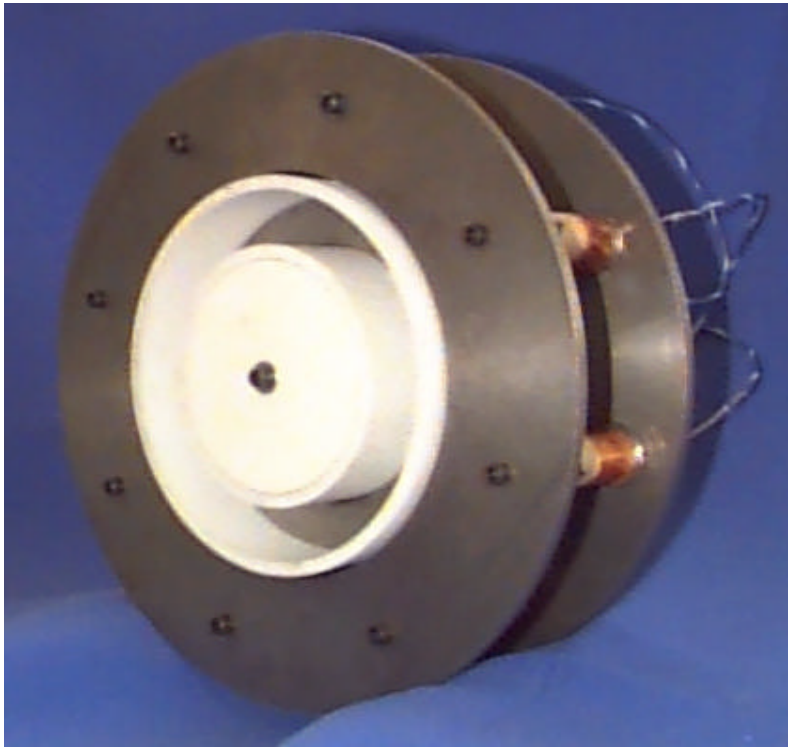
Peter Y. Peterson, James M. Haas, Richard R. Hofer,
Rafael A. Martinez, and Alec D. Gallimore
Plasmadynamics and Electric Propulsion Laboratory
University of Michigan
Ann Arbor, MI USA

Large Vacuum Test Facility

- PEPLs 6 m by 9 m vacuum chamber
- Base Pressure of $2*10^{-7}$ Torr on Air, with pumping speed of 300,000 L/s
- Operating Pressure of $5.1*10^{-6}$ Torr (Thruster Power Level of 1.6 kW) on Xenon, with pumping speed of 140,000 L/s
- Thruster mounted in center of chamber on two-axis linear positioning system

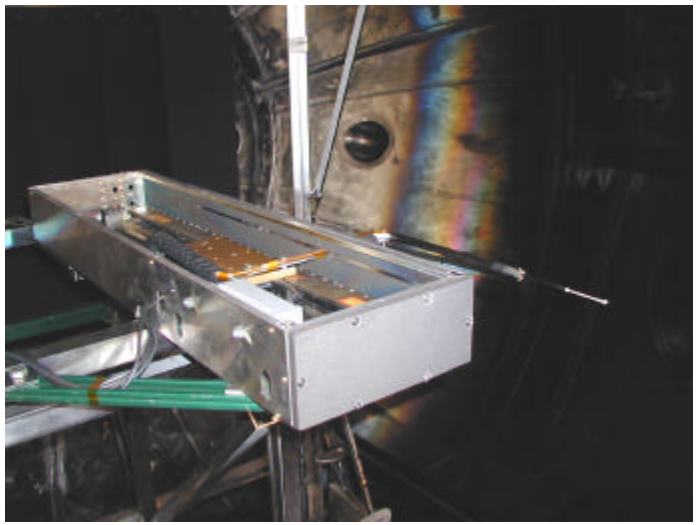


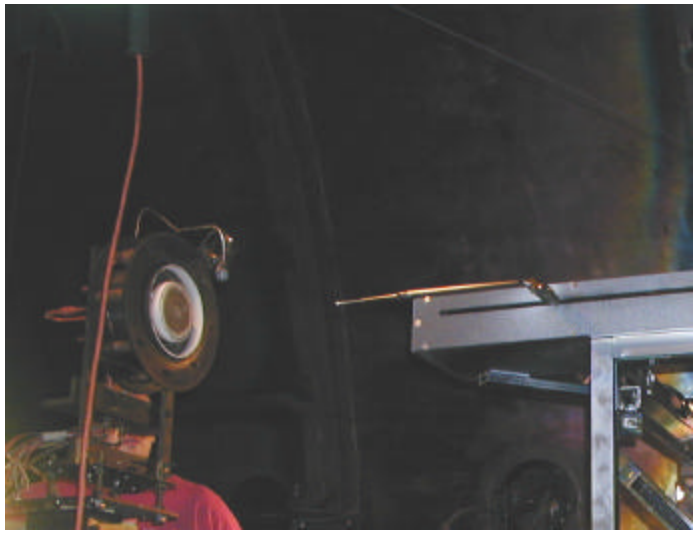
U-M/AFRL P5
5 kW Hall Thruster



- Developed by PEPL and AFRL
- Comparable thrust, specific impulse, and efficiency of commercial thrusters
- 1.6 kW: 300 V, 5.4 A operating conditions with a thrust of 95 mN, Isp of 1550 sec., and efficiency of 48 %
- 3 kW: 300 V, 10 A operating condition with a thrust of 180 mN, Isp of 1650 sec., and efficiency of 51%

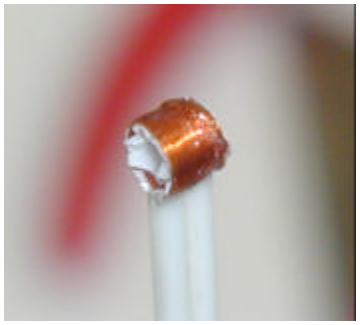
High-Speed Axial Reciprocating Probe (HARP) Positioning System





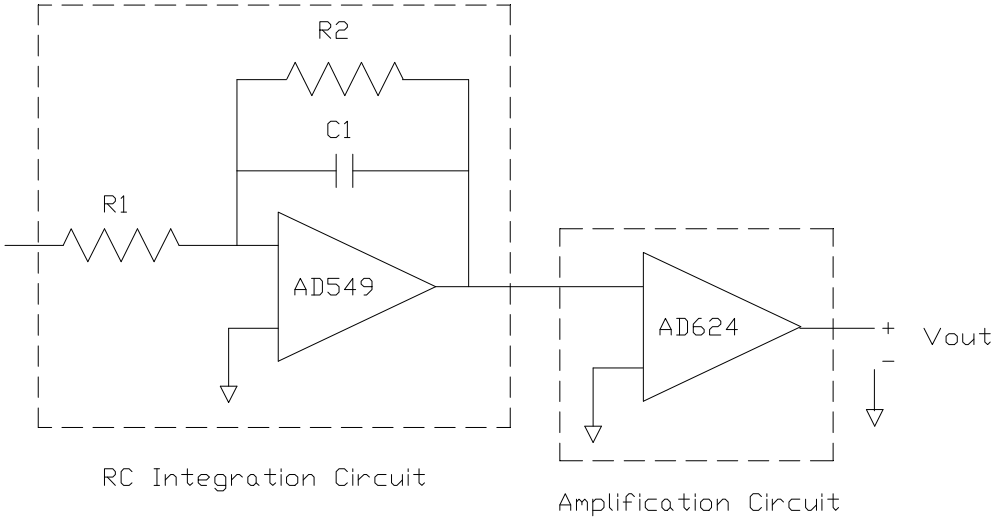
- Goal of the HARP system is to minimize the perturbation to the plasma in the discharge channel of a Hall thruster
- Residence time of a probe in the discharge channel is less than 80 ms
- Short probe exposure time to the plasma reduces probe heating, thus cooling is not required
- Short probe exposure time to the plasma reduces possible probe ablation and sputtering

B-Dot Probe/Circuit Design and Theory



- Coil Inner Diameter: 2.4 mm
- Number of Turns: 86

- Outer Probe Diameter: 4.3 mm
- Outer Probe Width: 4.0 mm



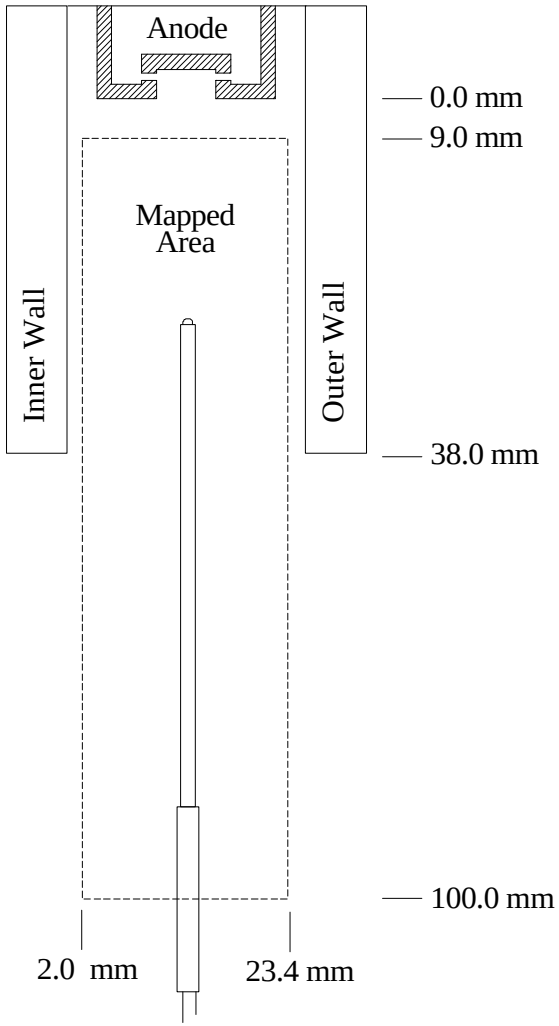
B-dot Probe Output Voltage

$$V = nA\frac{dB}{dt}$$

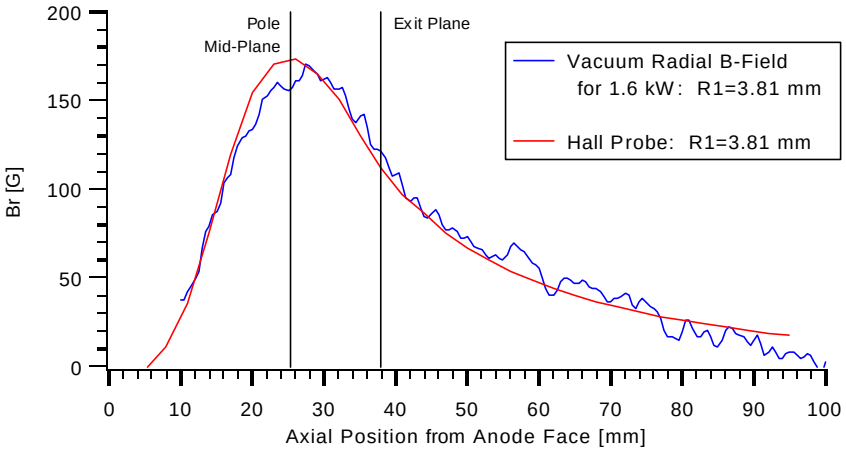
After Integration:

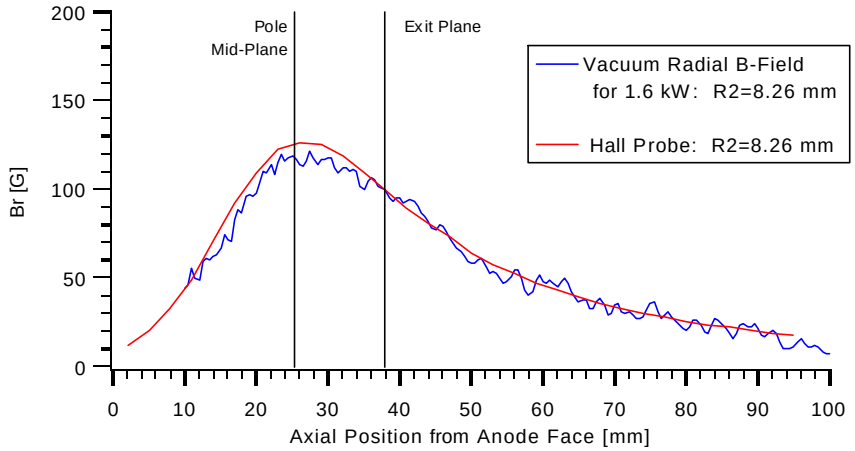
$$V = \frac{nA}{RC}B$$

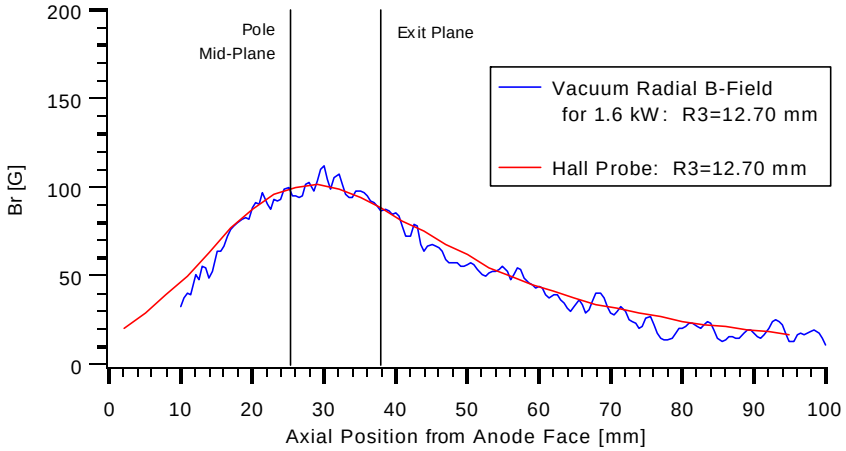
Data Collection Area

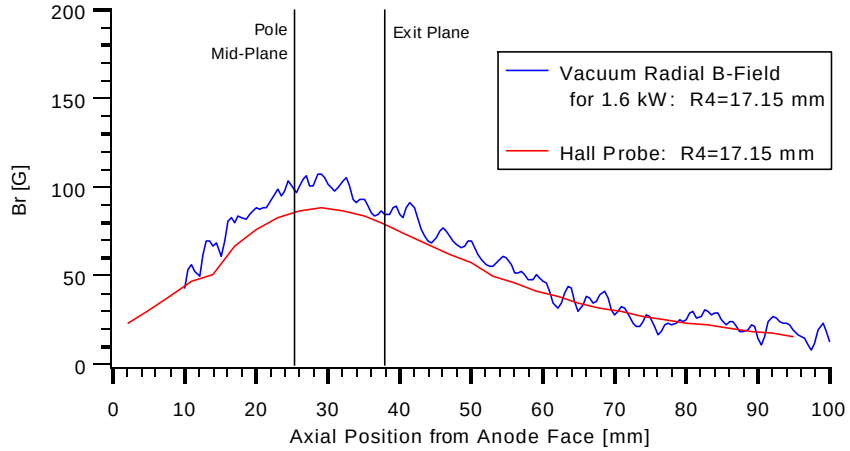


Experimental Results for the 1.6 kW Power Condition: Vacuum Case

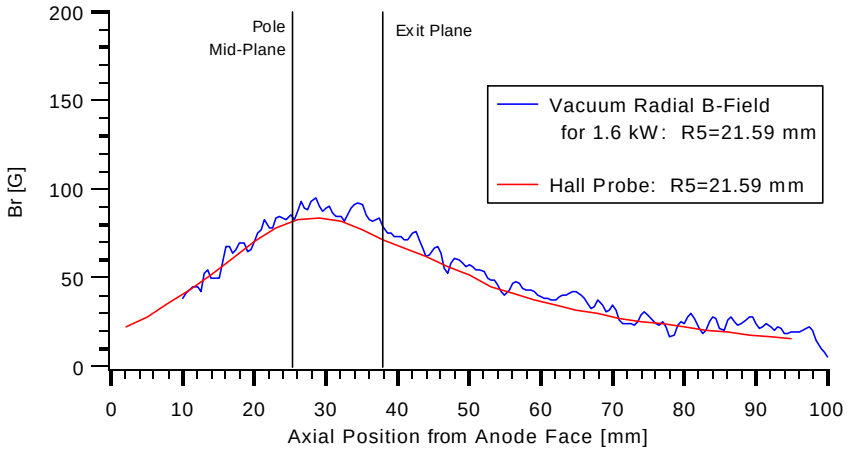


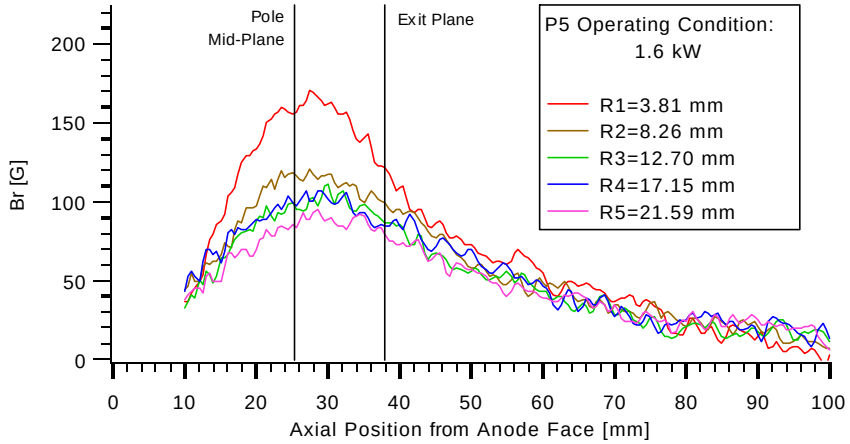


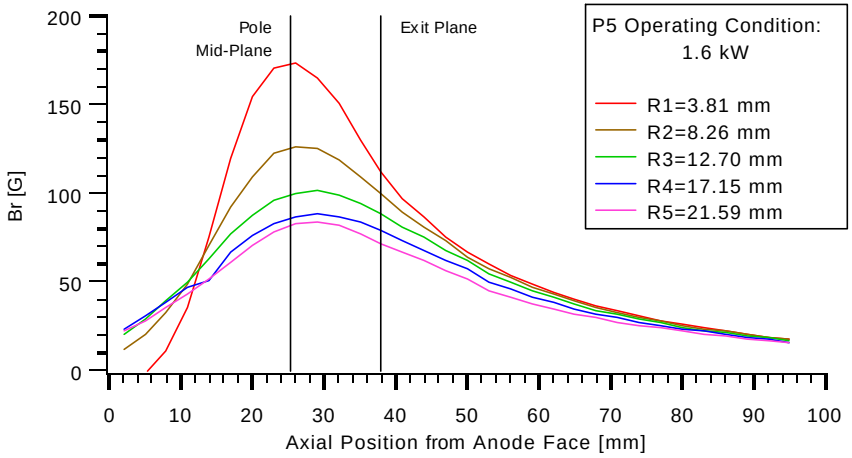




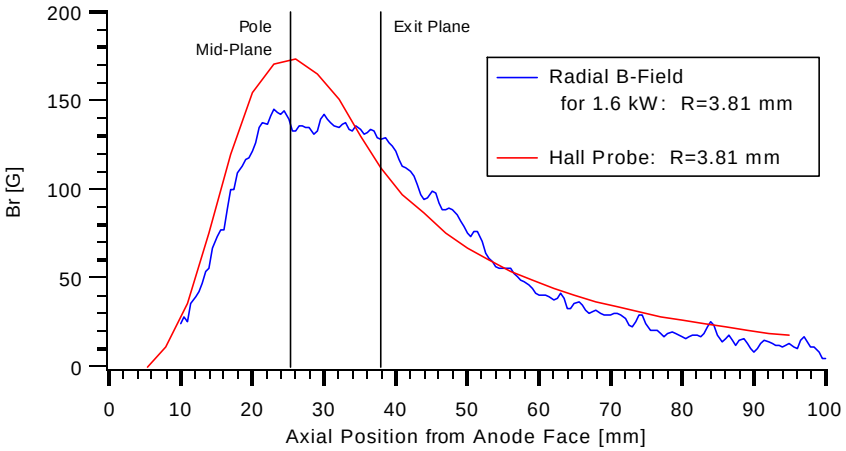
Experimental Results for the 1.6 kW Power Condition: Vacuum Case

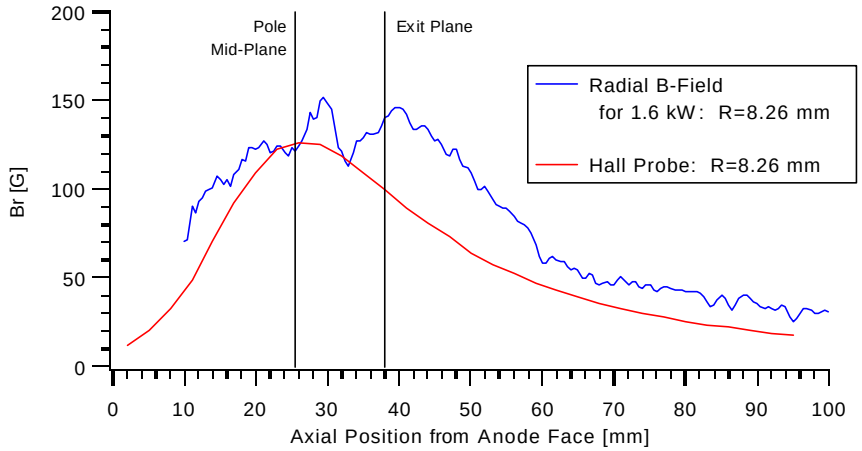


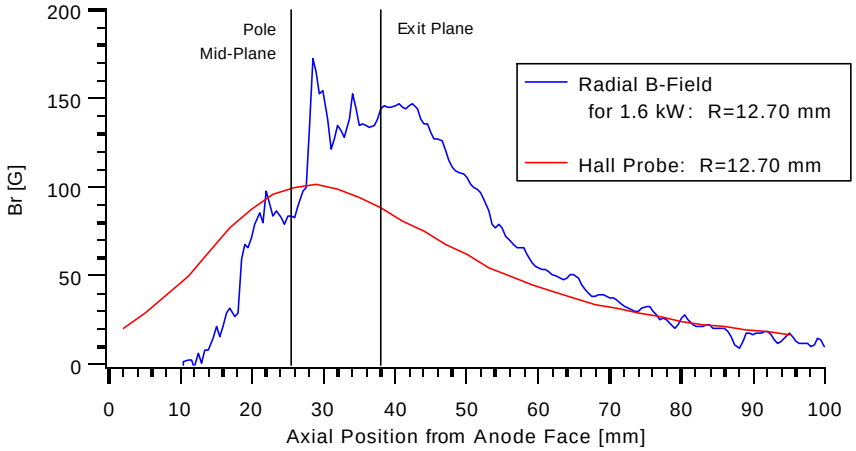


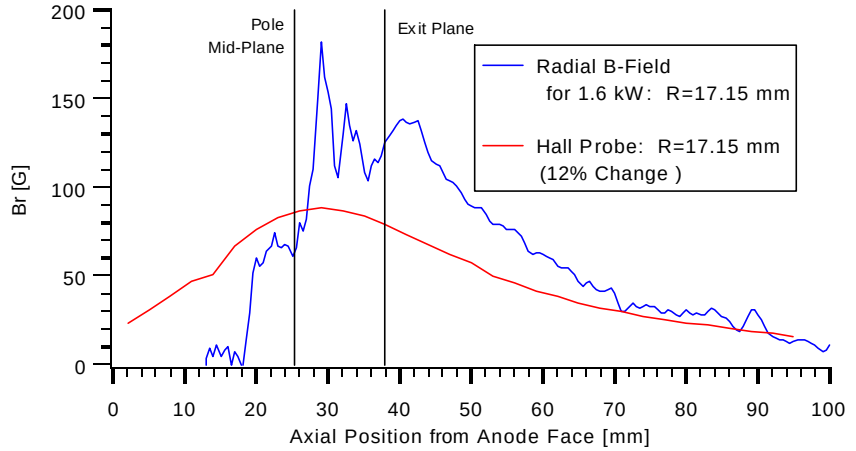


Experimental Results for the 1.6 kW Power Condition: Plasma Case

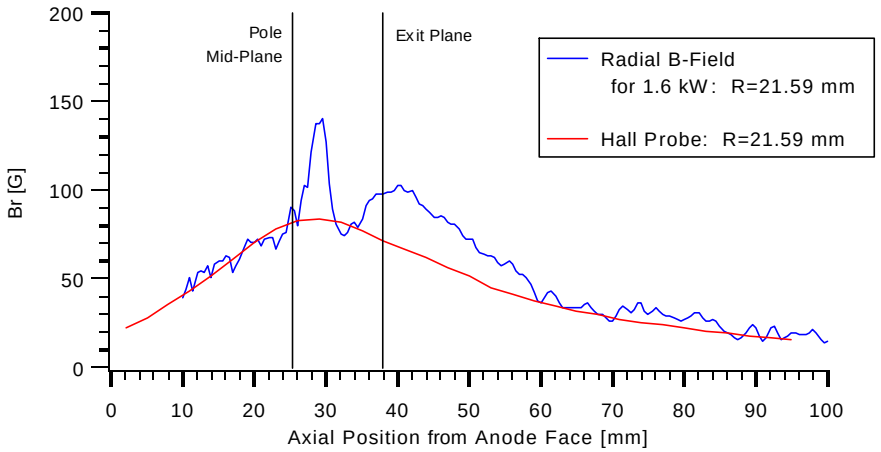


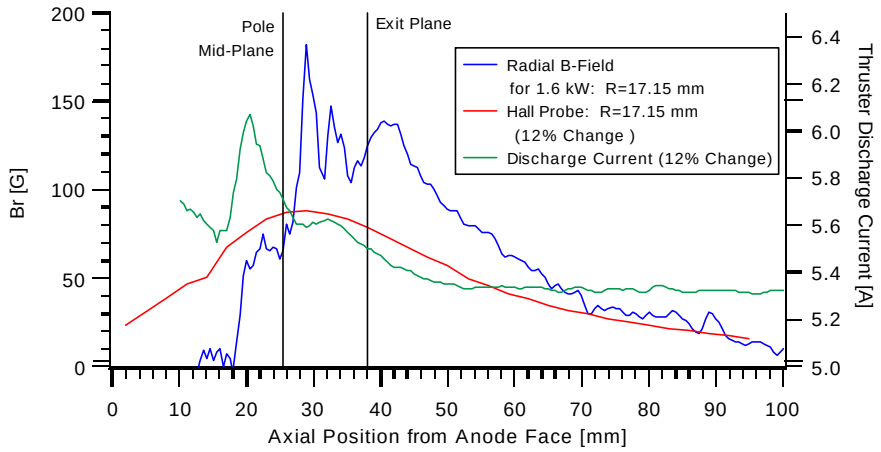


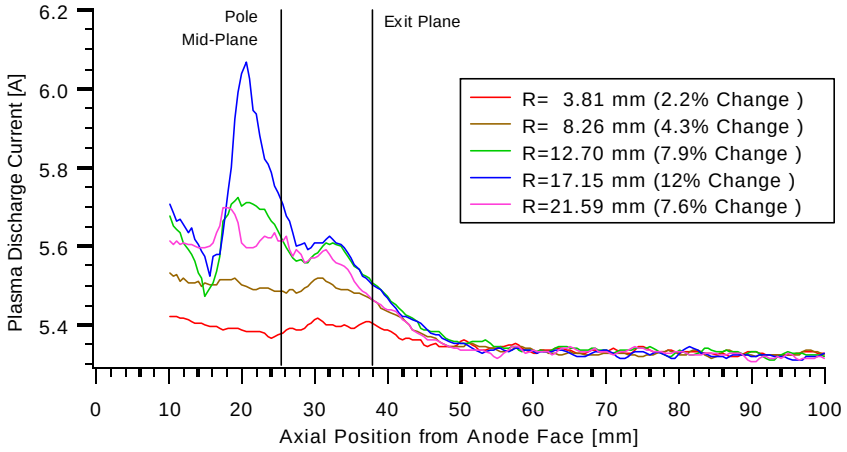




Experimental Results for the 1.6 kW Power Condition: Plasma Case

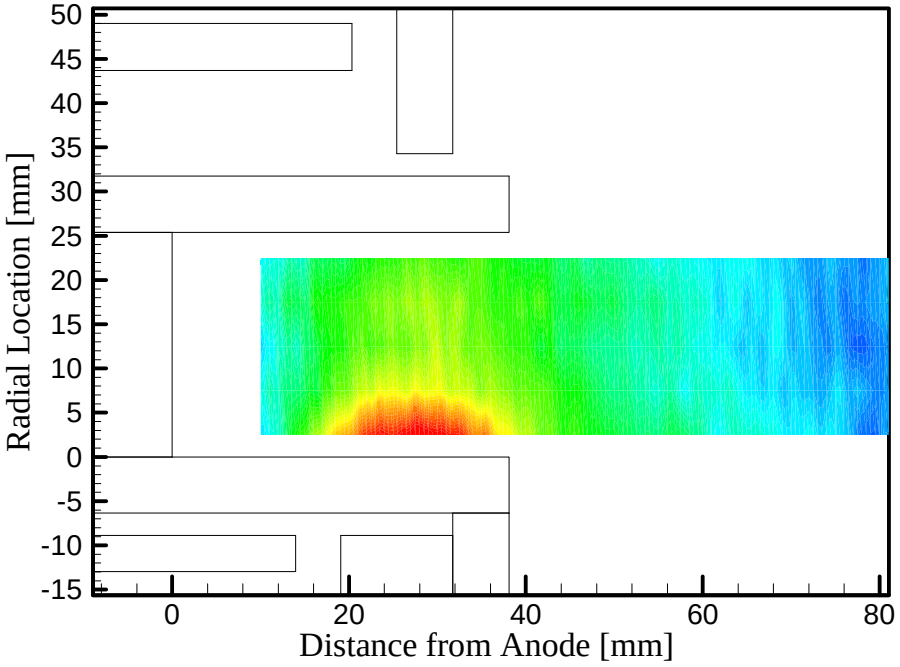




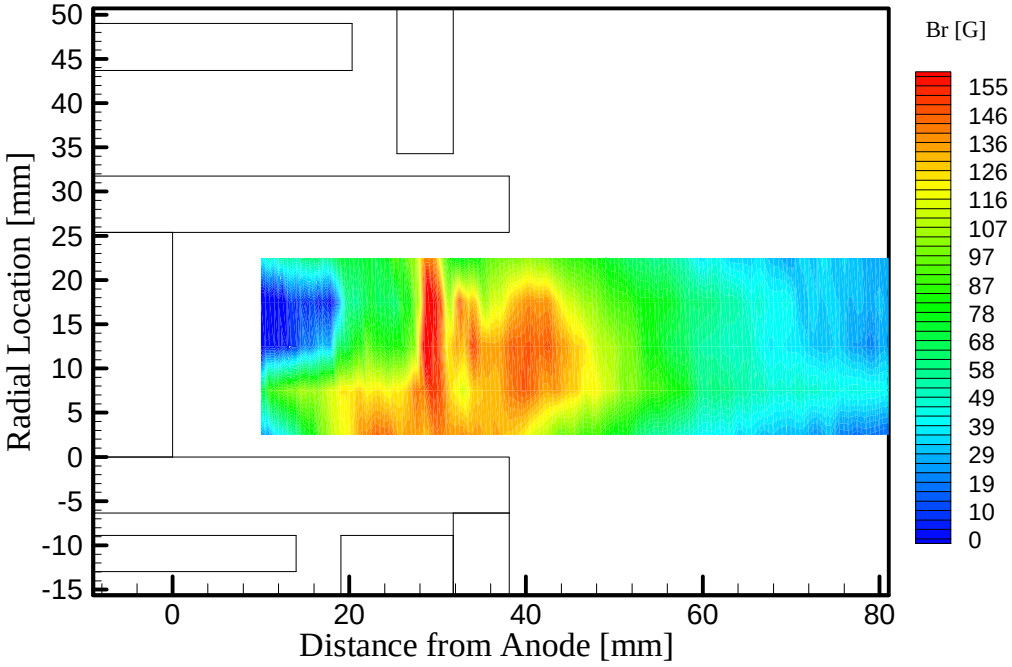


Experimental Results for the 1.6 kW Power Condition: Vacuum & Plasma

Vacuum Radial Magnetic Field



Radial Magnetic Field with Plasma



Conclusions & Future Work

- Radial Magnetic Field for the 1.6 kW Plasma varies from the Vacuum Field Measurements
- Results Impact Efforts to Design Next-Generation Hall Thrusters in that Current Modeling Packages may not Accurately Predict Operational Magnetic Field Topography
- Magnetic Field Variation Corresponds Spatially with Estimated Location of Maximum Electron ExB Drift Velocity
- Future Work will Involve Measurements at Higher Thruster Power Levels as well as the Measurement of Axial and Azimuthal Magnetic Fields

Hall Current Topography