Riverside Research Plasma Facility

Dr. James Duff, Dr. Stephen Parsons, Dr. Thomas Steinberger, Jacob Ochs
Riverside Research, Beavercreek, OH

AT A GLANCE

CIRCA 1967 COLUMBIA UNIVERSITY NY,NY

FREE OF FOREIGN OWNERSHIP, CONTROL, OR INFLUENCE

501(C)(3) NONPROFIT R&D COMPANY

Significant reinvestment to enhance customer success

41,000 FT² ACCREDITED OFFICES, LABS, AND NETWORKS

Champaign, IL · Lexington, MA · Dayton, OH · Manhattan, NY · Fairfax, VA (HQ) · *Remote Locations*

OPEN INNOVATION CONCEPT ENCOURAGES COLLABORATION

FOUNDED IN 1967 | CHARTERED TO ADVANCE SCIENTIFIC RESEARCH FOR THE BENEFIT OF THE NATION

Artificial Intelligence & Machine Learning · Software Engineering · Electromagnetics · System Engineering · Plasma Physics · THz Imaging · Radar · Tursted & Resilient Systems

CORE RESEARCH AREAS

BROAD SPECTRUM OF SUBJECT MATTER EXPERTS

TECHNICAL EXCELLENCE AND TRUSTED SOLUTIONS

FOR THE DEFENSE AND INTELLIGENCE COMMUNITIES

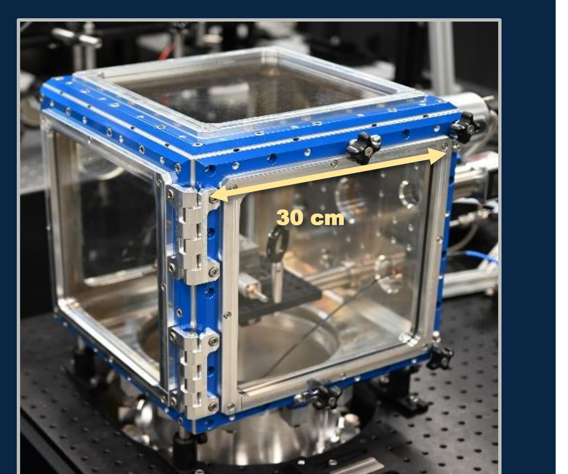
Large Chamber

- 25 m³
- Pumping Capacity: 11,800 L/s
  - 4 turbomolecular pumps
  - 2 cryopumps
- Create a large, flexible environment for various experimental campaigns
- Significant control over plasma density, background magnetic field, plasma species
- Upgrading diagnostic suite to improve plasma characterization capabilities

Medium Chamber

- 0.4 m³
- Significant optical and diagnostic access available
- Base pressure ~1uTorr
- Test bench currently used for plasma-material interaction studies
- See poster GP12.00015 for information on ongoing experiments.

Small Chamber



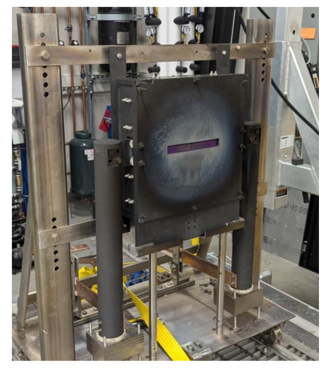
- 0.03 m³
- Highly customizable, each panel replaceable with:
  - windows
  - feedthrough ports
  - single ISO250 port
  - optical breadboards
- Attachable to larger chambers to increase pumping capacity while maintaining quick vent sessions

Experimental Equipment

CURRENT:
- LaB6 thermionic plasma source
- Microwave Plasma Sources
  - 2.54 GHz at 1000 W
  - 0.7 – 2.7 GHz at 100 W
  - 6 – 18 GHz at 10 W
- LPKF Protomat mill for custom PCBs
- 2 J/pulse Nd:YAG laser (1064/532 nm)
- 3 650 GHz coherent radiation sources (VDI)
- 3 stage additive/subtractive spectrometer
- 1.7 Farad capacitor bank
- 6 45 KW power source banks
- 120 kW power supply
- Langmuir Triple probe
- RFA probes
- Residual gas analyzers
- Supercontinuum MIR laser
- Vacuum compatible motorized stages
- Hall thruster

PLANNED:
- LIF system
- Mach probes
- Advanced interferometry system
- RF plasma source

Benchmarking LaB_6 Operation in the Large Chamber

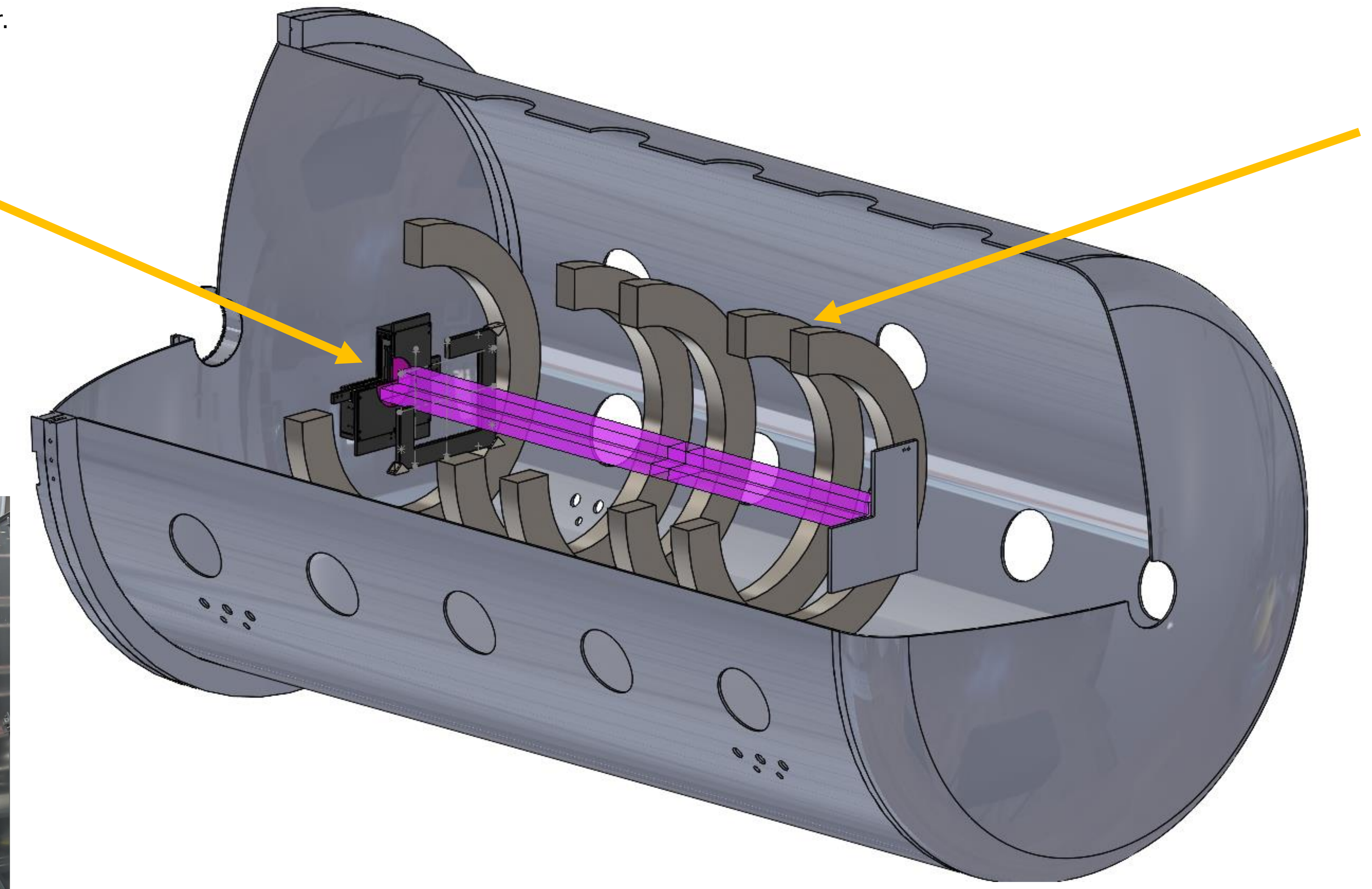


- LaB_6 thermionic emitter operated in large chamber.
- Four 4"x4" LaB_6 tiles with rotationally symmetric tongue-in-groove joints.
- 1"x8" slab graphite mask easily restricts plasma source area.
  - More masks (8" circular, 7.875" square) available to vary plasma source area.
- Operated plasma source in a variety of magnetic field configurations, gas species, and cathode temperatures.

- Graphite heating element can source up to 800 A
- Can heat LaB_6 up to ~2000 C.
- Measure cathode temperature with a 2-color pyrometer.

PULSED OPERATION
- In pulsed mode, trigger sent to 1.7 F cap bank, applying differential voltage between cathode and anode. Differential voltage applied for 20 ms, 1 Hz repetition rate.
- Cap bank can supply up to 5 kA of current in current configuration.
- Reproducible plasma discharges observed in preliminary operation.

DC OPERATION
- In DC mode, trigger pulls voltage from power supply to cathode and anode. Supplies voltage between 0-330 V and current from 0-330 A. Plasmas last between several seconds and several minutes.
- Useful testbed for turbulence studies.



- 5 Internal electromagnets.
- 96 turns each.
- 45 kW available for each magnet.
- Can operate with on-axis field up to 0.3 T.
- Individually controllable to customize magnetic field profile.

- Mass flow controller can operate up to 5000 SCCM.
- Can operate with any nonreactive species.
- MFC and pumping capacity can be tailored for specific background pressures.

LARGE CHAMBER PRIMARY EXPERIMENTAL GOALS, TO DATE:

Ionospheric research
- Match nondimensional plasma characteristics of ionosphere.
- Explore plasma instabilities that can affect satellite communications.

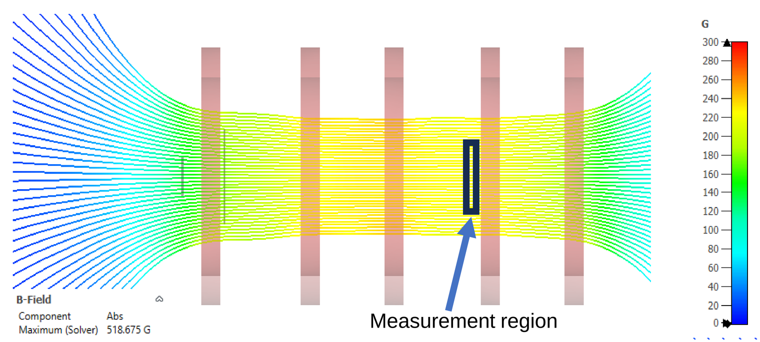
Hypersonic sheath characterization
- Creates dense, low field plasma and test standard communications systems.
- Explores mitigation schemes.

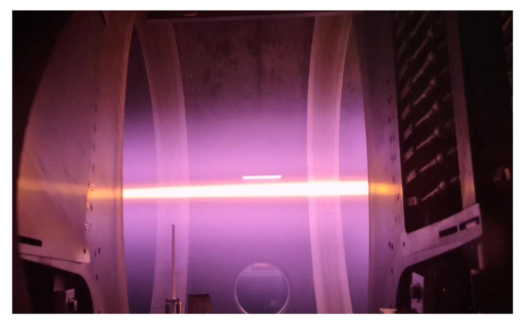
Plasma-based thrusters
- Electrothermal and electromagnetic thrusters.

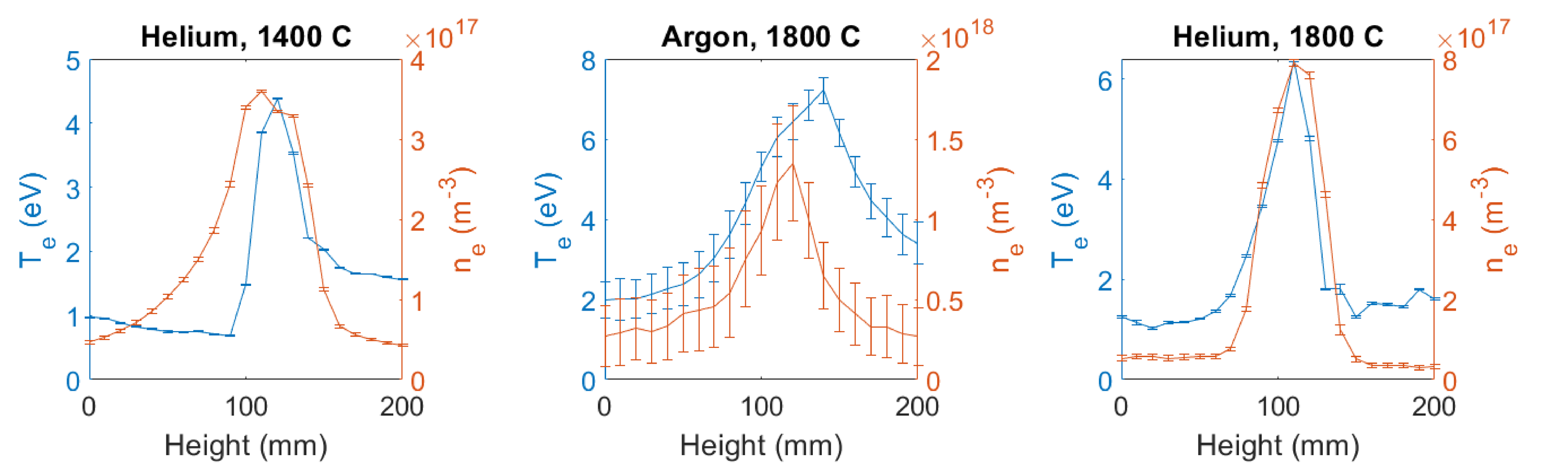
FUTURE EXPERIMENTAL GOAL:
Plasma-material interaction studies.

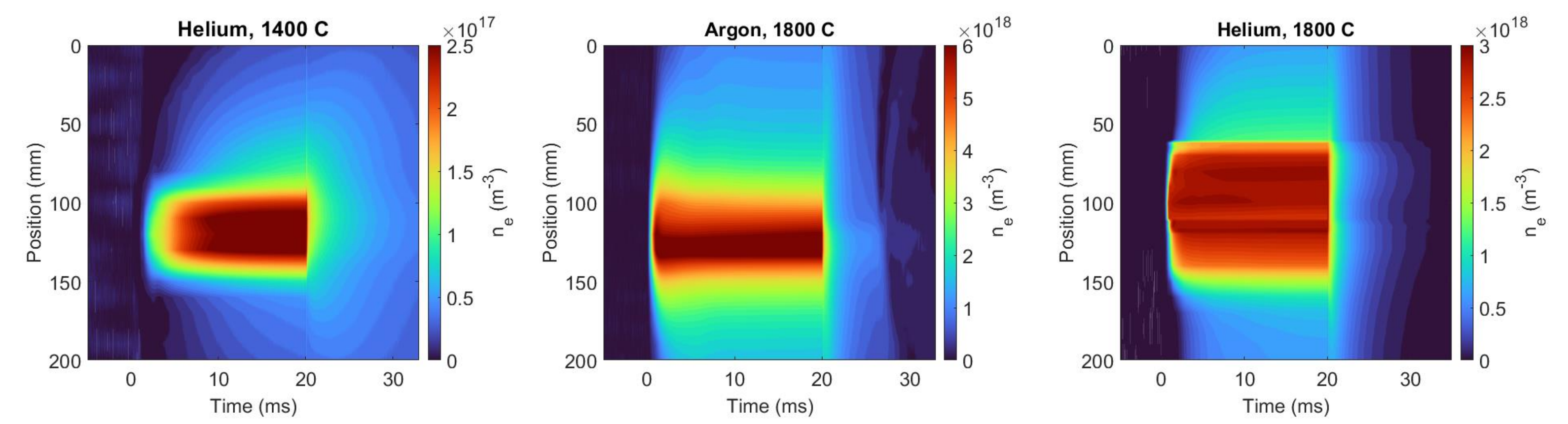
Uniform Field Operation

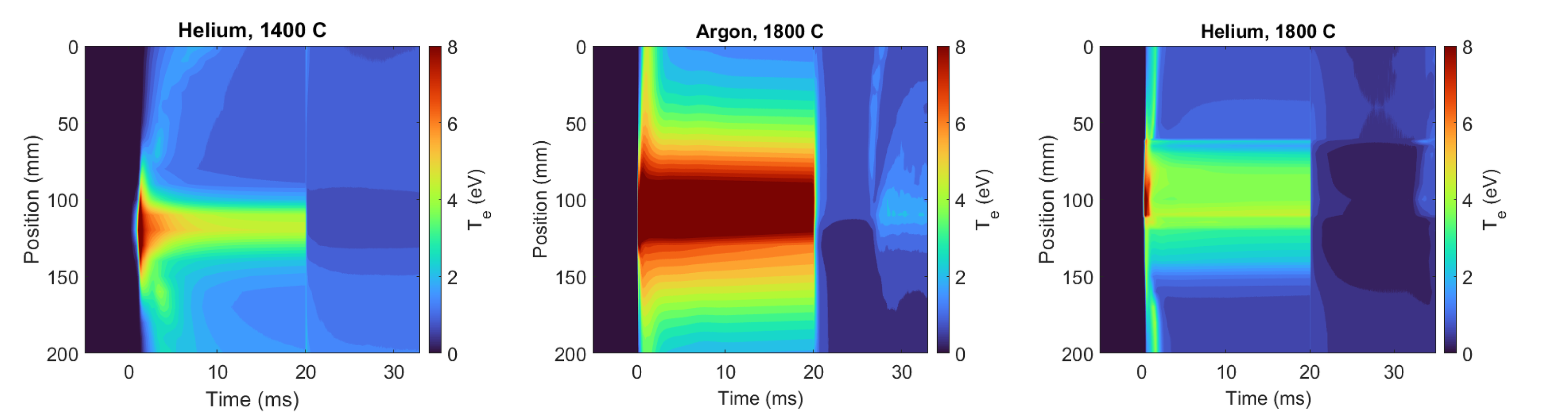
Magnet	Current	Voltage
1	99.8 A	7.7 V
2	99.5 A	7.7 V
3	99.1 A	7.5 V
4	99.8 A	7.7 V
5	99.9 A	7.7 V





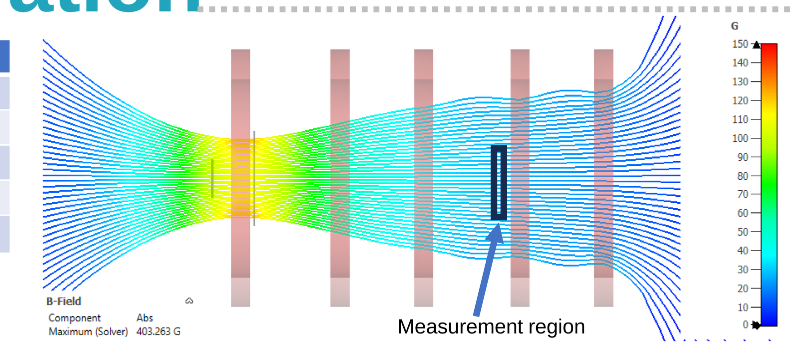


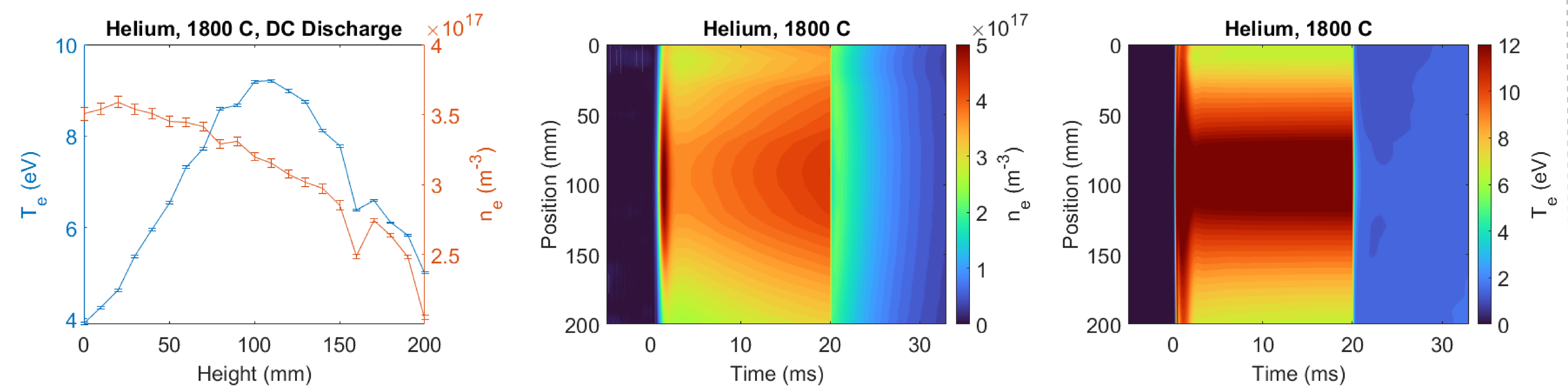




Low Field Operation

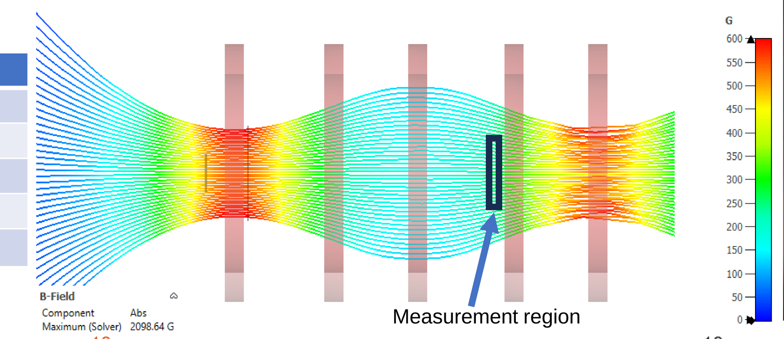
Magnet	Current	Voltage
1	99.8 A	7.8 V
2	9.63 A	0.76 V
3	8.96 A	0.71 V
4	9.86 A	0.77 V
5	9.84 A	0.78 V

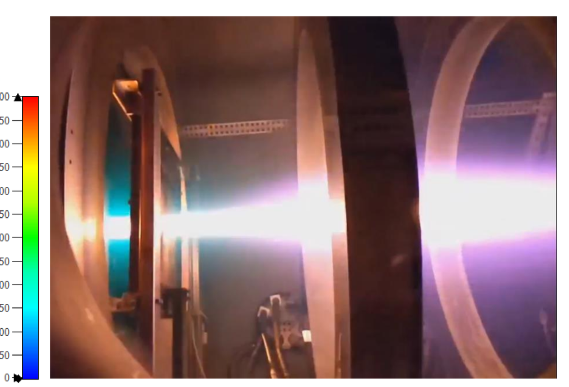


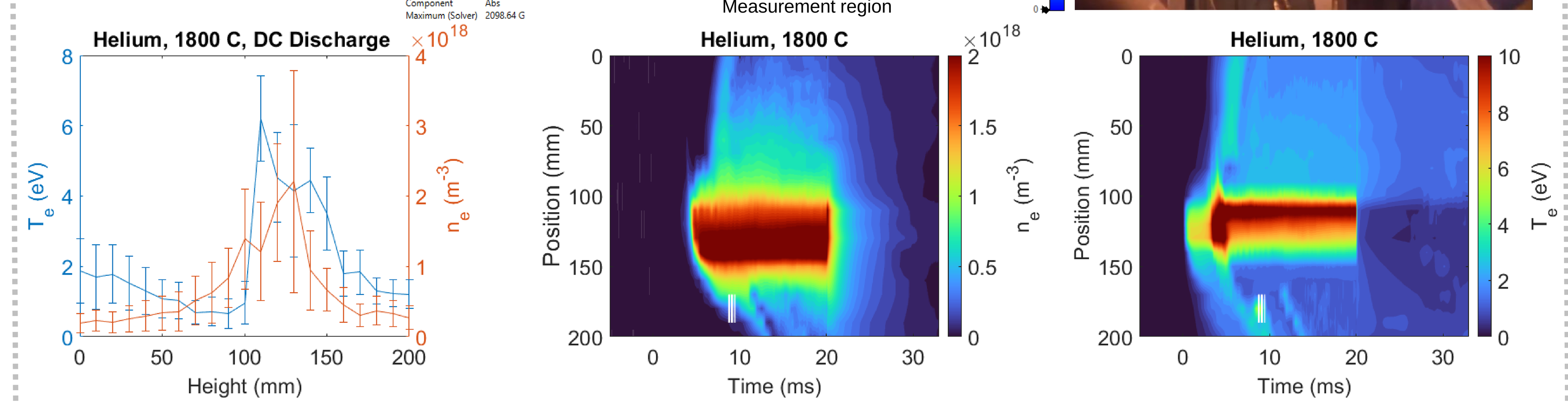


Mirror Field Operation

Magnet	Current	Voltage
1	500 A	39.8 V
2	9.63 A	0.77 V
3	8.96 A	0.71 V
4	9.86 A	0.78 V
5	500 A	39.2 V

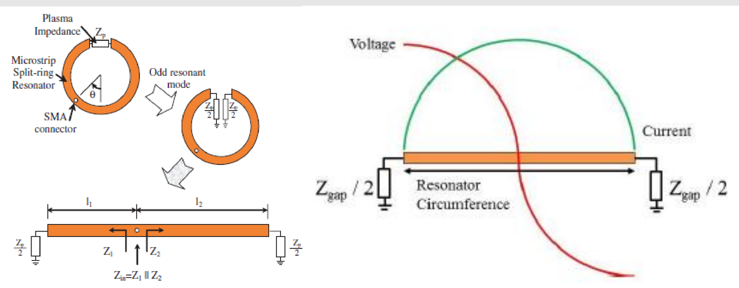


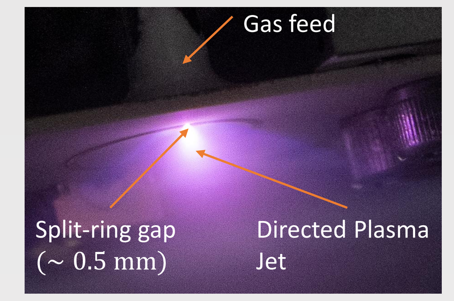




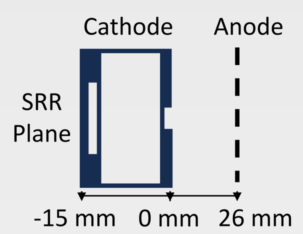
Neutralizer Study

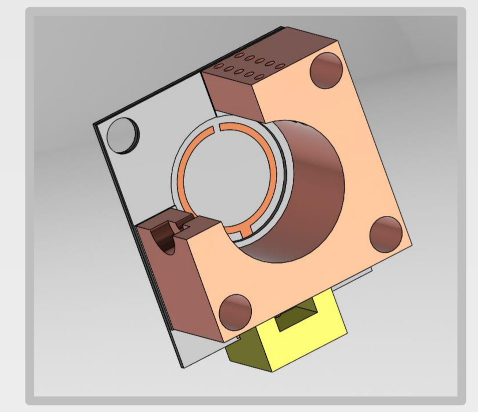
Quantity	Range
P	$0 - 100$ W
f_{Res}	~ 2 GHz
$P_{discharge}$	10 μTorr–atm.
T_e	≤ 10 eV
n_e	$\leq 10^{17}$ m^{-3}

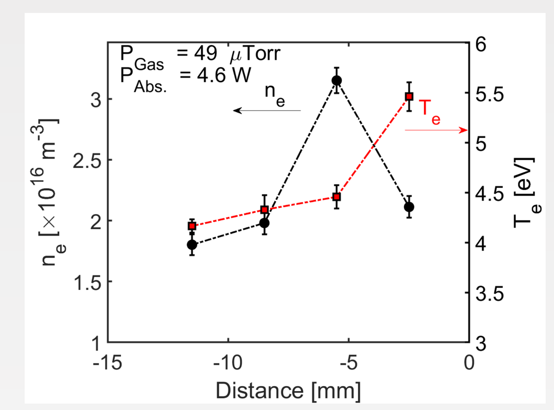


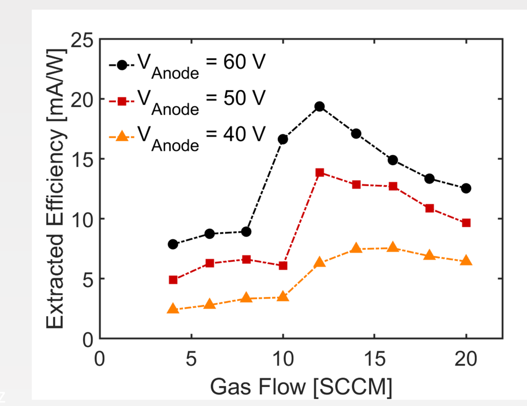


- Applications for plasma source generation and micro-thruster investigations.
- Design is easily scalable.
- Larger powers and pressures produce denser discharges.









Riverside Research Plasma Facility Takeaways

Large Chamber LaB6 plasma benchmarking

- LaB_6 thermionic emitter run in a variety of regimes.
  - Cathode mask used to match a desired plasma structure.
  - Future runs will be done with either a circular mask (8" diameter) or a large square mask (7.875" edge length) to form larger diameter plasmas. Can use arbitrary shaped masks to explore other physics effects.
- Individually controllable magnets significantly impact both plasma shape and dynamics.
  - Uniform field led to a relatively narrow slab plasma.
  - Low field led to a more diffuse, less dense plasma.
  - Mirror field led to a dense plasma with significant instability activity.
- Helium and Argon discharges explored in a variety of run conditions.
- Cathode temperature can be continuously varied up to ~2000 C.
  - Plasma was consistently run at 1400 C.
  - Plasma was significantly denser at 1800 C.
- Plasmas can be run repeatably, consistently, with a relatively short turnaround.
- The large plasma chamber can accommodate a wide range of experimental regimes.
- Plan on expanding diagnostics available for general operation.
  - Currently use LTP on a motorized stage, mid speed camera.
  - Expanding to Bdot probes, Mach probes, RFA, LIF, spectroscopy, interferometry.
- **Riverside Research facilities are open to contracts with outside partners. Please contact Dr. Stephen Parsons at sparsons@riversideresearch.org for additional information or work opportunities.**

Neutralizer study

- Small chamber is currently attached to the large chamber behind a gate valve.
  - Gives access to the pumping capacity of the large chamber while allowing for quick up-to-air periods to change experimental setup.
  - Can vent small chamber, change a setup, and be back to UHV in ~15 minutes.
- Running split ring resonator as plasma source for an electrothermal thruster neutralizer
  - Achieving electron density on order $3*10^{16}$ m^{-3} for low pressure operation.
  - Higher density operation available at higher pressures (~atmosphere)
  - Current efficiency ~20 mA/W.
- Microstrip resonator attached to a flowing gas line has potential applications as a general plasma source.

Work supported by AFOSR grant number FA9550-23-1-0038.