Riverside Research Plasma Facility

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AT A GLANCE

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

Artificial Intelligence & Machine Learning
Electromagnetics
Plasma Physics
Radar
Software Engineering
Systems Engineering
THz Imaging
Secure & Resilient Systems

CORE RESEARCH AREAS

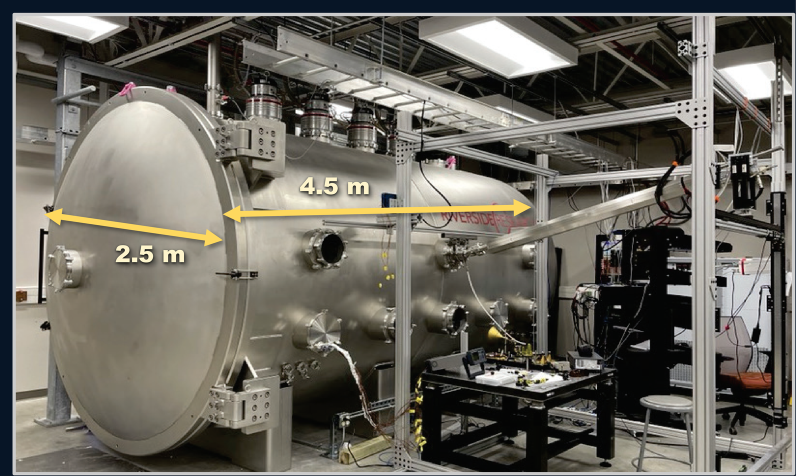
BROAD SPECTRUM OF SUBJECT MATTER EXPERTS

TECHNICAL EXCELLENCE AND TRUSTED SOLUTIONS

FOR THE DEFENSE AND INTELLIGENCE COMMUNITIES

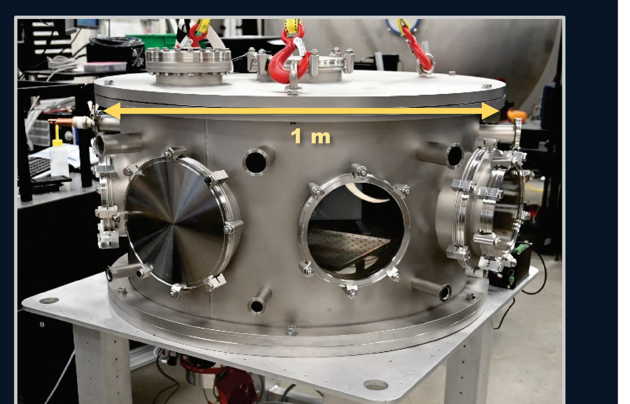
Large Chamber

- 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



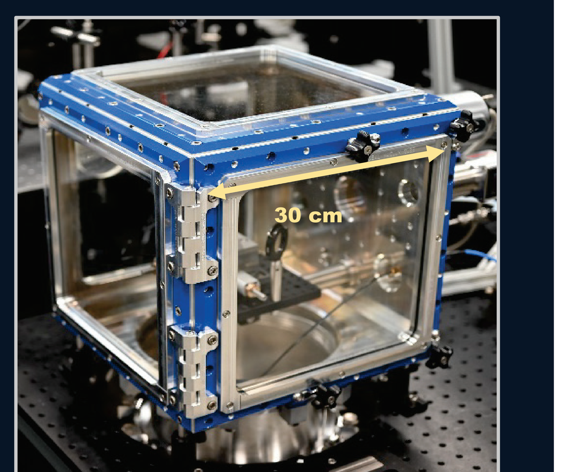
Medium Chamber

- 0.4 m³
- Significant optical and diagnostic access available
- Base pressure ~1μTorr
- Test bench currently used for plasma-material interaction studies
- See poster 16 in this session for more information.



Small Chamber

- 0.03 m³
- Highly customizable, each panel replaceable with:
  - Optical windows
  - Feedthrough ports
  - Single ISO250 port
  - Optical breadboards
- Attachable to larger chambers to increase pumping capacity while maintaining quick vent sessions
- See poster 27 in this session for more information



Experimental Equipment

CURRENT

- LaB_6 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
- 2 kW RF helicon plasma source
- Laser Induced Floressence system
- 2 J/pulse Nd:YAG laser (1064/532 nm)
- 3 650 GHz coherent radiation sources (VDI)
- Supercontinuum MIR laser
- 3 stage additive/subtractive spectrometer
- 1.8 Farad capacitor bank
- 6 45 KW power source banks
- 120 kW power supply
- Langmuir Triple probe
- RFA probes
- Residual gas analyzers
- Vacuum compatible motorized stages
- Hall thruster
- LPKF Protomat mill for custom PCBs

PLANNED

- Mach probes
- Advanced interferometry system
- 10 kW RF helicon plasma source
- Additional laser diagnostics

Standing up Hypersonic Plasma Interaction Research (HyPIR) Facility

NEW FACILITY FOR CHARACTERIZING HYPERSONIC MATERIALS

- Ground testing facility for hypersonic relevant materials.
- Building up facility with goals of high diagnostic access, high experimental repeatability.
- Testing in Mach 10+ conditions for temperature, oxidizing plasma environment, little to no flow. Future upgrades may include high enthalpy flow via 100 kW RF supply.

HIGH TEMPERATURE OPERATION

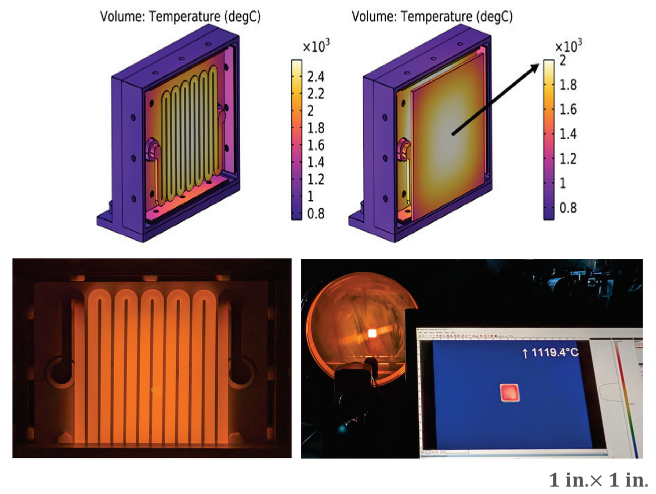
- Graphite oven heaters in vacuum heat samples up to ~2000 C.
- Heaters placed on a mobile cart so sample can be tested, heaters can be shielded with a gate valve during plasma operation.
- Sample temperature will be maintained with laser heating.

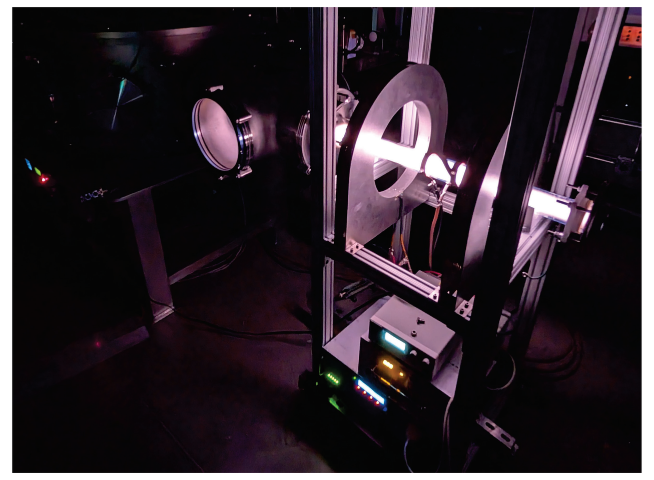
OXIDIZING PLASMA EXPOSURE

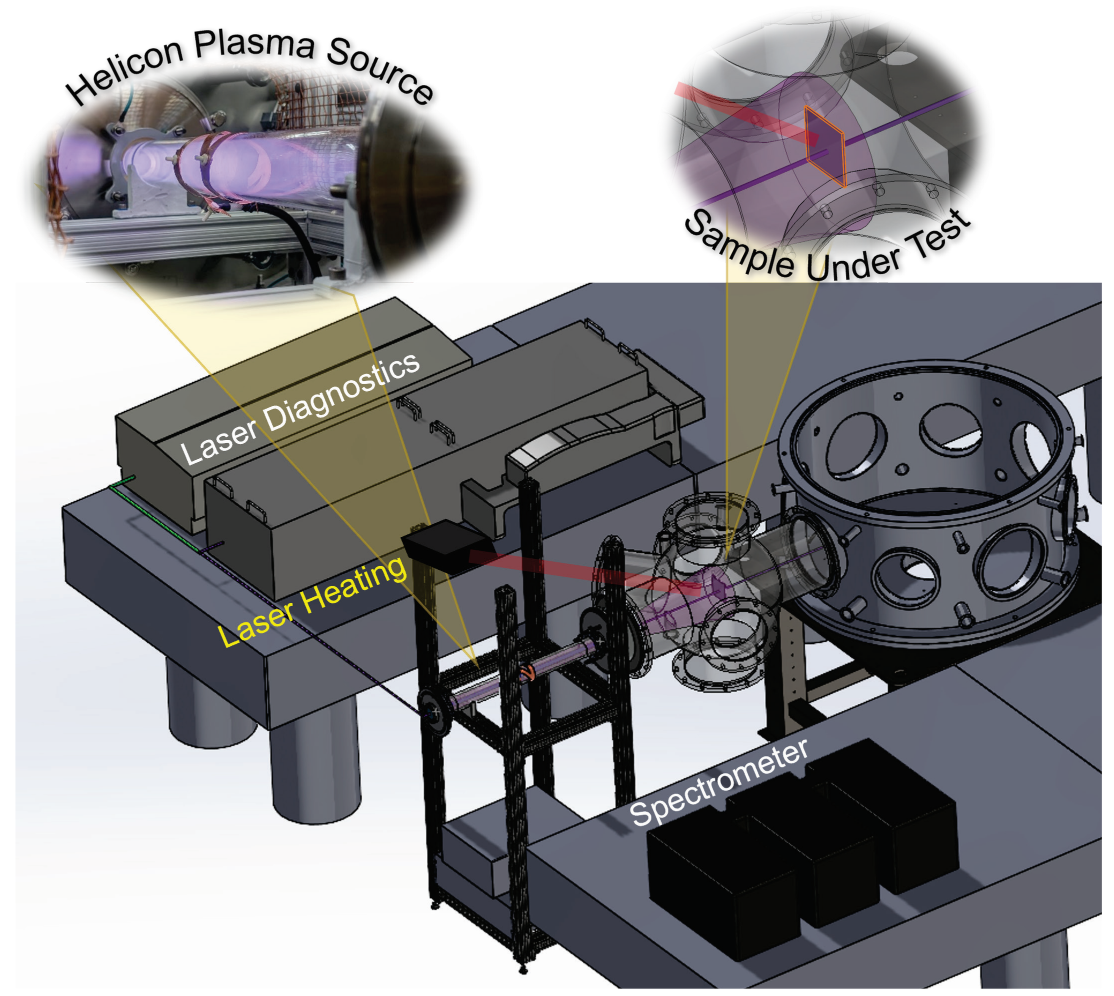
- RF antenna external to vacuum used to inductively form plasma.
- 2 kW RF power supply used to power antenna.
- Current experiments use argon; future experiments will use atomic oxygen or atmospheric gas mixes.

OPTICAL DIAGNOSTICS

- Developing various diagnostics to describe ion and neutral species behavior.
- Laser induced to explore physics of oxidizing species.
- Laser Induced breakdown spectroscopy being developed to explore behavior of material before, during, and after test.
- Thomson scattering and THz interferometry being developed to describe electron dynamics during test.







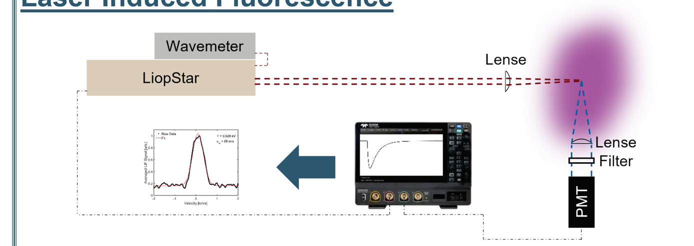
LiopTec LiopStar-E Dye Laser

Parameter	Value
Rep. Rate (Hz)	10
Δt_{Pulse} (ns)	6
Pulse Energy (mJ/pls)	≤ 130
Linewidth (cm⁻¹)	≤ 0.06
λ (nm)	193 - 900

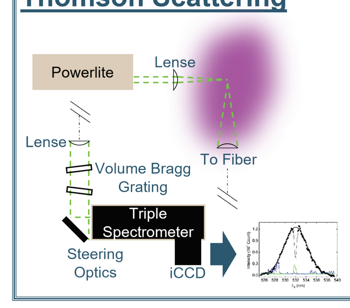
Continuum Powerlite 9010 Nd:YAG

Parameter	Value
Rep. Rate (Hz)	10
Δt_{Pulse} (ns)	$6-10$
Pulse Energy (J/pls)	2 (1064 nm), 1 (532 nm)
Linewidth (cm⁻¹)	1
λ (nm)	532, 1064

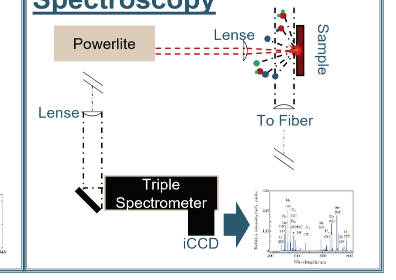
Laser Induced Fluorescence



Thomson Scattering

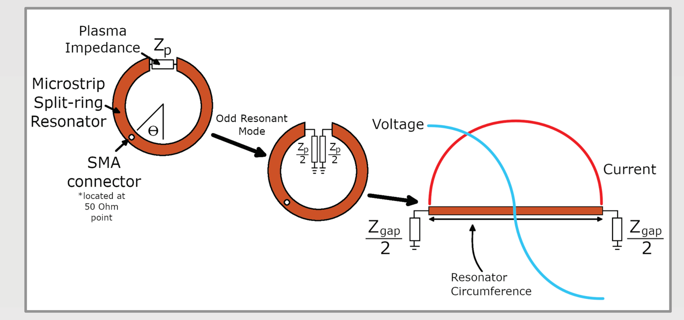


Laser Induced Breakdown Spectroscopy

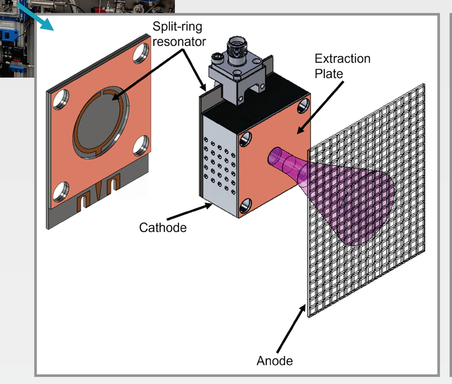


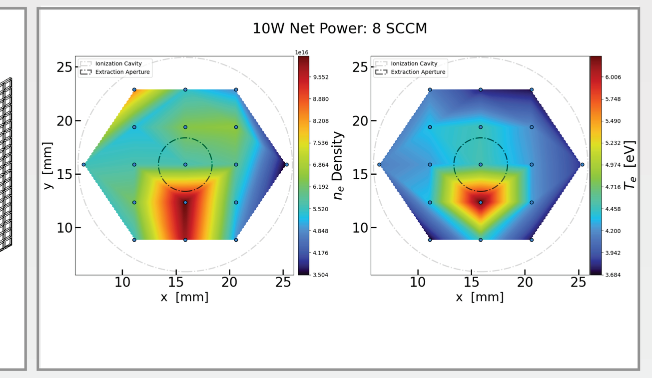
Neutralizer Study

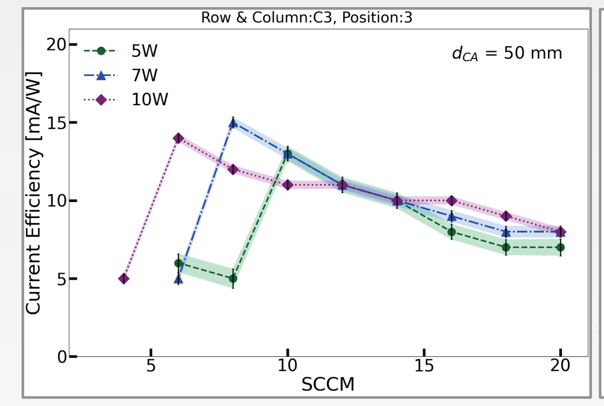
Quantity	Range
P	$0-100$ W
f_{Res}	~ 2 GHz
$P_{\text{discharge}}$	10 μTorr—atm.
T_e	≤ 10 eV
n_e	$\leq 10^{17}\ \text{m}^{-3}$

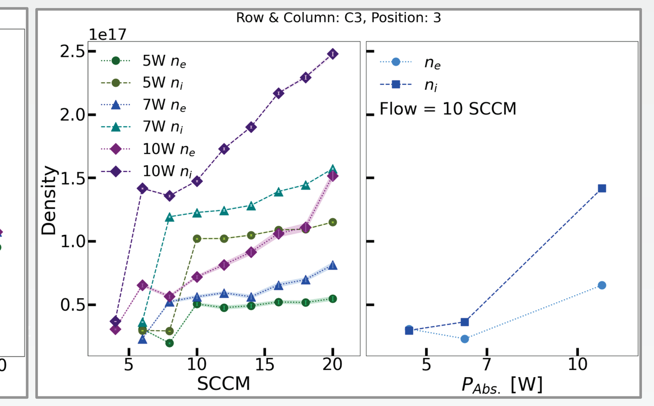


- Scalable, compact plasma generation from split ring resonator with large local electric field
- Appropriate bias fields facilitate extraction of electron current for neutralization of thruster plumes
- No heater, as opposed to thermionic emitters currently on market, leading to rapid start-up and turn off times.
- Work supported by AFOSR grant number FA9550-23-1-0038

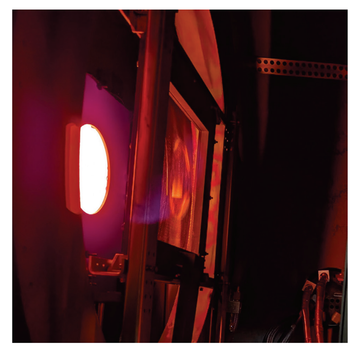








LaB_6 Operation in the Large Chamber



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

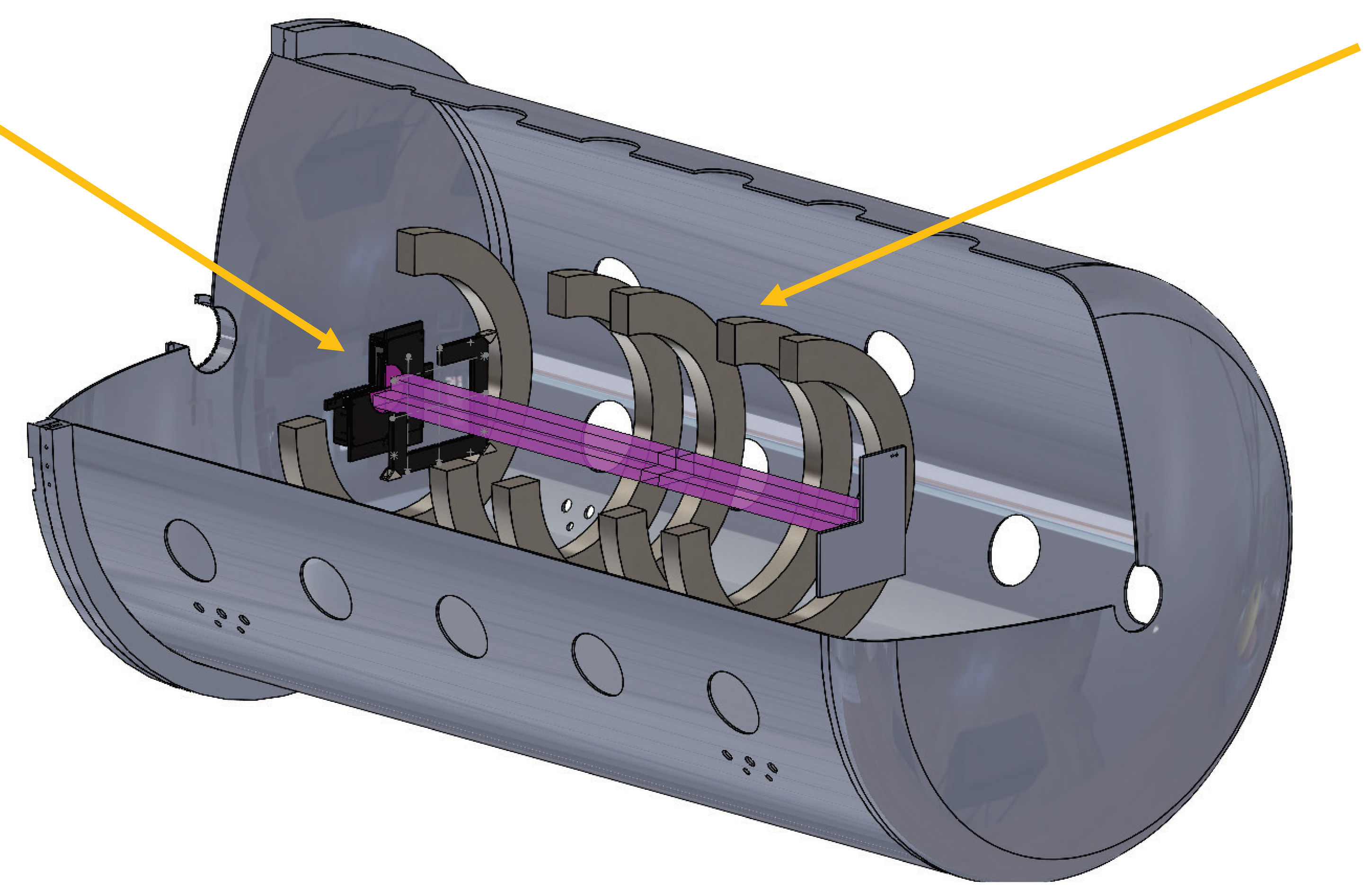
- Graphite heating element can source up to 800 A
- Can heat LaB_6 up to ~2000 C.
- Measure cathode temperature with a 2-color pyrometer.

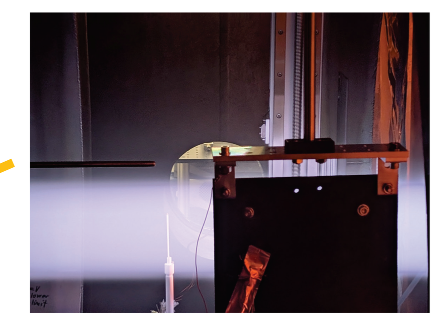
PULSED OPERATION

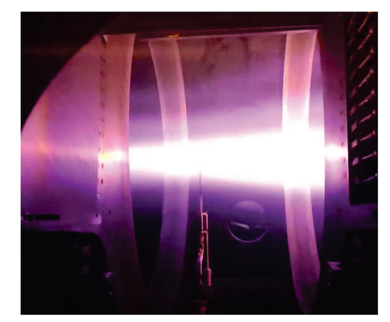
- In pulsed mode, trigger sent to 1.8 F cap bank, applying differential voltage between cathode and anode. Differential voltage applied for 20 ms, 1 Hz repetition rate.
- Cap bank can supply up to 5 kA of current in pulsed configuration.
- Reproducible plasma discharges observed in preliminary operation.

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.

Riverside Research Plasma Facility Takeaways

HyPIR Facility

- Facility for characterizing materials in extreme environments.
- Expose materials to atomic oxygen plasma while at high (~2000 C) temperature and observe changes in material properties.
- Simultaneously leverage optical diagnostics to track properties of ion, neutral, and electron species in the plasma region near the sample.

Large Chamber LaB_6 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 Low field led to a more diffuse, less dense plasma.
  - Currently use LTP on a motorized stage, mid speed camera.
  - Expanding to Bdot probes, Mach probes, RFA, LIF, spectroscopy, interferometry.

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.

Contact Information

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.