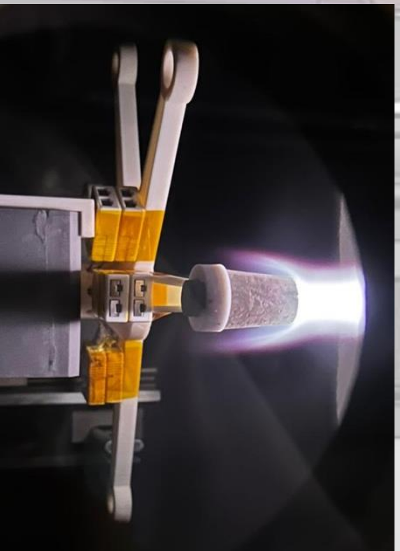
ARCTRON: A Rapid Experimental Proving Ground for TPS Experiments and Arcjet Technology Development



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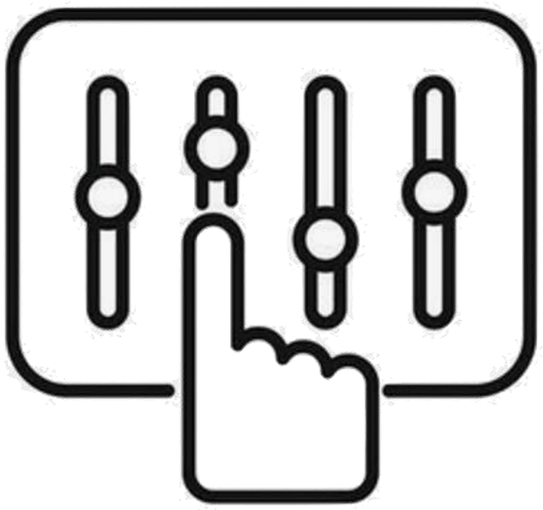
16th Ablation Workshop, September 1st, 2026, Las Cruces, NM

High Enthalpy Testing Has Three Major Challenges

CONTROL



MEASURE

ACCESS

- Can we modulate/isolate the physical mechanisms?

- Can we measure a modulated mechanism?

- Can we perform enough experiments?

ARCTRON Testing Philosophy

Traditional test-design

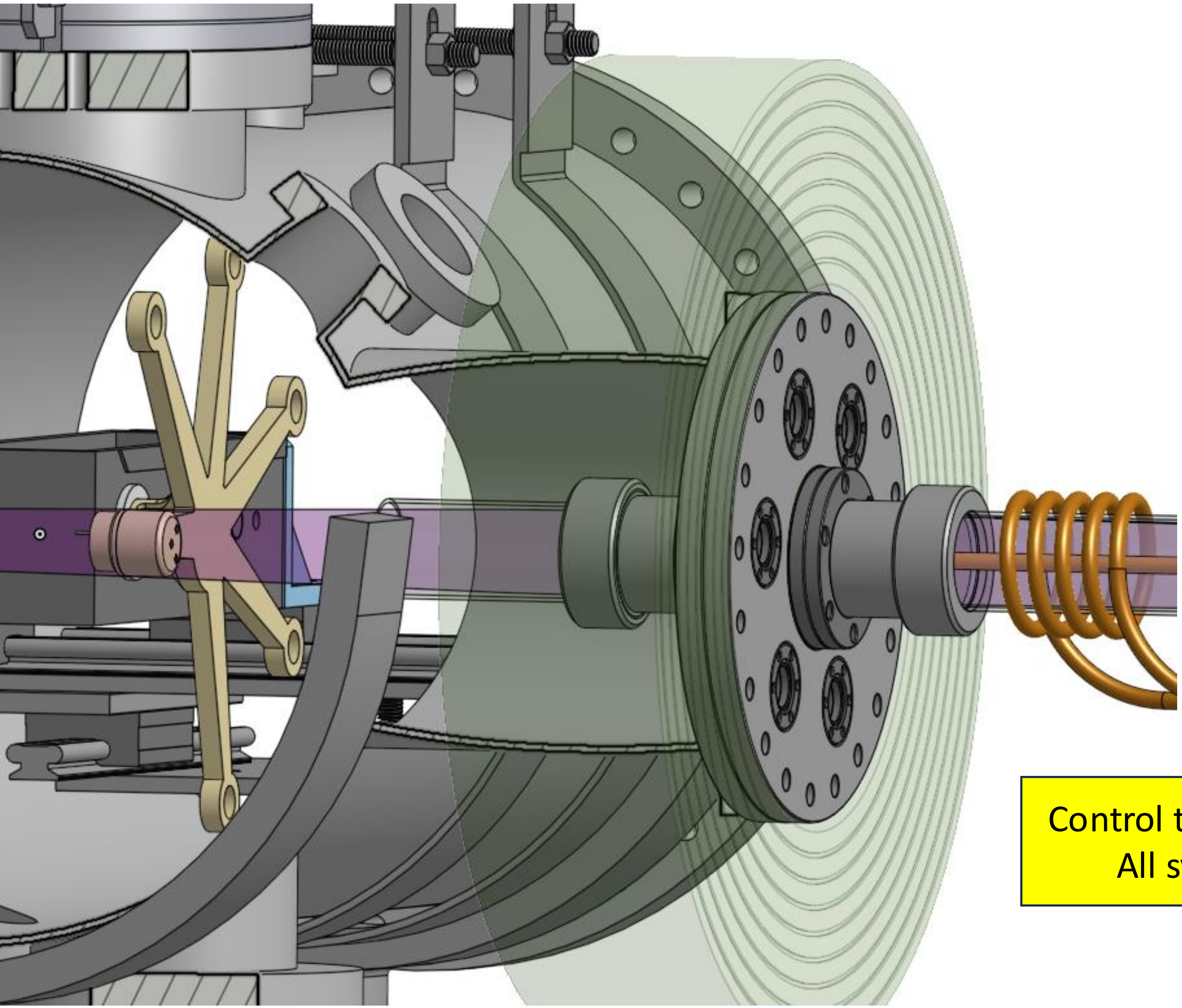
- “How accurately can we reproduce the flight environment?”

Information-driven test-design

- “What test environment will teach us the most?”

The Best Tests Reduce What We Don’t Know

ARCTRON: A Multi-Modal Experimental Proving Ground



CONTROL

HEAT

RF Plasma · Pulsed arc · DC arc · 2 kW laser

CONFIGURE

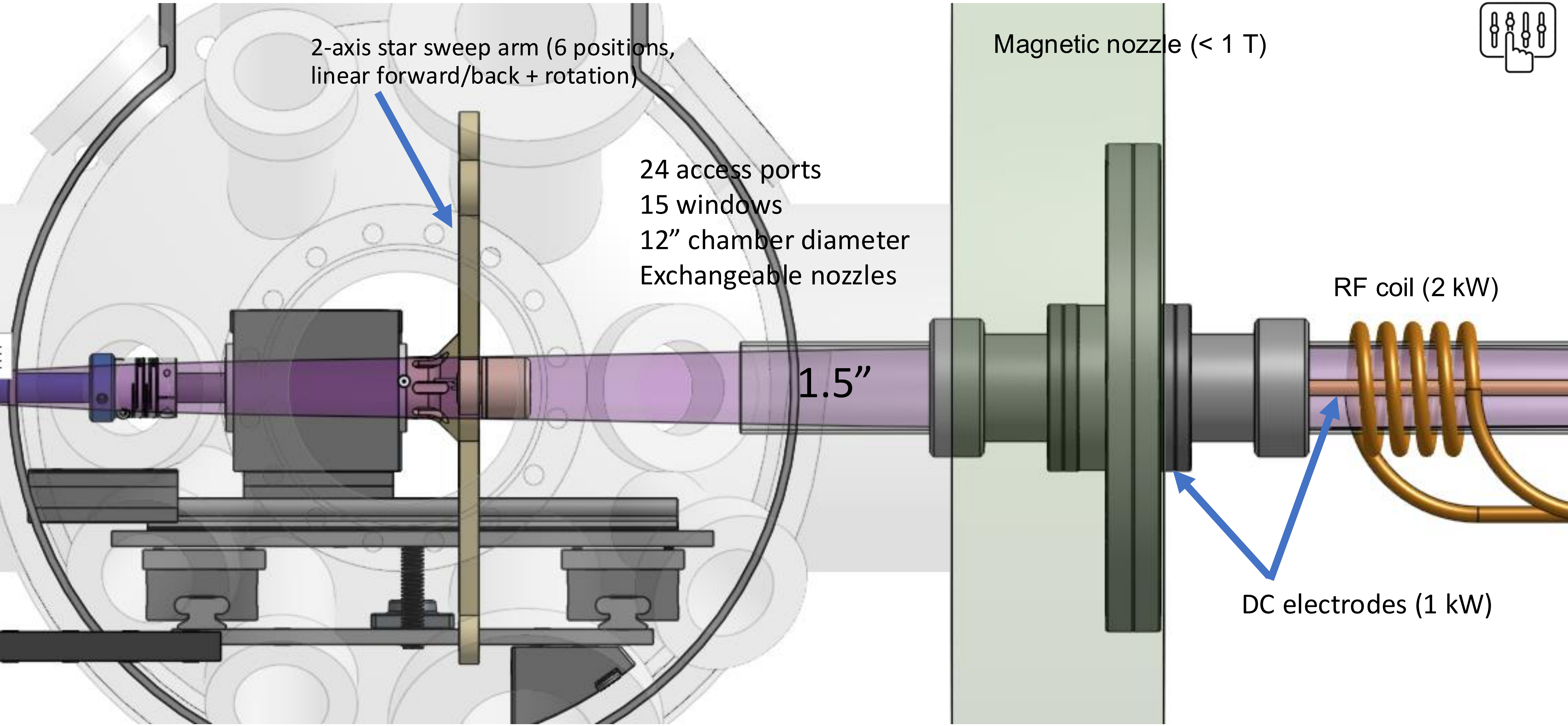
Gas (Ar, Air, CO_2, H/He) · flow rate · geometry

PERTURB

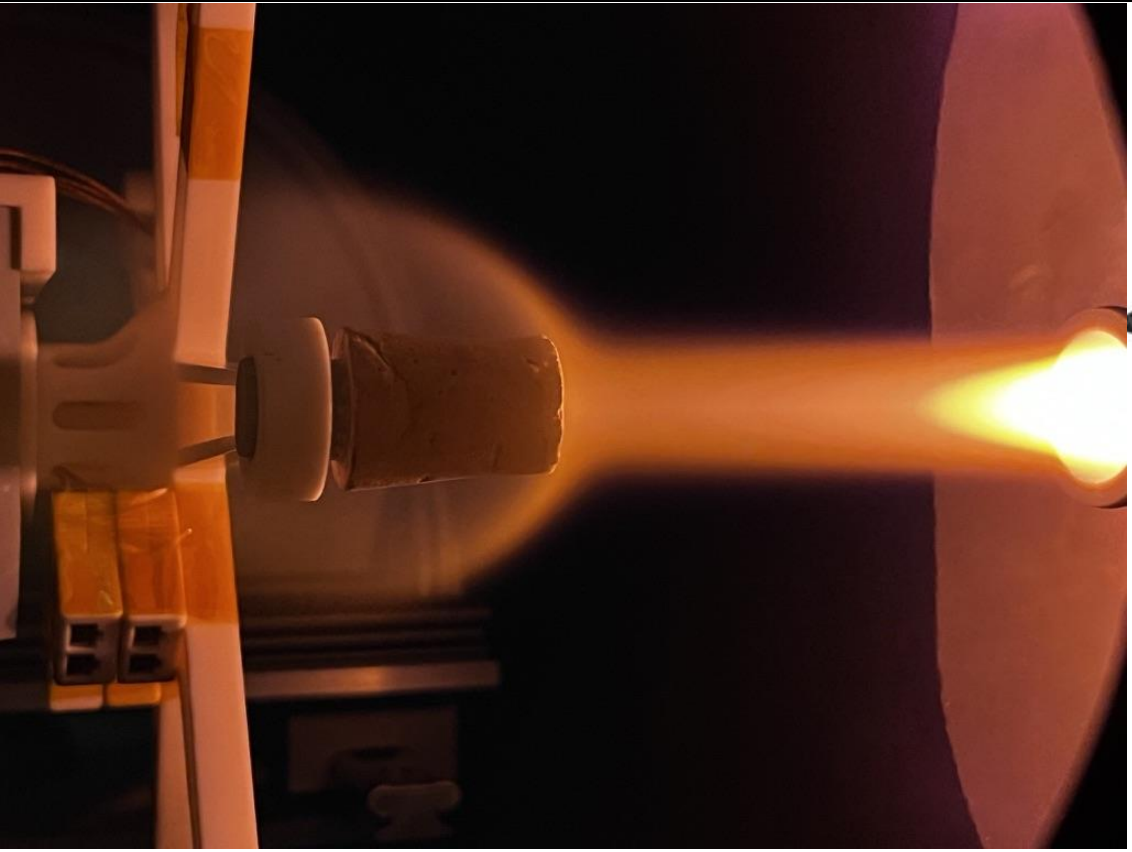
Magnetic field · 2D sweep arm · Electrical bias

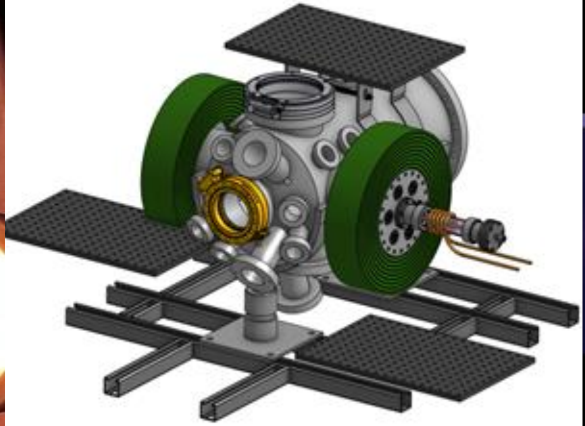
Control the environment without rebuilding the experiment
All systems are modular, all controls are automated

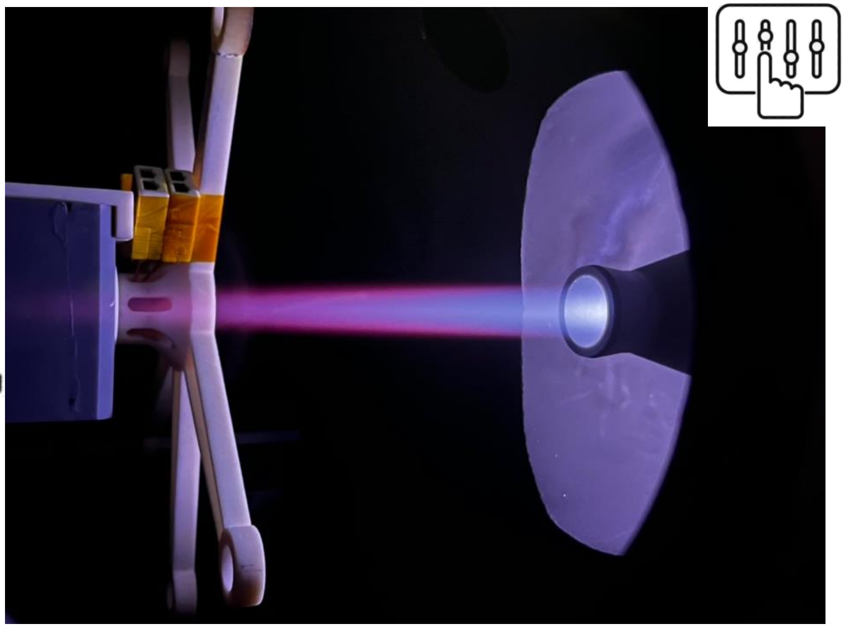
ARCTRON: A Multi-Modal Experimental Proving Ground



ARCTRON: A Multi-Modal Experimental Proving Ground

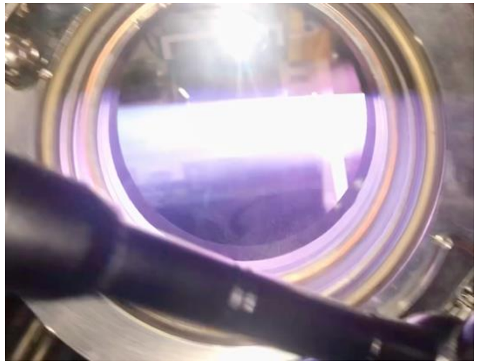




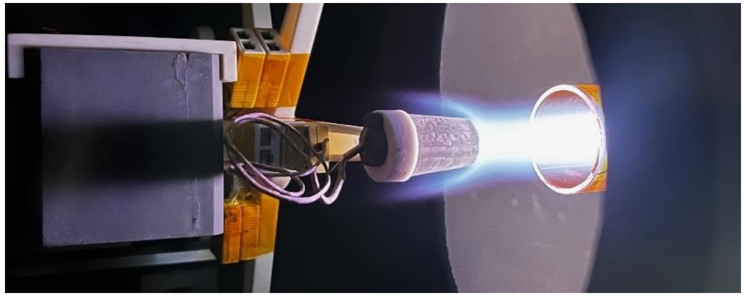


RF only

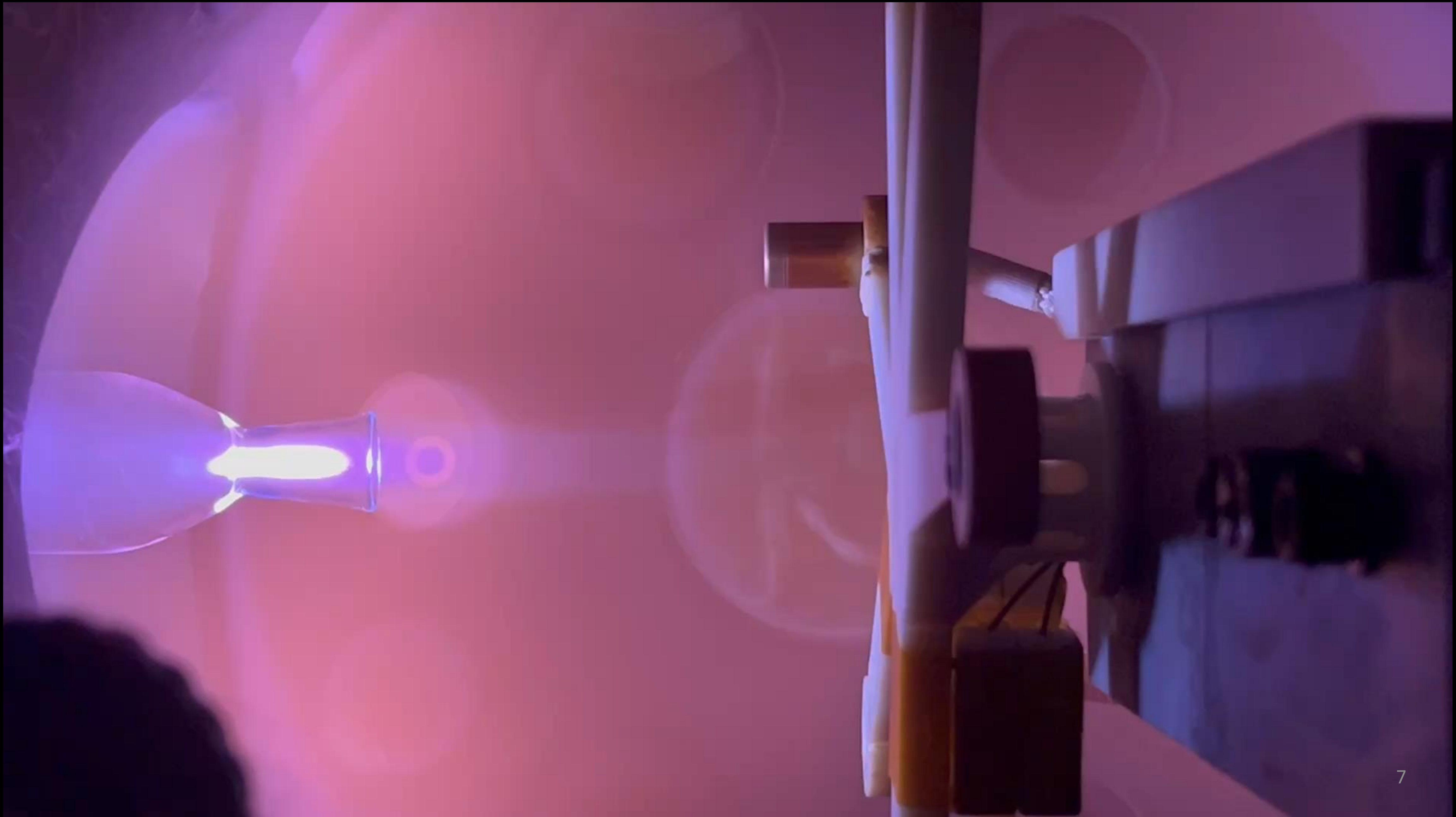
RF + Pulsed arc



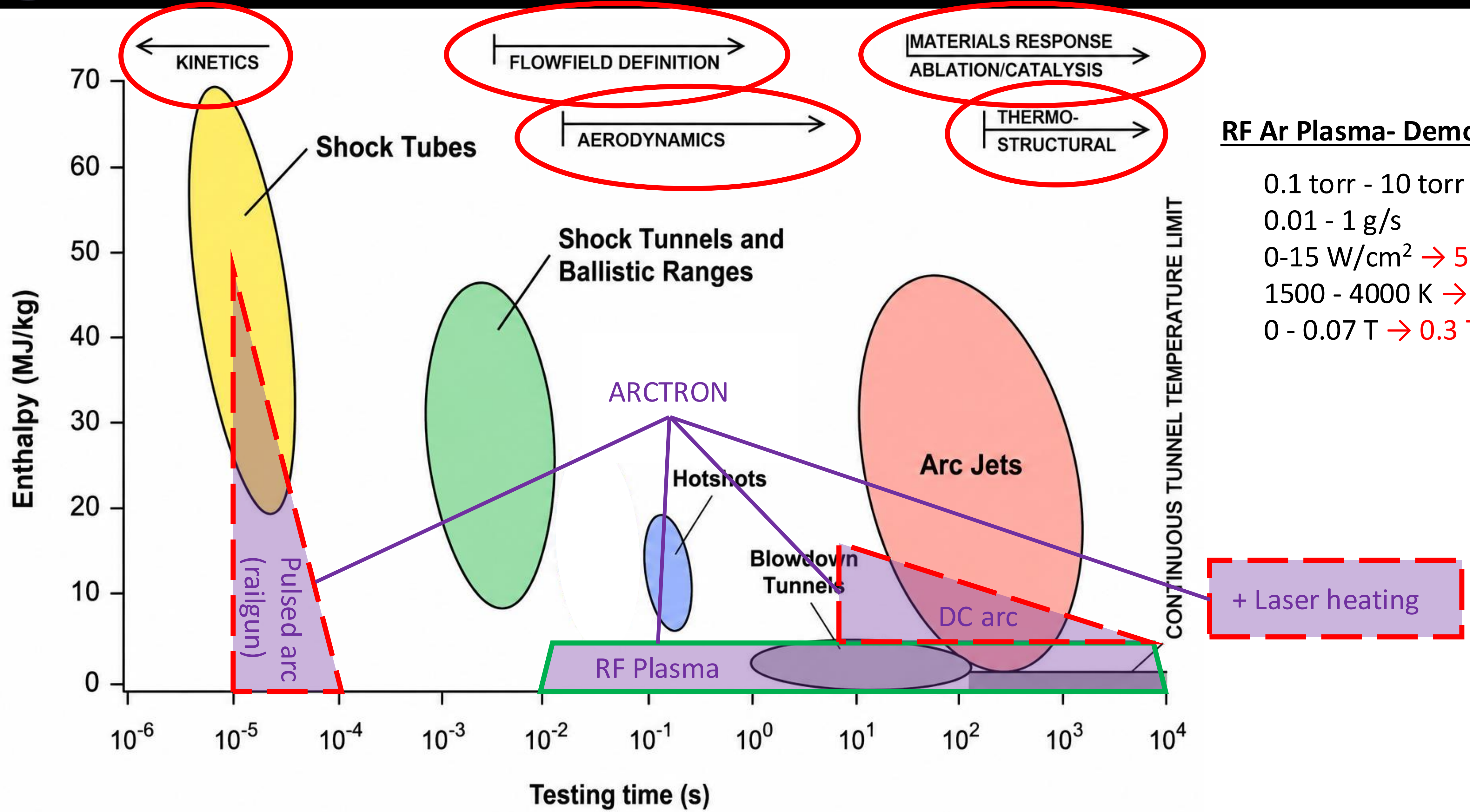
Calorimeter



ARCTRON: A Multi-Modal Experimental Proving Ground



Where Could ARCTRON Operate?



RF Ar Plasma- Demonstrated

0.1 torr - 10 torr
0.01 - 1 g/s
0-15 W/cm^2 → 50 W/cm^2
1500 - 4000 K → 6000K
0 - 0.07 T → 0.3 T

Diagnostic Suite

MEASURE

Diagnostics

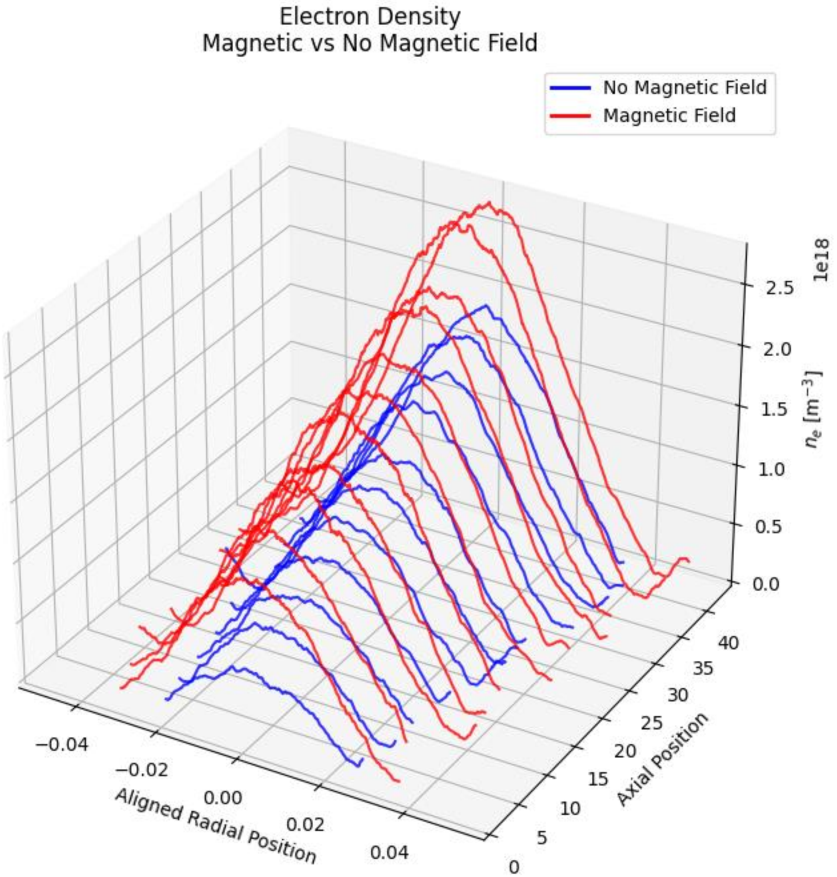
- Argon Laser induced fluorescence
- O* Laser absorption spectroscopy
- Optical emission spectrometers
- Langmuir fast-sweep probe
- Slug calorimeter
- Pitot probe
- Fast camera
- Pyrometer

Target measurements

- Ar temp & velocity
- O* density/temp
- Excitation temp, species comp
- Electron temp, density
- Heat flux
- Stagnation pressure
- Jet structure/dynamics
- Surface temperatures

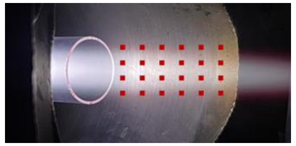
Survey of initial results

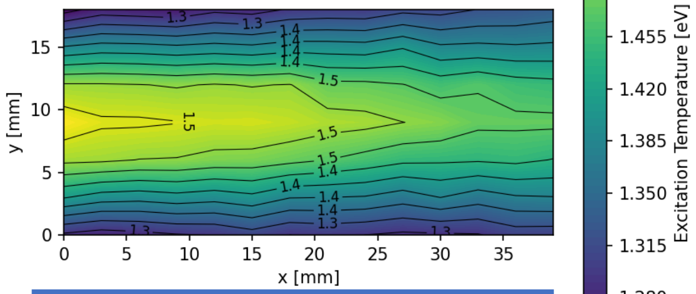
3D Langmuir measurements



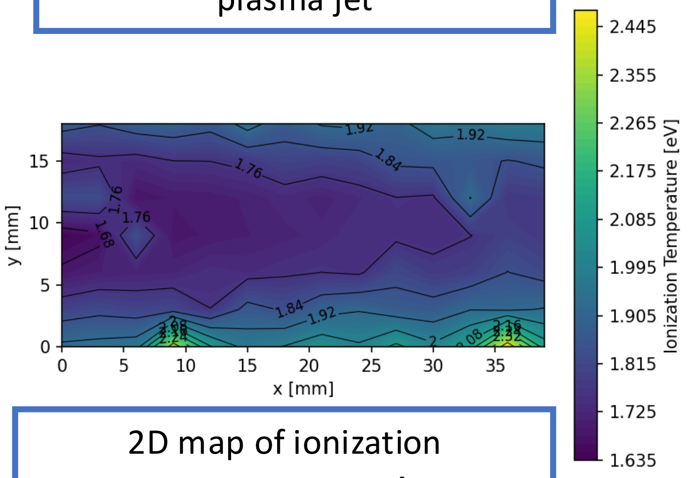
DC magnetic nozzle increases density and spread by 20-50%

OES 2D mapping





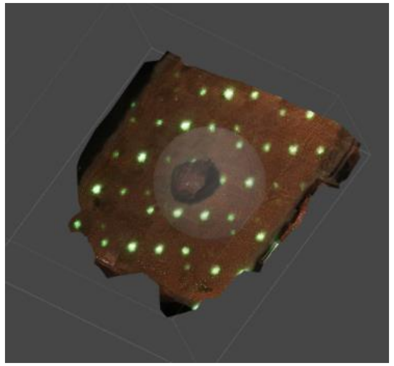
2D map of excitation temperature across Argon plasma jet



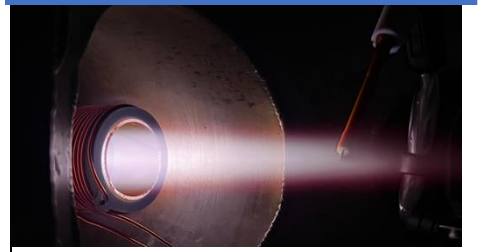
2D map of ionization temperature across Argon plasma jet

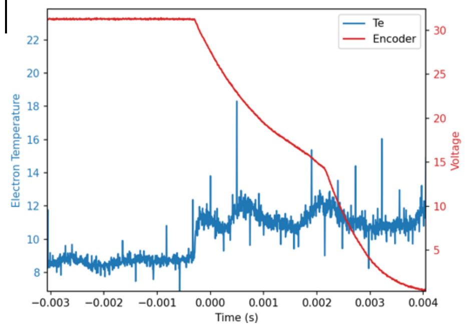
In-situ Photogrammetry

MEASURE



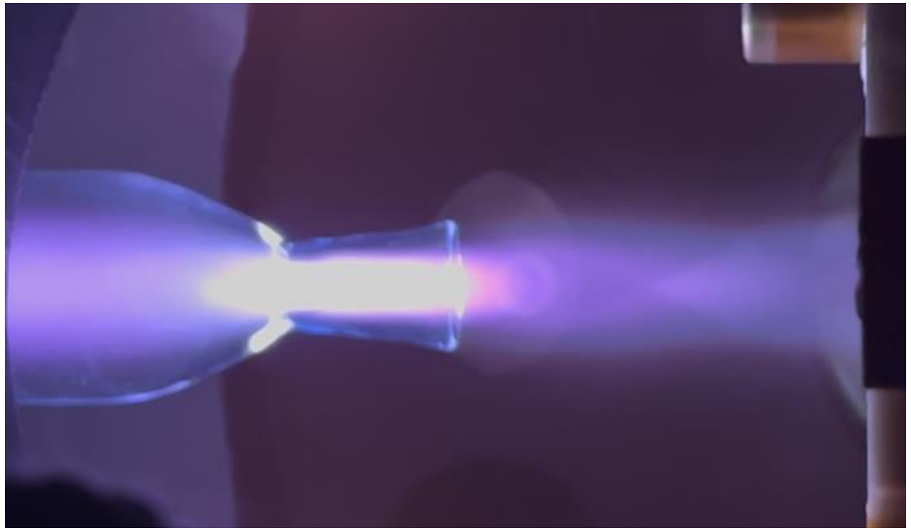
Pulsed magnetic nozzle doubles electron temperature

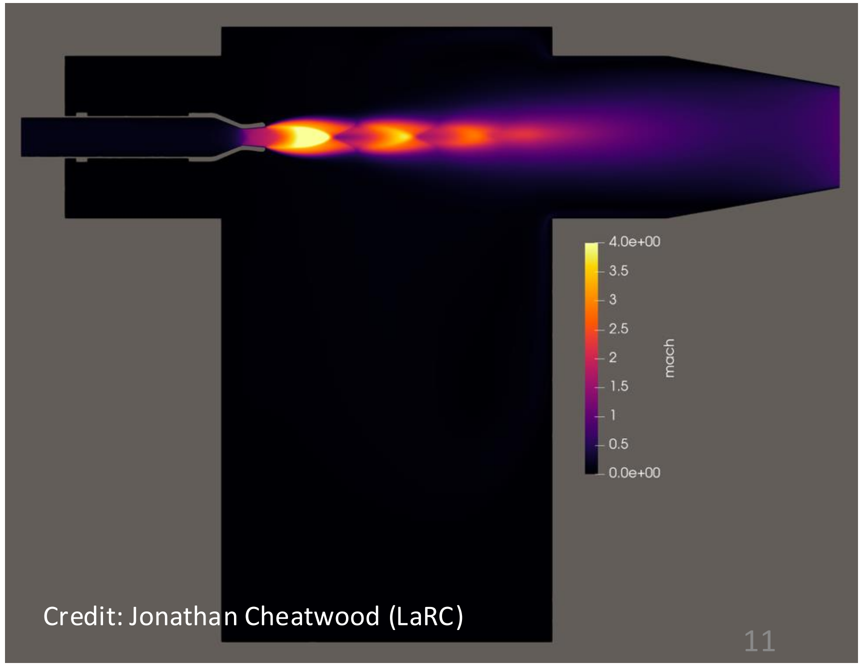




Hypersolve ARCTRON Modeling Task

- Ongoing ARC-LaRC collaboration effort with two primary goals:
  - Validation of HyperSolve Magnetohydrodynamic (MHD) capabilities and plasma physics models
  - Freestream characterization of ARCTRON facility and prediction of tunnel model environments
- Preliminary flowfield results and computational domain shown
- Future work:
  - Implementation of ICP coil modeling
  - Validation against empty-tunnel measurements

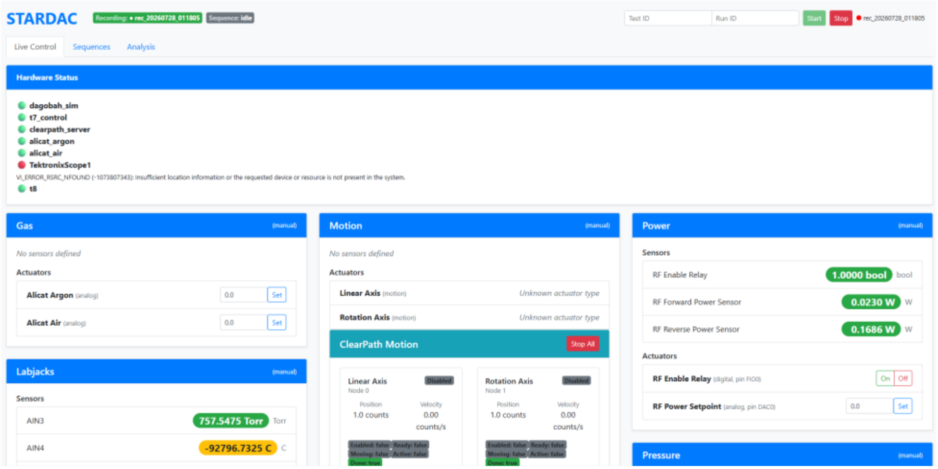




Credit: Jonathan Cheatwood (LaRC)

Automation & Data Infrastructure

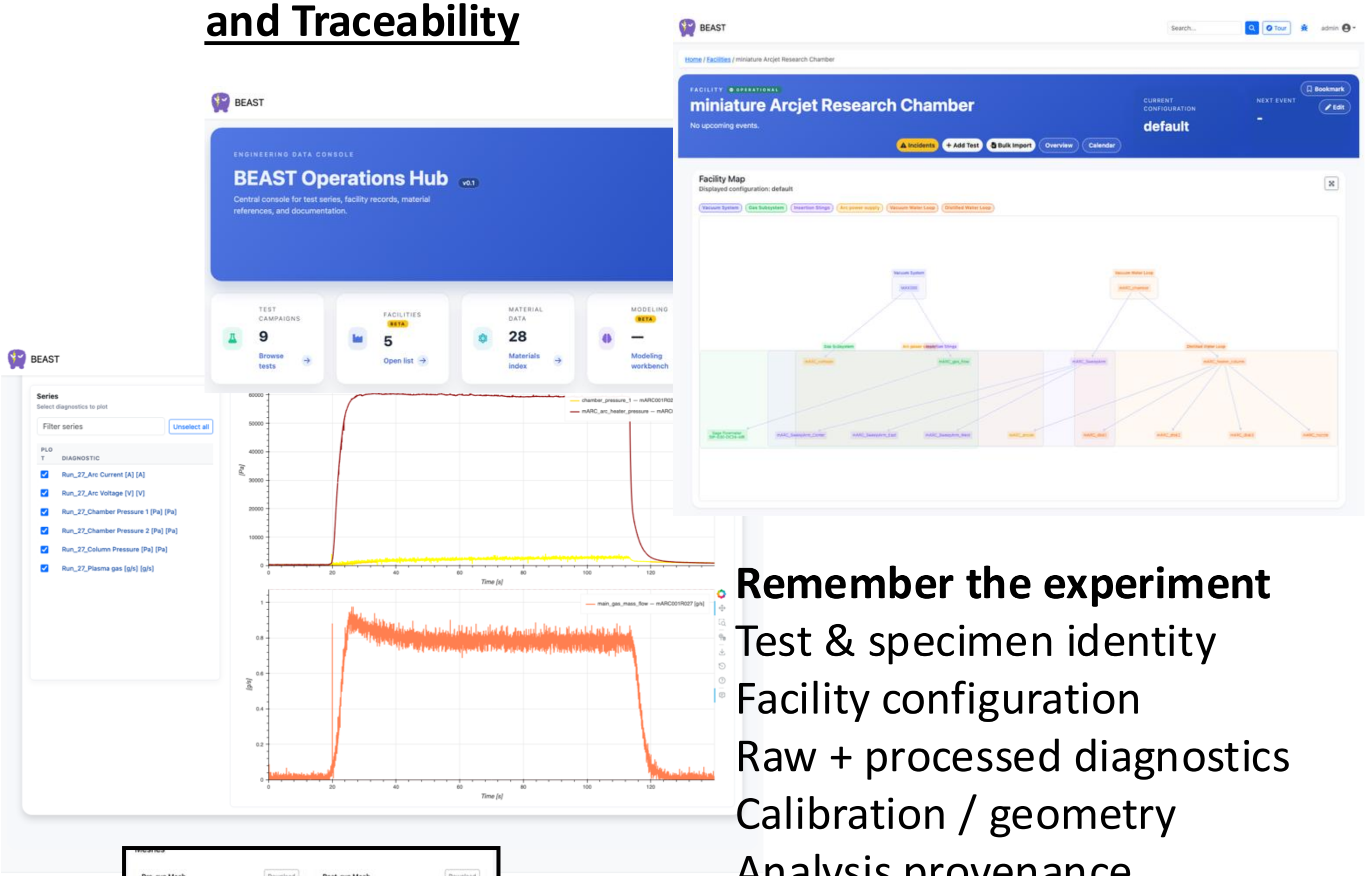
STARDAC - System for Test Automation and Reconfigurable Data-Acquisition & Control

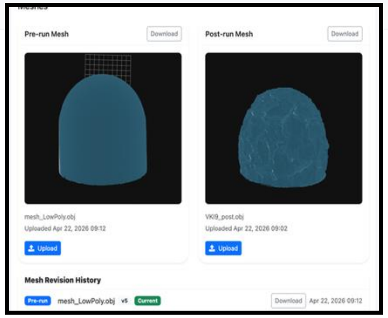


Run the experiments
YAML experimental sequencing
Synchronized data acquisition & control
Facility state / setpoints
Configuration recorded with each run

Enabled 60 conditions run in 60 min

BEAST – Backend for Experiment Analysis, Storage, and Traceability





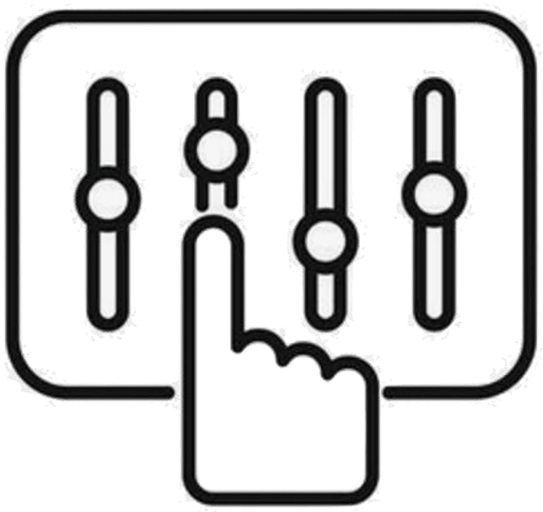
Remember the experiment
Test & specimen identity
Facility configuration
Raw + processed diagnostics
Calibration / geometry
Analysis provenance
Search & comparison across runs

Pending open-source release
See Poster by A. Quintart

The Best Tests Reduce What We Don’t Know

ARCTRON is not designed to reproduce a complete flight environment. Its purpose is to reduce the cost and time required to ask consequential questions about plasma behavior, TPS-plasma interfaces, diagnostics, and arcjet technology

CONTROL



MEASURE

ACCESS

- Isolate and control environment mechanisms
- Measure critical states
- Iterate across many experiments

- ***<u>***Sebastián Colom***</u>***
- **<u>Alex Quintart</u>**

- Interns
  - J Flores Govea
  - Royce Tuncar
  - Mateo Lopez
  - Steven Latimer
  - John Carter
  - Nicolas Tomic
  - Nicolas Derider
  - Ethan Leong
  - Giselle Onofre
  - Julian Ornelas
  - Koushik Chennakesavan

- Division support
  - Brett Cruden
  - Jocelino Rodrigues
  - Andrea Fagnani
  - Megan MacDonald

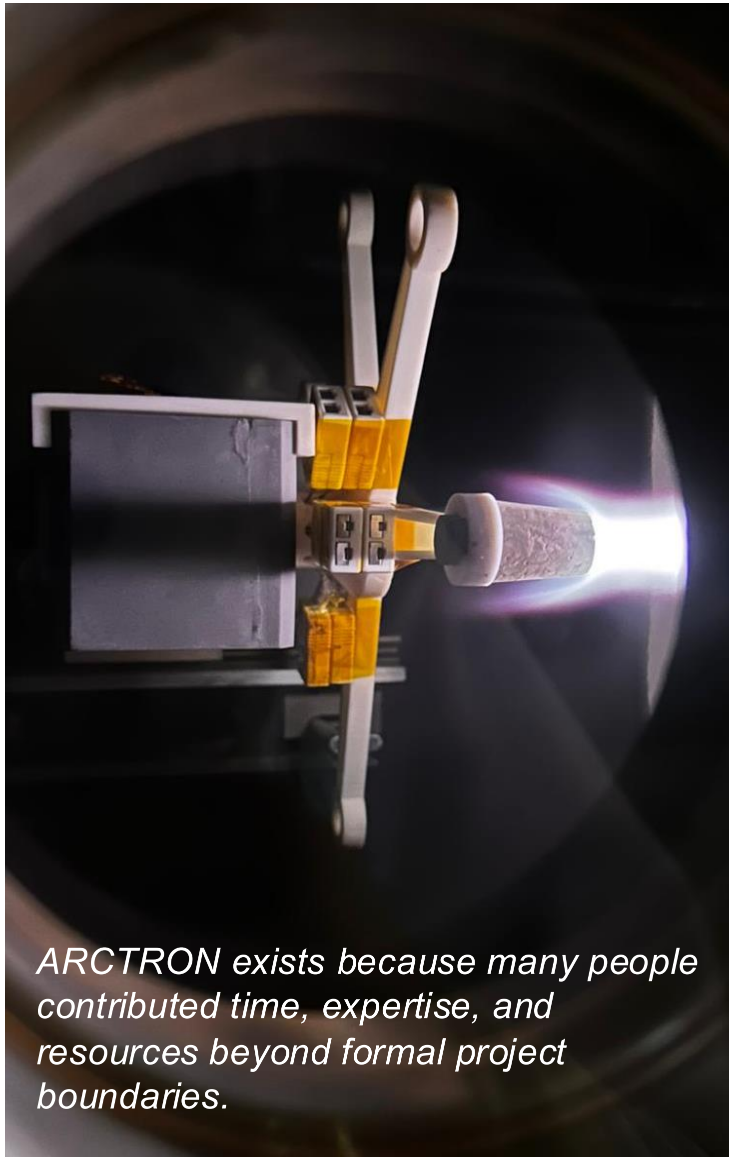
QUESTIONS?

Current Collaborators:

- mARC Facility: Diagnostic development for testing environments
- Entry System Modeling: Model validation for material responses under a wide-range of environments
- Jonathan Cheatwood (LaRC): MHD HyperSolve validation
- Dr. Ken Hara at Stanford University: Model validation for aerospace plasma physics
- Dr. Hisham Ali at CU Boulder: Validating sensor instrumentation and testing environments

Appreciation Shoutouts:

- **EM&I Project – for startup funding and continued support**
- **Mairead Stackpoole** – for continuously supporting us in making this happen and being our #1 fan!
- **Justin Haskins & Brody Bessire** – providing us the necessary tools and support



Contact: magnus.haw@nasa.gov

ARCTRON Specs

Overview

- Multi-gas, multi-heat-source plasma jet platform
- Reconfigurable geometry, chemistry, and EM fields
- Benchtop scale enabling rapid iteration with dense diagnostics

Power Sources

- 2 kW RF supply (ICP / helicon modes)
- 200 A DC arc supply
- 2 kW blue laser (radiative heating & calibration)
- 6 kV capacitor bank (pulsed / shock studies)

Vacuum System

- 2x Leybold D30A (27 CFM each)
- 1x Leybold WS251 blower (150 CFM)
- 1x Leybold D40BCD rotary vane (28 CFM)

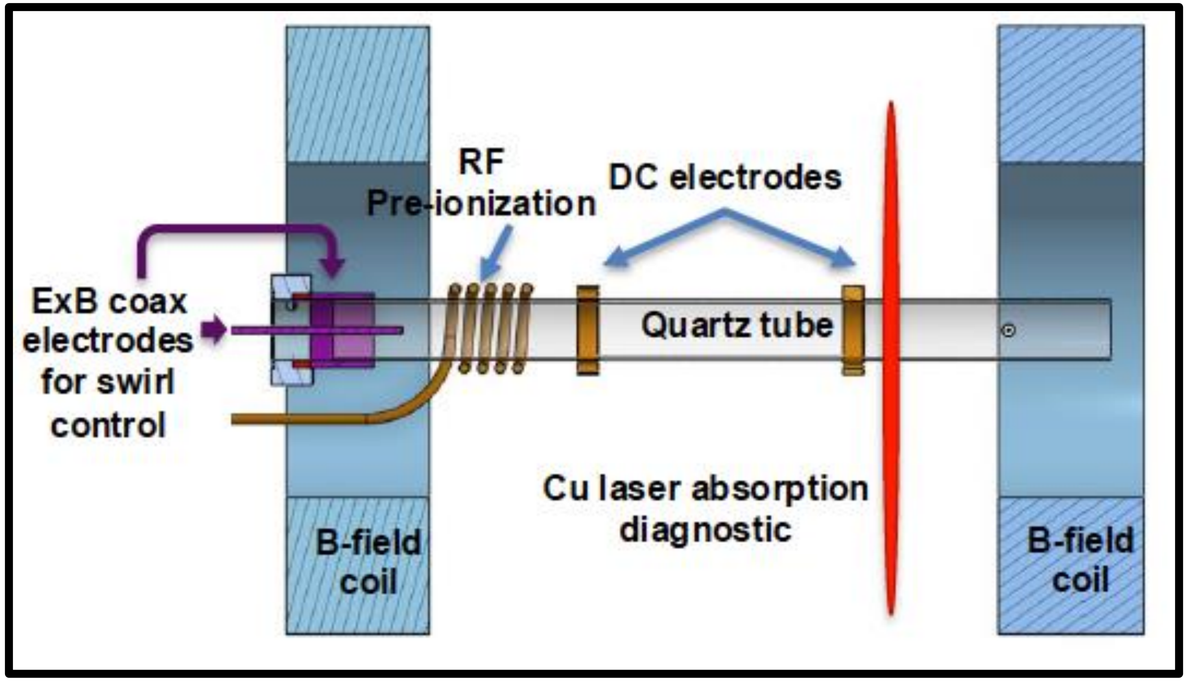
Control Parameters

- Multi-gas flow control (Ar, O_2, H_2, He, N_2, air)
- Magnetic field: dual coils (< 1 T)
    - Magnetic nozzle / flow shaping
- 6 kV HV supply (ExB swirl control)
- Laser coupling for controlled radiative input

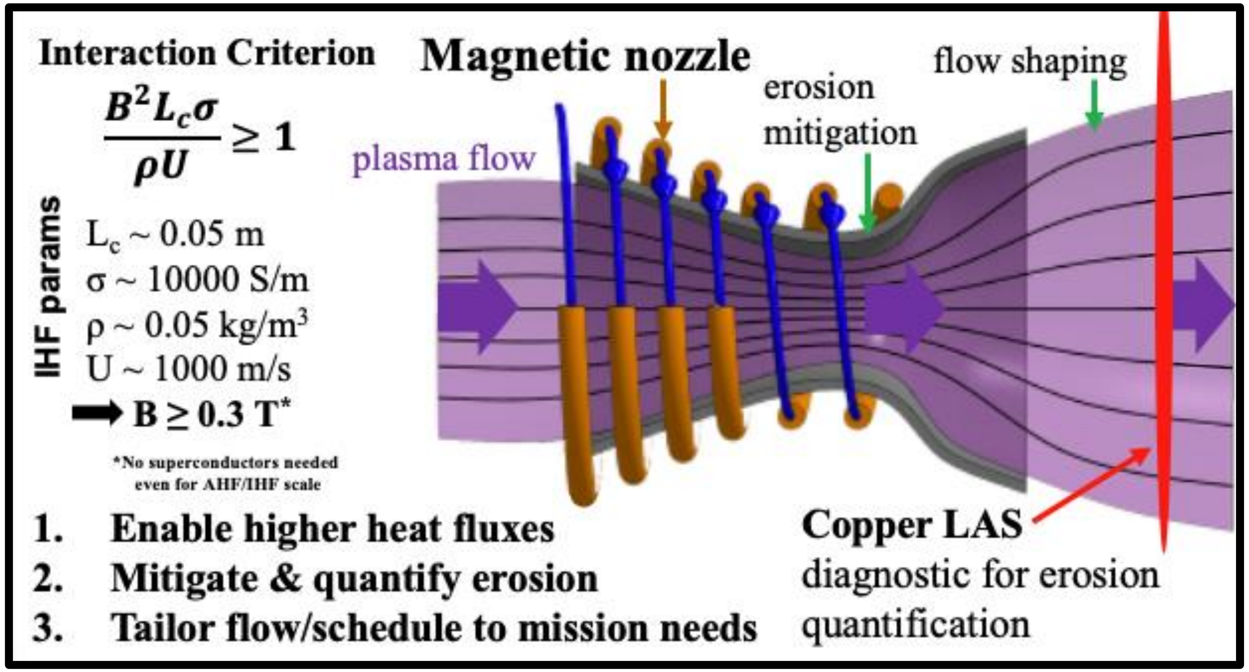
Diagnostic Access

- 2x linear insertion sting arms
- 1x 6-position 2D rotational sting
- 15 optical access windows

ExB swirl control

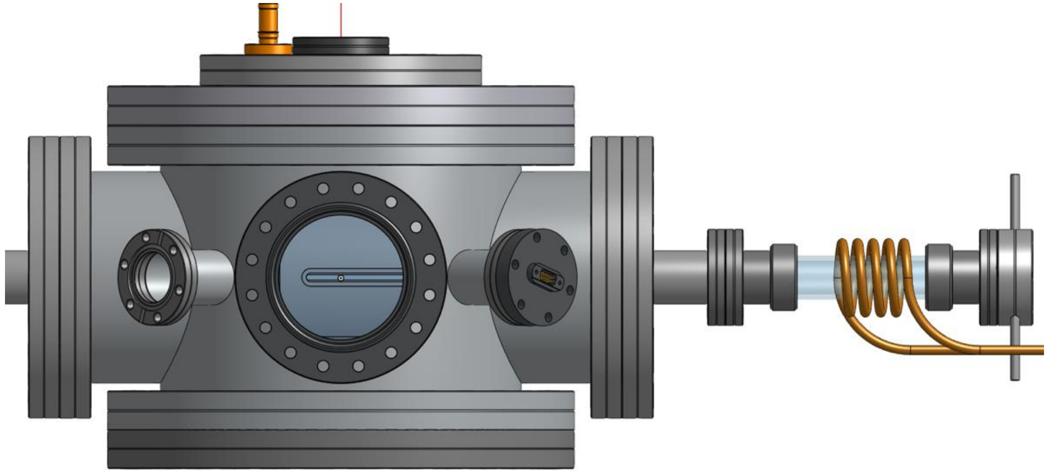


Magnetic flow modulation



Beta Chamber for Recombination Catalycity Characterization

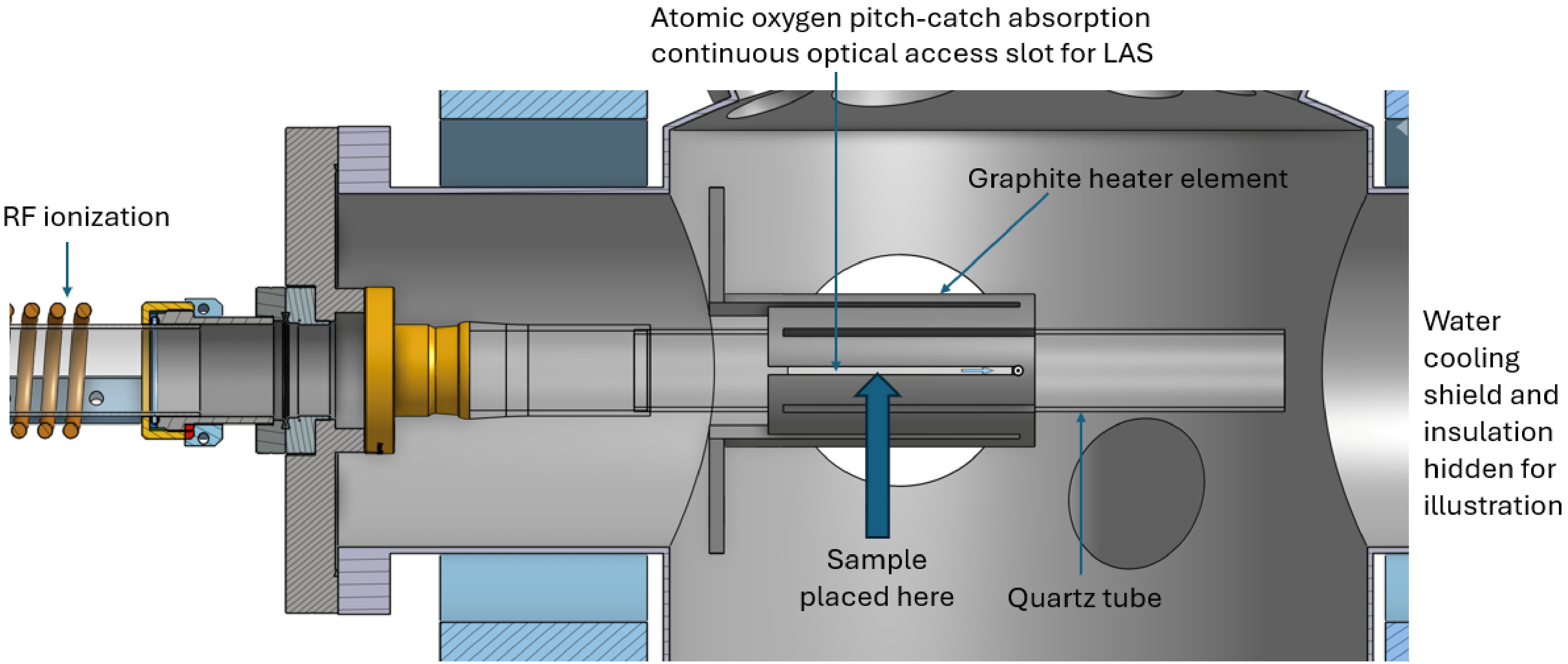
Repurposed extra vacuum chamber for dedicated high temperature catalycity setup



Catalycity Apparatus

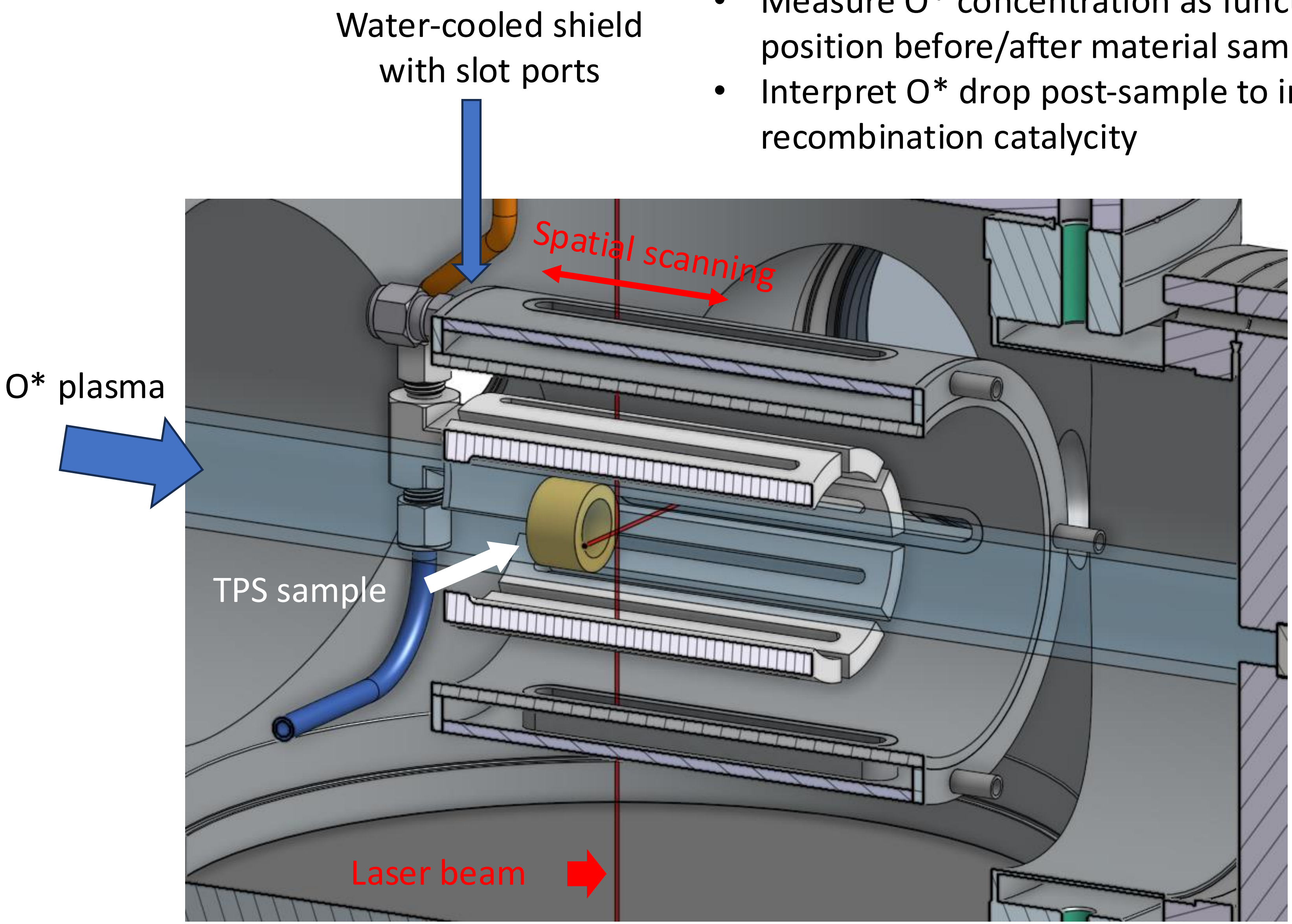
Recombination catalycity is a critical component of TPS heating but relatively uncharacterized above 200C

Designed for 20-1000C operation

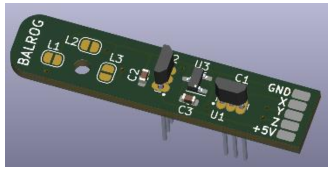


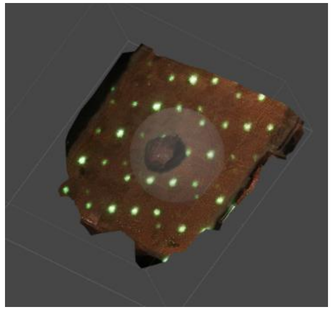
Catalycity Apparatus

- Measure O* concentration as function of position before/after material sample
- Interpret O* drop post-sample to infer recombination catalycity

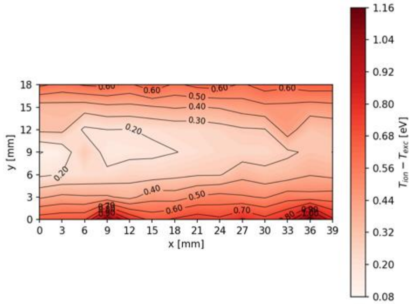


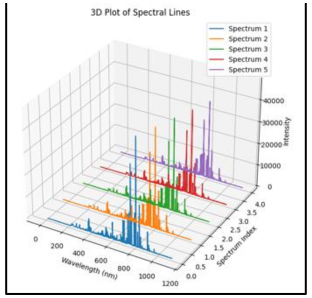
Current Research Areas

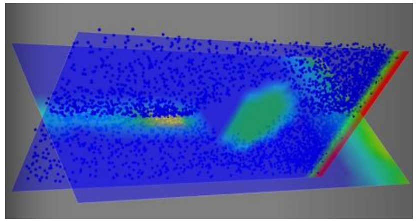




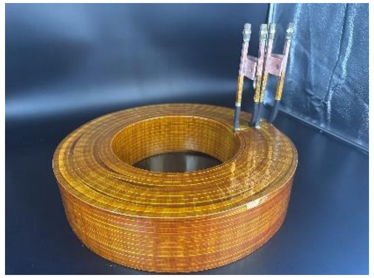
Diagnostic Development

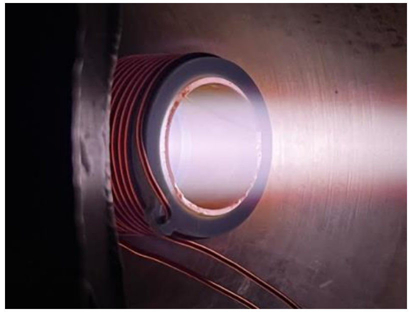




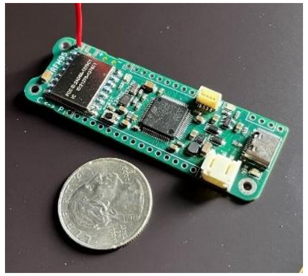


Simulation Validation





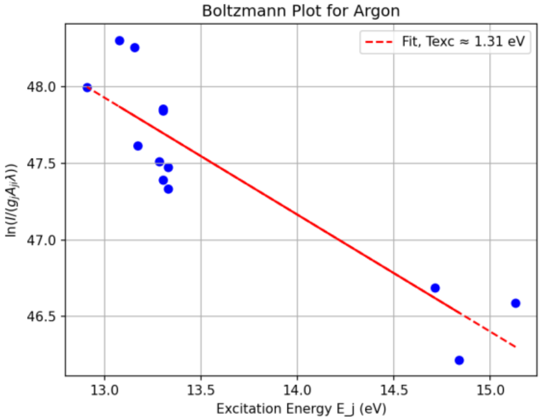
Arcjet Technology Development

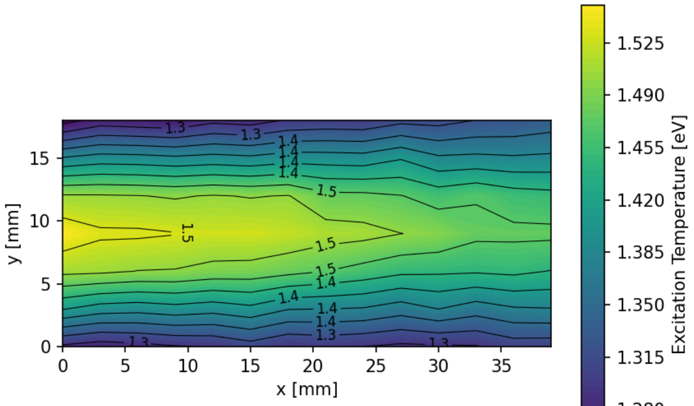


Data and Laboratory Modernization

2D Spatially Resolved OES

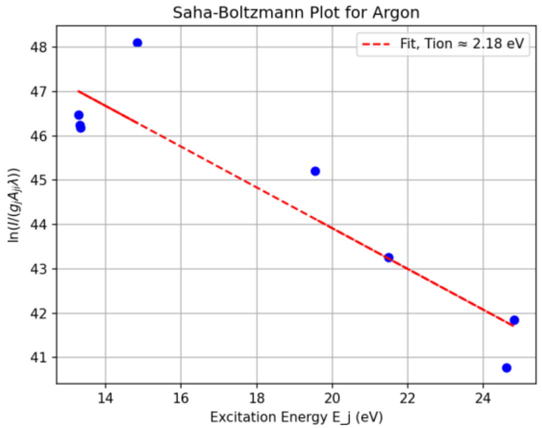
Boltzmann plot to measure excitation temperature

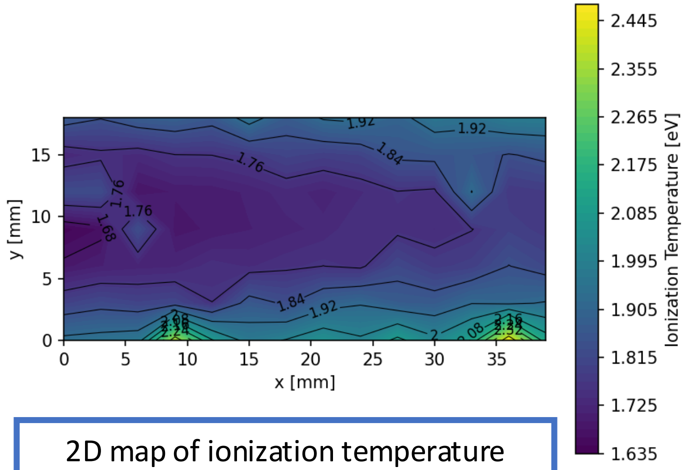




2D map of excitation temperature across Argon plasma jet

Saha-Boltzmann plot to measure ionization temperature

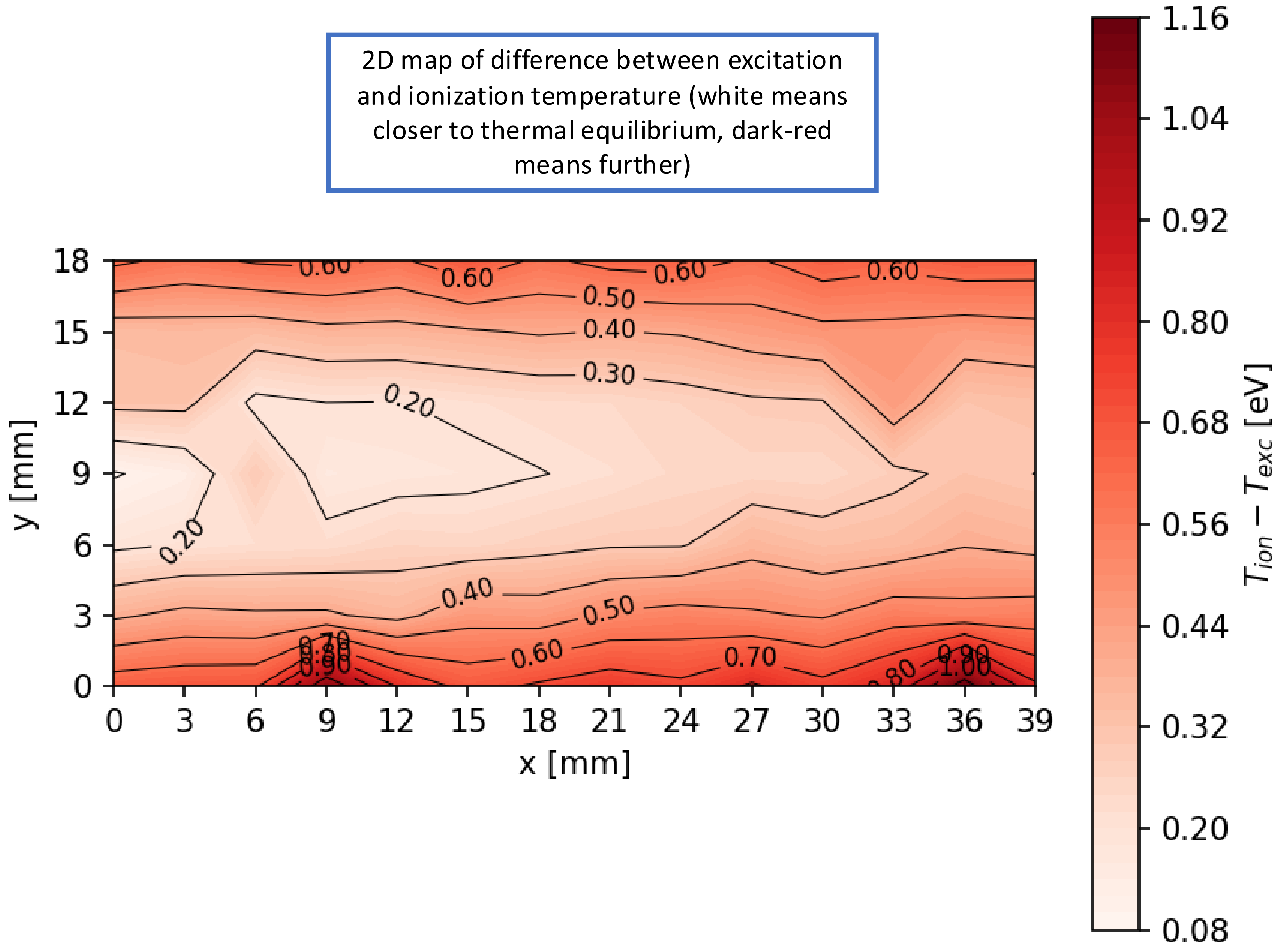




2D map of ionization temperature across Argon plasma jet

- Excitation temperature map reveals more collisions closer to centerline axis
- Ionization temperature reveals high energy deposited near the jet's rim related to ICP designs

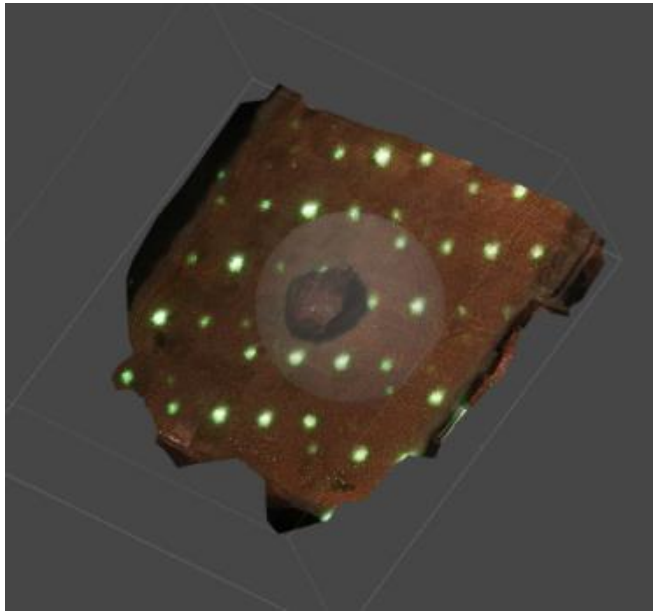
2D map of difference between excitation and ionization temperature (white means closer to thermal equilibrium, dark-red means further)



3D photogrammetry

- Building on the 3D scanner work, the technique is being extended for use in-situ during arcjet testing
- First measurements on ARCTRON were conducted by VKI visitors from the summer program: Nicolas Derider, Nicolas Tomic & Alex Quintart.

- Main difficulties
  - Insufficient lighting
  - Limited depth of field
- Can resolve these limitations via strobe lighting and iris reduction



Diagnostics: Argon LIF

- Major components acquired
  - Laser @697nm
  - Chopper
  - Lock-in amplifier
  - Notch filter for fluorescent emission @772nm
  - High sensitivity diode sensor
  - 2-axis mount for sensor scans
  - Acquired wavemeter + reference laser
- TBD
  - Integration/mounting/control
- Ar LIF will provide 3D Argon ion temperature & doppler velocity measurements. Density can be inferred using RadCol models.

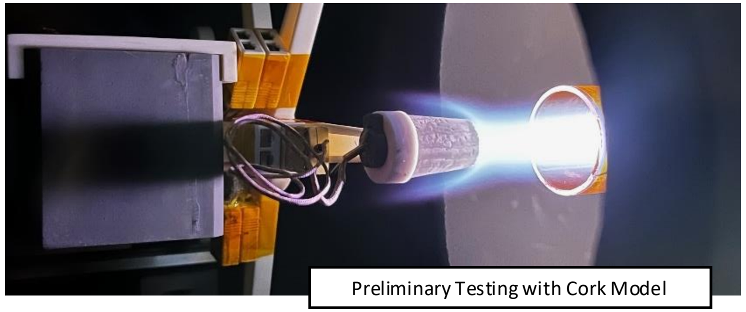
Diagnostics: O* Laser absorption

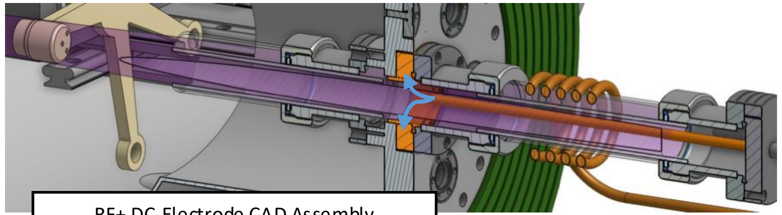
- Major components acquired:
  - O* 777nm laser (uses same laser controller as Argon LIF)
  - Fiber coupling
- TBD
  - Acquire beam shaping optics
  - Acquire O reference cell
  - Alignment with catalycity heater elements

ARCTRON

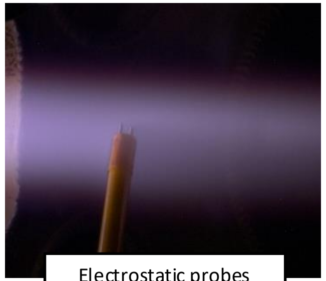
Flexible platform with parallel RF, DC-arc, and radiative heating sources + advanced diagnostics for TPS & arcjet research & development

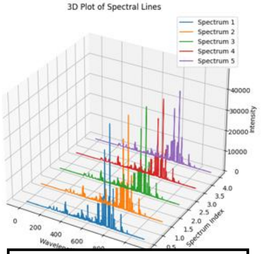
Arcjet & TPS Technology Development


Preliminary Testing with Cork Model

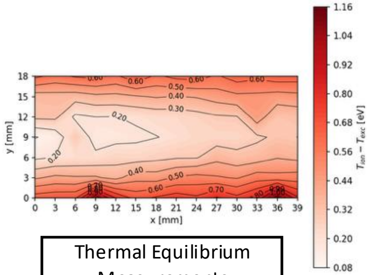

RF+ DC-Electrode CAD Assembly

Diagnostics Development

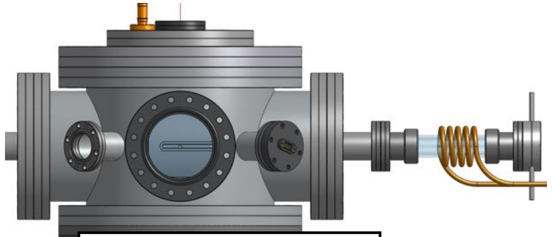

Electrostatic probes

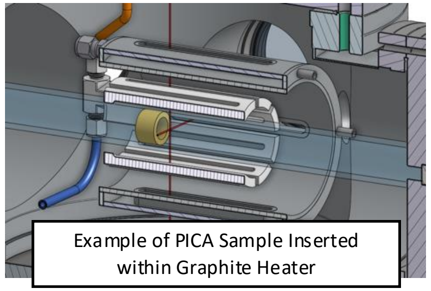


Emission Spectra

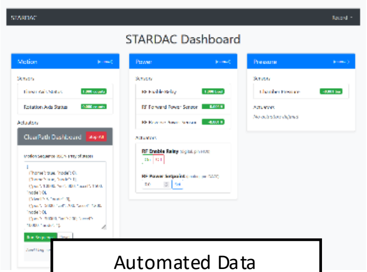

Thermal Equilibrium Measurements

Catalycity Characterization

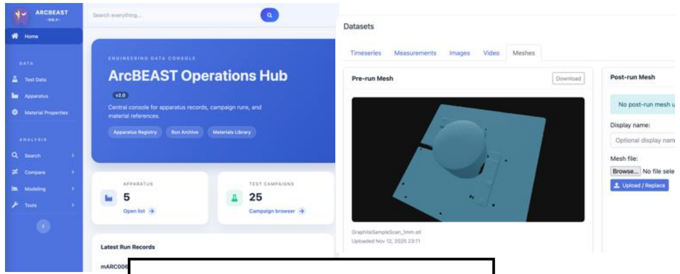

Chamber CAD Assembly


Example of PICA Sample Inserted within Graphite Heater

Controls & Data Automation



Automated Data Acquisition & Controls



Integration with BEAST database