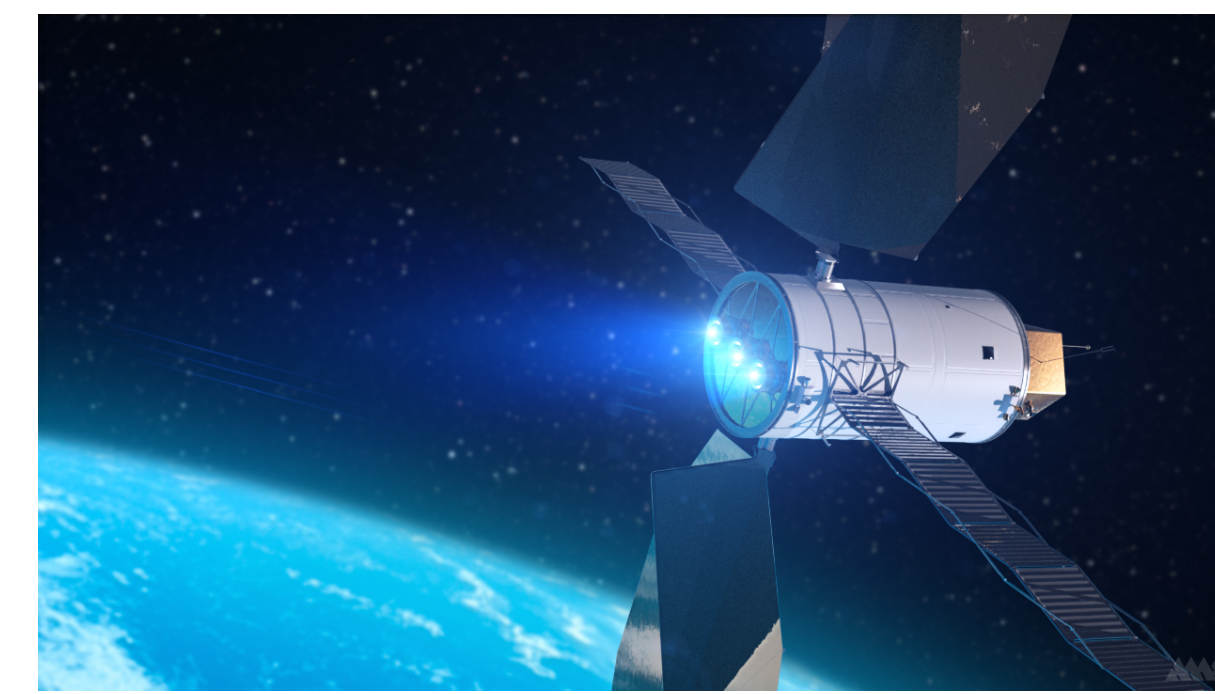


What is in-space electric propulsion?

Spacecraft utilize their propulsion system to move in space to accomplish two primary functions:

- Orbital positioning
- Spacecraft attitude and control

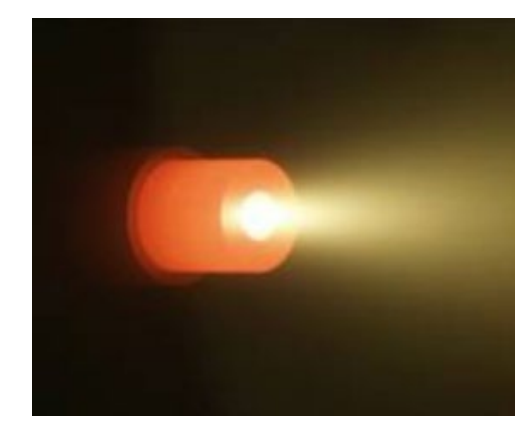


EP propelling an Earth-orbiting satellite (Photo credit: NASA)

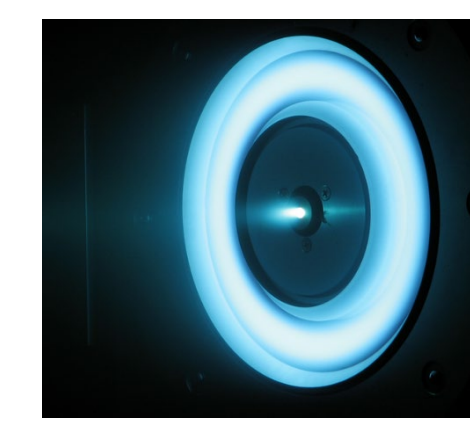
What is electric propulsion (EP)?

Electric propulsion is a type of in-space propulsion that uses electromagnetic forces to accelerate a propellant to generate thrust

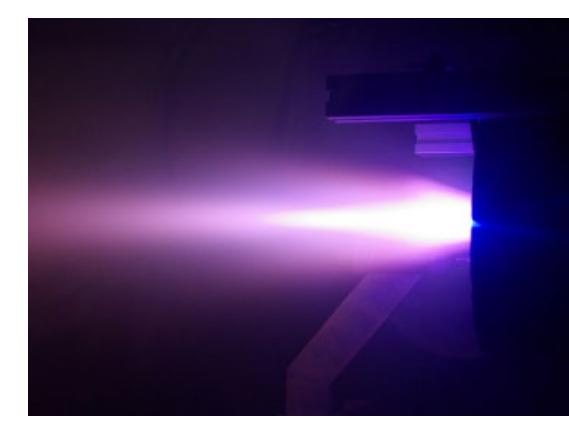
3 types of EP



Electrothermal (TALOS Arcjet)

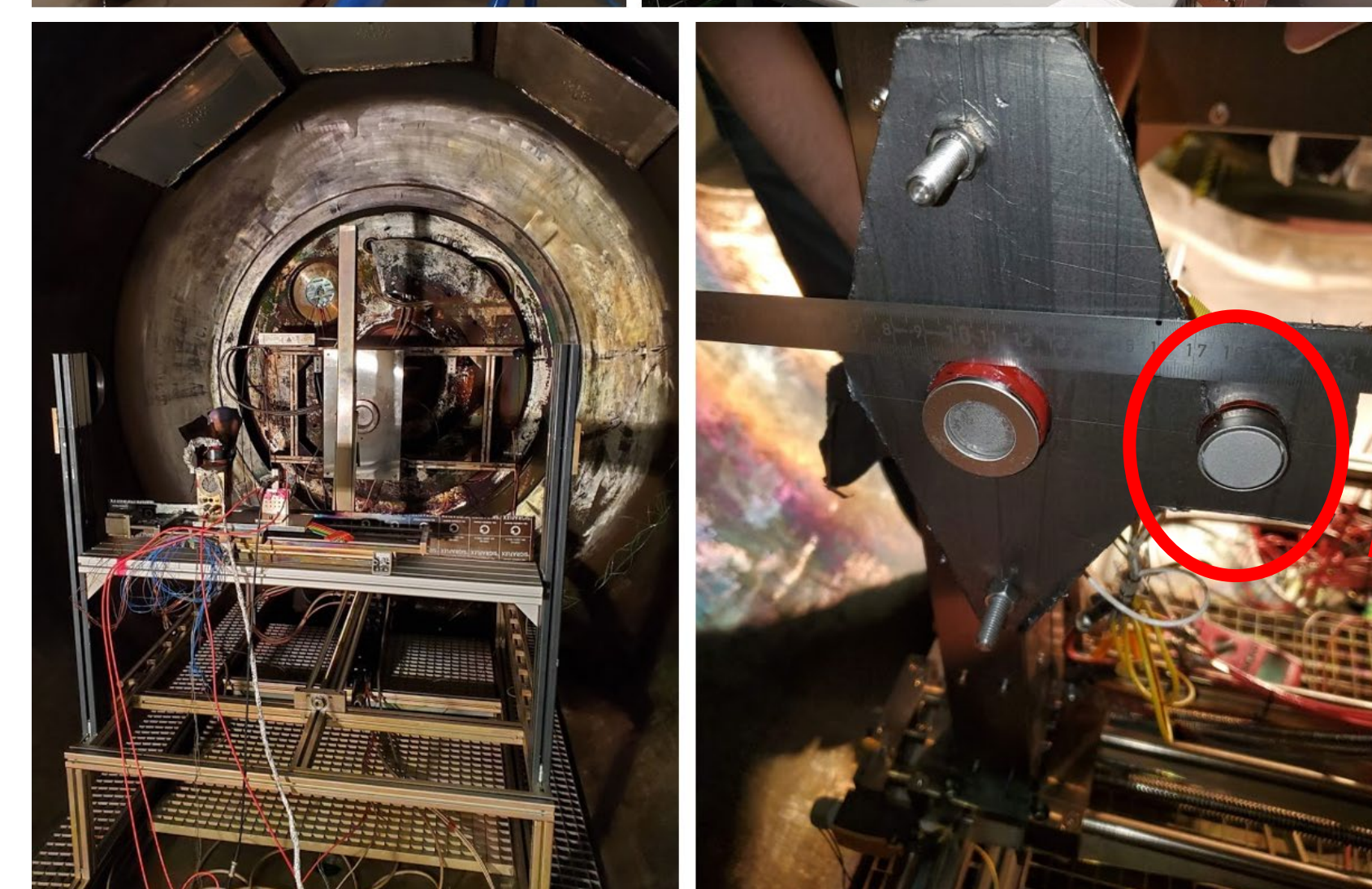
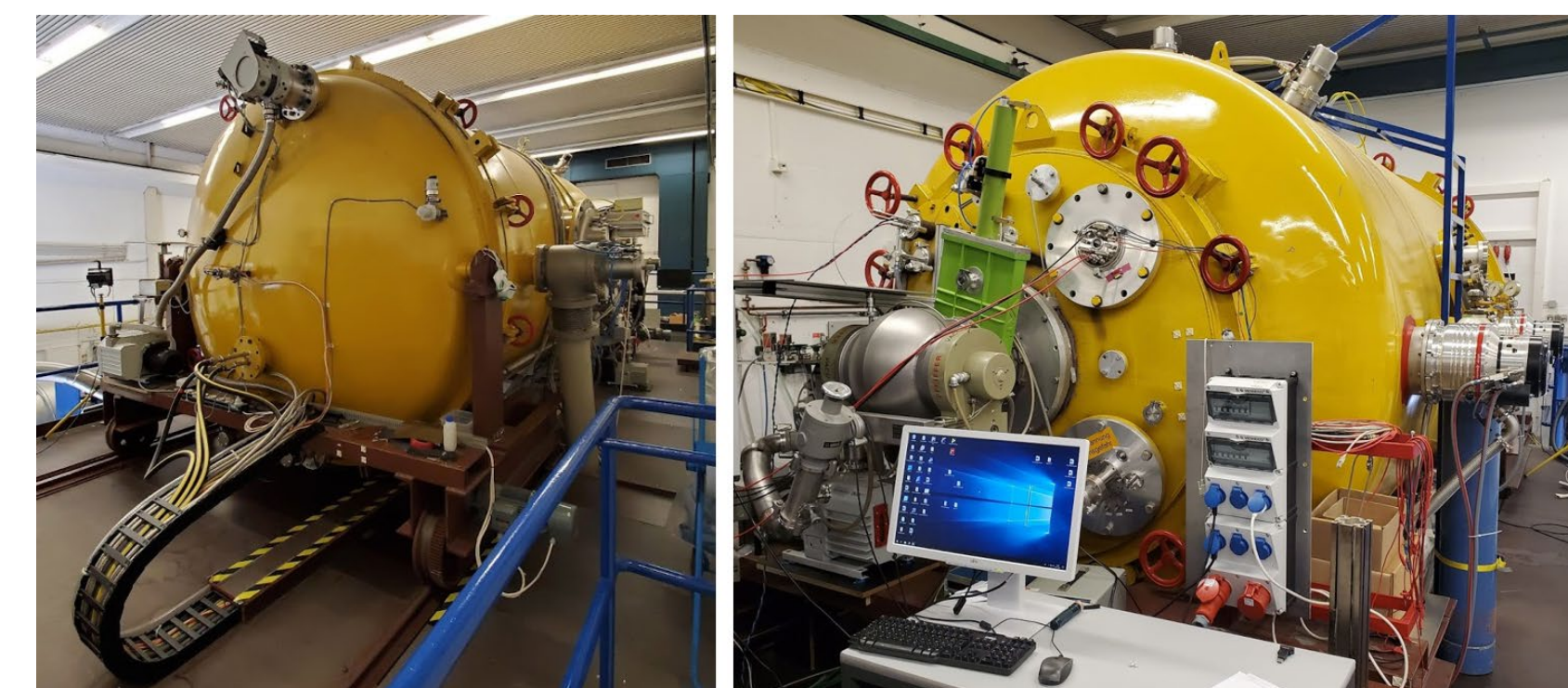


Electrostatic (6-kW HET)



Electromagnetic (ZTI MPD Thruster)

How do we measure the performance of EP thrusters?

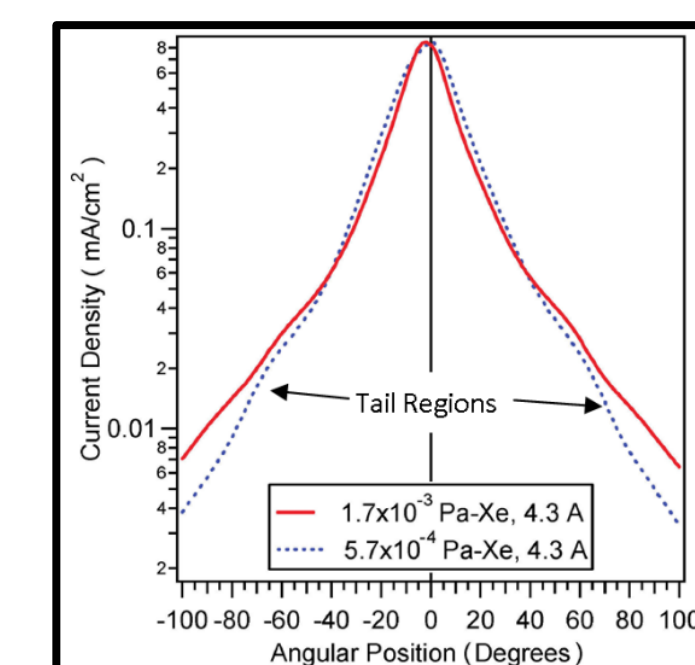


Thrusters are tested in vacuum facilities that can simulate the space environment

- A key objective is to understand the pumping configurations that create and maintain vacuum pressure levels as low as 1×10^{-8} Torr
- Pumping mechanisms used to achieve vacuum:
 1. Momentum exchange (turbomolecular pump)
 2. Fluid entrainment (cryo and diffusion pumps)



HPEPL Faraday probe and ion current density scan for the P5 HET¹



JUMBO vacuum test facility at Justus-Liebig University in Giessen, Germany during the July 2019 RIT-10 test campaign

Plasma diagnostics measure the plume properties of an operating EP thruster

- Probes are electrical devices that are immersed in the plume generated by the thruster and operated to collect data
- Faraday probes measure the ion current density profile in the plume of the thruster



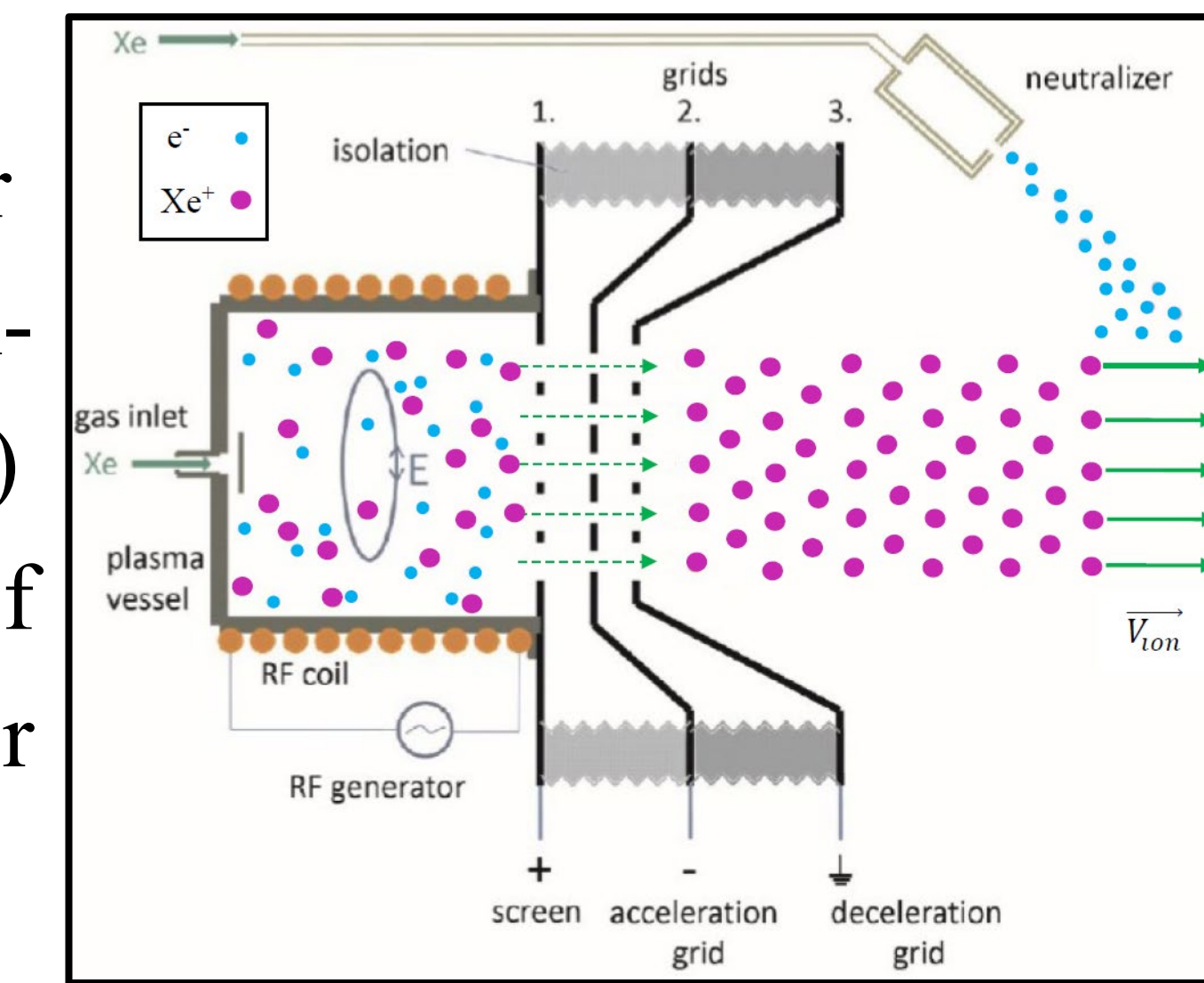
Thruster plume can interact with spacecraft solar arrays (Photo credit: Orbion)

Faraday probes enable us to quantify the beam divergence angle and other locations where the thruster may interact with the spacecraft

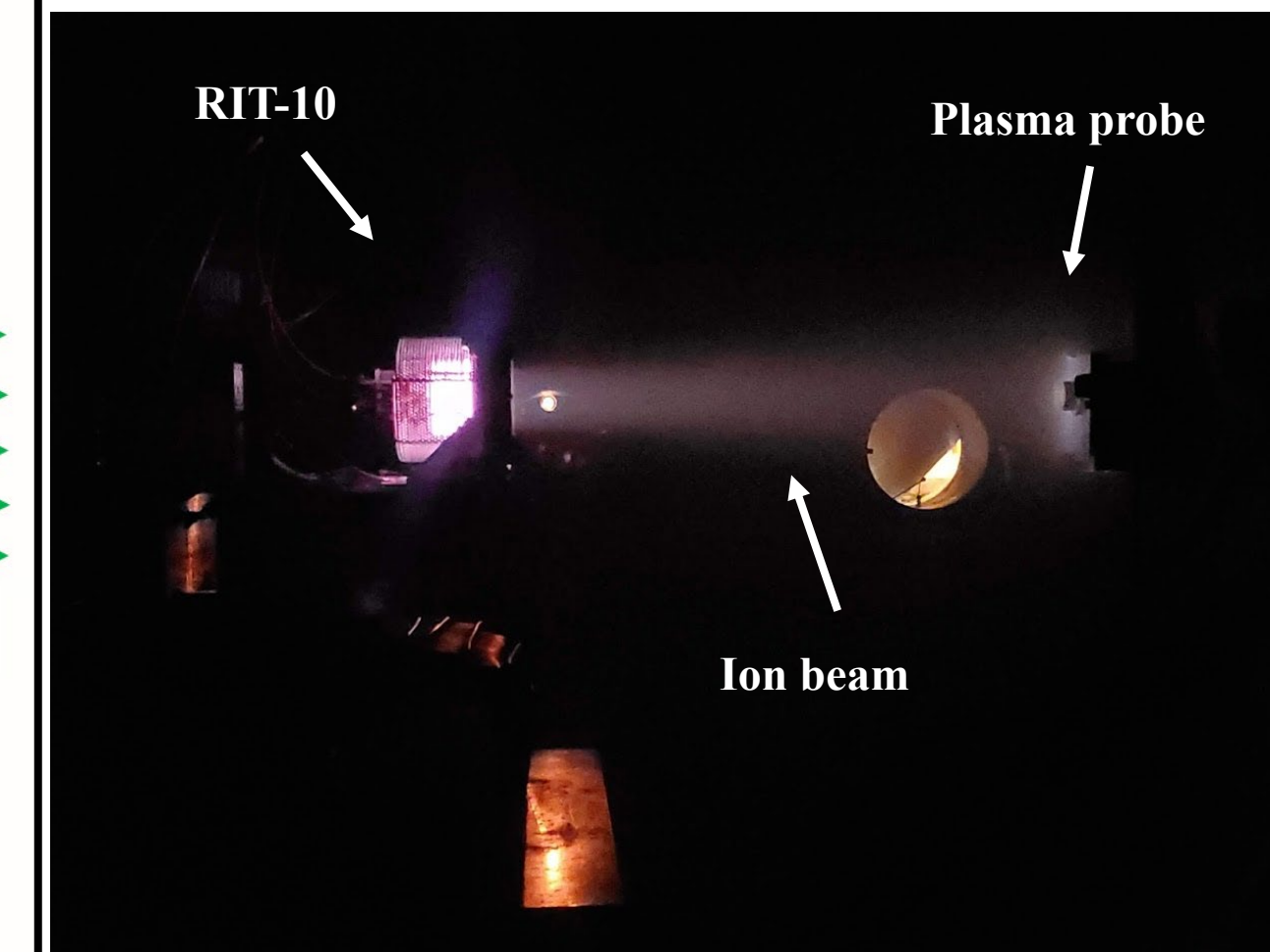
EP Thruster: Radiofrequency Ion Thruster 10 cm, RIT-10

Radiofrequency Ion Thruster (RIT) Basics

- Neutral xenon gas is injected into the discharge chamber
- A time varying electromagnetic field enables electron-neutral particle collisions creating a plasma (Xe^+, e^-, Xe^0)
- Heavy ions are accelerated through a series of electrically biased extraction grids out of the thruster exit plane
- External cathode neutralizes the ion beam downstream



RIT-10 thruster schematic



RIT-10 operating at HPEPL's VTF-1 in November 2019 with no neutralizers

Facility Effects on the RIT-10 Plasma Plume

Does the facility pumping configuration effect the ion flux measurements of the RIT-10?

Facility: JUMBO at Justus-Liebig University

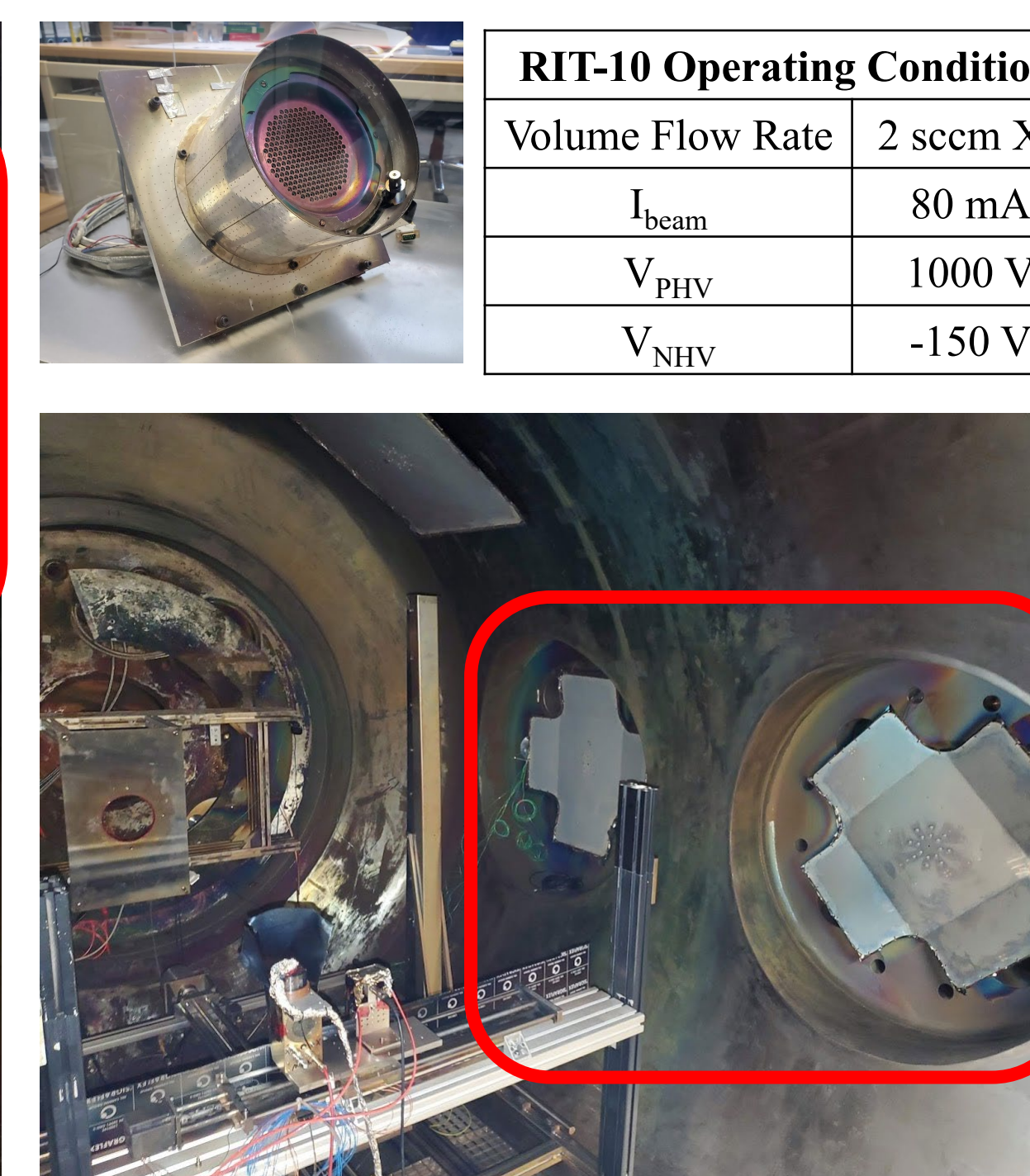
- Dimensions: 5 m L x 2.6 m D
- 2 rough pumps, 4 turbo pumps, and 8 cryopumps

Experiment

Vary JUMBO's cryopumping configuration and use a Faraday probe to capture ion flux measurements for a fixed RIT-10 operating condition



Cryopump Configuration 1
Top Cryopumps 1 - 4 ON

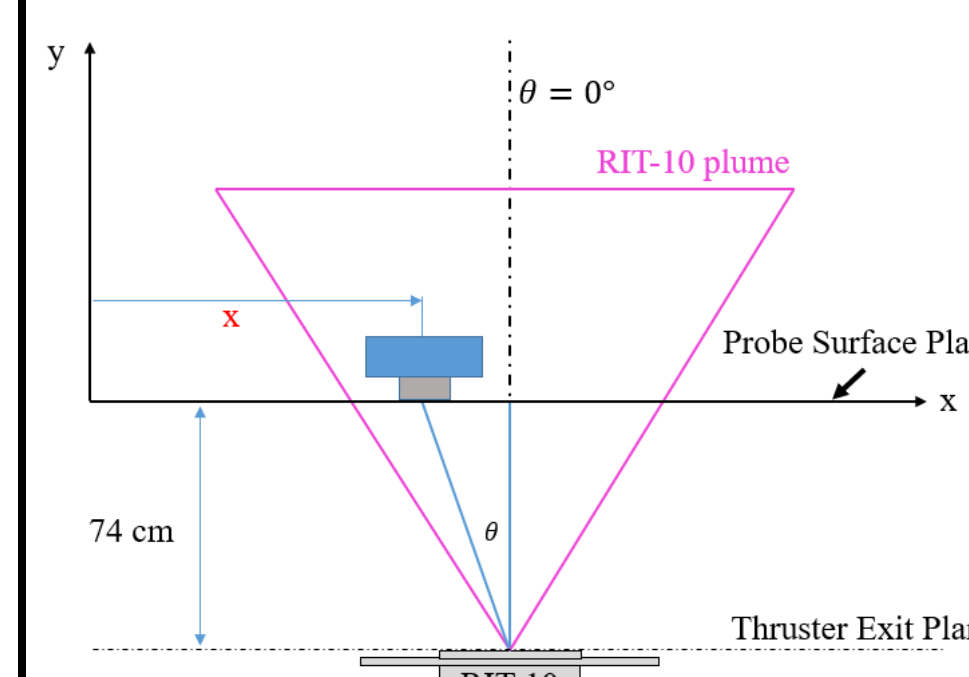
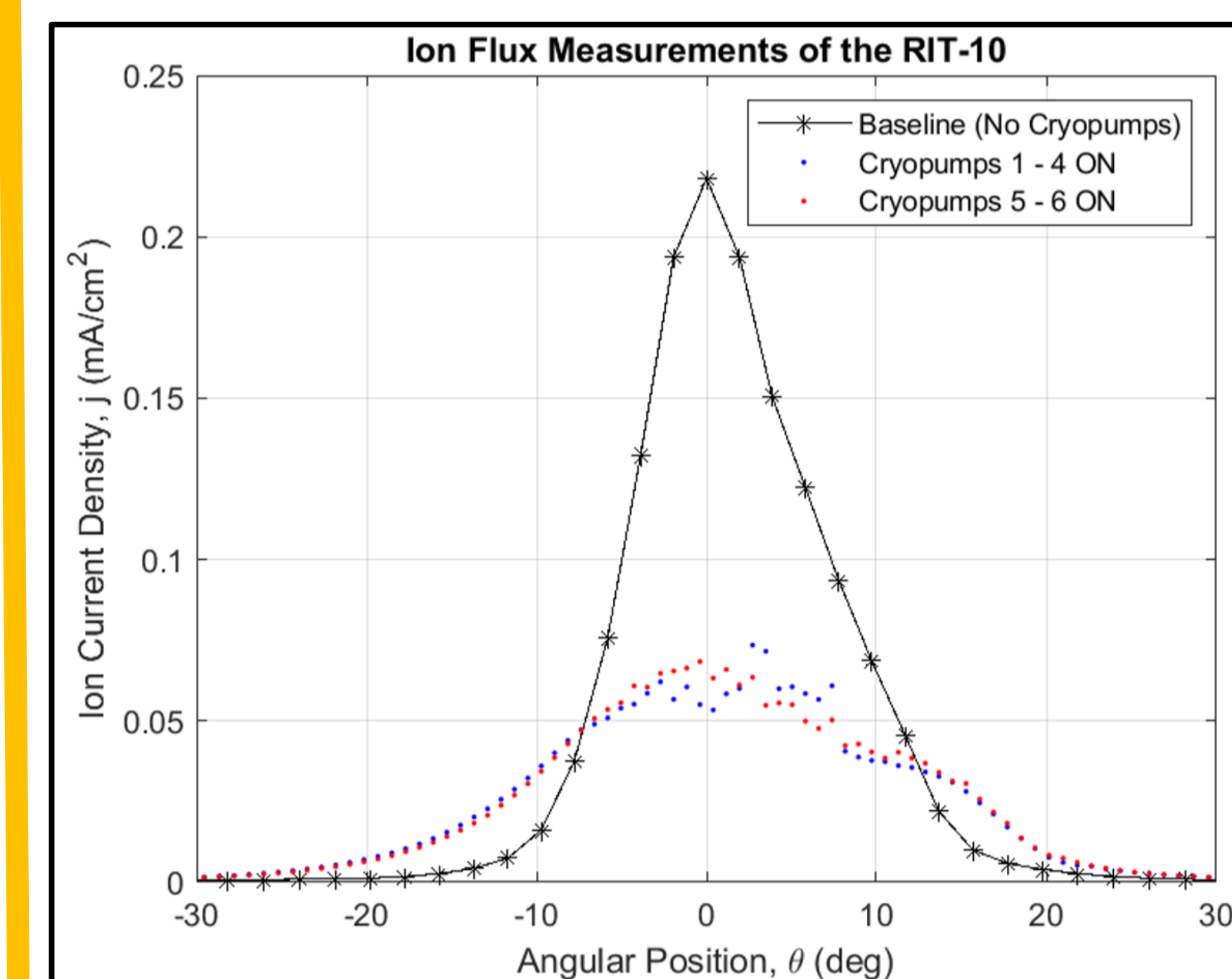


Cryopump Configuration 2
Side Cryopumps 5 & 6 ON

RIT-10 Operating Condition	
Volume Flow Rate	2 sccm Xe
I_{beam}	80 mA
V_{PHV}	1000 V
V_{NHV}	-150 V

Results

Ion flux measurements show a reduction of 68% in the peak current density and a beam divergence angle increase from 10° to 24° with the cryogenic pumps turned on



Schematic of the experimental setup inside JUMBO

	Baseline	Configuration 1	Configuration 2
j_{max} [mA/cm ²]	0.205	0.073	0.069
Plume Divergence Angle [°]	10	23	24

Conclusion

Experiment helped identify and solve the effect of charge-up on cryopump surfaces that increases beam divergence angle

Future Work

1. Compare the ion flux measurements between the HPEPL VTF-1 and the JLU JUMBO facilities
2. Modify cryopump surfaces using metallic nets to reduce charge-up effect and measure beam divergence angle

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References:
1. Walker, J.A. "ELECTICAL FACILITY EFFECTS ON HALL EFFECT THRUSTER OPERATION," Ph.D. Dissertation, School of Aerospace Engineering, Georgia Institute of Technology, Atlanta, GA, 2016, pp. 8 - 10