The Development of Test Facilities for Induced, High-frequency Plasma Instabilities

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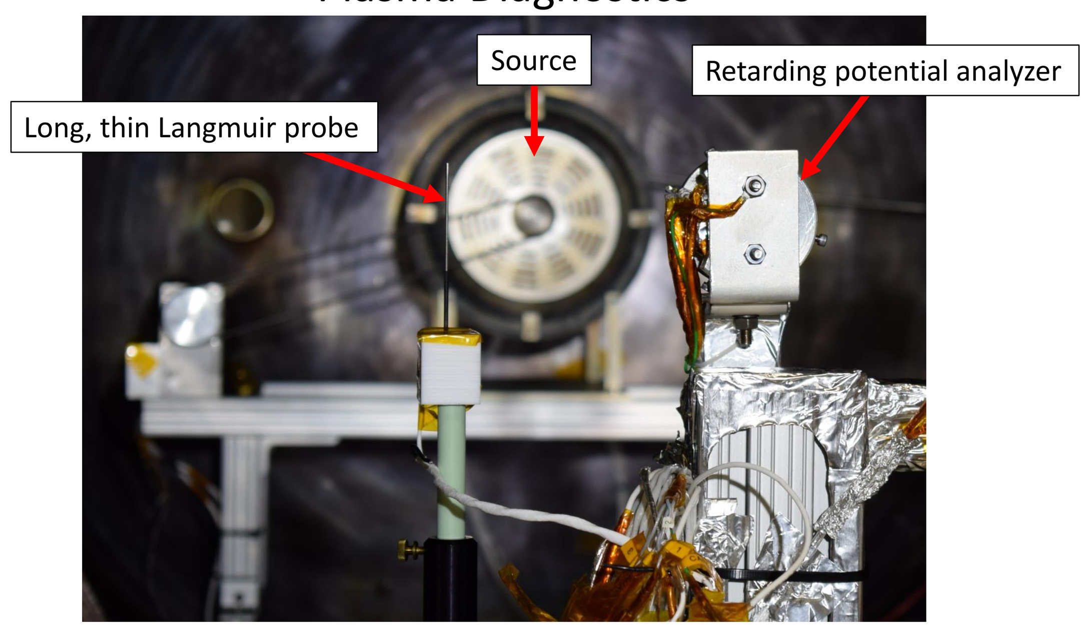
Abstract

We present results from modifications to test facilities equipped with a plasma source capable of producing a LEO–type environment. The modifications impose an oscillation to the output, thus simulating ionospheric disturbance. The frequency of the oscillations is adjustable as well as the base-line output of the source. Test results indicate that the density of the plasma can be varied with minimal impact on other plasma properties such as electron temperature. It is, therefore, possible to simulate realistic plasma environments such as day/night transitions or localized turbulence. The modified source is an effective tool for testing space instruments in a relevant environment increasing the instruments technology readiness level.

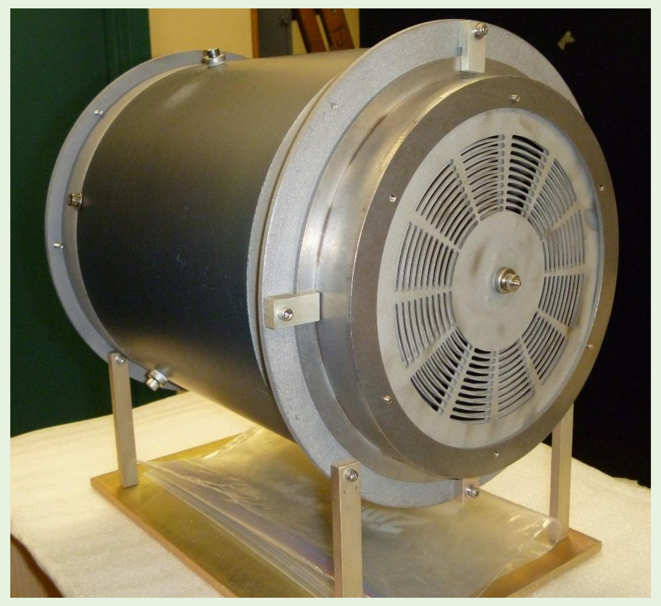
Plasma Diagnostics



A long, thin Langmuir probe and retarding potential analyzer were used to determine the plasma properties. The equipment was positioned 169 cm downstream of the source.

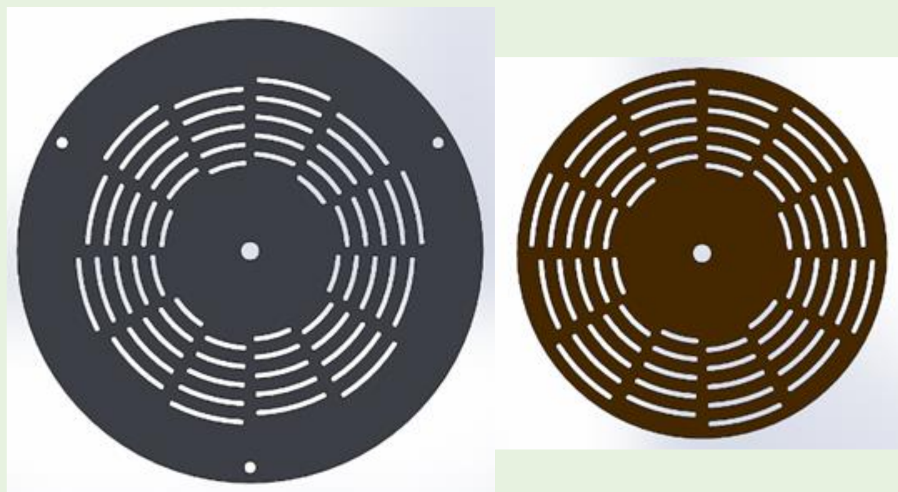
Experimental Setup and Modifications

Original Design



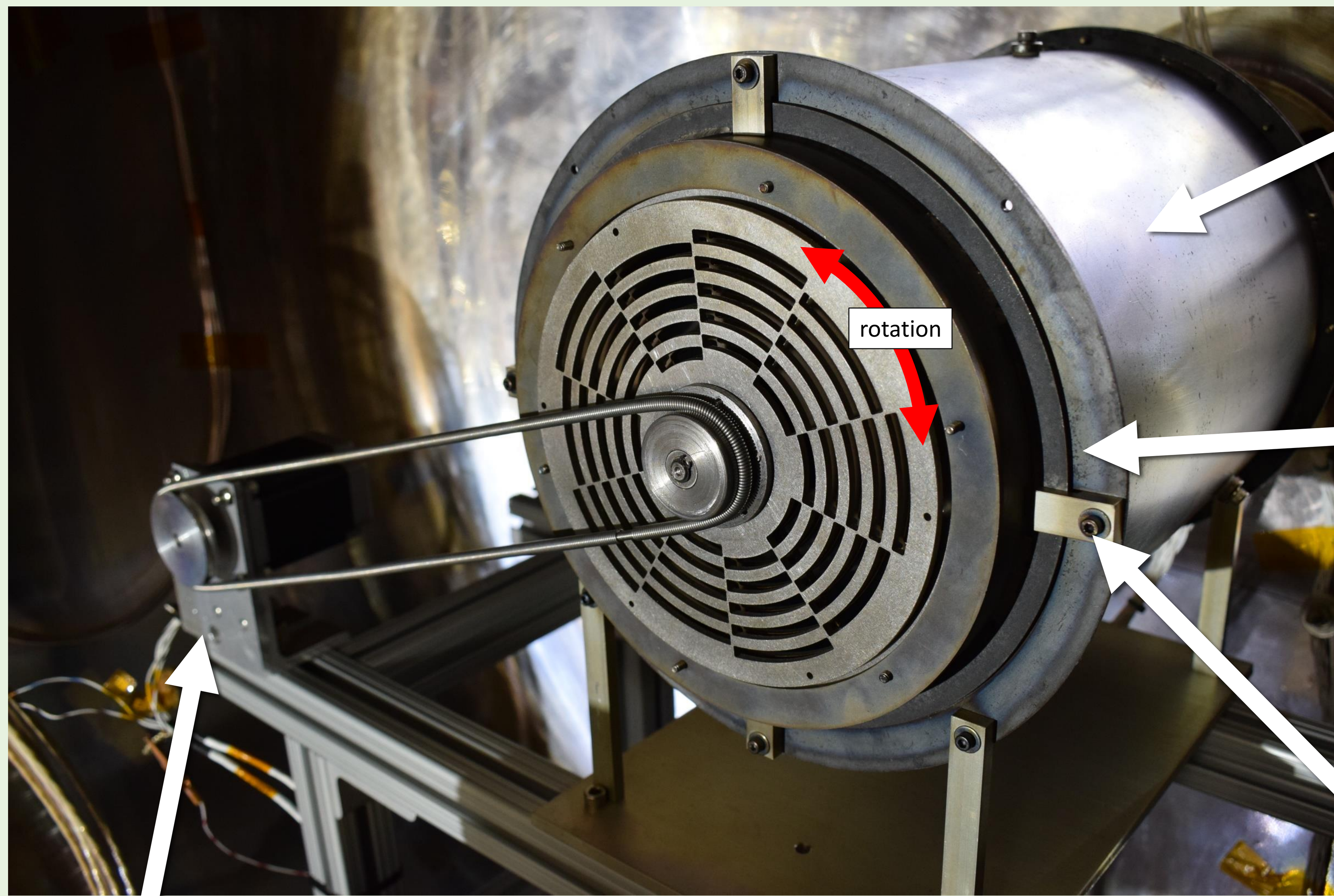
Design of the original, unmodified source. The output grids are fixed. Therefore, the effective aperture is fixed. The source is capable of producing streaming ions (1–4 eV) and relatively low temperature electrons (~0.1 eV) [1].

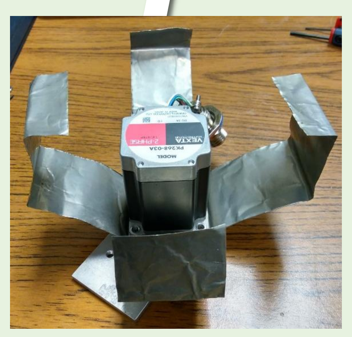
Modification



Adjustable grid with a) an inner, larger part and b) an outer, smaller part. The outer part is free to rotate around its center, which is concentric with the inner part.

Modified Source at NASA Marshall Space Flight Center





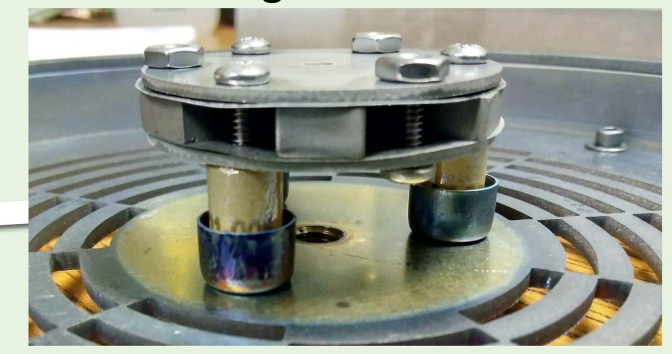
Magnetic Shielding

The motor that actuates the grids were wrapped in mu metal, a ferrous material that shunts magnetic fields. The covering mitigates electromagnetic interference in the plasma chamber.

Hollow Cathode

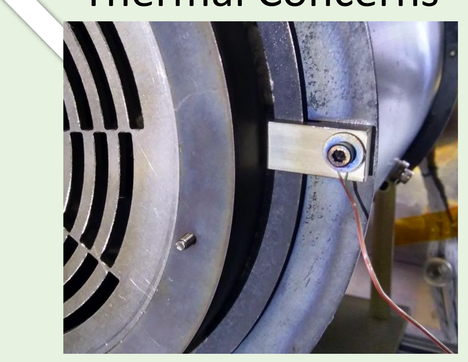
A hollow cathode inside the source produces the plasma.

Magnetic Filter



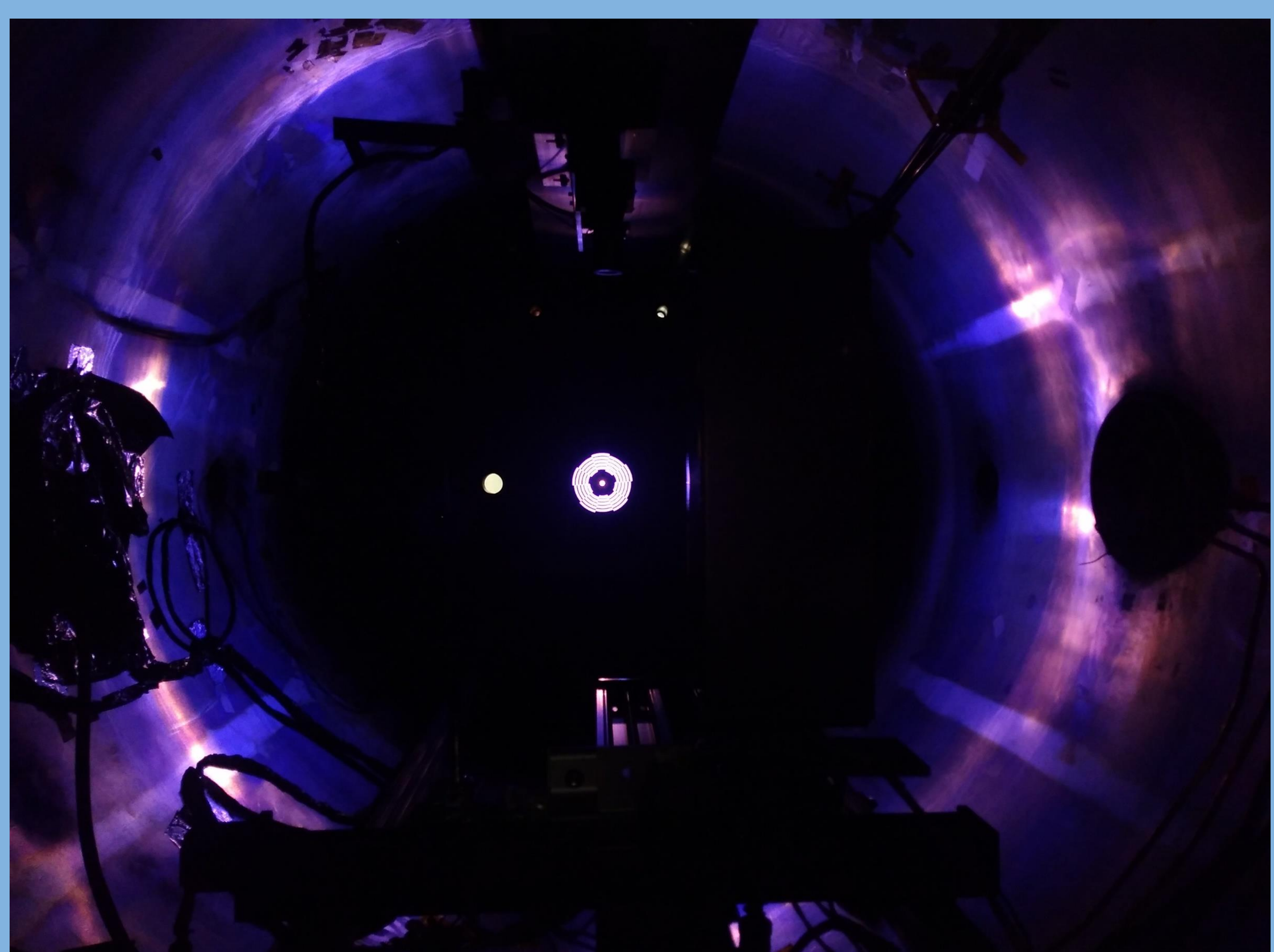
High energy electrons are prevented from exiting the source via a ring cusp magnetic filter. We increased the number of magnets to increase the filtering capability (i.e., decrease the electron temperature). This becomes increasingly more important when the source become hot through Joule heating.

Thermal Concerns



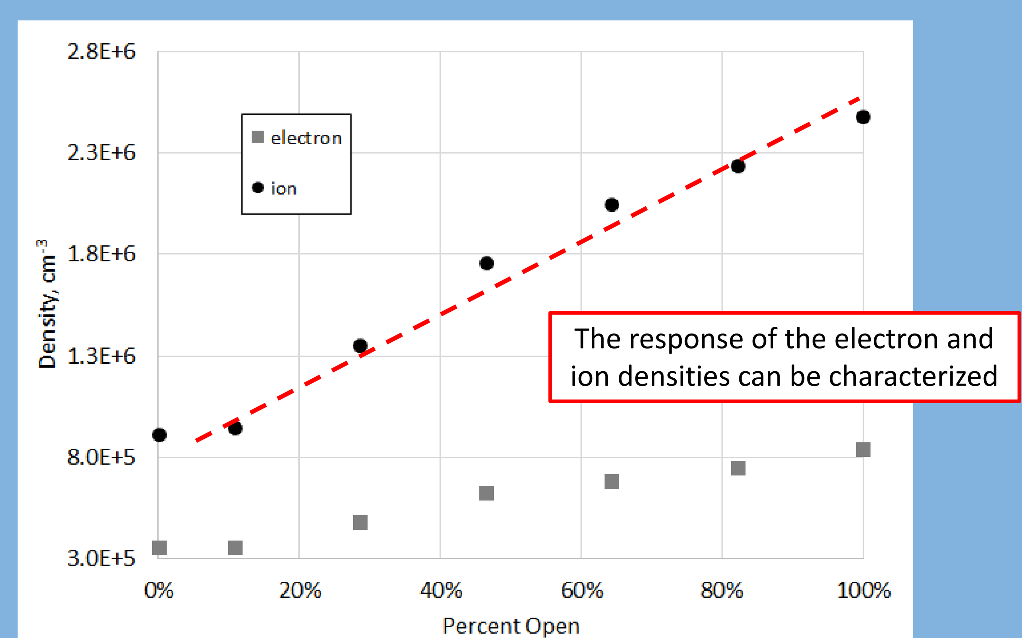
Thermocouples mounted to the exterior of the source indicated that temperatures can exceed 225 degrees Celsius. This heating can diminish the efficacy of the magnetic filter, which results in an increase in electron temperature. Additionally, high temperatures affect the bearings, though this has not yet been fully characterized.

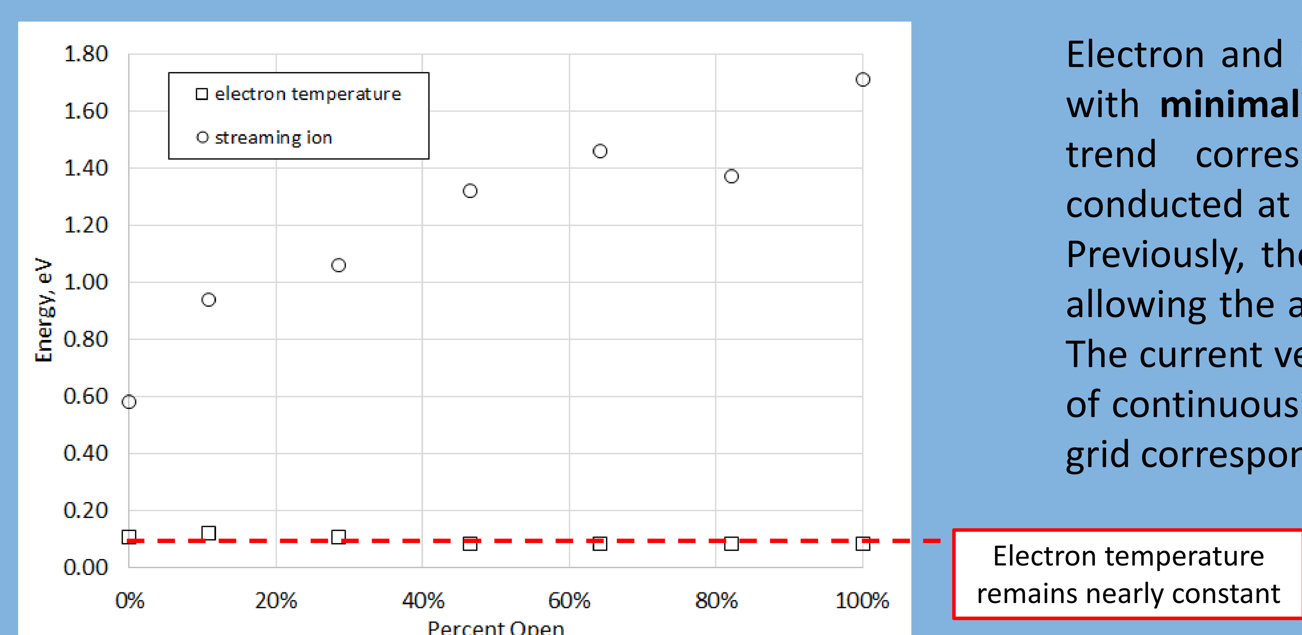
Results



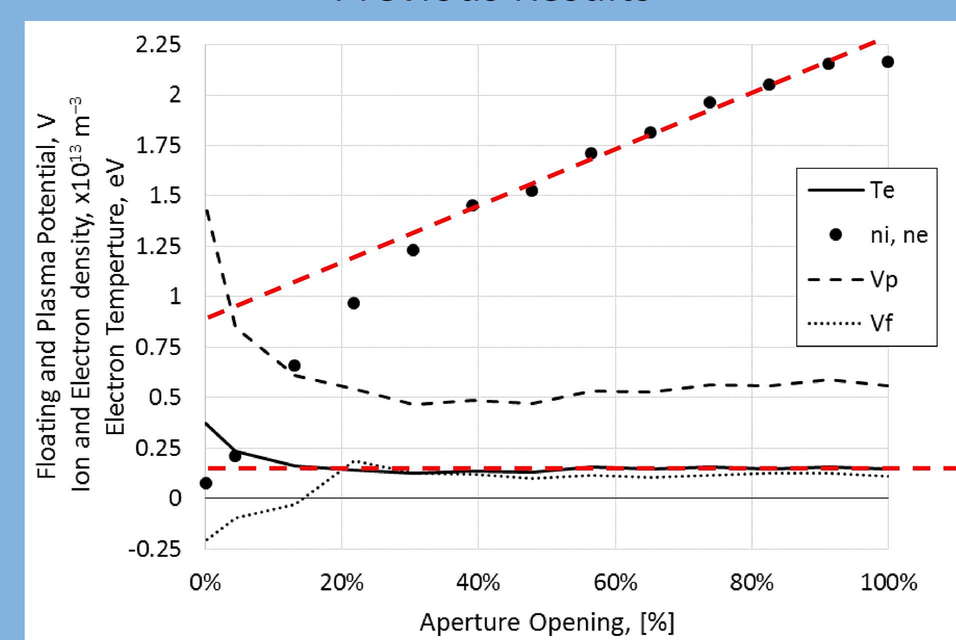
The purple glow of an argon plasma reflects off of the chamber walls. The chamber is approximately 2.41 m (95 in) in length and 1.21 m (48 in) in diameter.

Current Results





Previous Results



Electron and ion density increased with aperture opening with **minimal impact on the electron temperature**. This trend corresponds well with previous research we conducted at Penn State (figure used with permission) [2]. Previously, the grids were only able to rotate 30 degrees, allowing the aperture to go from fully open to fully closed. The current version has no angle restrictions and is capable of continuous rotation. One complete rotation of the outer grid corresponds to five open/close cycles.

Discussion

The modified source at NASA MSFC is capable of producing a variable-density, LEO-like plasma that creates a realistic environment for the development of space instrumentation and plasma diagnostics tools. Manufacturing errors introduced a gap between the grids that prevents them from fully closing. This will be addressed in the next version. Additionally, we will spin the grids at high frequency to simulate plasma turbulence. Preliminary tests indicate that a rotation rate of 30 Hz (150 Hz on/off cycles) is obtainable. We plan to achieve an on/off frequency of greater than 1 kHz.

[1] Rubin, B., Farnell, C., Williams, J., Vaughn, J., Schneider, T. and Ferguson, D., "Magnetic Filter Type Plasma Source for Ground-Based Simulation of Low Earth Orbit Environment," *Plasma Sources Sci. Technol.* **18**, 025015, 2009.

[2] McTernan J., Bilén, S., and Williams, J., "Real-time Plasma Density Control via a Modified Hollow-Cathode Plasma Source with a Variable Aperture," in *14th Spacecraft Charging Technology Conference*, ESA/ESTEC, Noordwijk, 2016.