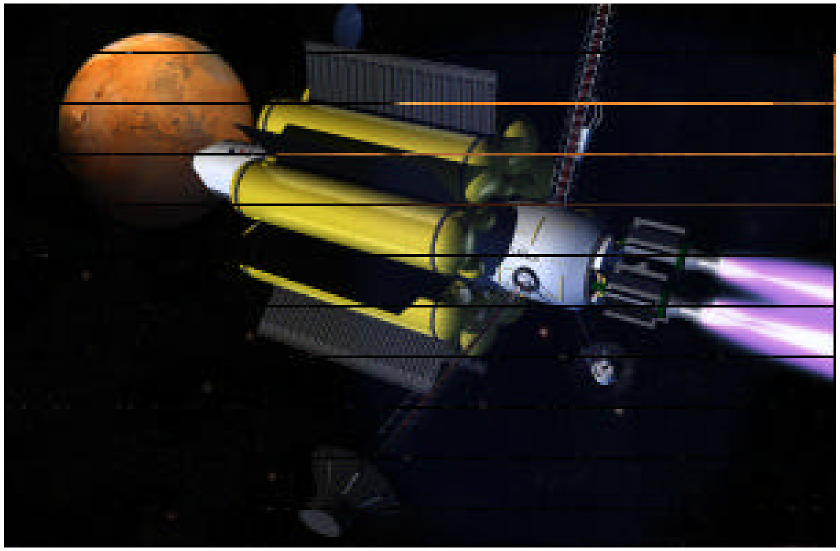
# A Fuel Efficient Plasma Thruster for Interplanetary Travel

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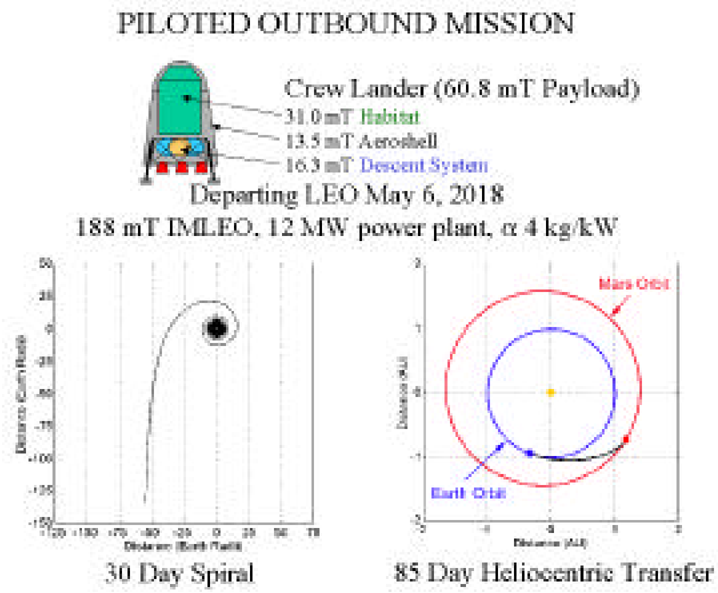
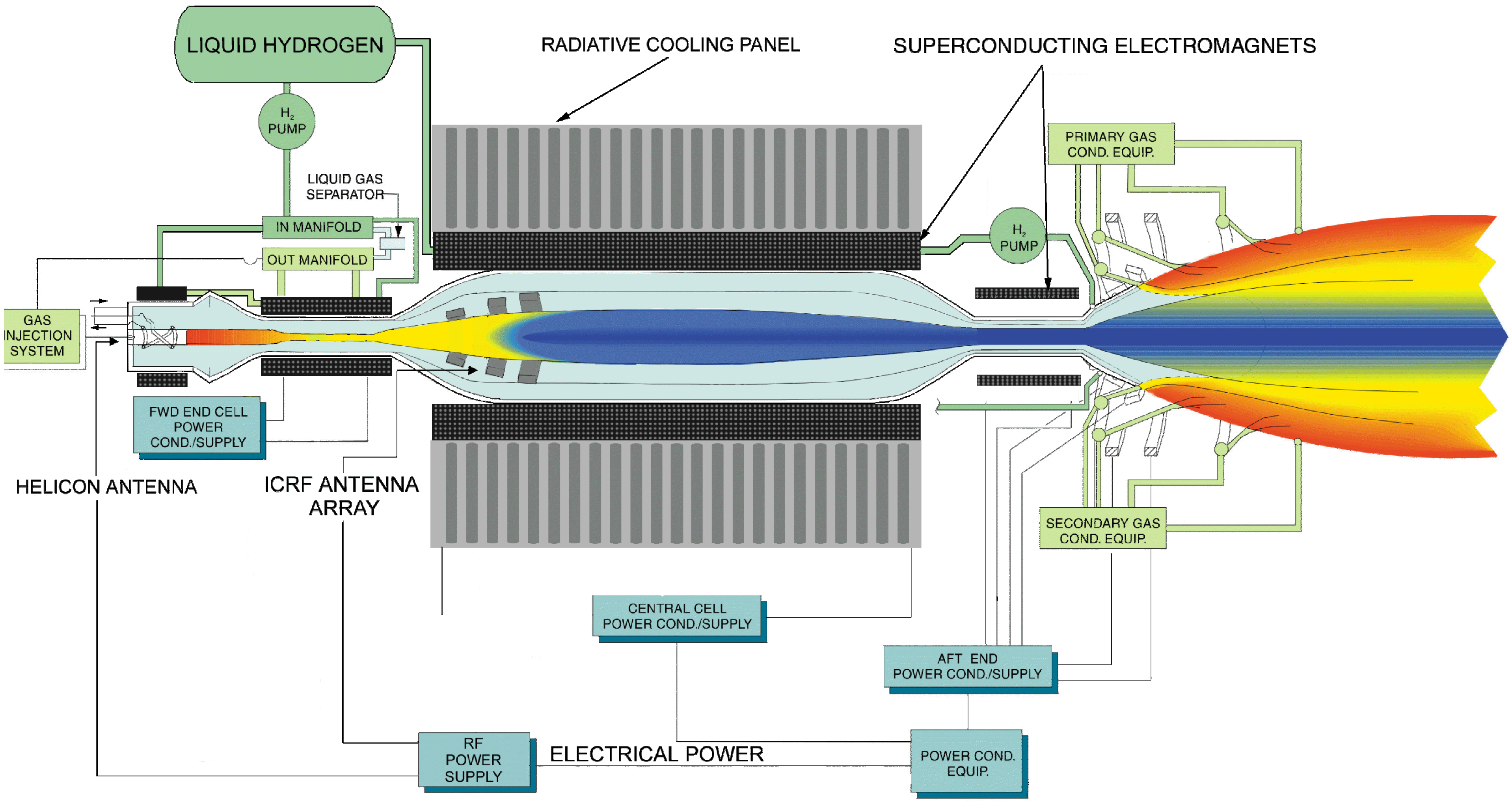
# The final frontier . . .

The human dream of traveling through space to other worlds is an old one. Johannes Kepler and Jules Verne imagined fantastic voyages to the moon; innumerable authors, playwrights, artists and musicians have subsequently envisioned journeys to the planets of our solar system and beyond. Mars in particular has captured humanity’s collective imagination. In much of science fiction, the red planet is a stepping stone to the stars. In popular culture, a human visit to Mars has been treated as a near inevitability since the first lunar landing in 1969.

Yet Mars has remained out of reach. Werner van Braun called for a manned Martian landing by 1983; President George Bush tried to rally support for a landing in 2004. At present, NASA has no official plan for human exploration of Mars. Reasons for the delay have been more sociopolitical in nature than technical. Nevertheless, there are significant technological hurdles to be overcome before the first human explorer sets foot on Martian soil. Perhaps chief among these is the design of a propulsion system that will carry fragile human passengers across interplanetary distances.





LIQUID HYDROGEN
RADIATIVE COOLING PANEL
SUPERCONDUCTING ELECTROMAGNETS
H2 PUMP
LIQUID GAS SEPARATOR
IN MANIFOLD
OUT MANIFOLD
GAS INJECTION SYSTEM
H2 PUMP
PRIMARY GAS COND. EQUIP.
FWD END CELL POWER COND./SUPPLY
HELICON ANTENNA
ICRF ANTENNA ARRAY
SECONDARY GAS COND. EQUIP.
CENTRAL CELL POWER COND./SUPPLY
AFT END POWER COND./SUPPLY
RF POWER SUPPLY
ELECTRICAL POWER
POWER COND. EQUIP.

# Summary

The production of a Variable Specific Impulse Magneto-plasma Rocket (VASIMR) prototype depends upon the development of a reliable, efficient plasma source. The source must make efficient use of

1) Hydrogen fuel:

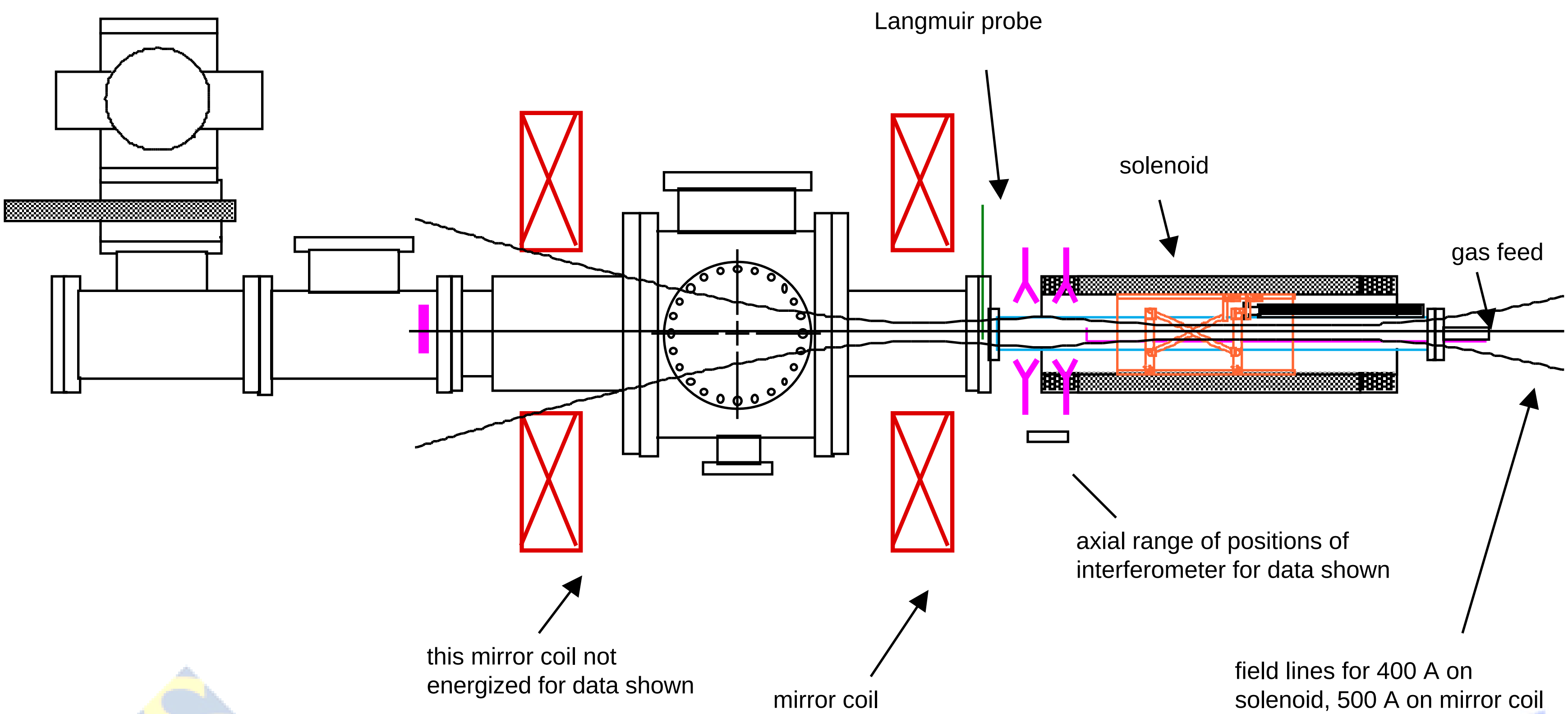
All rocket propulsion systems are subject to a kind of "Catch-22": Increasing the mass of a spacecraft requires that additional fuel be added to the system for launch and maneuvering capabilities. Increasing the fuel requirements of a craft in turn increases its mass; thus making increased demands for propellants disproportionate with increases in payload.

2) RF power:

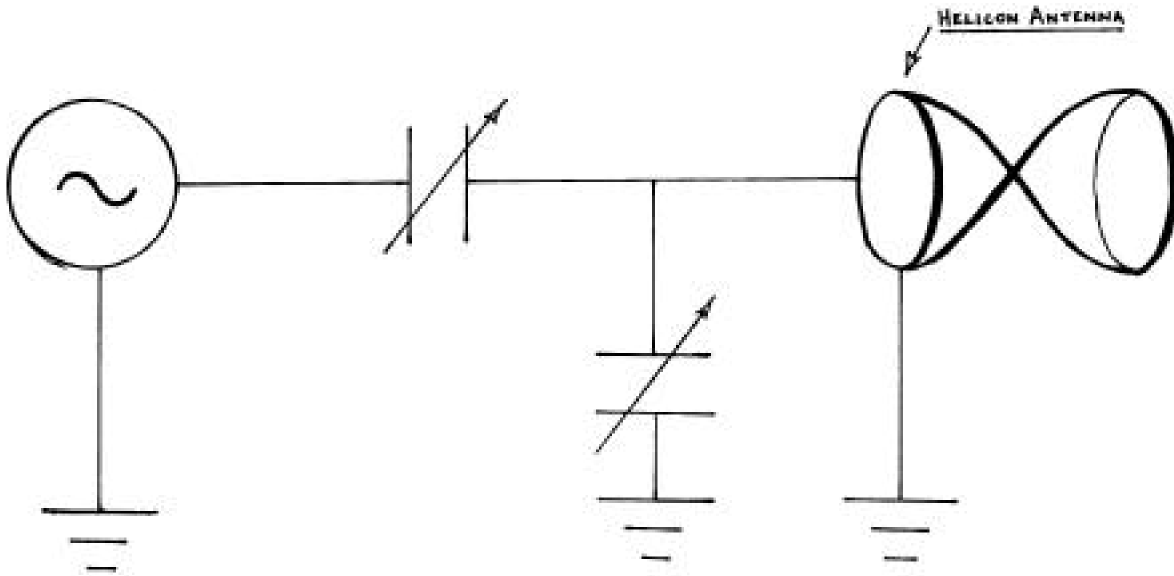
Although a VASIMR engine will propel a spacecraft, it must rely on solar panels or nuclear reactors for electrical power. High power demands will add unwanted weight and bulk to the propulsion system.

This experiment is part of an effort to quantify and optimize the performance of a helicon plasma source for VASIMR.

# Mini-RFTF/STX schematic



# MATCHING CIRCUIT



# All density measurements were made with a 70 GHz interferometer

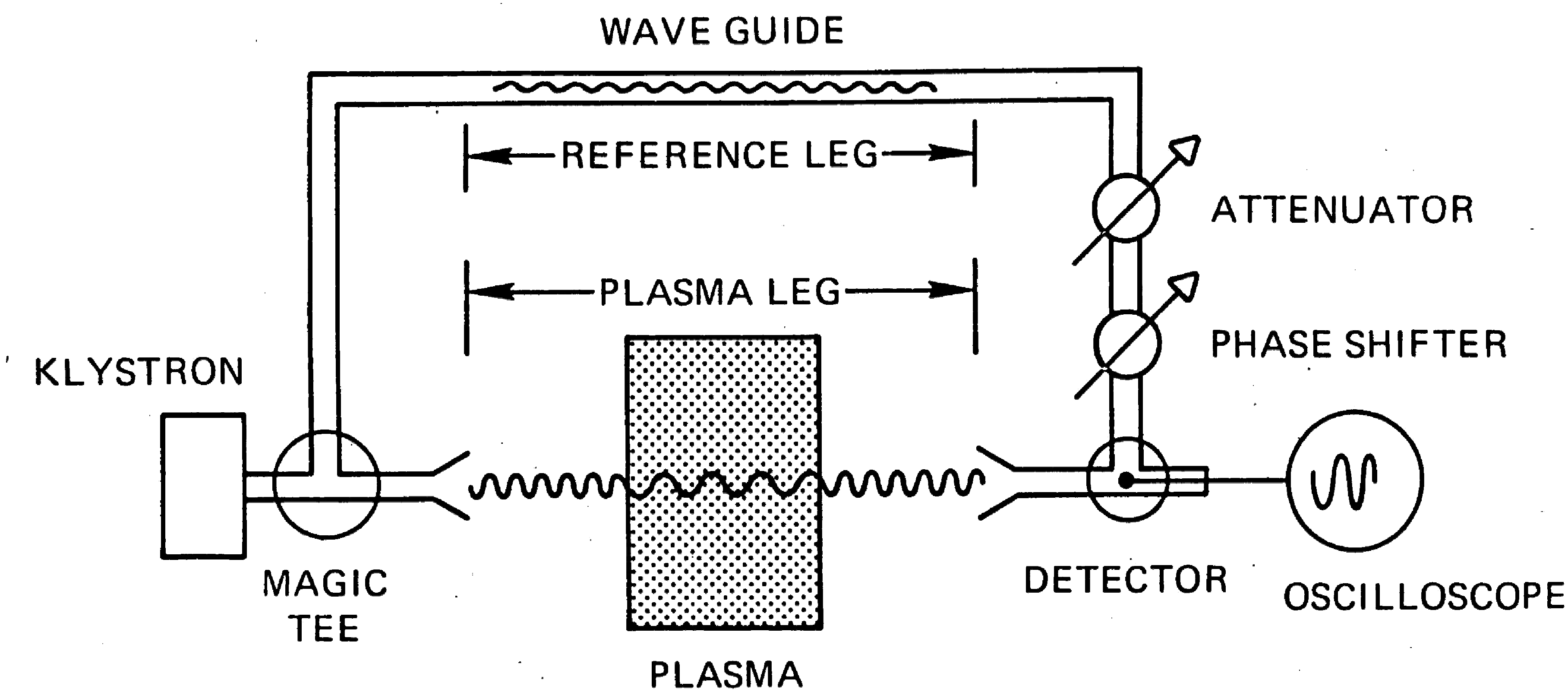
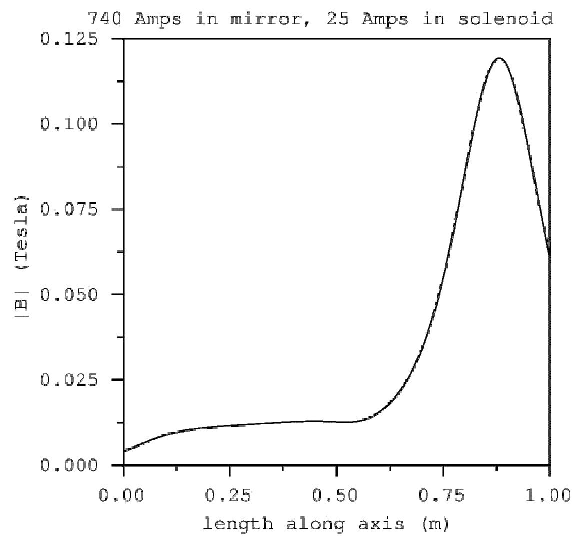
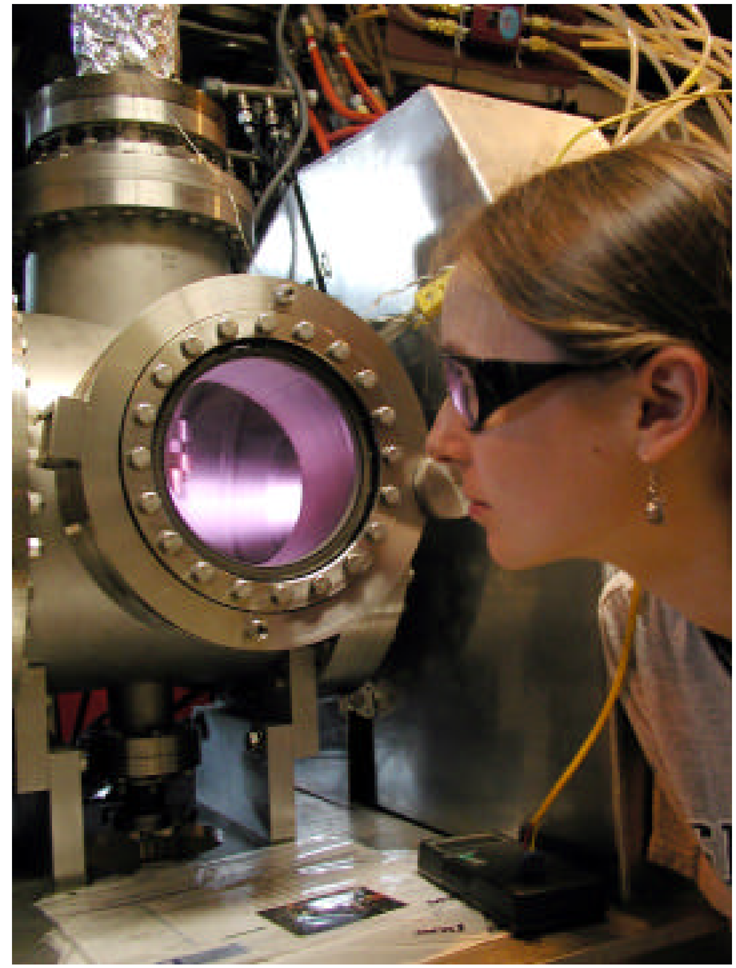



**FIGURE 4-28** **A microwave interferometer for plasma density measurement.**

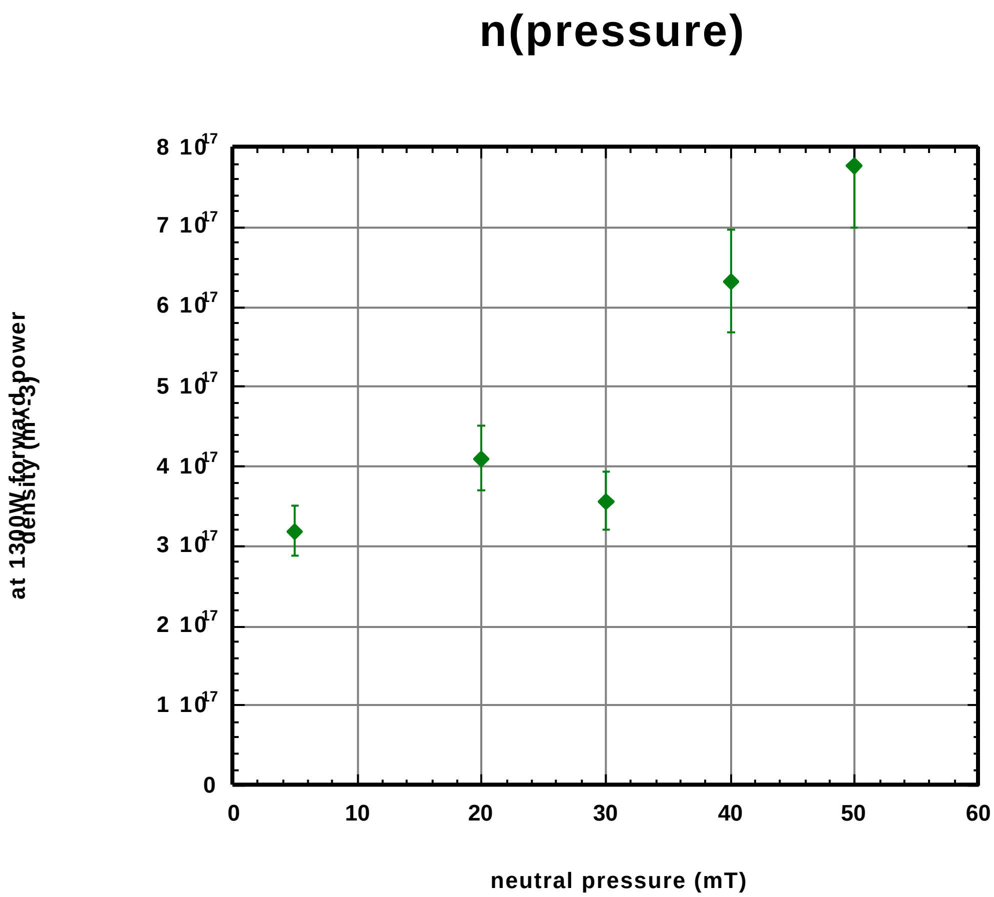
# Operation Parameters

Hydrogen gas was used with an rf heating frequency of 16.00 MHz for this experiment.  The helicon source was run in pulsed and constant wave (cw) mode.  A pulse length of 1 second was used to obtain electron densities. The current/voltage probe used to determine loading information required us to run the helicon source in cw mode. The current in the solenoid magnet was 25 amps and the current in the mirror magnet was 740 amps for all runs.

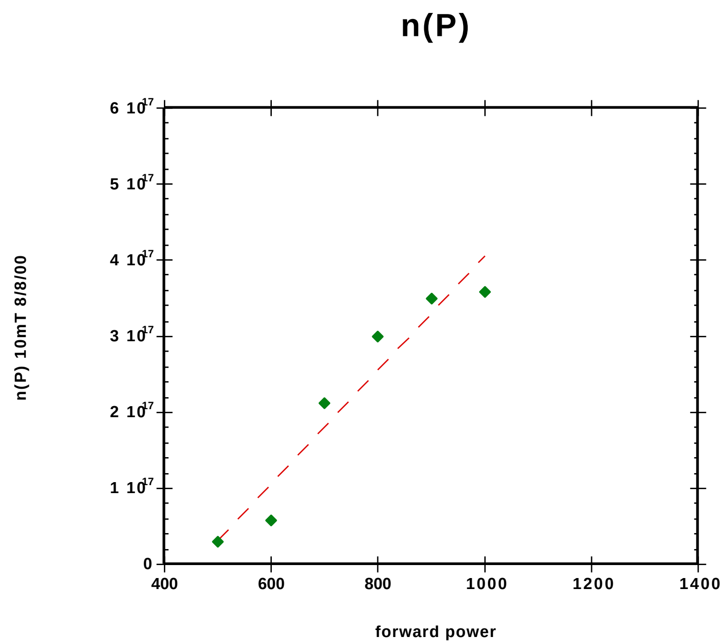


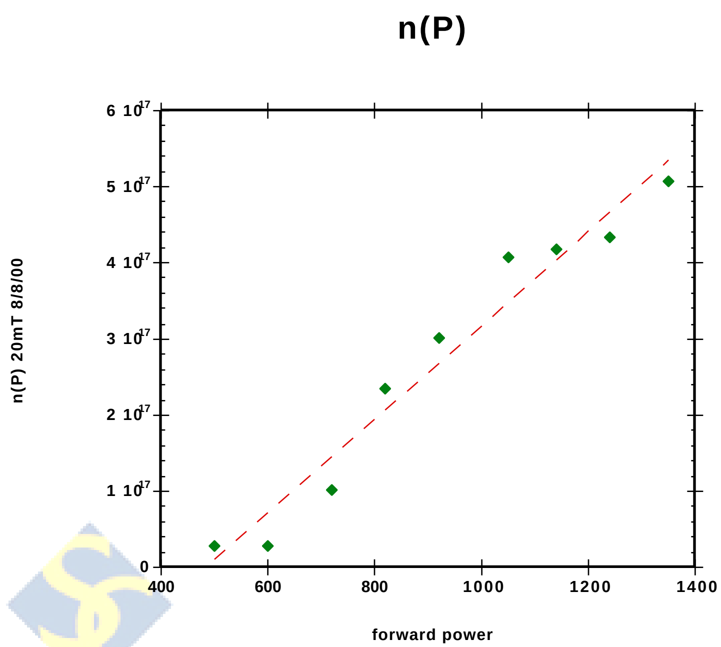
# Dependence of electron density on pressure

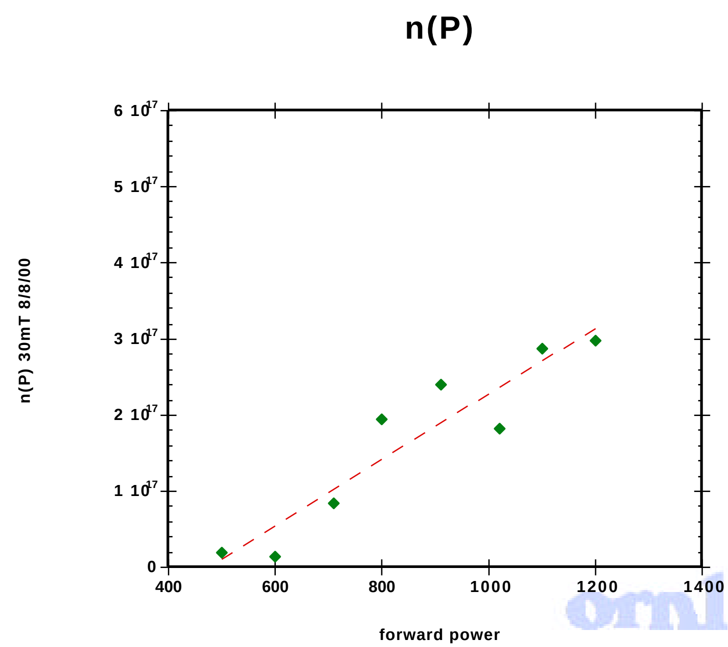



At low neutral pressures, density increases linearly with pressure (as seen at left). At higher pressures, fueling of the plasma core becomes difficult and the curve levels off.

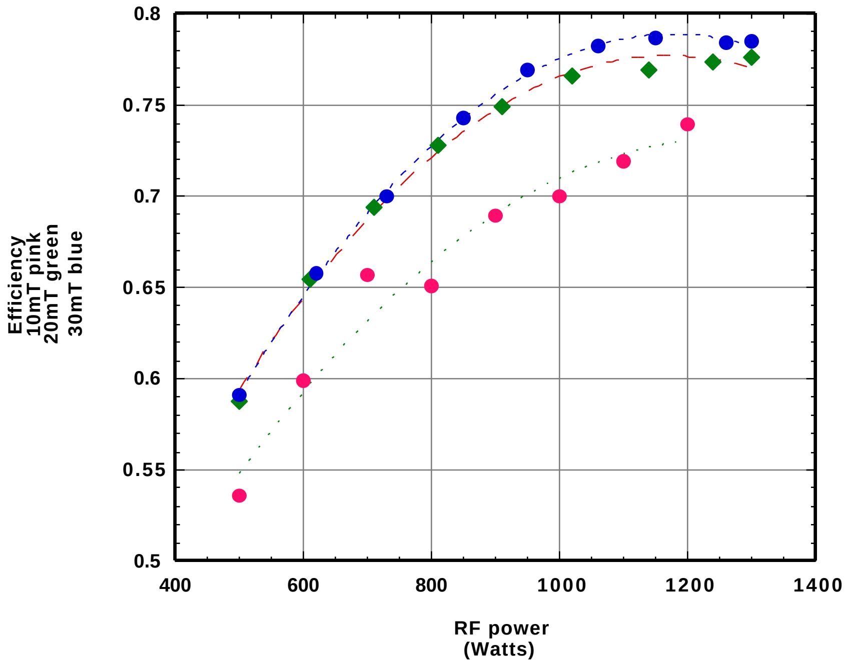


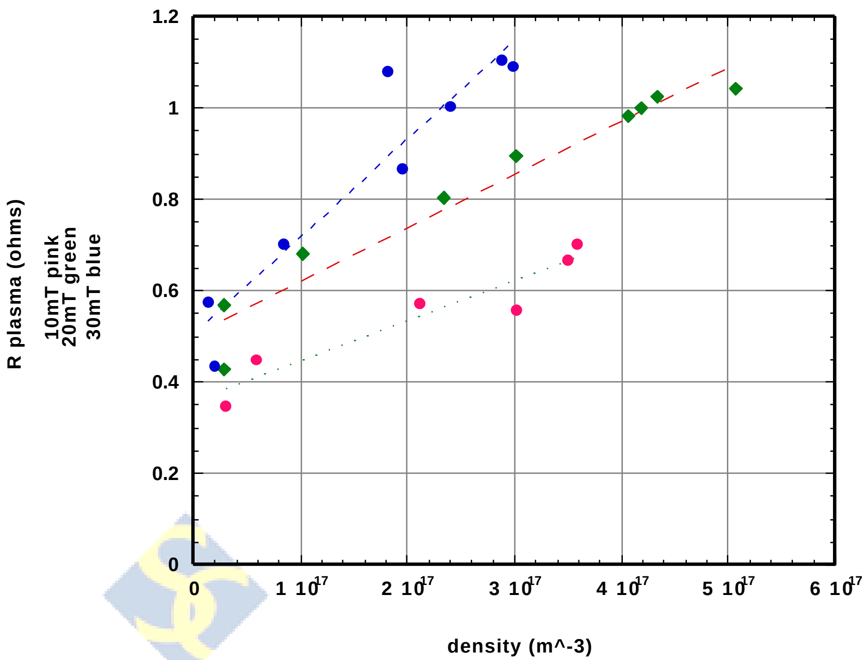

Electron density shows a linear dependence on forward power at a variety of neutral pressures.



Voltage and current were measured in the RF antenna circuit. The plasma loading resistance was then derived using a mathematical model of the circuit.



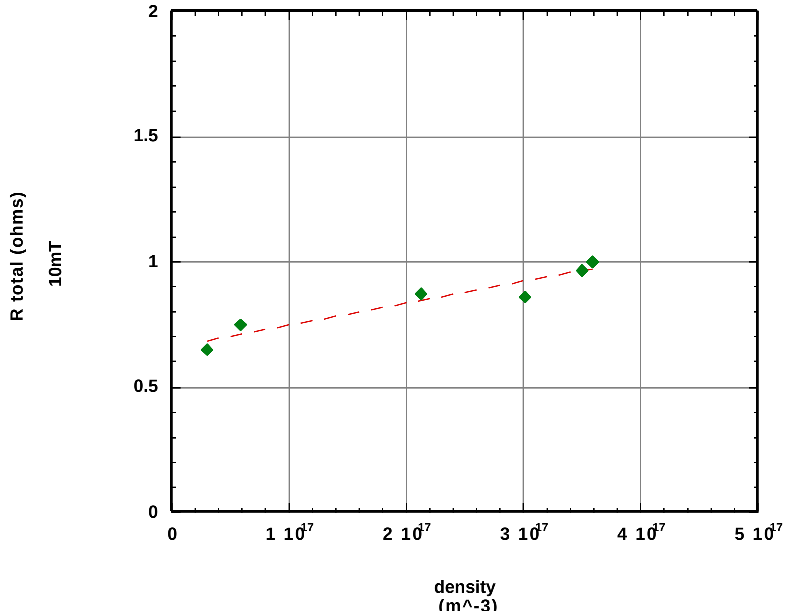




Plasma resistance was converted to power efficiency using the relation:

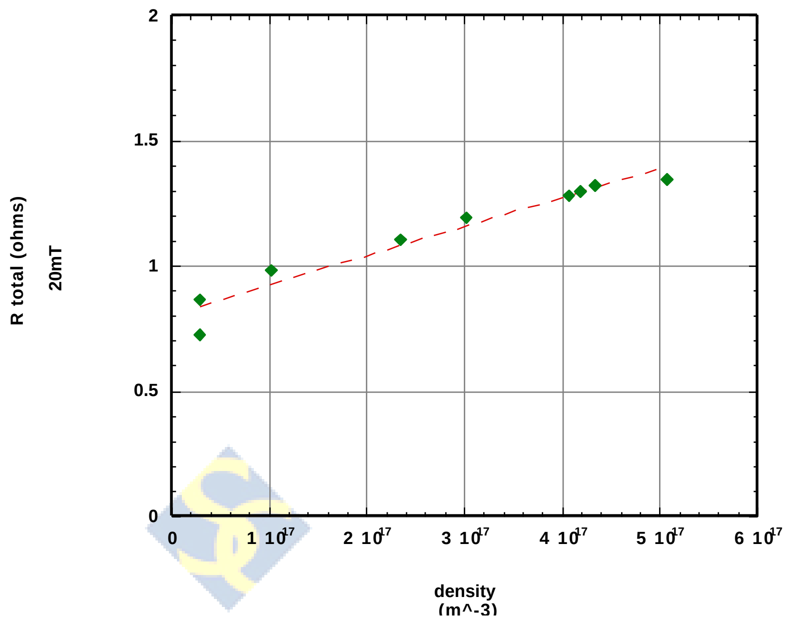
$$\eta = \frac{R_{plasma} - R_{loss}}{R_{total}}$$

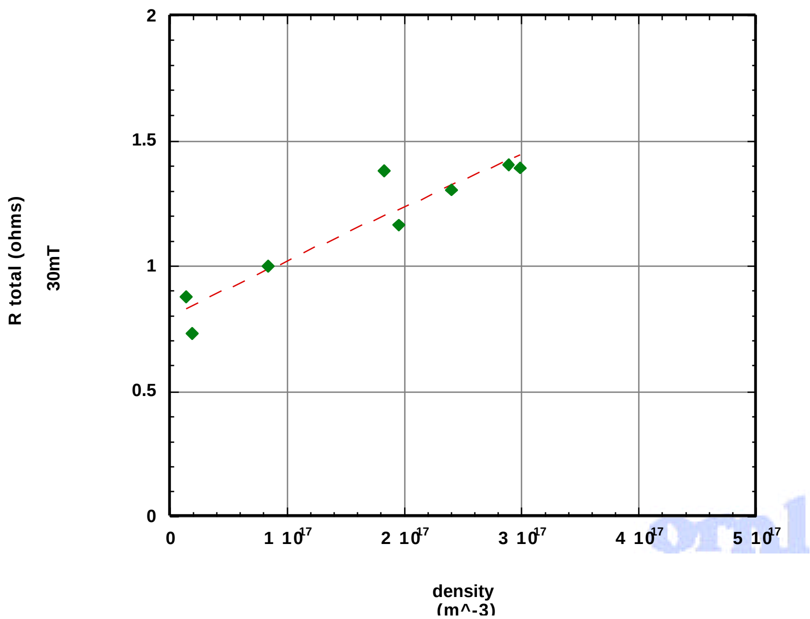
# Loading vs Electron Density

## Neutral pressures of 10, 20 and 30 mT

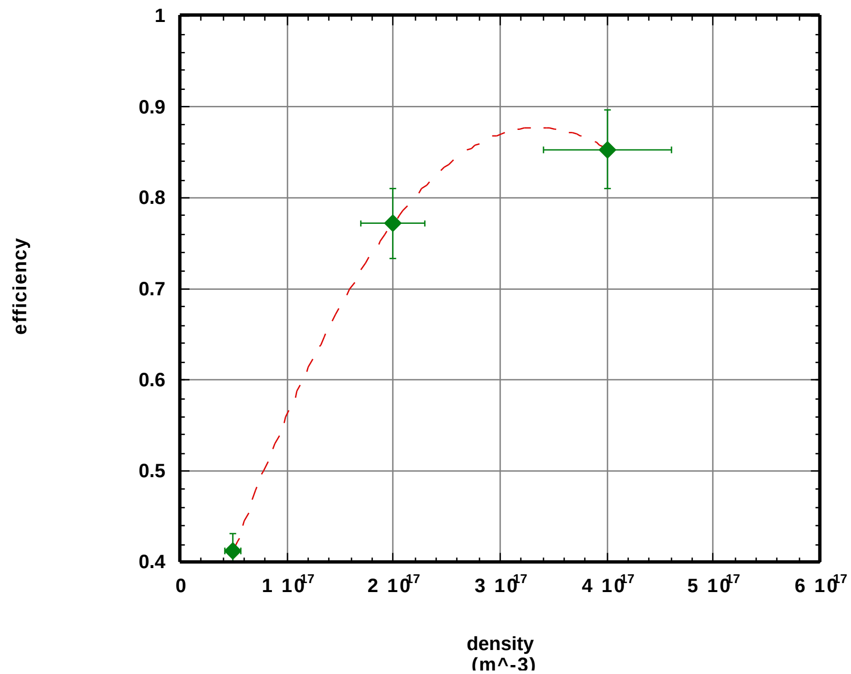



Loading increases linearly with density in this mode of operation (low magnetic field, low density).

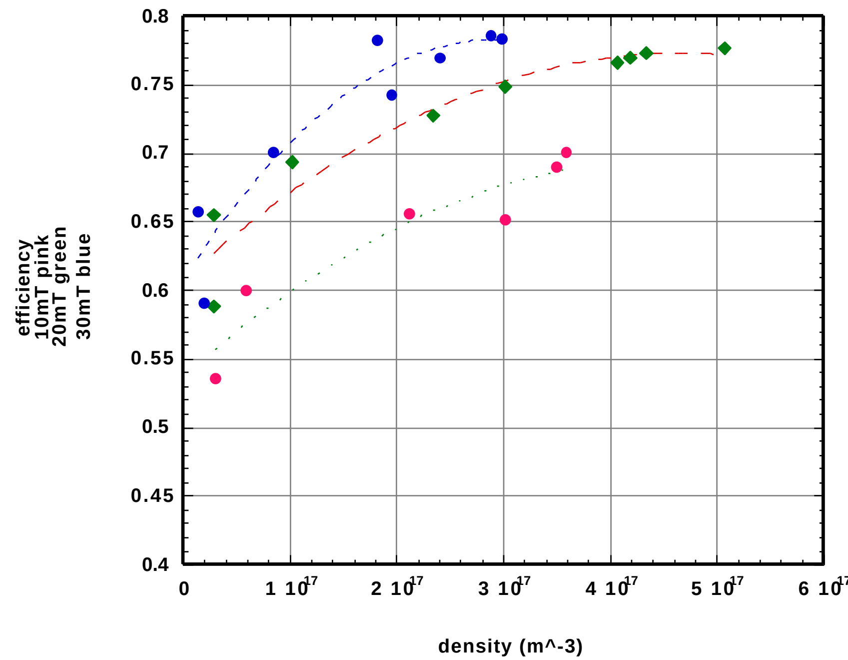


## Theoretical
(capacitive loading not accounted for)




## Experimental
(capacitve and inductive loading present)



# Acknowledgements

- Oak Ridge National Laboratory
- National Aeronautics and Space Administration, Johnson Space Center
- ORISE
- Special thanks to Franklin Chang-Diaz, Rick Goulding, Wally Baity, Danielle Pavarin, Mark Carter, Dennis Sparks, Andy Fadnek, Dave Rasmussen, Phil Ryan, Gary Bell, John Wilgen, Tim Bigelow, John Caughman, and everyone else who helped over the course of the summer.

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