Scaled Inertial Electrostatic Confinement Plasma Source

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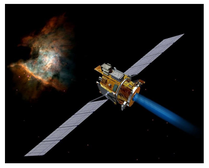
INTRODUCTION

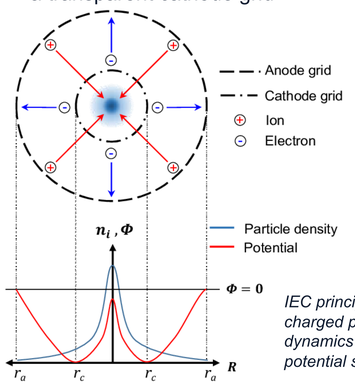
Electric propulsion (EP) systems use electromagnetic (EM) fields to accelerate the propellant to high speeds and generate thrust. [1].



Deep Space 1 (1998) - first US EP spacecraft with ion thrusters [2]

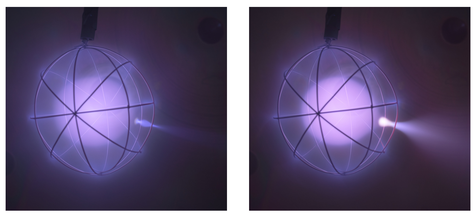
Inertial electrostatic confinement (IEC) systems:

- Use direct current (DC) electric fields to ionize propellant gas
- Sustain plasma by recirculating ions through a transparent cathode grid



IEC principle showing charged particle dynamics within the DC potential structure [3].

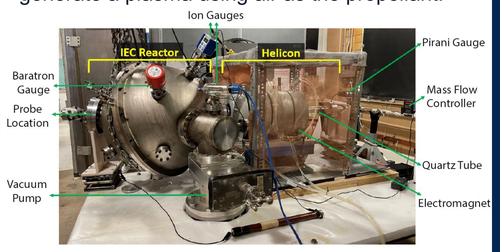
The plasma beam ejects as a collimated jet or diverging spray, capable of producing thrust.



Jet (left) and spray (right) mode [4]

OBJECTIVE

Set up a scaled-down helicon-IEC thruster and generate a plasma using air as the propellant.

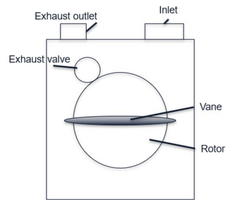


HIIPER experimental setup [4]

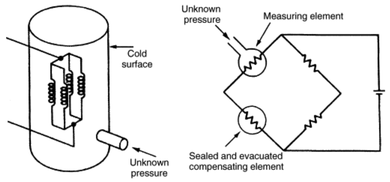
EXPERIMENTAL SETUP

VACUUM COMPONENTS

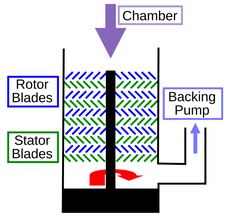
Classification	Pressure Range	Vacuum Pump	Pressure Gauge
Low Vacuum	Atmosphere to 10^{-3} torr	Rotary Vane Pump	Pirani Gauge
Medium-High Vacuum	10^{-3} torr to 10^{-7} torr	Turbomolecular Pump	Ion Gauge



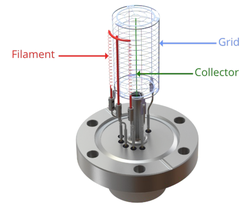
Rotary vane pump



Pirani gauge [5]



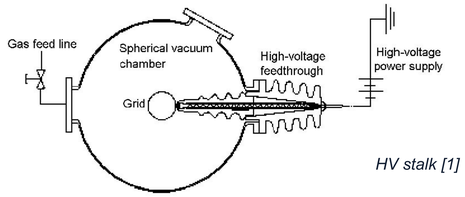
Turbomolecular pump [6]



Ion gauge [7]

STALK

- Insulates the high-voltage (HV) conductor
- Shields the conductor from the plasma
- Minimizes the electric field stresses



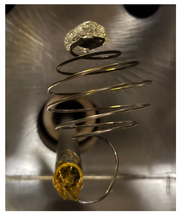
HV stalk [1]

CATHODE GRID

Negative DC bias causes dielectric breakdown of the propellant gas.

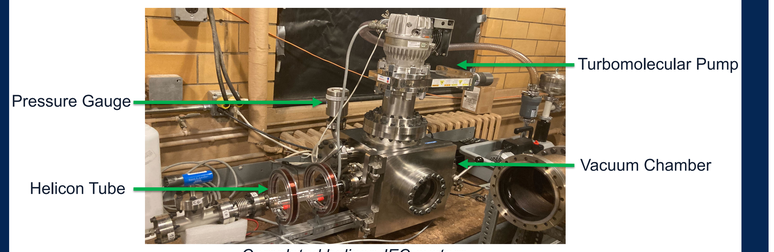
Symmetrical grid

Asymmetrical grid



Test grid

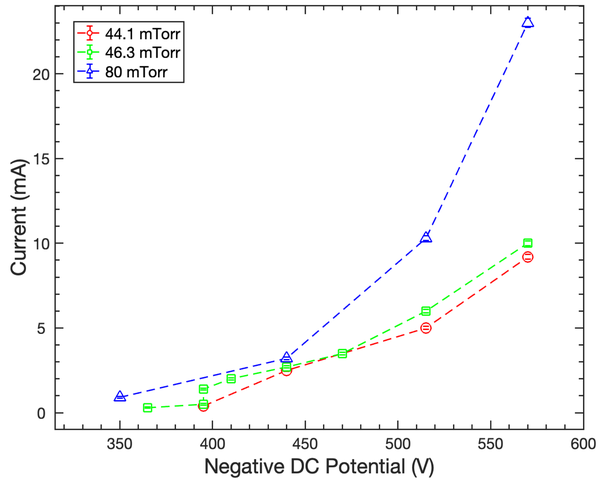
FINAL SETUP



Completed helicon-IEC system

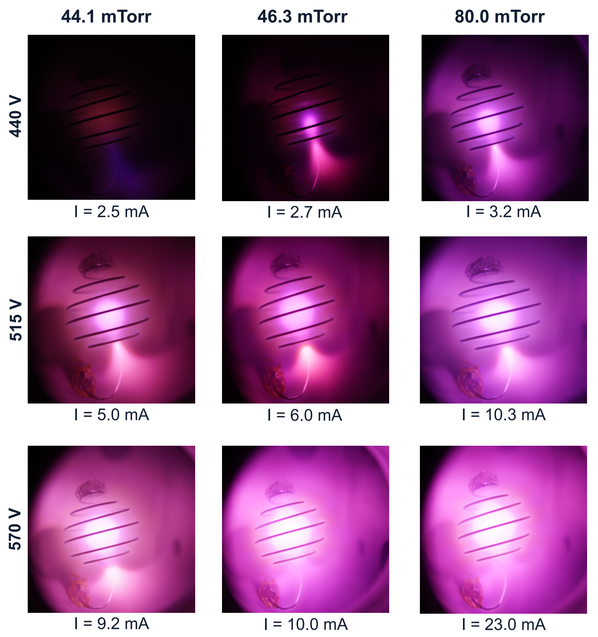
RESULTS

- Grid draws higher current at higher voltages, keeping pressure constant
- For the same voltages, grid draws higher current at higher background gas pressures



Discharge characteristics

- The images increase in brightness at higher pressures
- The images increase in brightness at higher voltages
- At both higher pressures and voltages, the light intensity of the plasma becomes more uniform



High resolution images of the discharge at various operating conditions

RESULTS

- For 46.3 mTorr, an abrupt increase in current is observed at 395 V

I = 0.5 mA I = 1.4 mA

Plasma discharge at 46.3 mTorr and 395 V

- Background gas pressure measured with lowest mass flow controller (MFC) setting

Pressure reading obtained using convection enhanced Pirani

DISCUSSION

The discharge current is directly proportional to the background gas pressure as well as the magnitude of the applied potential.
The light intensity of the plasma increases with drawn current.
A mode transition is observed when the current drawn by the grid increases abruptly, maintaining a fixed voltage at a constant pressure.

FUTURE WORK – Repeat the experiment at lower pressures and with different propellants.

ACKNOWLEDGEMENTS

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