Numerical and Experimental Validation of Ion Extractor Grids

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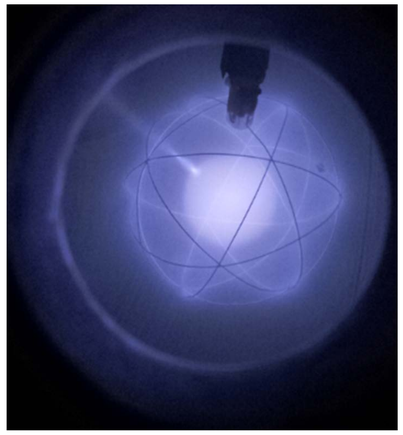
Introduction

- HIIPER (Helicon-Injected Inertial Plasma Electrostatic Rocket) is a promising plasma-based propulsion method being investigated at the Nuclear Engineering Laboratory at the University of Illinois at Urbana Champaign.
- It is composed of two distinct components: an Inertial Electrostatic Confinement cathode, and a Helicon used as external plasma source. HIIPER could achieve both High ISP/Low Thrust or Low ISP/High Thrust operating points by altering either the mass flow rate from the Helicon or the IEC's potential.
- The IEC itself has different modes of operation. The so-called "Jet-Mode" where a unique plasma beam shoots through an asymmetry created in the IEC's structure is a characteristic of HIIPER



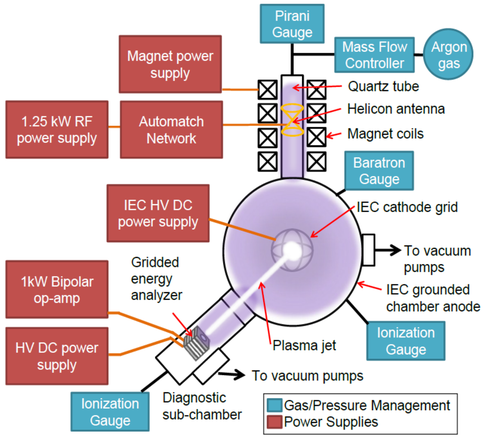
IEC operating in Jet Mode

Aim

Improving heavy particles extraction from the IEC core by means of extractor grids.

- Previous studies [1] have shown that the plasma beam exiting the IEC is electron-dominated. Electrons, unlike ions or neutrals, have a very small mass and therefore have a very small momentum.
- In order to improve HIIPER's capabilities, the proportion of heavier particles in the exiting beam must increase.
- Extractor grids, a set of polarized electrodes of different geometry and bias, are envisioned as a way to extract more ions from the plasma core at the center of the IEC.

HIIPER Experimental Setup



HIIPER experiment

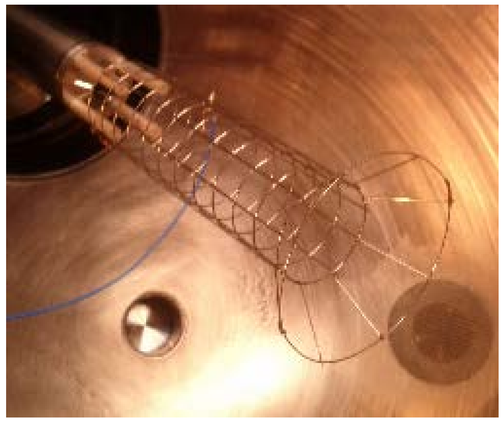
- Argon gas is used
- Operating pressure range : [1,2] mTorr.
- Particle density was estimated around 10^{14} m^{-3}

Extractor grids

Extractor grids are polarized electrodes whose bias voltage modifies the shape of the potential well inside the system, therefore allowing the escape of particles otherwise trapped inside the well.

- Can vary in size (length, width, number of biased elements) and location.
- Several designs:
  - Cylindrical grids (single bias voltage)
  - Einzel Lens
  - Any combination of the two above

The focus of this work is on determining which design of extractor grids would perform best and could improve HIIPER's performance the most

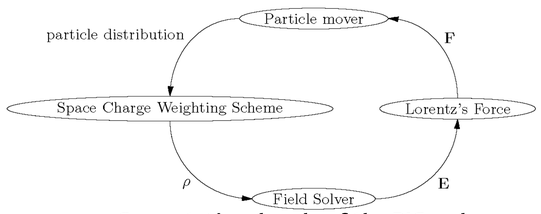


Cylindrical extractor grid

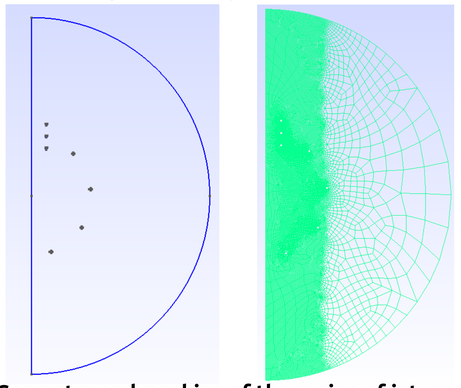
Numerical Validation

Particle-In-Cell codes are a solution of choice for the study of low-density plasmas by coupling particle-tracing and field-based solving methods[2].

- Allows for the presence of multiple species (ions, electrons, neutrals).
- Any axisymmetric extractor grid design can be added to the system.
- Tracks escaping particles and allows for a trade-off of different extractor grid designs.



Computational cycle of the PIC code



Geometry and meshing of the region of interest

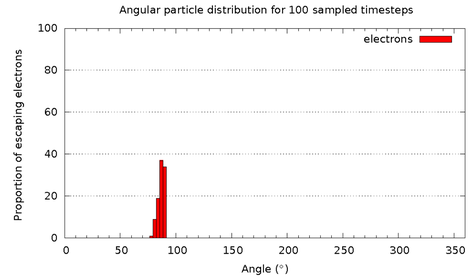
Experimental Validation

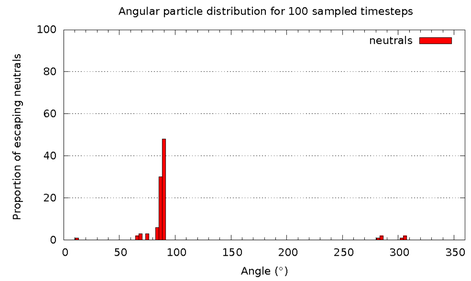
- Thrust measurement is performed by means of a deflection plate.
- A neutralizing cathode is located between the IEC and the deflection plate.
- The best extractor designs according to the results of the PIC code will be made and tested

Titanium deflection plate

Ongoing and future work

- Escaping particle tracking is operational





- Net momentum flux can be evaluated.
- Tests cases (geometries that will be simulated) are yet to be frozen.
- Best tests cases will be selected and validated experimentally.

Conclusions

- Promising results from the numerical simulation
- Experimental validation still to be carried out

Acknowledgments

- NASA
- Air Force Research Lab
- NPL Associates, Champaign, IL
- Aerospace Engineering Department, University of Illinois

References

- [1] Ben A. Ulmen (2013*), Formation and Extraction of a Dense Plasma Jet from a Helicon-Plasma-Injected Inertial Electrostatic Confinement Device*, PhD Thesis
- [2] C.K Birdsall, *Plasma physics via computer simulation*

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