Numerical and Experimental Validation of Ion Extractor Grids

Benjamin Bercovici, Drew Ahern, George Miley, George Chen, Ben Ulmen, Paul Keutelian
Department of Aerospace Engineering, College of Engineering, University of Illinois at Urbana-Champaign

**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.

**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.

**HIIPER Experimental Setup**

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

**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.

**Conclusions**

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

**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.

**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

**References**