Design and Preliminary Performance Testing of Electronegative Gas Plasma Thruster

Thomas M. Liu[1], Natalie R. Schloeder[2], and Mitchell L.R. Walker[3]
Georgia Institute of Technology, Atlanta, GA 30332

Kurt A. Polzin[4] and John W. Dankanich[5]
NASA Marshall Space Flight Center, Huntsville, AL 35811

and

Ane Aanesland[6]
Laboratoire de Physique des Plasmas (LPP), CNRS-Ecole Polytechnique, 91128 Palaiseau Cedex, France

In classical gridded electrostatic ion thrusters, positively charged ions are generated from a plasma discharge of noble gas propellant and accelerated to provide thrust. To maintain overall charge balance on the propulsion system, a separate electron source is required to neutralize the ion beam as it exits the thruster. However, if high-electronegativity propellant gases (e.g., sulfur hexafluoride) are instead used, a plasma discharge can result consisting of both positively and negatively charged ions. Extracting such electronegative plasma species for thrust generation (e.g., with time-varying, bipolar ion optics) would eliminate the need for a separate neutralizer cathode subsystem. In addition for thrusters utilizing a RF plasma discharge, further simplification of the ion thruster power system may be possible by also using the RF power supply to bias the ion optics.

Recently, the PEGASES (Plasma propulsion with Electronegative gases) thruster prototype successfully demonstrated proof-of-concept operations in alternatively accelerating positively and negatively charged ions from a RF discharge of a mixture of argon and sulfur hexafluoride.[i] In collaboration with NASA Marshall Space Flight Center (MSFC), the Georgia Institute of Technology High-Power Electric Propulsion Laboratory (HPEPL) is applying the lessons learned from PEGASES design and testing to develop a new thruster prototype. This prototype will incorporate design improvements and undergo gridless operational testing and diagnostics checkout at HPEPL in April 2014. Performance mapping with ion optics will be conducted at NASA MSFC starting in May 2014.

The proposed paper discusses the design and preliminary performance testing of this electronegative gas plasma thruster prototype.

I. Survey of Past Electronegative Gas Plasma Thruster Efforts

Past theoretical, analytical, and experimental work regarding electronegative gas plasma thrusters will be reviewed to assess the state-of-the-art for the technology. Key design, operational, and systems challenges for the technology will be identified and discussed.

[1] Research Engineer, Department of Aerospace Engineering, thomas.liu@ae.gatech.edu, AIAA Member
[2] Graduate Student Researcher, Department of Aerospace Engineering, nschloeder3@gatech.edu, AIAA Student Member
[3] Associate Professor, Department of Aerospace Engineering, mitchell.walker@ae.gatech.edu, AIAA Member
[4] kurt.a.polzin@nasa.gov
[5] john.dankanich@nasa.gov
[6] ane.aanesland@lpp.polytechnique.fr

II. Design of Electronegative Gas Plasma Thruster Prototype

Design improvements incorporated into the present thruster prototype compared to existing state-of-the-art will be discussed. These design improvements may be in the areas of:

- Plasma discharge and propellant injection schemes to improve RF power coupling to the plasma and the generation of desired plasma species
- Electron filtering via a magnetic barrier region to produce an ion-ion plasma interface with the ion optics
- Ion optics design and bipolar operational schemes to extract and accelerate both positively and negatively charged ions
- *In situ* diagnostics to characterize electronegative gas plasma thruster behavior

III. Performance of Thruster Prototype During Gridless Operations

Thruster prototype testing without ion optics along with the corresponding diagnostics checkout will be conducted in HPEPL's 4.3-m diameter by 6.7-m long Vacuum Test Facility 1. Plasma properties both before and following the magnetic filter will be characterized as a function of RF power, propellant flow rate, and magnetic filter strength; this data will be utilized in ion optics design optimization. Far-field, on-axis ion energy distributions will be mapped, and thrust will be measured with a null-type, inverted pendulum thrust stand.

IV. Performance of Thruster Prototype During Preliminary Gridded Operations

At MSFC, the thruster prototype will undergo performance mapping as a function of RF power, propellant flow rate, and magnetic filter strength with the inclusion of ion optics. Grid-collected currents, far-field ion energy distributions, and generated thrust will be measured to characterize performance.

---

[i] Aanesland, A., *et al*., "The PEGASES Gridded Ion-Ion Thruster Performance and Predictions", IEPC-2013-259, 33rd International Electric Propulsion Conference, Washington, D.C., 6-10 October, 2013.