Experimental Characterization of a Radio Frequency Microthermal Thruster

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Introduction

• Thruster Overview

• Thrust Stand/Calibration

• Important Results (power, frequency sweeps)

• Conclusions and Future Work
Overview

- Need: Propulsion technology for micro/nanosats that’s better than cold gas in the 10-1000 micronewton range

- Problem: *Severe* constraints (mass, volume, power, voltage, complexity, cost, etc.)

- Difficult to meet all requirements by scaling down existing chemical or EP thrusters!
RF microthermal thruster has already demonstrated promising capabilities in lab tests:

Thrust: 30-800 micronewtons
Isp: 60-85 s with Argon propellant (30-80% higher than cold gas Isp)
Power used: 10-80 W
Voltage used: 30-90 V
Complexity: Very low!
Overview

- How it works: Place a radio frequency (RF) voltage between coaxial electrodes and stream cold gas through.

- Even at low power, at the proper frequencies (have tested between 100, 250 MHz) the propellant partially ionizes and heats up (2 distinct and important heating mechanisms).
Calibration/Setup

• All work done at the Purdue Laboratory for Advanced and Electric Propulsion (LEAP)
Calibration/Setup

- Thrust stand calibration via non-contact procedure with electrostatically charged interlaced fins (see paper/references)
- Delivers +/- 1-2 micronewton accuracy between 10, 1000 micronewtons
Results

• Broad conclusions: Thrust increases at lower mass flow rates, increases approximately linearly with power, but varies considerably based on frequency and geometry interactions.

• Testing philosophy: Sweep power at a constant frequency and vice versa for different geometries to get a top-level view of the performance envelope.
Results

• Test parameters:
  0.1-1.0 mg/s mass flow rate
  Operating pressure: 2-100 microtorr
  Power: 10-80 W
  Frequency: 110-180 MHz (for these runs)

Only one geometry will be presented here for time’s sake: A conical converging 0.025” throat diameter nozzle on the front of the thruster; the results are broadly representative of other tests (details in paper)
Results

- Power Sweep at 140 MHz:
Results

- Frequency Sweep at 40 W:
Results

• Comparison with theory? Power sweep at 140 MHz
Future Work

• Fix impedance matching issues: Currently losing significant portion of power fed in to reflections (i.e. next thruster is likely to be significantly more efficient than shown here)

• Test other propellants (neon, helium, nitrogen, etc)- tradeoffs on mass, storability, heating efficiency

• Test different internal geometries (ceramic spacer, etc)

• Design a final optimized prototype and test!
Conclusions

• RF microthermal thrusters hold great promise for micro and nano-satellite propulsion, due to their simplicity and low power requirements compared to most traditional EP thrusters.

• Experimental analysis of these thrusters is well underway, and shows that improving cold gas performance by over 50% is easily achievable with minimal power and voltage expenditure, and that doubling cold gas performance or more is possible with finer analysis and testing of thruster geometry.
Questions?