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!

Overview

- RF microthermal thruster has **already** demonstrated promising capabilities in lab tests:

Thrust: **30-800 micronewtons**

Isp: **60-85 s** with Argon propellant **(30-80% higiher than cold gas Isp)**

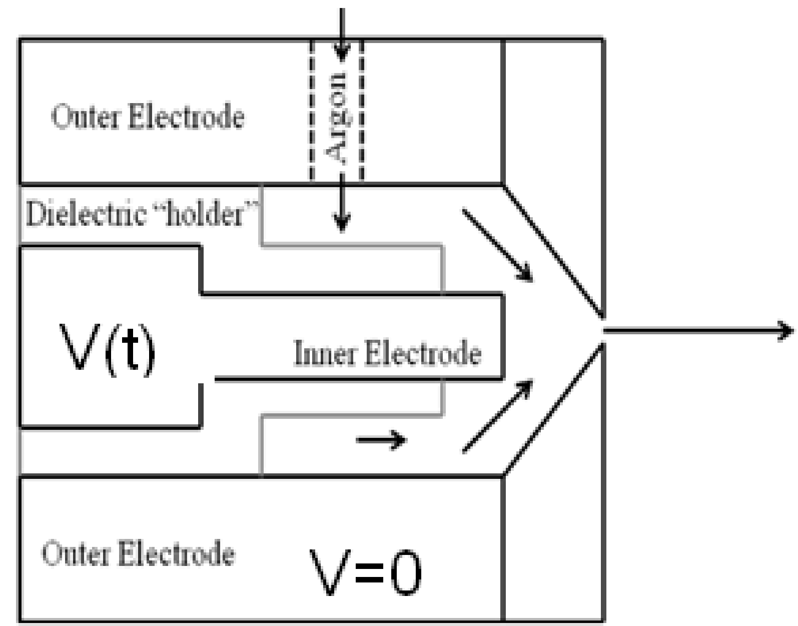
Power used: **10-80 W**

Voltage used: **30-90 V**

Complexity: **Very low!**

Overview

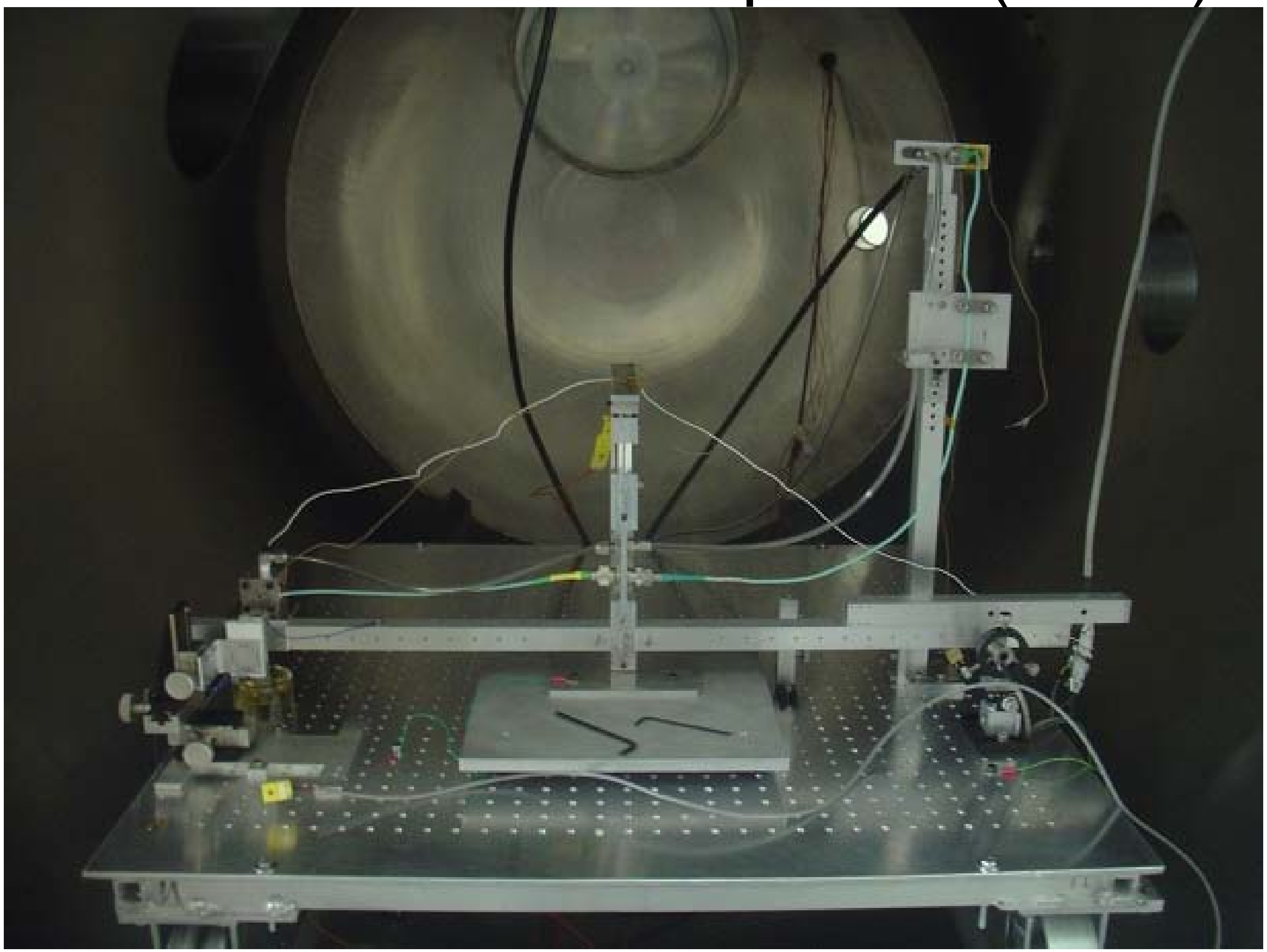
- How it works: Place a radio frequency (RF) voltage between coaxial electrodes and stream cold gas through



- 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)

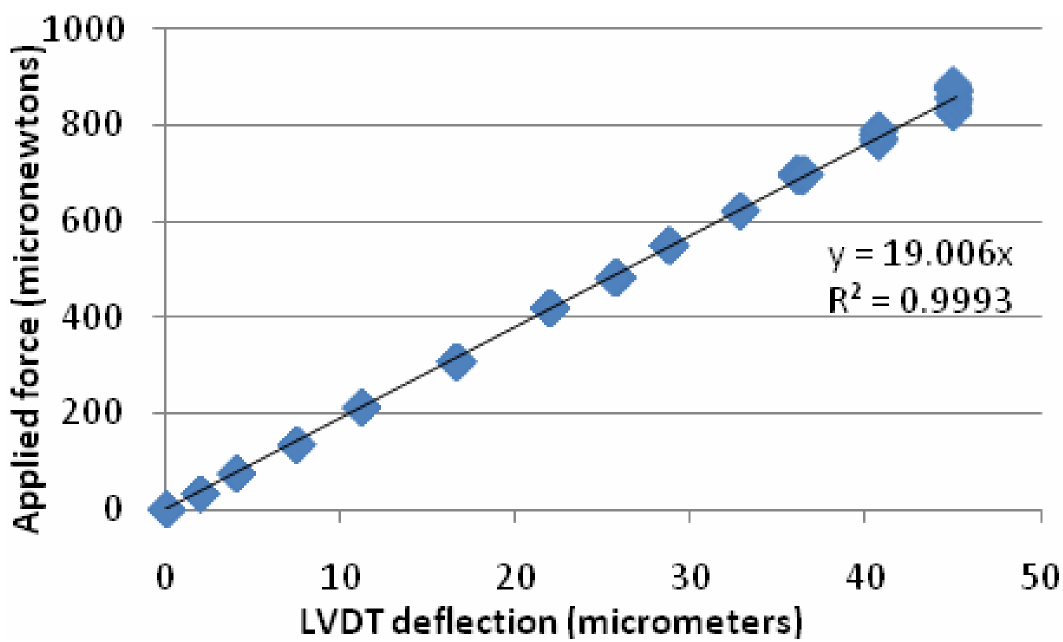
Calibration/Setup

- 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

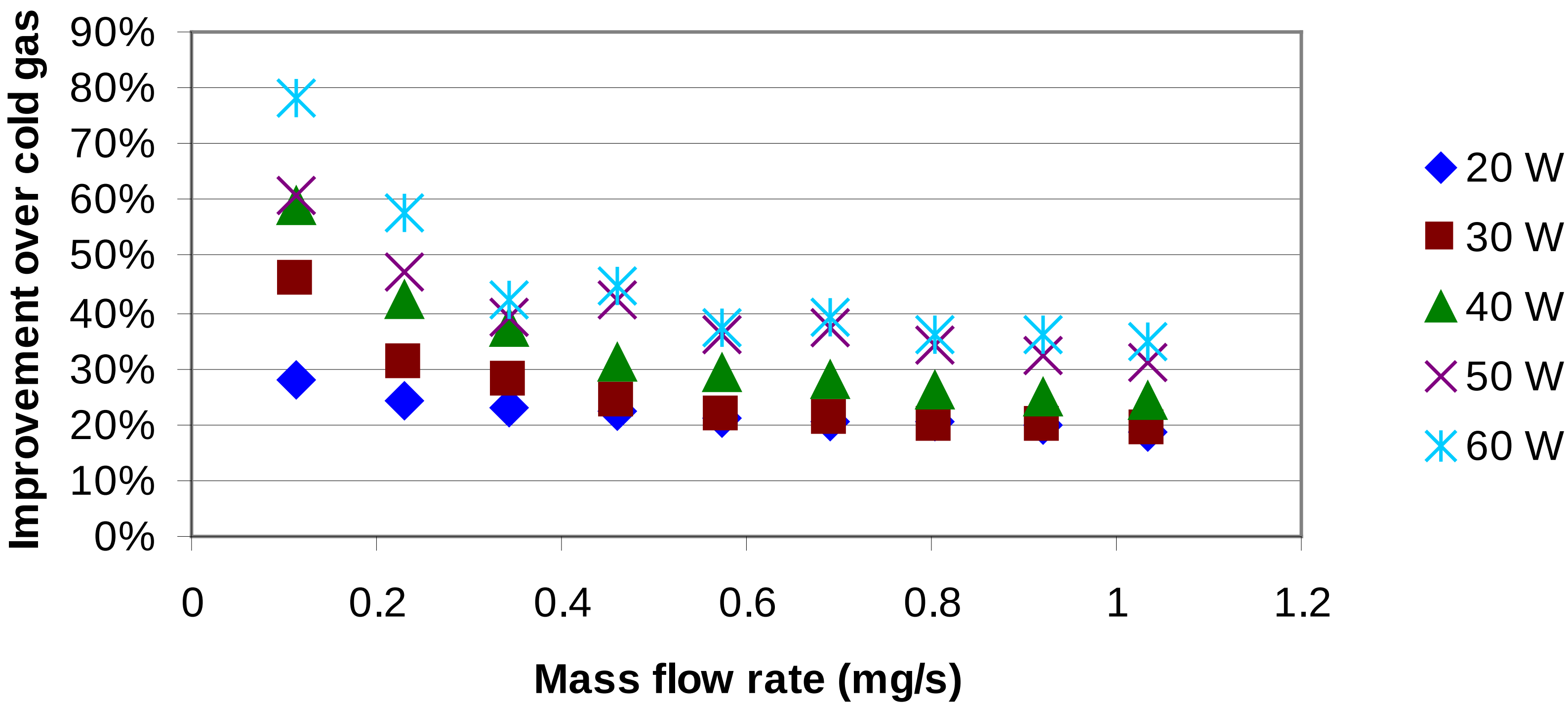
Power: 10-80 W

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)

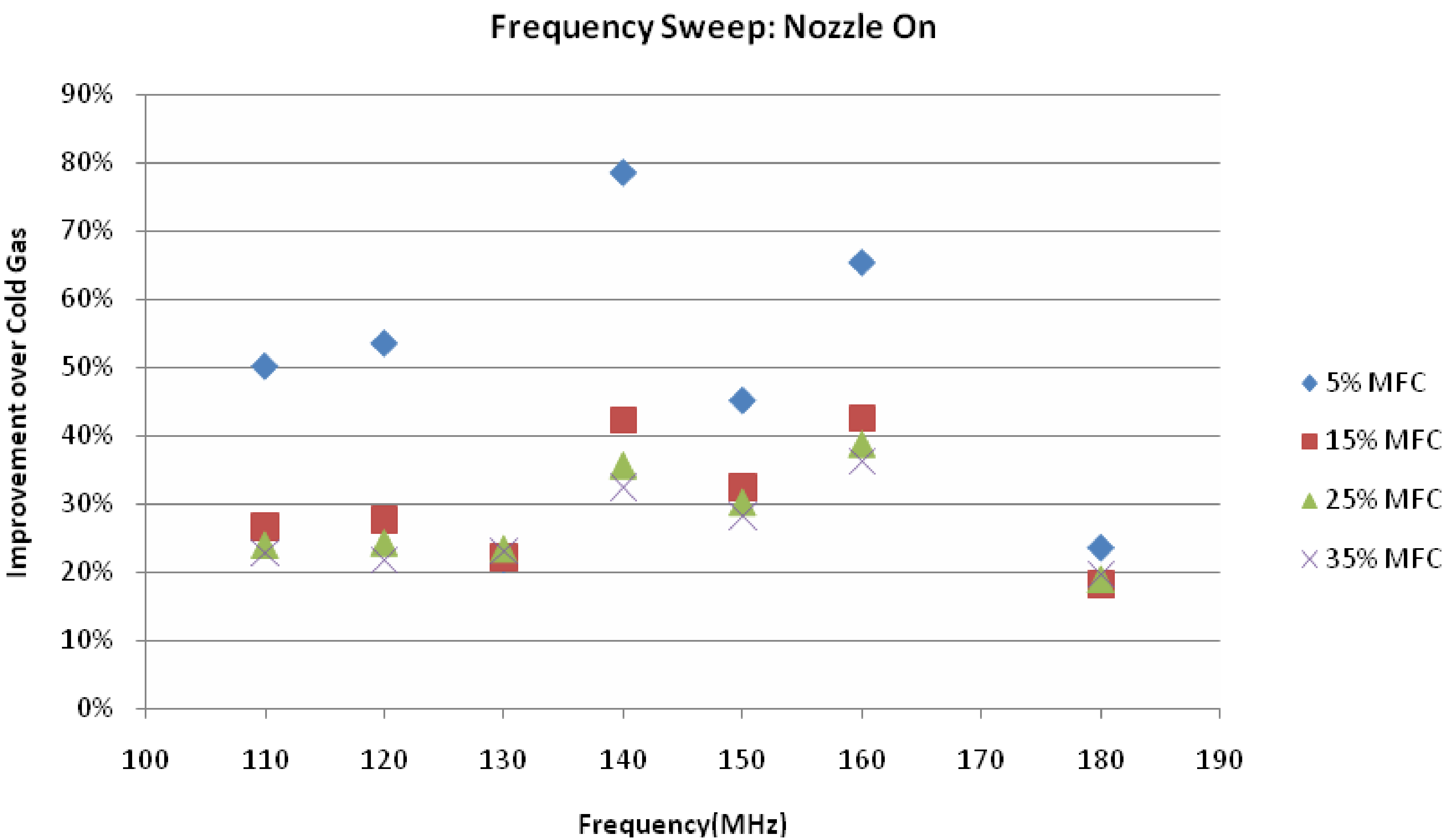
Results

- Power Sweep at 140 MHz:



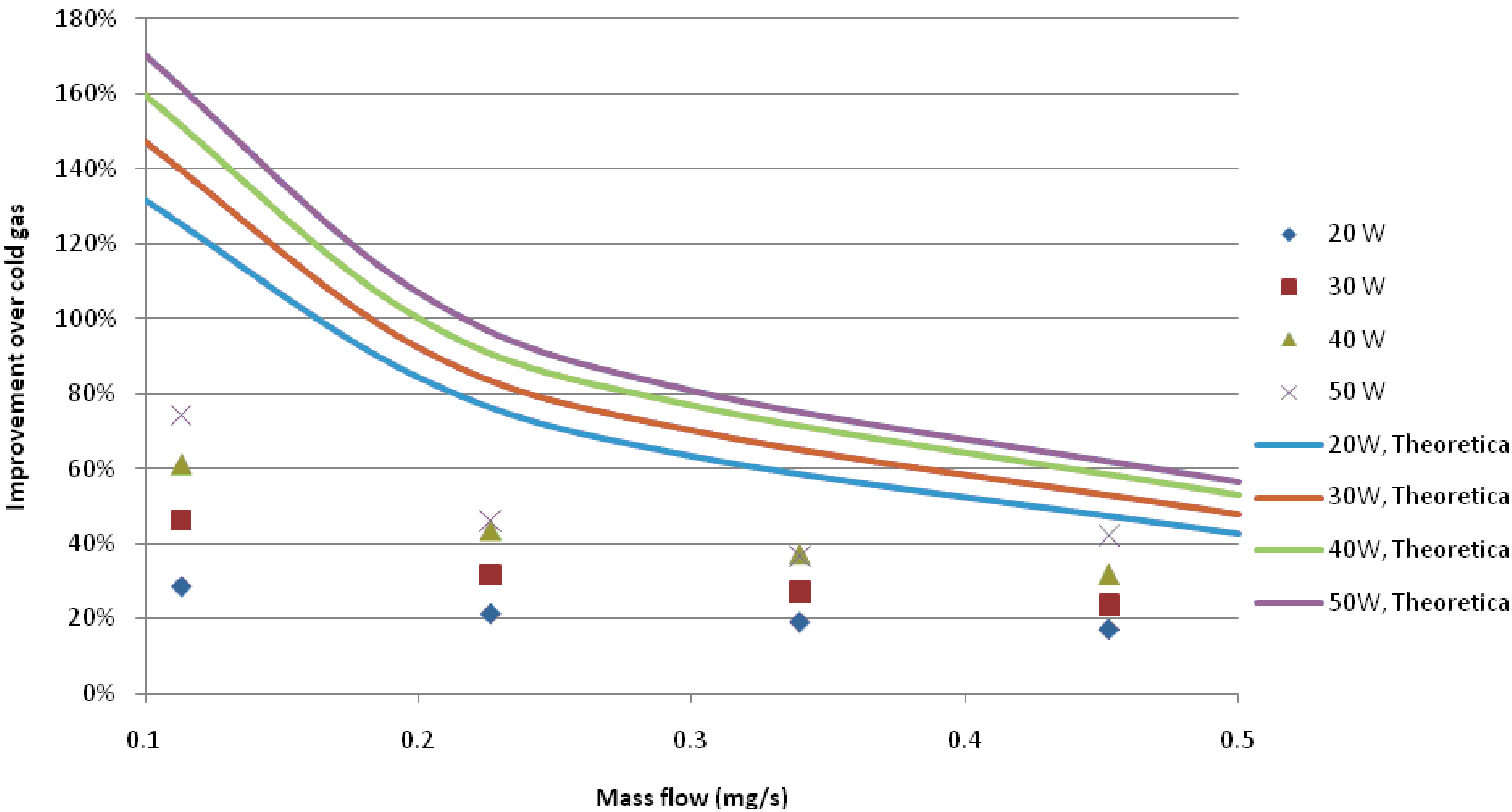
Results

- 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?