Ion Energetics of the Modes of the CubeSat Ambipolar Thruster

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Introduction

The CubeSat Ambipolar Thruster (CAT), pictured in Figure 1, is an electrodeless, permanent magnet, helicon thruster being developed to increase the qV capabilities of nanosatellites to > 1000 m/s, thereby enabling a wide array of missions [1, 2]. Two of the primary performance characteristics of a thruster are the thrust and specific impulse, which are related to the mass flow rate of propellant and the ion energy.

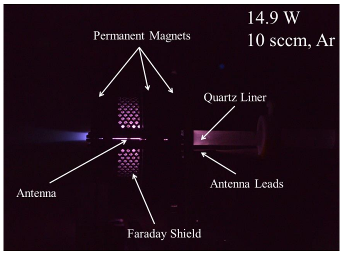


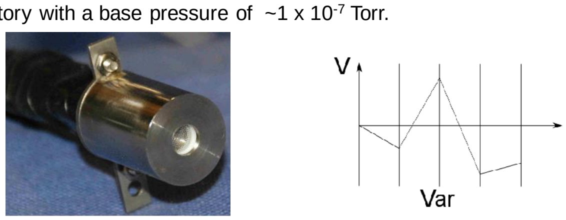
Figure 1: A photograph of CAT, with the major components highlighted.

Objectives

1. Investigate the ion energetics of the various operating modes of CAT
2. Identify potential high specific impulse modes.

Materials and Methods

The ion energy distribution was measured using a 5 grid Retarding Potential Analyzer (RPA), shown in Figure 2, and the plasma potential was measured with an emissive probe. These measurements were made in a vacuum chamber at the Plasmadynamics and Electric Propulsion Laboratory with a base pressure of ~1 x 10^{-7} Torr.



a) b)

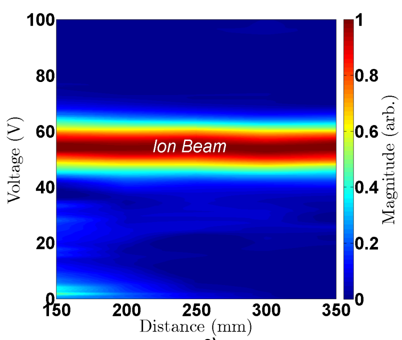
Figure 2: **a)** A photograph of the RPA. **b)** The potential distribution of the grids within the RPA.

Results and Discussion

The first mode that exhibited an energetic ion beam was a low propellant flow rate, high power mode. Figure 3a shows CAT operation on xenon in this mode.

Important mode details:

Â ~ 1 x 10^{-6} Torr back pressure
Â Varying power did not change ion energy (Figure 3b)
Â Evidence of a double layer (Figure 3c)



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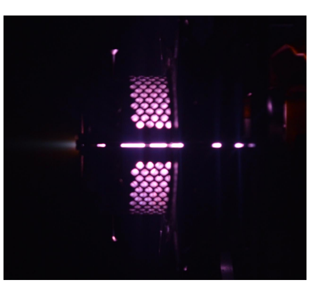

a)

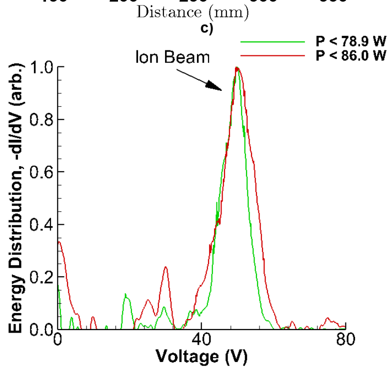

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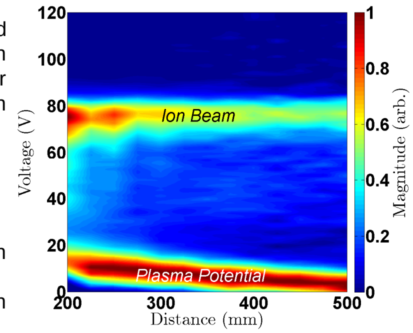
Figure 3: **a)** A photograph of CAT operating in this mode. **b)** The ion energy distribution with varied power. **c)** The ion energy distribution with varied distance downstream.

The second mode that exhibited an energetic ion beam was a high propellant flow rate, low power mode. CAT operation on argon in this mode is shown in Figure 4a.

Important mode details:

Â ~ 1 x 10^{-4} Torr back pressure
Â ~ 7 cm charge exchange mean free path
Â Varying power changed ion energy (Figure 4b)
Â Evidence of acceleration via ambipolar fields (Figure 4c)



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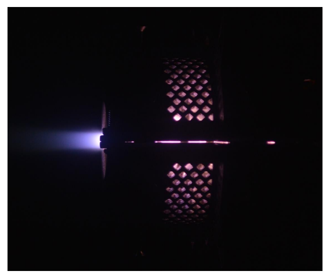

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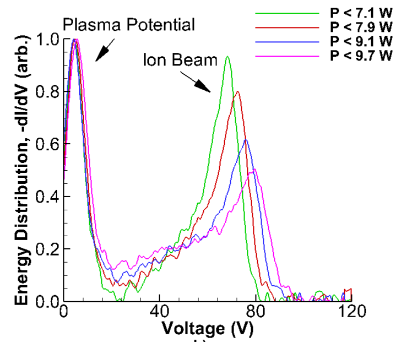

b)

Figure 4: **a)** A photograph of CAT operating in this mode. **b)** The ion energy distribution with varied power. **c)** The ion energy distribution with varied distance downstream.

Conclusions

Two of the three modes observed during CAT observation include a highly energetic ion population. The ion energy of the high power, low flow rate mode indicates that this mode may be a high specific impulse mode. Conversely, the low power, high flow rate mode may be a moderate specific impulse, high thrust mode. The behavior of these two modes when the RPA position downstream and the input power provide evidence of the physics within the plume. In the high power, low flow rate mode there is evidence of a double layer near the throat. In the low power, high flow rate mode there is evidence of ambipolar acceleration.

Future Work

To fully understand the physics driving the operation of CAT in the various modes observed the a number of tests need to be conducted, including:

1. Direct thrust measurement
2. Direct measurement of the input power
3. 2D plume property mapping
4. Determination of plume composition
5. Determination of system efficiencies

Acknowledgements

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References

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