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Open Source Development of Low Cost, Low Power, Sub-Joule Micro-Pulsed Plasma Thrusters for PocketQubes and Cubesats

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Since the first successful use of electric propulsion aboard the Zond 2 in the 1960s, electric propulsion has served an important and critical role in satellite applications. However, despite the numerous advances over the decades in the field, cost and accessibility of propulsion has remained prohibitive for lower funded educational and enthusiast groups. With current trends in research initiatives and funding models for propulsion development, there is little-to-no market incentive to pursue low-cost simplified propulsion solutions outside of those for critical defense, military, space-agency, and major corporations. Due to the nature of development, technical aspects of these thrusters remain closely guarded secrets by companies developing them, or restricted to limited information published in academic papers. Scaling, especially for the emerging class of small-sized low-cost PocketQube satellites, in terms of power and form factor, has also not yet been realized in a practical, deployable solution. While numerous propulsion solutions do currently exist for Cubesats, these options have remained costly.

Work is currently underway to develop a new class of open-source, low power, small-form factor micro-propulsion thrusters based on a novel low-profile pulsed plasma thruster. The AIS-gPPT, or Applied Ion Systems Gridded Pulsed Plasma Thruster series is at the forefront of these efforts, offering a unique and radically different approach towards propulsion solutions, focusing on a fully open-source design and development approach, with emphasis on ultra-low cost construction (estimated less than $1k for a complete thruster module), as well as a simplified topology for ease of manufacture.

Currently, the second-generation AIS-gPPT2 thruster has passed successful high vacuum ignition testing and impulse bit measurements, operating from an input energy range of 0.40J to 0.84J, with corresponding impulse bit ranging from 0.78uN-s to 3.52uN-s. The thruster has also been demonstrated at main capacitor bank energies as low as 0.23J (680V charging voltage), and repetition rates up to 2Hz. Current lifetime limits for this thruster are on the order of 500 pulses.

The third generation of thrusters, the AIS-gPPT3 series, is currently in the manufacturing and testing stage, and aims to greatly increase lifetime with improved fuel bore geometry, as well as exploring the use embedded permanent magnets for a magnetic output nozzle to improve thrust. This thruster series also explores the use of novel propellants in addition to standard Teflon, including Ultem, PEEK, and Bismuth-Tin. This class of thruster aims to radically improve micro-PPT lifetime and performance in a form factor compatible with 1P PocketQubes, and will allow for propulsion clusters to be implemented to further increase overall lifetime. It is expected that a cluster of 9 thrusters can be incorporated in a single 1P frame, with a total cross sectional area not exceeding 1P, and a total depth not exceeding 0.25P. Expected power requirements for such a thruster will be limited to 1W max, and utilize fully integrated electronics with the stacked-plate thruster assembly to create a complete low-profile module.

By starting out with the smallest scale thruster size possible for pulsed plasma thrusters, it becomes possible to not only accommodate solutions for the smallest class of satellites, but allows for scaling to larger Cubesats. In particular, due to the larger available power budget and volume for Cubesats, scaling up power, size, and cluster number becomes simpler. A highly experimental version of the gPPT series, the AIS-gPPTx-MAGE1, will explore new concepts for pulsed plasma thrusters, including magnetic confinement and enhancement of plasma, high surface area fuel, and gridded electrodes in a flat profile, for larger Cubesat applications. The normal gPPT series thrusters could also be employed for Cubesat attitude control, as well as clusters for the main propulsion drive.

Significant advances through novel and unconventional approaches, such as low profile geometries and new fuels must be implemented to overcome challenges associated with scaling to such small form-factors and power levels. With open-source accessibility to fully characterized and simplified thruster technology, new possibilities can arise in the small satellite community. Increased orbital lifetimes, orbital maneuvers, and planned deorbiting offer significant opportunities to advance the field and ultimate capabilities of small satellites.

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