Applied Ion Systems

AIS-TR-006

AIS-gPPT3-1C Integrated Propulsion Module V1

Phase I - Ignition Testing - 09/06/2019

Testing Report and Summary

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I. TEST PARAMETERS

- **System:** AIS-gPPT3-1C Integrated Propulsion Module V1
- **Main Bank Capacitor:** 0.2uF X7R ceramic capacitor
- **Main Bank Charging Voltage:** 944V
- **Shot Energy:** 0.09J
- **Pulse Repetition Rate:** 0.30 Hz
- **Total Number of Shots:** 50
- **Maximum Chamber Pressure During Testing:** 1 x 10^-5 Torr
- **Testing Status:** SUCCESFUL

II. OVERVIEW

This test represents Phase I of testing and development for the AIS-gPPT3-1C Integrated Propulsion Module V1. The purpose of the test was to verify successful and reliable ignition of the full thruster module with the completed AIS-gPPT3-1C thruster stack and full electronics board, representing the first completed thruster module for these efforts for the development of sub-Joule micro-PPTs for PocketQube-class satellites. Both the electronics board and new gPPT3 thruster stack were prior untested in high vacuum.

The AIS-gPPT3-1C Single-Channel Gridded Pulsed Plasma Thruster represents the latest iteration of the Gridded Pulsed Plasma Thruster line at *Applied Ion Systems.* The AIS-gPPT3-1C features the same ignition electrode topology as its predecessor, the *AIS-gPPT2-1C* while utilizing a reduced diameter and longer length fuel bore to greatly increase lifetime. The thruster also features a new experimental concept to the gPPT series thrusters by employing an embedded permanent-magnet based magnetic nozzle to reduce plasma plume divergence and increase thrust performance. The thruster also utilizes tapped holes on the front anode plate, reducing the total hardware needed and streamlining assembly.

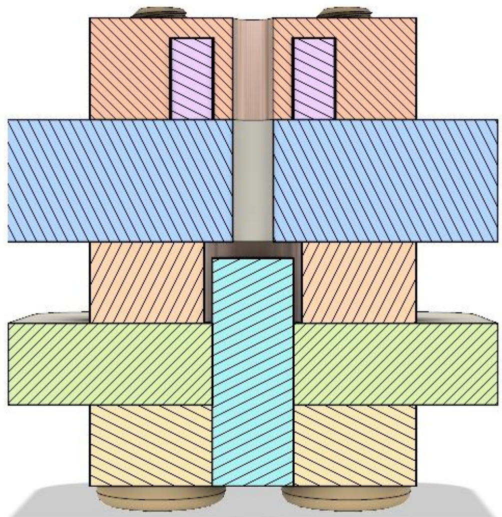

FIGURE 1: *Cross-sectional view of the AIS-gPPT3-1C thruster stack. From top to bottom: anode plate (with embedded magnet), Teflon fuel plate, igniter, Teflon insulating space, cathode.*

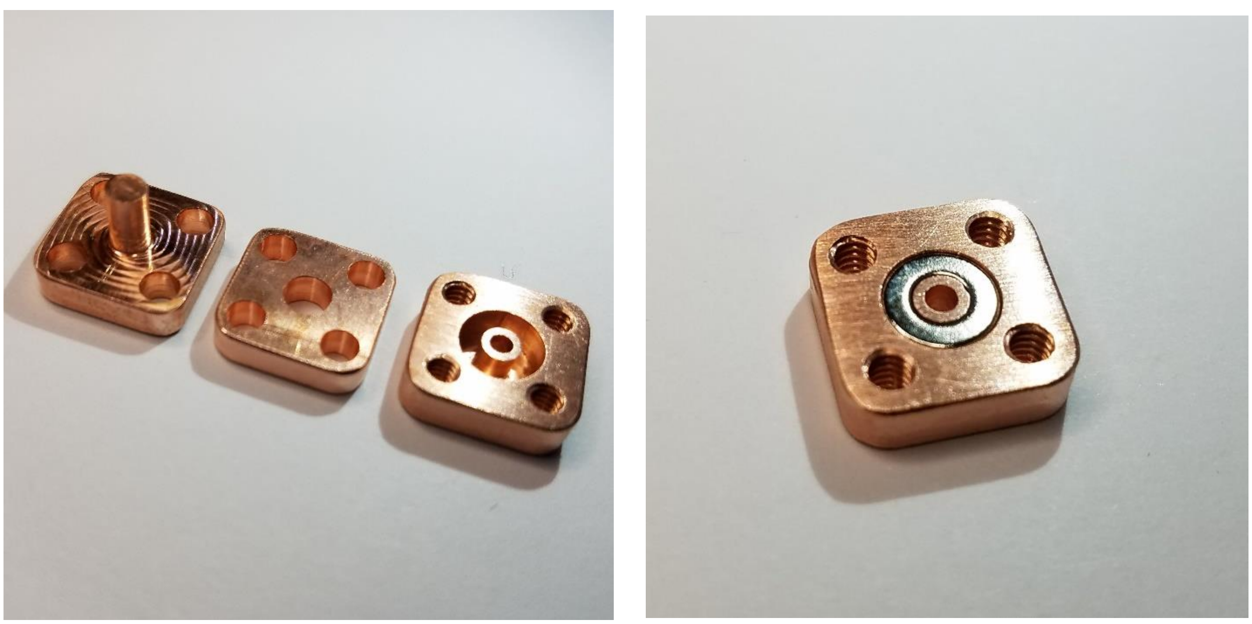

FIGURE 2 & 3: *Copper electrodes for the AIS-gPPT3-1C thruster stack. Left: cathode, igniter, anode. Right: anode with embedded permanent magnet.*

FIGURE 4 & 5: *Fully assembled AIS-gPPT3-1C thruster stack with Teflon fuel and spacer. Left: isometric front view. Right: side view.*

The thruster module integrates the thruster stack with the custom electronics. The board provides all high voltage power for the main thruster drive as well as ignition, and is designed to be directly driven off of standard 3.3V PQ main power. High voltage enable is controlled via high side load switch, driven from standard PQ logic output to directly turn on and off the high voltage supply as needed. For ignition, standard PQ logic pulses can be used to switch the sensitive-gate thyristor, set to the desired firing rate, after high voltage has been enabled. The full propulsion module volume fits within a footprint not exceeding 40mm x 38mm x 24mm.

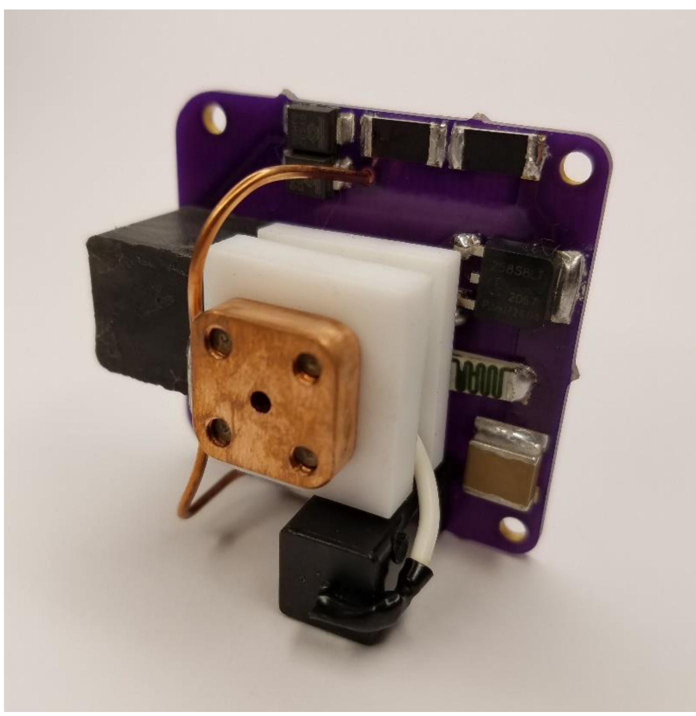

FIGURE 6: *Completed AIS-gPPT3-1C-T V1 Integrated Propulsion Module*

III. TEST SUMMARY

The AIS-gPPT3-1C-T thruster was mounted to the conflat feedthrough adapter utilizing a simplified direct feedthrough connection from the high voltage conflat feedthrough to a zero-clearance reducer on the micro propulsion testing chamber. 0.25”OD x 0.1875”ID Teflon tubes were used to secure and support the thruster to the feedthrough. 18 AWG bare copper wire with pin sockets soldered to the wire ends were used for all power and control inputs. Connection pins were soldered to the thruster to interface with the wire connections. Thruster mounting lengths were determined based on the length required to center the thruster in the adjacent 6” conflat viewport.

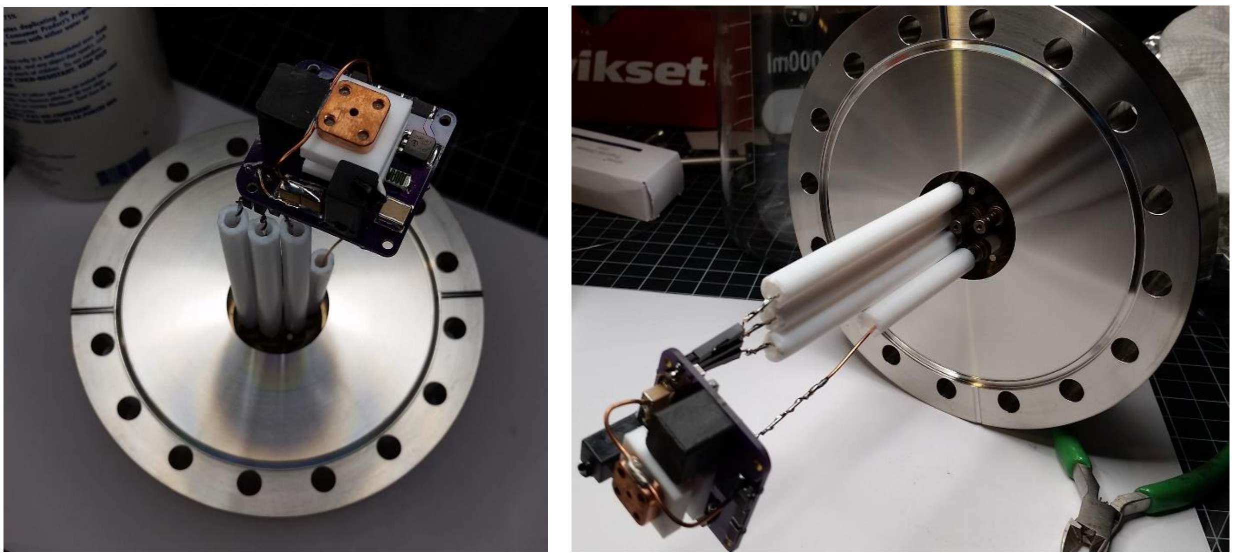

FIGURE 7 & 8: *Propulsion module mounting to the conflat feedthrough.*

The repetition rate for ignition testing was set to 0.30 Hz, controlled by the external Arduino Uno microcontroller. A simple control program was written to allow for enabling and disabling of the high voltage supply with the onboard load switch (active LOW for ON), as well as triggering of the thruster. A 100ms pulse was generated through one of the Arduino microcontroller digital output pins, and stepped down to 1V via external voltage divider, to provide the proper control pulse command for the ignition thyristor on the propulsion module. The thruster module itself was powered via 3.3V from the Arduino Uno 3.3V power pin.

FIGURE 9: *View of propulsion module mounted in high vacuum chamber through the viewport.*

Testing was performed in the Micro Propulsion Testing Chamber using the Integrated High Vacuum Test Stand. Ignition testing vacuum levels were first verified at 1 x 10^-5 Torr before attempting ignition. During testing vacuum levels were unaffected from the thruster firing.

IV. TEST RESULTS

Upon enabling of the high voltage supply and issuing the trigger pulse command, the characteristic plasma plume was immediately observed from the thruster. The resulting plume capture can be seen below:

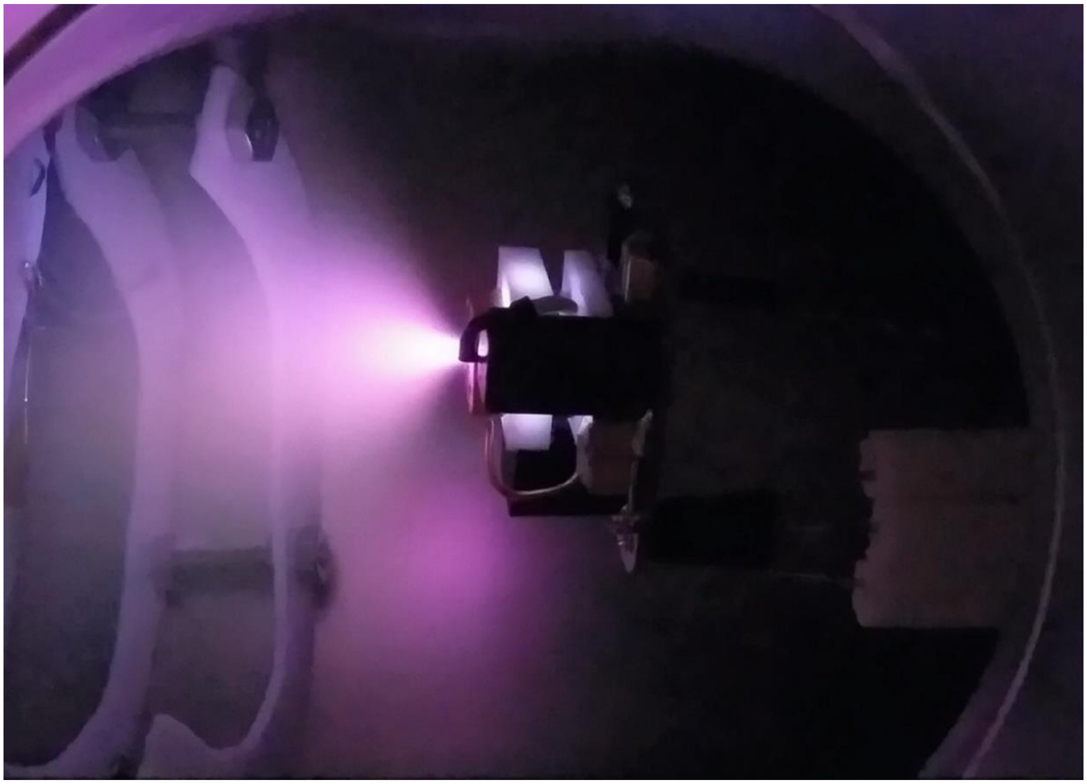

FIGURE 10: *Plasma plume capture during successful ignition and firing of the propulsion module.*

During the ignition testing, a total of 50 shots were performed with the thruster, with near 100% ignition reliability. No failures or external arcing was observed during the duration of the test. With an input of 3.3V, the resulting output voltage on the main bank was found to be 944V, corresponding to a shot energy of 0.09J for a bank capacitance of 0.2uF. During the firing sequence, it was observed that the Arduino Uno would glitch occasionally due to interference during the plasma pulse.

It can be observed that the plume divergence in the present topology with the embedded permanent magnet nozzle, is roughly around 104 degrees.

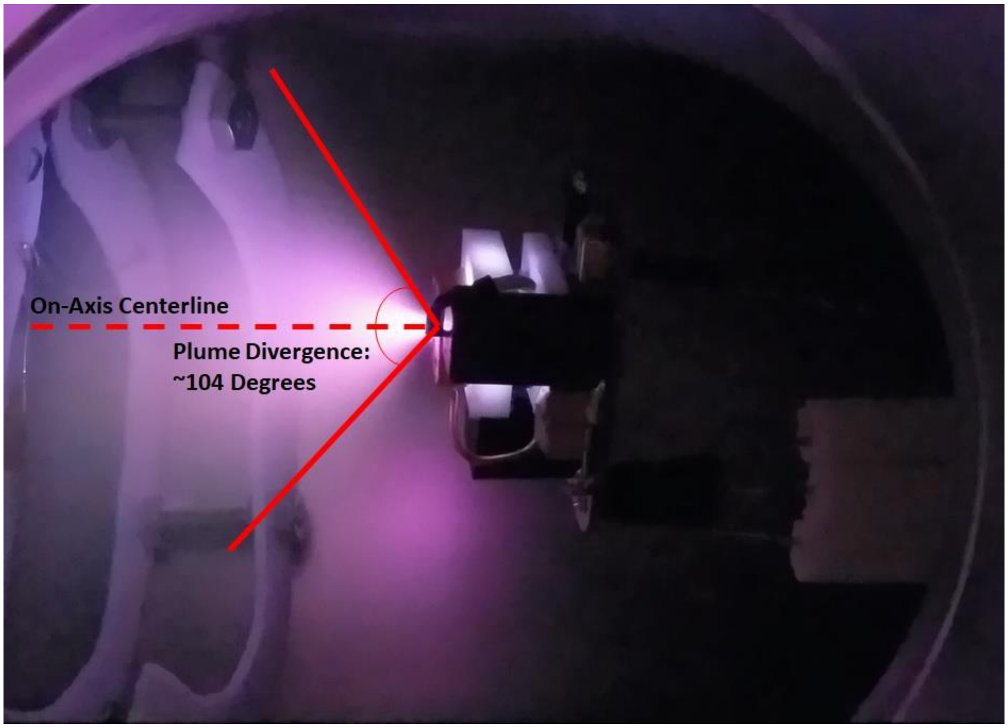

FIGURE 11: *Initial plasma plume divergence measurement estimate during successful ignition and firing of the thruster.*

V. CONCLUSION

This test represents the first successful ignition testing and operation of the both the new AIS-gPPT3-1C thruster stack design as well as the completed AIS-gPPT3-1C Integrated Propulsion Module with full thruster assembly and electronics at high vacuum under nominal operating conditions. This is also the first successful testing of the first completed thruster package developed at Applied Ion Systems. With successful ignition, and Phase I testing of this new thruster module is complete, and additional thruster qualification can begin. The next phases of testing will include impulse-bit measurements, as well as lifetime testing of the thruster.