Applied Ion Systems

AIS-TR-017

AIS-EPPT1 Micro Pulsed Plasma Thruster V1

Ignition Test 2 - 09/22/2020

Testing Report and Summary

Michael Bretti – 10/26/2020

I. TEST PARAMETERS

- **System:** AIS-EPPT1 Micro Pulsed Plasma Thruster
- **Fuel:** Teflon
- **Maximum Chamber Pressure During Testing:** 1.5 x 10^-5 Torr
- **Testing Status:** COMPLETE
    - **Phase I:** Fueling – NOT REQUIRED
    - **Phase II:** Ignition – PARTIAL SUCCESS

II. OVERVIEW

This test represents the second ignition test of the new AIS-EPPT1 micro pulsed plasma thruster for Cubesats and PocketQubes.

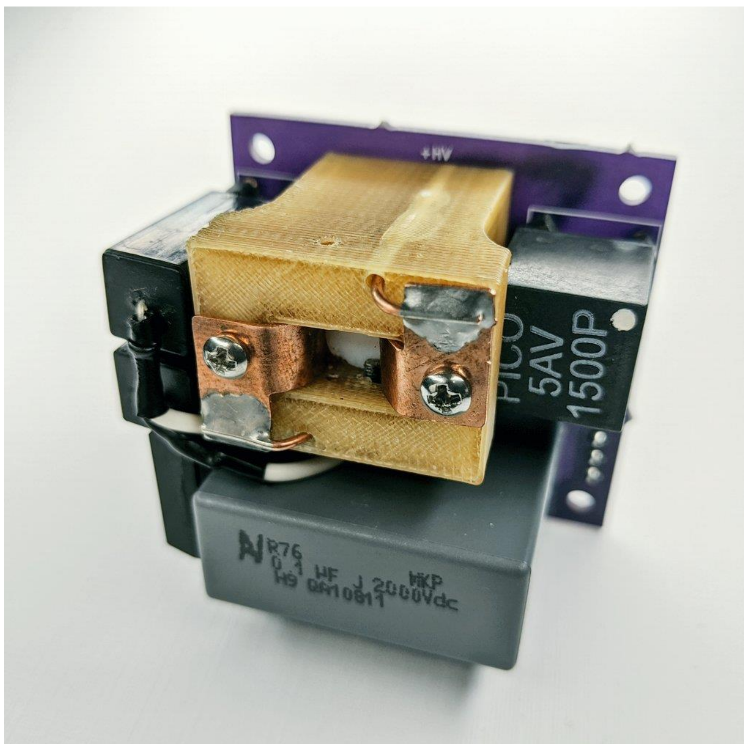

FIGURE 1: *Completed AIS-EPPT1 V1 thruster assembly modified for anode-side triggering.*

This system takes lessons learned from the original AIS-gPPT3-1C Integrated Propulsion Module and further expands its capabilities with massively increased fuel capacity, as well as aims for improved ignition, performance, and ultimately lower cost and simpler manufacturing. The thruster heavily utilizes 3D printing for the custom housing to provide integration with all mechanical and electrical components into a compact form factor, reducing size of the system.

Several new enhancements to the EPPT1 over the older gPPT series includes spring fed Teflon fuel, diverging rail electrodes, dual ignition transformers, higher-power trigger thyristor, higher power and more efficient Pico Electronics HV supply, 3D printed housing, and polypropylene film capacitor for the main pulse cap.

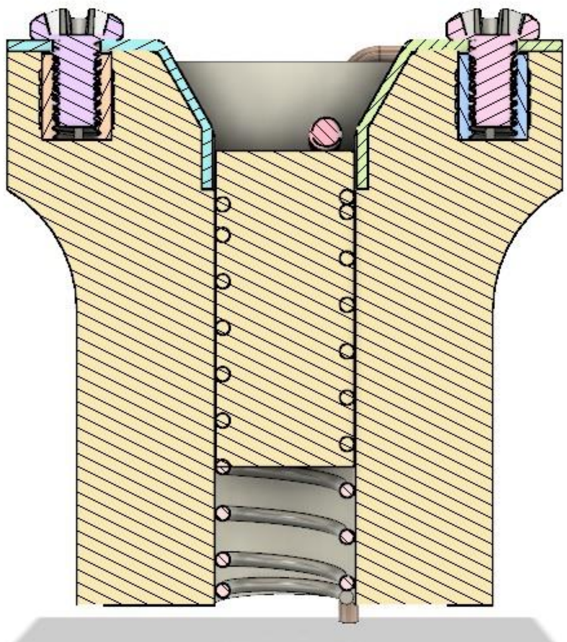

FIGURE 2: *EPPT1 thruster housing cross-section, showing spring fed Teflon fuel, anode/cathode rails, and the igniter pin.*

The entire thruster fits within a 45x45x25mm form factor, with the ability to be easily expanded to include much more Teflon fuel, and larger pulse capacitors for higher stored energy operation at reduced repetition rates. The same commands are used with the EPPT1 as the old gPPT3, with improved bank readouts at 1V/kV division.

III. THRUSTER MODIFICATIONS

From the prior first ignition test of the EPPT1, it was found that the igniter would arc significantly more readily to the anode than to the cathode. This is mainly due to the igniter pulse being at -10kV, with the anode charged up to 1.4kV. As such, it was decided to take advantage of this natural state of operation and leverage it for improved reliability. The thruster was modified to place the igniter pin on the reverse side of the housing, spaced closely to the anode. With the initial ignition pulse, a portion of the anode energy from the main cap bank would be diverted though the secondary of the pulse transformer to ground. This additional energy would increase the arc intensity of the ignition arc further, allowing for more stable operation. Since the secondary winding has a resistance of several hundred ohms, peak current passing through the secondary windings during the pulse would be kept relatively low for the short duration of the pulse at less than 10A.

IV. IGNITION TEST SETUP

After modifications and re-assembly of the thruster, the thruster was mounted to the same flat PEEK baseplate used in the first ignition test, and loaded into the chamber to keep the thruster oriented properly during testing, as well as insulated away from the conductive metal vacuum chamber walls. Teflon coated wire was used to secure the thruster to the baseplate, tied through the corner mounting holes on the thruster board and wrapped around the baseplate. The thruster was then loaded into the chamber, positioned in clear view of the 6" conflat viewport, and wired for power, enable, and trigger pulse control. An external adjustable DC power supply and function generator was used to provide power and trigger control to the thruster.

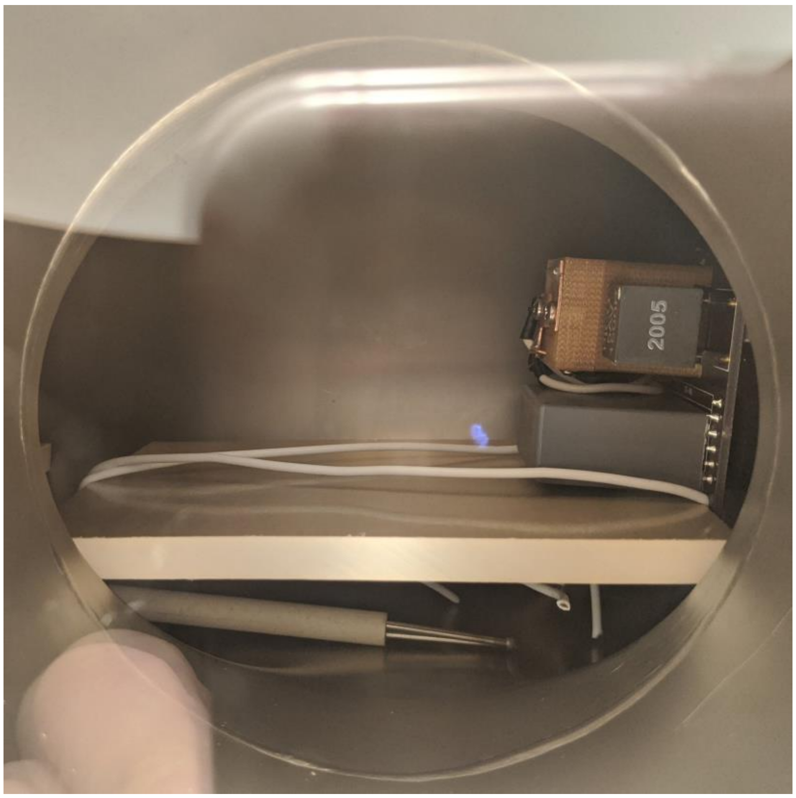

FIGURE 3: *EPPT1 mounted on the PEEK baseplate inside the vacuum chamber, tied down to the baseplate with Teflon coated wires.*

V. TEST PHASE II – IGNITION

The chamber was evacuated to a pressure of 1.5x10^-5 Torr before starting up the thruster. Thruster power was turned on, and slowly raised to near peak voltage at 1.4kV. Triggering was turned on and brought up to full signal voltage, starting at a low repetition rate of less than 1Hz. The thruster began firing immediately without any external arcing or flashovers seen in the prior test. After several pulses at 0.3Hz, the thruster was slowly brought up to a repetition rate of 1Hz. Controlled ignition was observed, with minimal misfires. The thruster was operated in this mode for several minutes before further increasing the repetition rate to 2Hz. The thruster was able to fire at this increased repetition rate, with slightly more misfires during operation.

After several tens of shots, operation became sporadic, and eventually successful ignition of the thruster could no longer be achieved. While the ignition pulse could be seen, the thruster failed to ignite reliably. Although ignition could no longer be achieved, the igniter pulse, which was far more intense than prior testing due to anode-side triggering and the additional energy from the main bank during the pulse, still operated. As a result, the ignition signal was pushed up to 3Hz, which showed repeated and reliable firing of the igniter arc only.

It was also noted that like the prior ignition test, on a couple of occasions the thruster voltage would suddenly drop out. Cycling the thruster power, operation was able to be resumed. This would happen in particular when a successful ignition occurred at levels around 1.5kV, and for the remainder of the test, the thruster was kept at reduced voltage levels.

VI. POST TEST VIDEO ANALYSIS

During the ignition test, video was captured of successful thruster operation. Below is a captured shot of the plasma plume during successful ignition.

FIGURE 4: *Successful ignition and firing of the EPPT1 and resulting plasma plume.*

Unlike the prior test, no external faults were observed, and the thruster was able to fire immediately. The thruster was successfully brought up to 2Hz rep rates with occasional misfires, however total operation lasted for a few minutes before reliable ignition ceased. During the end of the test, the igniter was tested up to 3Hz successfully without issue. It was noted that the igniter pulse plume was significantly more intense on its own than any other PPT test to date at AIS. This validates the use of anode-side triggering for improved performance with this setup, and that the ignition arc was indeed utilizing additional energy from the main bank during the pulse. No damage to the pulse transformers were observed.

FIGURE 5: *Plasma plume resulting from the ignition arc pulse alone. Intensity is significantly higher than all other PPT testing to date due to anode-side triggering.*

VII. CONCLUSION

The second ignition test of the AIS-EPPT1 micro pulsed plasma thruster has been completed. During the test, ignition was achieved for a brief period without external arc faults, an operated up to 2Hz. A summary of key takeaways from the test are as follows:

- Anode side triggering can significantly enhance the ignition arc intensity using pulse transformer ignition configurations.
- Anode side triggering does not appear to damage or degrade the performance of the pulse transformers, despite the additional energy dumped through the secondary windings of the transformers.
- The ignition circuit can reliably fire up to 3Hz, with the thruster firing at 2Hz.
- Ignition is still unreliable, requiring redesign of the thruster.
- External arcing and internal housing arcs were eliminated with proper igniter spacing.

Going forward, the key issue to address is improving thruster reliability. With the validated anode-side triggering and enhanced ignition pulse, focus should shift towards improving the anode-cathode spacing and fuel interface geometries for reliable operation. Recommendations include reduced anode-cathode spacing, square fuel rod as opposed to cylindrical, as well as permanent modifications to the housing for anode side triggering.