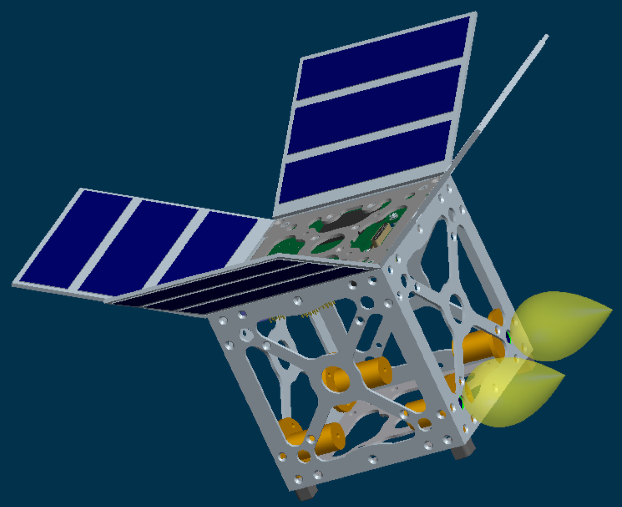

Magnetically-Enhanced Vacuum Arc Microthruster for Small Satellite Control

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Principal of operation

New type of micro-cathode thruster (μCT) is considered. The thruster utilizes magnetically enhanced vacuum arc between tubular solid anode and cathode separated by isolator as shown in Figure1. The operation of the μCT relies on the natural expansion of arc plasma jet in vacuum. As a result of self-consistent ambipolar electric field in the expanded plasma, ions are accelerated in plasma jet up to 10^4 - $3{\cdot}10^4$ m/s. An applied magnetic field works to transform radial cathodic jet flow into axial flow as shown in Figure 1. The arc spot is developed at the boundary between the metallic cathode and ceramic spacer ring. Multiple spots are exist with current per spot of about 10-30 A dependent on cathode material. Magnetic field leads to cathode spot motion in the azimuthal direction well-known as – JxB thus causing uniform cathode erosion. In the considered configuration the cathode spots are attached at the cathode-spacer interface leading to the cathode edge erosion near that interface.

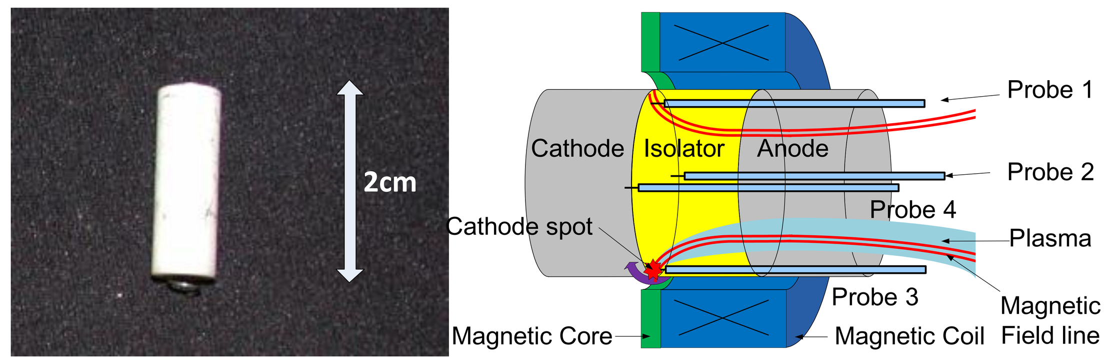
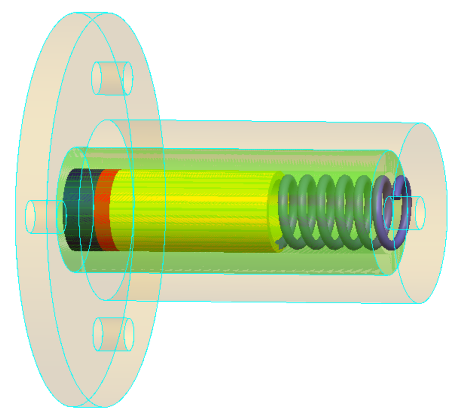
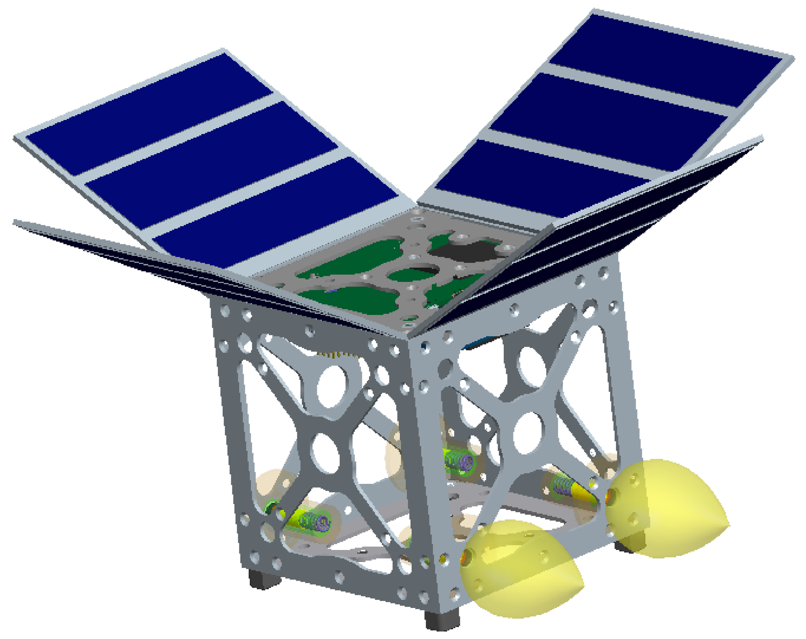


Figure1. (a) Micro-Vacuum Arc thruster (without magnetic coil here), (b) Schematic of the μCT.

μ–thruster for cube satellite





Power Processing Unit

Plasma source uses the inductive energy storage for the Power Process Unit (PPU). The equivalent circuit is shown in Figure2. (center figure). PPU is based on generation of high voltage pulse (of about *Ldl/dt*) at fast break of circuit containing inductor. Utilization of this PPU allows arc initiating without a need in external high voltage source for breakdown.

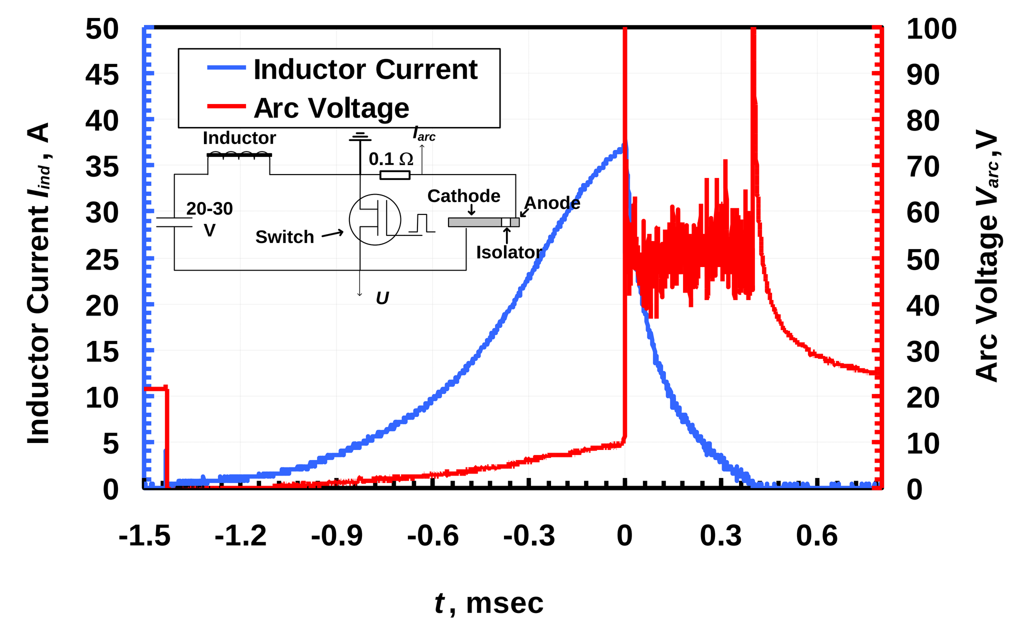


Figure2. Temporal evolution of anode-cathode voltage and inductor current. Inset shows the equivalent circuit of an inductive energy storage Power Process Unit.

Arc rotation with adding magnetic field

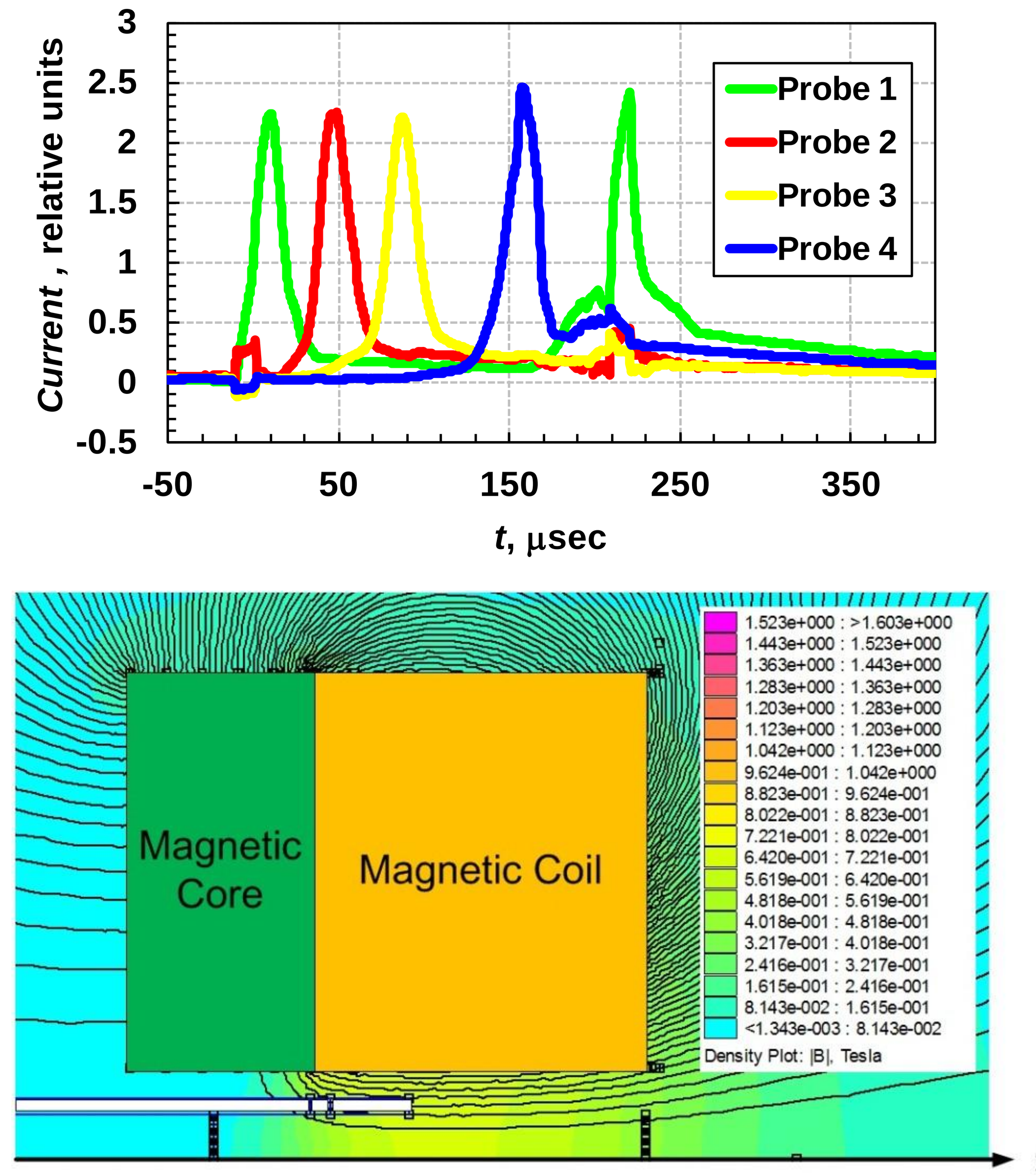
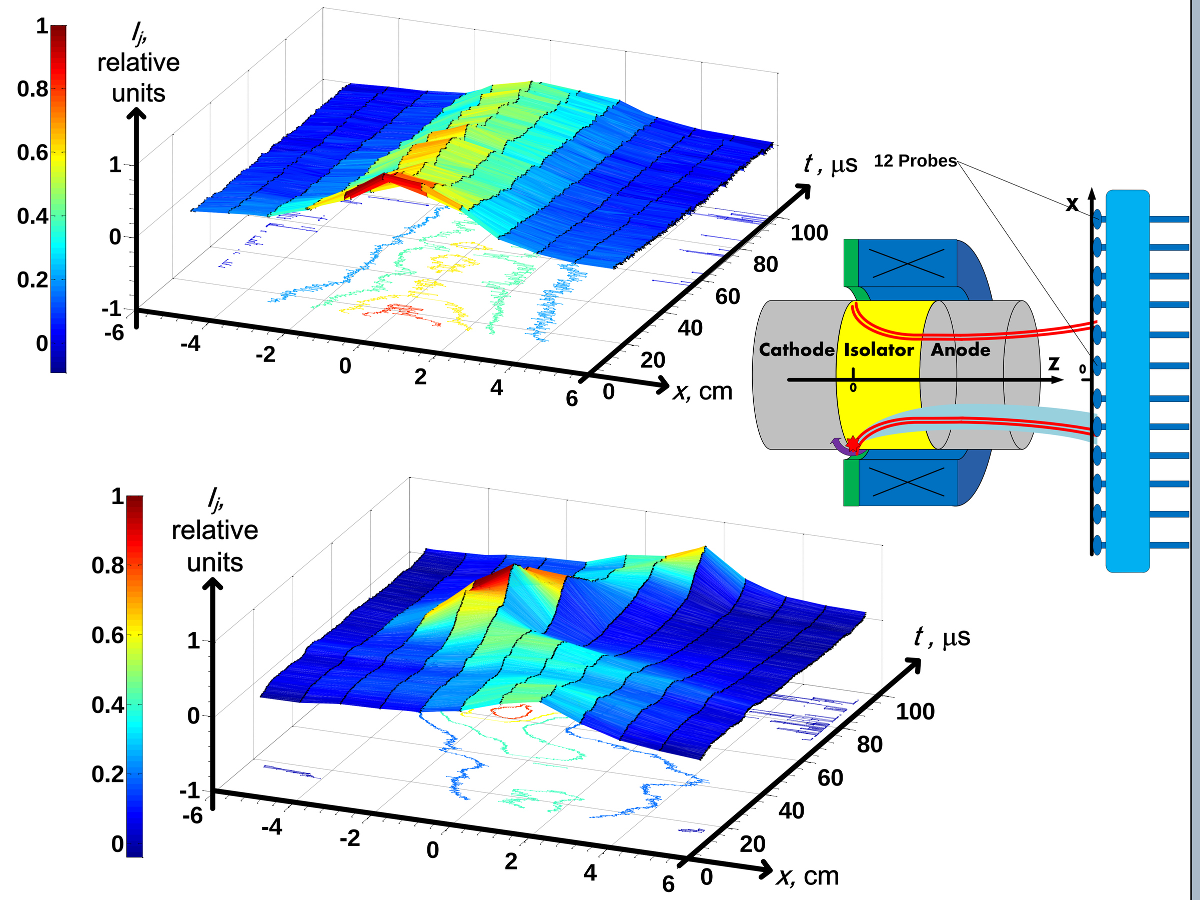


Figure3. (a) Temporal evolution of a signal from 4-probe assembly indicating rotation of the cathodic spot. (b) Magnetic field simulated numerically using FEMM Software.

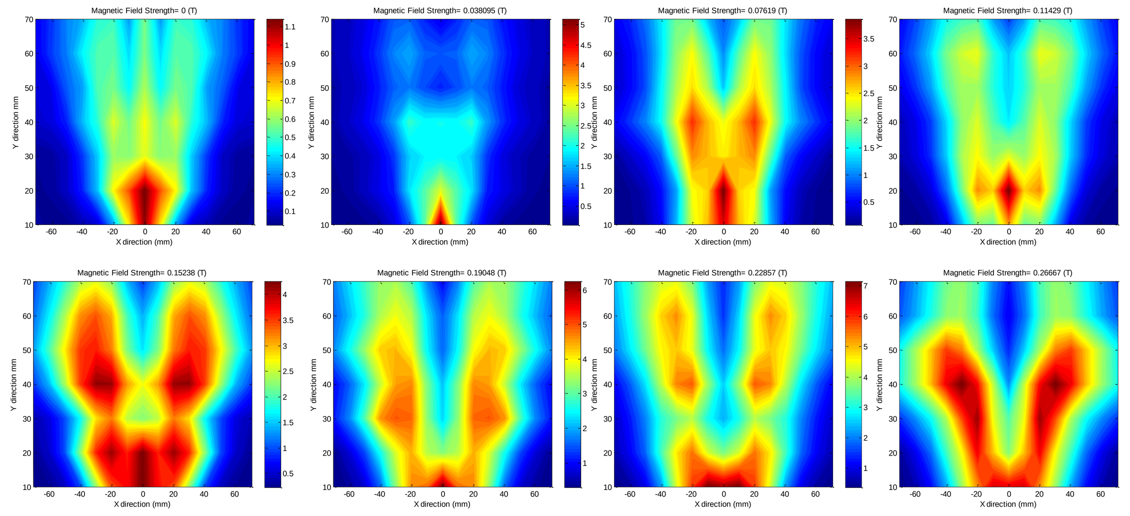
Guiding of plasma by magnetic field

Figure4. Temporal evolution of the radial distribution of ion current at the distance of about 7.6 cm from the source exit.(a) Schematic of assemble 12 probe setup, (b) Without magnetic field, (c) With magnetic field, of about 0.3 T.



Importing Tables & Graphs

To measure the spatial distribution of output ion current, special assemble of concentric circles plan probe was used to measure the ion current distribution outside the thruster channel. Figure5. is showing the spatial evolution of the ion current distribution outside the source channel with different magnetic field strength. The concentric circles plan probe was biased -30V with respect to the cathode. As shown in Figure5. It is shown that plasma generated at the cathode spot is guided along the magnetic field line. And different magnetic strength has the different ability the guide the plasma.



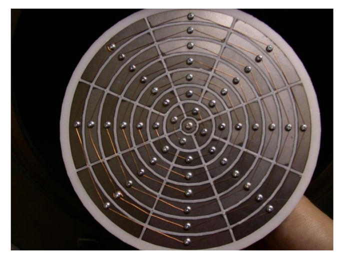


Figure5. Spatial evolution of the ion current distribution outside the source channel with different magnetic field strength.

Thruster Advantages

1. Simple design
2. Electrically activated thrusting
3. Lower energy consumption per mass ionized, due to the low ionization potential of metals
4. High ionization degree (~100 %) in the cathode spot that is a fundamental property of the vacuum arc
5. Able to operate at low voltage (20-30V) available at satellite - no need in step-up voltage conversion
6. Low power consumption
7. Self-generation of high voltage pulse required for breakdown
8. Reduced integration concerns due to large choice of propellant (any conducting material)
9. Relatively easy thrust bit control (by varying arc current and duration)
10. Scalable

Ion Current Measurement

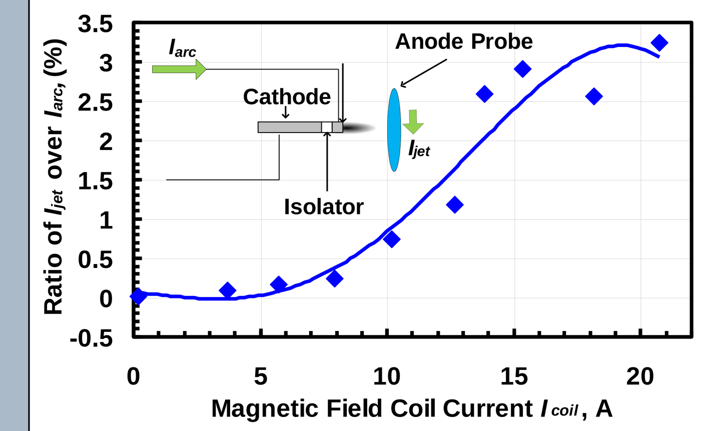


Figure6. Ratio of (I_{jet}) (average over the pulse) over the total arc current. Magnetic field strength is referred to the cathode isolator edge.

Velocity Measurement

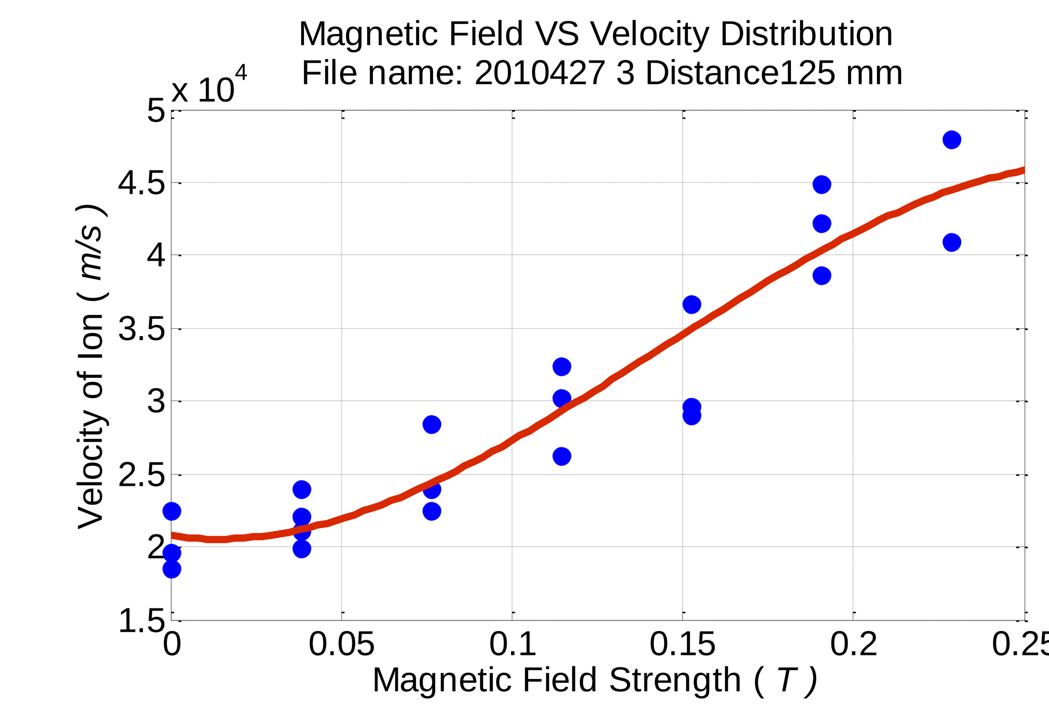


Figure7. Velocity distribution along the outside the source channel with different magnetic field strength.

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