Field Emission Propulsion Systems in Regions of Strong Magnetic Fields

Leading to significant cost reduction for deep space exploration around planetary bodies

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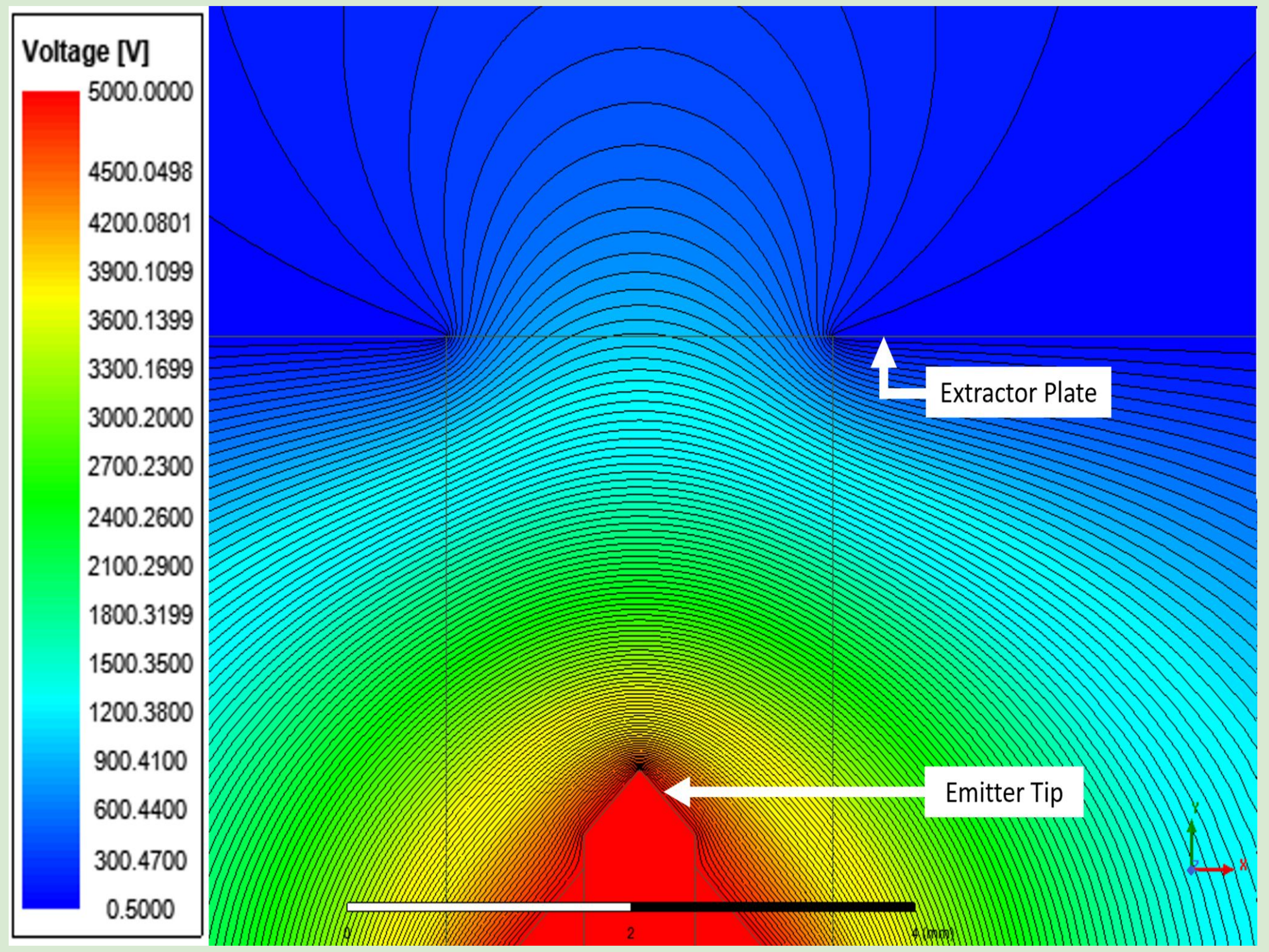
Summary

Field Emission Electric Propulsion (FEEP) is a novel technology that will enable new capabilities for **small satellites**. FEEPs use an array of liquid metal ion sources to provide **micronewton** scale thrust with **low noise**, and **high specific impulse**. The indium propellant can be stored in **solid form** and then melted. Transport is conducted via **capillary forces** prior to firing. The present work is focused on examining the effect of magnetic fields on FEEP performance via simulations and empirical work. **Our work aims to characterize these effects to for future work to develop mitigation techniques or restrictions on FEEP use in deep-space missions.**

Highlights

- The trajectories of charged species which comprise a FEEP ion plume is affected by external magnetic fields.
- Taylor cone formation and ionization of propellants may be affected by the presence of external magnetic fields
- Experimental and analytical methods will be employed to determine the extent to which these external magnetic fields affect the performance of the FEEP thrusters



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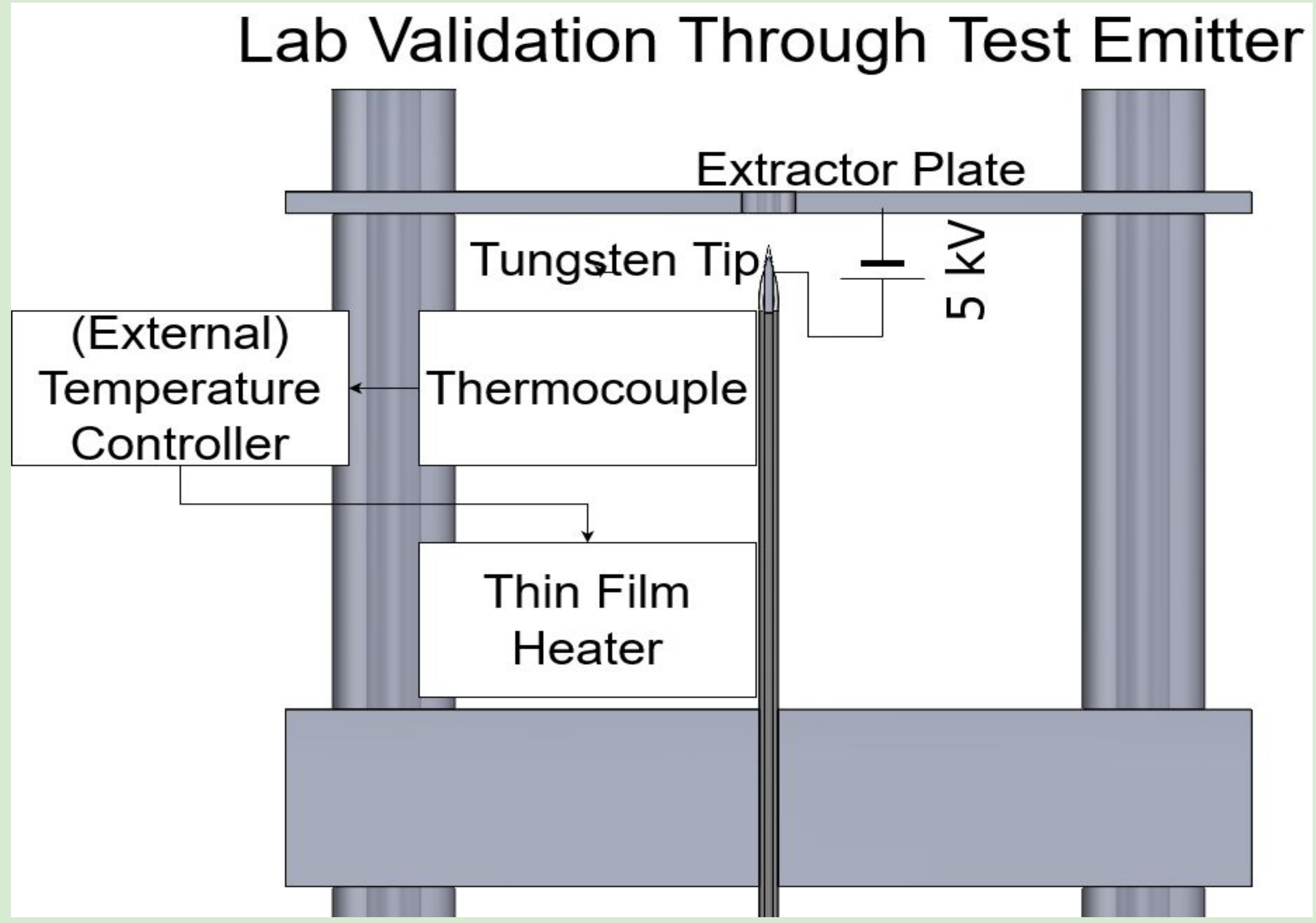
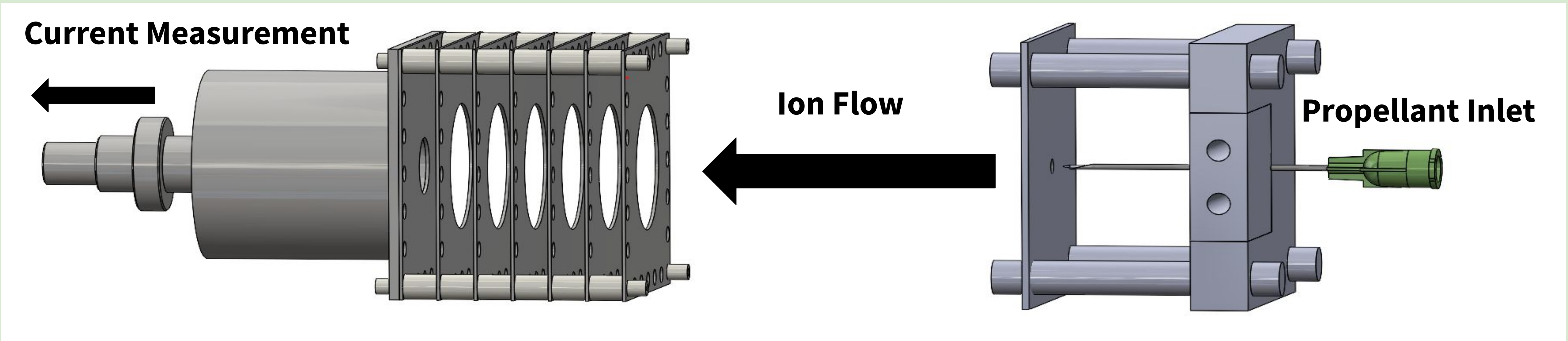


B

(**A**) Voltage contours produced around an operating FEEP tip. This map highlights the instability produced by the localized tip of the Taylor cone and the decrease in potential with increased distance from the tip
(**B**) Cross section of CAD model, indicating the **temperature control loop** setup and power connections



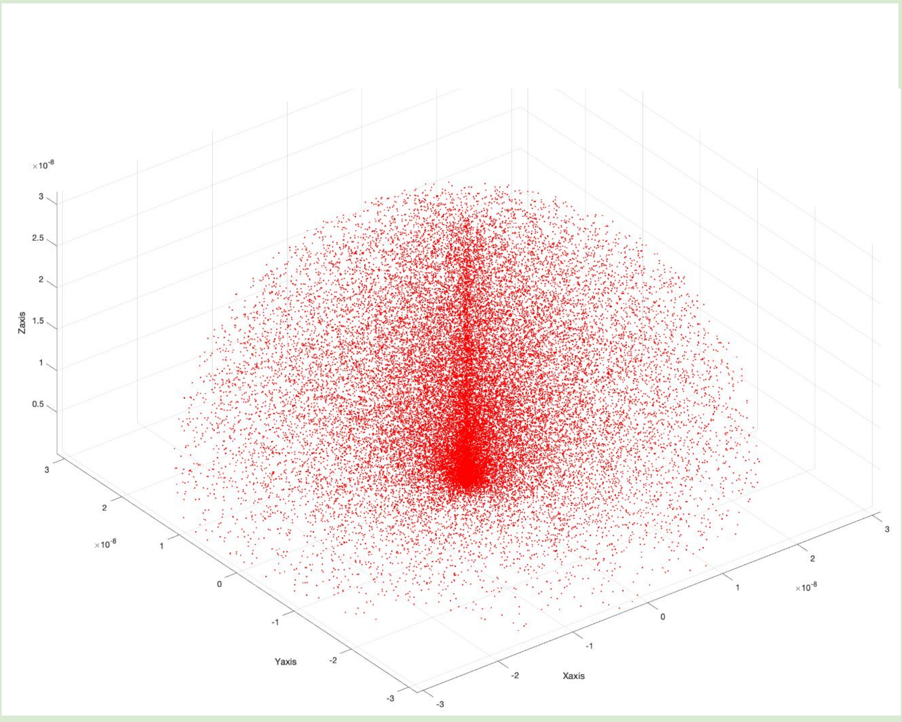
Retarding Potential Analyzer (RPA)

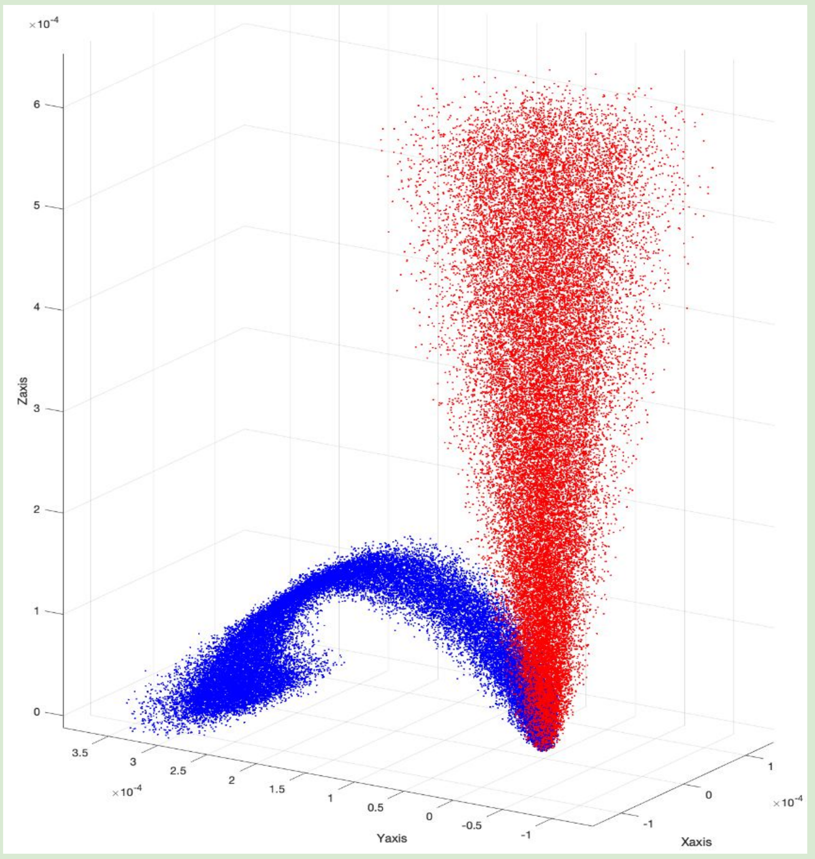
The FEEP plume can be quantitatively analyzed with a retarding potential analyzer (left). The RPA can provide an **energy spectrum of the plume** being emitted from the thruster, giving us an indication of the **efficiency** of the thruster as well as quantifying **directional losse**s which may be encountered as a result of deflection of the ion plume

Field-Emission Thruster

Current design of the **5 kV single emitter liquid metal ion source** (right) involves a **150 Celsius** hypodermic needle clamped to an aluminum base, with a steel extractor plate held in front by four **PEEK** rods. The hypodermic needle is filled with **indium**, and a **tungsten tip** is placed at the end of the needle.

N-Particle Simulation





In the N-Particle simulation, Indium atoms are initialized in a hemisphere (left) then ionized and accelerated by an **electric field aligned with the Z-Axis**. Simulation also captures the **electrostatic forces** incident on each particle due to the other particles in the plume. The magnetic environment was simulated by adding a **magnetic field aligned with the the X-Axis**.
The right figure shows the action of the FEEP plume with (**Blue plume**) and without (**Red Plume**) the magnetic field. Clear **deflections** are shown as a result of the magnetic field which would foreseeably result in **thrust vector profile changes**.

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