Electrically Isolated System Response to Rapid Charging Events Using Hollow Cathode Neutralization

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Introduction

A high-power electron beam can be emitted from a spacecraft in the magnetosphere to better understand the space environment and the Earth's magnetic field behavior all the way to near the Earth's surface. However, the density of the ambient plasma in this region is too sparse to maintain spacecraft neutrality while the electron beam is operating. Particle-in-Cell (PIC) simulations suggest that the spacecraft can be adequately neutralized by using a hollow cathode to produce a dense, ion emitting plasma which balances the beam's electron emission [1,2]. Here we present the results from a series of experiments which were performed at Michigan's Plasmadynamics and Electric Propulsion Laboratory's (PEPL's) 6x9m Large Vacuum Test Facility (LVTF). These experiments were geared towards validating the PIC simulations and improving our understanding of the plasma-spacecraft interactions in this environment. The focus of this presentation will be on the "Spacecraft" system setup, response, and key parameters.

Materials and Methods

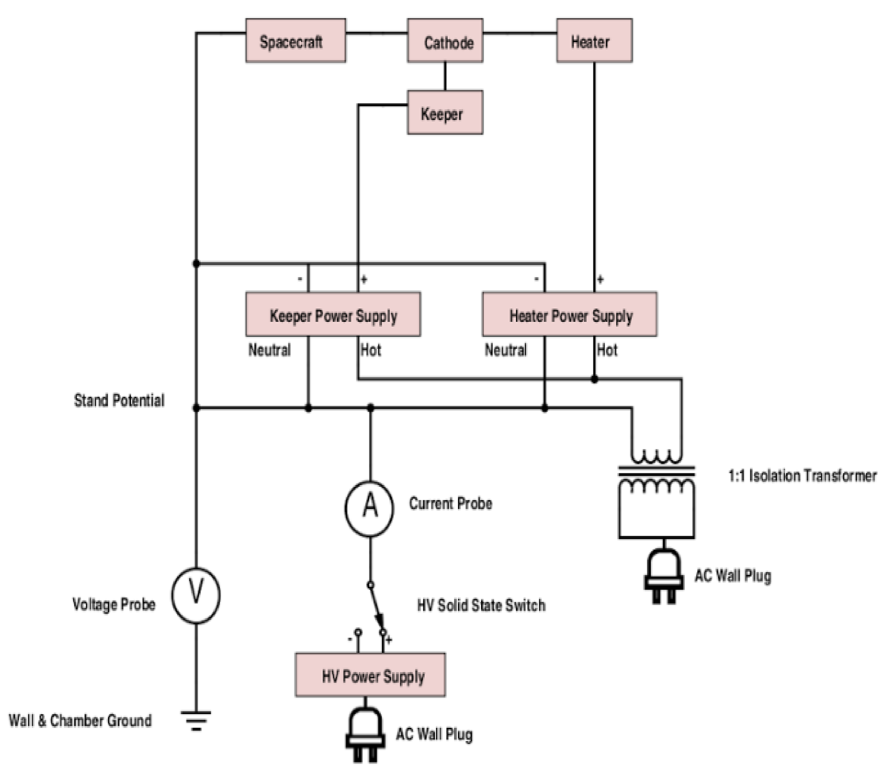


Figure 1: "Spacecraft" isolation circuit diagram. The hollow cathode and "spacecraft" were isolated using an isolation transformer.

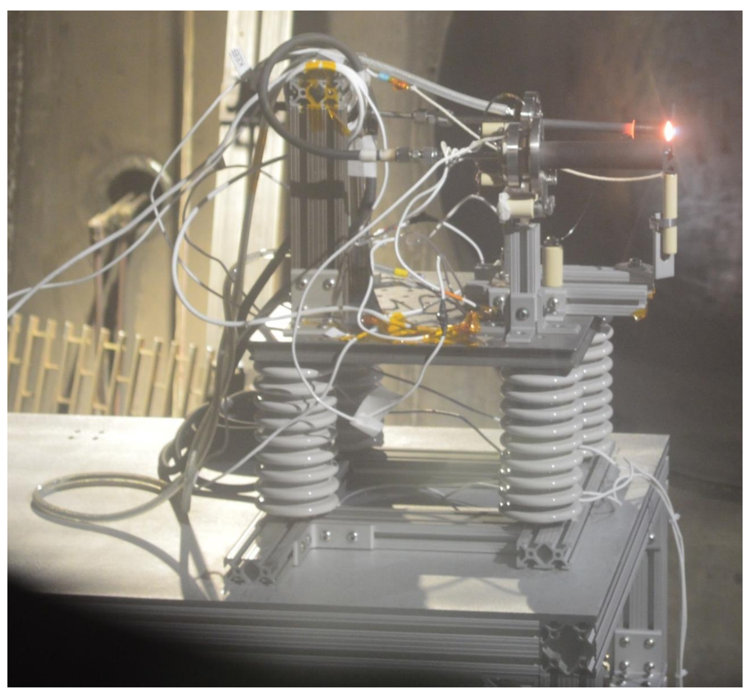


Figure 2: Hollow cathode in operation on the "spacecraft". Ceramic voltage standoffs are used to ensure isolation.

Results and Discussion

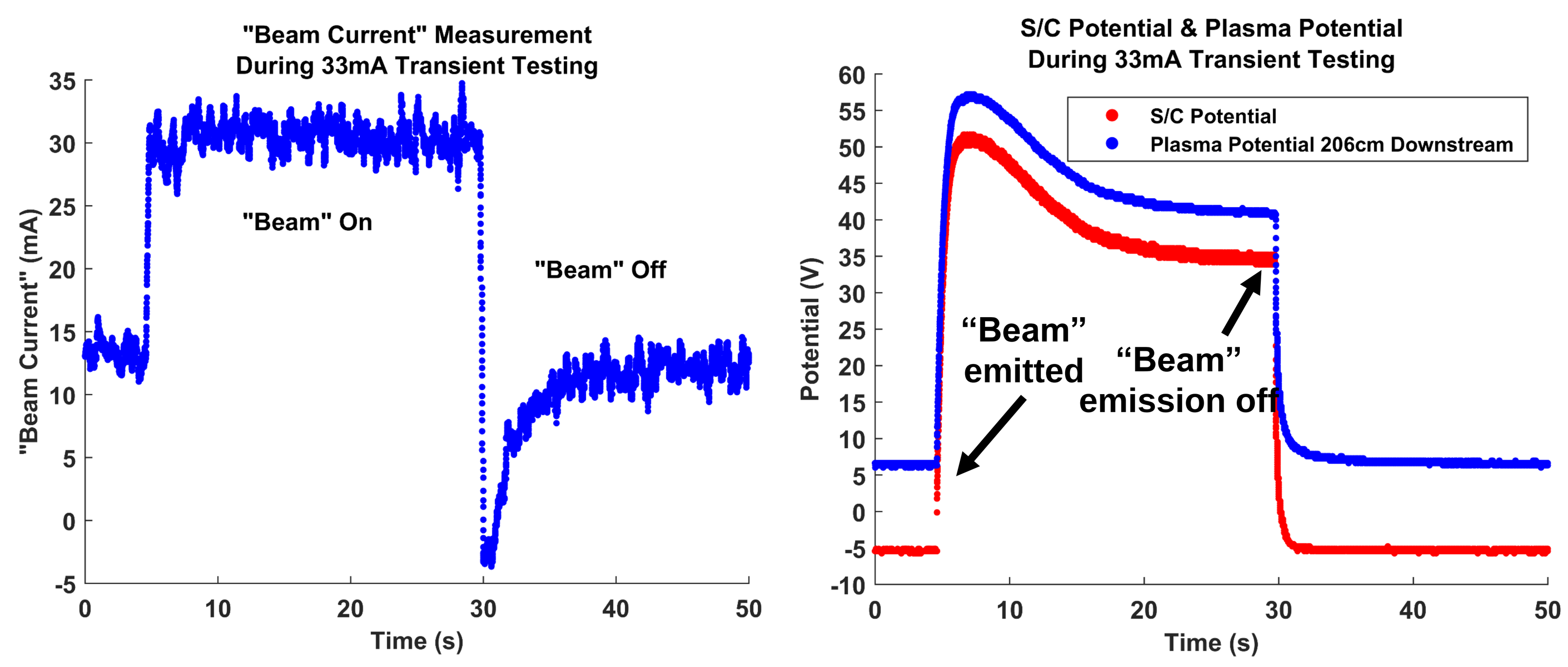


Figure 3: Measured "beam current" from the power supply shows effective replication of electron beam emission. Both the plasma and "spacecraft" potentials have long transients before reaching equilibrium when the "beam" is fired.

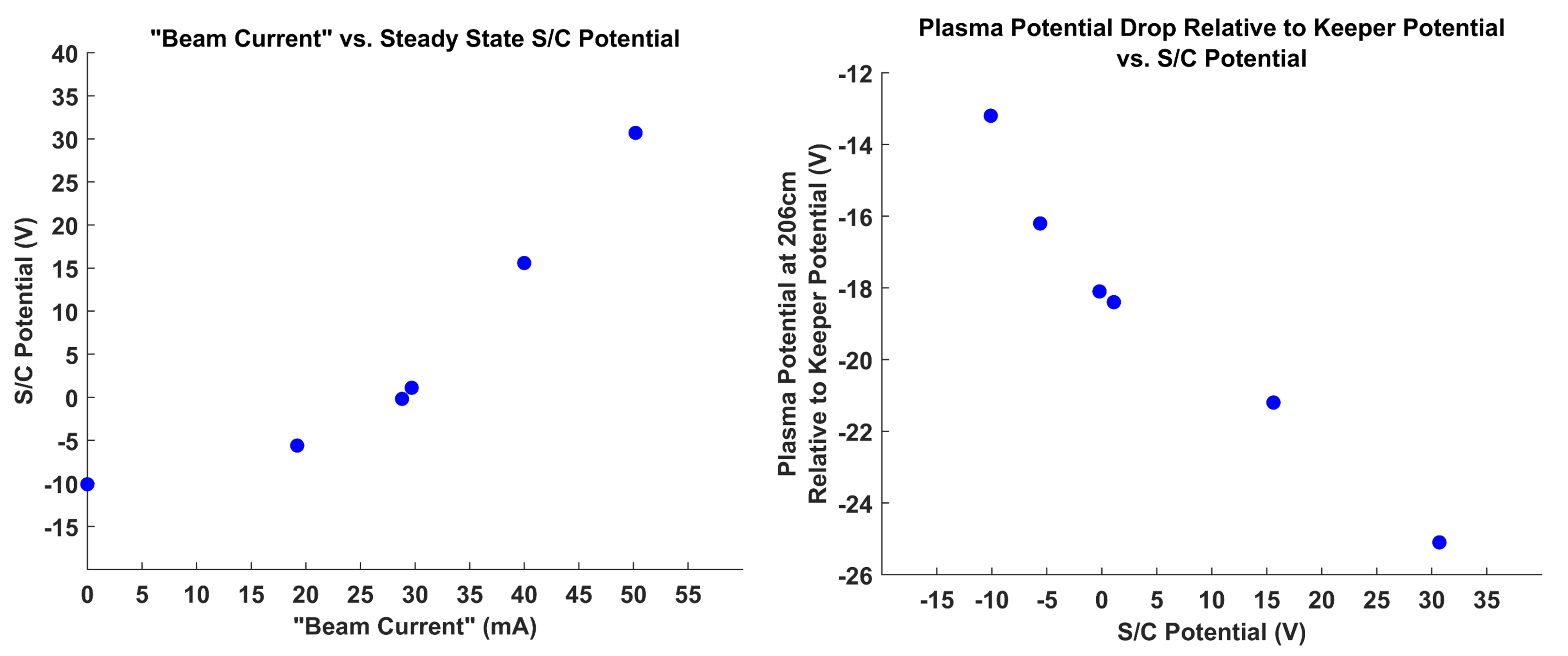
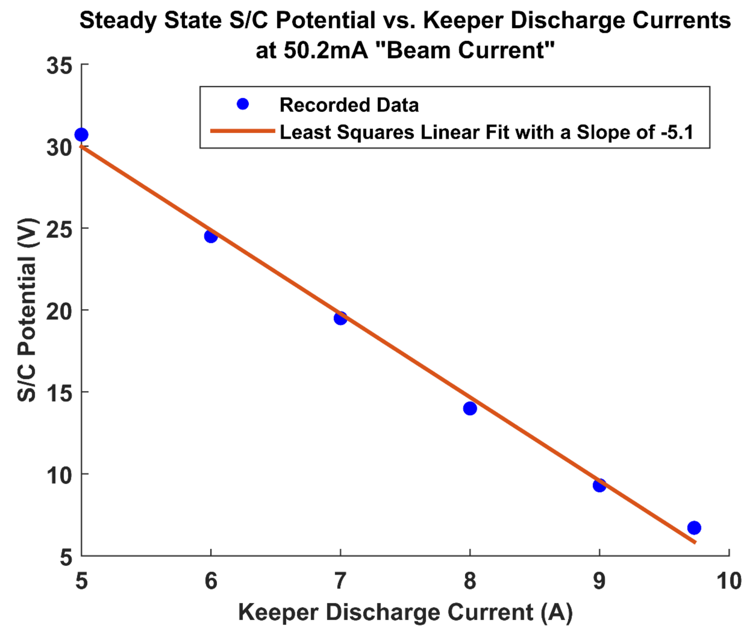


Figure 4: Steady state "spacecraft" potential increases with beam current, as does plasma potential drop off from the keeper potential.



Configuration	1	2	3
Keeper Current (A)	5	5	9
Heater Current (A)	0	5	0
Combined Cathode & Heater Power (W)	135	208	201
Beam Current (mA) SS S/C Potential = 0V	13.7	9.3	10.3
Beam Current (mA) SS S/C Potential = 30V	38.1	28.2	51.8
Beam Current (mA) SS S/C Potential = 60V	39.5	35.8	63.7

Figure 5: Keeper discharge current (and thus ionization fraction and contactor current) played a dominant role in the efficacy of neutralization. Turning on the heater and increasing the hollow cathode temperature decreased the efficacy of neutralization.

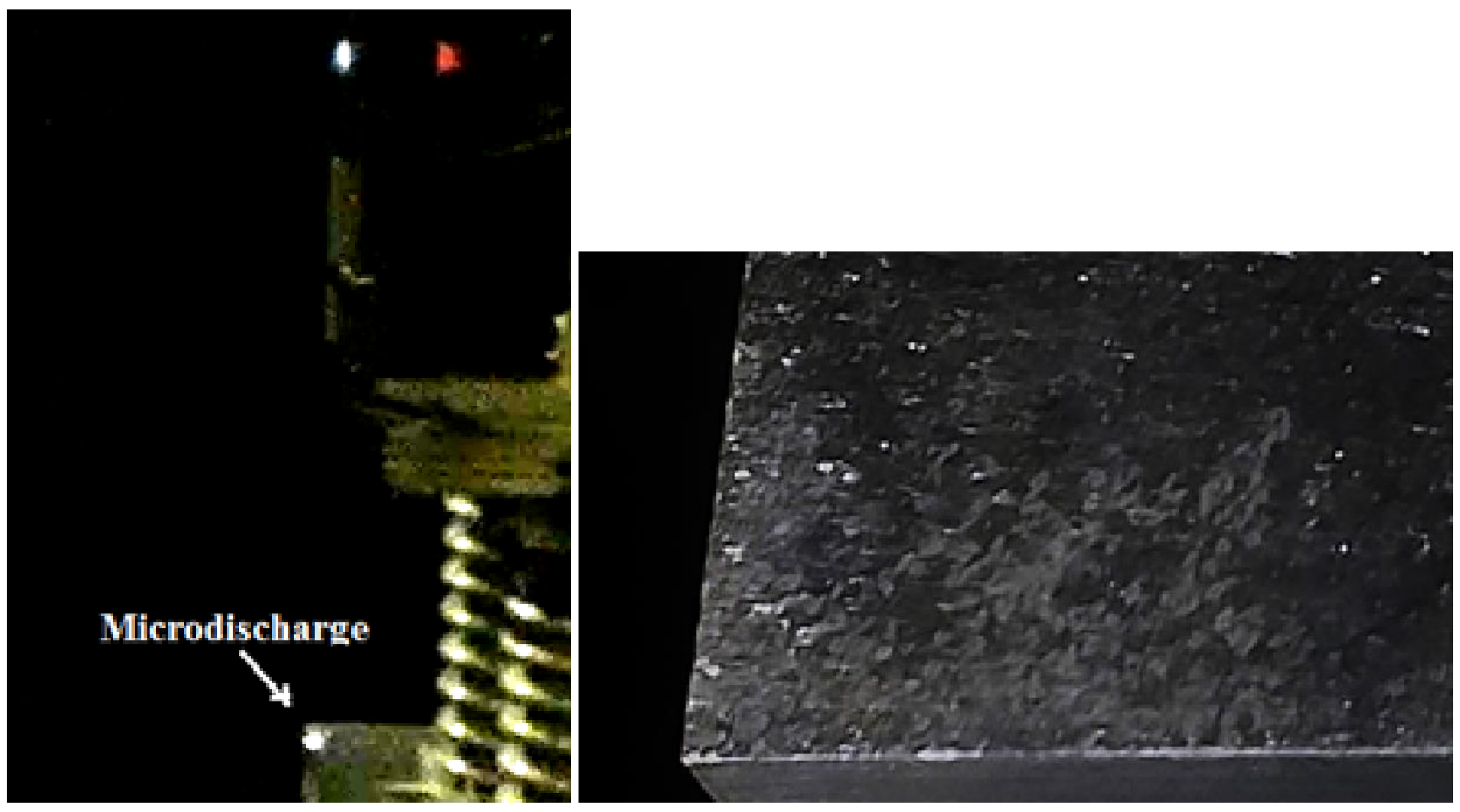


Figure 6: Evidence of microdischarges during testing. Bursts of light were observed accompanied current transients. The rough aluminum plate showed scarring at the location of these microdischarges.

Conclusions

- Hollow cathode neutralization via ion emission appears a viable method to mediate rapid charging events
- Long charging transients (on the order of several seconds) were observed, which were much longer than the plasma response time
- Increasing beam current increases charging as expected
- Higher keeper discharge currents increase the contactor current and the neutralization efficiency
- The contactor current is more important than the amount of power supplied to the hollow cathode/hollow cathode temperature
- Microdischarges produce a relatively low upper limit on testing potentials (roughly 100V)

Acknowledgements

We wish to thank Dr. Iverson Bell for his guidance and support throughout this research. We would also like to acknowledge the PEPL team for their help during the setup and implementation of the experiment.

References

[1] G.L. Delzanno, J.E. Borovsky, M.F. Thomsen, J.D. Moulton, E.A. MacDonald, *Future beam experiments in the magnetosphere with plasma contactors: how do we get the charge off the spacecraft?*, Journal of Geophysical Research (2015)

[2] G.L. Delzanno, J.E. Borovsky, M.F. Thomsen, J.D. Moulton, *Future beam experiments in the magnetosphere with plasma contactors: the electron collection and ion emission routes*, Journal of Geophysical Research (2015)