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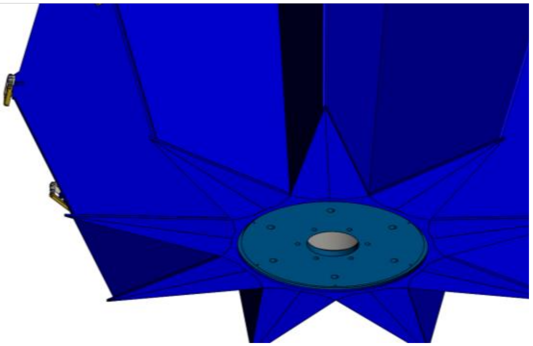


Experiments on the Clam Shell Magnetically Insulated Transmission Line (CSMITL2) on Saturn

Ben Ulmen, J. Pace VanDevender

U.S. DEPARTMENT OF ENERGY   NNSA National Nuclear Security Administration

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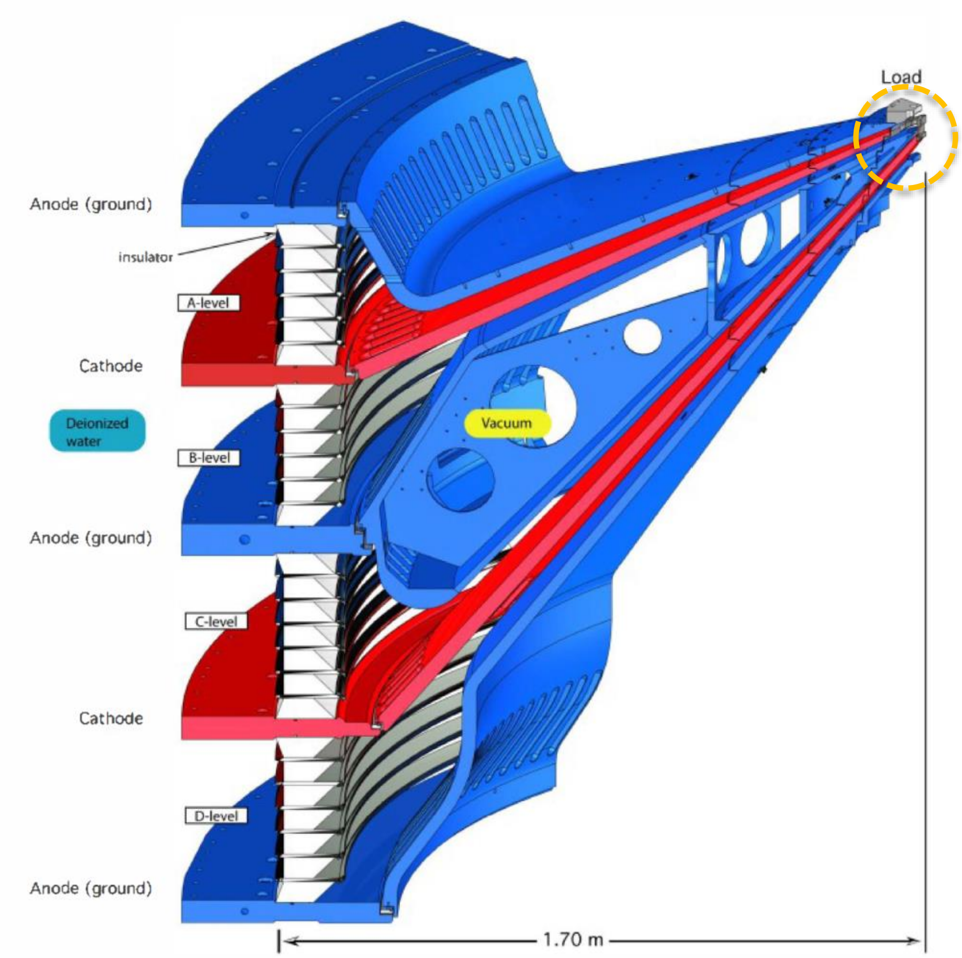
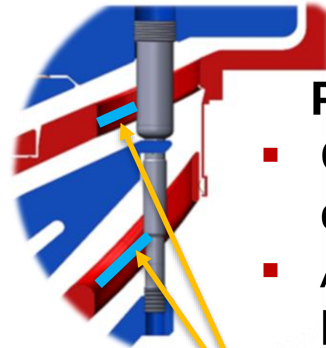
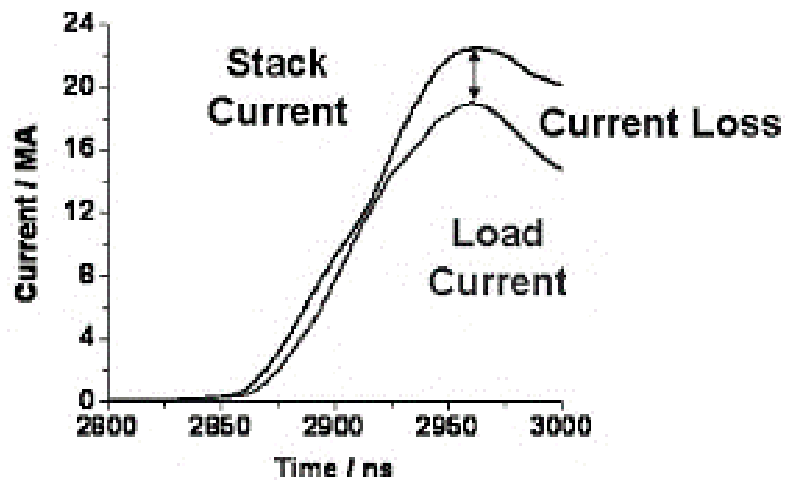
Anomalous current loss limits output on large multi-level accelerators.





Post-Hole Convolute

- Complex fields with electrode plasma flow
- Abrupt transitions with high gradient electron flow
- Magnetic nulls



M. E. Savage, et al., IEEE PPC 2011

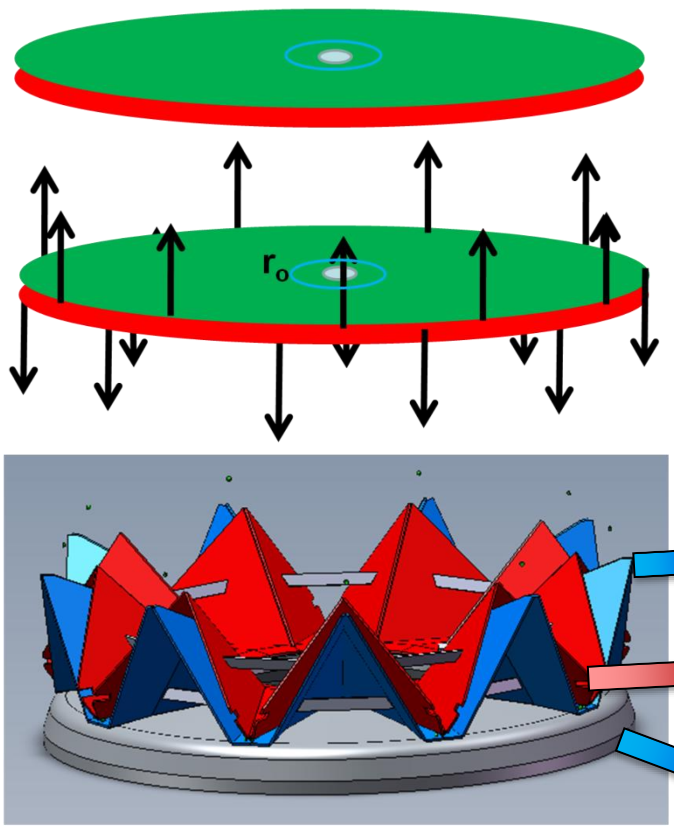
C. A. Jennings, et al., IEEE PS **38**, 4 529 (2010)

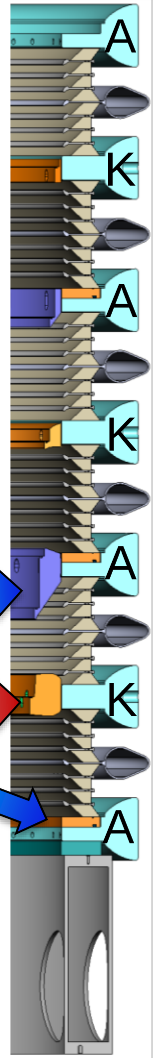
Clam Shell MITL provides a different approach to the multi-level convolute.

Move the magnetic nulls and complex B field configurations to large radius where the electric field can be kept below the emission threshold.

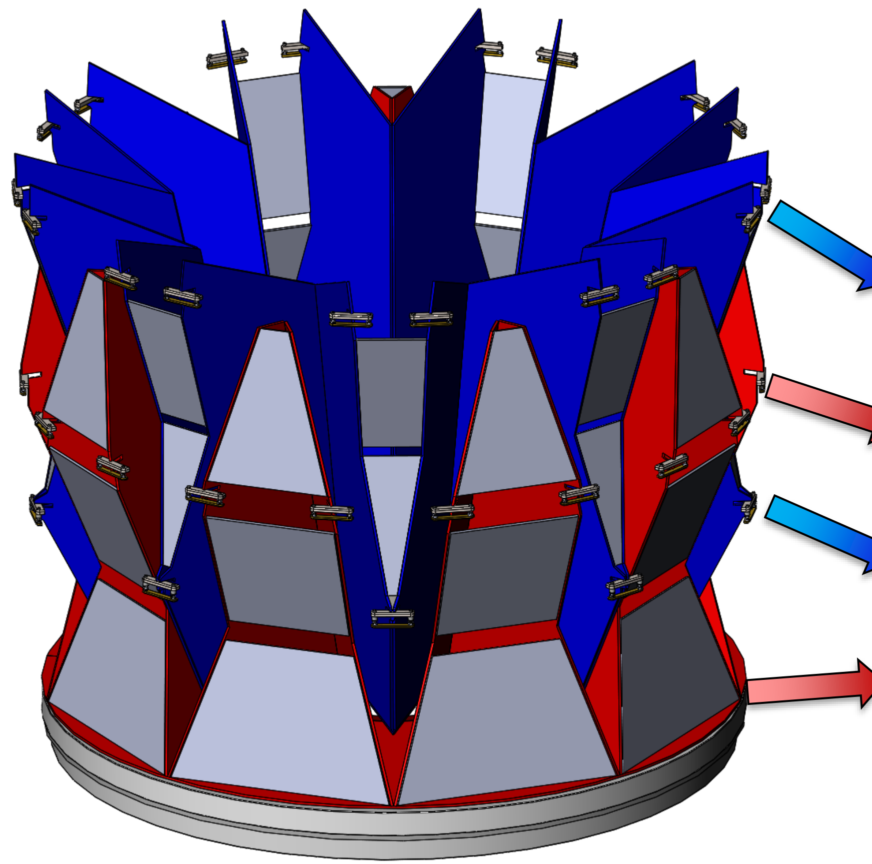
- Topological smoother geometry
- No electron loss at magnetic nulls
- Potentially lower inductance
- Potentially more robust for multiple shots without refurbishment

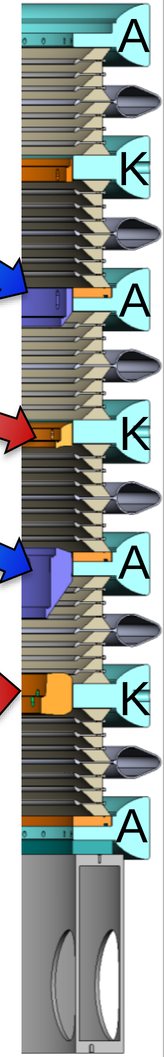
CSMITL2 combines more levels for more power.





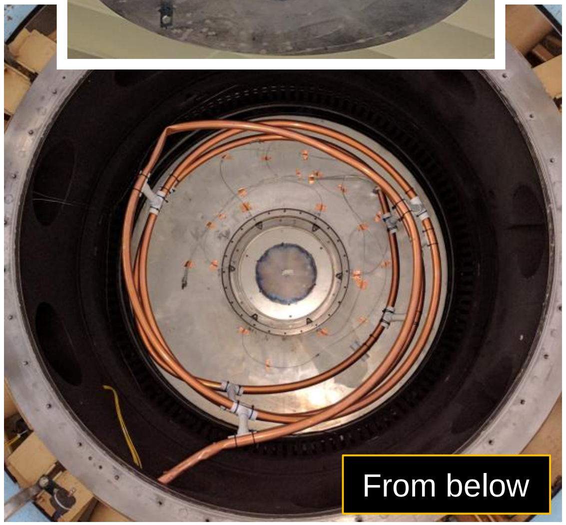
CSMITL1
2 Anodes, 1 Cathode
2-TW, half machine



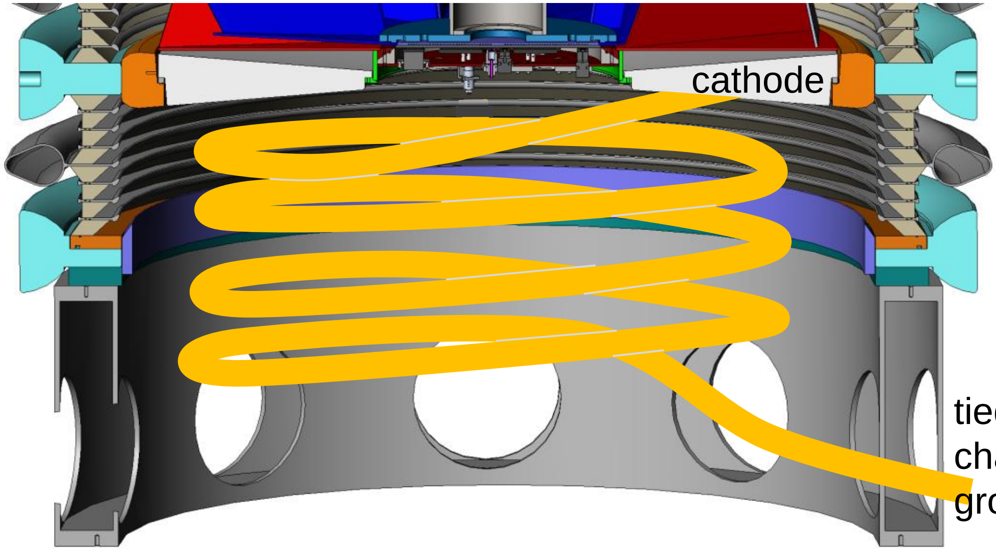


CSMITL2
2 Anodes, 2 Cathodes
8-TW, full machine

CSMITL2 inverts polarity to illuminate targets through transparent cathode.



- Proton beam passes through thin cathode.
- Low-energy Bremsstrahlung x-rays can illuminate test objects through thin cathode.
- Inductive isolation coil (L/R ~ 1000 pulse duration) allows cathode-side electrical diagnostics without significant power loss.



CSMITL2 satisfies all 20 proposed MITL requirements.

- Requirements for self-magnetically insulated transmission lines.

  J. Pace VanDevender, Timothy D. Pointon, David B. Seidel, Kenneth W. Struve, Christopher Jennings, Bryan V. Oliver, and Larry X. Schneider. *Phys. Rev. ST Accel. Beams* **18**, 030401 (2 March 2015).

- New self-magnetically insulated connection of multilevel accelerators to a common load.

  J. Pace VanDevender, William L. Langston, Michael F. Pasik, Rebecca S. Coats, Timothy D. Pointon, David B. Seidel, G. Randal McKee, and Larry X. Schneider. *Phys. Rev. ST Accel. Beams* **18**, 030403 (4 March 2015).

Lessons learned from first experiment were applied to CSMITL2.

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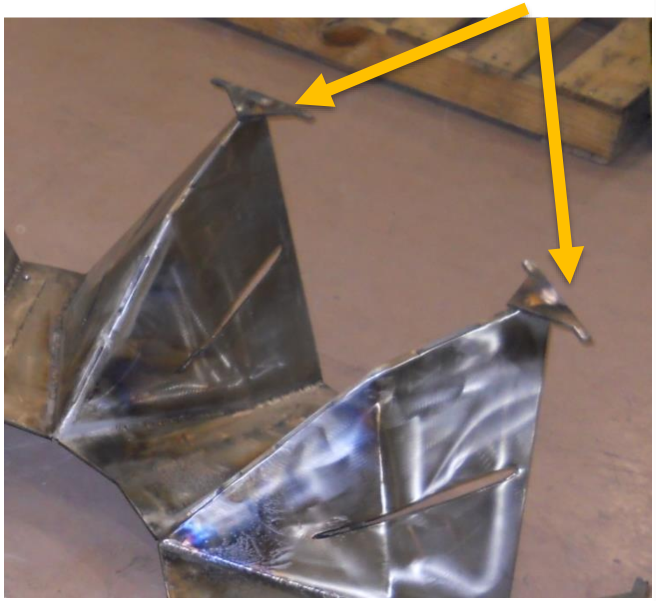
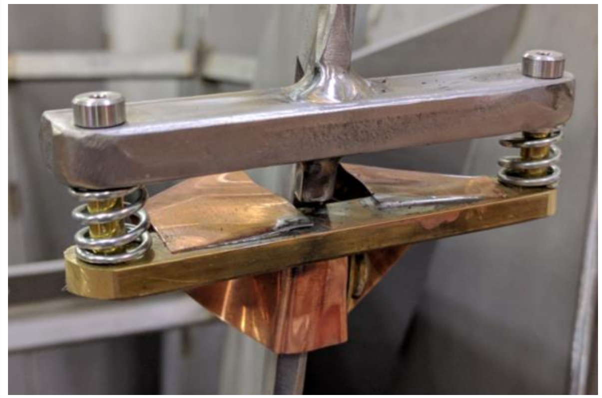
CSMITL1 current contacts



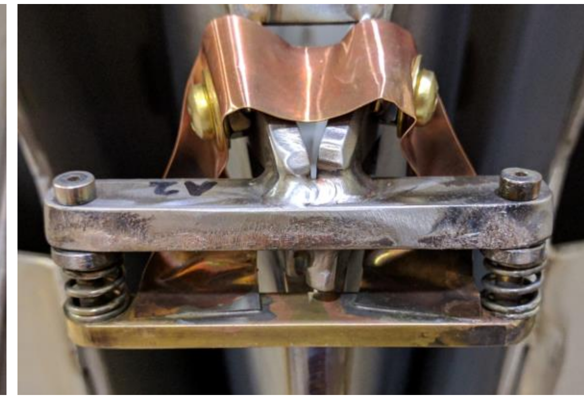
Stainless steel contact on aluminum support ring

Welded on every shot

CSMITL2 current contacts



Upper anode and middle cathode

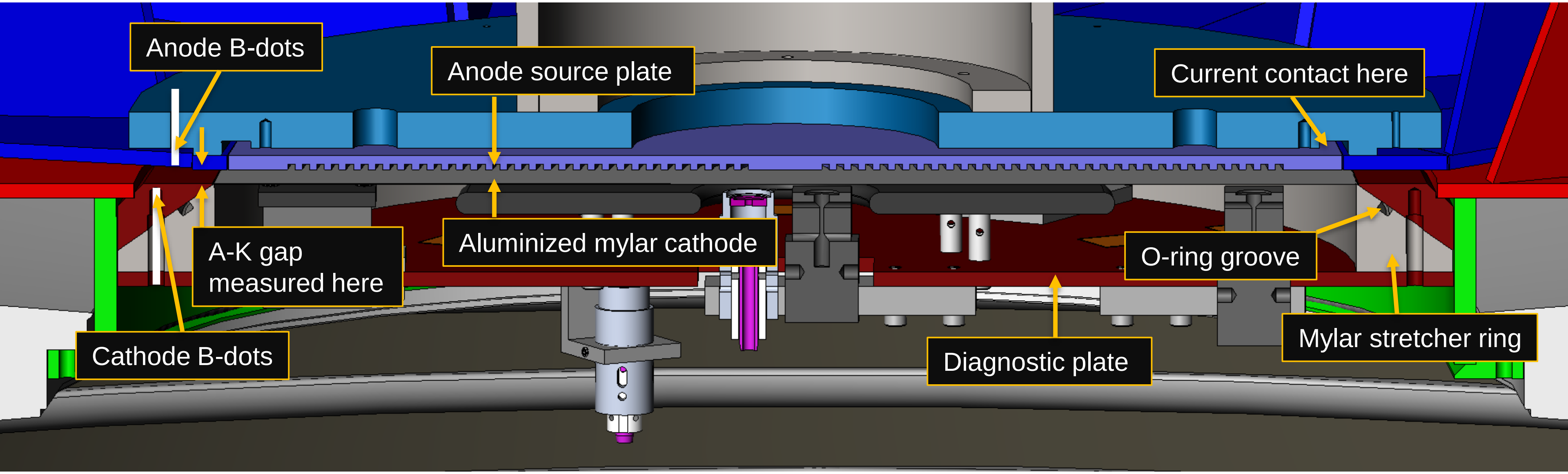


Lower anode

Spring-loaded brass contact on aluminum support ring

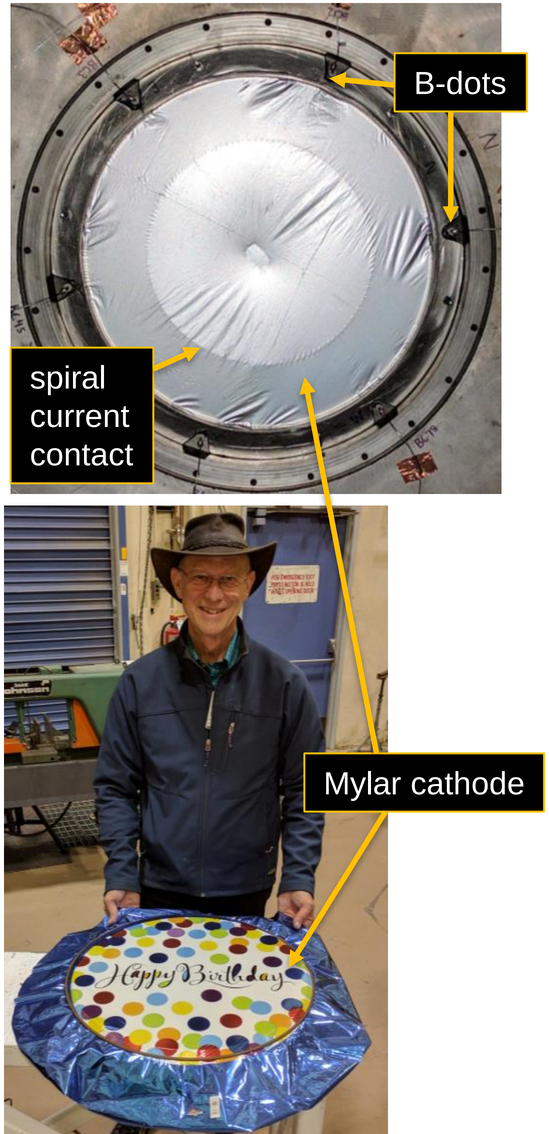
No welding

1,600 cm^2 load region accommodates multiple diodes and diagnostics.

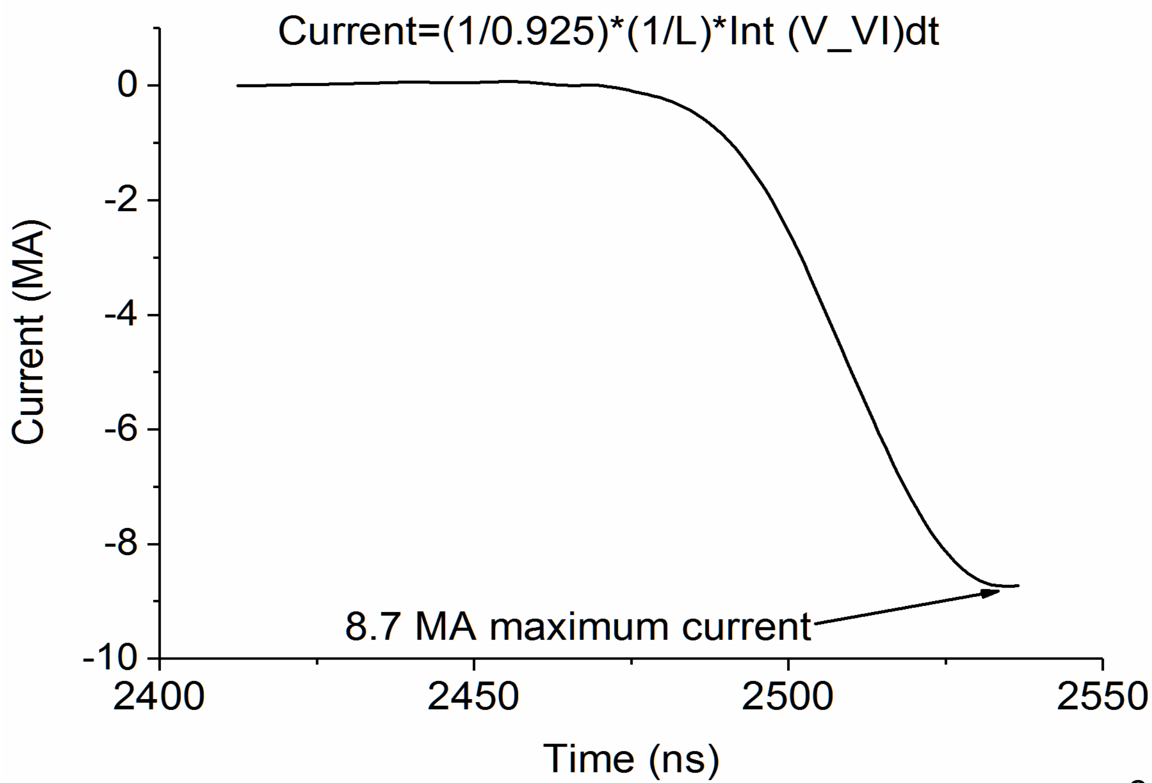


- Inductive loads, electron-beam sources, and ion-beam sources
- 0 to 6 mm A-K gap set by adjusting positions of support rings (limited in-situ ability to adjust gap)
- Rapid turn over of source hardware after a shot

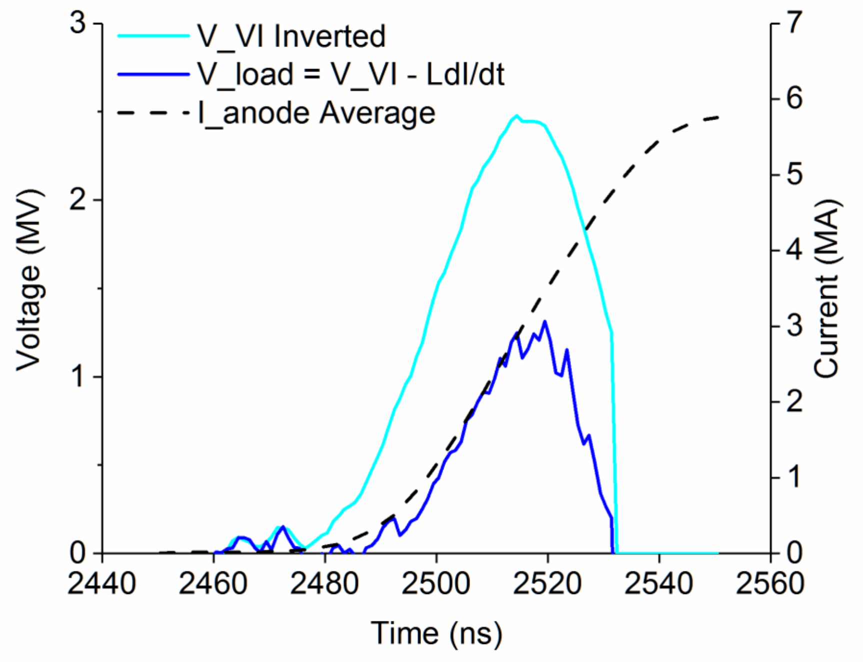
B-dots were calibrated by a short circuit shot.

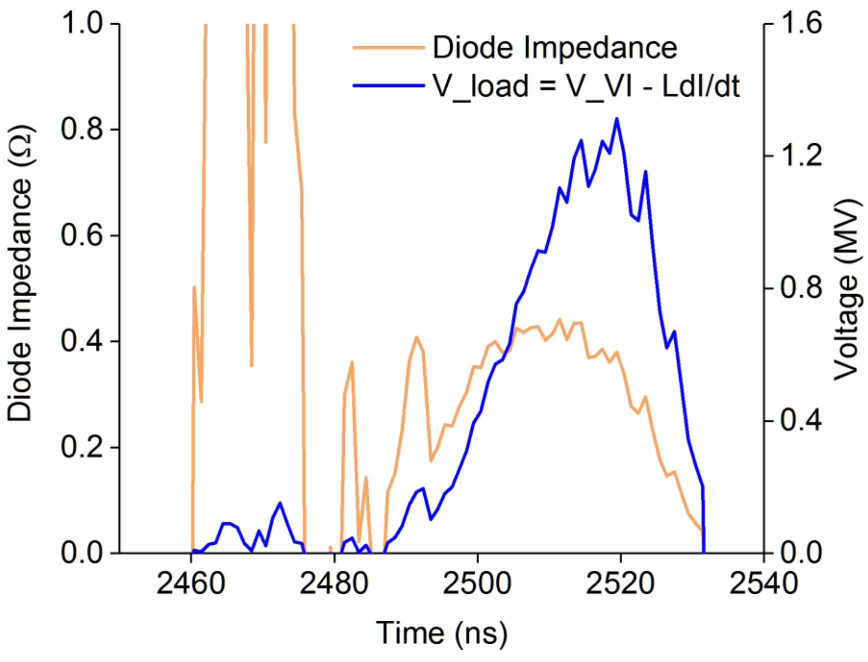


- 6.1 mm A-K gap, 1.25 mil single-sided aluminized Mylar cathode
- Transit time effects in inductor compensated by (1/0.925) factor from SCREAMER circuit simulation



The electron beam diode ran as a self-limited MITL.

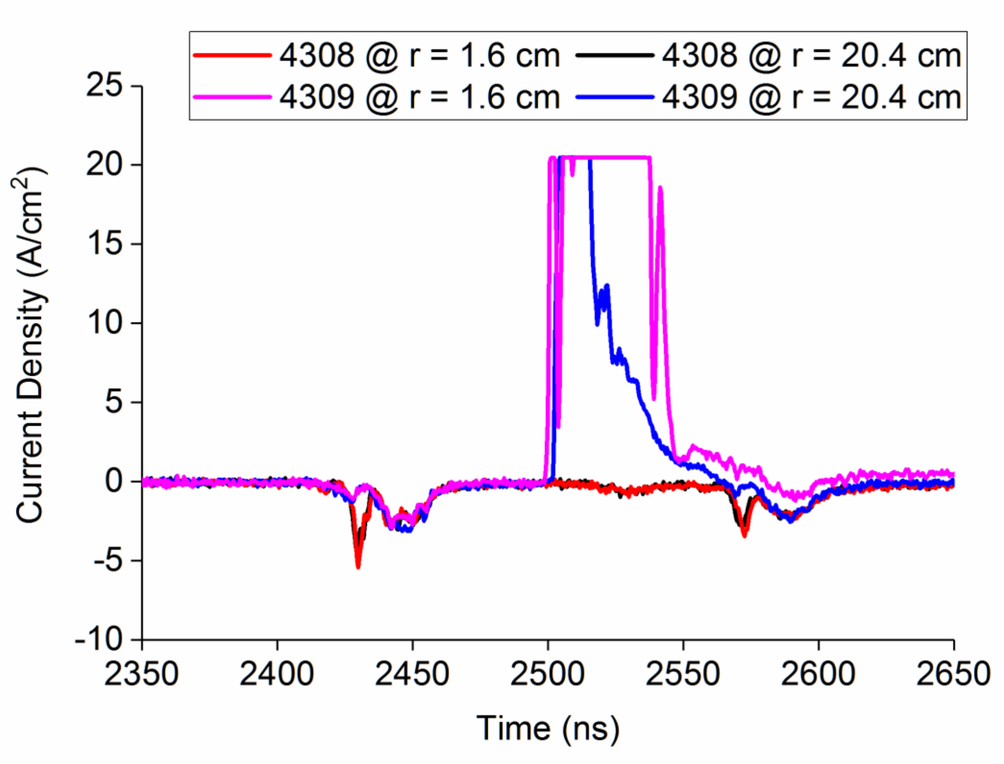




- 3.2-mm A-K gap, 1.25 mil single-sided aluminized Mylar cathode
- Late time arc at a 5.0-mm diagnostic hole with B-dot probe shows 3.2-mm AK gap is too small with 5-mm holes in cathode

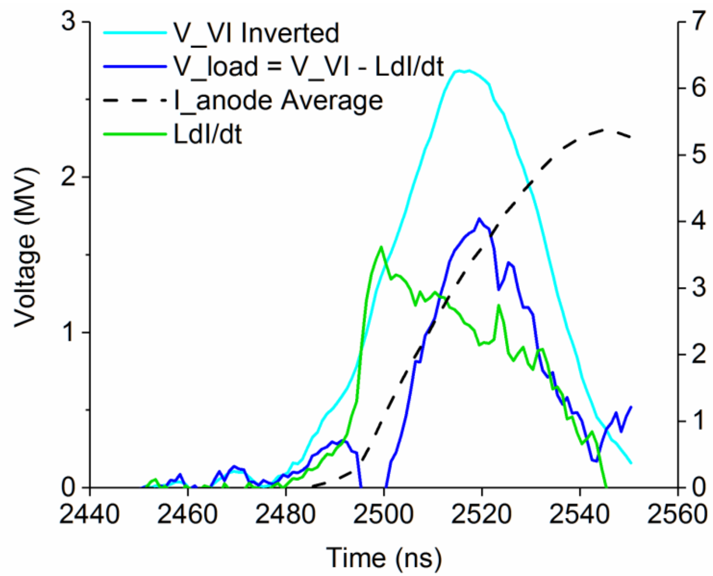
Bare anode gave no ions and flashover anode gave copious ions.

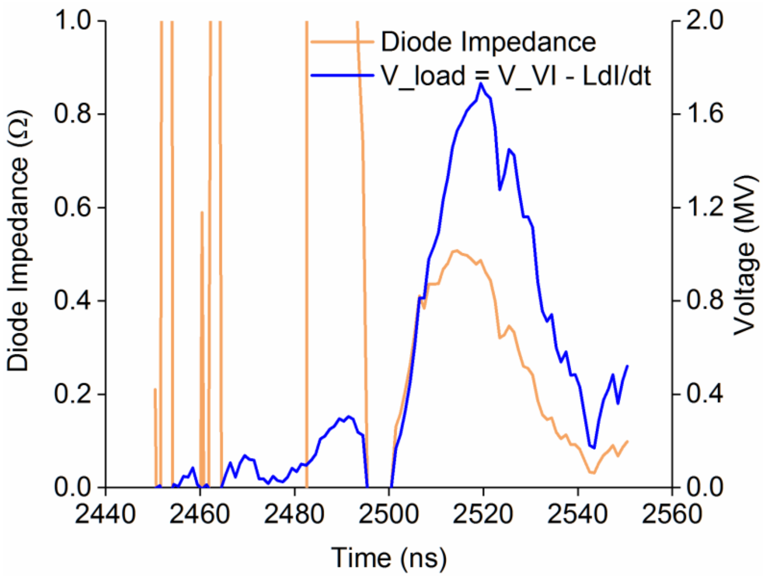
- Faraday cups with strong magnetic field deflecting electrons
- Stainless steel anode in electron mode (Shot 4308)
- Flashover ion source in ion beam mode (Shot 4309)

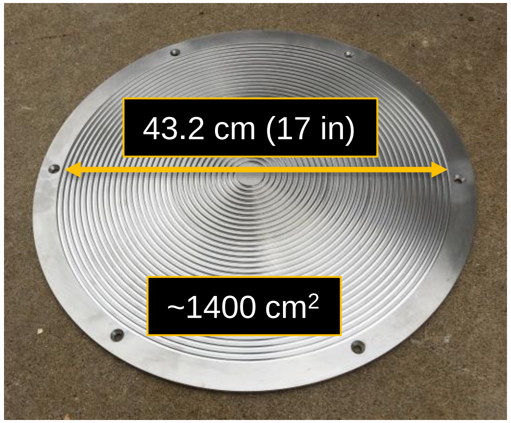


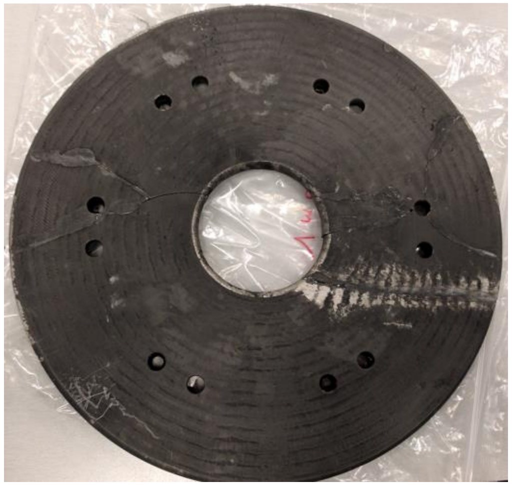
- Ion signal off scale for ion source, non-existent for e-beam source
- Early termination at outer radius consistent with magnetic deflection of ions
- Duration of ion source at inner radius consistent with voltage pulse

6-mm AK gap and flashover ion source provided promising ion beam.



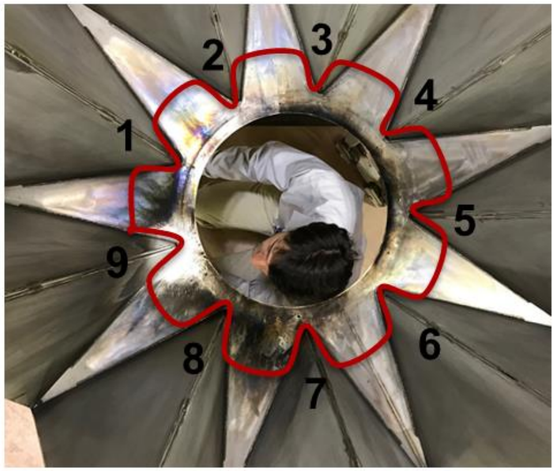




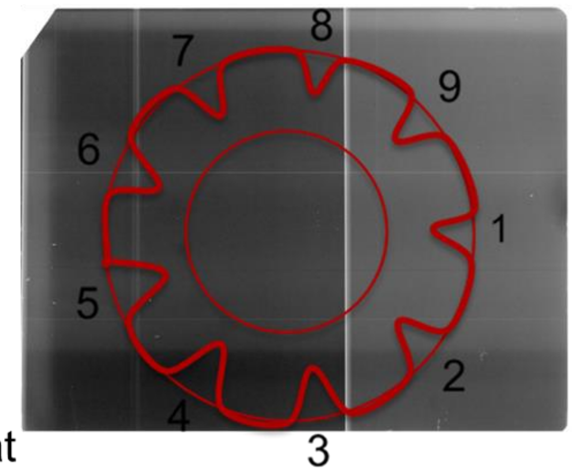


- Epoxy flashover source in 3 mm wide and deep grooves
- 6.6 mm A-K gap, 0.25 mil double-sided aluminized Mylar cathode
- Late time arc initiated near flaw in cathode may or may not be "conditioning" event

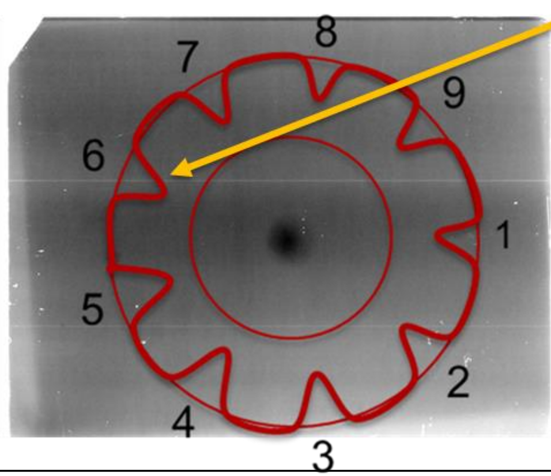
Pinhole camera shows only scanning artifacts—no high energy electron loss.



4307 Short circuit

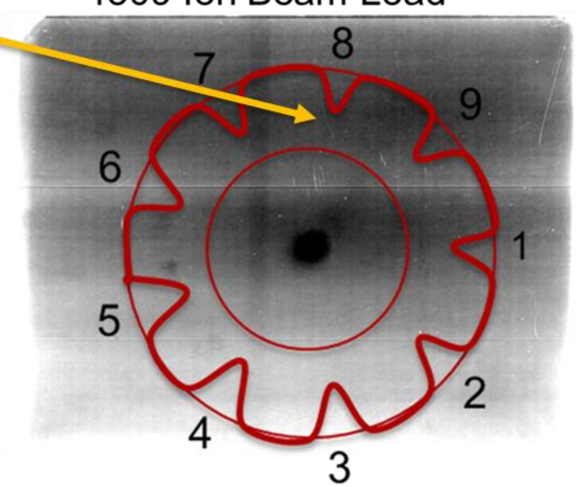


4308 Electron beam Load



No x-ray emission at damage sites indicates late time arcs at low voltage.

4309 Ion Beam Load



Unlike CSMITL1, CSMITL2 had no arc damage in MITL “tents”.

Conclusions

- CSMITL2 successful initial hardware integration
- Promising ion diode source
- CSMITL2 delivered 8 TW—four times the power of CSMITL1.

Thanks to the Saturn crew for their support in making this experiment happen.
Special thanks to Johnny Santillanes for his expert welding technique!