Study of the Initiation Phase of Thick, Metallic Liners at 1MA

UCSD

PULSED POWER PLASMAS GROUP

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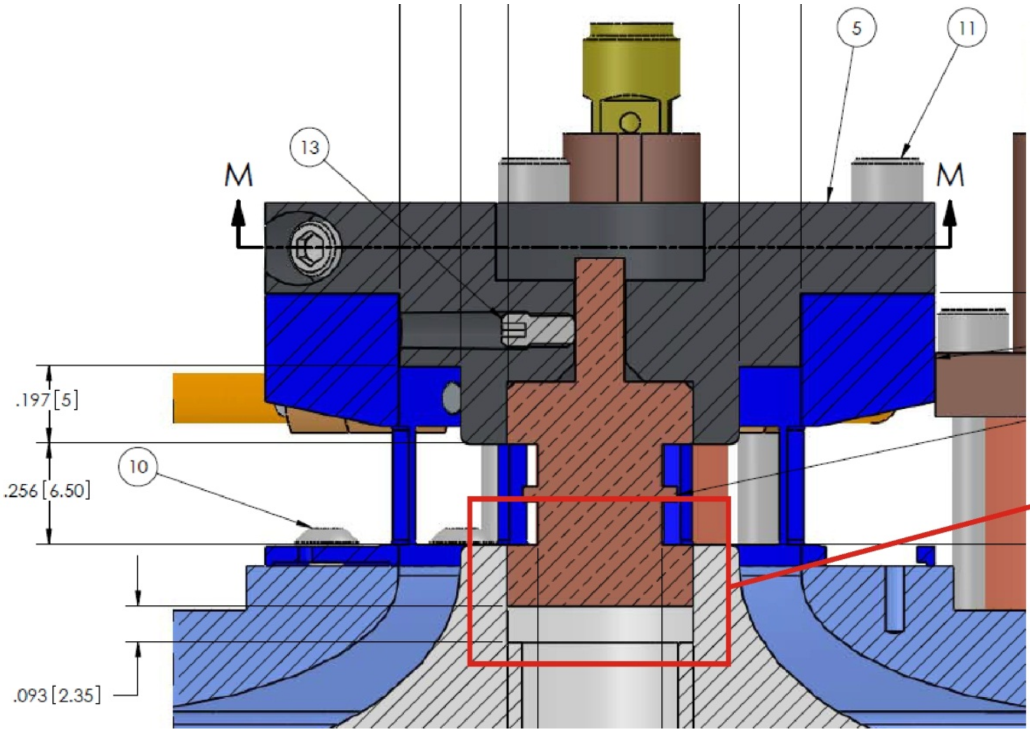
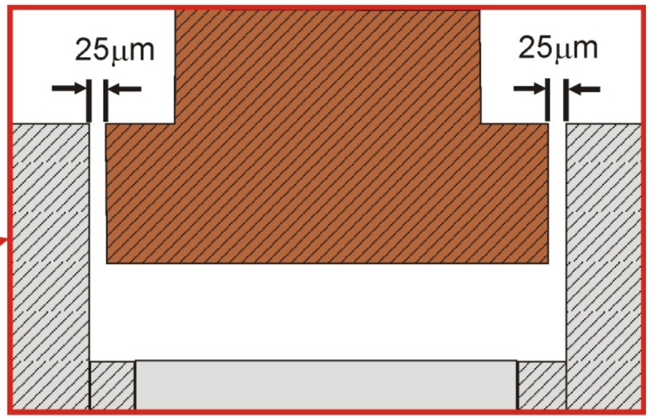
Sandia National Laboratories

Cornell University

Motivation: Power Feed Gap

- Does a gap in the cathode power feed influence the initiation of liners?
- Present precision liner mounting system is nearly a ‘push fit’ at the cathode: a 25μm gap is left around the liner





What might be the issue?

- Resistive phase leads to heating at electrical contact point
- If gap is closed in non-uniform fashion, this may be reflected in the plasma formation, and liner acceleration profile

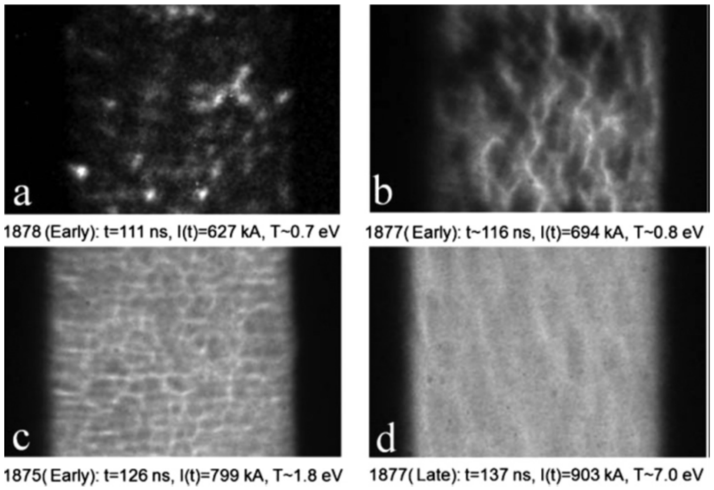
Motivation: MagLIF liners at 1 MA

- What can we learn about Z scale liners on a MA device?

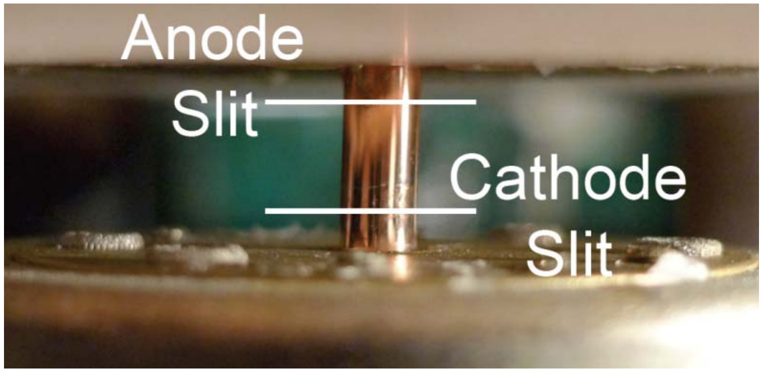
  Differences: total energy deposition, peak B-fields, voltages, etc

  Scaling important (e.g. Ryutov *et al*, *Phys. Plasmas* **19**, 062706 (2012)

  Previous and present work has proven interesting in terms of basic physics



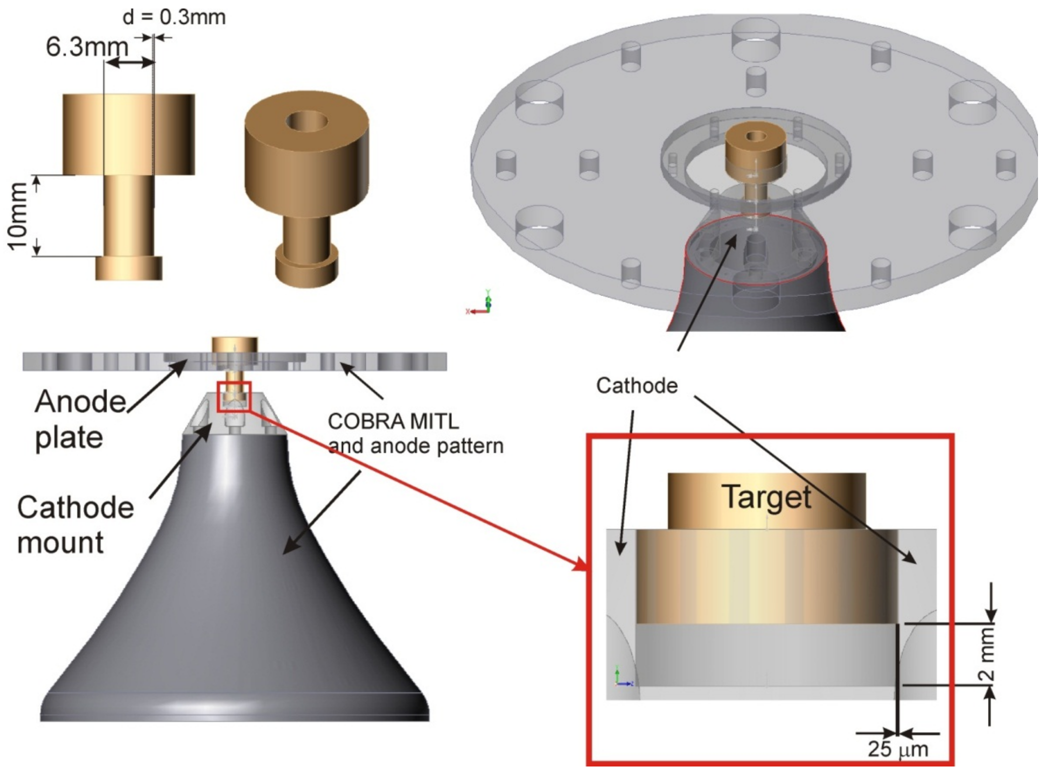
T. Awe *et al, Phys. Plasmas* **18**, 056304 (2011)
B-field threshold of 2.2MG for surface plasma formation



I. C. Blesener *et al*; Streak photography of 0.6-25μm Cu showed threshold current density rate of 3.5×10^{16} A/cm2/s for rapid initiation (~1ns)

MagLIF-scale liners on COBRA

- 1 MA, in 100 or 240ns



Brent Blue, General Atomics

- Liners are 6mm or 3mm in diameter, and 300 μm or 150 μm in thickness
- All below the Awe B-field threshold, and the Blesener current density threshold for uniform plasma formation
- Alignment of liner to cathode power feed done manually through electrical continuity test

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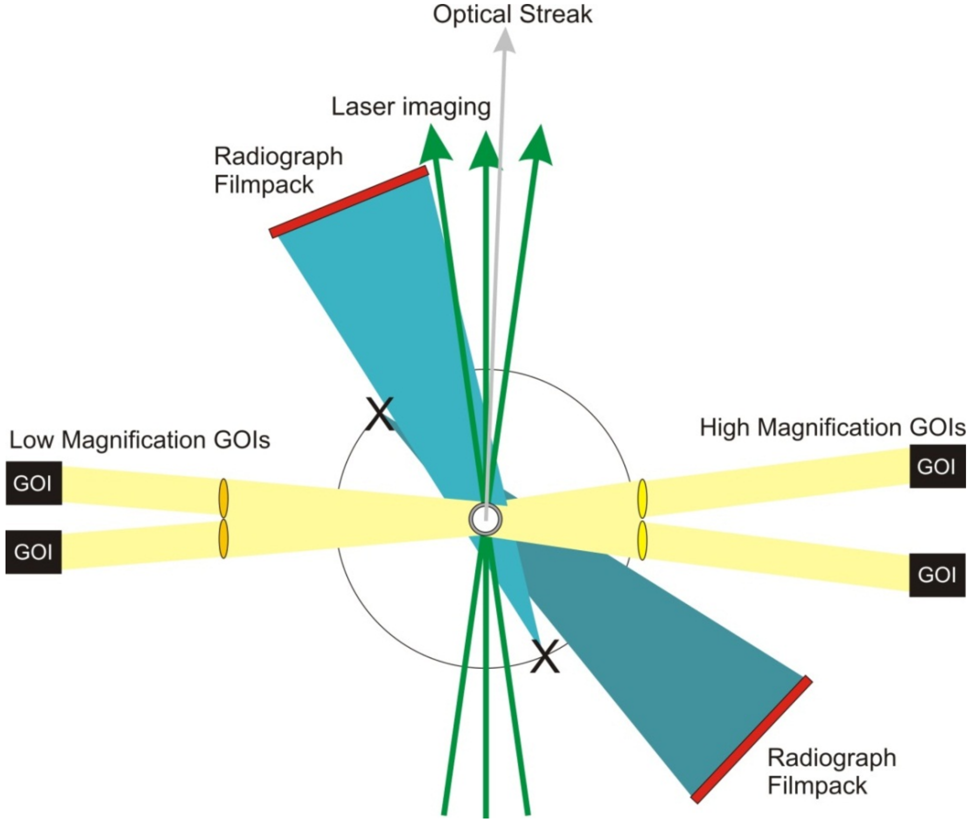

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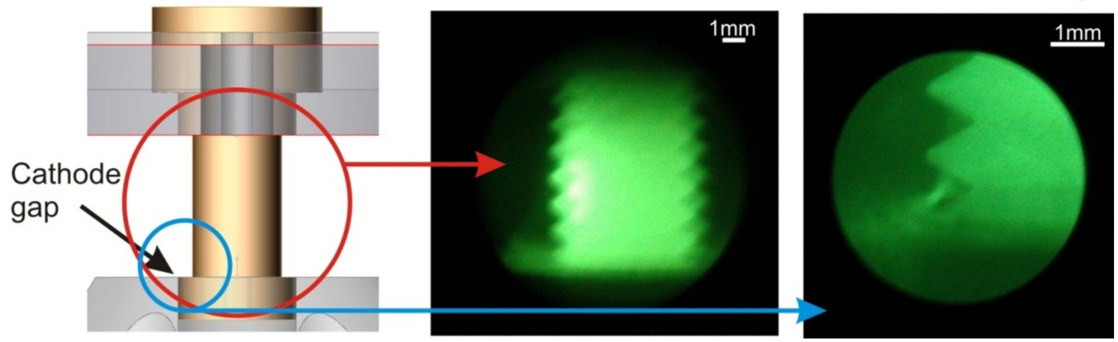
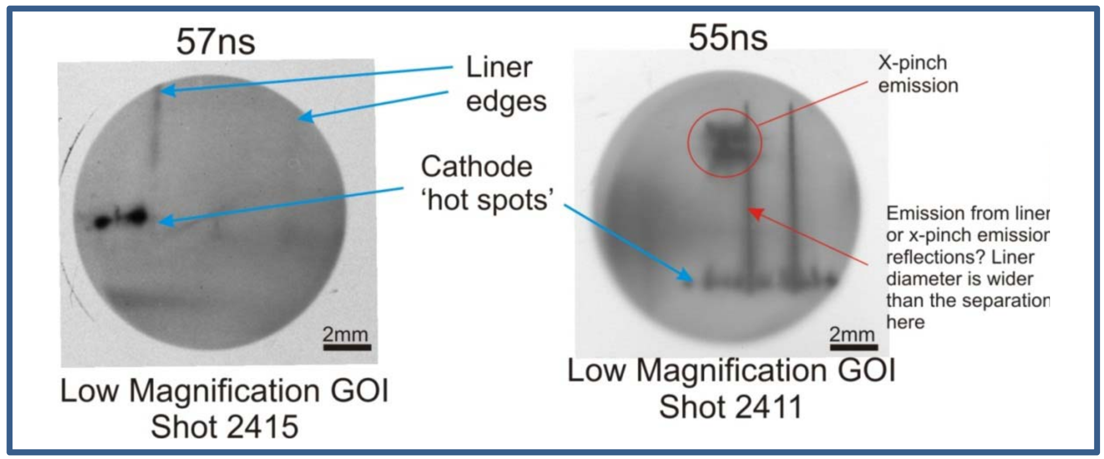
Gated Optical Emission Imaging

- Gated (5ns) optical imaging camera (on loan from Sandia)
- Localized emission observed at early time in most cases





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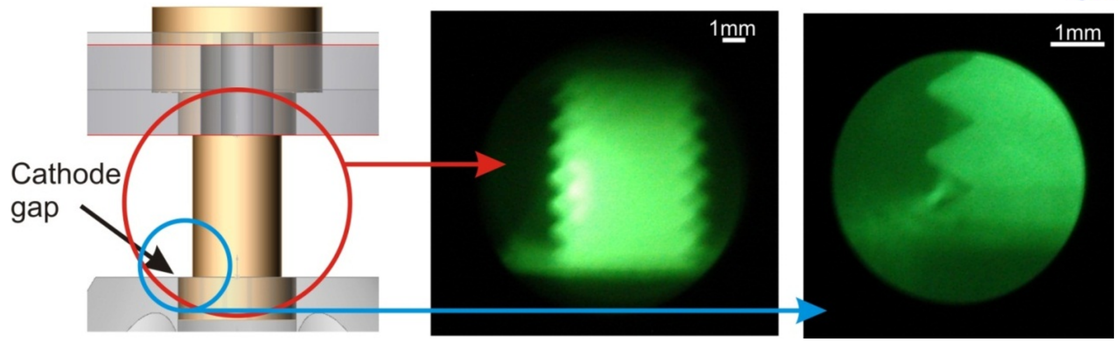
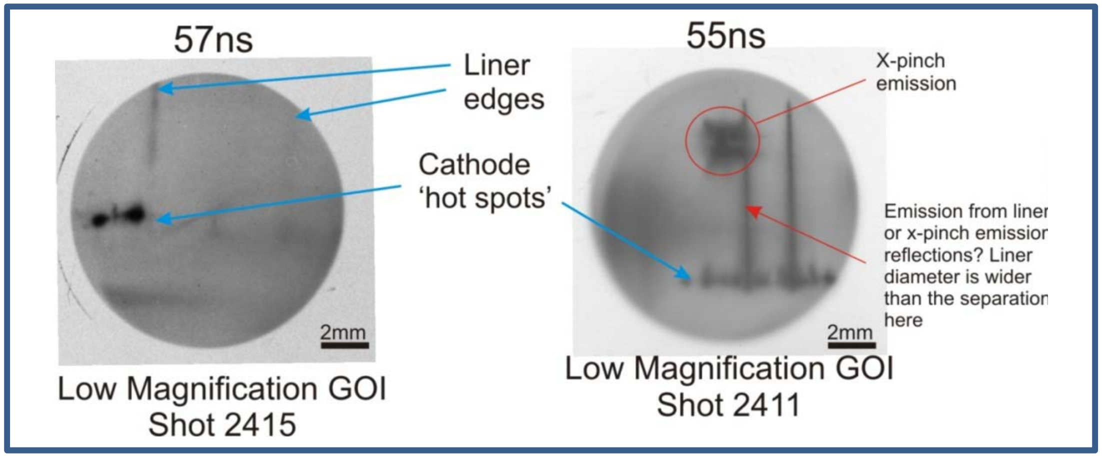
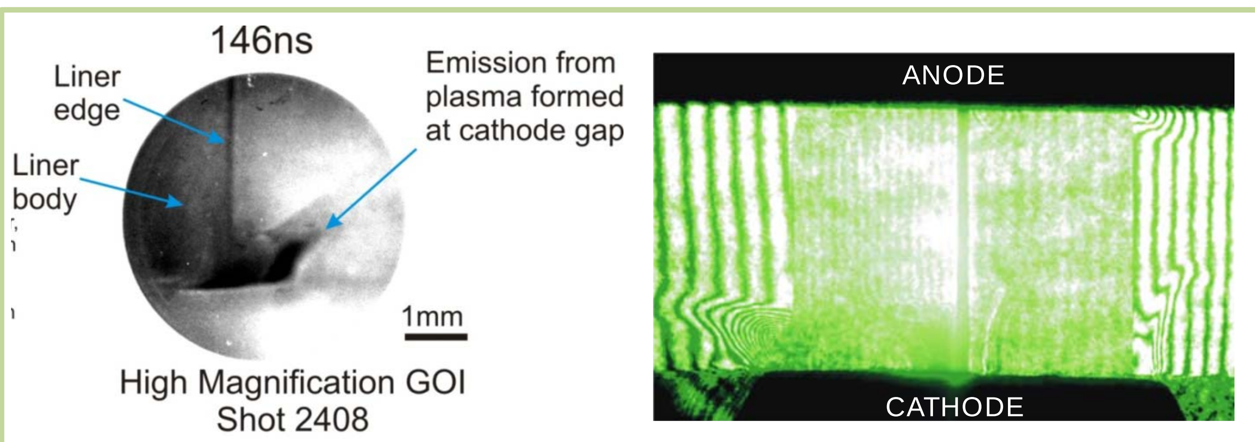
- Plasma generated at gap expands away from liner







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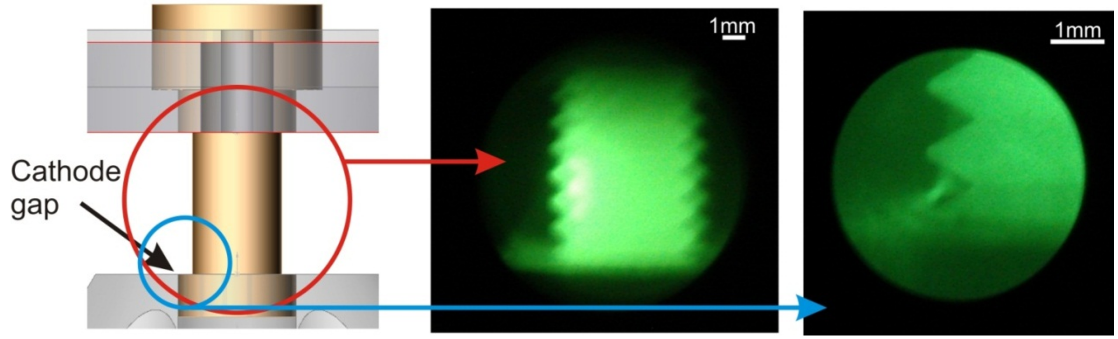
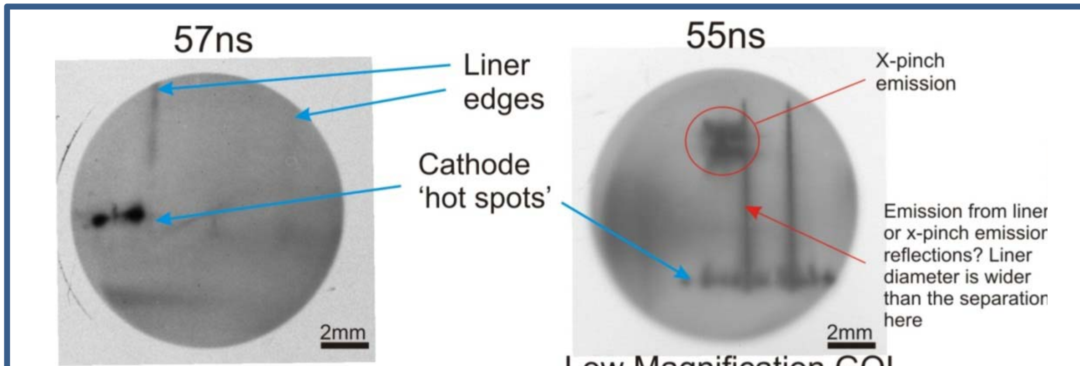
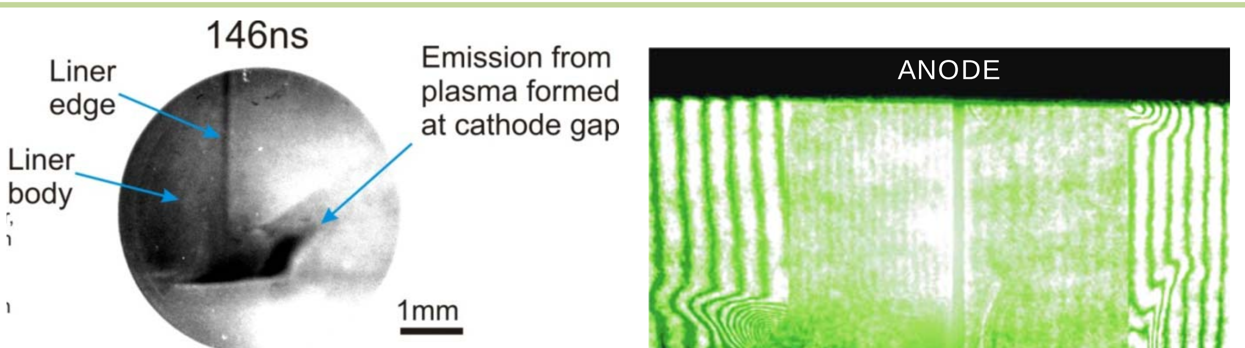
- Plasma generated at gap expands away from liner
- Relatively complete light-up of liners observed in some cases



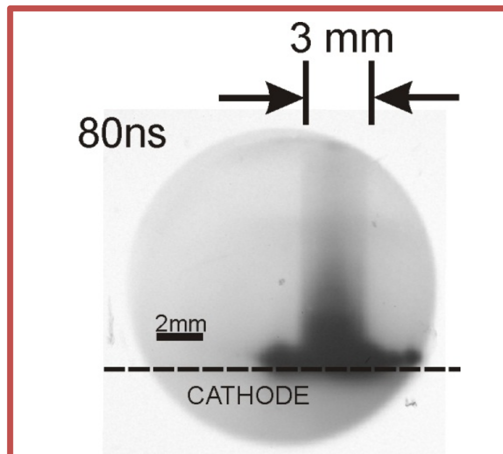


Low Magnification GOI Shot 2415

Low Magnification GOI Shot 2411

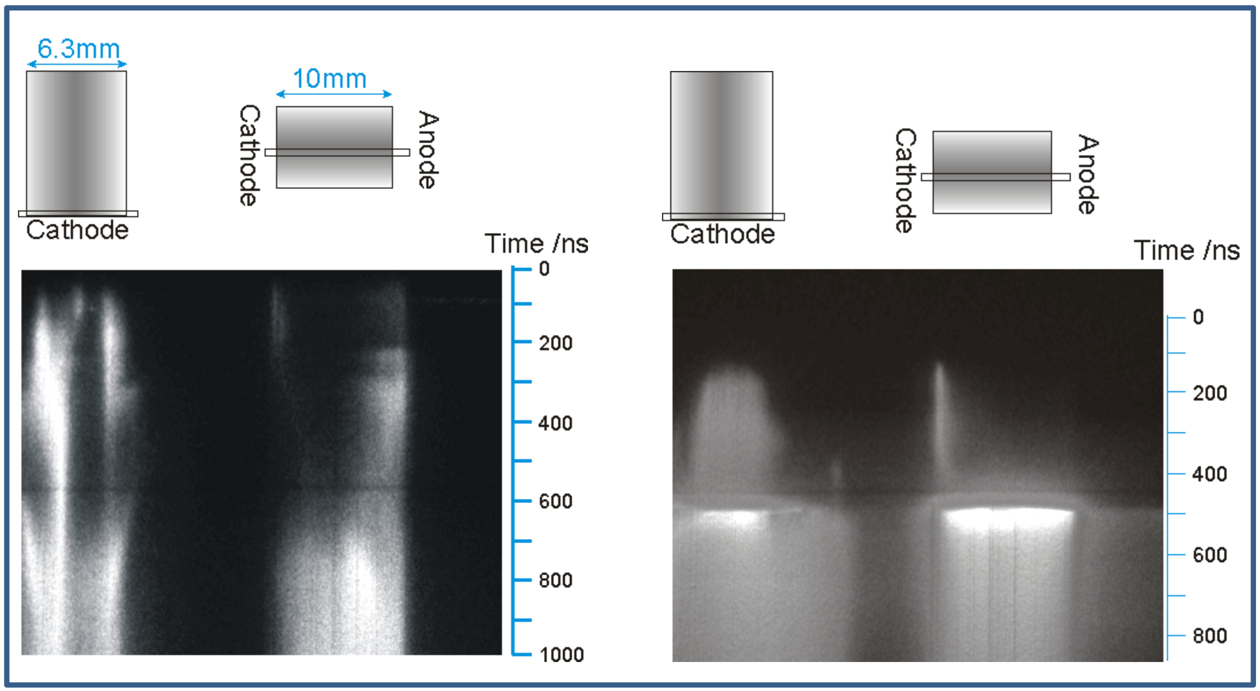


High Magnification GOI Shot 2408

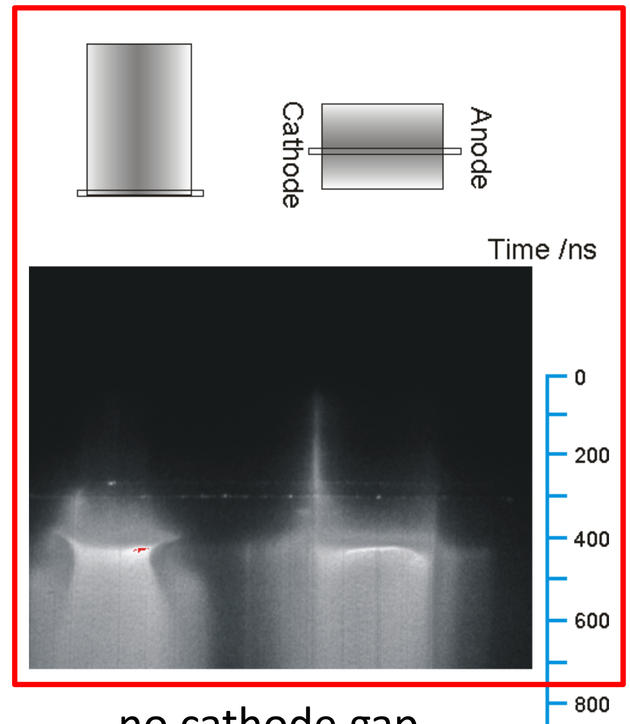


Optical Streak Measurements

- Streak images show variability in emission with nominally identical loads and gaps
- Multiple emission regions often observed at cathode
- Loads without a gap seem to show much later light up
- Uniform light up of liners not observed until very late time (>500 ns) for 6mm diameter liners



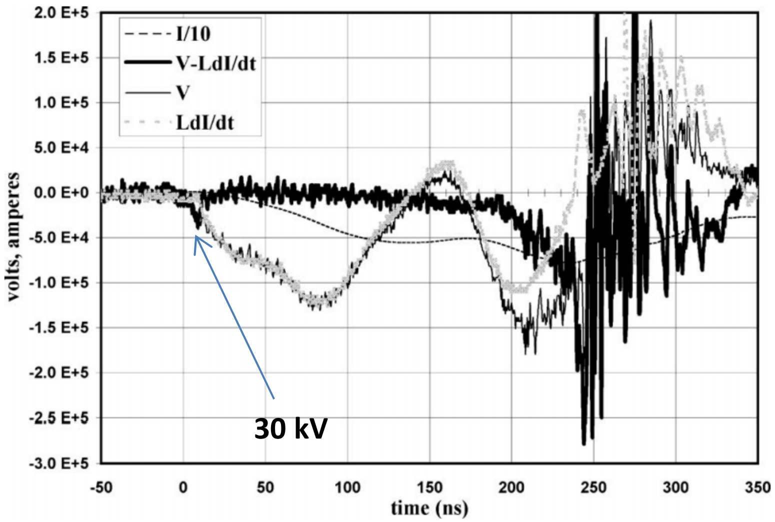
100mm cathode gap



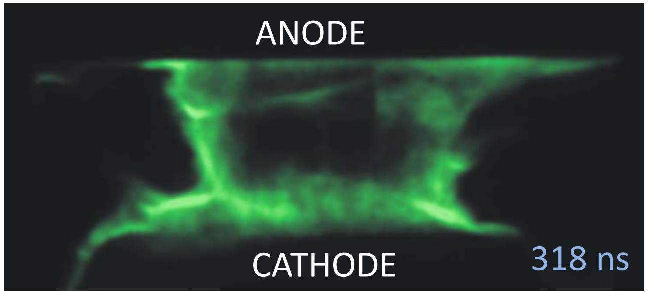
no cathode gap

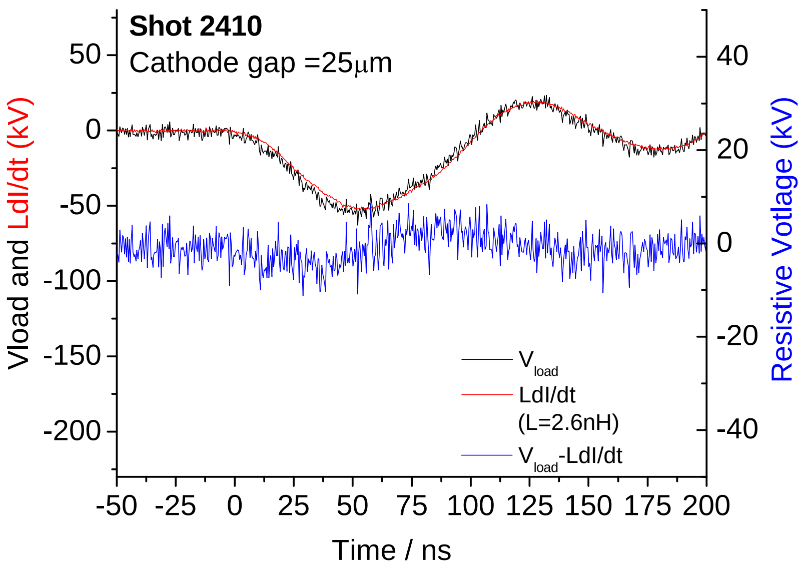
Voltage probe measurements

- For wire arrays, resistive voltage at wire breakdown observed
- Measurements taken for set-ups with gaps from 0 to 400 μm; no corresponding voltage peak found for liners
- Perhaps upper limit on breakdown voltage is ~10 kV
- Thermal processes likely very small: starting at RT, and liner remains cool through experiments



J. B. Greenly *et al*, *Rev. Sci. Instrum*. **79**, 073501 (2008)

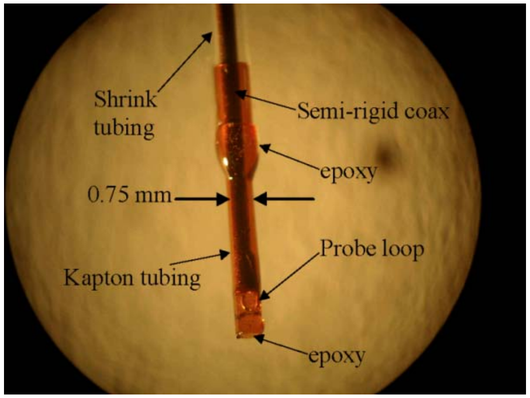




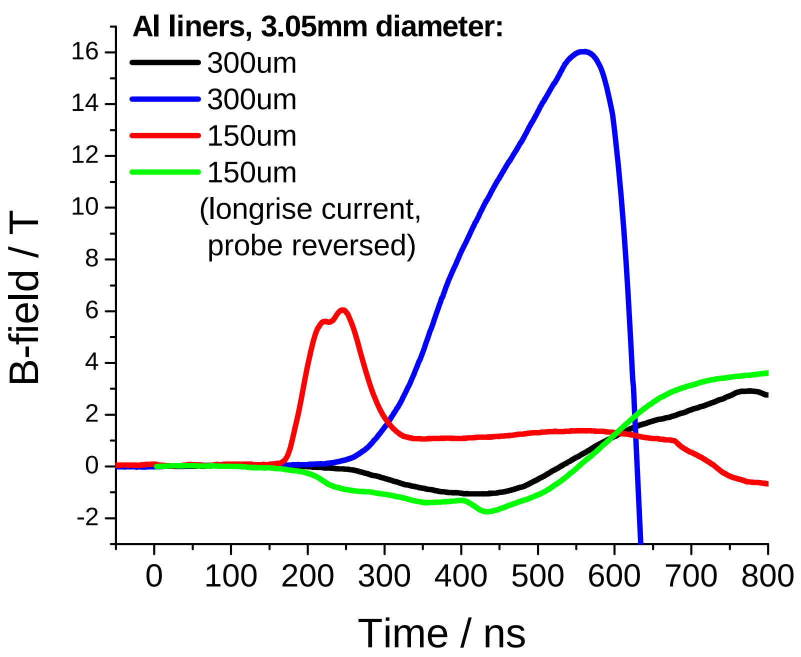
- Using limits above, field emission again likely small, although enhancement at protrusions may play a role.
- Rapid cathodic needle growth?

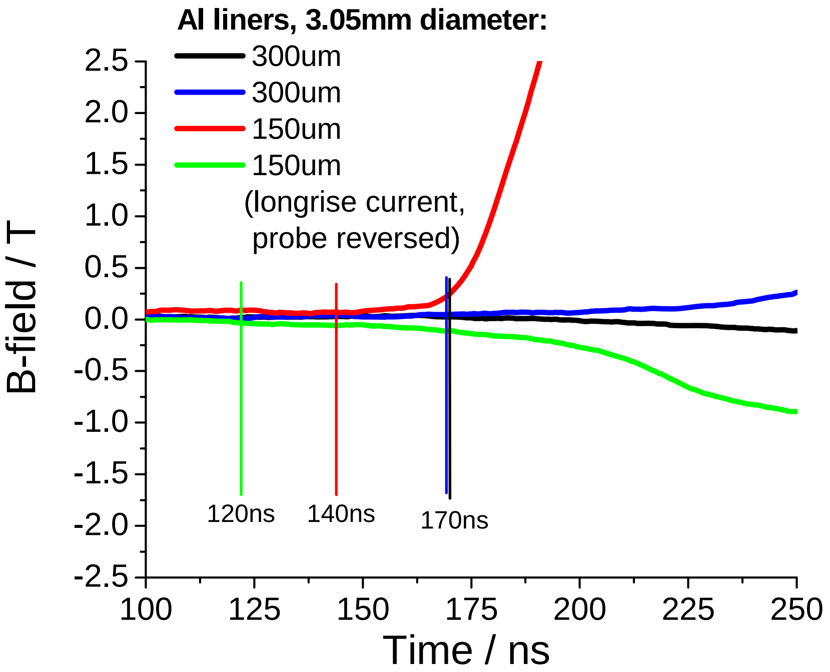
Magnetic probe measurements

- Probes are 0.1mm^2 active area, and placed 0.5 mm from liner inner surface at mid-plane
- Probes set up to give positive signal if current centered at axis.
- No measurements for 300μm, 6mm liners
- Signals recorded for 150 μm, 6mm and both 300 μm and 150 μm, 3mm liners



Greenly *et al, AIP Conf. Proc*. **1088**, 53 (2009)

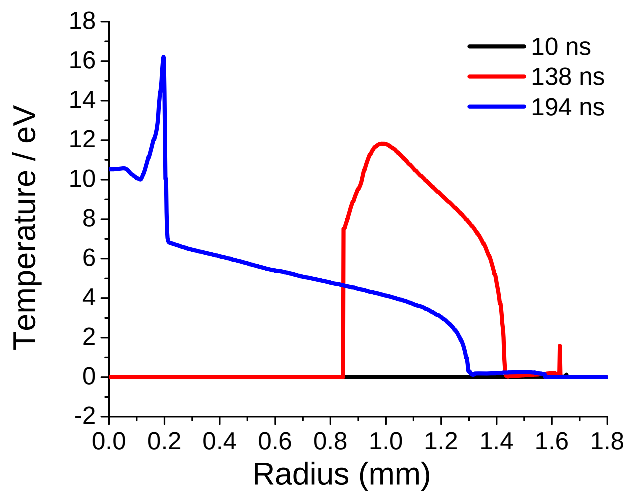


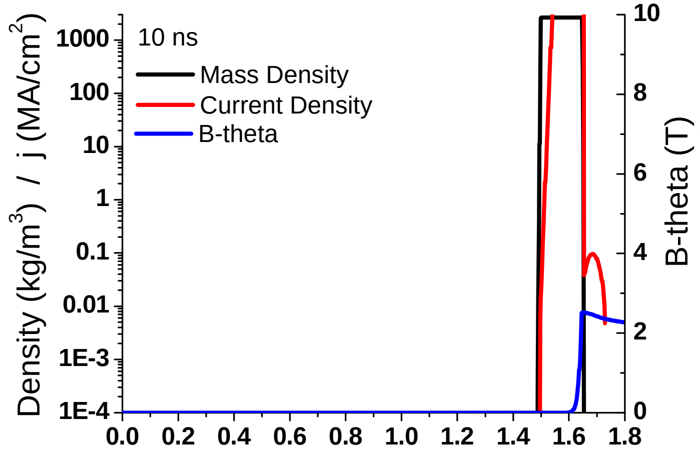


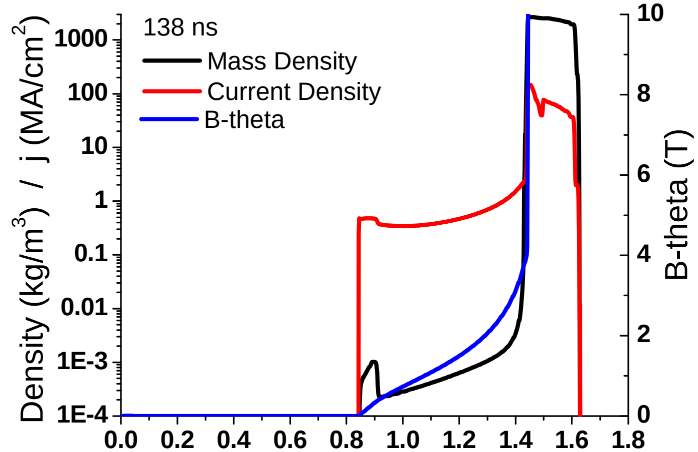
1D MHD Gorgon Simulations

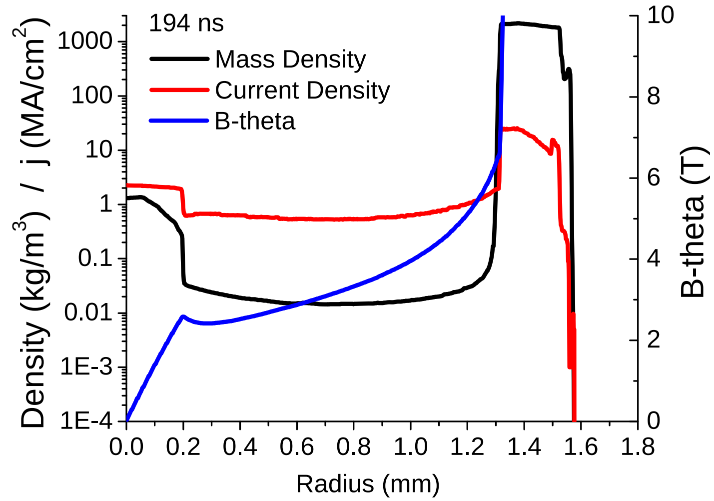
Evolution of the 3.05mm diameter, 150µm thick Al liner

- Simulations completed for the smaller diameter Al liners (3.05 mm diameter) where bdot signals were most clearly observed in the experiments
- Thicknesses of 150 µm and 300 µm examined for a typical COBRA current drive
- 2 micron cell size, Al EOS, and Lee-More-Desjarlais resistivity model



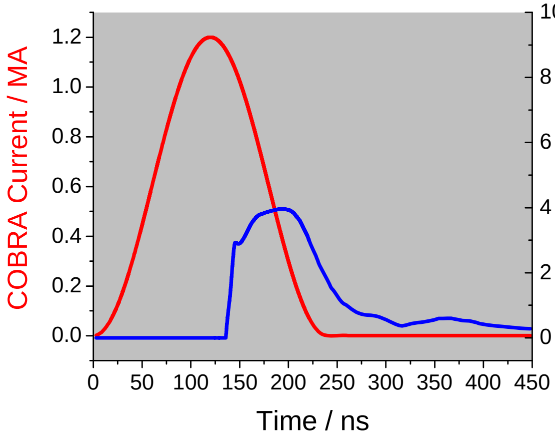


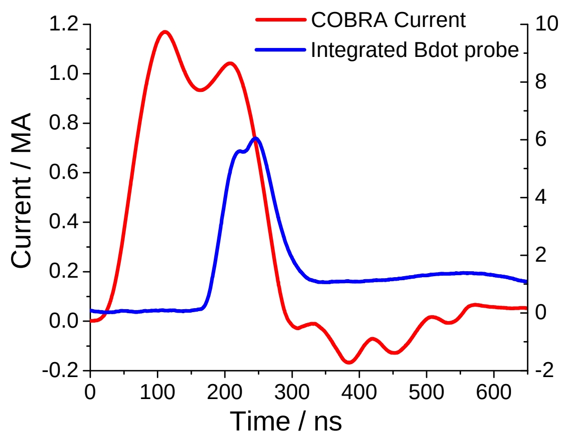


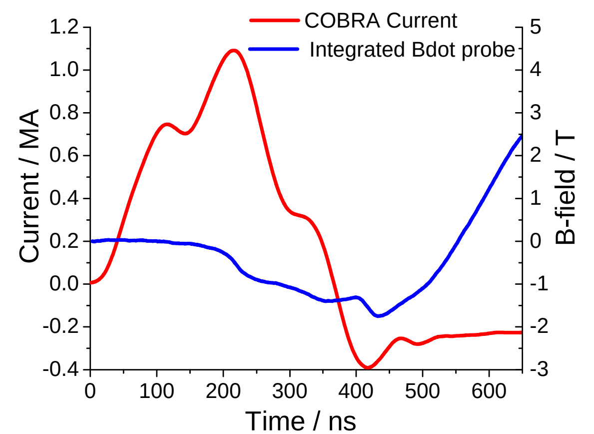


Comparison of Simulation to Experiments

3.05 mm diameter, 150um thick Al liners

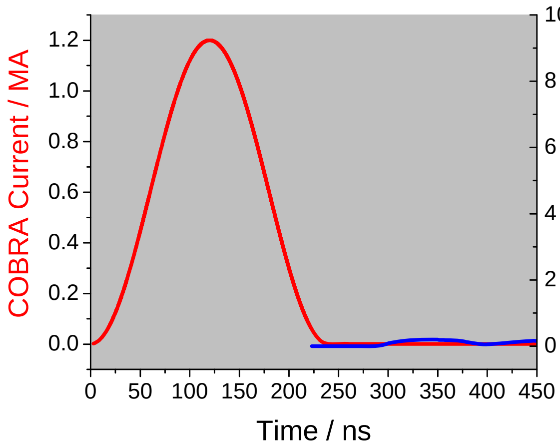


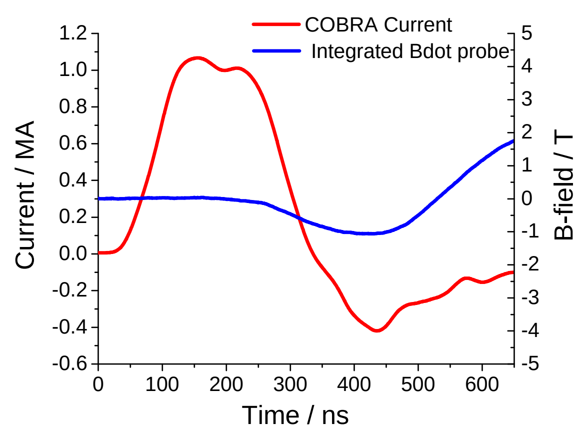


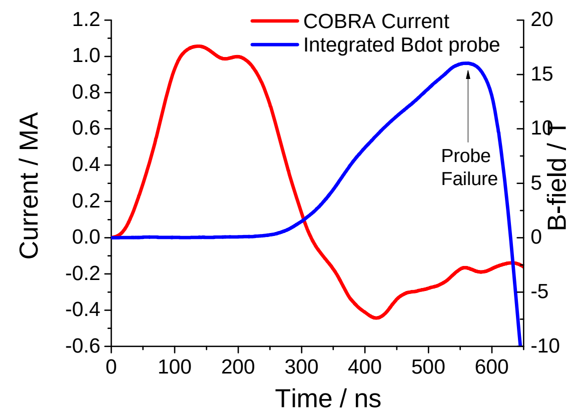


Long current pulse & Probe reversed

3.05 mm diameter, 300um thick Al liner



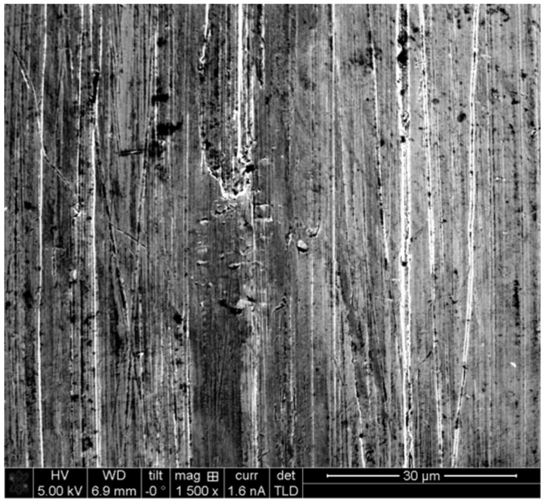


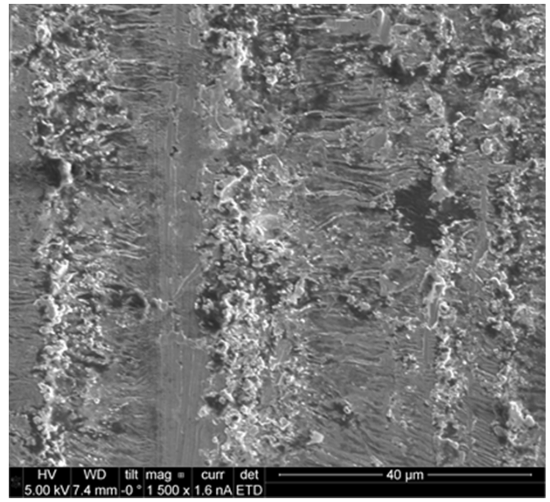


- Generally, the 1D simulations do a reasonable job of the form and magnitude of the signals
- Note that the simulation use an ideal current contact
- Experimental variability is an issue

Comments for Z and simulations

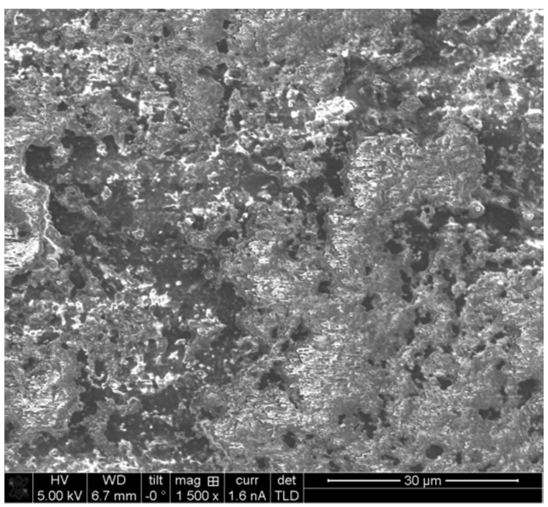
- Machined surface perturbations do not seem to disappear under local melting at 1 MA





SEM images of Al 6160 targets machined at Cornell University, x1500 of pre- and post-shot liner target (Courtesy of Cornell Center for Materials Research (CCMR) though award NSF DMR 1120296)

- Tumbling of liners gives random surface perturbations (c.f. machined striations) through oxidization of the Al surface



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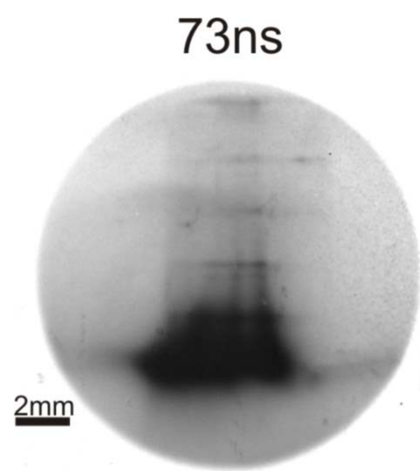

Conclusions

- Power feed gaps do lead to sparks non-uniform azimuthally
- Can also lead to relatively uniform optical emission
- Reasonable agreement between 1D simulation and experimental bdot measurements, as well as qualitative agreement on low plasma formation at outer and inner surfaces
- Bdot measurements indicate variability in experimental signal – possibly due to azimuthally non-uniform current initiation
- Needs more investigation: next we will seek a causal link between plasma formation and B-field penetration.