UC San Diego

AZIMUTHAL CURRENT DENSITY DISTRIBUTION RESULTING FROM A POWER FEED VACUUM GAP IN METALLIC LINER EXPERIMENTS AT 1 MA

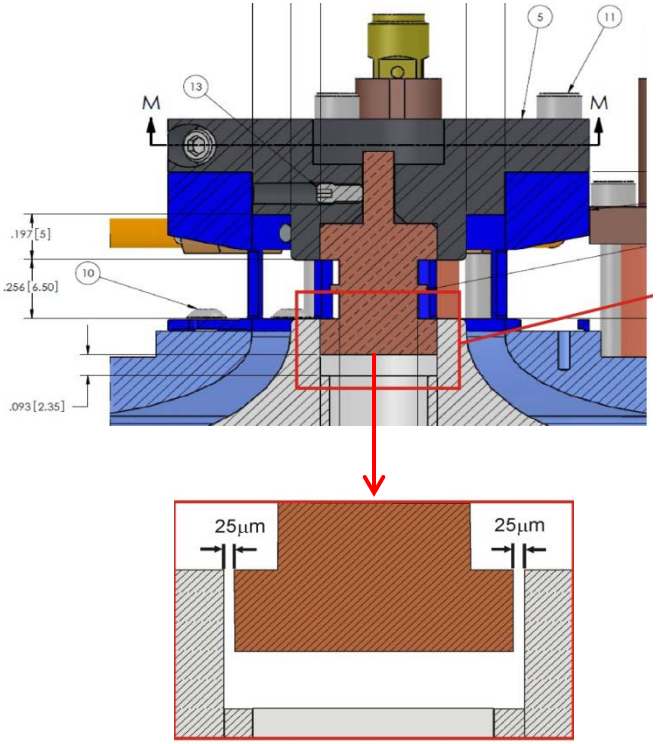
S. C. Bott-Suzuki, S. W. Cordaro, L. S. Caballero Bendixsen,
University of California San Diego, CA, USA

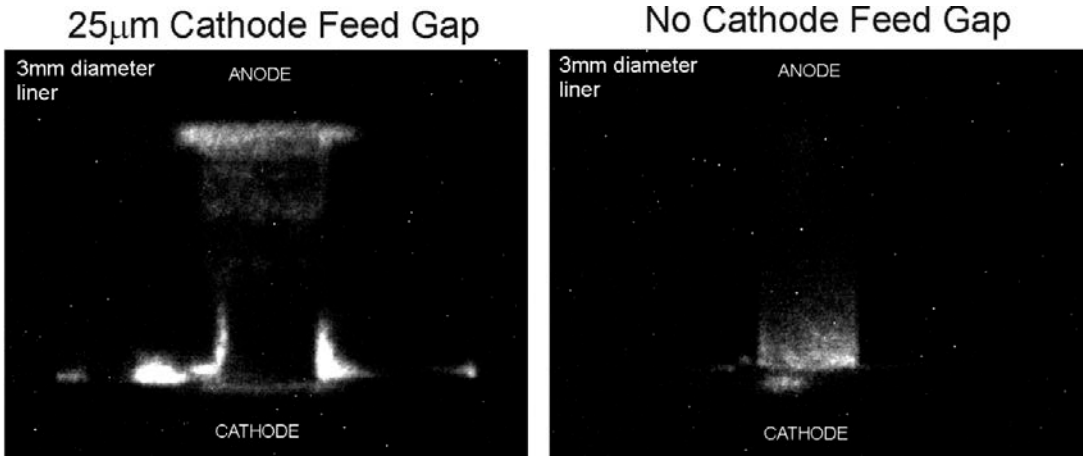
Levon Atoyan, Tom Byvank, William Potter, B.R. Kusse, J.B. Greenly, C. E. Seyler, D. A. Hammer
Cornell University, Ithaca, NY, USA

Cornell University

*Supported by the Center of Excellence in Pulsed Power High Energy Density Plasmas under the NNSA SSAA program through DOE Cooperative Agreement DE-FC03-02NA00057

Previously on "COBRA liners with Cathode vacuum gap"……..





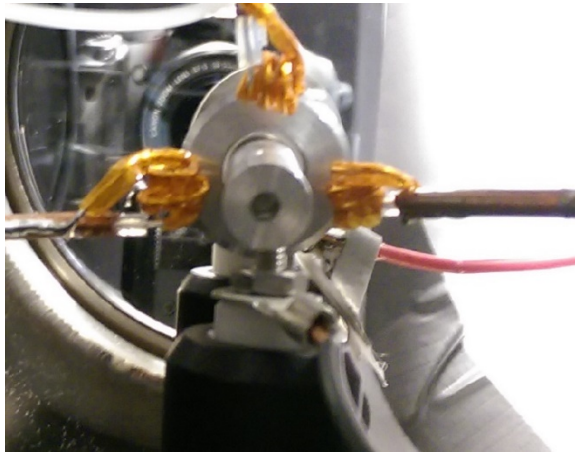
Gated optical images (10ns exposure) of Z-scale liners (300μm thick, 6.3mm OD and 10mm tall)

- The presence of a gap at the cathode clearly has an effect on plasma formation and evolution

S. C .Bott-Suzuki, *Phys. Plasmas*, **22**, 094501 (2015)

High Voltage Vacuum Gap Breakdown Experiment at UC San Diego

- Examines coaxial HV vacuum gap breakdown (15 – 30kV, 100-200 A)



- Use of bdot probes are multiple azimuthal positions allow triangulations of the effective current position

- $R = \frac{\mu \mathrm{I}}{2\pi B}$, for each peak B-field value to estimate the corresponding distance from break down. The R value corresponds to the distance the breakdown is from the probe

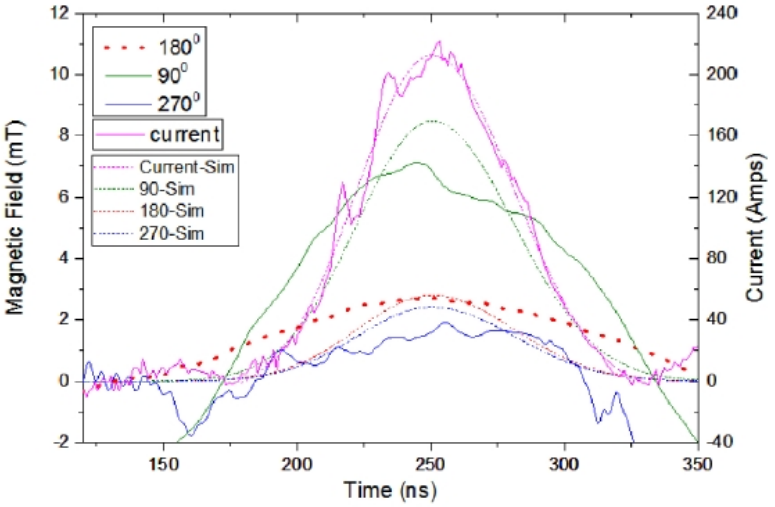
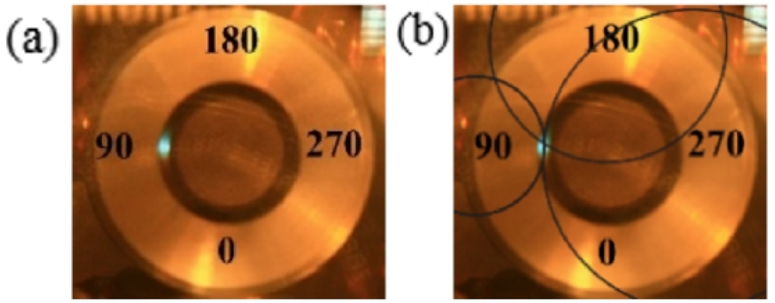


FIG. 7. Experimental vs. analytical magnetic field and current, shot no. 34.

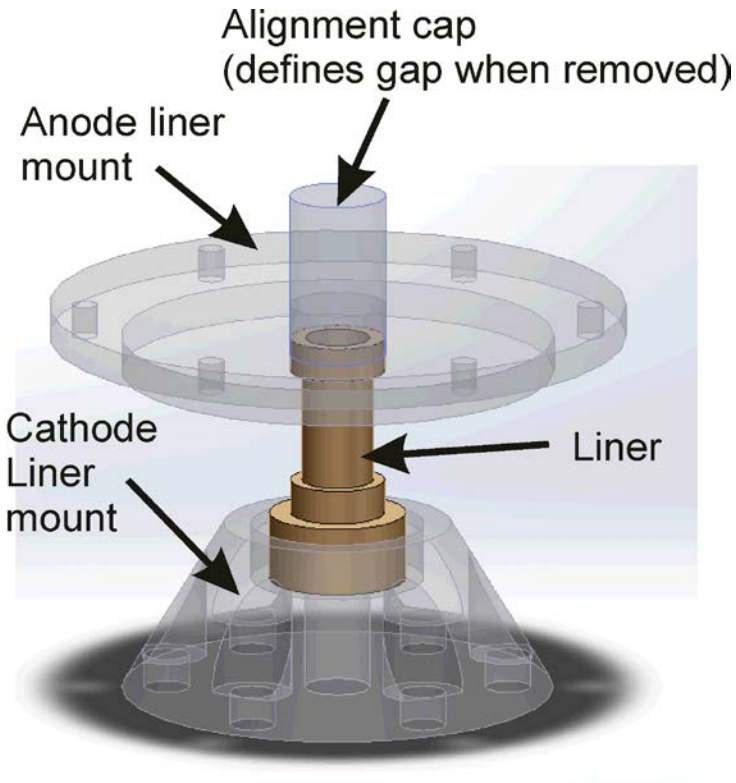


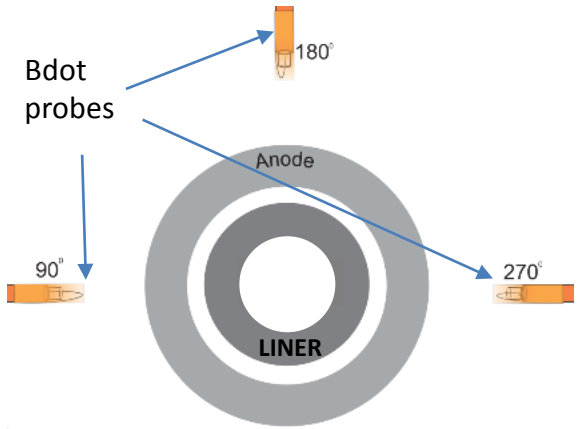
Cordaro *et al, Rev. Sci. Instrumen.*, **86**, 073503 (2015)

COBRA Liner Shots with an Anode vacuum gap

- Gap alignment more accurate and reliable
- Direct imaging access to power feed gap using gated (5ns) multi-frame optical camera
- Bdot array used to enable triangulation method

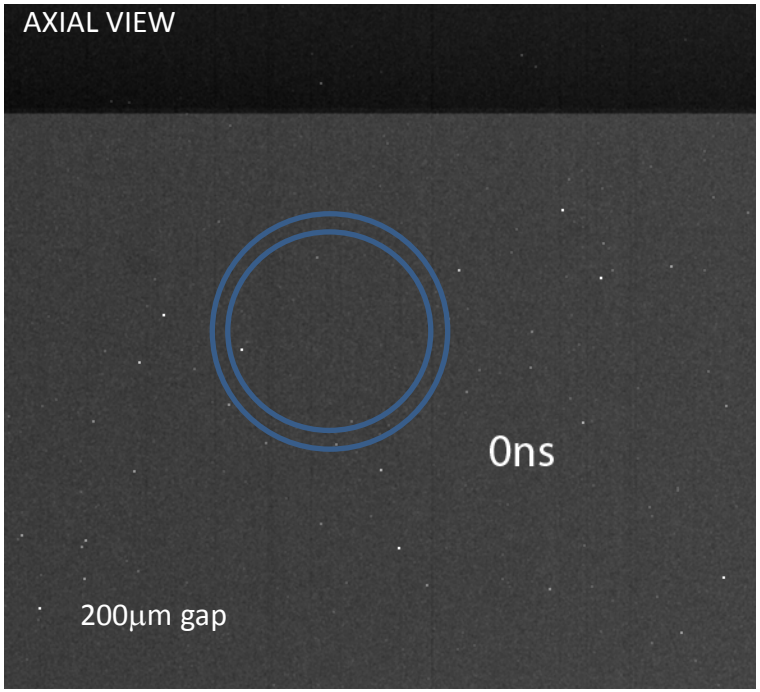
Z-scale liners, aluminum
(150μm thick, 3mm OD and 10mm tall)

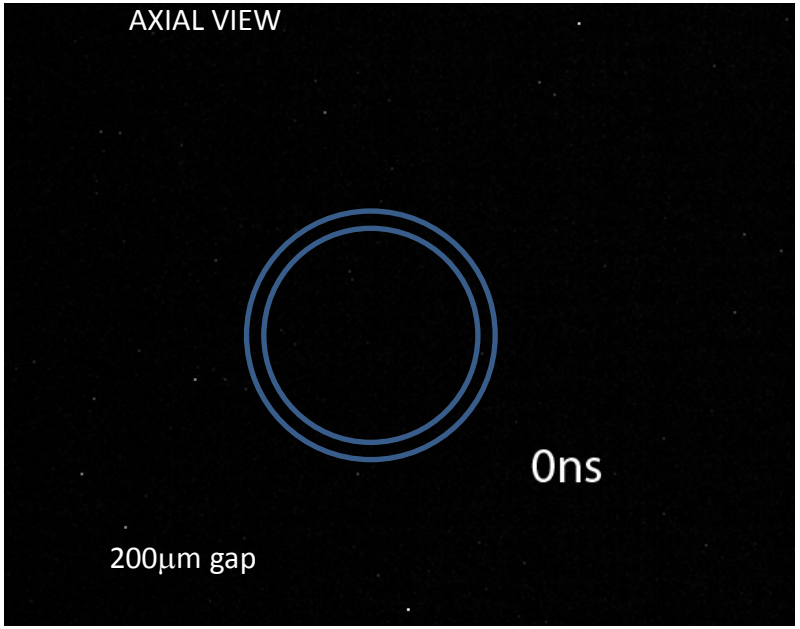




AXIAL VIEW FOR OPTICAL IMAGING

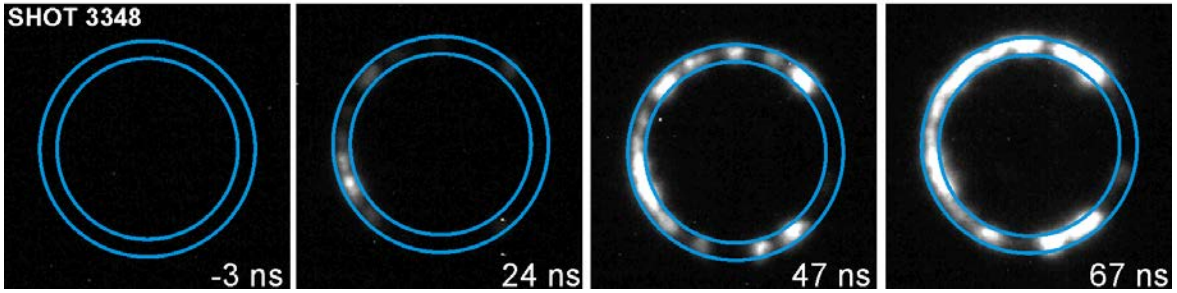
Multi-frame optical camera is ideal for following plasma evolution



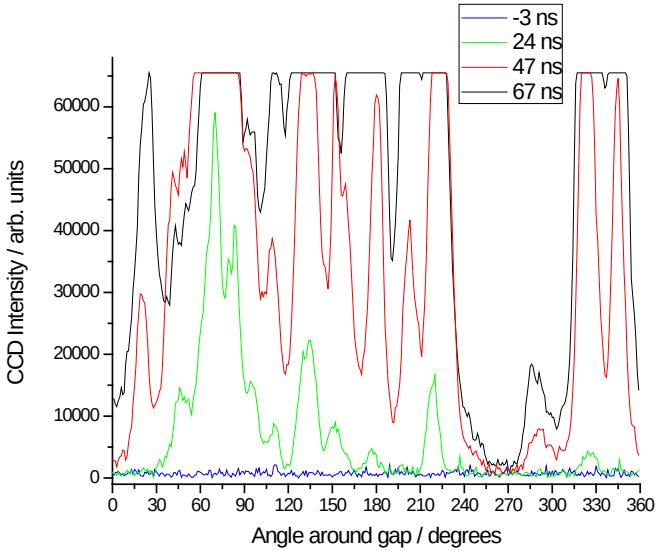


- "Identical" shots show similar behavior
- Initial breakdowns form multiple hotspots which evolve relatively slowly
- Alignment of gap seems excellent

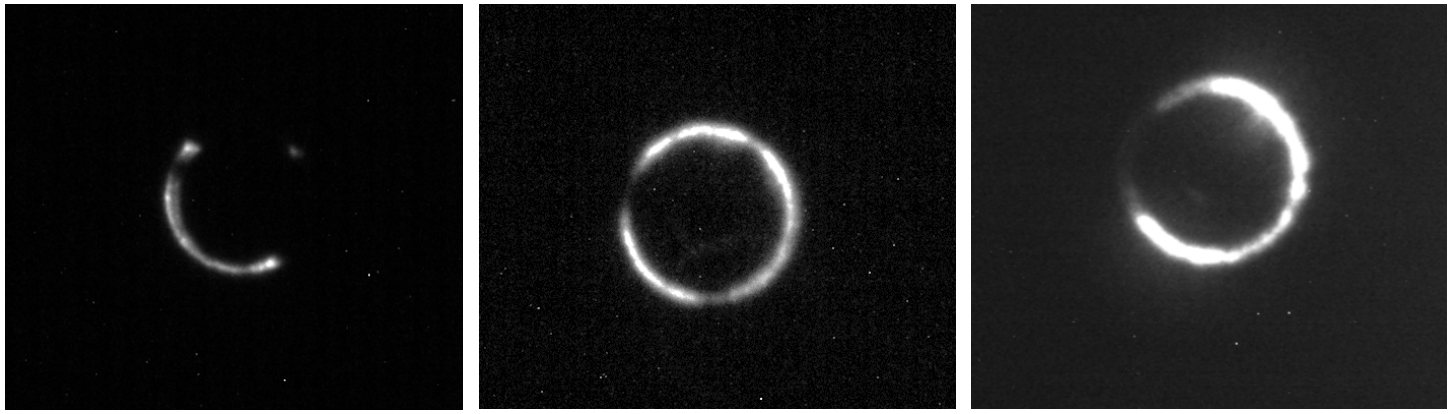
Anode gap is not uniformly closed in any shot at any time



200μm gap



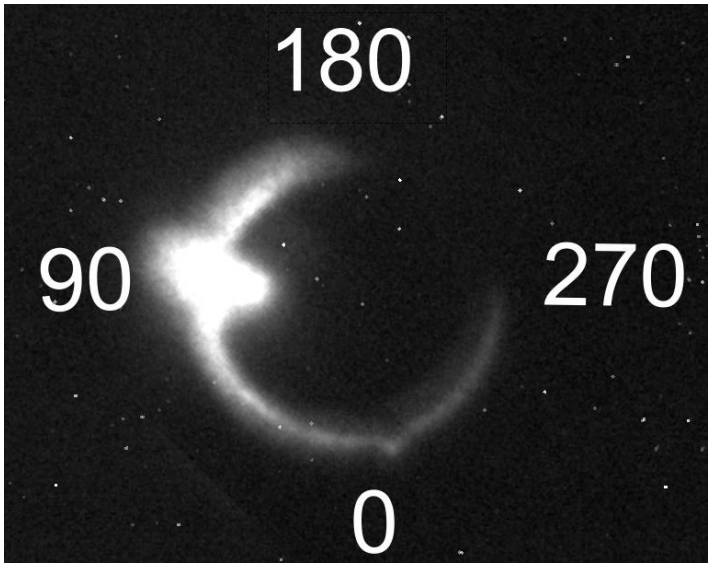
- No clear trend with gap size (electric field strength)

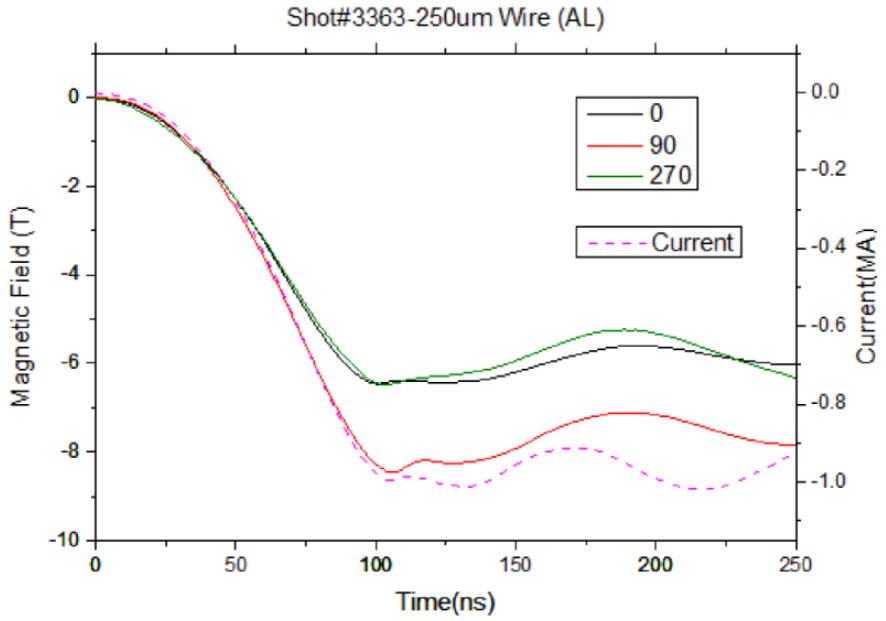


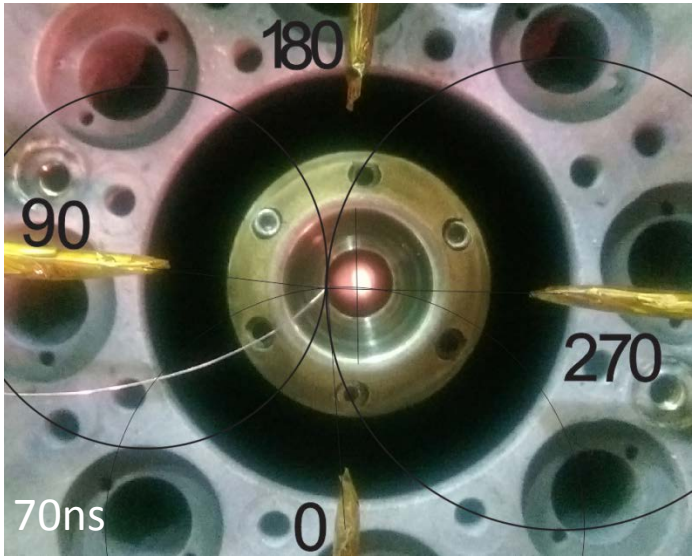
100um 200um 400um

Testing of Bdot triangulation method on COBRA

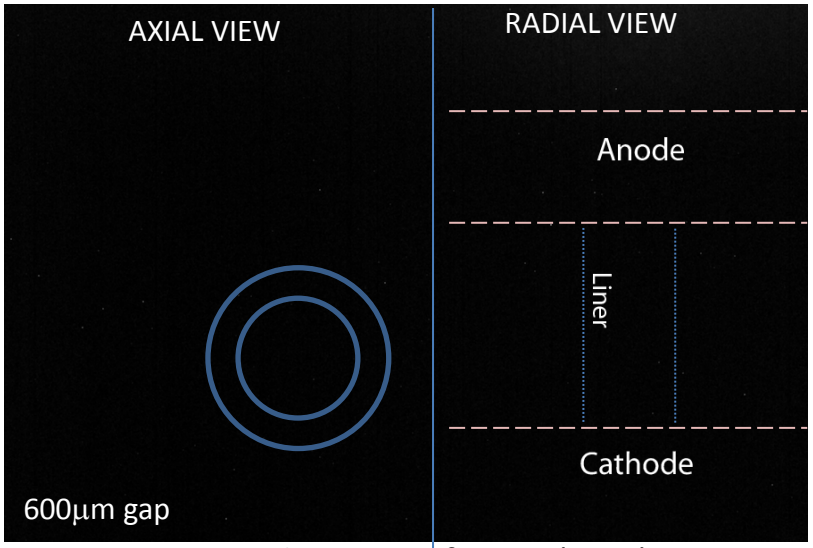
- "Sanity check" of triangulation method uses a single Al wire offset to one side
- Provides a single and stationary current path
- Triangulation at peak current gives excellent correlation to wire location



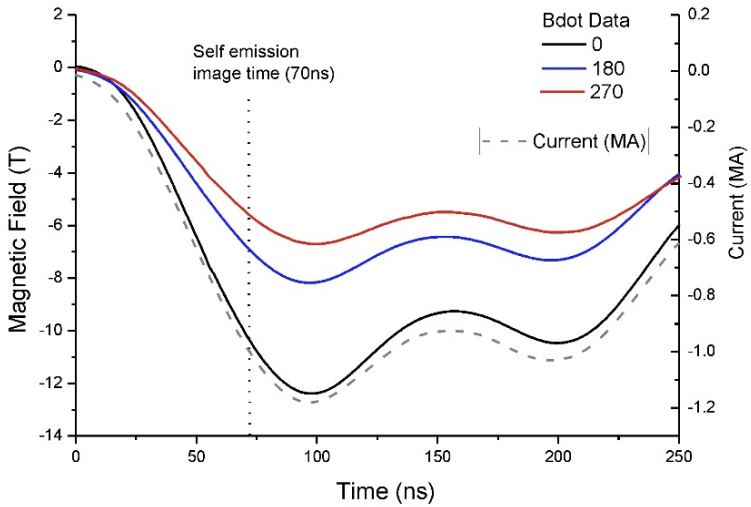


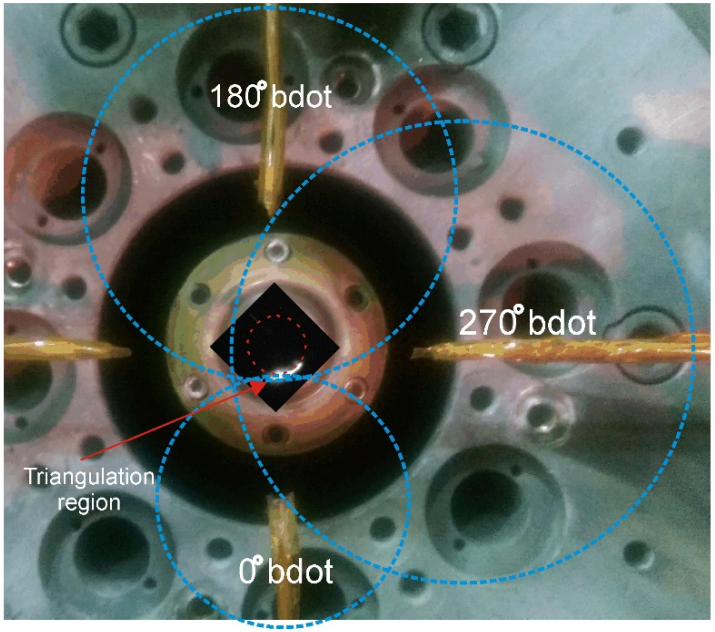


Bdot triangulation method correlated to imaging for COBRA liners



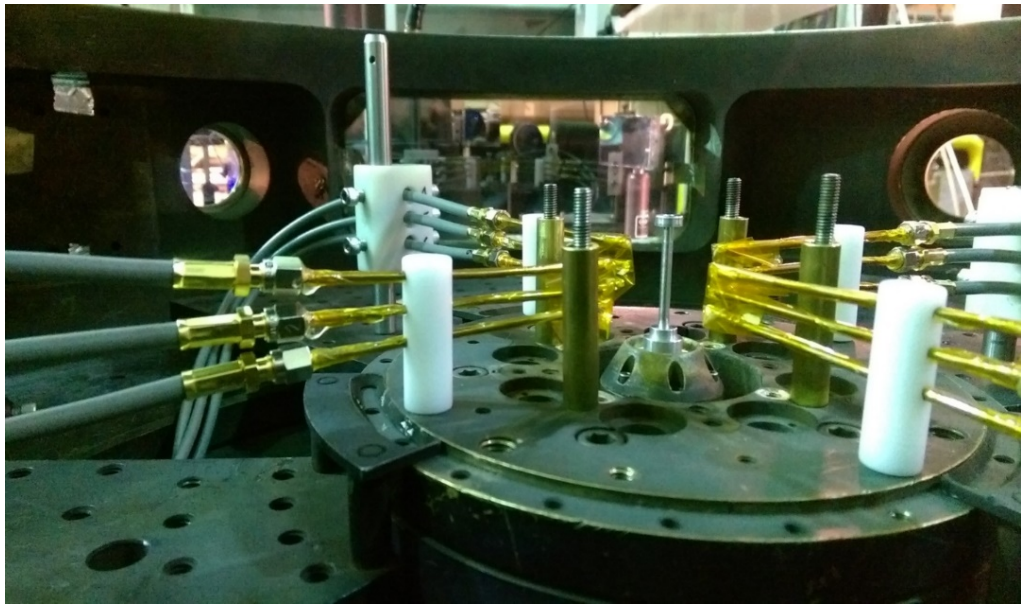
Optical emission frames (10ns)

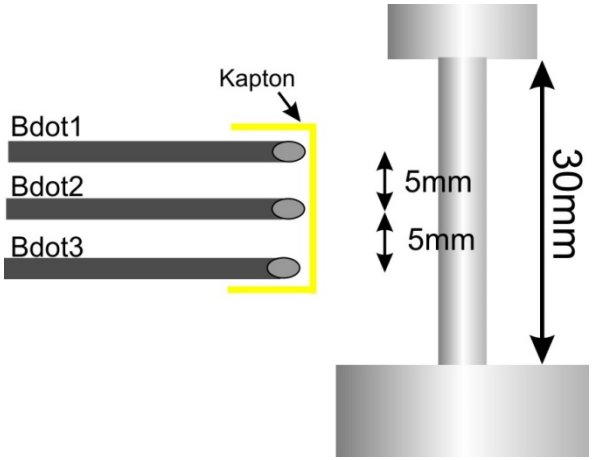




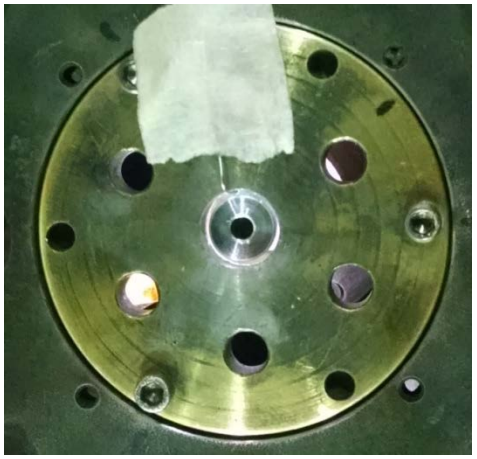
- In some shots, plasma one azimuthal position appears to dominate the profile for much of the current drive
- Effectiveness of the bdot triangulation links emission to current density
- This assumes all current at a single point

Investigations of current density as a function of axial position

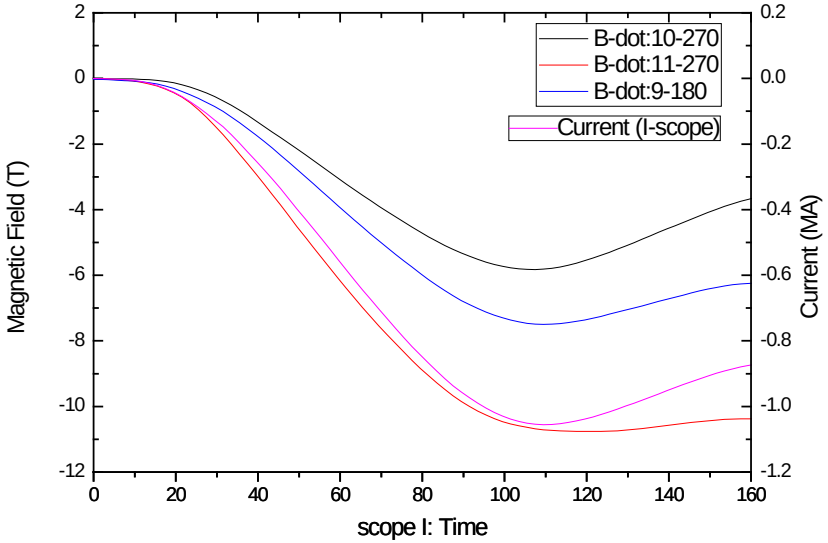


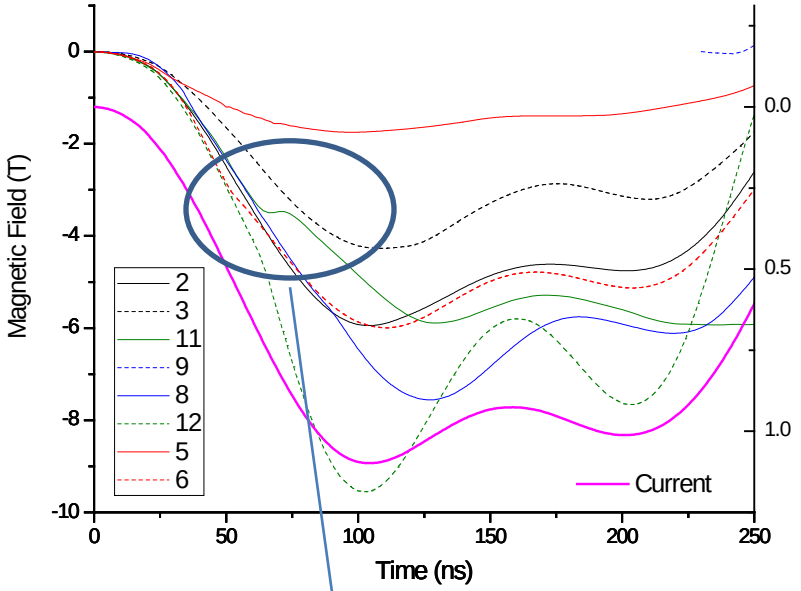


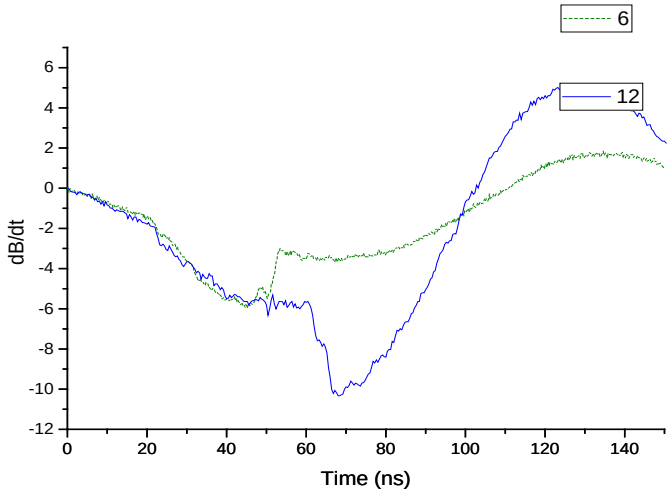
- Probes well-protected and can we used for several shots before repair is required
- Pre- and post shot calibration on repaired probes identical
- Using a ‘trigger pin’ determines initial breakdown position

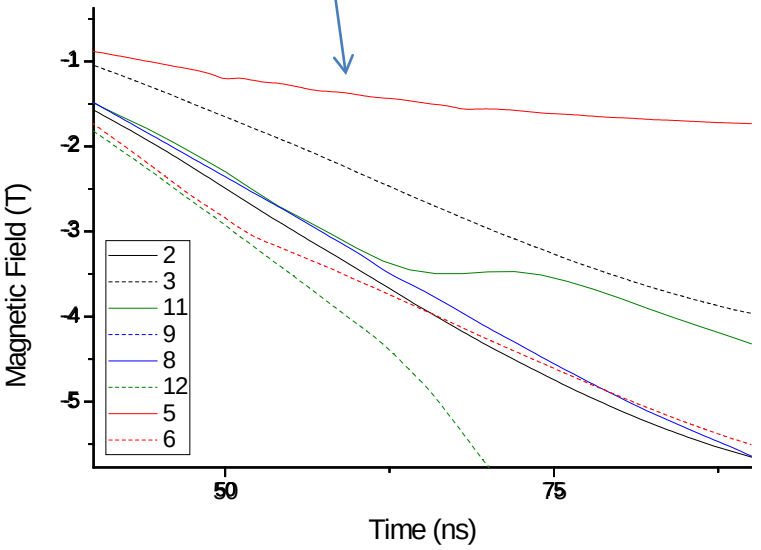


dB/dt and integrated traces show clear changes in azimuthal current distribution



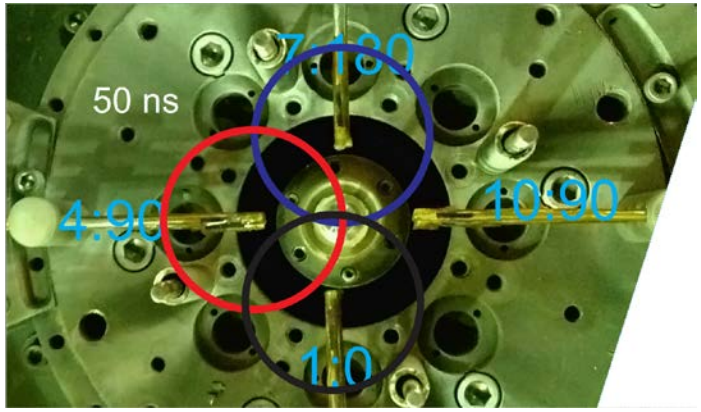




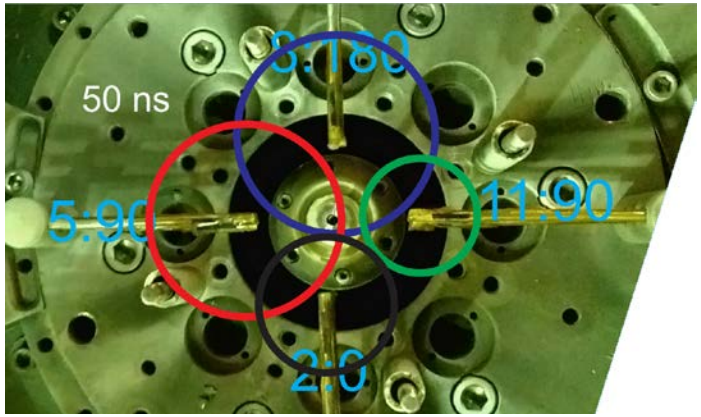


SHOT 3672

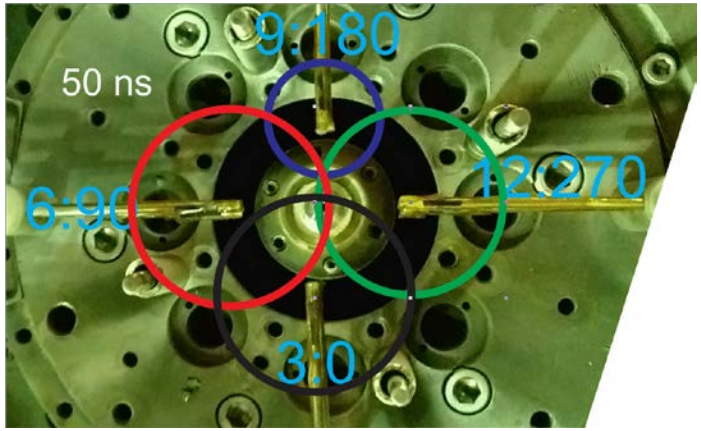
Top
(1,4,7,10)

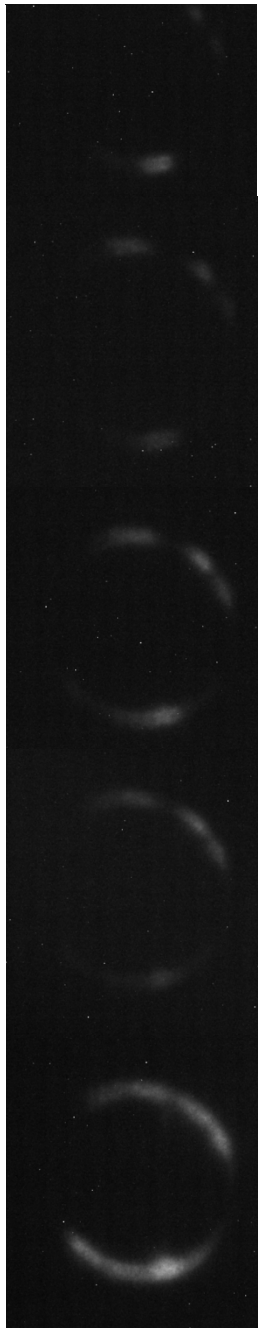


Middle
(2,5,8,11)



Bottom
(3,6,9,12)





50ns

60ns

70ns

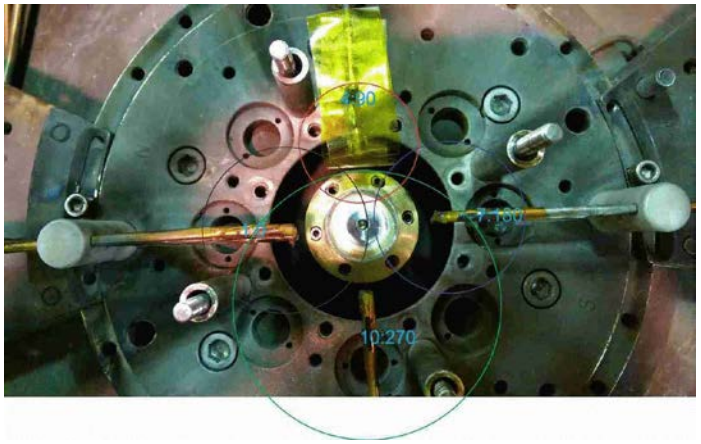
80ns

100ns

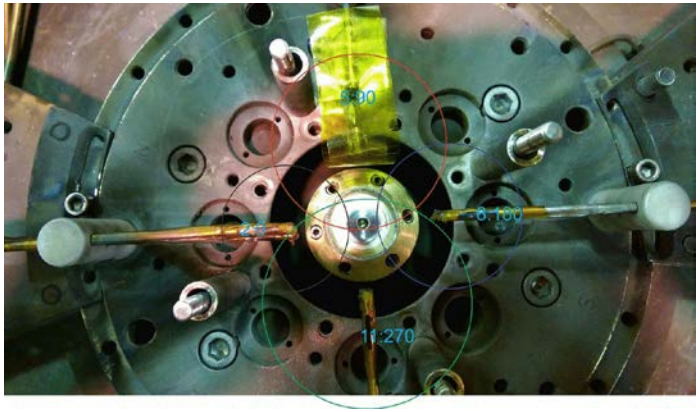
SHOT 3675

Al liner with trigger pin

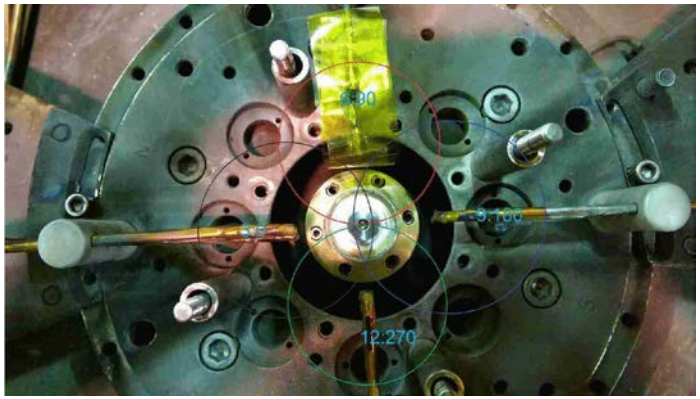
Top (1,4,7,10)

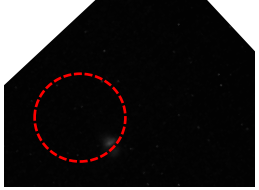


Middle (2,5,8,11)

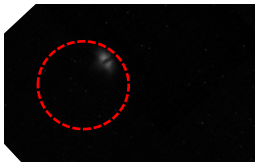


Bottom (3,6,9,12)

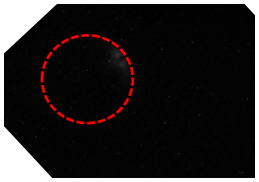




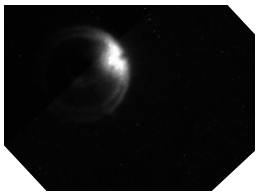
50ns



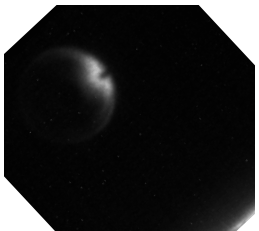
60ns



70ns



80ns



100ns

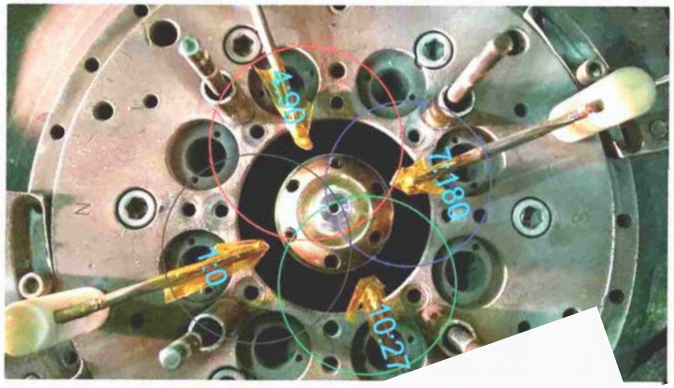
SHOT 3678

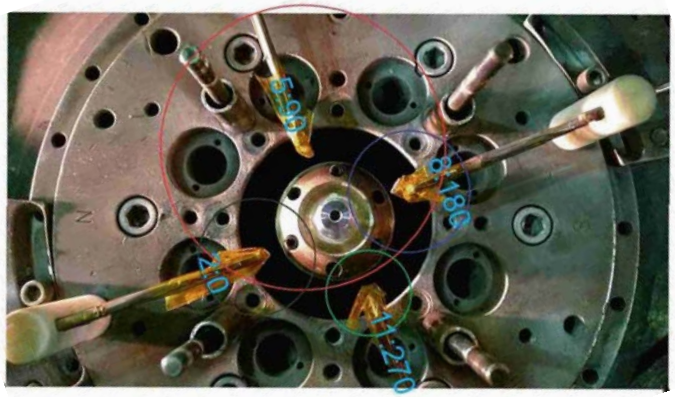
Al liner with trigger pin

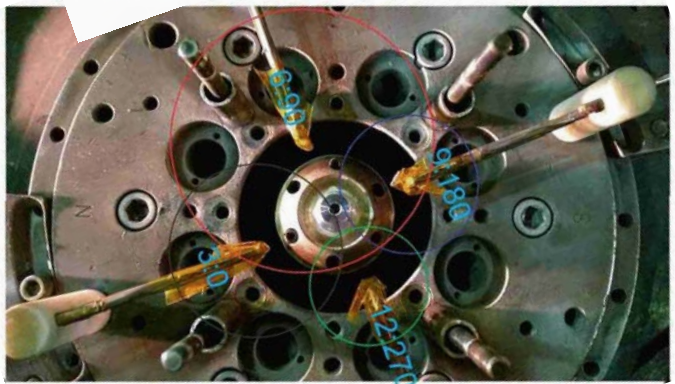
Top (1,4,7,10)

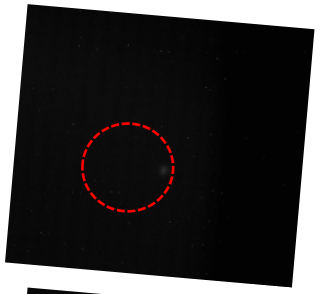
Middle (2,5,8,11)

Bottom (3,6,9,12)

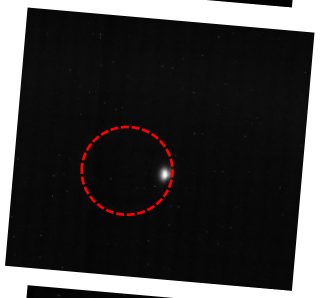




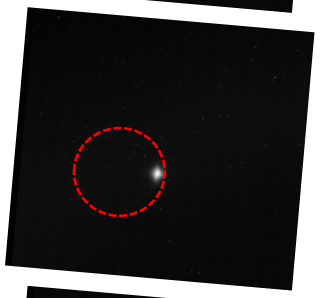




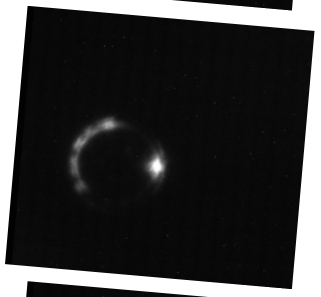
50ns



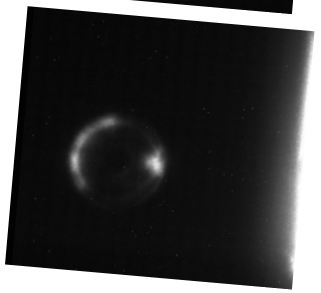
60ns



70ns

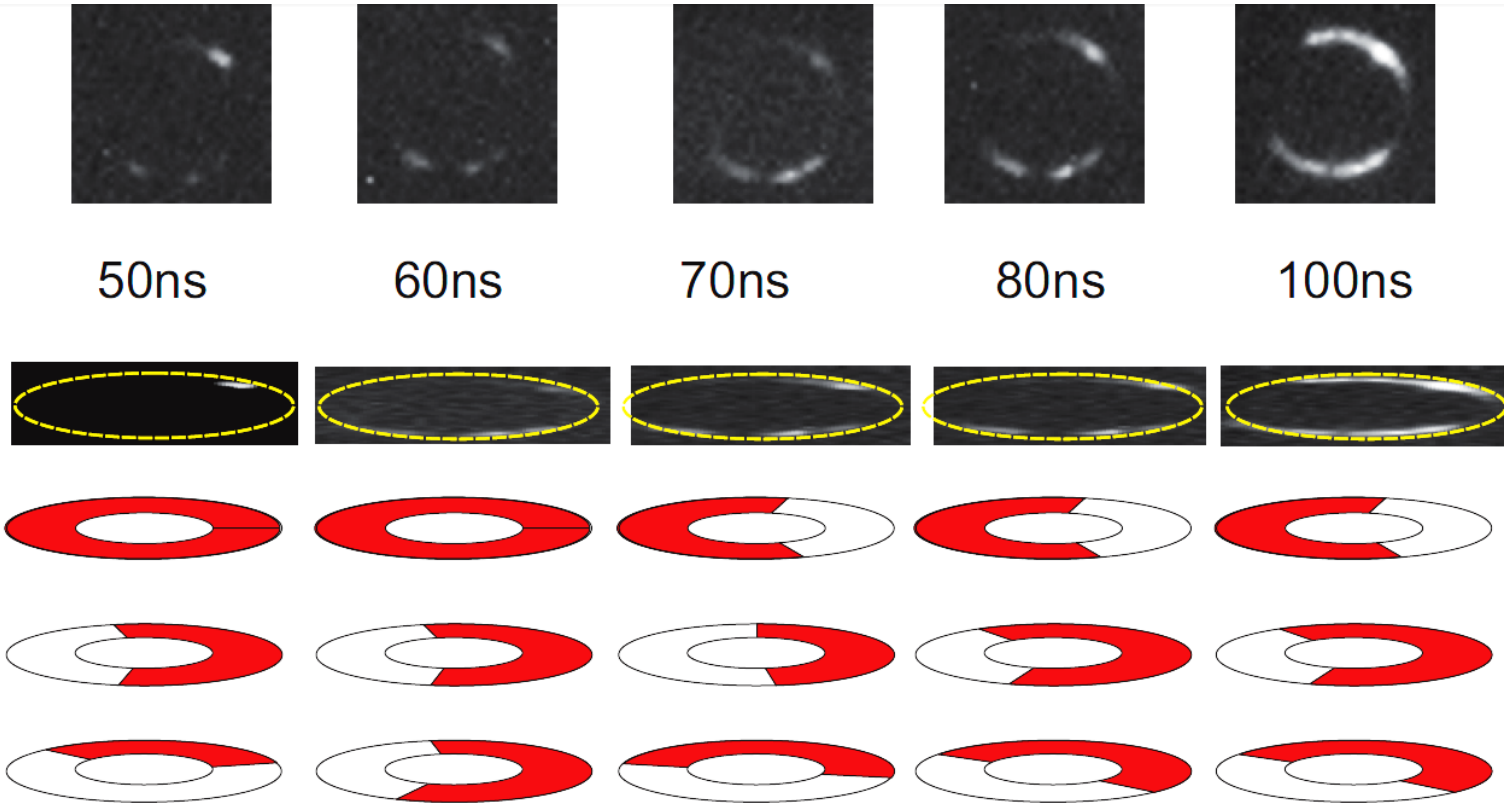


80ns

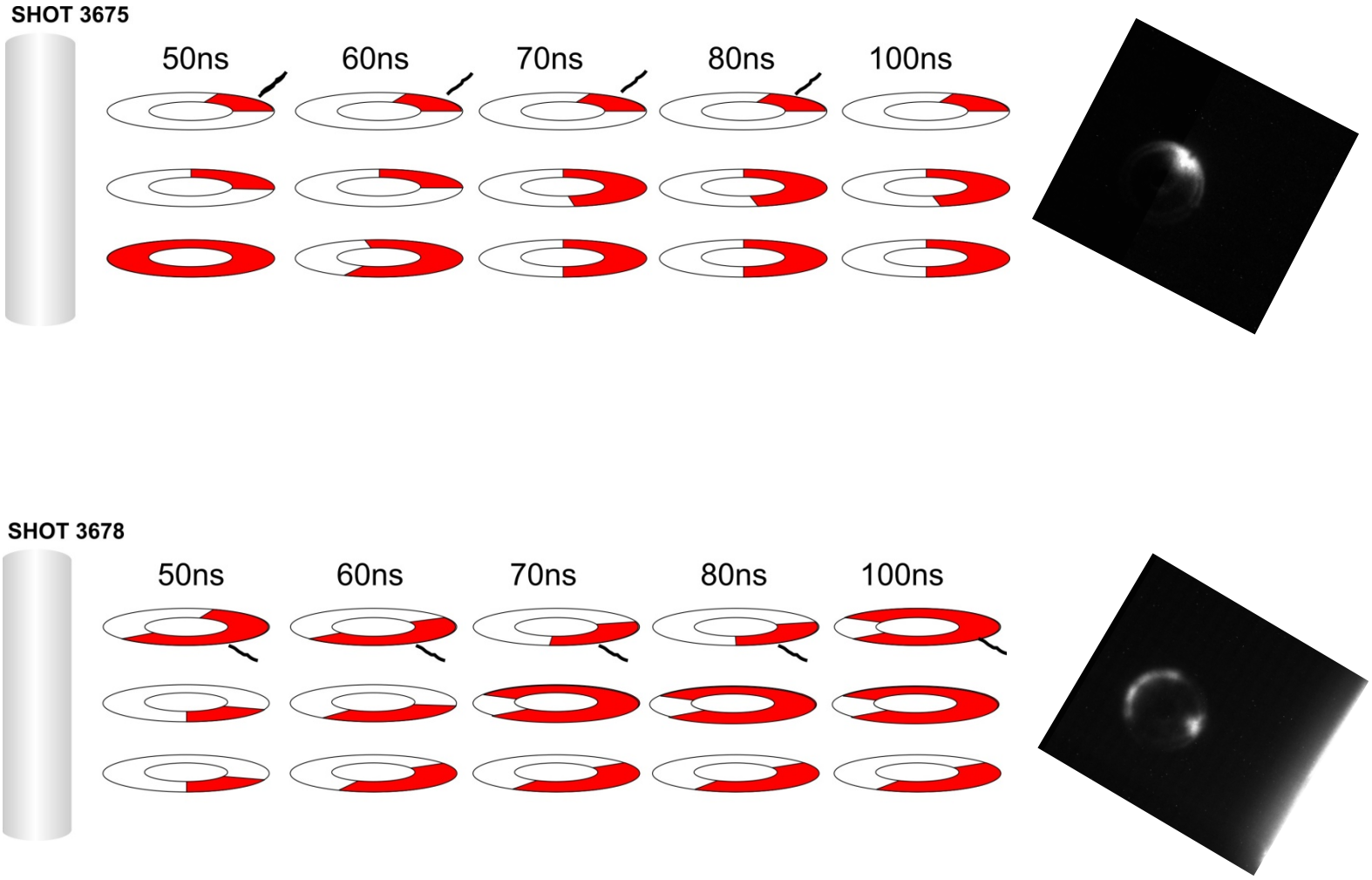


100ns

“Visualization” of the current density distribution



“Visualization” of the current density distribution



Summary

- Presence of a vacuum gap in the power feed strongly affects plasma formation, and the azimuthal uniformity of the current distribution is directly affected

- Current density is rarely uniform either azimuthally or axially for COBRA loads

- Induced asymmetry at the vacuum gap does not become evolve to uniform current density distribution over >15 mm axially in >100ns.

- Limitations of the triangulation methods
  - Does not have high spatial resolution
  - Uniform does not mean evenly distributed

Next Steps

- Simulation work using GORGON. We have a good test problem with trigger pin loads

- Upgrade UCSD current driver and reduce electrode dimensions on HV breakdown expts to drive up current density. Will highlight driving factors and allow scaling arguments