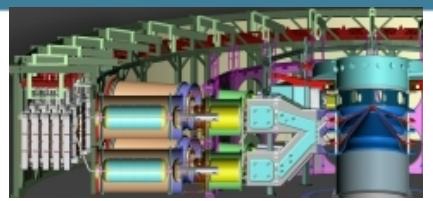
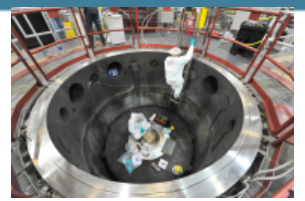
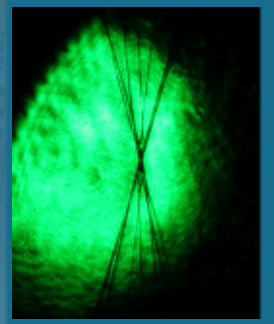
SAND2021-10150C

Sandia National Laboratories

Developing an extended convolute post to drive an X-pinch for radiography at the Z facility







Matthew R. Gomez, C.E. Myers, M.W. Hatch, B.T. Hutsel, C.A. Jennings, D.C. Lamppa, M.C. Lowinske, A.J. Maurer, A.M. Steiner, K. Tomlinson, T.J. Webb, D.A. Yager-Elorriaga, D.J. Ampleford

Presented at the 48th IEEE International Conference on Plasma Science

September 13, 2021

U.S. DEPARTMENT OF ENERGY | NNSA

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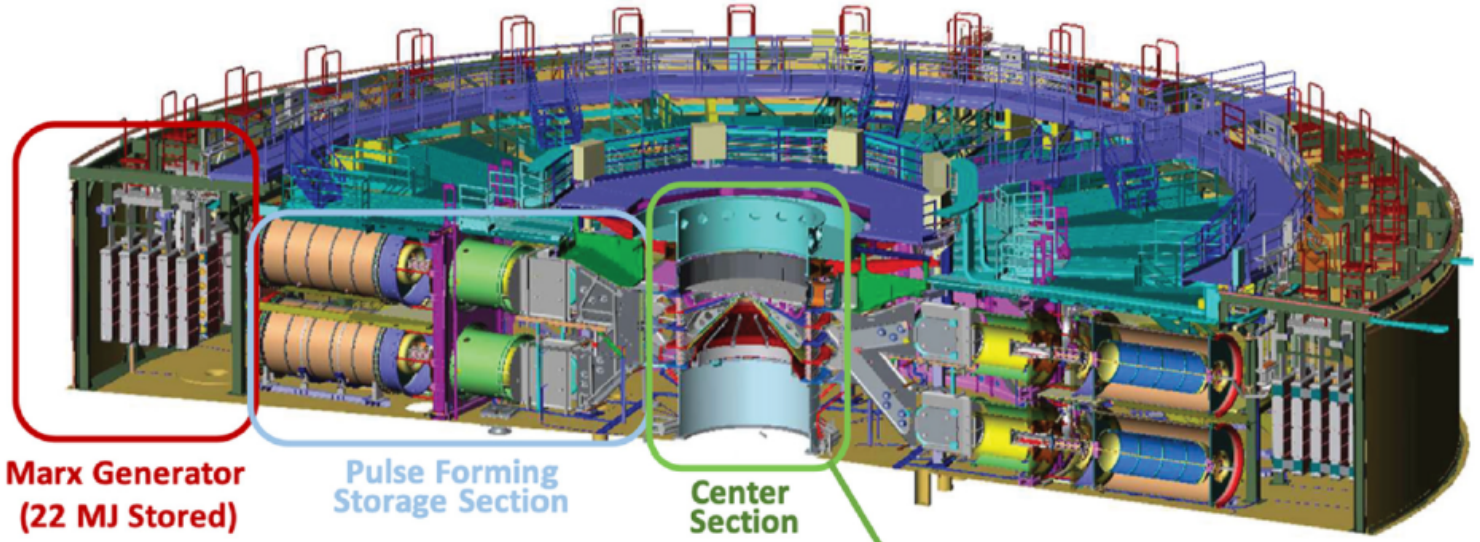
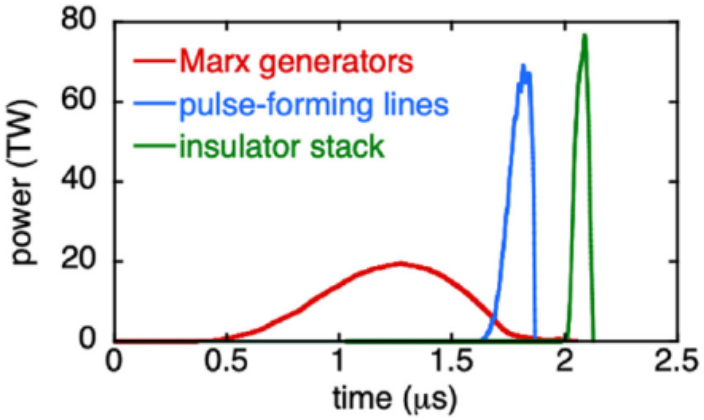
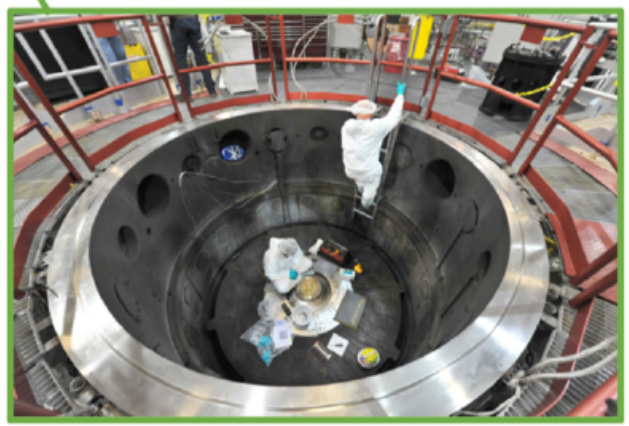
The Z facility at Sandia National Labs conducts a variety of High Energy Density Science experiments

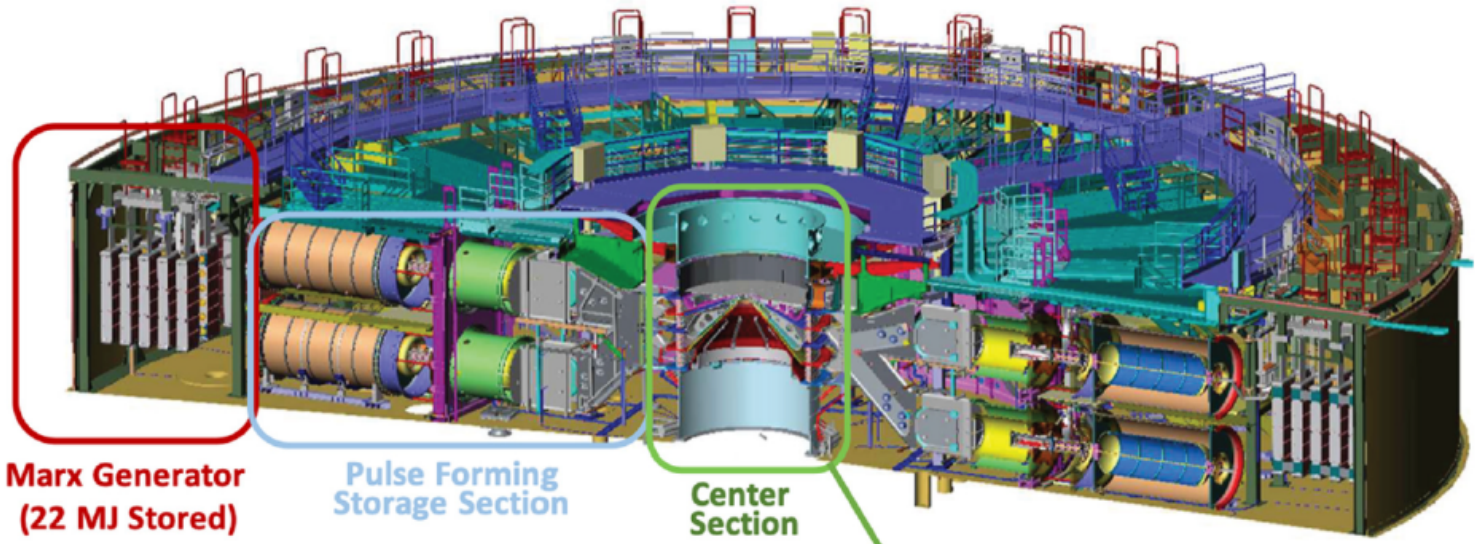


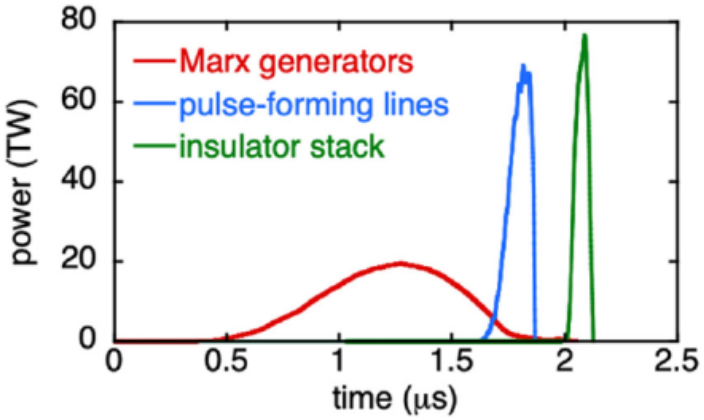


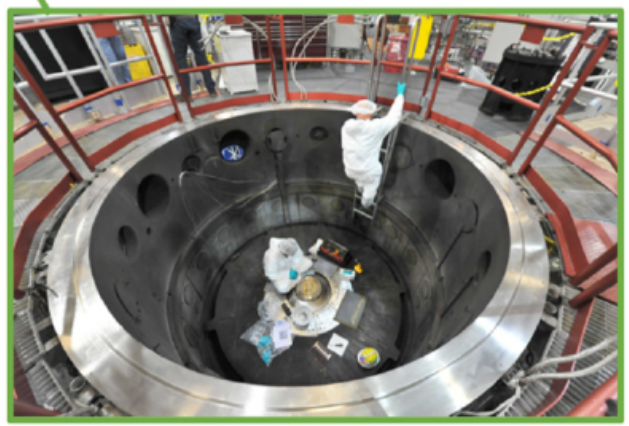


D.B. Sinars, et al., Phys. Plasmas **27**, 070501 (2020).

Radiography is a powerful tool used to diagnose these HEDS experiments

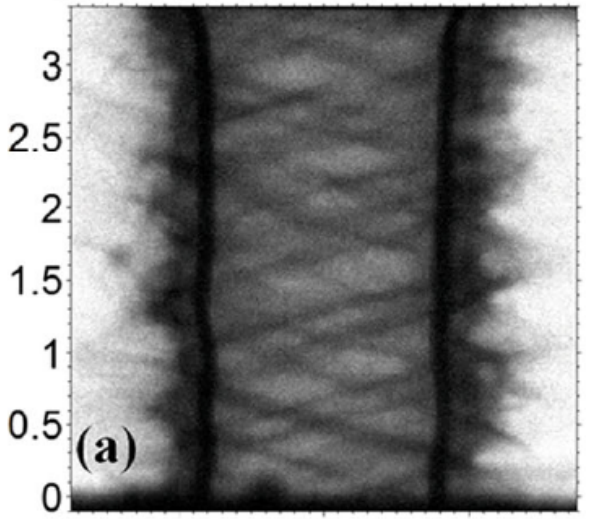






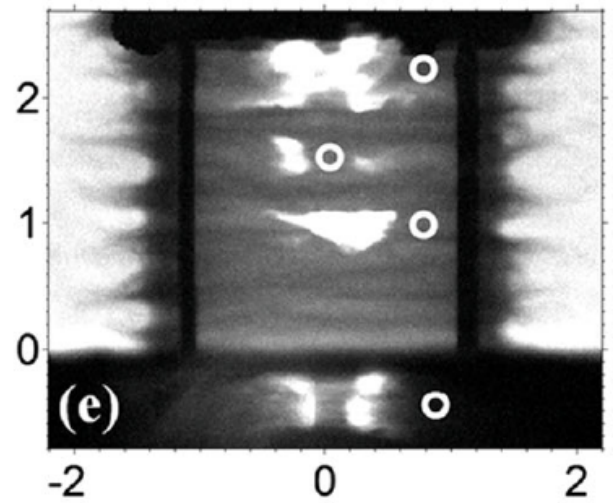
$B_{z,0}$ =7 T

Z2480-t1: *CR*= 2.7, *t*=3094.3 ns



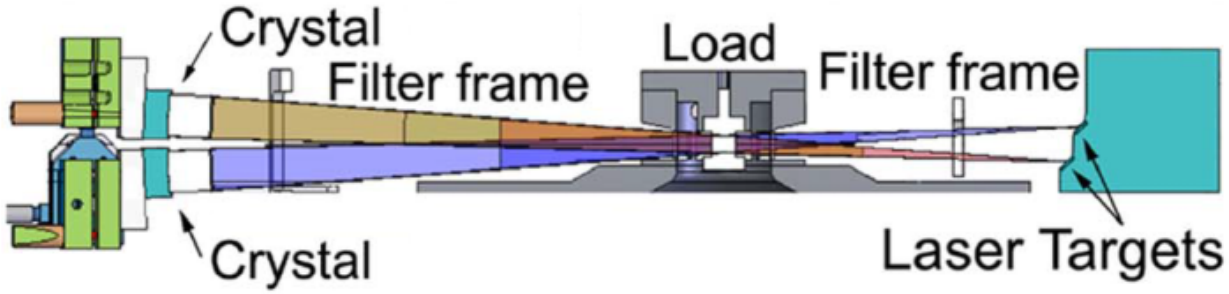
$B_{z,0}$ =0 T

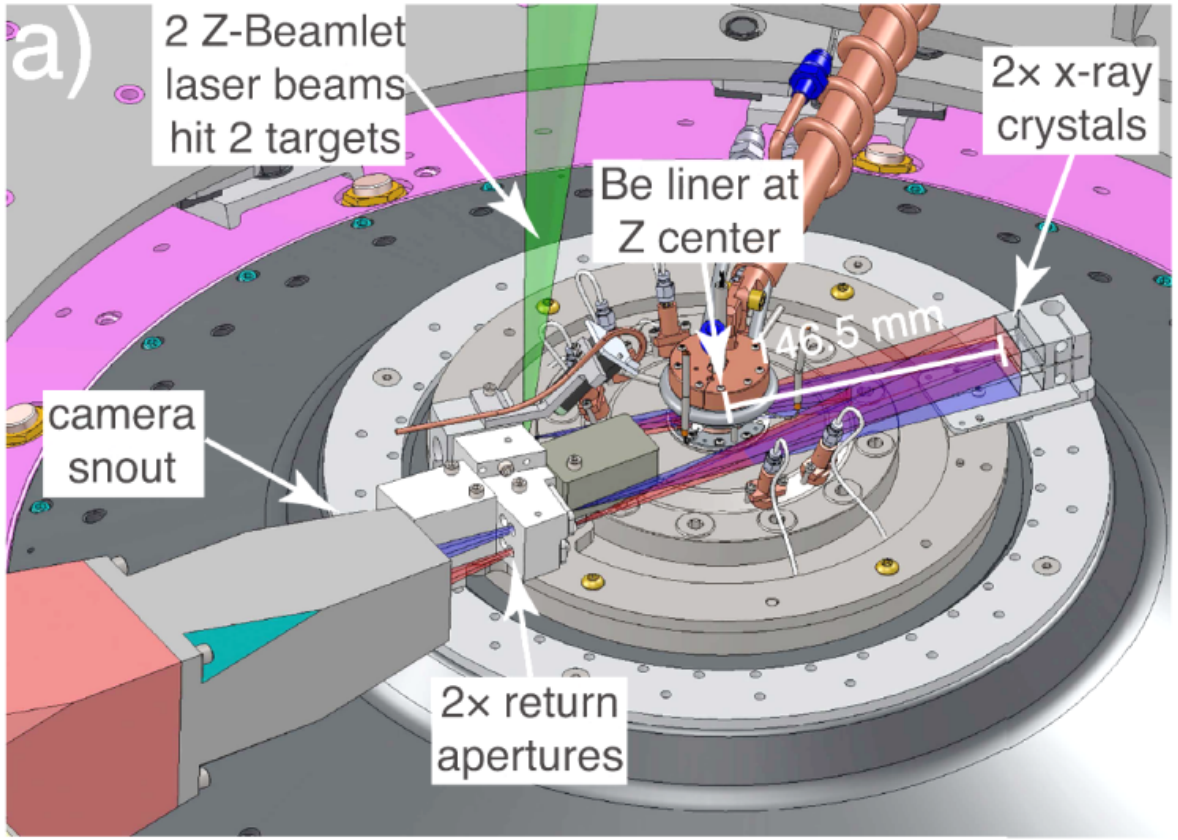
Z2465: *CR*=2, *t*=3093.2 ns



D.B. Sinars, et al., Phys. Plasmas **27**, 070501 (2020).
T.J. Awe, et al., Phys. Rev. Lett. **111**, 235005 (2013).

The Z beamlet laser is typically used to generate the x-rays for radiography at the Z facility



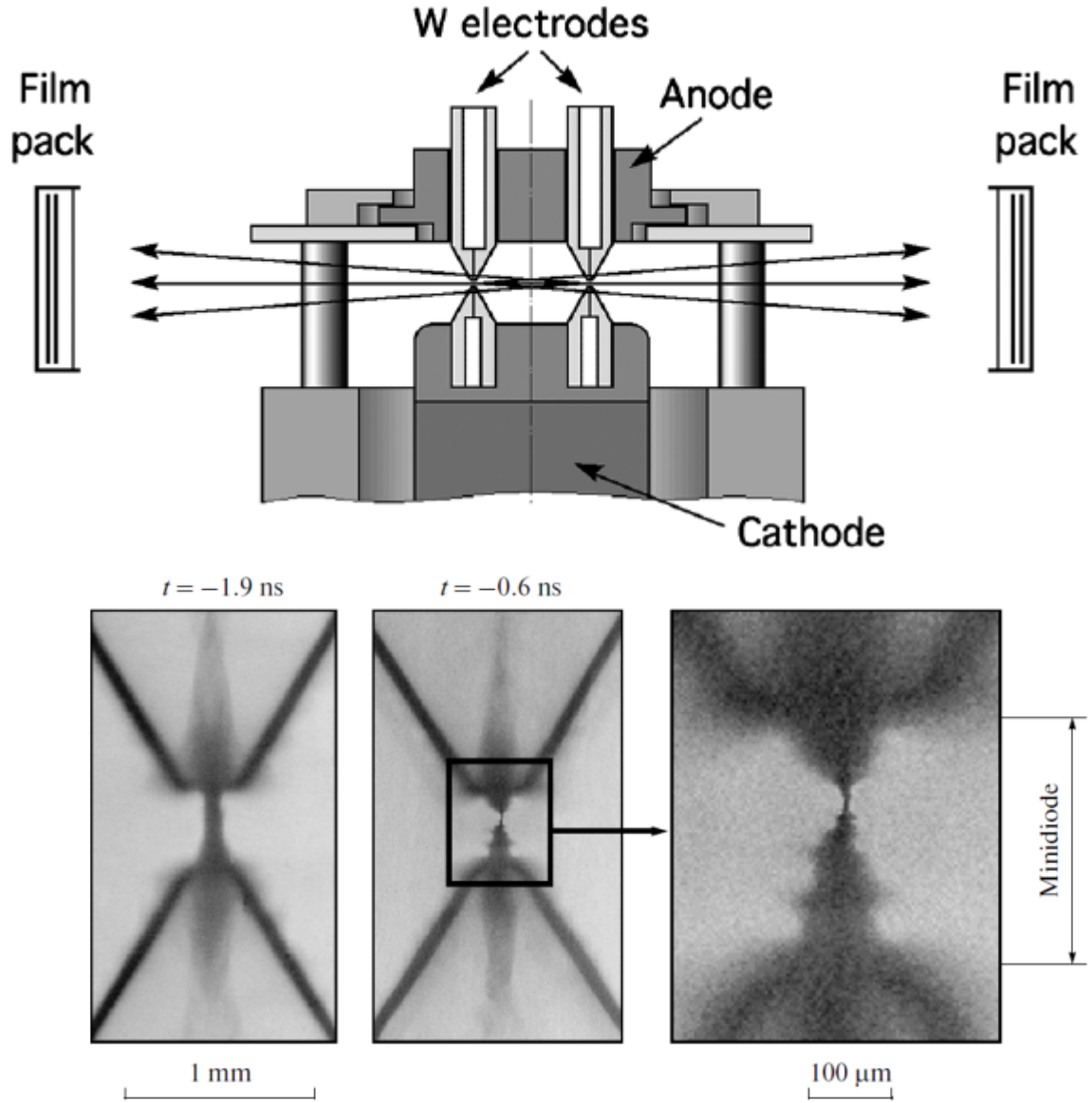


- 1 kJ laser pulse used to generate ~1 ns long x-ray source
  - Up to 2 frames along nearly the same line of sight
- Spherically bent crystal provides monochromatic image at 1.9, 6.2, or 7.2 keV
  - Magnification ~6x
- Cannot be used in MagLIF experiments since Z beamlet used for preheat

M.S. Schollmeier, et al., Rev. Sci. Instrum. **88**, 103503 (2017).
D.B. Sinars, et al., IEEE Trans. Plasma Sci. **39**, 11 pp. 2408-2409 (2011).

X-pinches have been used very effectively for backlighting on university facilities

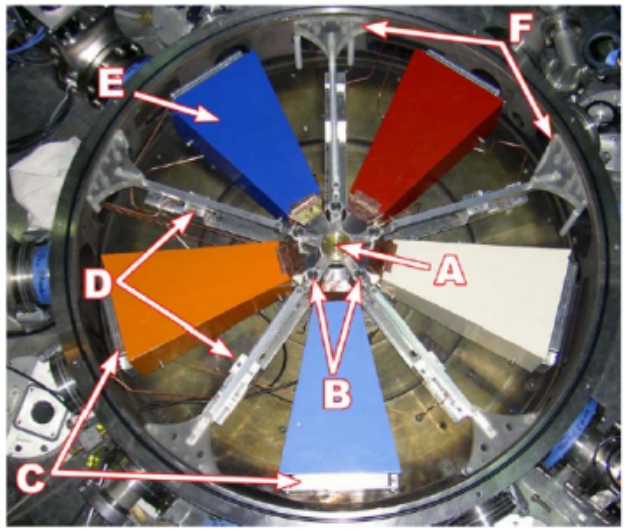
- X-pinches have been used to study themselves
  - Two pinches in parallel as the primary load
  - Each X-pinch images the other

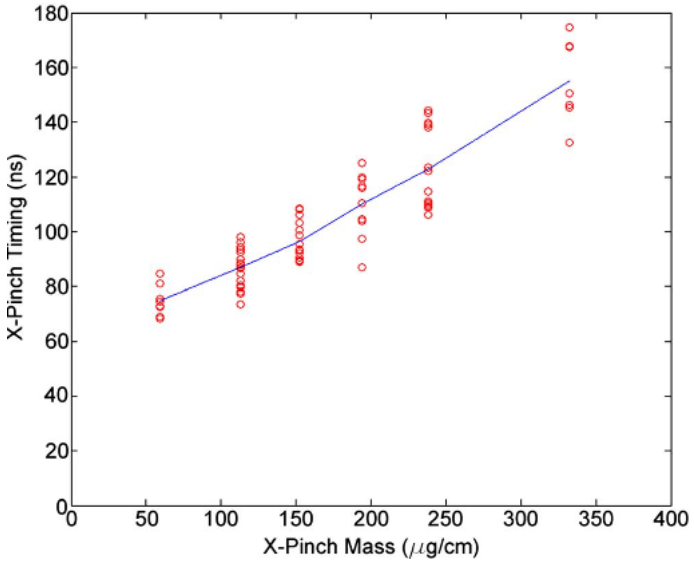


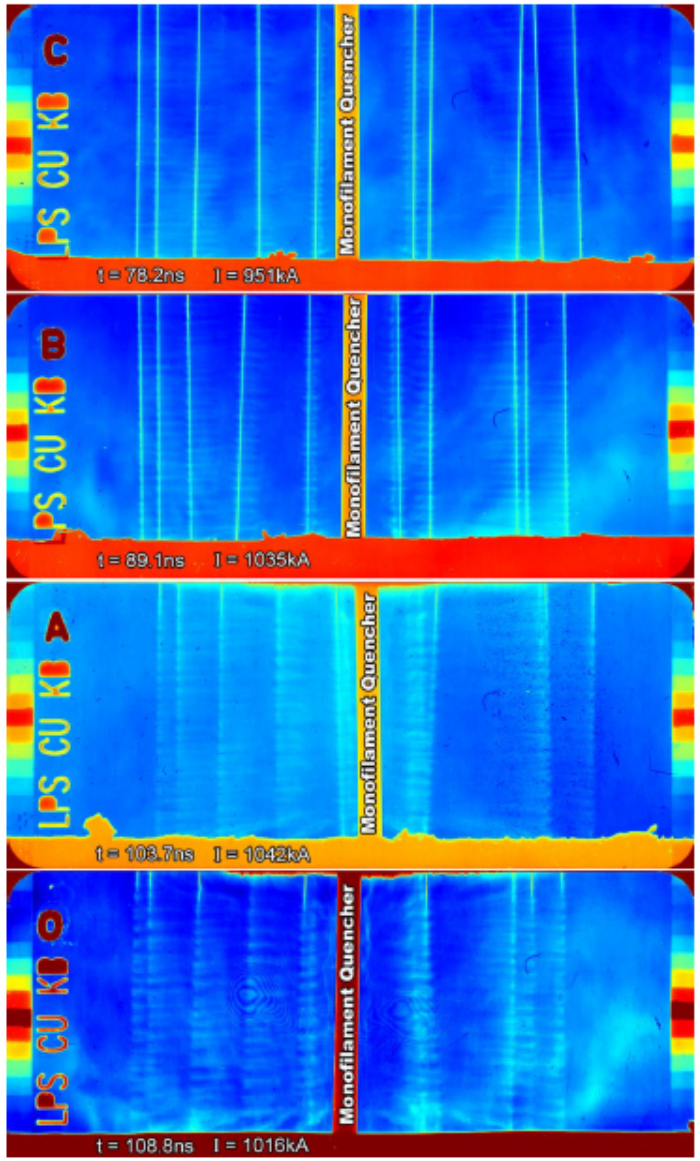
T.A. Shelkovenko, et al., Plasma Phys. Reports **38**, 5 (2012).
T.A. Shelkovenko, et al., Phys. Plasmas **17**, 112707 (2010).

X-pinches have been used very effectively for backlighting on university facilities

- X-pinches have been used to study themselves
  - Two pinches in parallel as the primary load
  - Each X-pinch images the other
- Time sequence images of the load have been obtained
  - Multiple X-pinches in different return current paths
  - Varied mass/length to shift timing

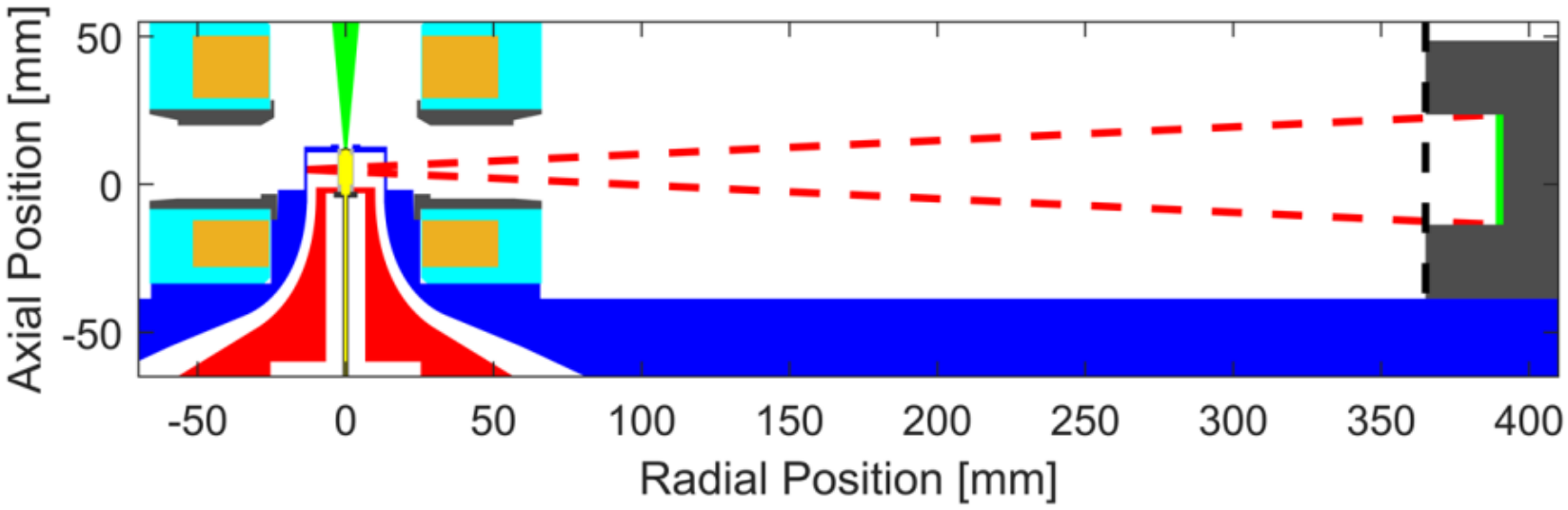




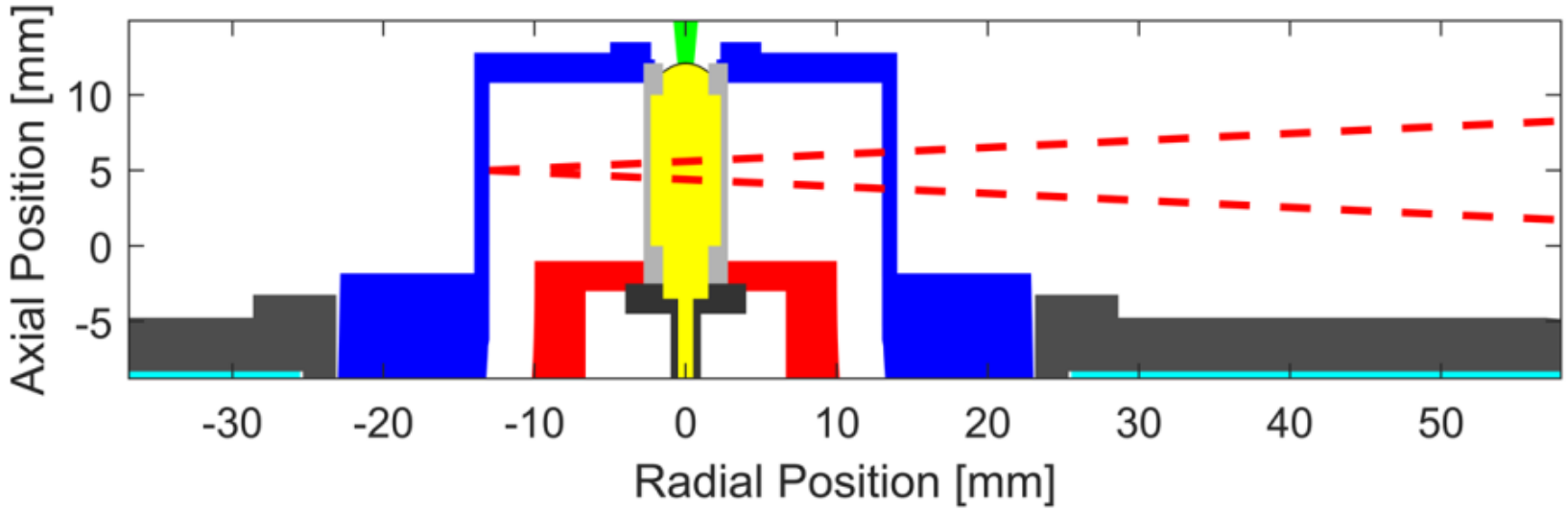


J.D. Douglass and D.A. Hammer, Rev. Sci. Instrum. **79**, 033503 (2008).

Geometric constraints have prevented the use of X-pinches for radiography at the Z facility



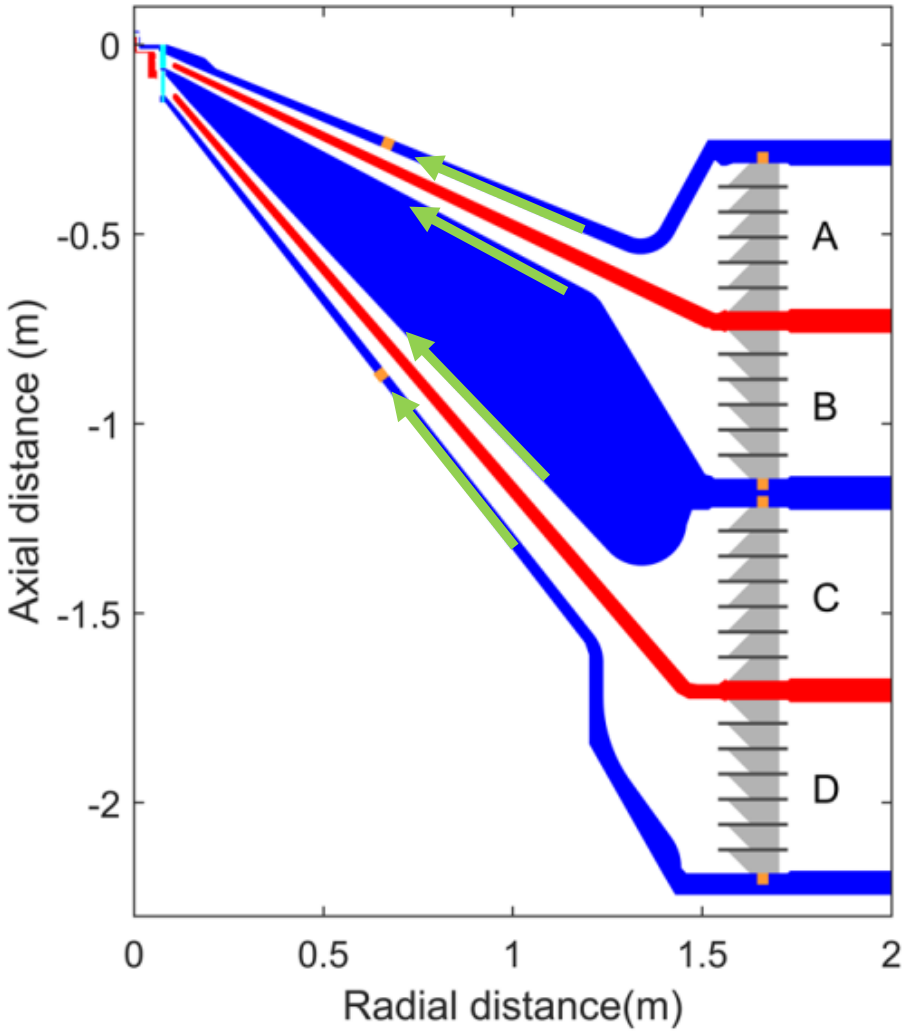
- Minimum magnification is ~30x
  - Typical return can radius = 13 mm
  - Detector located outside of blast shield >390 mm from axis



- Target size is comparable to the distance between the return can and target
  - Magnification is varying significantly throughout the target

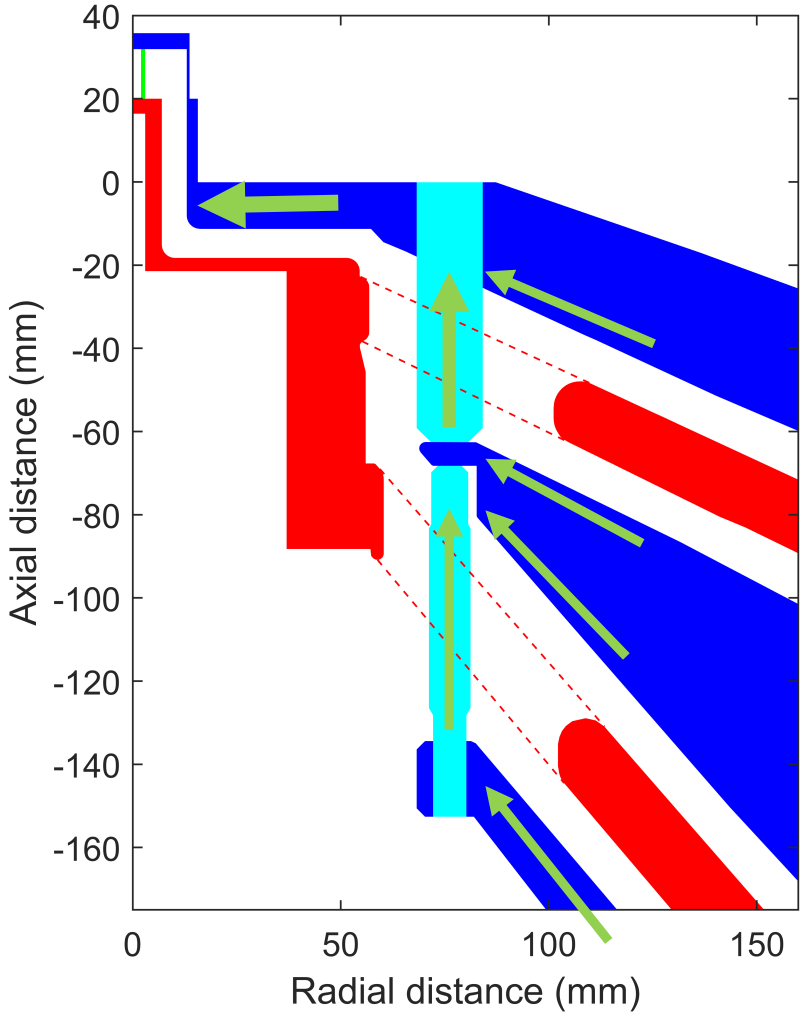
One option to introduce an X-pinch into the current path at a more ideal location is to use an extended convolute post

- Four parallel transmission lines are used on Z to reduce the inductance of the system



One option to introduce an X-pinch into the current path at a more ideal location is to use an extended convolute post

- Four parallel transmission lines are used on Z to reduce the inductance of the system
  - The double post-hole convolute is used to combine the currents from these 4 transmission lines into a single transmission line near the load



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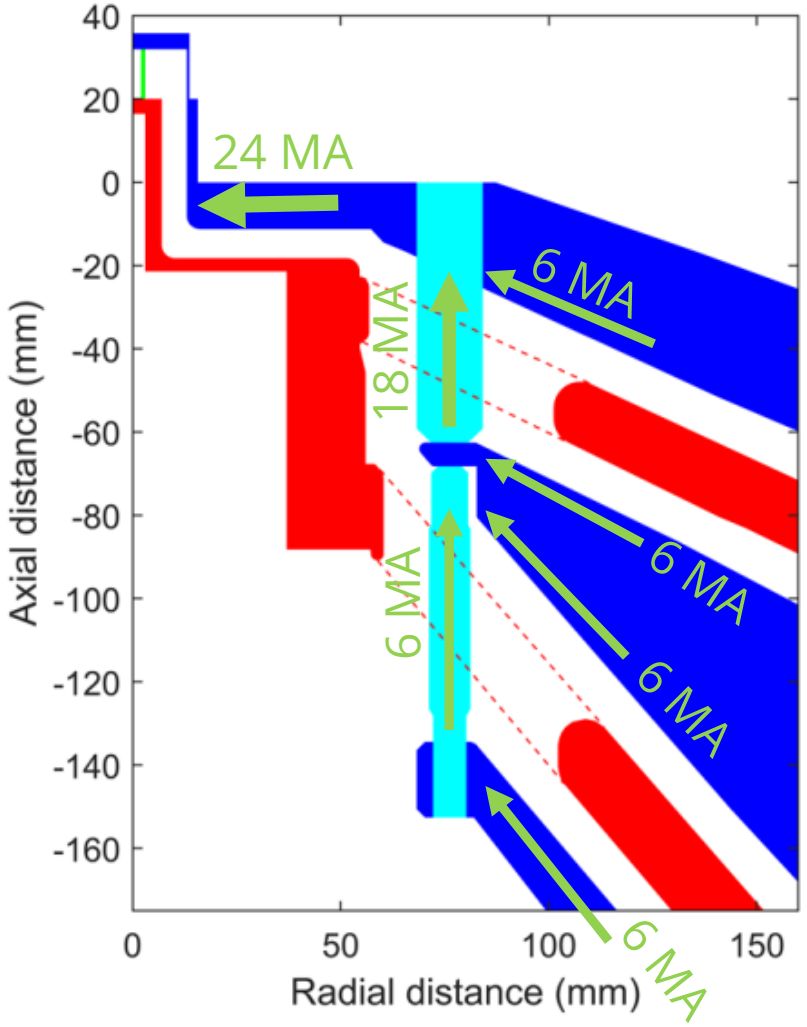
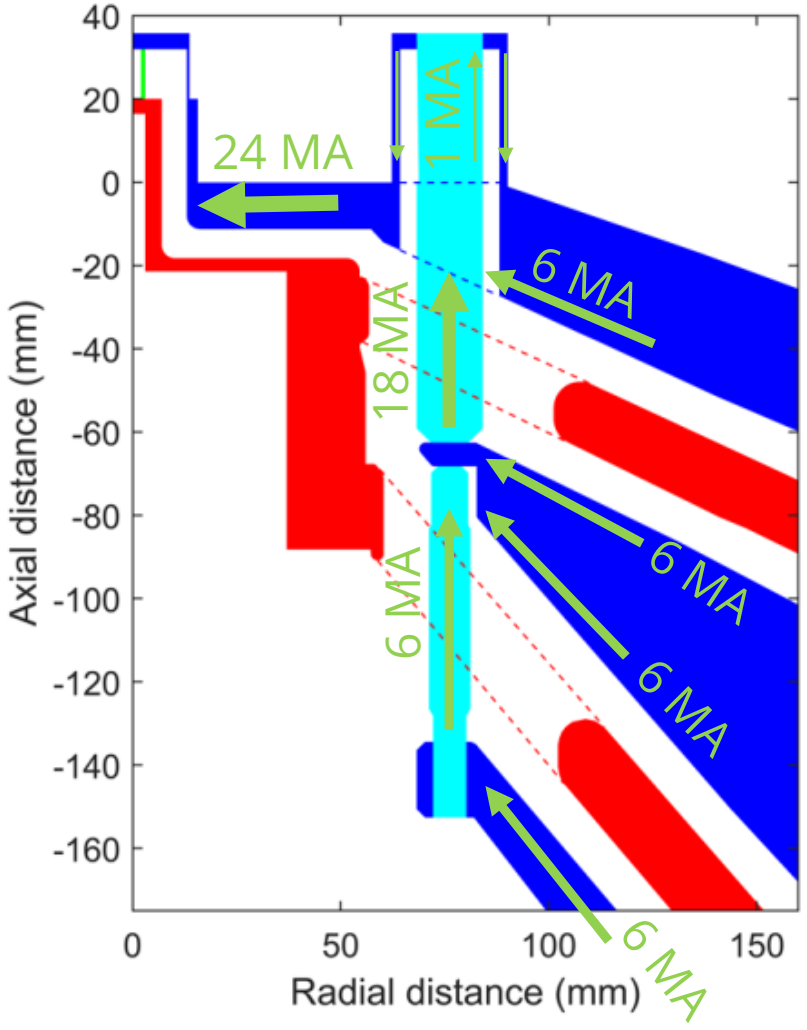
- Four parallel transmission lines are used on Z to reduce the inductance of the system
  - The double post-hole convolute is used to combine the currents from these 4 transmission lines into a single transmission line near the load
  - Assuming 24 MA evenly split between the 4 levels we have ~6 MA per level so 18 MA flows through the upper convolute posts
  - There are 12 upper posts, so there is ~1.5 MA flowing through each

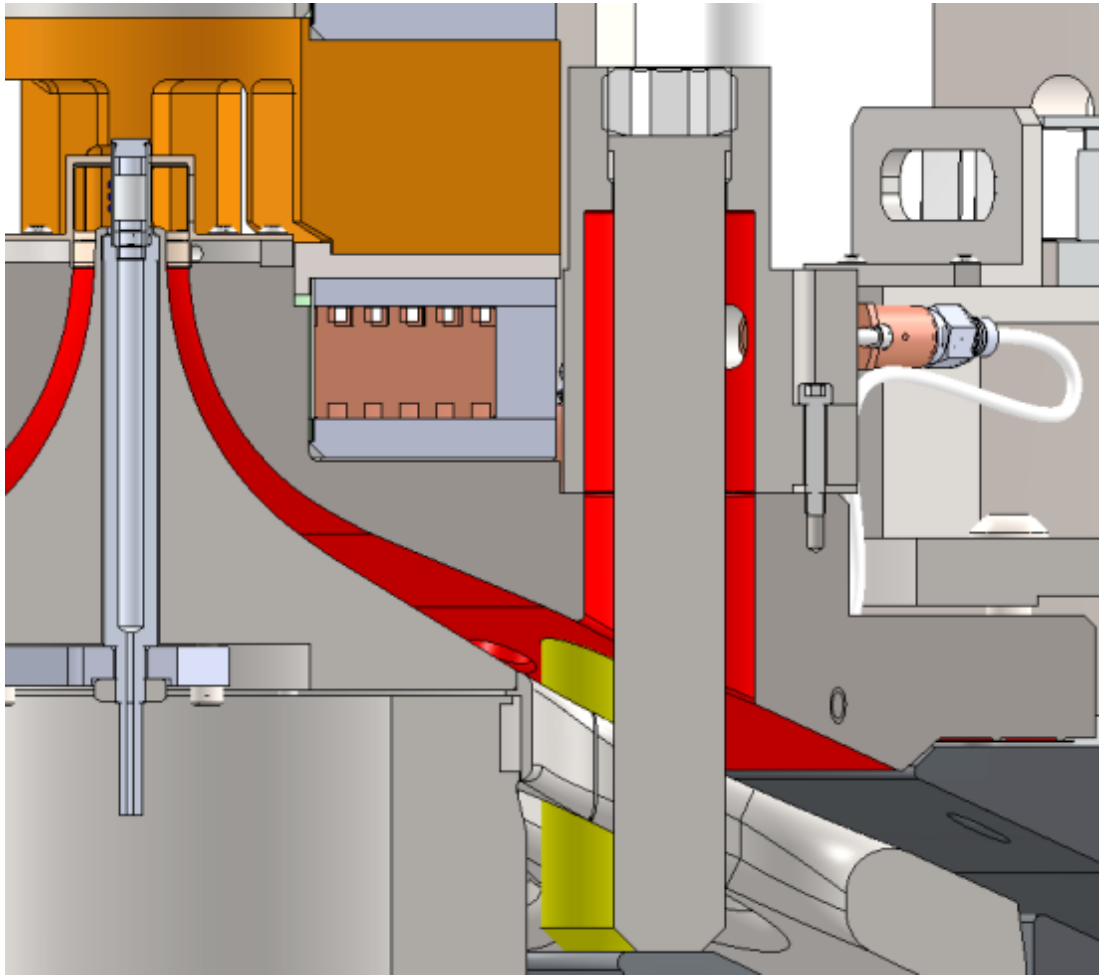


One option to introduce an X-pinch into the current path at a more ideal location is to use an extended convolute post

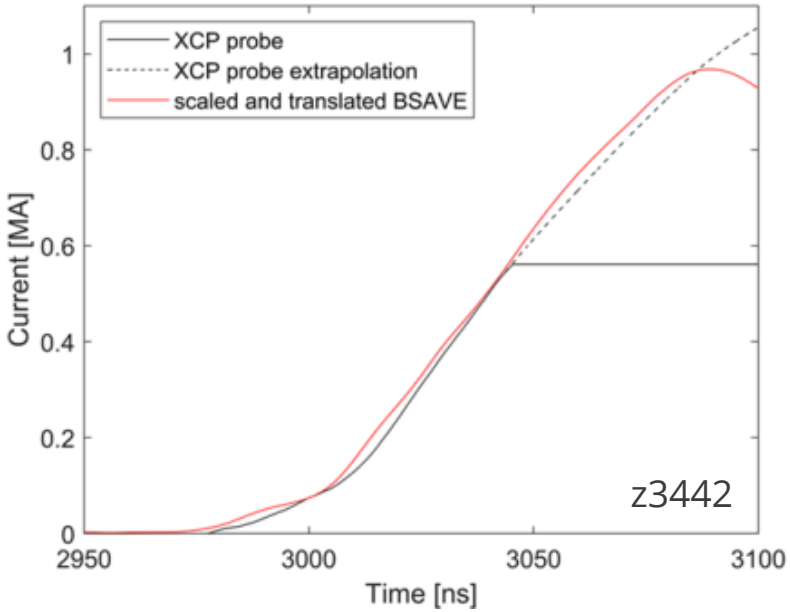
- One post can be extended through a hole in the upper anode and connected back down with a return current can
  - Extended post is in series with the primary load – current is not diverted
  - Added inductance to this post is ~6 nH, but overall change in inductance is negligible (~0.02 nH)
- The increase in inductance will reduce the current through the extended convolute post
  - Still expect ~1 MA will pass through extended post before traveling to the load
  - Other posts carry ~0.05 MA more current than normal to compensate



The extended convolute post geometry has been successfully tested on several experiments with a short circuit load

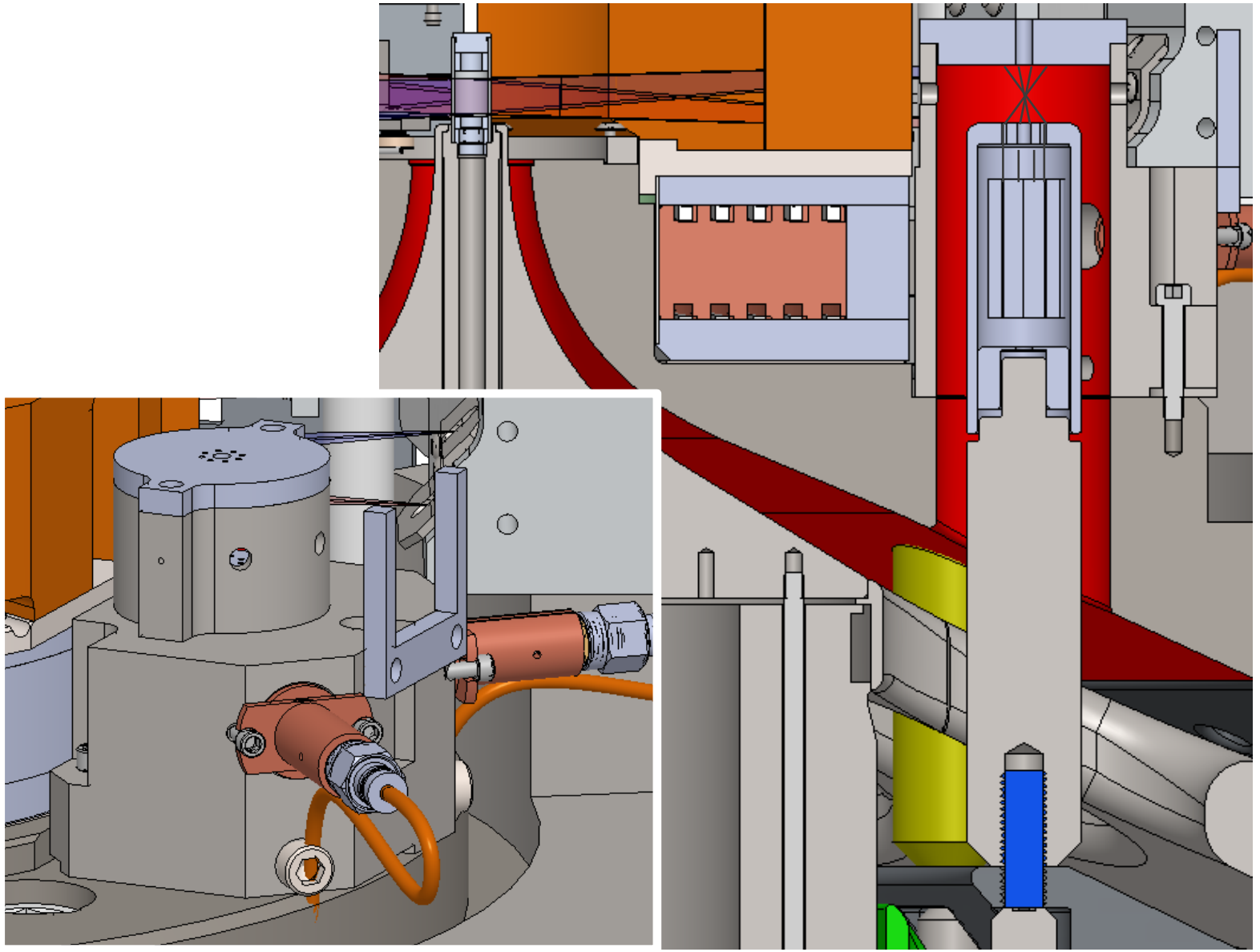


- B-dot signals from the extended convolute post (XCP) indicate the current through the extended post is comparable in shape to the stack current
- Stack current scaled by 1/25 to match amplitude of XCP signal over first half of pulse

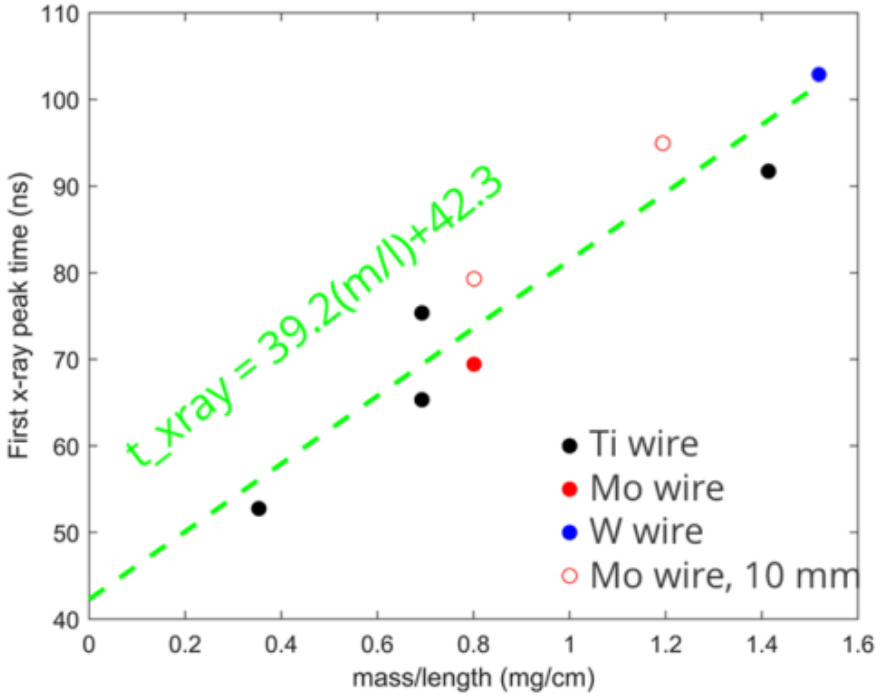


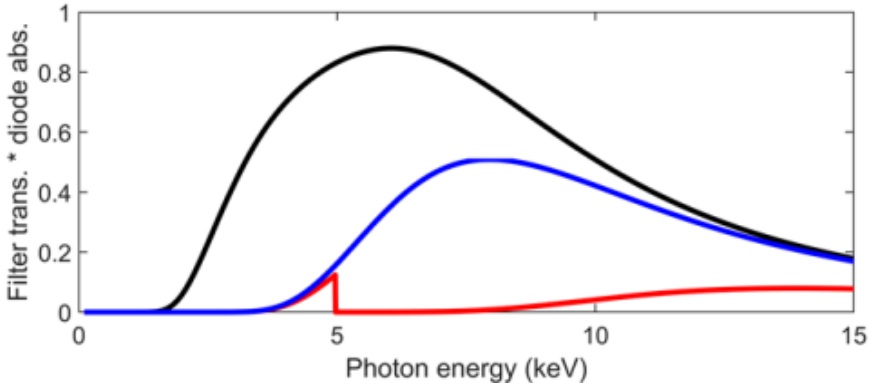
A hardware design that enables an 8-wire X-pinch to be fielded with an extended convolute post has been developed

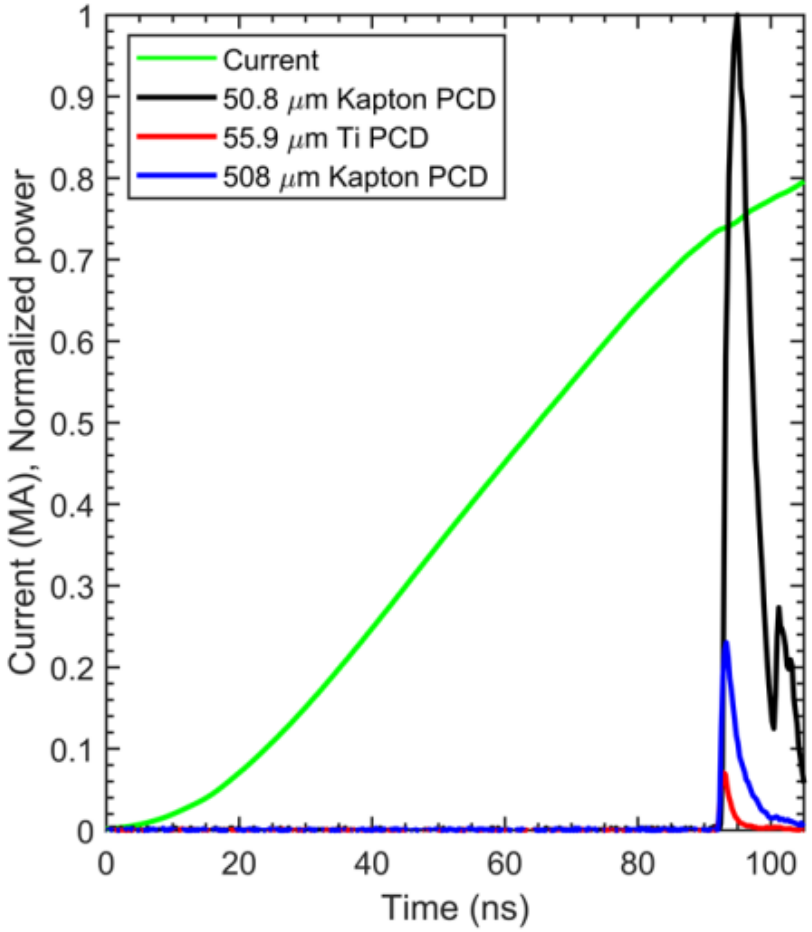
- 76 mm from source to axis
  - Mag 6-10x viable
- 8x ~40 μm diameter Mo wires
- 8 mm anode-cathode gap
- Maintaining 30 degree angle between wires and axis
- 190 degree twist to ensure contact at the cross point
- B-dots to monitor current drive



Offline testing of the X-pinch design is being conducted on the ~1 MA Mykonos pulsed power facility







- X-pinch intended to occur close to peak current
  - CR ~1.3-1.5
  - We would like to push later
- X-pinch expected to generate >2 J of >5 keV photons
  - Expect ~300-750x 5-8 keV photons per pixel
  - Comparable signal on IP with ZBL (~450x 6.2 keV photon per pixel)

Continued development of the concept and commissioning experiments are planned for the near future

- Further Mykonos testing of the X-pinch configuration is planned for Fall 2021
- The first hardware set with an X-pinch load on the extended convolute post has been designed and ordered
  - We hope to test this configuration in the next year
  - If successful, we can consider quasi-orthogonal imaging in the future with multiple extended convolute posts
- We are considering ways to push the X-pinch timing later in the pulse
  - Can we generate a useful x-ray source after peak current?
- We are also interested in applying this concept to experiments with ~300 ns rise time
  - Need to think about appropriate facilities to conduct pre-shot testing of the long pulse design
- Other methods of driving X-pinches on the Z facility are also being pursued
  - Inductively driven transmission lines: C.E. Myers, et al., Rev. Sci. Instrum. **92**, 033501 (2021).