Sandia National Laboratories

DIVERTING CURRENT TO DRIVE AN X-PINCH FOR POINT PROJECTION RADIOGRAPHY ON THE Z FACILITY

H. Hasson[1], M.R. Gomez[1], K. Chandler[1], C.E. Myers[2], C.A. Jennings[1], B.T. Hutsel[1], A.M. Steiner[1], K. DeZetter[1], M.W. Hatch[1], D.A. Yager-Elorriaga[1], P. Reyes[1], T.J. Webb[1], D.C. Lamppa[1], R. Obregon[1], M.C. Lowinske[1], J. Hargrove[1], D.J. Ampleford[1], J. Schwarz[1]

[1]*Sandia National Labs, Albuquerque, NM 87185, USA*
[2]*Commonwealth Fusion Systems, Devens, MA 01434, USA*

X-pinches as diagnostics

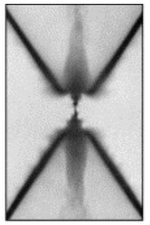

Fig.1 X-pinch mid-pinch. Pikuz et al. 2001

X-pinches are loads typically consisting of 2 or more wires that cross at a point. When current pulse with $dI/dt > 1$ kA/ns [1] is applied, the cross-point undergoes a magnetically-driven pinch that creates a T~1 keV hotspot that generates a ~1 J x-ray burst [1]. The x-rays from the burst can be leveraged for point-projection or monochromatic crystal radiography.

By tuning the material and mass/length of the wires, we may manipulate the timing and photon energies of the x-rays emitted.

Power flow geometry

We propose to add an x-pinch to the convolute post (fig. 2) connecting the lower anodes to the top anode. By extending the post past the top anode, we can add an x-pinch in the jutting path that can produce x-rays for imaging the load (at center).

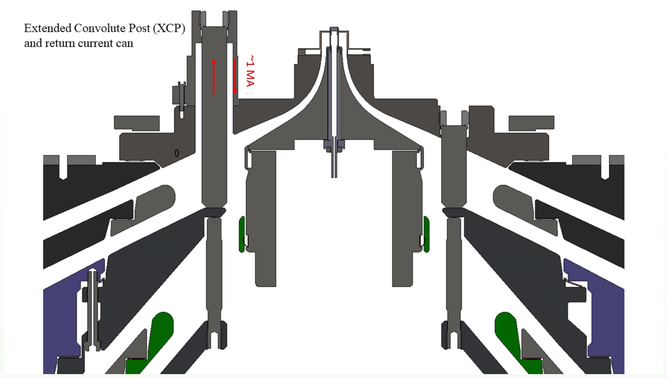

Fig. 2 Cross-section of Z machine center section transmission lines with extended convolute post for x-pinch.

Comparison to ZBL radiographs

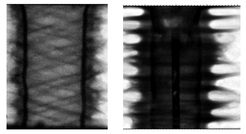

Fig.3 ZBL radiographs of MagLIF shots. Awe et al. 2013

ZBL radiographs	X-pinch radiographs
Monochromatic	Continuum or monochromatic
Spherical crystal imaging	Point projection or crystal imaging

X-pinch radiography would allow radiographs for shots where the ZBL laser is used to drive the experiment, such as MagLIF.

- ZBL can produce radiographs with about **450 photons/pixel** by shooting Mn to produce E~6.15 keV photons.
- Ti x-pinches can produce 1.4-3.9 J yields of K-shell He-α radiation [2].
- Estimating ≈ 2 J at the He-α resonance line (4.75 keV), we get 2.6e15 photons.
- If our image plate has a solid angle of 4.58e-11 from the x-ray hotspot, we get **~220 photons/pixel with a 1.5 mm Kapton filter.**

Optimization campaign

We used the ~1MA, 150ns-rise Mykonos driver [3] at Sandia to test a variety of wire compositions, thicknesses and configurations to find how we could affect
1) the yield in the first x-ray burst and
2) the timing of the first x-ray burst

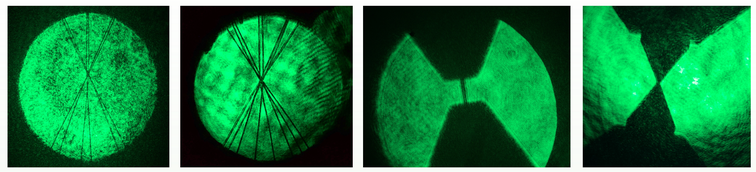

Fig. 4 Shadowgraphs of x-pinch configurations tested. The machined x-pinches yielded no x-rays and thus do not appear in data analysis.

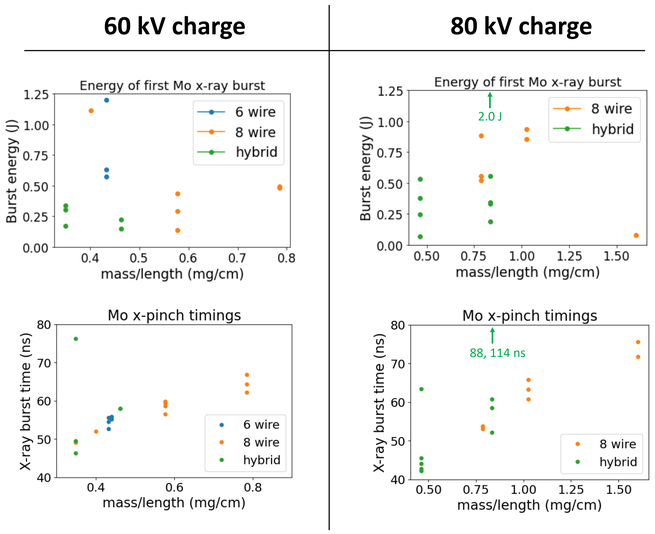

Fig. 5 First x-ray peak energies (top row) and timings relative to the current pulse (bottom row) as a function of mass/length for two machine charging voltages.

Z ride-along tests

On 2/10/2023, we obtained a successful test radiograph on the Z Machine by imaging a tungsten mesh. The image had 24.3x magnification, imaging a mesh of 20 μm diameter wires with 150 μm wire-to-wire spacing.

A projectile broke through the filters and damaged the image plate.

Going forward we will attempt:
- Radiographing MagLIF loads
- Obtaining x-pinch spectra
- Modifying detector filtration & baffle

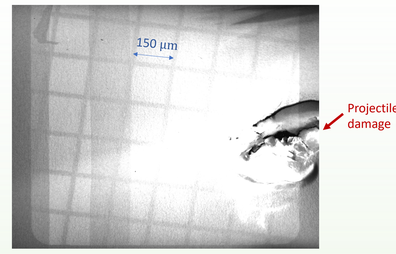

Fig. 6 X-pinch radiograph of W wire grid

References:
1. Shelkovenko et al. (2018). Evolution of X-pinch loads for pulsed power generators with current from 50 to 5000 kA. Matter and Radiation at Extremes, 3(6), 267-277.
2. Hoyt, C. (2015). Noncollective X-Ray Thomson Scattering Diagnostic Development Based On A Titanium Hybrid X-Pinch X-Ray Source.
3. Mazarakis, M. G. et al. (2011, June). Experimental validation of the first 1-MA water-insulated MYKONOS LTD voltage adder. In 2011 IEEE Pulsed Power Conference (pp. 625-628). IEEE.

U.S. DEPARTMENT OF ENERGY
National Nuclear Security Administration

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

SAND2024-04679C

Sandia National Laboratories