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DEVELOPMENT AND OPTIMIZATION OF AN X-PINCH RADIOGRAPH CAPABILITY FOR THE Z MACHINE

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Radiography with X-pinches

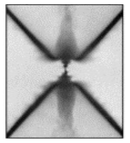


Fig.1 X-pinch mid-pinch. Pikuz et al. 2001

X-pinches are loads of typically 2 or more wires that cross at a single 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.

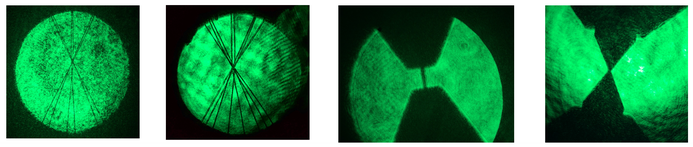
Using x-pinches as radiography sources on the Z Machine would allow radiographs to be taken on shots when the ZBL laser is used to drive the experiment (i.e. for MagLIF).

Point-projection radiography study

We used the 150ns-rise Mykonos driver [2] with a 650 kA peak current to test a variety of wire compositions, thicknesses and configurations to find how we could affect

1) The broad-spectrum yield in the first x-ray burst and
2) the timing of the first x-ray burst

We tested 4 different configurations of x-pinches



6 wire cross-wire x-pinches | 8 wire cross-wire x-pinches | hybrid x-pinches (single wire) | machined x-pinches

Fig. 2 Shadowgraphs of x-pinch configurations tested. The machined x-pinches yielded no x-rays and thus do not appear in data analysis.

We found a clear trend in the Mo x-pinch timings, but did not observe a trend in the energy of the first x-ray burst

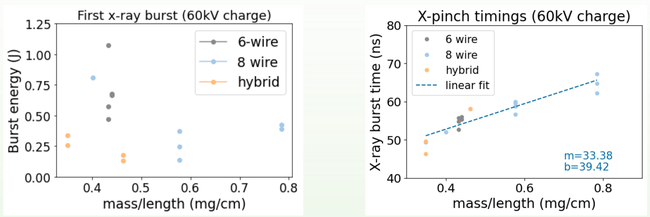


Fig. 3 First x-ray peak energies (left) and timings relative to the current pulse (right) as a function of mass/length for different configurations of Mo x-pinches.

Z ride-along tests

We added an x-pinch to the convolute post (fig. 4) 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).

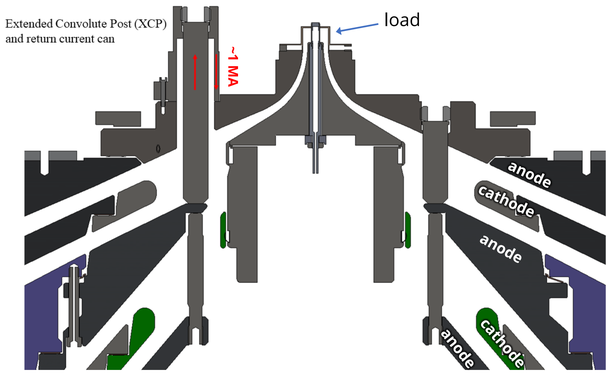


Fig. 4 Cross-section of Z machine center section transmission lines with extended convolute post for x-pinch.

- We have captured 2 test radiographs by imaging a W mesh
- Images had 24.3x magnification, imaging a mesh of 20 μm diameter wires with 150 μm wire-to-wire spacing.

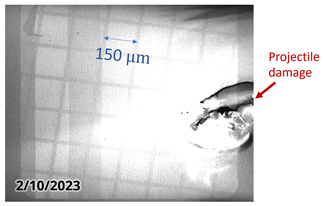


Fig. 5 X-pinch radiograph of W wire grid

However,
- the load's x-ray output overwhelmed the x-pinch back-lighter (thus no target radiograph)
- debris often hit image plates.

Spherical crystal imaging is likely the best option going forward

X-pinch line emission study

In August 2024 we used Mykonos again to look at crossed-wire x-pinches of 2 alloys with candidate lines for spherical crystal imaging:

MP35N – 35% Ni, 34% Co, 21% Cr, 10% Mo

Stablohm 710 – 70% Ni, 30% Cr

We tested iterations of 3-8 wires with varying thickness in the x-pinches, looking to maximize and characterize K-α and He-α line outputs.

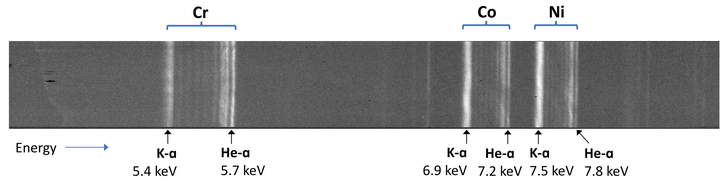


Fig. A sample image of a TIXTL spectrum from an 8-wire MP35N x-pinch.

Again the Mo x-pinch timings were correlated but not the energy of the first x-ray burst

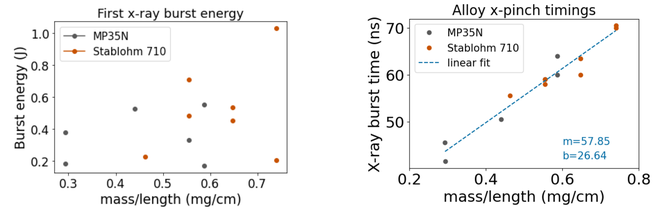


Fig. First x-ray peak energies (left) and timings relative to the current pulse (right) as a function of mass/length for two different alloy wire materials.

From 10 shots with high quality spectra we found:
- The Ni K-α line was the brightest line on 90% of shots
- the Cr K-α>He-α on 50% of shots and Ni K-α>He-α on 90% of shots
- The variation in intensity across all K-α and He-α lines in a shot was on average 24%, so we can pick any of the lines with a similar assumed intensity

We consider the crystal-line combinations from these x-pinches with similar reflection angles (~83°) that could be used for a spherical imager

ZBL foil line	Spherical crystal used [3]	X-pinch emission lines	Spherical crystal options
Si He-α 1.865 keV	Quartz (1 0 1)	**Cr K-α, He-α** 5.415, 5.682 keV	Si (2 2 4)
Mn He-α 6.151 keV	Quartz (2 2 3)	**Co K-α, He-α** 6.930, 7.242 keV	Ge (3 3 5), GaAs (3 3 5), Si (2 0 6)
Co He-α 7.242 keV	Ge (3 3 5)	**Ni K-α, He-α** 7.478, 7.806 keV	Quartz (3 1 5) & (2 4 0)

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2. 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.
3. Schollmeier, M. S. et al. (2017). A 7.2 keV spherical x-ray crystal backlighter for two-frame, two-color backlighting at Sandia's Z Pulsed Power Facility. *Review of Scientific Instruments*, *88*(10).