A new compact Plasma Radiation Source at IAC: **X – Pinch Diagnostics**

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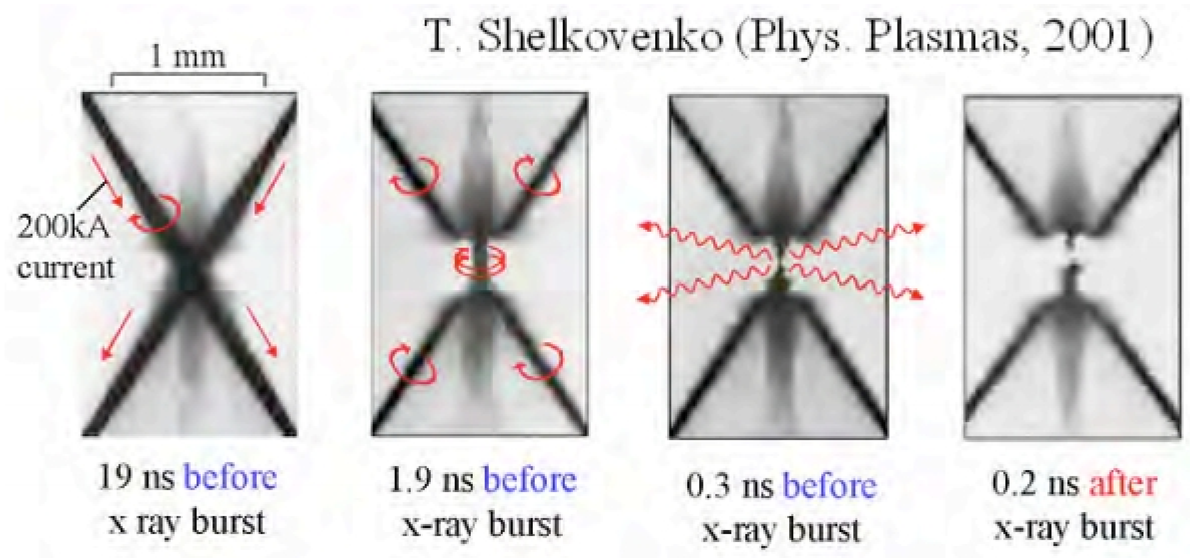
Outline

1. X–Pinch and X-Ray radiation
2. Motivation for X – Pinch diagnostics at IAC
3. Possible X - ray diagnostics (Δt, Δl, ΔE, dose)
4. Load monitoring (I and V)

X–Pinch and X-Ray radiation

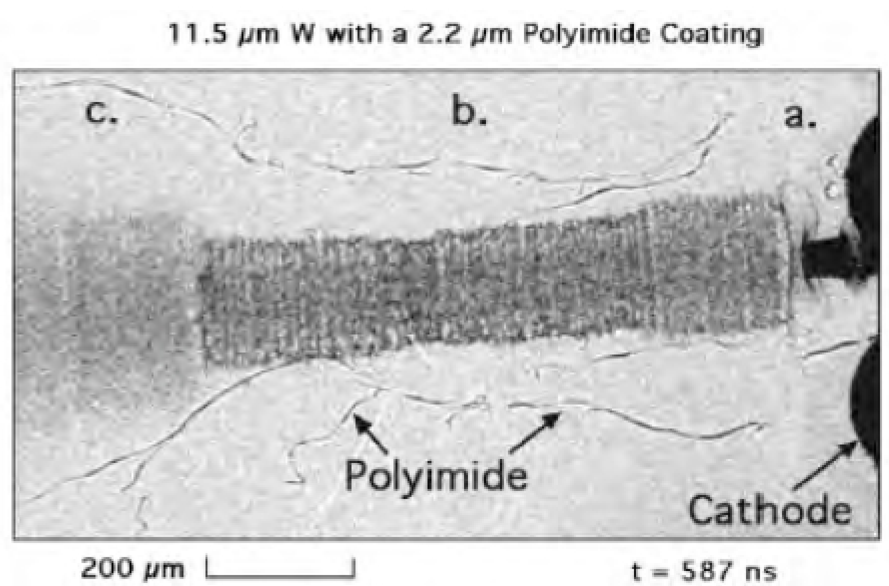


* two or more 5 – 100 um metal wires crossed at one point

* 100 – 300 kA, 1 kA/ns and more

They are good for imaging

* X - Ray:
  short (5 ps – 10 ns)
  small (few um)
  bright (hundreds of mJ and more)
  XUV, SXR, HXR



Motivation for X – Pinch Diagnostic at IAC

RACL 60 “Adaptation of ISIS Induction-Cell Driver to a Low-Impedance Plasma Radiation Source Driver”

Task 1: Design and construction of PRS chamber

Task 2: Testing and refinement of PRS chamber

Task 3. Preliminary X – Pinch tests

Task 4: Assembly of radiation diagnostics.

“ …In addition to rudimentary diagnostics needed for Task 3, we will need more sophisticated diagnostics for task 5 – 7 …“

Task 5: Optimization of radiation parameters for imaging.

“Optimizing the X – Pinch for imaging requires 1) reproducibility, 2) properly matched energy band, 3) smallest possible source size, 4) highest ratio of bright spot to other radiation, and 5) in some cases shortest possible duration. …
The grantee will find optimal X – Pinch loads for low (<1keV), intermediate (1-8 keV), and high (8-20 keV) energy bands”

There are many techniques for rudimentary and advanced X – Ray diagnostics

See, for example, T. A. Shelkovenko, S. A. Pikuz, D. B. Sinars, K. M. Chandler, and D. A. Hammer
“X Pinch Plasma Development as a Function of Wire Material and Current Pulse Parameters”

XP pulser at Cornell
470 kA peak current
100 ns FWHM

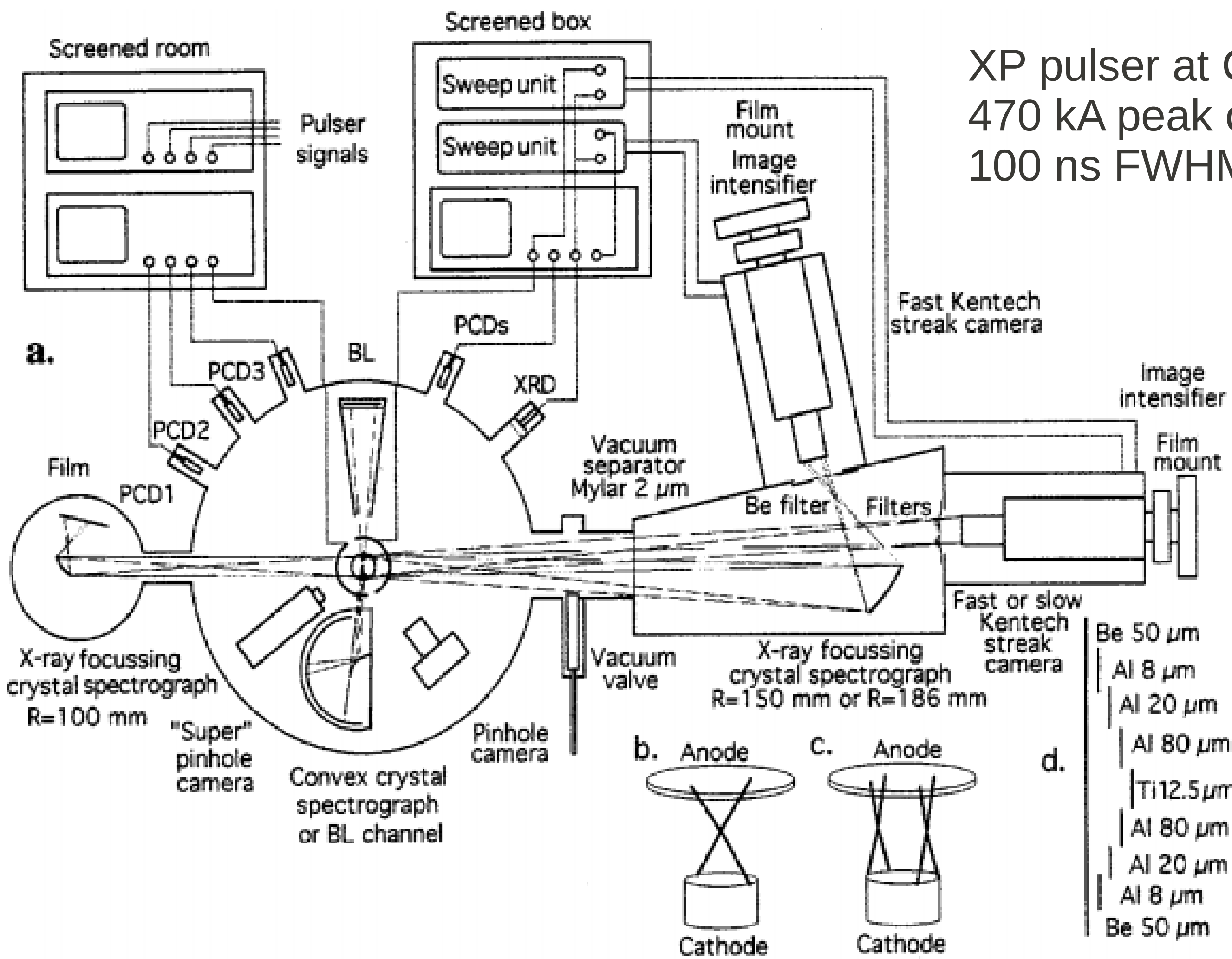


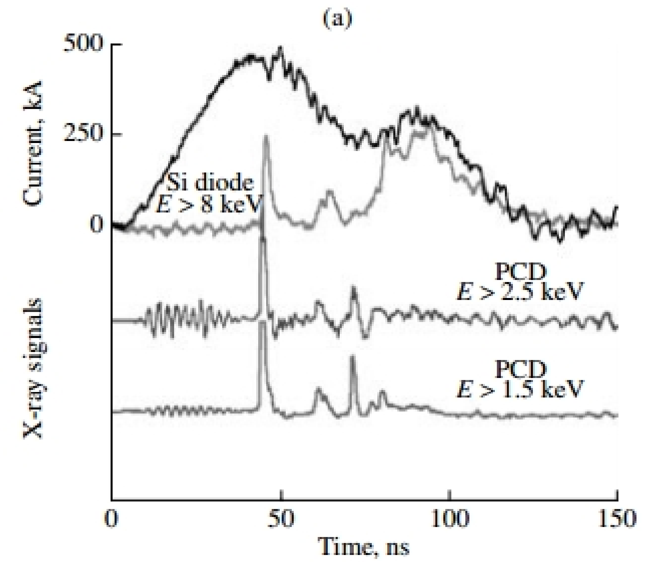
Fig. 1. (a) Schematic diagram of the X pinch experimental arrangement showing the many X-ray diagnostics. (b) Illustration of one X pinch as the load for the pulser. (c) Illustration of two X pinches as the load (“double X pinch” configuration). (d) Filter arrangement used with the X-ray streak camera for direct measurement of the X pinch X-ray emission.

Possibilities for temporal X – Ray diagnostics

See, for example,

S. A. Pikuz, T. A. Shelkovenko, ... “**Temporal characteristics of X-ray emission from X-pinches.**”

* XUV: **X-Ray vacuum diodes**
* SXR: **Diamond PCDs**, resolution ~ 200 ps
* HXR: **Si-diodes**, resolution ~ 700 ps
* energy filters (Be165, Be165+Ti12.5 etc.)



With a help of **fast streak camera** we can achieve 3 – 5 ns time resolution

Table 2. Durations of X-ray pulses measured by the fast streak camera

Filter and photon energy range*	Be50 $E > 1.8$ keV	Be50Al8 $E > 3$ keV	Be50Al20 $E > 4.5$ keV	Be50Ti12.5 3 keV $< E < 4.9$ keV, $E > 6$ keV	Be50Al80 $E > 6$ keV
Wire material	Pulse duration, ps				
Al	100–400	50–250	50–100	30–120	**
Ti	250–300	100–200	100–150	100–160	**
NiCr	50–100	20–30	<20	50–70	<20
Mo	50–100	30–40	10–30	10–50	5–10
W	15–40	10–30	10–30	10–30	3–15

There are many ways for spectral X – Ray diagnostics

See, for example:

1. T. A. Shelkovenko, S. A. Pikuz, D. B. Sinars, K. M. Chandler, and D. A. Hammer. **X Pinch Plasma Development as a Function of Wire Material and Current Pulse Parameters**

2. Tatiana A. Shelkovenko, Sergey A. Pikuz, Jonathan D. Douglass, Ryan D. McBride. **Multiwire X-Pinches at 1-MA Current on the COBRA Pulsed-Power Generator**

* **focusing spectrograph** with spatial resolution (FSSR) (spherically bent MiCa crystal spectrograph)

* **convex crystal** spectrograph

* **flat crystal** spectrograph (KAP crystal)

***** **pinhole cameras** with different sets of filters

* **Slit-Step-Wedge Camera** (SSW-camera)

* **etc...**

To obtain time resolution, we, again, need a **streak camera** (for example, a fast **Kentech streak camera** capable of <10 ps time resolution can be used)

Dose Rate / Dose X – Ray diagnostics

See, for example,

Shelkovenko et al. **Diagnostics on the COBRA pulsed power generator**

TABLE I. Solid-state detectors with conditions used in COBRA experiments. The range of lower energies cited for the PDCs and the AXUV-5HS diodes is because these detectors are used with a variety of filters.

Detector types	Photon energy range (keV)	Sensitivity	Distance from the load (cm)	Temporal resolution (ns)
XRDs (Al photocathode)	>0.3	Not calibrated	50	~1
PCDs (Fast diamond photoconductor detector)	>0.7–8	5×10^{-3} A/W	50–100	~0.25
AXUV-5HS diodes	>6–25	Not calibrated.	50–100	~0.3
AXUV-1HS diodes	>0.7	Not calibrated	20–50	~0.25

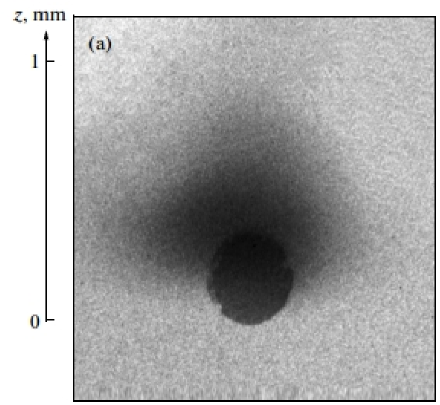
"**Calibrated PCDs** with different filters enable the energy yield in different energy bands to be obtained in each X pinch micropinch burst or in the x-ray pulse stemming from a wire array implosion"

Some approaches for spacial X – Ray diagnostics

See, for example,

1. G. A. Mesyats, T. A. Shelkovenko, ... **X-pinch source of subnanosecond soft X-ray pulses based on small-sized low-inductance current generator.**

with a help of **pinhole camera**



Typical pinhole image of an X-Pinch formed by four Mo wires 25 um in diameter. Pinhole diameter is 250 um

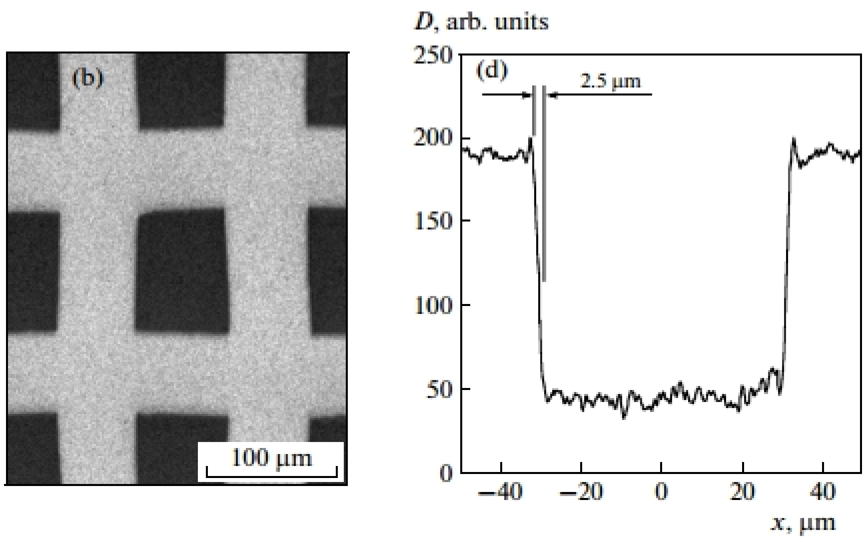


Image of a grid formed by steel wires 60 um in diameter in radiation emitted by tungsten (four 20 um wires) X-Pinch with a magnification of x10.

point – projection imaging (by analyzing the images of various test object obtained with a high magnification. Penumbra.)

...and **many more** methods...

And, of course,we can use Rogowski coil, B-dot and D-dot for current and voltage monitoring