KURCHATOV S-300 INSTITUTE

Study of the Multiwire X-Pinch as a Load for Mega-Ampere-Range Pulsed Power Generators

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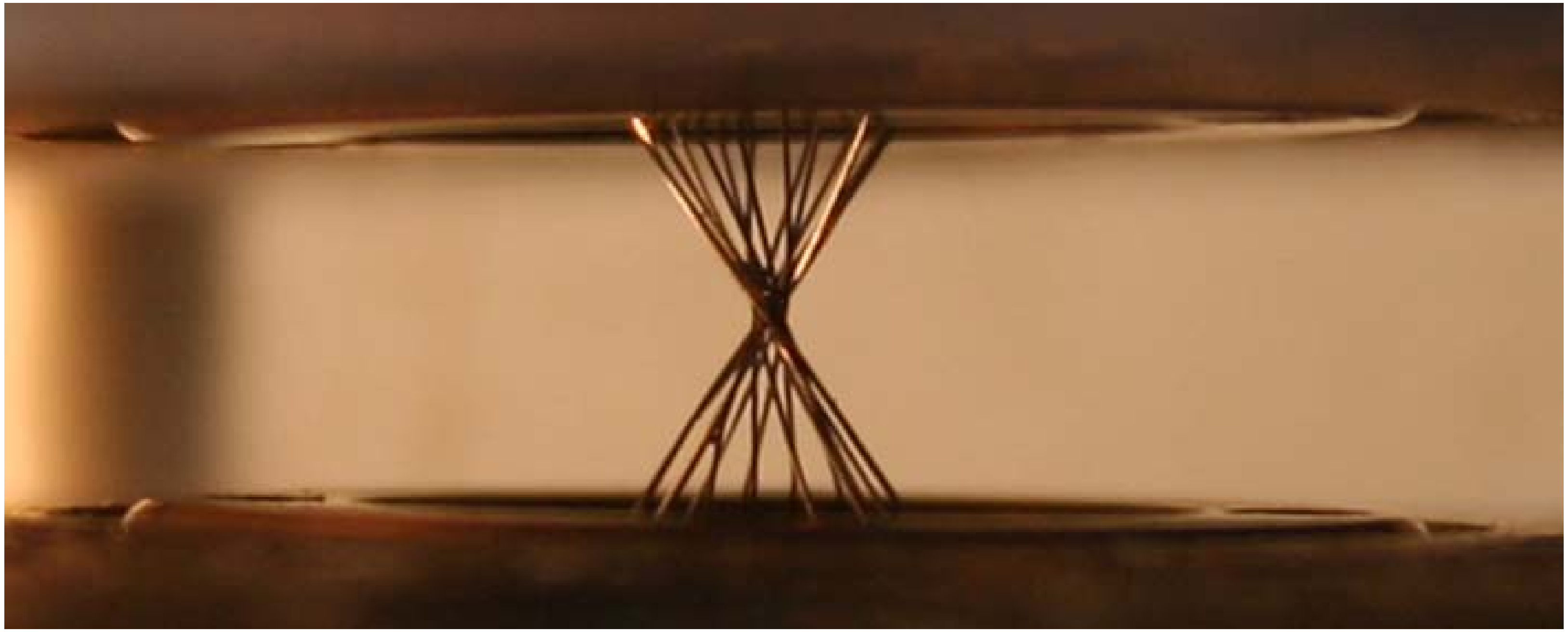
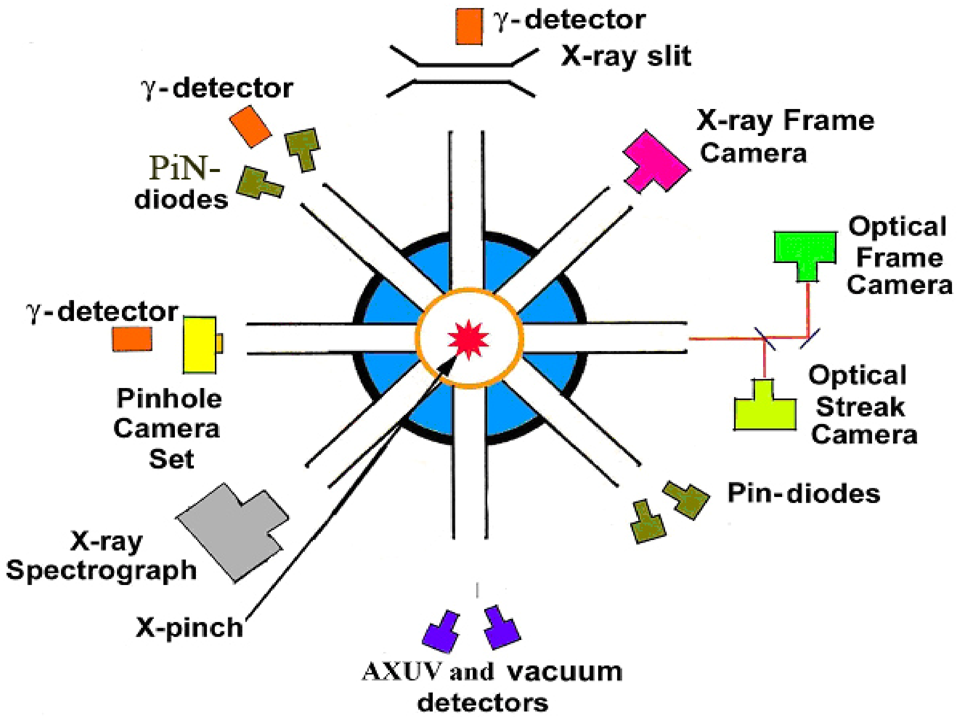
X-Pinch of Mega-Ampere-Range



Current amplitude:	**up to 2.3 MA**
Materials:	**W, Mo, nichrome, stainless steel**
Number of wires:	**from 2 to 20**
Linear mass m_l:	**from 3.7 to 40 mg/cm**

Diagnostic setup



- Three pin-hole cameras with X-ray filters
- X-ray spectrograph for 1.5-8 keV range
- Measurement of X-ray power in different spectral range (100 eV - 1 MeV)
- Visible light registration in chronographic and frame regimes

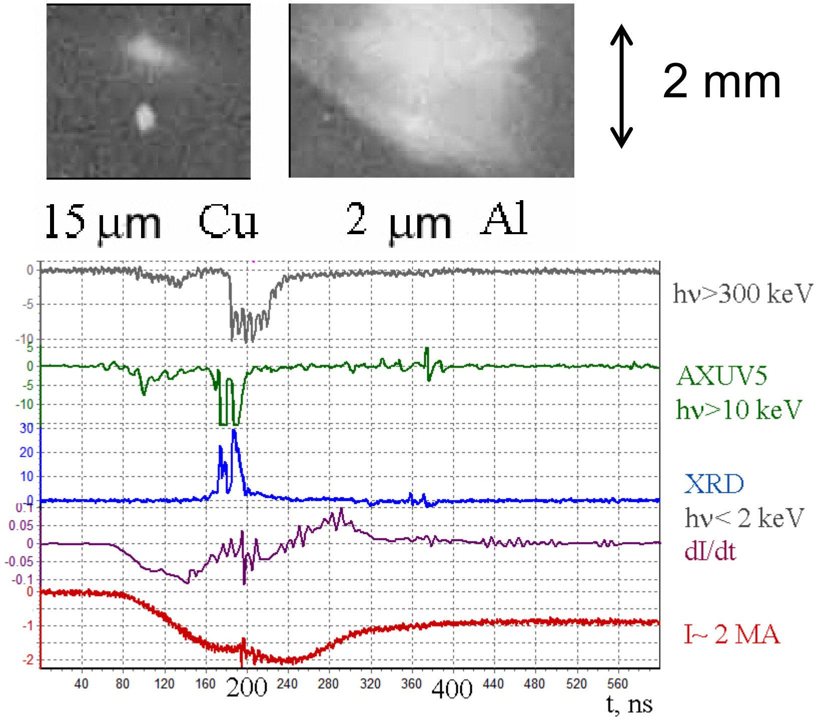
Diagnostic capabilities

- Time-integrated measurements of dimensions in soft X-ray range …………………Δx~5 μm
- Frames in soft X-ray …………………Δx~0,3 mm, Δt~5 ns
- Time-integrated X-ray spectrograph ………………..hν~1,5–8 keV, $\lambda/\delta\lambda$~300
- Frames in visible light ……………Δt~0,5 ns and Δt~5 ns
- Streak in visible light ………………Δt~5 ns, Δx~0,3 ns
- X-ray power:

hν~1–3 keV	Δt ~ 1 ns
hν~3–40 keV	Δt ~ 2 ns
hν~60–1000 keV	Δt ~ 4 ns

Experimental result at 1.3-2.3 MA currents

Several pulses

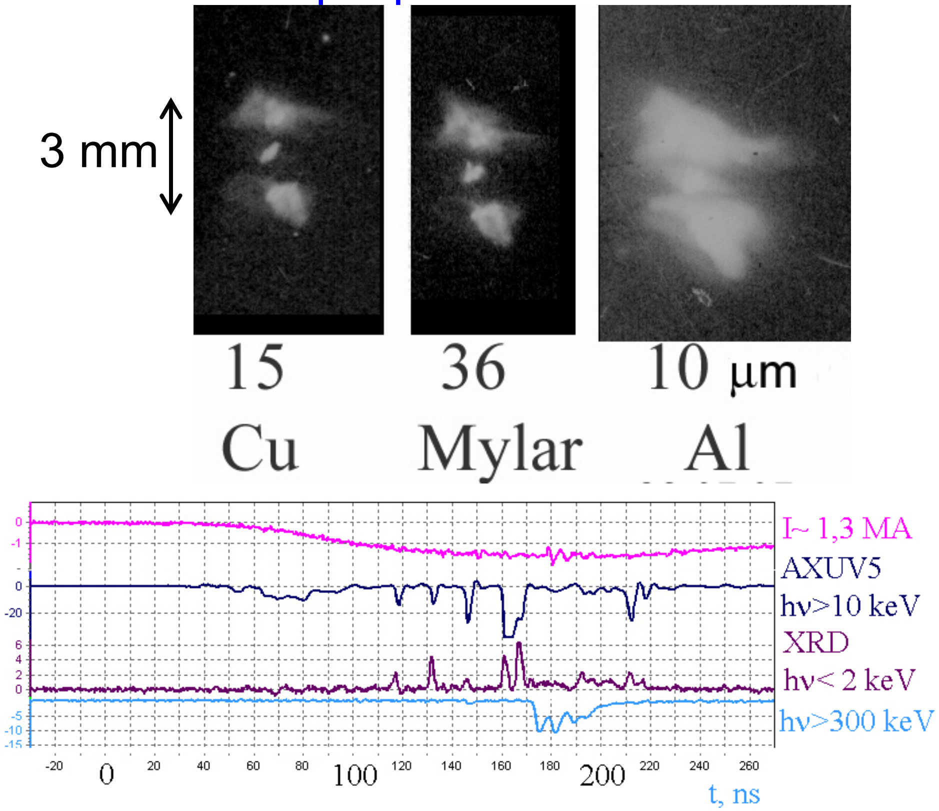


I_{max} ~ 2.0 MA

stainless steel: 16*100 µm

m_l ~ 10 mg/cm

Multiple pulses



I_{max} ~ 1.3 MA

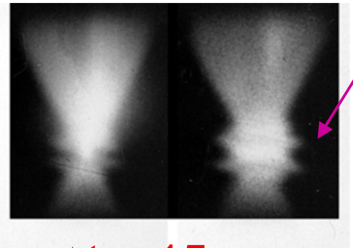
stainless steel: 12*100 µm

m_l ~ 7,5 mg/cm

Typical plasma dynamics
optical frames and streak

W, 8x55 µm
I_{max} = 1.5 MA

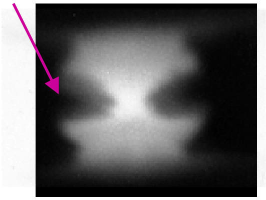
necks



Δt = 15 ns

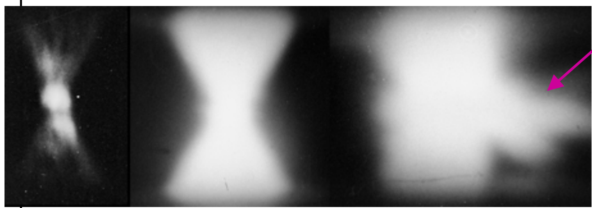
Stainless steel, 16x100 µm

I_{max} = 0.8 MA



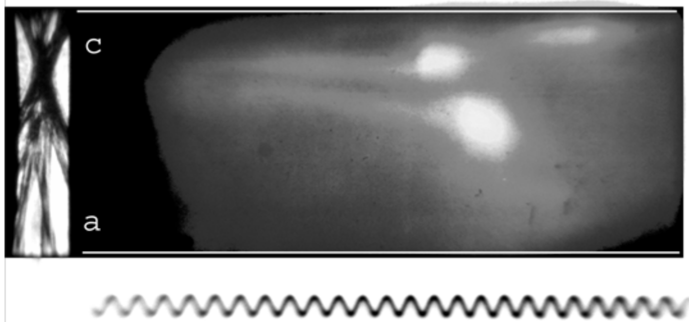
I_{max} = 2.3 MA

side jets



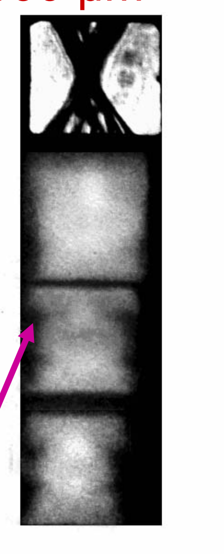
Δt = 50 ns

Mo, 16x70 µm I_{max} = 2.0 MA



Streak image along the X pinch axis:

St.steel, 16x100 µm
I_{max} = 2.3 MA



58 ns

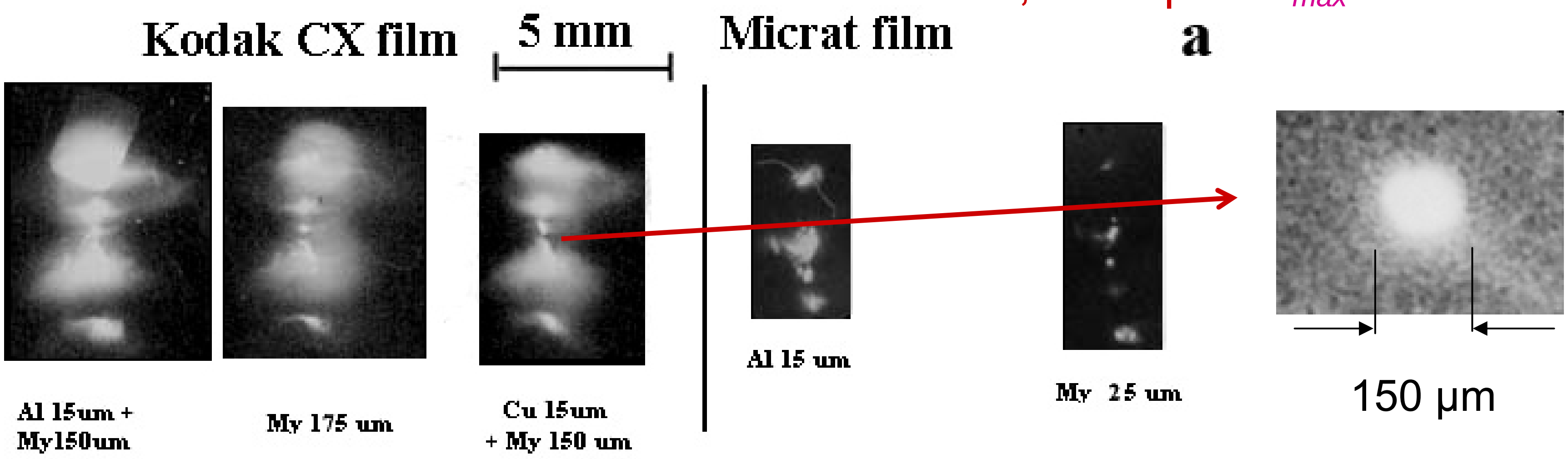
58+3,2 ns

58+6,4 ns

Mini-diode formation?

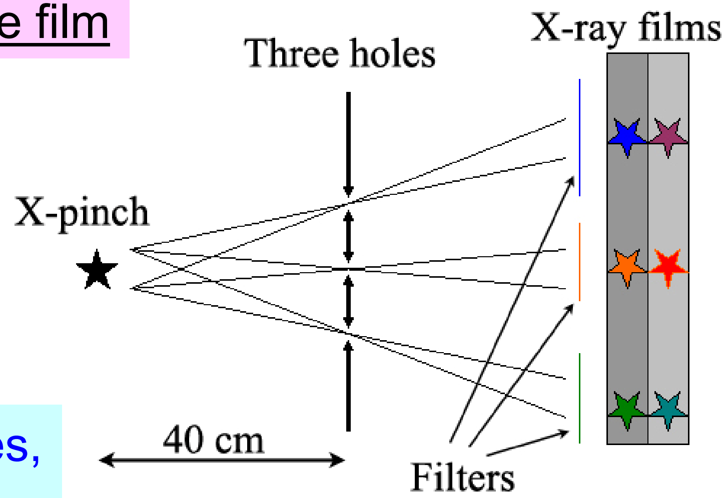
X-ray images (time-integrated pinhole)

W, 8x55 μm I_{max} = 1.5 MA



Backside film

Frontside film

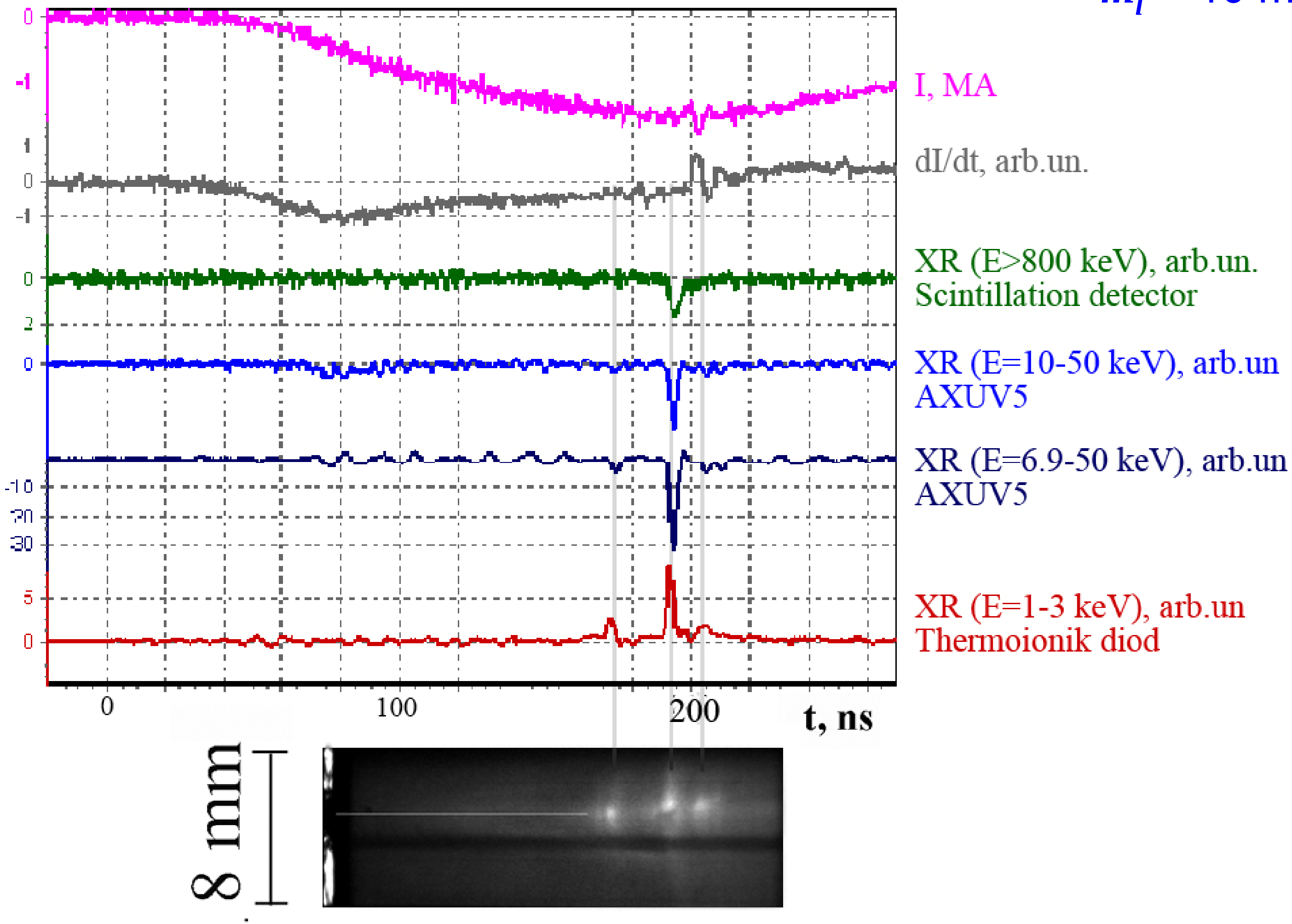


Three-channel pinhole camera with ~50 μm holes, equipped with various filters. Scale 1:1.

Optical streak synchronized with current and X-ray measurements

I_{max} = 1.7 MA

Load nichrome:
16×100 μm
m_l ~ 10 mg/cm

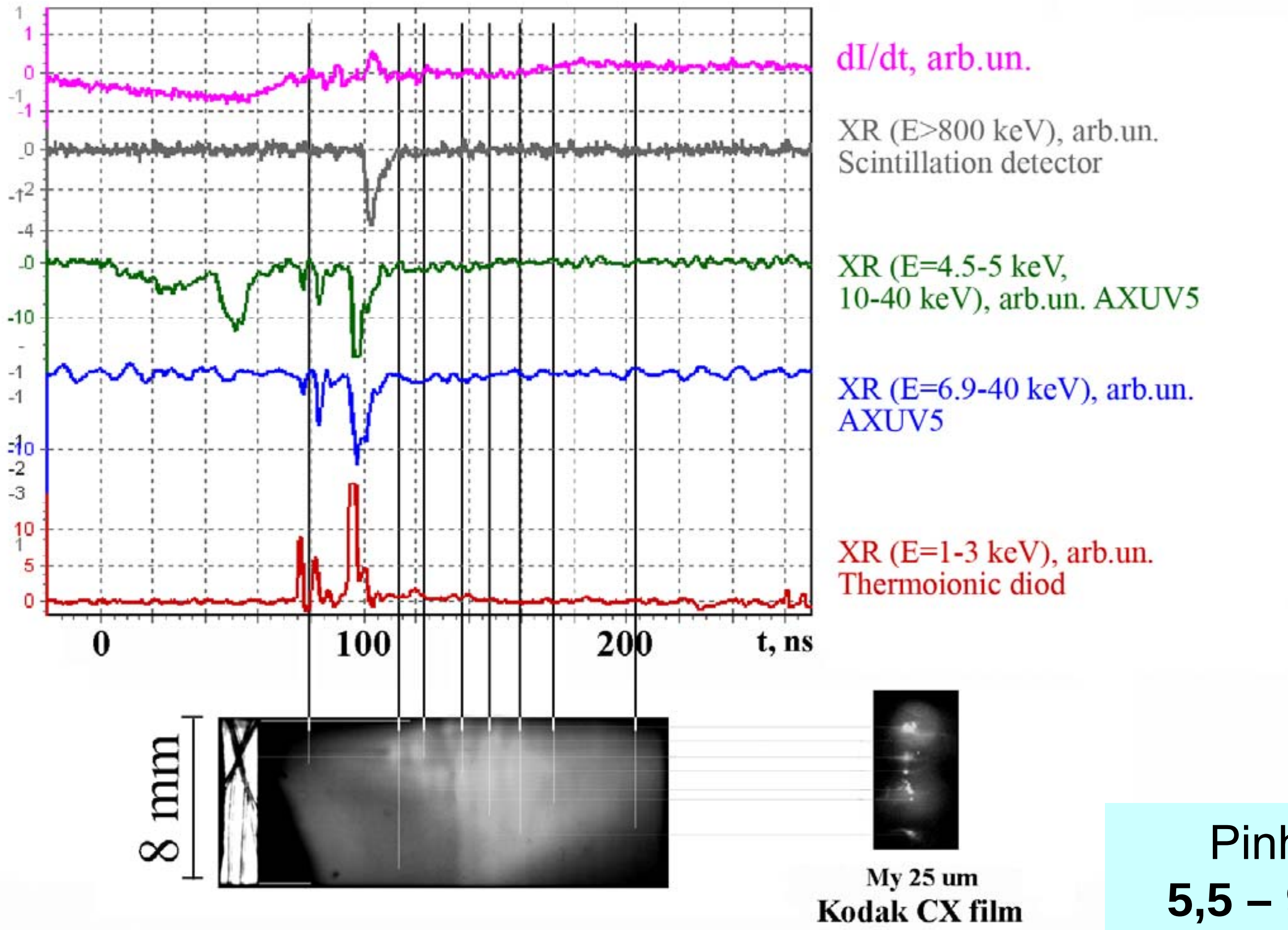


Optical streak synchronized with current and X-ray measurements

Load W: 8×55 μm

m_l ~ 3,7 mg/cm - «low mass»!

I_{max} = 1.5 MA



Optical streak

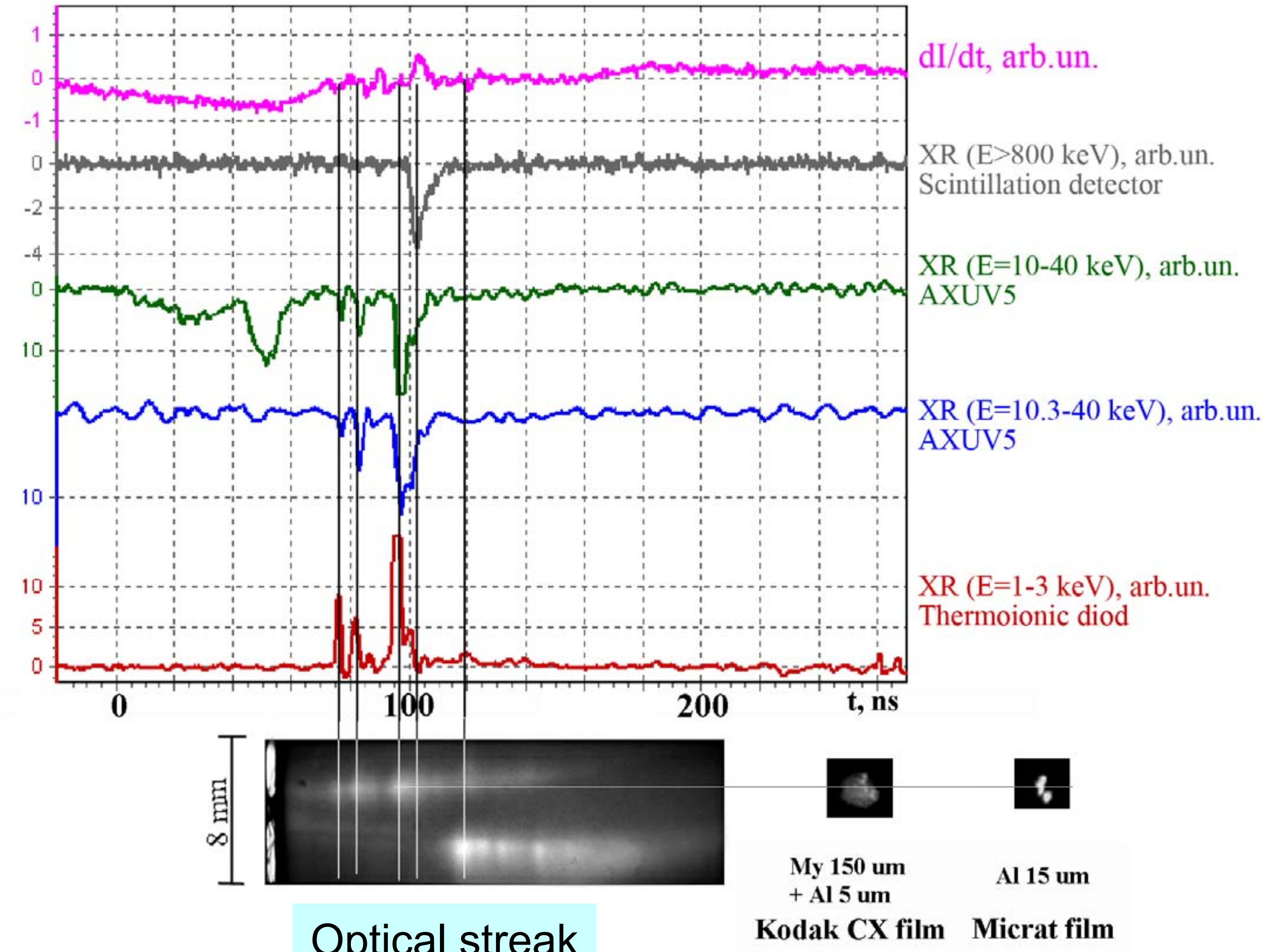
Pinhole
5,5 – 9 keV
>12 keV

Optical streak synchronized with current and X-ray measurements

I_{max} = 1.5 MA

Load W: 16×55 μm

m_l ~ 7,4 mg/cm



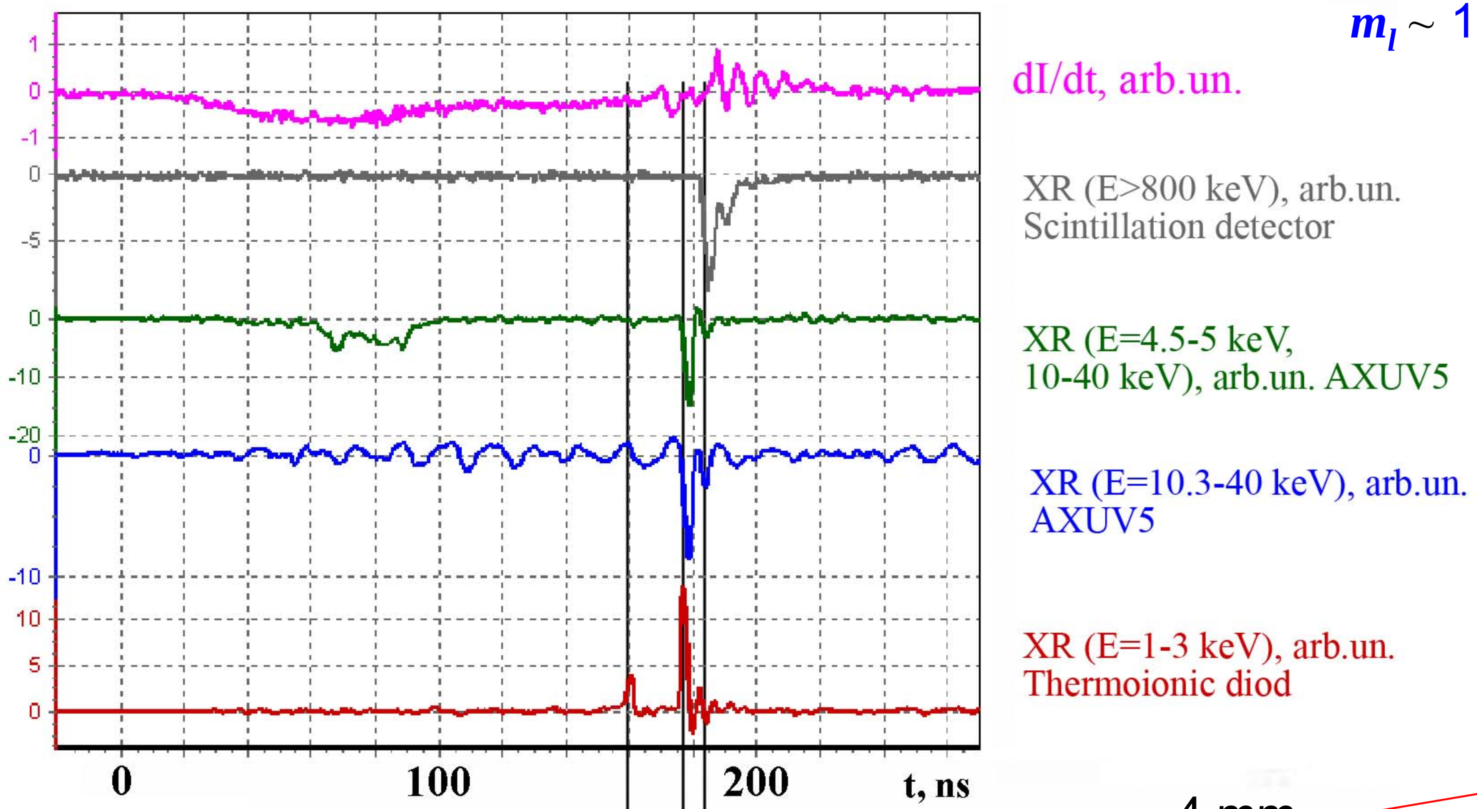
Optical streak

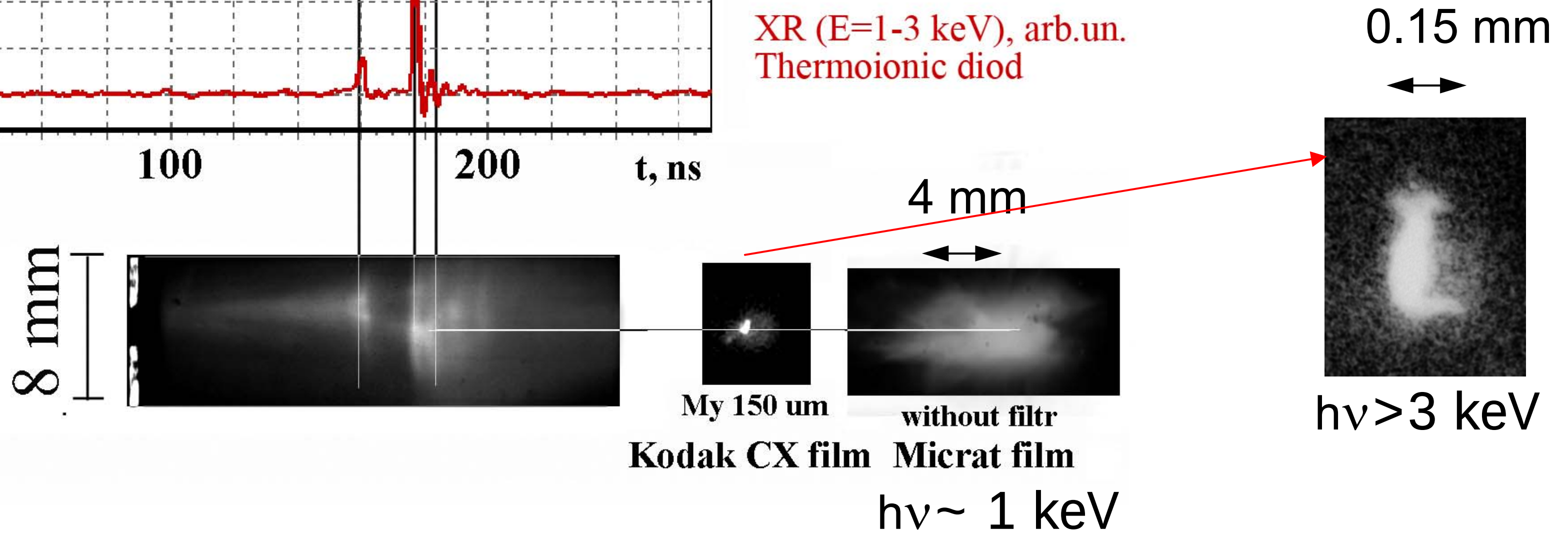
X-ray images, radiation dynamics and optical streak

I_{max} = 1.9 MA

Load Mo **16*100 μm,**

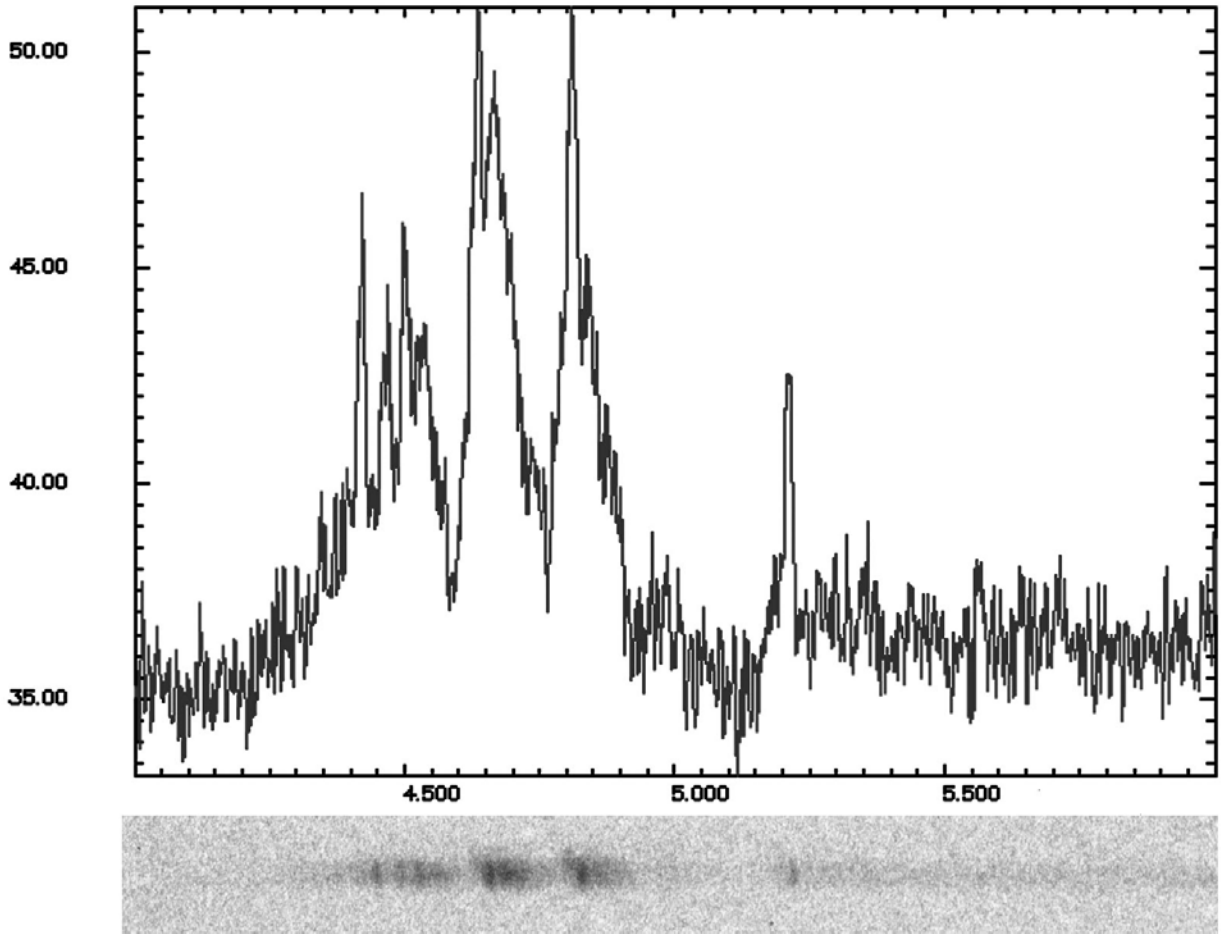
$m_l \sim$ 13 mg/cm



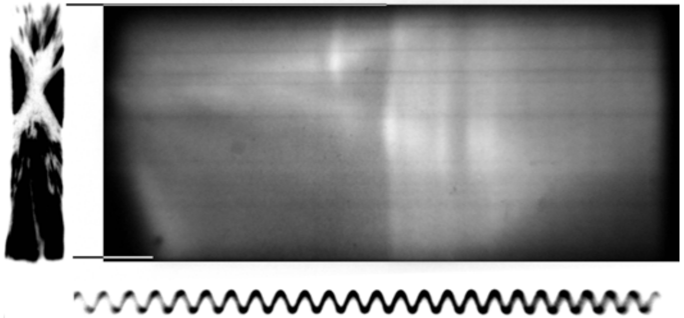


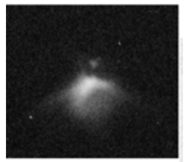
Line radiation

Mo, 20×70μm, m_l ~ 7.9 mg/cm

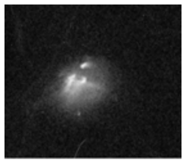


I_{max} = 1.45 MA





15 μm Cu

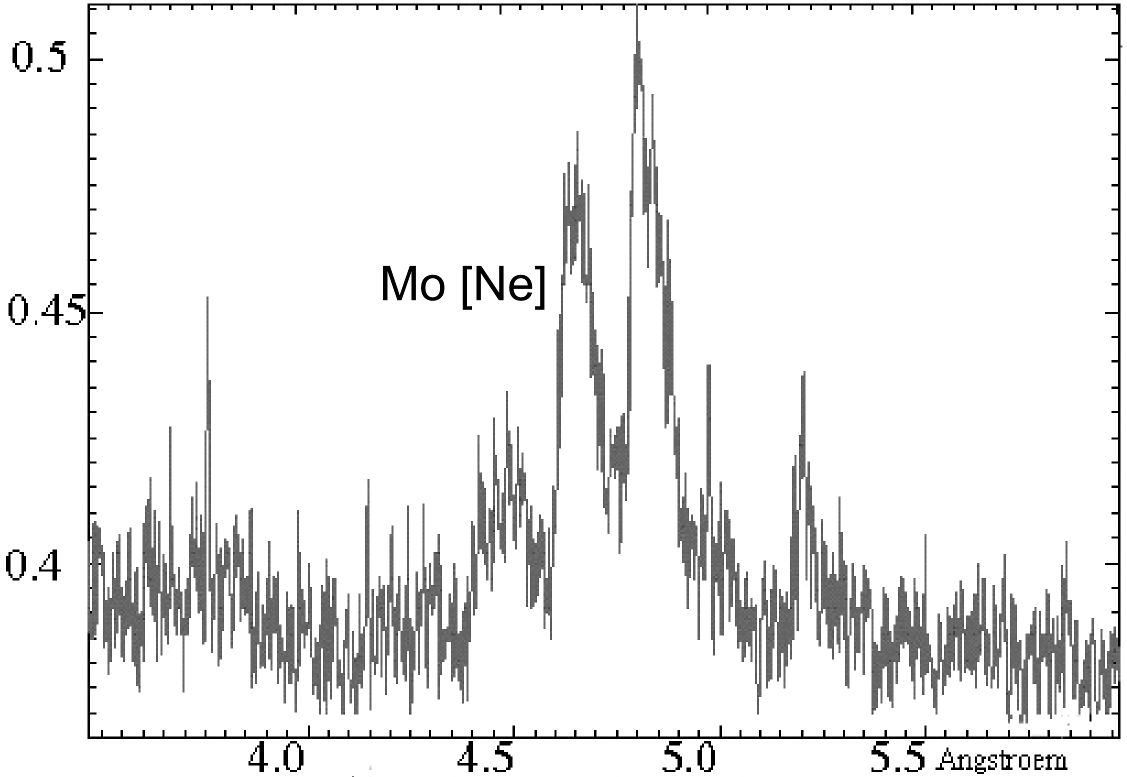


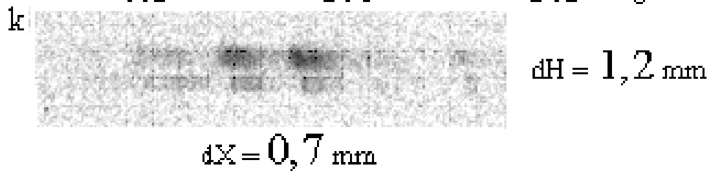
24μm My

$D_{pinhole}$ = 50 μm

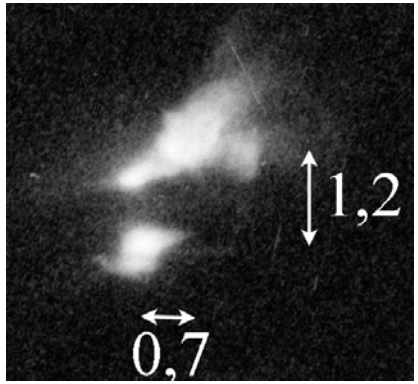
Line radiation

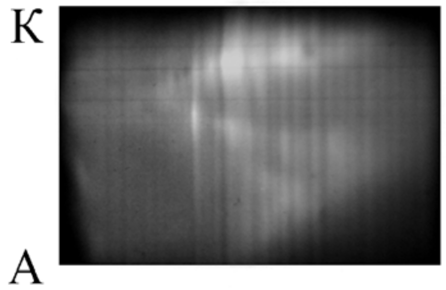
Mo, 16×70μm m_l ~ 6.3 mg/cm



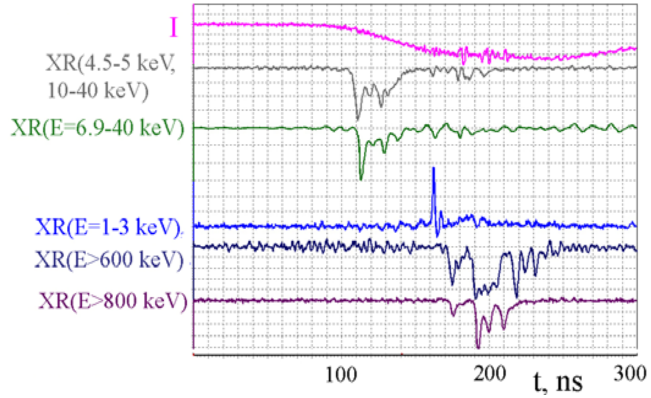


Energy in 2 points
2 J and 6 J





I_{max} = 2.0 MA

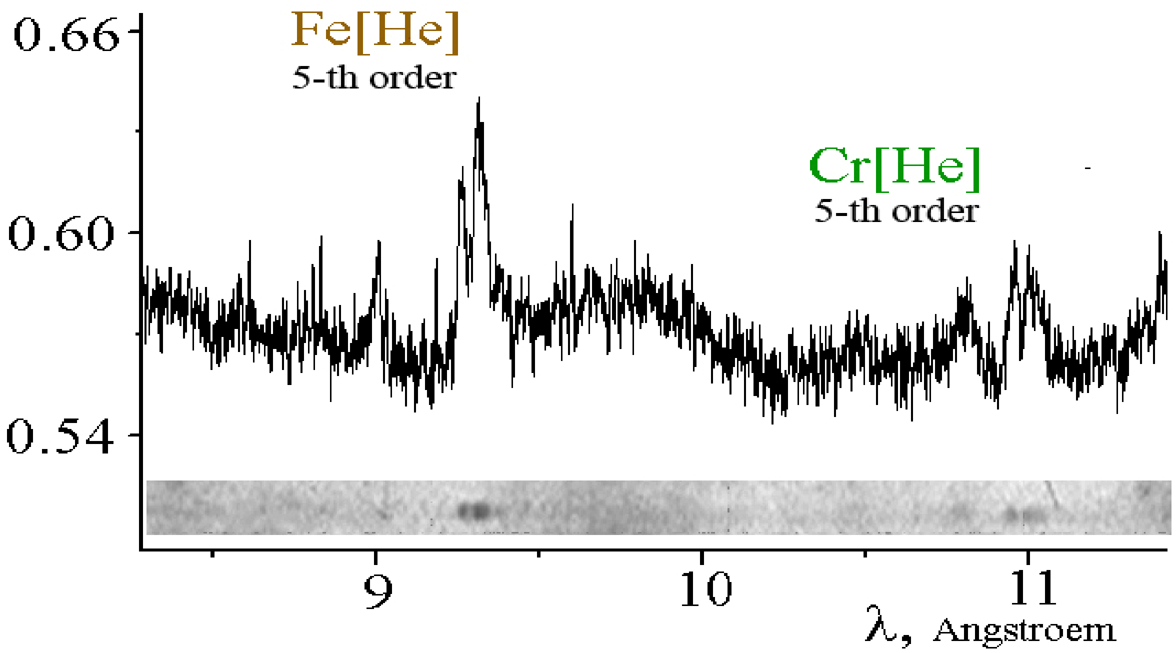


T_e~0.8-1.0 keV, n_e ~10^{20}-10^{21} cm^{-3}

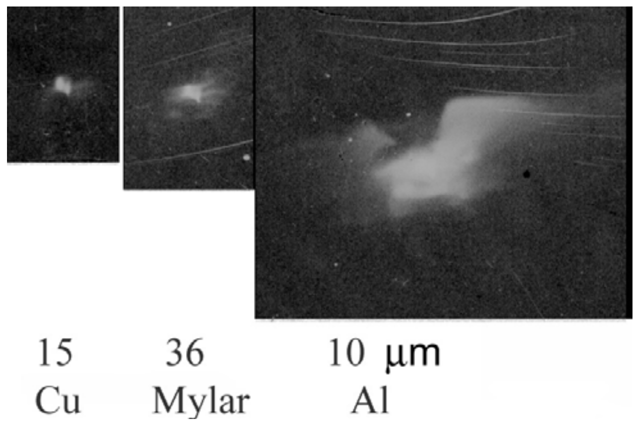
According to comparison with S.B.Hansen, A.S.Shlyaptseva, S.A.Pikuz et al., Physical Review E 70, 026402 (2004).

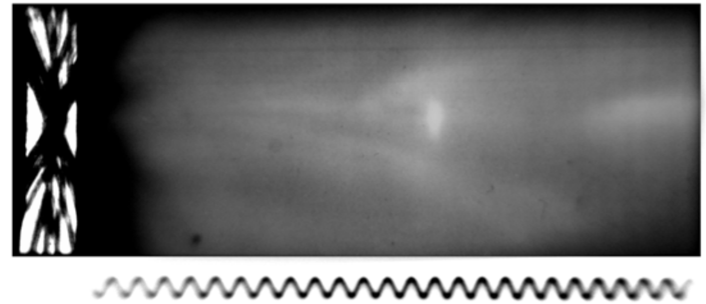
Line radiation

Stainless steel, 16×100 μm, m_l ~ 10 mg/cm



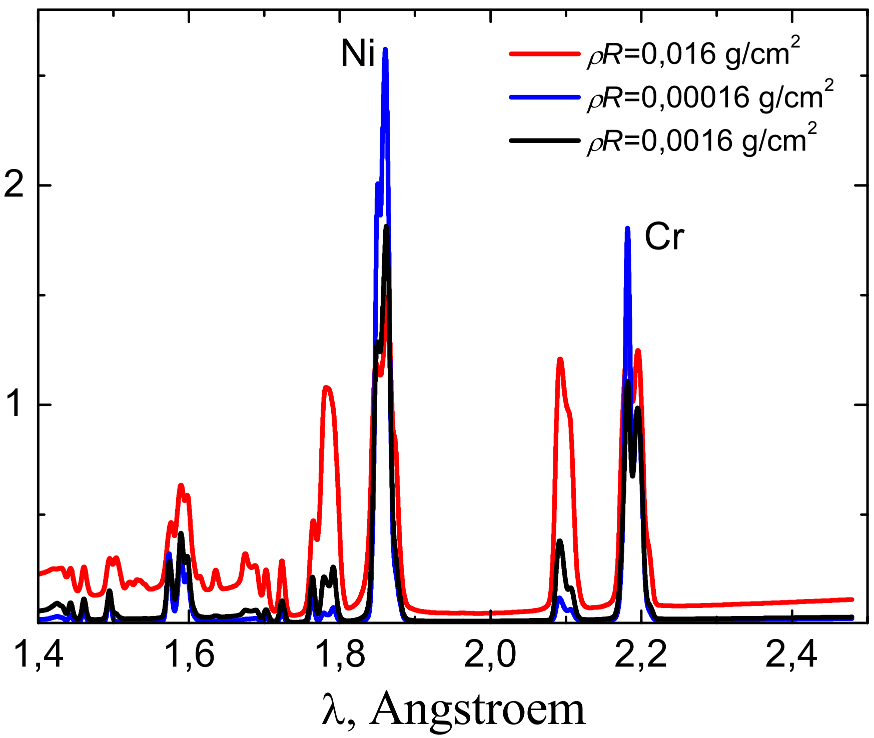
I_{max} = 1.75 MA

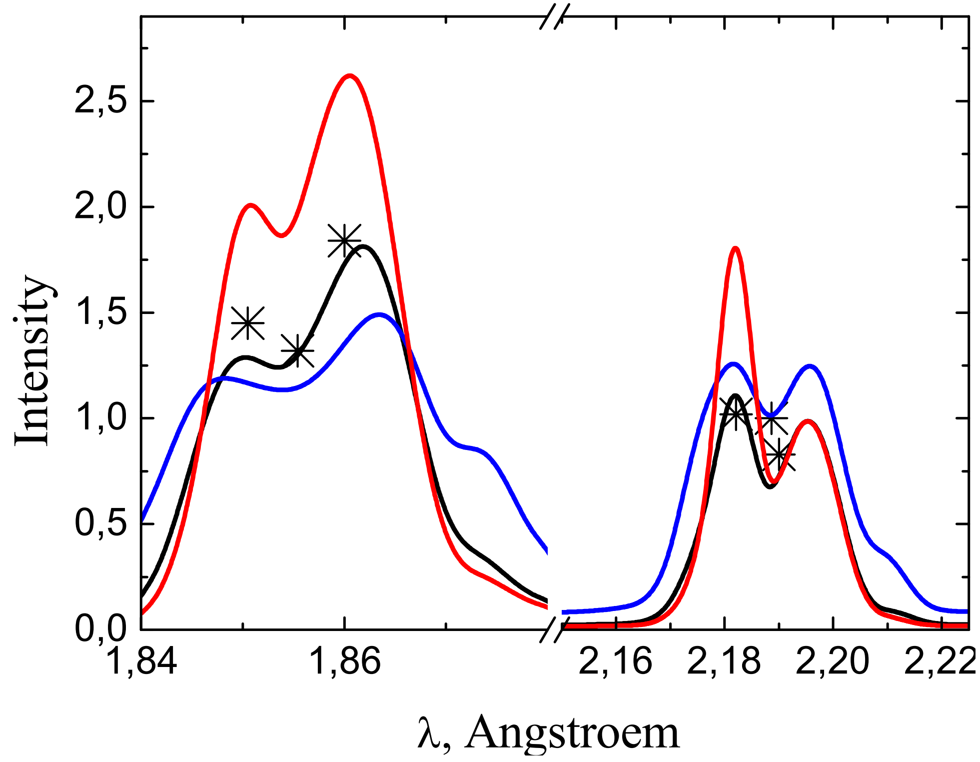




Using the experimental data 10^{18} eV of the emitted energy in the resonance He-like CrXXIII line, and calculated spectral luminosity (~10^{18} erg/(cm^2·sr·s·eV)) we evaluate the emission duration to be about 7 ps.

Plasma Parameters





PrizmSPECT

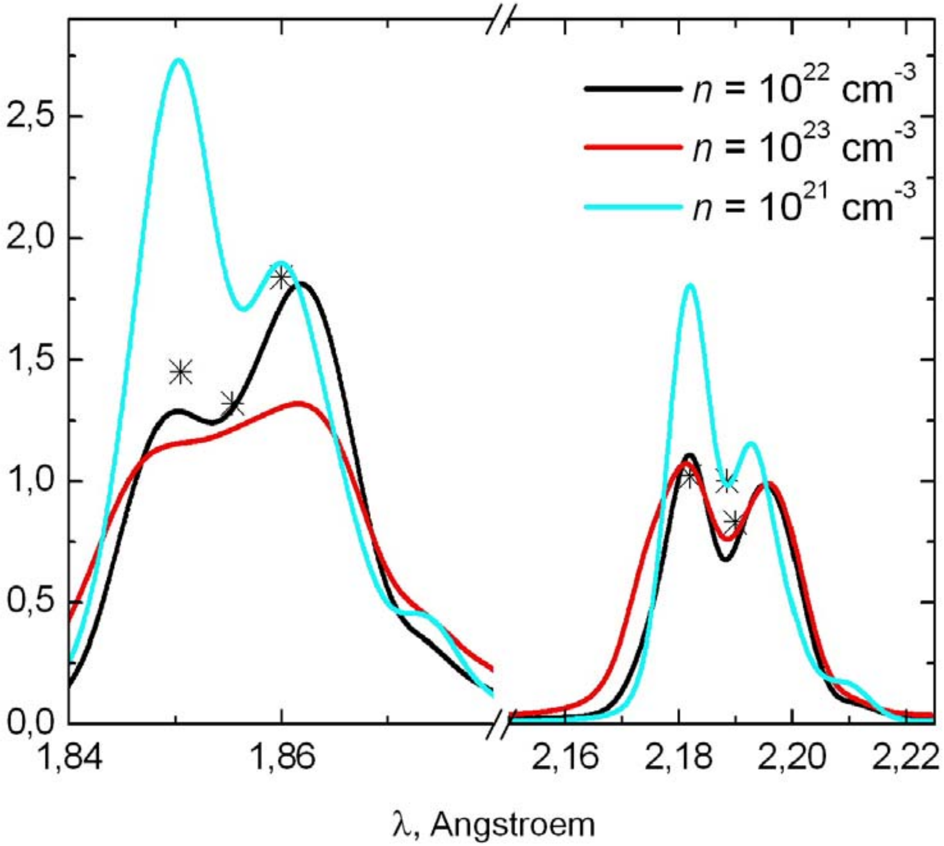
Lines intensity ratio modelling results:

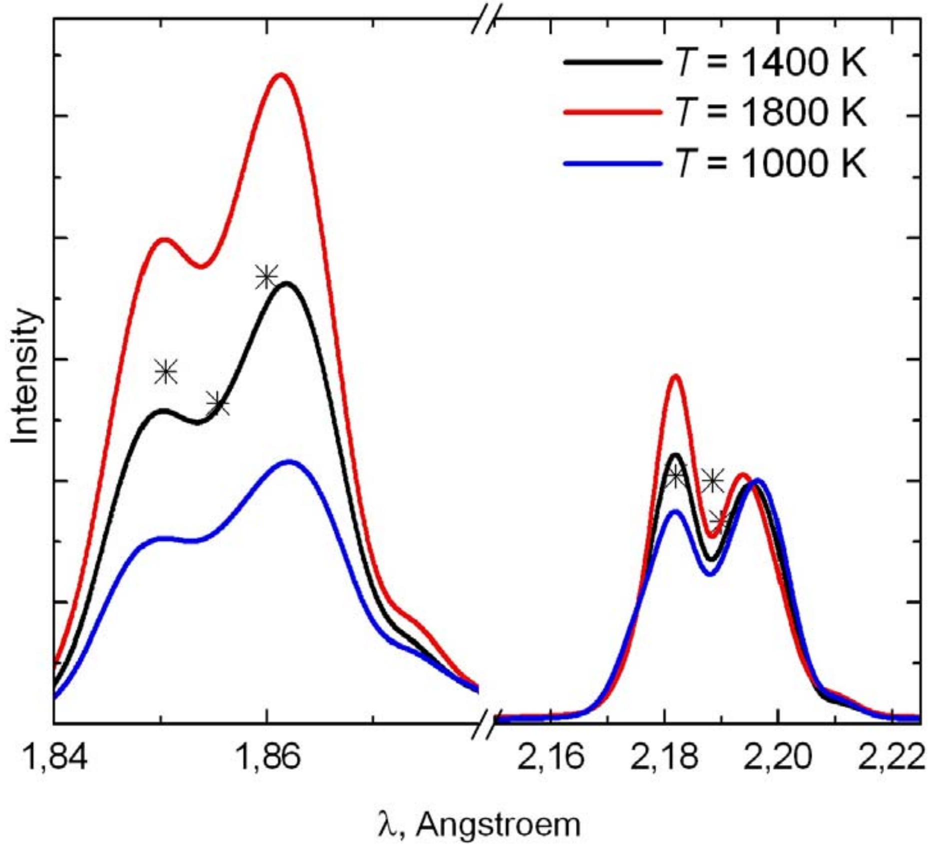
T_e ~ 1200 – 1400 eV

N_i~10^{22} см$^{-3}$

d ~30 μm

Plasma Parameters





http://www.prism-cs.com/Contact/Contact_overview.htm

Experimental investigations of the X-pinch have been carried out at currents up to 2.3 MA. The experimental results on high-current multi-wire X-pinches made of stainless steel, nichrome, Mo, and W, confirmed basic features of their dynamics, as well as basic statements made on the base of earlier experiments with lower current.

The total energy of Mo X-pinch radiation in the range of the quantum energy 2.5–3 keV exceeds 10 J. Direct measurements of space scales and radiated power show that the bright formation arise during the X-pinch evolution, with the brightness exceeding 10^{15} W/(cm^2 sr) in the range of the quantum energy 1–3 keV, by the typical linear size of the hot spot ~ 20 μm and the radiation power ~ 120 GW. It is important to note that such extreme plasma parameters determined from the time-integrated parameters (not from those resolved in time!) have been recorded for the first time.

Using experimental data related to the energy 10^{18} eV in the spectral range $\delta E \sim 70$ eV for the resonant He-like CrXXIII line, together with the calculated hot spot space scale and the spectral brightness of the source, one could estimate the typical time of emission as $\Delta t \sim 7$ ps. Such a duration is typical of the hot spot radiation. Thus, one may conclude that the real SXR radiation power is essentially higher than that recorded by the diodes (their resolution being ~ 1ns).

The HXR radiation of an X-pinch in the range of the quantum energy > 800 keV has been recorded and studied.