XUV Emission Generated by Fibre Z-Pinch

Daniel Klír, Jozef Kravárik & Pavel Kubeš

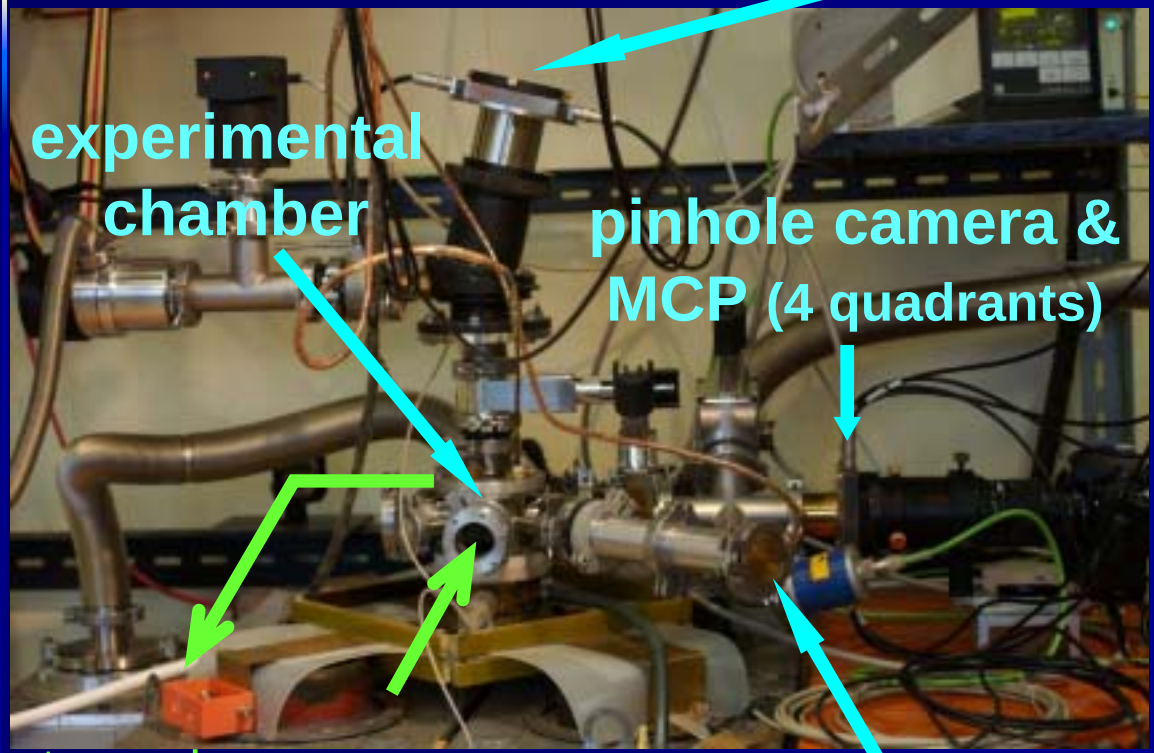
Czech Technical University
Faculty of Electrical Engineering

Outline

- Experimental set-up and diagnostics
  - Z-pinch discharge with carbon fibre
- Experimental results
  - PIN diode signals
  - Time-resolved XUV spectra 2-5 nm, 8-24 nm
  - Time-resolved pinhole images
  - Schlieren images
- Discussion of results
  - Comparison of results with carbon fibres of 20 and 120 μm diameter
- Conclusion

Experimental Set-Up

XUV spectrograph & MCP (4 stripes)

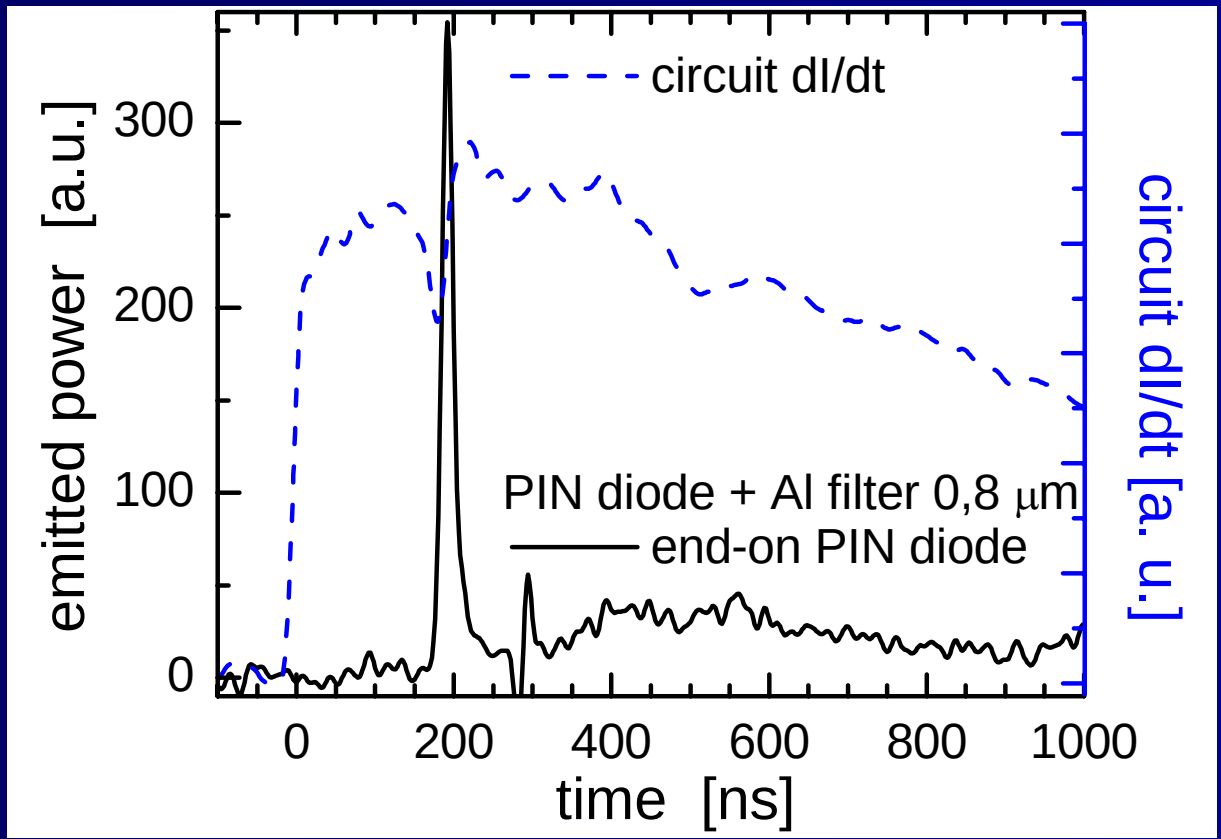


Capacitor banks
4 x 3 μF
Charging voltage
20 – 30 kV
Electric current
100 kA, 600 ns
Load
carbon fibre
∅ = 20,120 μm
(8 mm length)
Pressure
$<10^{-1}$ Pa

Al-filtered PIN diode signal

Carbon fibre

Shot no. 0105093, carbon fibre 120 μm, U=27 kV



260 ± 50 ns (120 μm)
210 ± 30 ns (20 μm)
after current breakdown

dI / dt drop

FWHM

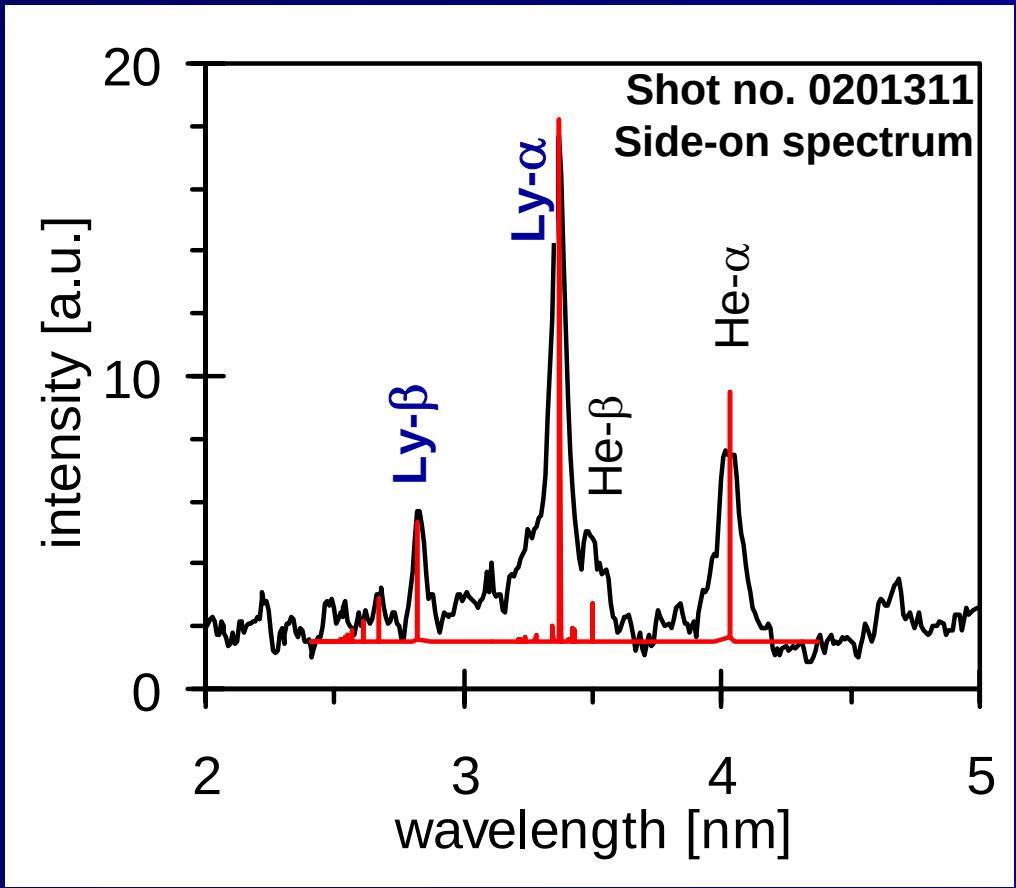
50 ± 30 ns (120 μm)
15 ± 5 ns (20 μm)

Energy

10 – 100 mJ

Time integrated
XUV spectrum 2-5 nm

Carbon 120 μm



Collisional-radiative code FLY (R.W.Lee)

T_e = 80 eV

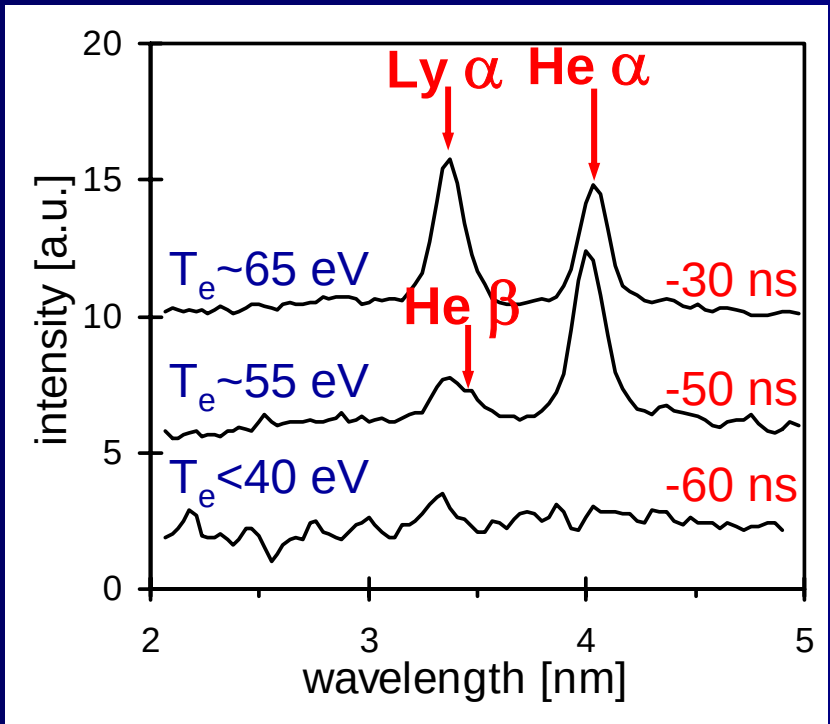
$n_e = 10^{20}$ cm^{-3}

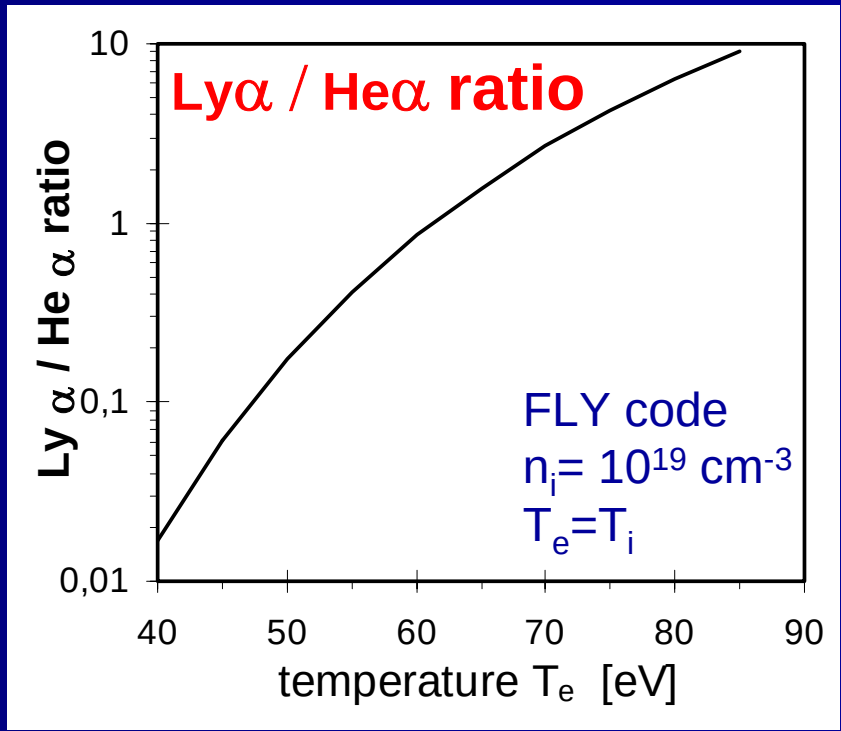
l_Ω = 5 μm

ion	transition		λ [nm]
C VI	1s $^2S_1$ - 3p $^2P_2$	Lyβ	2,85
C VI	1s $^2S_1$ - 2p $^2P_{2,1}$	Lyα	3,37
C V	1s^2 $^1S_0$ - 1s3p $^1P_1$	Heβ	3,50
C V	1s^2 $^1S_0$ - 1s2p $^1P_1$	Heα	4,03

Time resolved
XUV spectrum 2-5 nm

Carbon 20 μm

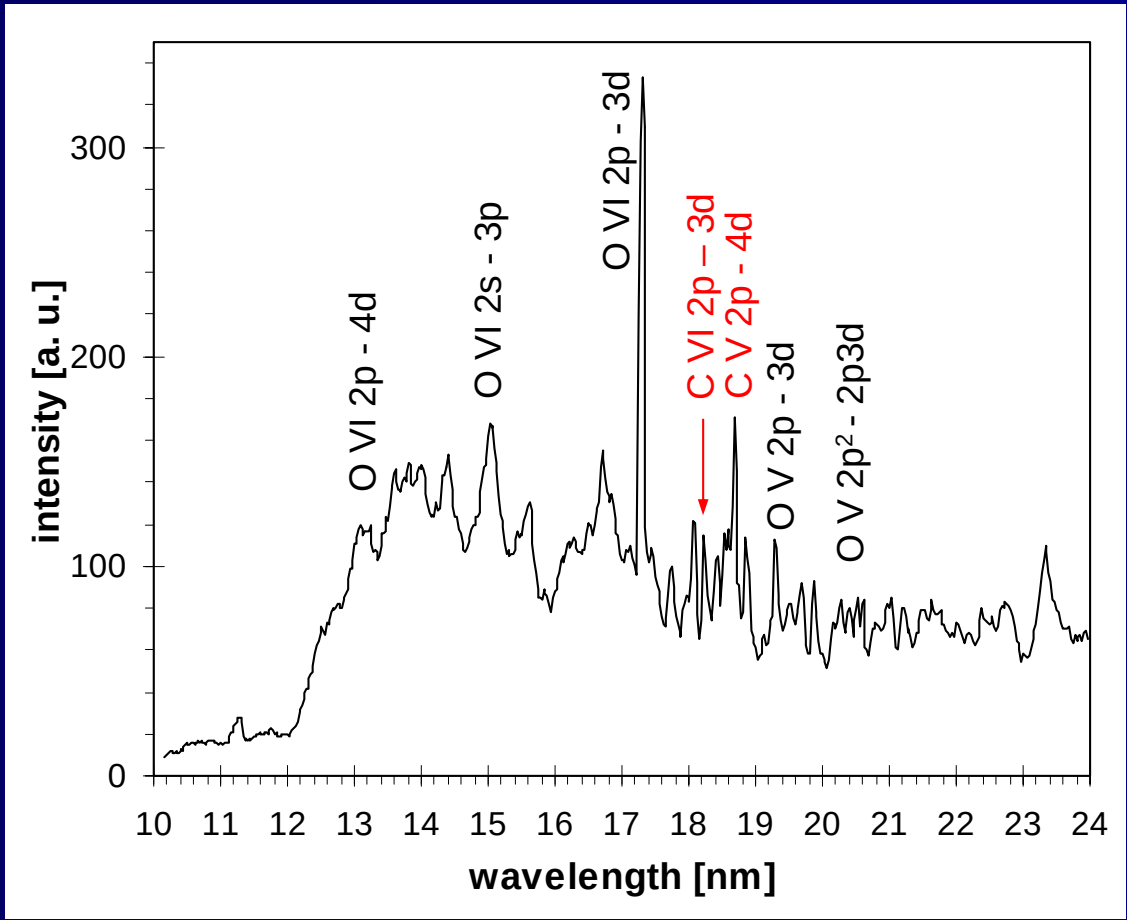




Shot no. 0110313, voltage 23 kV
Grating 1200 gr./mm, side-on spectrum
MCP: 5 ns exposure time

Time integrated
XUV spectrum 10-24 nm

Carbon 120 μm



No. 0105091

Voltage 27 kV

Grating 600 gr./mm

End-on spectrum

Detector: UV-4 film

Identified transition

O IV-VI ions

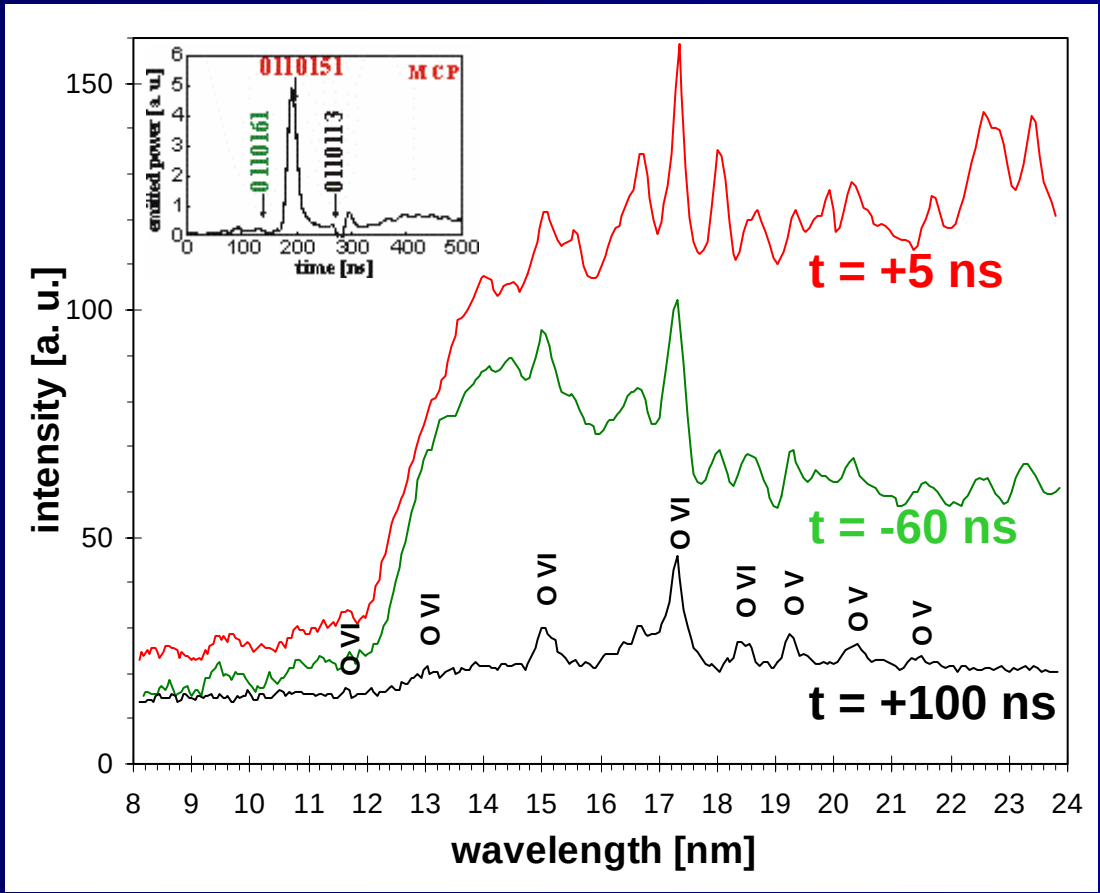
C V, C VI ions

Temperature

T_e ~ 15 eV (O VI)

Time resolved
XUV spectrum 8-24 nm

Carbon 120 μm



Voltage U=24 kV
Grating 600 gr./mm
Side-on spectrum

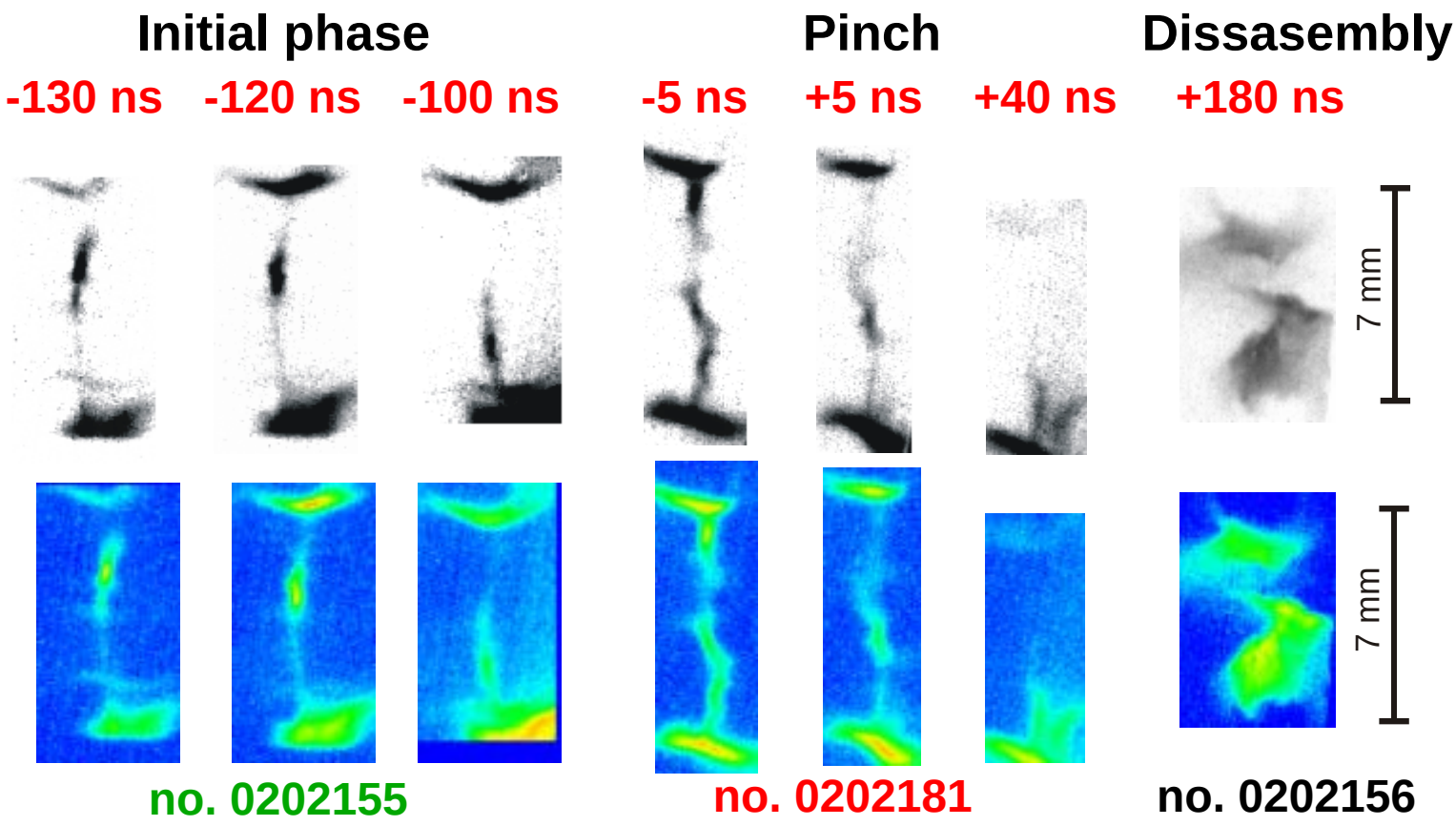
10 ns exposure time

-60 ns: no. 0110161
5 ns: no. 0110151
100 ns: no. 0110113

Temperature (O VI)
T_e ~ 25 eV

Time resolved
VUV pinhole images

Carbon 20 μm



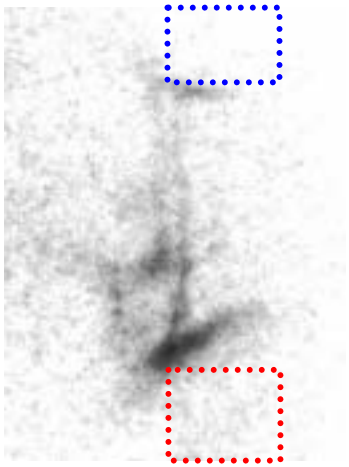
MCP with exposure time 5 ns, spatial resolution 200 μm.

Time resolved
XUV pinhole images

Carbon 120 μm

XUV Image
0,8 μm Al filter

cathode

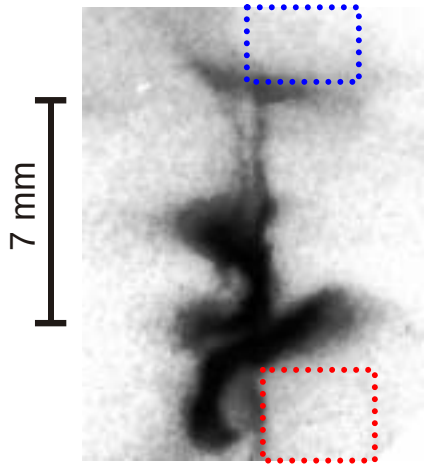


anode

-30 ns

VUV Image
Without any filter

cathode

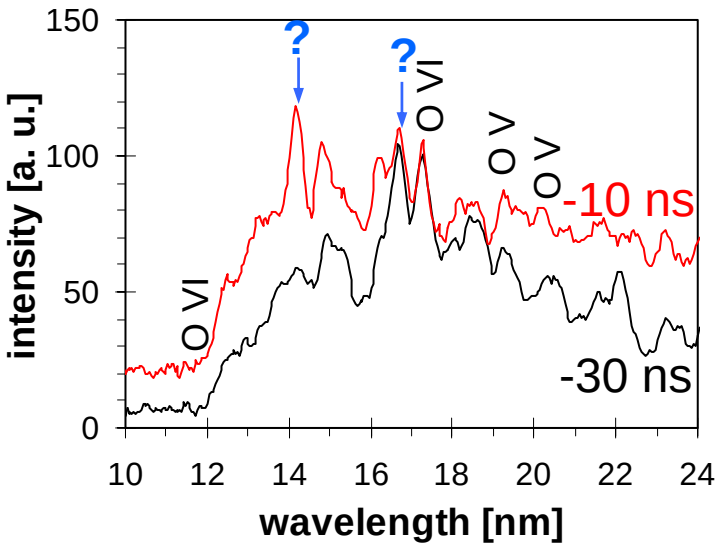


anode

-10 ns

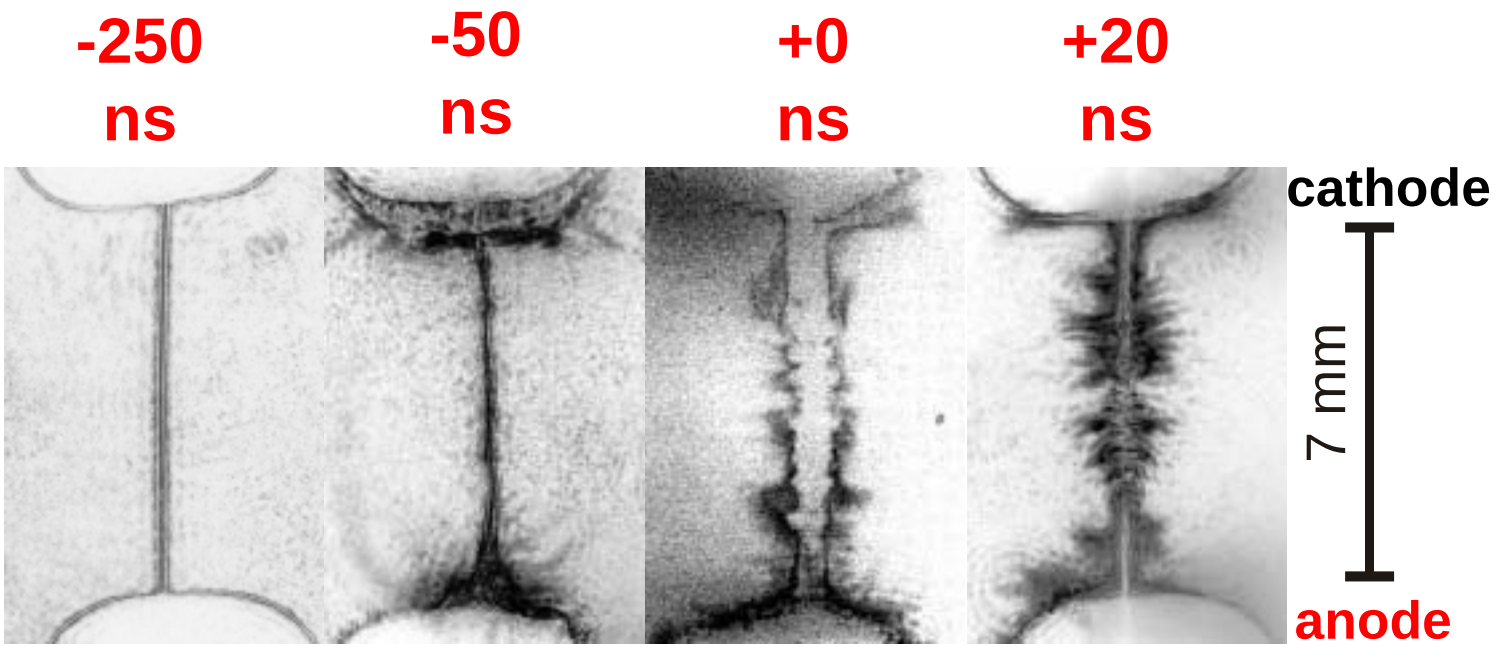
Shot no. 0210141
Voltage 20 kV

XUV spectrum 10-24 nm



Schlieren images

Carbon 120 μm

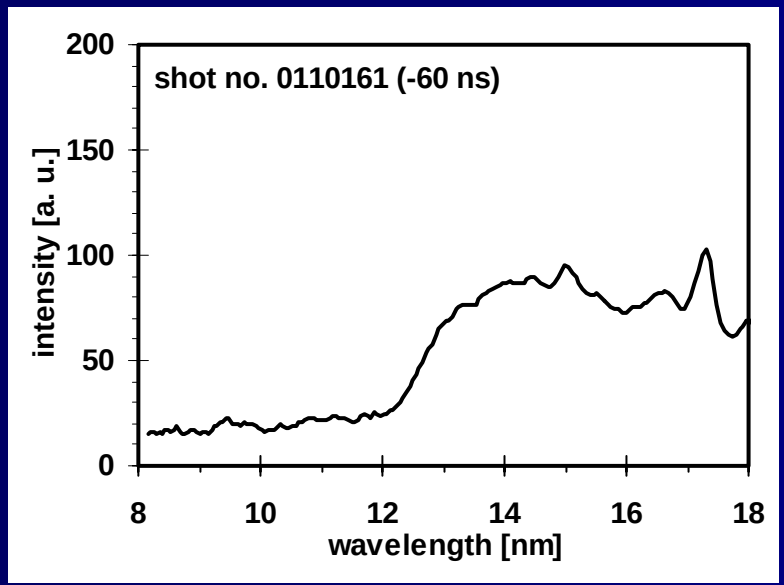


Laser probing, 3 ns exposure time, 2HG Nd:YAG

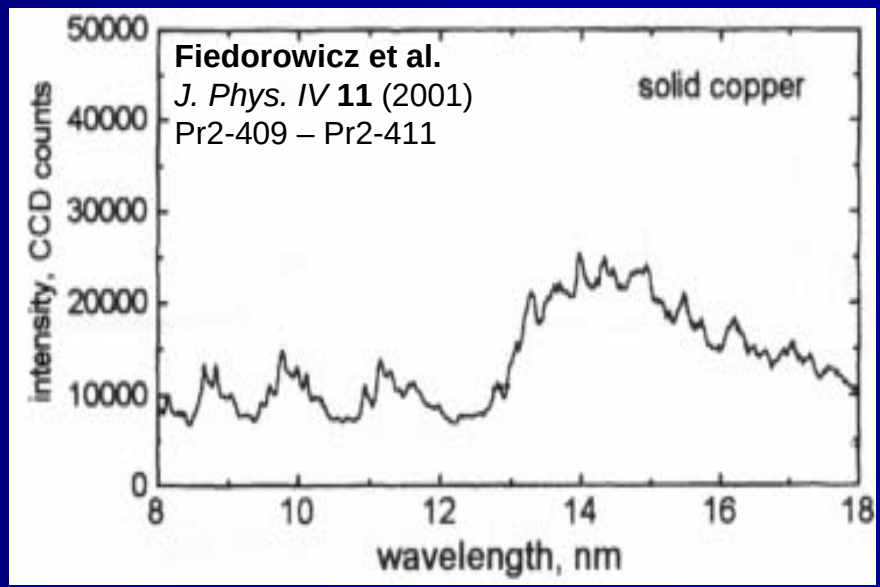
XUV spectrum 8-18 nm (Copper plasma)

Carbon fibre

Our result (brass electrodes)



Laser produced plasma (solid copper)



Comparison of carbon fibres with 20 and 120 μm diameter

Diameter of carbon fibre	**120 μm**	**20 μm**
XUV pulse:		
emitted at	**260 ± 30 ns**	**210 ± 30 ns**
FWHM	**50 ± 30 ns**	**15 ± 5 ns**
XUV spectrum 8-24 nm	**more impurities**	
Temperature T_e (O VI)	**15 eV**	**15 eV**
Temperature T_e (C V, C VI)	**60 eV**	**80 eV**
El. density n_e (C V, C VI)	**3.10^{19} cm^{-3}**	**10^{20} cm^{-3}**

The peak current as well as the maximum emitted power were the same in the both cases.

Conclusions

- Experiments with temporal XUV diagnostics
  - XUV spectroscopy
  - Pinhole imaging
  - Schlieren imaging
- Electron temperature and density estimation
- XUV, VUV and electron density gradient images with temporal resolution
- Comparison of carbon fibres with 20 and 120 μm diameter

- This research has been supported by the research program No. J04/98:212300017 "Research of Energy Consumption Effectiveness and Quality", the CTU in Prague, by the programs INGO LA055 "Research in Frame of the ICDMP", and LN00A100 "Research Center of Laser Plasma", the Ministry of Education, Czech Republic.