2D imaging X-ray spectrometer on WEST : results and technical challenges

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INTRODUCTION

A 2D X-ray imaging crystal spectrometer (XICS) was installed on WEST [1]
A remote-controlled rotating stage allows to choose one of 3 crystals, focusing on:

- Intrinsic FeXXV K-alpha spectrum (~1.86 A) (intrinsic Fe, low S/N)
- Injected Ar XVII K-alpha spectrum (~3.97 A) (injected Ar, good S/N)
- Injected ArXVIII Lyman-alpha spectrum (~3.73 A) (for high Te, low S/N otherwise)

Designed to indirectly measure:
Te (line ratio), Ti (Doppler broadening), vi (Doppler shift)

Installation, in-situ alignment & metrology

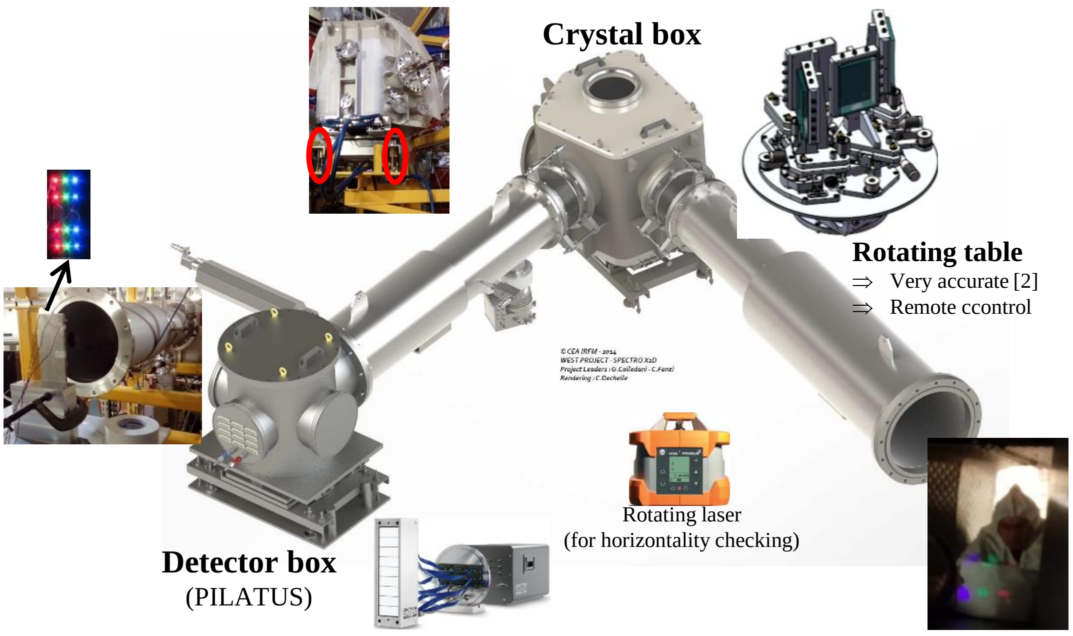

Fig. 01: Sketch of the XICS set-up on WEST and alignment apparatus. The detector camera is located tangentially to a best fit of the three crystals' Rowland circles.
Horizontality was checked with a rotating laser, micro-screws were used for fine-positioning of the boxes and of each crystal to determine the best focalization of a slit source, and lines of sight were finally embodied by retro-lighting using a panel of diodes on a mock detector frame.

First experimental spectra and extra lines from W

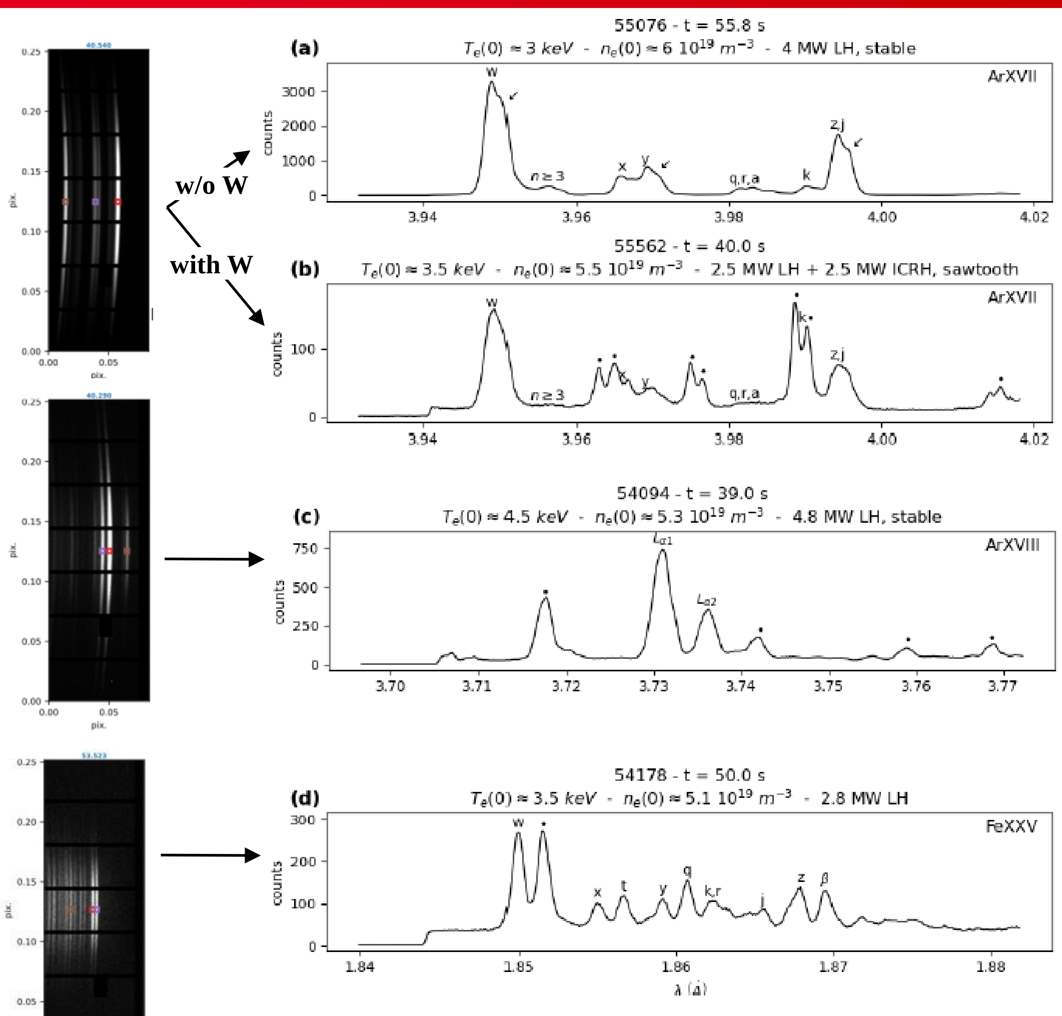

Fig. 02: (left column) Examples of typical 2d spectra images on the detector for each crystal (right column) typical associated 1d spectra
(a) and (b) Ar XVII spectra, with and w/o W lines (dots) - line doubling indicated by arrows
(c) Ar XVIII spectrum, with W pollution (d) FeXXV spectrum

Extra lines from W, identified in [3], are visible in plasma conditions that remain to be systematically characterized.
⇒ Induce spectral pollution (short-term), but vehicles extra information (long-term)

Lines doubling

Observation: all lines seem to be doubled

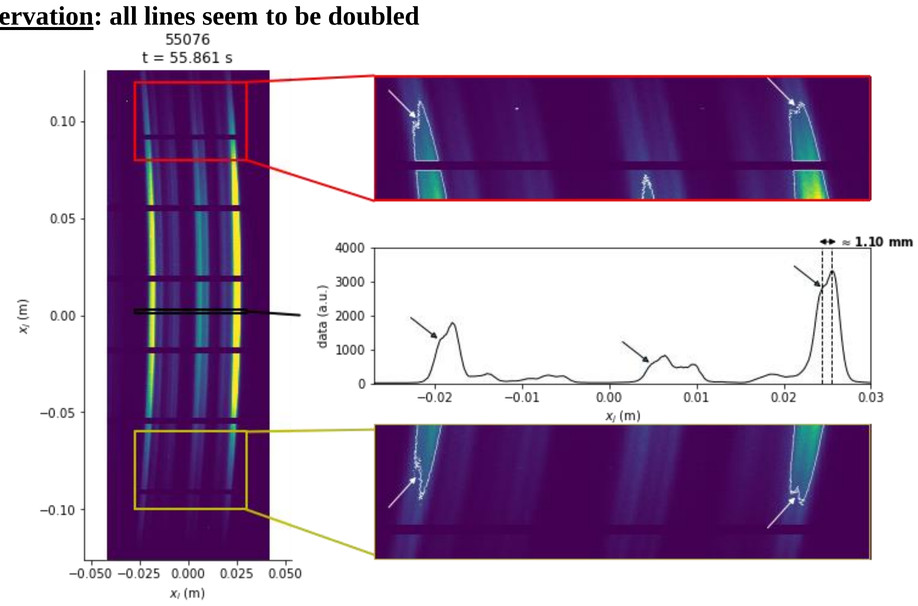

Fig. 03: Evidence of the line doubling on data from campaigns C3 and C4

Context: crystals manufactured in 2 halves, glued side by side on a common support.

Hypothesis: parallelism between inner lattice and optical surface = accuracy of cut. Tolerance on each half cumulates to a non-negligible discrepancy (spectral shift) between the spectra focused by each crystal half => 2 shifted spectra superimposed.

id	mat.	thick. (μm)	mesh	cut (Miller)	d ($\AA$)	parallel. (arc min)	dim. ($mmxmm$)	curv. (m)	λ_{ref} ($\AA$)	$\beta(\lambda_{ref})$ (deg.)	α_{ref} (deg.)
Ar XVII	Quartz	197	hex.	(1,1,-2,0)	2.454	$\leq$ 1.5	(2x40)x100	2.743	3.96	53.8	1.3405
Ar XVIII	Quartz	197	hex.	(1,0,-1,2)	2.279	$\leq$ 1.5	(2x40)x100	2.743	3.75	55.3	-101.0
Fe XXV	Ge	176	cubic	(4,2,2)	1.155	$\leq$ 1.0	40x(2x53)	2.743	1.86	53.6	-181.9705

Lines doubling compatible with crystal specs

Lines doubling modelled

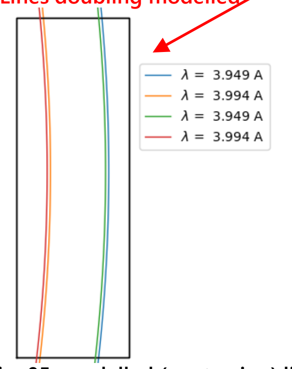

Fig. 05: modelled (ray tracing) line doubling with a 3 arcmin non-parallelism for lines w and z of Ar XVII

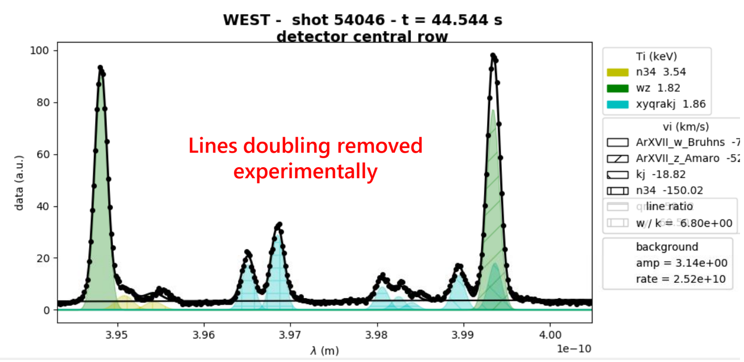

Fig. 04: In campaign C5, one half of each crystal was covered by an Al plate, leading to the disappearance of the line doubling => experimental confirmation of the hypothesis

CONCLUSION and Perspectives

Conclusion:

- **Spectrometer installed, aligned, operated**
- **Spectra as expected except:**
  - **W extra lines (identified by another team in [3])**
  - **Lines doubling (explained in this poster)**

Short term / ongoing efforts, using tofu [4]:

- **Determination of an optimal set of operation parameters**
- **Optimization of fitting routines (inc. doubling)**
- **Accurate 3D modelling accounting for observations (non-parallelism, vignetting…)**
- **Automated production of line-integrated proxys of Te and Ti issued**
- **Synthetic diagnostics**

Longer term:

- **Better understanding of injected Ar behavior (transport…)**
- **Triple inversion algorithms to get local (Te, Ti, vrot) fields [5]**
- **Cross-validation with other diagnostics (ECE, multi-energy SXR camera…)**
- **Replace crystals with single-piece**

References

[1] D. Vezinet et al, ECPD conference; Lisboa, 2019, poster P3.6
[2] G. Colledani patent number 1653710 from the 27th April 2016
[3] J E Rice et al 2021 J. Phys. B: At. Mol. Opt. Phys. 54 095701
[4] D. Vezinet et al, Nuclear Fusion, 56, 2016