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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 Å) (intrinsic Fe, low S/N)
- Injected Ar XVII K-alpha spectrum (~3.97 Å) (injected Ar, good S/N)
- Injected ArXVIII Lyman-alpha spectrum (~3.73 Å) (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

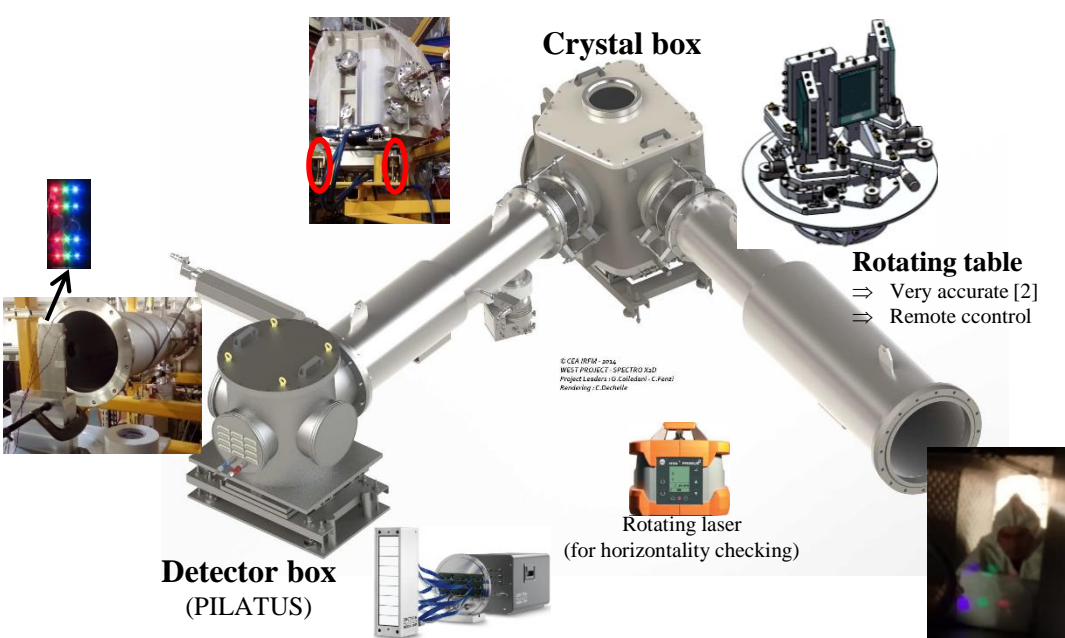


Fig. 01: Sketch of the XICS set-up on WEST and alignment apparatus. The detector camera is located tangentially to a best fit of the three crystals' Rowland circles. Horizontality was checked with a rotating laser, micro-screws were used for fine-positioning of the boxes and of each crystal to determine 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

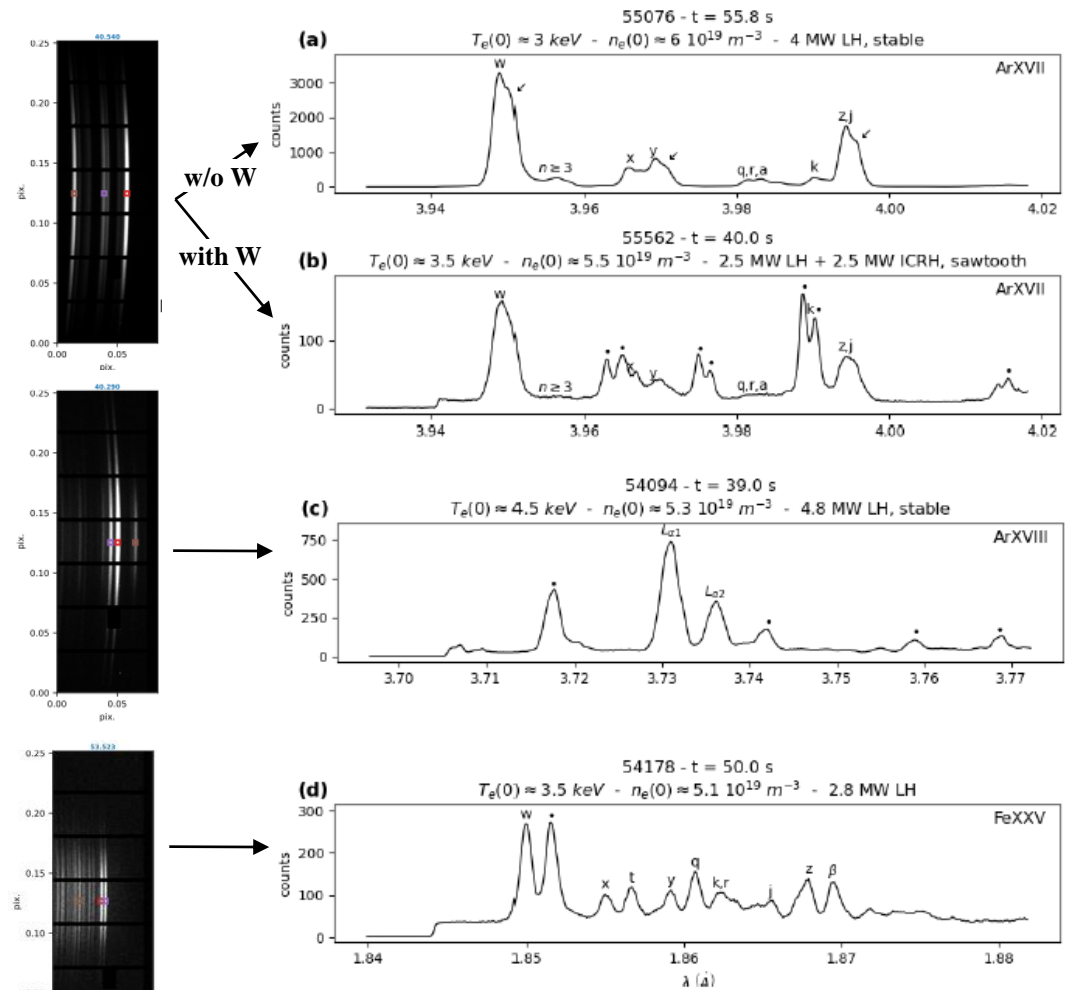


Fig. 02: (left column) Examples of typical 2d spectra images on the detector for each crystal (right column) typical associated 1d spectra
(a) and (b) Ar XVII spectra, with and w/o W lines (dots) - line doubling indicated by arrows
(c) Ar XVIII spectrum, with W pollution (d) FeXXV spectrum

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

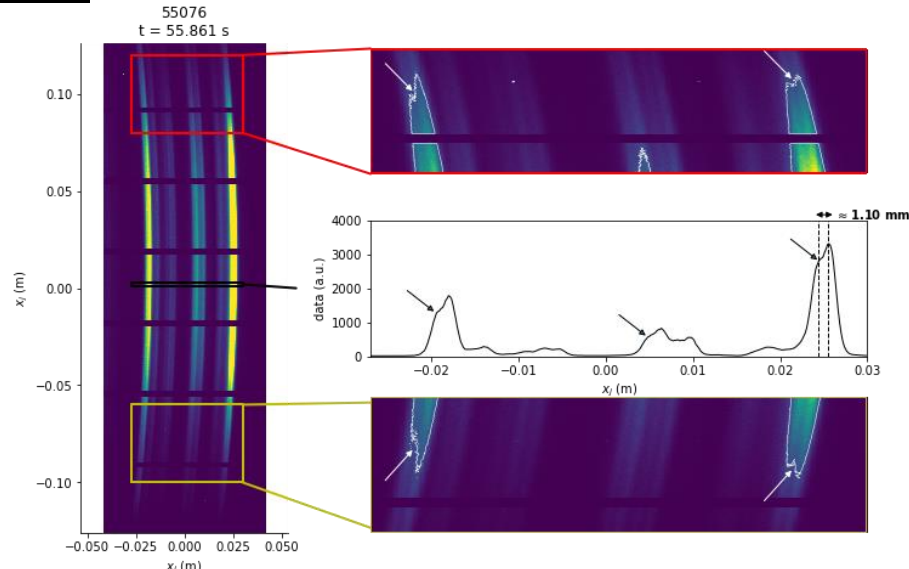


Fig. 03: Evidence of the line doubling on data from campaigns C3 and C4

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 (Å) | parallel. (arc min) | dim. (mmxmm) | curv. (m) | λ _{ref} (Å) | β(λ _{ref}) (deg.) | α _{ref} (deg.) |
|----------|--------|-------------|-------|--------------|-------|---------------------|--------------|-----------|----------------------|-----------------------------|-------------------------|
| Ar XVII | Quartz | 197 | hex. | (1,1,-2,0) | 2.454 | ≤ 1.5 | (2x40)x100 | 2.743 | 3.96 | 53.8 | 1.3405 |
| Ar XVIII | Quartz | 197 | hex. | (1,0,-1,2) | 2.279 | ≤ 1.5 | (2x40)x100 | 2.743 | 3.75 | 55.3 | -101.0 |
| Fe XXV | Ge | 176 | cubic | (4,2,2) | 1.155 | ≤ 1.0 | 40x(2x53) | 2.743 | 1.86 | 53.6 | -181.9705 |

Lines doubling compatible with crystal specs

Lines doubling modelled

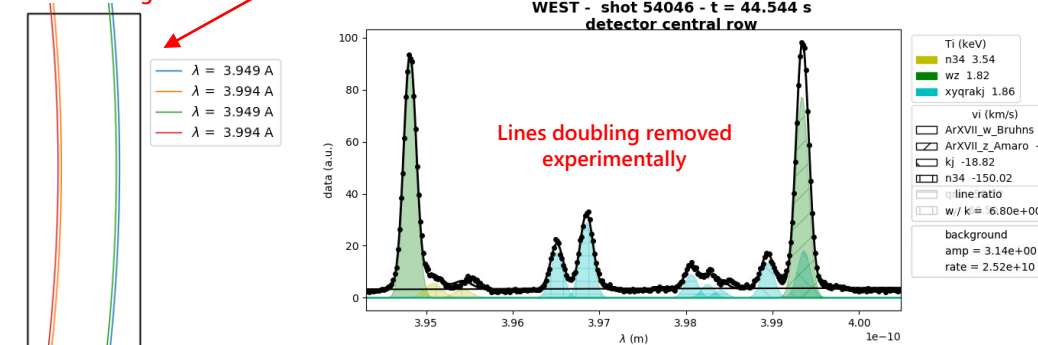


Fig. 05: modelled (ray tracing) line doubling with a 3 arcmin non-parallelism for lines w and z of Ar XVII

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