

A. Da Ros¹, D. Vezinet¹, G. Colledani¹, F. Bombarda², V. De Leo² and the WEST Team³

¹ CEA, IRFM, F-13108 Saint Paul-lez-Durance, France

² ENEA-FSN, Frascati (Rome), Italy

³ See (<http://west.cea.fr/WESTteam>) for the WEST Team

(adrien.daros@cea.fr)

Introduction

A 2D X-ray spectrometer with imaging crystals is operated on WEST tokamak. [1] 3 sets of Bragg crystals are mounted on a rotating table [2].

LOS-integrated measurements:

- Te : line intensity ratio
- Ti : Doppler broadening
- Vi : Doppler shift

➤ C3/C4 campaigns data: influence of the half-crystals defects

➤ C5 campaign data: impacts of polluting spectral lines on Te profiles

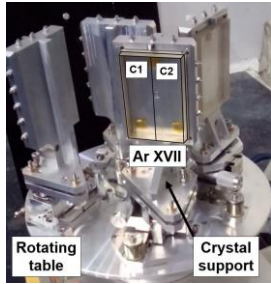


Fig. 1: Rotating table equipped with Ar XVII crystal showed here made in 2 halves

Experimental set-up and Ar XVII spectra

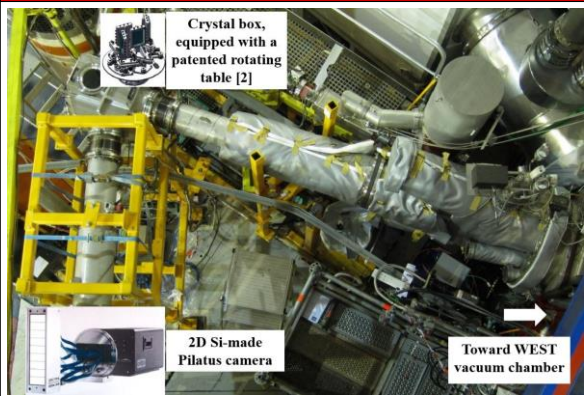
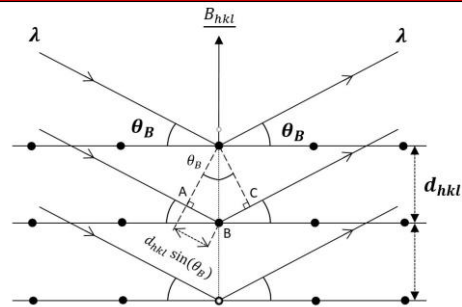


Fig. 2: Top view picture of the XICS spectrometer on WEST



Bragg relation:
 $n\lambda = 2d_{hkl} \cdot \sin(\theta_B)$

Fig. 3: Sketch of the diffraction process on a Bragg crystal of inter-reticular spacing d_{hkl}

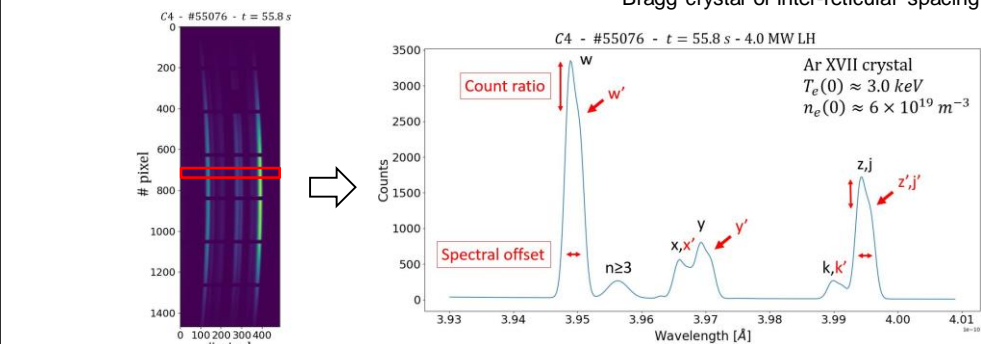


Fig. 4: Example of 2D spectra picture (left column), extracted 1D spectra (right column), showing a line-doubling phenomena (red arrows) doubling all spectral lines recorded, characterized by a **count ratio** and a **spectral offset**

Aim: understand both causes and effects of the spectral offset & the count ratio.

Numerical diffraction profiles

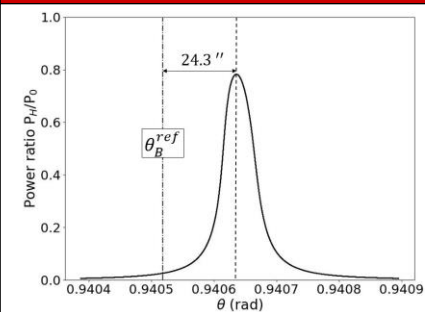


Fig. 5: Computed diffraction pattern for a Quartz Bragg crystal at the resonance line w versus diffracting angles θ . [3]

2 issues can affect the diffraction pattern :

- A miscut angle α between optical surface and reticular planes
- Ambient temperature changes : $d_{hkl}(T) \propto \Delta T$ [4]

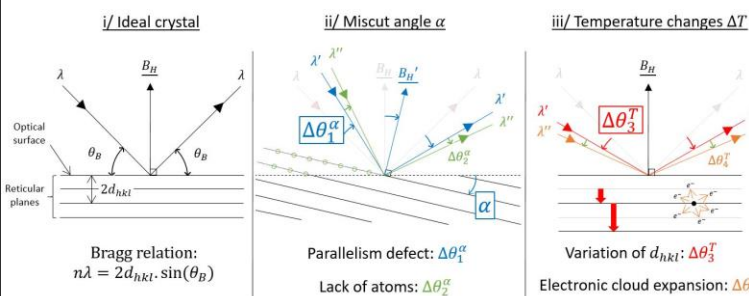


Fig. 6: Induced angular offsets on the direction of diffraction by α and ΔT .

Order of magnitude : $\Delta\theta_1^\alpha \approx \Delta\theta_3^T \gg \Delta\theta_2^\alpha > \Delta\theta_4^T$

$\Rightarrow \Delta\theta_1^\alpha$ & $\Delta\theta_3^T$ are the main angular offset components.

\Rightarrow Same order of magnitude as fitted with experimental data?

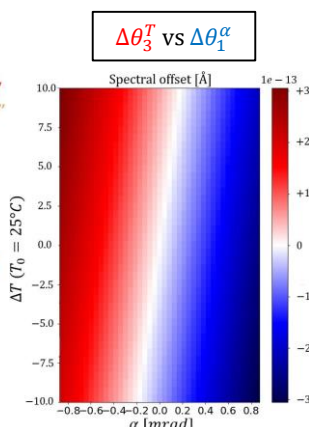


Fig. 7: 2D map of the computed angular offset versus $\Delta\theta_1^\alpha$ and $\Delta\theta_3^T$ variations.

Modelling lines on XICS synthetic diagnostic

Fig. 8: Modelled resonance w line positions, diffracted with both Ar XVII half-crystals (C1 and C2), with specified α and ΔT , for the XICS synthetic diagnostic, and comparison with pixel offset recorded from a C4 experimental spectrum.

From Fig. 8:

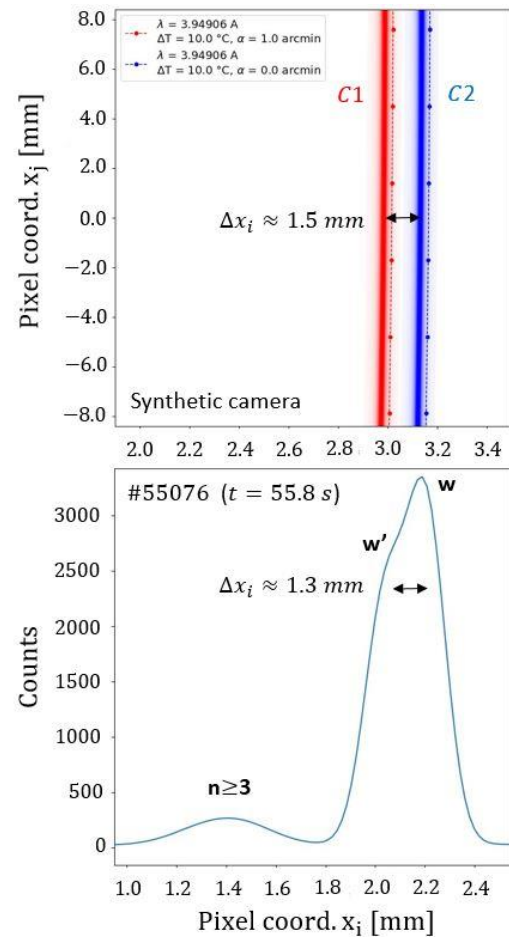
1. Same temperature : $\Delta T = 10^\circ C$
2. Half-crystal 1 : $\alpha = 1.0'$
3. Half-crystal 2 : $\alpha = 0.0'$

- $\Delta x_i \approx 1.5 \times 10^{-3} m$
 $\sim 10^{-3} m = \Delta x_i^{w/w'}$
($\approx \Delta x_{i,x/y}$)

\Rightarrow Good agreement between :

- i. the modelling of spectral lines under α and ΔT
- ii. the spectral offset fitted from the experimental spectra.

\Rightarrow No apparent link between these sources of error and the count ratio issue.



Electronic temperature profiles

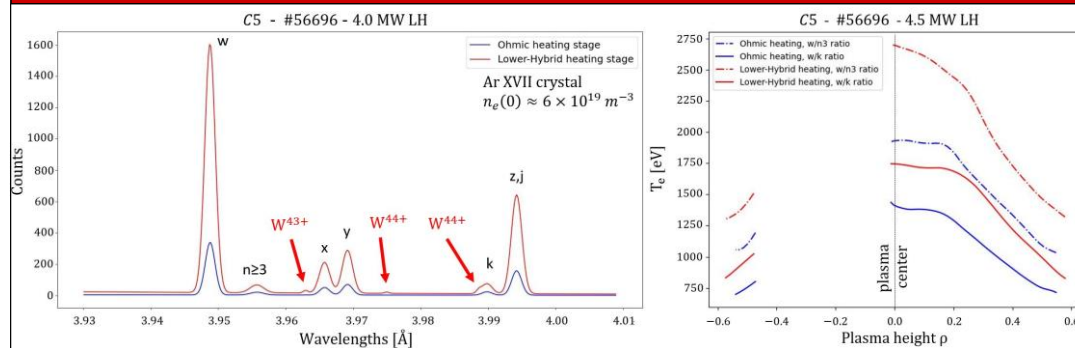


Fig. 9: Spectra from Ar XVII crystal w/o line-doubling

Fig. 10: Te LOS-profiles, for Ohmic and Lower Hybrid heating stages, from the resonance line w to the dielectronic satellite k line ratio and to $n \geq 3$ satellites line ratio

- 2 consecutive plasma heating stages: $P_{Ohm}(0.5 MW) < P_{LH}(4.5 MW)$

➤ At low power, temperature plateaus reached at the plasma center

➤ At high power, $T_{e,w/k}(0 < \rho < 0.2) = 1.8 keV \Rightarrow$ saturated

$T_{e,w/n3}(\rho = 0) = 2.7 keV \Rightarrow$ no issue noticed

\Rightarrow Disagreement between w/k and $w/n3$ line ratios due to polluting W lines [5], next to the Ar Li-like satellite line k .

Conclusion

- Line-doubling phenomena due to different structural properties of half-crystals; Computation of the diffracting pattern of a Bragg crystal, depending on:
 - The parallelism defect between the optical surface and reticular planes;
 - The ambient temperature to which the crystal is subject.
- \Rightarrow Better understanding of the spectral offset \Rightarrow improve synthetic diagnostic

- With or w/o this issue, presence of some polluting W lines (on Ar XVII spectra) affecting the measured intensity of the k lines \Rightarrow errors on Te profiles

In the next months:

- Identify the causes of the count ratio comparing all plasma campaigns data;
- Identify accurately the polluting spectral lines, especially the W lines in Ar spectra.

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] R. Bartiromo, F. Bombarda et al., Nucl. Instrum. Methods Phys. Res. A 221, 453 (1984)
 [4] L. Delgado-Aparicio et al., Plasma Phys. Control. Fusion 55, 125011 (2013)
 [5] J. E. Rice et al., J. Phys. B: At. Mol. Opt. Phys., 54 095701 (2021)