Investigation of the Extreme-UV background emission in WEST tokamak

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Background & Motivations

- Tungsten (W) density can be determined experimentally from its spectral line brightness [1]: $B_{ij} = \int n_e N_W f_z C_{ij}\, dl$

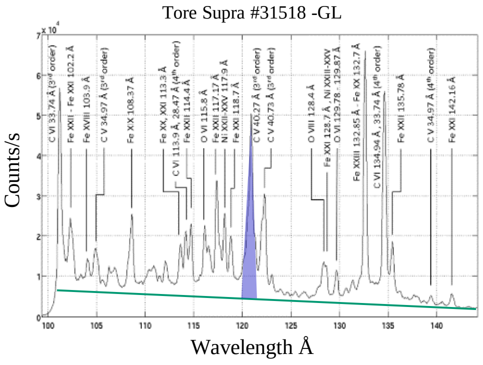
- Errors in line brightness determination due to background estimation.

- Low Z spectra (Tore Supra):

- Small background compared to lines.

→ Minor role on brightness values. Uncertainties are small.

Tore Supra #31518 -GL

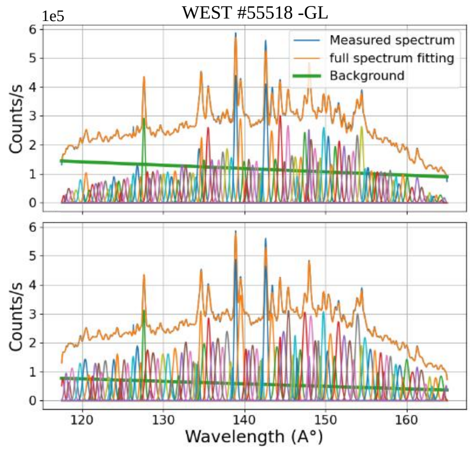


- High Z spectra (WEST):

- Apparent background is not small.
- Fitting procedure results depend strongly on the initial guesses.

→ What is the background real value ?

WEST #55518 -GL



We attempt to answer this question by assuming that the measured spectrum B_{tot} (in the wavelength region 115-165 Å) is composed of:

→ $$B_{tot} = B_{line} + B_{ff} + B_{fb} + B^{m>1}$$

Bremsstrahlung; Recombination radiation; Higher diffraction orders emission

Higher diffraction orders emission

- Light propagation Inside the spectrometer:

$$B^m(m\lambda) = B_0 E_G^m(\lambda) E_D(\lambda)$$

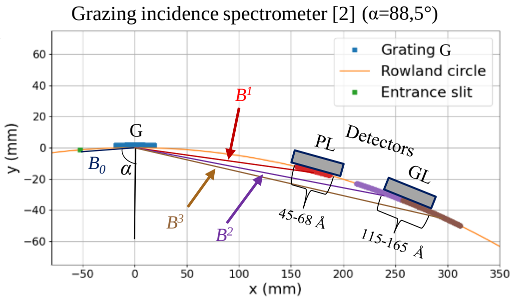
Measured brightness; Grating efficiency; Detector efficiency

$$\frac{B^{m>1}(m\lambda)}{B^1(\lambda)} = \frac{E_G^{m>1}(\lambda)}{E_G^1(\lambda)} \frac{E_D^{GL}(\lambda)}{E_D^{PL}(\lambda)} = K^{m>1}(\lambda)$$

→ $$B^{m>1}(m\lambda) = B^1(\lambda) K^{m>1}(\lambda)$$

Higher orders; First order

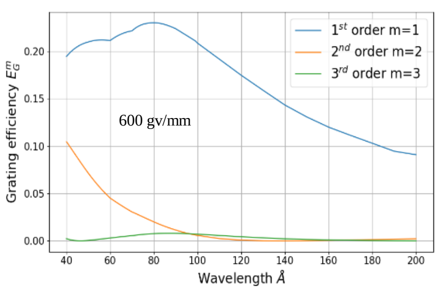
Grazing incidence spectrometer [2] (α=88,5°)



Grating efficiency simulation

- Differential method [3]
- Wavelength region : λ = 40 – 200 Å
- Grating parameters:

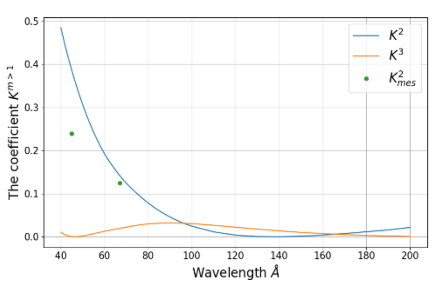
Grating length	Grating radius	Incidence angle α	Blaze angle	Coating
35 mm	1999.5mm	88.50°	1.5°	Gold



- $K^{m>1}(\lambda)$ coefficient :

relates the spectrum brightness of a particular order m $B^{m>1}$ to the first order spectrum B^1.

- Identical detectors (their efficiency ratio ~1)
- Good agreement:
  2nd order K^2 calculations and measurements.
- Errors : concave grating aberrations (5-15 %).



Bremsstrahlung & recombination radiation

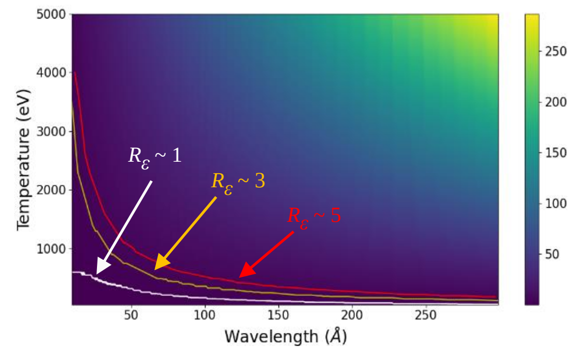
Continuum emission calculations (ff, fb)

- Maxwellian emission coefficients (C_{ff}, C_{fb}) [4].
- Impurity : tungsten (Z=74).
- Wavelength range : λ = 10 – 300 Å.
- Temperature range : T_e = 50 – 5000 eV.

→ Reasonable and fast estimation of the two processes

- The comparison of Bremsstrahlung (ff) and radiative recombination (fb) is done by calculating the local emissivity ratio R_ε of the two processes:

$$R_\varepsilon = \frac{\varepsilon_{ff}}{\varepsilon_{fb}} = \frac{\sum_z f_z C_{ff}^z}{\sum_z f_z C_{fb}^z}$$



- λ < 50 Å: fb is not negligible and can be dominant below 500 eV.
- λ > 50 Å: fb is negligible with respect to ff for almost all temperatures (λ=115-165 Å in particular).

- Total Bremsstrahlung [5] : $$\varepsilon_{ff}(\lambda) = 9.584.10^{-14} \frac{n_e^2}{\lambda\sqrt{T_e}} Z_{eff} \overline{G_{ff}} \exp(-\frac{hc}{\lambda T_e})$$

Analysis of a low temperature spectrum (T_e ~ 1 keV)

- Application to spectrum measured by GL (115-165 Å) during the discharge #55647:

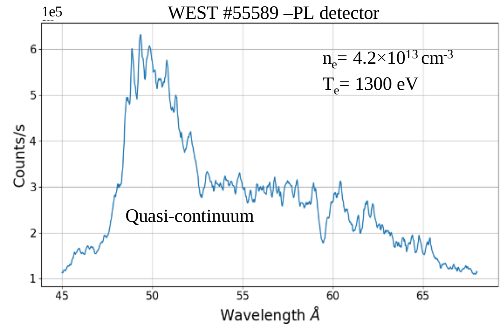
Higher diffraction orders B^2 and B^3

- Estimated using a spectrum measured by PL (45-68 Å) during the discharge #55589.

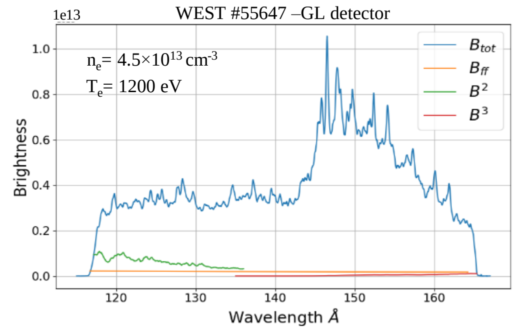
Bremsstrahlung B_{ff}

- Evaluated using #55647 plasma parameters and Z_{eff}=2.5.

WEST #55589 –PL detector



WEST #55647 –GL detector



- Bremsstrahlung (B_{ff}) is negligible.
- 2nd order B^2 may contribute to the spectrum.
- spectral lines dominate the emission (merge into an apparent background ?).
- Individual lines wavelengths above 145 Å correspond very well with those of 47-53 Å quasi-continuum, which casts some doubt on the 3rd order calculation.

→ Uncertainties in line brightness (therefore W density) determination may not be small.

Conclusion & Perspectives

- In the wavelength region 115-165 Å at low temperatures (Te ≈ 1 keV) :
- Continuum emission (Bremsstrahlung and recombination) is very weak.
- Higher diffraction order emission may contribute to the spectra.
- Spectral lines dominate the emission.

$$B_{tot} = B_{line} + \cancel{B_{ff}} + \cancel{B_{fb}} + B^2 + \cancel{B^3}$$

- What about spectra measured in different wavelength and temperature ?

References:
[1] R. Guirlet, et al. Plasma Physics and Controlled Fusion, 2022.
[2] J.L. Schwob, et al. Review of scientific instruments 58.9: 1601-1615, 1987.
[3] E. Popov, M. Neviere. J. Opt. Soc. Am. A, 18, 2886–2894, 2001.
[4] A. Burgess, H.P. Summers, Monthly Notices of the Royal Astronomical Society, 226(2):257–272, 1987.
[5] M.E. Foord, et al, Review of Scientific Instruments, 53(9), 1407-1409, 1982.

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.