§ 45. Optimization of TESPEL CXRS Diagnostic in the Visible Spectral Range for the Impurity Transport Study on LHD

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The behavior of impurity tracer ions deposited locally in the core plasma by means of TESPEL injection can be measured by the observation of the line emission due to charge exchange reaction of injected impurity nuclei, I (nuclear charge Z) with the neutral beam injection (NBI) hydrogen atoms, H (assumed to be in their ground state):

$$I^{Z+} + H_{1s} \Rightarrow I^{(Z-1)+} + H^{+} \qquad (1).$$

This method allows us to estimate the local impurity diffusion coefficients, which is already obtained by Li III (λ_{Li}=449.9 nm) on CHS [1,2]. In TESPEL CXRS experiments with the Li tracer on LHD, however, Li III emission in the visible spectral range could not be measured due to the low S/N ratio and/or other reasons. As was mentioned in [3], the key parameter of this problem is the cross-section of the reaction (1). It is well known that the CX total cross-section depends on NBI beam energy (E_{NBI}) and Z impurity charge. On Li III case the value of CX cross-section for LHD (E_{NBI} = 150kev) is about 30 times less that that for CHS (36keV). During the 6th LHD campaign, according to the theoretical optimization of the TESPEL CXR signals for various impurities in the visible spectral range under the conditions of the LHD plasma [3], the TESPEL CXRS experiments with other tracer materials, such as Fluorine (F, $\lambda_{F(n=10\rightarrow9)}$=479.3 nm) and Magnesium (Mg, $\lambda_{Mg(n=12\rightarrow11)}$=478.9 nm), have been carried out. The F tracer was used as a teflon $(C_2F_4)_n$ block and the Mg tracer as a powder. In our experiments, the TESPEL outer diameter is ranged from 600 to 900 μm. Since it is difficult to evaluate the amount of these impurities due to its amorphous shape, we assumed that the 50 % (~ 2 x 10^{-12}m^{-3}) by volume of the inner core of the TESPEL is occupied by the tracer material. Then, the total amount of the impurities injected by TESPEL was approximately 1 x 10^{17} for the F tracer, and 8 x10^{16} for the Mg tracer, respectively. In the case of the F tracer, in only few shots, a small signal was observed at one of the eight channels. In the case of the Mg tracer, the signal as the CXR emission was not observed.

For comparison with our results, the CXR emissions of other materials, such as Ne ($\lambda_{Ne(n=11\rightarrow10)}$= 524.7 nm), B ($\lambda_{B(n=7\rightarrow6)}$=494.6 nm) and C ($\lambda_{C(n=8\rightarrow7)}$=529 nm), were investigated. This could be done after the impurity injection, such as the gas puffing and the pure pellet injection. In the case of the pure impurity pellet, the total amount of the impurity in that is approximately 3 x 10^{19} and 1 x 10^{20} for C and Ne, respectively, which is several orders of magnitude more than in the TESPEL. In this case, the CXR signal measured at the plasma periphery was two orders of magnitude larger than the F tracer CXR signal level measured as shown in Fig.1.

Judging from these experimental results, the CXR measurement in the visible range is expected to be possible by increasing the tracer amount. The inner core diameter in the current TESPEL setup can be increased up to 300 μm, and the resulting tracer amount up to 4 x 10^{18}. As seen from Fig.1, the increase of the CXR signal by one order of magnitude is expected by increasing the impurity amount, if we assume the same level of coefficient of visible light emission for each tracer material. In addition, since the increase of the CXR cross-section is expected in the VUV and ultra soft x-ray spectral range, the measurement in that domain will be performed for the next campaign.

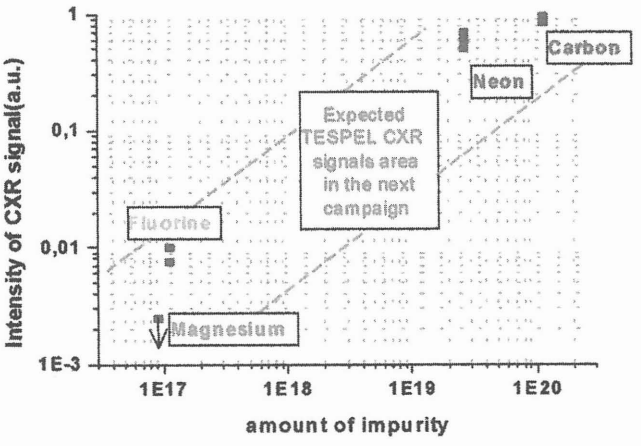

Fig.1. Comparison of the CXR signal intensity measured in the visible spectral range from the TESPEL (Fluorine (λ_F=479.3 nm), Magnesium (λ_{Mg}=478.9 nm)) and from the pure impurity pellet (Neon (λ_{Ne}=524.7 nm) and Carbon (λ_C=529 nm)). The amount of the impurities was different.

References:
1) K. Khlopenkov, S. Sudo, Plasma Phys. Control. Fusion 43 (2001) 1547
2) Sudo S. *et al.*, Plasma Phys. Control. Fusion **44** (2002) 129
3) Sergeev V.Yu. et al., Plasma Phys. Control. Fusion **44** (2002) 277