accuracy of hydrogen isotope ratio measurements in the ITER scrape-off layer by hα diagnostics without using optical dUmps

1,2,3Kukushkin A.B., 1Neverov V.S., 1Alekseev A.G.

1NRC “Kurchatov Institute”, Moscow, Russia, [Kukushkin\_AB@nrcki.ru](mailto:Kukushkin_AB@nrcki.ru)  
2Moscow Research Nuclear University MEPhI, Moscow, Russia  
3Moscow Institute of Physics and Technology, Dolgoprudnyi, Moscow oblast, Russia

Using the approach of synthetic Hα-diagnostics in the tokamak main chamber, basic principles of which were formulated in [1], we analyzed the accuracy of measuring the hydrogen isotope ratio in the ITER scrape-off layer (SOL) with the differential measurement scheme, which uses spatial inhomogeneity of the light reflectance of the first wall. Such analysis is required because the measurement targeting on the first wall cannot be stabilized under conditions of its mechanical movements during the discharge, and the diagnostics cannot guarantee that the entire observation spot on the line of sight (LoS) will be allocated in the narrow optical dump. The calculations were performed for the LoS, inclined from the normal to the first wall by 25°. This LoS corresponds to the lowest ratio of the divertor stray light (DSL) to the useful signal among all the LoSs from the ITER equatorial port-plug. The synthetic spectra of Dα and Tα lines in the SOL were calculated using the Ballistic Model [2] while the temperature and density profiles of electrons and ions in the SOL, required for the Ballistic Model, were generated by the SOLPS (B2-EIRENE) numerical code [3–5] on an expanded numerical mesh with a wide variation of plasma parameters near the first wall [6].

It is shown that even without the DSL, the absolute error of the recovered tritium concentration in the D-T plasma, T/(T + D), can reach a value of 0.4, which in the case of equal concentrations of tritium and deuterium in the mixture corresponds to a relative error of 80%. Such a large error is the result of the complicated shape of the observed spectrum, that is caused by: (i) the strong asymmetry of the spectral line shapes of Dα and Tα lines, caused by the net inward flux of D and T atoms from the wall into the plasma, and (ii) the fact that the observed signal contains the contributions from the emissive layers on both the high and low magnetic field sides of the SOL. It is possible to minimize the effect of the DSL on the measurement accuracy by using the differential (bifurcated-LoS) measurement scheme but only in the scenario with a high plasma density in the SOL and only when the intensity of the DSL on one LoS is lower than that on the another, neighboring LoS by a factor of 1.5. In this case, the absolute error of the T/(T + D) ratio is close to that without the DSL (~0.4).

References

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