§29. He Gas Exhaust Experiments in LHD Closed Divertor with Pumping Function and Resonance Magnetic Perturbation Coils

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i) Introduction

Although the ratio of the alpha ash confinement time to the energy confinement time should be $\tau_\alpha^*/\tau_E<7.5$ to realize FFHR helical reactor, enough research has not been conducted. He exhaust experiments using the local island divertor (LID) with pumping function had been conducted in LHD to estimate this value. However it was difficult to derive the accurate He density profiles from the He CX signal data because the He plume was superimposed on the profile signals due to the tangential viewing configuration.

In this annual report, we present the reanalyzed past data on He^+ and He^{++} lines based on the Fonck model. In the measured density regime, τ_α^*/τ_E with LID is acceptable for He ash exhaust in a helical reactor. While final solution of a divertor has not been obtained, LID configuration could be reconsidered as one of solution if the heat flux problem is solved.

ii) S/N ratio based on the 2D Fonck model

In Fig. 1 is shown the line-integrated signal excited by NBI and noise from He^+ plume along the viewing sight line, which is calculated on 2D geometry of LHD configuration. The bi-Fermi profile of He^{++} ion is assumed for He gas puffing. As the ℓ-mixing effect of the He^+ electron excitation, enhancing the He ion plume, is found to be reduced by the recent ADAS system, the S/N ratio is improved to ~3 compared to the previous work [1].

iii) 3D magnetic field line effect

3D magnetic field line calculated by the late Professor Emeritus T. Watanabe is shown in Fig.2. Upper figure shows the side view of the magnetic field line starting at inboard side of R=3.3678m. The magnetic field line shifts down as going leftward from the NBI injection part. On the outboard side (R=4.2549m), the magnetic field line shifts up due to the rotational transform. Between those points, the magnetic field line exists on the equatorial plane. However, the magnetic field and viewing sight lines intersect at the oblique angle, the He plume signal is further reduced. Therefore, we can almost interpret that the obtained signal has smaller He plume noise.

iv) Re-analysis of LID He exhaust experiments

In the case of the line density of $0.7\text{x}10^{19}$ m^{-3}, diagnostic NBI is modulated to distinguish He^{++} ion signals from the background He^+ signal. We note that the He plume effect cannot be removed by NBI modulation [1]. In Fig.3 is shown the CX measured signals. With NBI, the He^{++} ion is observed, and He^+ signal is obtained in no NBI phase. After subtraction of fitting curve for no NBI phase from the modulated signal, He^{++} density decay is obtained as shown in Fig.4. From this decay curve, the confinement time of He^{++} for t=1.9～2.3s is τ_α^*～350 ms, which is estimated by dn/dt=S-dn/ τ_α^* (here S=0). As the energy confinement time is τ_E～69 ms at t=1.91s, τ_α^*/τ_E～5.0 has been obtained. Therefore, it is found that the exhaust capability achieved in LID configuration is at least necessary to realize a helical reactor.

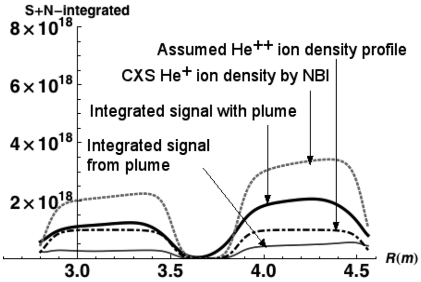

Fig. 1. Integrated signal and noise from He^+ plume along the sight line for $n(0)=1.0\text{x}10^{19}$ m^{-3} and $T_e(0)$=1.5 keV.

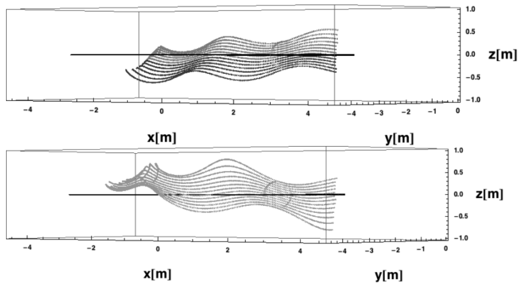

Fig. 2. Magnetic field line of LHD viewing from the outboard on the equatorial plane. Upper : R=3.3678 m and Lower: R=4.2549 m.

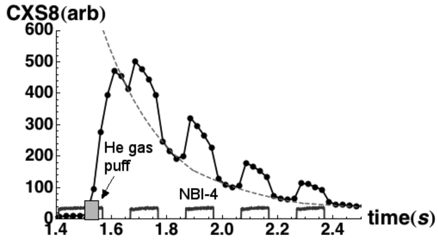

Fig. 3. Observed 4686 Å line at R=4.03 m after He gas puffing during diagnostic NBI modulation (#73556). Red dotted line is the fitting curve showing no NBI phase, revealing He^+ ion decay in the plasma edge.

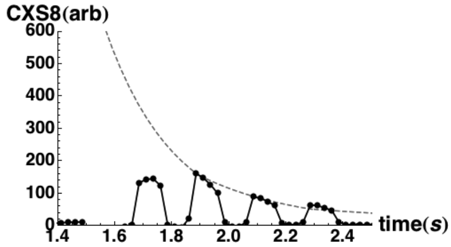

Fig.4. After subtraction of no NBI fitting curve from the modulated signal, He^{++} density decay is obtained (#73556). Red dotted line is the same as in Fig.3.

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[1] R. J. Fonck, et al., Physical Review A, 29 (1984) 3288