§11. Preliminary Study on the He Gas Exhaust in LHD Closed Divertor with Pumping Function

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The ratio of the alpha ash confinement time to the energy confinement time (τ_α^*/τ_E) is one of important parameters in designing the FFHR helical reactor. To study the alpha ash confinement time, He exhaust experiments have been performed. However, it is difficult to evaluate its value accurately due to complicated observation geometry in the LHD CXS system. For experimental data analysis we are preparing the numerical tools to obtain the profile of charge exchanged excited He ions by NBI from the line-integrated signal. In the previous report we assumed that plume He^+ ions drifts to infinite distance. In this report the drifting distance is assumed to be limited to ±3.75 m (±60 degree) in both the toroidal directions from the NBI injected area.

He^{++} ion density in the plasma surface by gas puffing is assumed by Bi-Fermi profiles as

$$\left[\frac{n(r)}{n(0)}\right]_{He++} = \left[\exp\left[40\left\{\left(\frac{\rho_\phi}{a_\phi}-\frac{r_{ED}}{a_o}\right)^2-\Delta a_\phi\right\}\right]+1\right]^{-1} + \left[\exp\left[40\left\{\left(\frac{\rho_\phi}{a_\phi}+\frac{r_{ED}}{a_o}\right)^2-\Delta a_\phi\right\}\right]+1\right]^{-1} \quad (1)$$

where r_{ED} is the peak distance from the plasma center R_o=3.6m, Δa_ϕ is its width. CXS observation geometry is shown in Fig, 1.

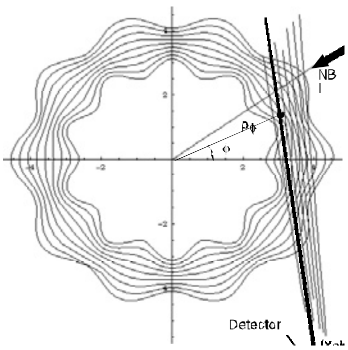

Fig. 1. Approximated magnetic field line on the equatorial plane in the LHD, and the observing lines of the CXS.

The neutral density profile in NBI with the simplified ionization cross section for the parabolic density profile is given by

$$\left[\frac{n_{NBI}(r)}{n_{NBI}(0)}\right] = exp\left(-a_\phi \cdot \frac{A_{NBI}Z_{eff}}{5.5\times10^{-3}E_{NBI}[keV]} \cdot \frac{n(0)}{10^{20}}\left(\frac{2}{3}-x+\frac{x^3}{3}\right)\right) \quad (2)$$

with $x=\rho_\phi/a_\phi$, E_{NBI}=40keV, Z_{eff}=2, A_{NBI}=1, and the peak electron density n(0). Thus, excited He^+ ions by charge exchange is proportional to the product of Eqs.(1) and (2).

The integrated signal along the sight line is calculated by

$$\frac{I(y)}{I(0)} = \int_{-\phi max}^{\phi max}\left[\frac{n(r)}{n(0)}\right]_{He+*}\sqrt{\frac{1}{c^2}+1}\,\frac{\left(x_{ob}-\frac{y_{ob}}{c}\right)}{\left(\cos\phi-\frac{1}{c}\sin\phi\right)^2}d\phi \quad (3)$$

In Fig. 2 and 3 are shown the cases of the peak density of 0.5×10^{19} m^{-3} and 2×10^{19} m^{-3}. Left figure shows the signal (excited He^+ ions by NBI) on the sight line through the point of R=3.6m in the NBI injected area. As the plume is assumed to be from -24 to 96 degree in Fig. 1 and Fig. 2-(Left), the signal from the inboard side is reduced. Right figure shows the integrated signal (solid red line) along the sight line for various minor radii and excited He^+ ion profile by NBI (dashed line). In the low-density regime of 5×10^{12} m^{-3} (Fig. 2) NBI penetration is good, therefore signals come from the inboard and outboard sides. However, in the higher density (Fig. 3) the signal comes only from the outboard side due to poor NBI penetration.

The 3D magnetic field line through the NBI injected area is shown by Mathematica in Fig. 3, which was calculated by Prof emeritus T. Watanabe. The rotation of the magnetic field line indicates importance of the finite NBI beam

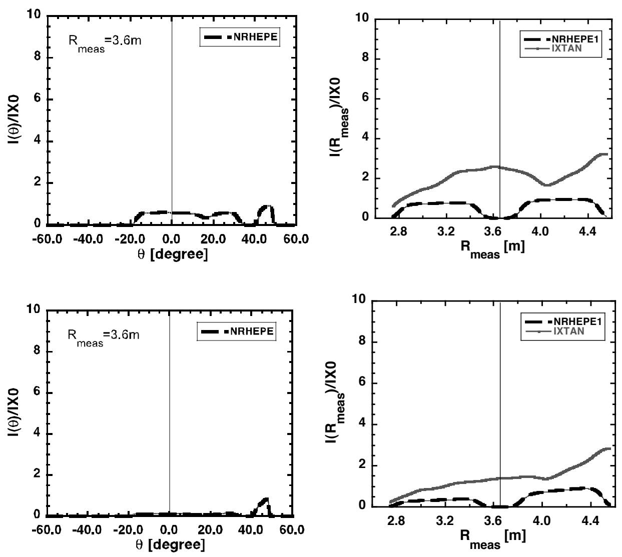

Fig. 2. (Left) Distributed signal along the tangential sight line (Black). (Right) The observed integrated intensity (solid red line) along the tangential sight line for the excited He^+ ion distribution (dashed line) by NBI. (Upper: $n(0)=0.5\times10^{19}$ m^{-3} and Lower: $n(0)=2\times10^{19}$ m^{-3})

geometry to take the plume effect into account.

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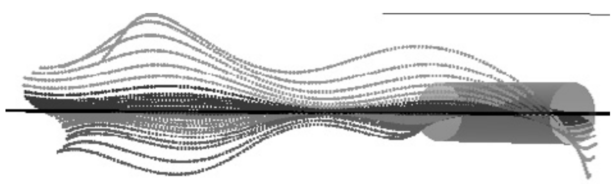

Fig. 3. Horizontal view from the outboard side of the 3D magnetic field lines through the NBI (right circular column) injected area and CXS sight line (horizontal black line) for He ion plume analysis.