§22. Study on the He Exhaust Characteristics during LID Operation in LHD

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The ratio of the alpha ash confinement time to the energy confinement time ($\tau_\alpha{}^*/\tau_E$) is one of important parameters in 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 this report we present the numerical results on how the line-integrated signal from charge exchanged excited He ions by NBI is seen on the viewing sight line in the LHD CXS system. We here assume that plume He^+ ions drifting to the toroidal direction emit the 4868 Å line as in the NBI injection area.

Using the polar coordinate the measured position ρ_ϕ from the plasma center on the tangential sight line is given by

$$\rho_\phi = r - R_o = \left(x_{ob} - \frac{y_{ob}}{c} \right) / \left(\cos\phi - \frac{1}{c}\sin\phi \right) - R_o$$

where c is the inclination of the sight line, (x_{ob},y_{ob}) is the detector focal point, and ϕ is the toroidal angle of the observation points. The outer magnetic field line on the equatorial plane is approximated by toroicoid curves given by

$$a_\phi = a_o \left\{ \frac{1+k}{2} + \frac{k-1}{2}\cos(m\phi) \right\}$$

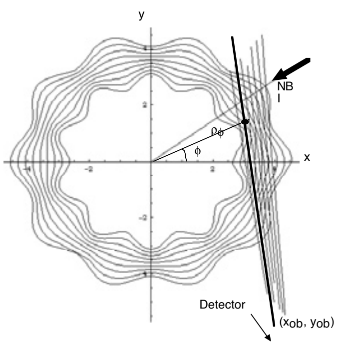

Fig. 1. Approximated magnetic field line on the equatorial plane in the LHD, and the observing lines of

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

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

$$\left[\exp\left[40\left\{ \left(\frac{\rho_\phi}{a_\phi} + \frac{r_{ED}}{a_o} \right)^2 - \Delta a_\phi \right\} \right] + 1 \right]^{-1}$$

where r_{ED} is the peak distance from the plasma center R_o=3.6m, Δa_ϕ is its width. The particle density profile in NBI with the simplified ionization cross section for the parabolic density profile is given by

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

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

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

In Fig. 2 and 3 are shown the cases of the peak density of $0.5\mathrm{x}10^{19}$ m^{-3} and $2\mathrm{x}10^{19}$ m^{-3}. Left figure shows the signal (excited He^+ ions by NBI) viewing on the sight line through the point of R=3.6m in the NBI injected area. The signal around -30 degree (closer to the detector) is from the outboard profile, and signal at -20~+40 degree from the inboard profile, signal at +45 degree again from the outboard profile.

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 (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 detailed He ion plume and 3D magnetic field line effect should be further taken into account.

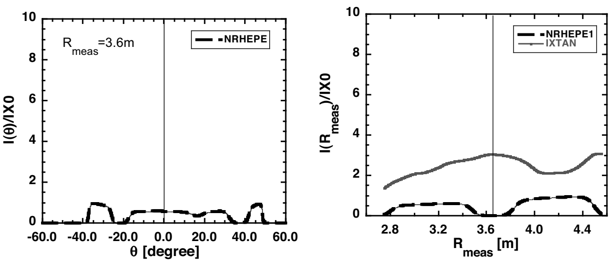

Fig. 2. (Left) Distributed signal along the tangential sight line(Black). (Right) The observed integrated intensity (solid red line) along the tangential sight line for the excited He^+ ion distribution by NBI (dashed line). n(0)=$0.5\mathrm{x}10^{19}$ m^{-3}

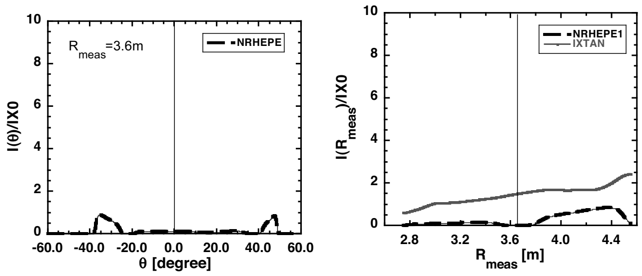

Fig. 3. The same as in Fig. 2 except for n(0)=$2\mathrm{x}10^{19}$ m^{-3}

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