§12. Stereoscopic Observation of Pellet Ablatant in LHD

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Applying stereoscopic technique[1] three dimensional motion of an ablating pellet in presence of tangential NBI beam is discussed.

Stereoscopic images are taken for the ablating pellets, injected from the repetitive pellet injector [2] to tangentially NBI heated plasma [Clock wise (CW) - 3.7 MW and Counter clockwise (CCW) - 2.8 MW] in LHD. The images taken by fast camera are of spatial resolution ≈ 90 K pixels and temporal resolution of 50 μs with 2 μs exposure time. Using projection matrices and the image points obtained from the pair of images, the three dimensional pellet position is reconstructed. A schematic of the stereo observation with NBI injection in LHD is shown in Fig.1.

Observation of the H_α and the camera data shows a peak in signal outside Last Closed Flux surface (LCFS) only for a CW NBI injected plasma. This observation indicates the heating of pellet by the CW NBI, as it comes under the direct influence of beam path before entering into the plasma.

Deviation of pellet trajectory from its injected direction [radial] has been seen in presence of both NBI conditions. An example of deflection of pellet trajectory and the deflection velocity along radial (V_R), vertical (V_Z) and toroidal (V_ϕ) direction for CW NBI injected pellet along the toroidal plane is shown in Fig. 2. The toroidal deflection observed in both NBI cases is ≈ 20 cm but poloidal deflection observed in case of CW NBI only, is ≈ 10 cm. Toroidal deflection velocity lies in the range 400 m/s - 800 m/s for CW NBI and 200 m/s - 500 m/s in case of CCW NBI. Toroidal acceleration for CW NBI is (0.7 - 1.5)$\times 10^6$ ms^{-2} and (0.4 - 0.8)$\times 10^6$ ms^{-2} in other case. The deflection observed is probably due to the asymmetric ablation on both side of pellet by fast ions generated from tangential NBI and subsequently formation of rocket effect in the toroidal direction. Considering one-dimensional heat flux term in the equation of motion along the toroidal direction, pellet acceleration calculated in the range (0.15 -1.5)$\times 10^6$ ms^{-2}, which is in close agreement with the observed acceleration in both cases.

The trajectory deflection starts at a normalized minor radius $\rho \approx 0.85$ for CW NBI and $\rho \approx 0.75$ for CCW NBI. This observation can be explained in terms of co-injection and counter-injection. As the toroidal magnetic field is in the CW direction, the CW NBI is co-injection and CCW NBI is counter-injection. The drift orbit of fast ions shifts outward for co-injection and inward for counter-injection. Hence the observation qualitatively agrees with the fast ion deposition profile in LHD. In case of CW NBI injection, pellet speed slowing down along injection direction has been seen but there is an acceleration of pellet at the last phase of motion for CCW NBI injected pellet. The reason behind this is still unclear and to be investigated. The penetration depth observed in this context ($\rho \approx 0.75$) is much less than calculated ($\rho \approx 0.63$) value in case of CW NBI and it is more ($\rho \approx 0.65$) than calculated value ($\rho \approx 0.7$) for CCW injection. This result is obvious by considering the radial speed V_R, within pellet life time. Additionally in case of CW NBI, pellet deflecting to a squeezing plasma cross section where as the deflection for CCW NBI is to an expanding cross section, which affects the pellet penetration depth in terms of normalized minor radius ρ

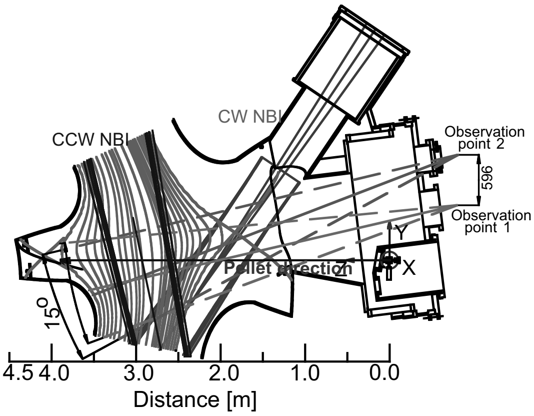

Fig. 1: Schematic of the stereo observation with NBI configuration in LHD

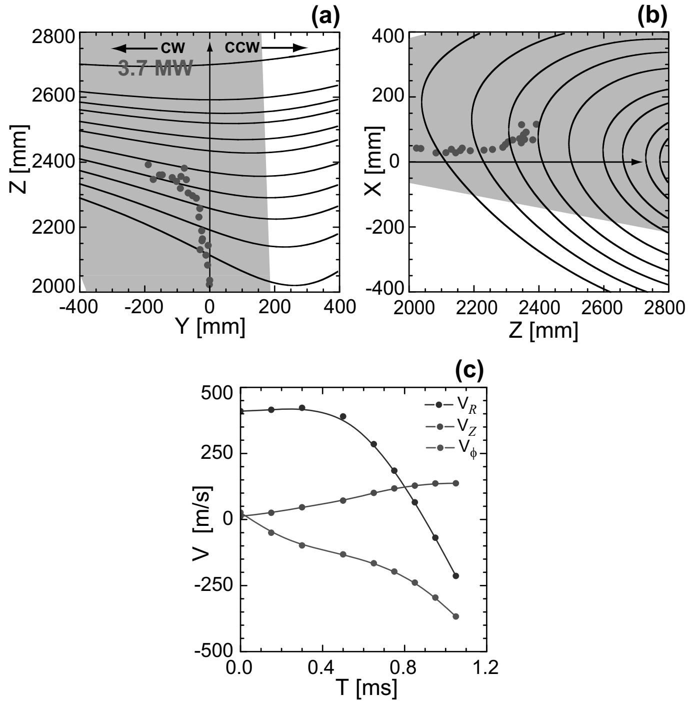

Fig. 2: Trajectory deflection along (a) toroidal plane (b) poloidal plane and (c) ablating pellet speed in radial (V_R), vertical (V_Z) and toroidal (V_ϕ) direction in presence of CCW NBI.

1) R. Sakamoto *et al*, Rev. Sci. Inst. 76, 103502 (2005)
2) H. Yamada *et al*, Fusion Eng. and Design 69 (2003)