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Measurement of toroidal rotation velocity profile and calculation of external momentum input by NBI in Heliotron J
ヘリオトロンJにおけるトロイダル回転速度分布計測ならびに
NBI外部運動量入力計算

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This paper describes measurement of the toroidal rotation velocity profile in Heliotron J. The toroidal rotation velocity is measured using CXRS and the external momentum input is calculated with the FIT code. The measured toroidal rotation velocity profile is a center peaked one. In the plasma periphery, the toroidal rotation, which is independent of the injected NB direction.

1. Introduction

Measurement of the toroidal plasma rotation (v_ϕ) profile is important to investigate the momentum transport in the magnetically confined plasma. Neutral Beam Injection (NBI) is one of momentum sources for the plasma. The injected neutral beam drives v_ϕ of the plasma. It is important to estimate the external momentum input by NBI and to investigate the effect of NBI on v_ϕ.

A Charge-eXchange Recombination Spectroscopy (CXRS) method [1] is a useful diagnostic to measure the toroidal rotation velocity profile. This method is to measure a line emission from charge-exchange recombination reactions between fully ionized impurity ions (A^{z+}) and energetic hydrogen atoms of the neutral beam (H^0). We could estimate v_ϕ from the Doppler shift of the measured emission spectra. In Heliotron J, we have installed a CXRS system to measure v_ϕ. Heliotron J is a helical-axis heliotron device [2,3]. Two tangential neutral beam lines (BL1, BL2) are installed in Heliotron J. One is co direction (BL2) and the other is counter (ctr) injection (BL1) in the normal direction of the magnetic field. Here, the co-direction is defined as the direction of plasma current, which increases the rotational transform. These beams are not only used for plasma heating but also as diagnostic beams for CXRS.

In this paper, we describe measurement of the toroidal rotation velocity profile and preliminary comparison with the external momentum input by NBI profile in Heliotron J.

2. Charge-exchange Recombination Spectroscopy System in Heliotron J

Figure 1 shows the schematic of CXRS system in Heliotron J. This system measures the CVI emission line (n=7-8, 529.05 nm). We installed two sets of optical fiber (beam and background region), which are installed at two helically symmetric positions, to remove the cold component. Each optical set has 14 sightlines, which are parallel to the magnetic axis to achieve high spatial resolution. We installed a Czerny-Turner monochromator, whose dispersion is 0.0112 nm/pix at 529.05 nm. A camera with

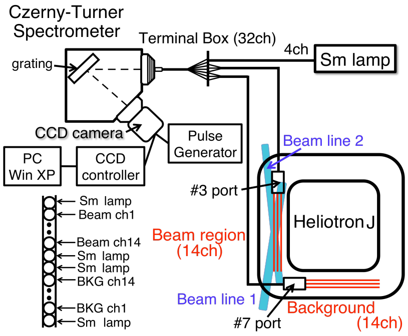

Fig.1 Schematic view of CXRS system in Heliotron J.

back-illuminated charge coupled device is mounted on the Czerny-Turner monochromator. The measurable area in the plasma is $0.07 < \rho$ $(=<r/a>) < 0.94$ and the spatial resolution, $\Delta\rho$, is about 0.05.

3. Experimental Result and Preliminary Comparison with the calculated external momentum input by NBI

Figure 2 (a) and (b) show that the time evolution of line averaged electron density and stored energy in the NBI heating phase, respectively. In this phase, co- or ctr-NB, whose P_{nbi} were 600 kW and 450 kW, is injected. The line averaged electron density is 1.2 $\times$ 10^{19} m^{-3} and stored energy is 1.1 kJ around 230 ms in both cases. Figure 2 (c) and (d) shows that the measured v_ϕ profile and the calculated external momentum input ($d(mnv)_{NB}/dt$), respectively.

The external momentum input is estimated using the FIT code [4] based on the calculated fast ion distribution by NBI with a three-dimensional Monte Carlo simulation code including orbit loss and charge exchange loss of fast ions. The external momentum input is calculated as follow:

$$[d(mnv)_{NB}/dt](\rho) = \frac{P_{nbi} m_f Z_f v_f \left(H_{\|}(\rho)/H_{(\|+\perp)}(\rho)\right) K_i}{eE_{nbi}}, \quad (1)$$

Here, P_{nbi}, H, K_i, E_{nbi} are the port through power of NB, the fast ion distribution, which is considered orbit loss and charge exchange loss, the deposited fraction of initial fast-ion toroidal momentum by NBI [5] and the acceleration voltage of NB, respectively.

In this experiment, the scanning of CXRS is performed every 5 ms. The toroidal rotation velocity profile is plotted 232.5 ms in the co-NBI plasma, 227.5 ms in the ctr-NBI plasma. The external momentum input is calculated at this time. The measured toroidal rotation velocity profile, which is center peaked one, is qualitatively consistent with the shape to the calculated external momentum input profile in the region of $\rho < 0.6$. In the plasma center ($\rho = 0.07$), the ratio between v_ϕ in the co- and ctr-NBI plasma ($v_{\phi ctr}/v_{\phi co}$) is about 0.7, which is close to the

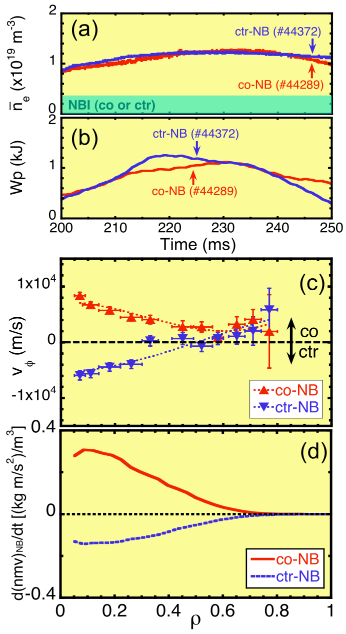

Fig.2 Time evolution of (a) line averaged electron density, (b) stored energy. (c) toroidal rotation velocity profile, (d) calculated external momentum input profile.

ratio of $d(mnv)_{NB}/dt$, which is about 0.55. From this result, the external momentum input by NBI might be one of dominant momentum sources. However, the offset of toroidal rotation and the momentum transport also should be investigated. On the other hands, in spite of small $d(mnv)_{NB}/dt$, v_ϕ of co direction, which is about 2~4 km/s and independent of the injected NB direction, is observed in the region of $\rho > 0.6$. For the future work, the driving mechanism of this rotation and the momentum transport should be investigated.

4. Summary

We measured the toroidal rotation velocity using CXRS and make a preliminary comparison with the calculated the external momentum input by NBI with the FIT code in Heliotron J. The measured toroidal rotation velocity profile is qualitatively consistent with the calculated NBI induced external momentum input profile in the plasma core.

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