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Poloidal Flow Measurement with Charge-eXchange Recombination Spectroscopy in Heliotron J
ヘリオトロンJにおける荷電交換再結合分光法を用いたポロイダルフロー計測

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A Charge-eXchange Recombination Spectroscopy (CXRS) system is newly installed to measure the radial and temporal profile of poloidal flow velocity in Heliotron J. In this system, two tangential neutral beams for plasma heating are used as the diagnostic beam and the spatial resolution is $\pm0.01<\Delta r/a<\pm0.17$ for the measurement area of $0.31<r/a<0.95$. An Echell monochromator is fabricated to obtain high spectral resolution. This system is applied to NBI plasmas to obtain the time evolution of the poloidal flow velocity profile.

1. Introduction

The radial structure of toroidal/poloidal flow and the radial electric field have been discussed for the confinement of high temperature plasmas, since poloidal flow velocity and radial electric field shear were observed and have been recognized to contribute to an improvement of plasma confinement in the so-called high confinement mode (H-mode) plasmas [1,2]. A Charge-eXchange Recombination Spectroscopy (CXRS) method has been utilized for the measurements of the radial profile of the impurity ion temperature and flow velocity in high temperature fusion plasmas [3]. In Heliotron J, a CXRS system has been developed to measure the ion temperature and the parallel flow velocity in the range of $0.07<r/a<0.94$ with the spatial resolution of $\Delta r/a \approx \pm0.05$ [4,5], where r is the averaged minor radius, and the r at the plasma boundary is $r=a$. We have recently installed a new objective optical system to measure the poloidal flow velocity. We present the results of the radial profile and the time evolution of the ion poloidal flow velocity.

2. Charge-eXchange Recombination Spectroscopy system in Heliotron J

Figure 1 shows the poloidal CXRS system in Heliotron J, a helical-axis heliotron device with an L/M=1/4 helical coil (L: pole number, M: helical pitch of the helical coil). Two Neutral Beam Injection (NBI) lines (BL1: ctr-injection, BL2: co-injection, here the co-direction is defined as the direction of plasma current, which increases the rotational transform) with positive ion sources are used as diagnostic beams for CXRS. This system measures CVI line (n=7–8, 529.05 nm). We install two sets of optical fiber (beam and background region) to remove the background emission, and they are adopted to be symmetrical against poloidal direction. Each optical set has 32 sightlines, where the optical fibers' numerical aperture (NA) is 0.2 and the core diameter is 0.8 mm. The high spectral resolution is required for the poloidal CXRS because poloidal flow velocities are expected to be smaller than those of parallel flow. Therefore, the plasma emission is led to an Echell monochromator whose F number is 2.9, focus length is 200 mm and grating is 31.6 grooves/mm. A CCD camera (ANDOR DV-887, 512×512 pixels, 16×16 μm, Maximum scanning frequency: 400 Hz), is mounted on the Echell monochromator. Additionally, the measurable wavelength range is too small to determine the accurate λ_0 (529.05 nm) position on the CCD image with single-element lamps, as a result, we prepared a calibration system using two monochromators.

The measurement location and the spatial resolution are evaluated from the CXR emissivity calculation. The calculation method for the measurement location and the spatial resolution of

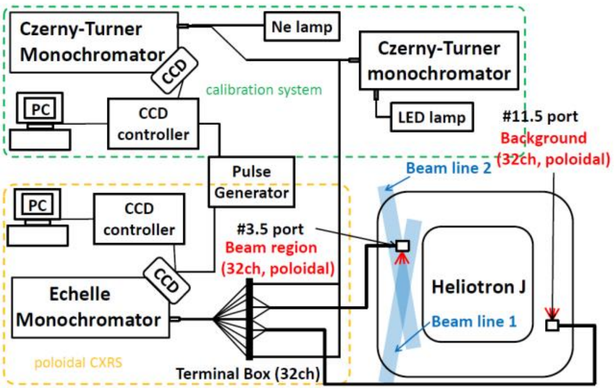

Fig.1. poloidal CXRS system in Heliotron J

the parallel CXRS system is reported in Ref. [4,5], which is also used for the poloidal CXRS system. The measurement area is $0.31<r/a<0.95$ with BL1 for the standard magnetic configuration and the spatial resolution is $\pm 0.01<\Delta r/a<\pm 0.17$.

3. Experimental results

Figures 2(a) and 2(b) show the time evolutions of line averaged electron density and stored energy in the NBI plasmas (ctr-injection, P_{NBI}=400 kW) with and without the Electron Cyclotron resonance Heating (ECH) (P_{ECH}=331 kW, $N_{//}$=0.4), respectively. The time evolutions and the radial profiles of poloidal flow are shown in Figs. 2(c) and 2(d), respectively. In the peripheral region r/a>0.6, the intensity of the CXR emission are too low to estimate the poloidal flow velocity. In this experiment, the time resolutions of the poloidal and the parallel CXRS are 10 ms and 5 ms, respectively. As shown in Fig. 2(c) and 2(d), the direction of the poloidal flow near the core is changed depending on the ECH. In the case that the 2nd ECH is not applied, the poloidal flow is in the electron diamagnetic direction whereas that is in the ion diamagnetic direction when the 2nd ECH is applied. As seen in Figs. 2(e)-2(g), the electron and ion temperature is 0.2 keV and 120 eV and the radial profile of electron density has a peaked shape when the 2nd ECH is not applied, respectively. On the other hand, when the 2nd ECH is applied, the electron temperature at the plasma core increases up to 1.5 keV, the electron density profile becomes hollow and a slightly decrease in ion temperature is observed.

4. Summary

The poloidal CXRS system is newly designed and installed in Heliotron J. The time evolutions of the poloidal flow velocity profiles are measured with this system in the NBI plasmas with and

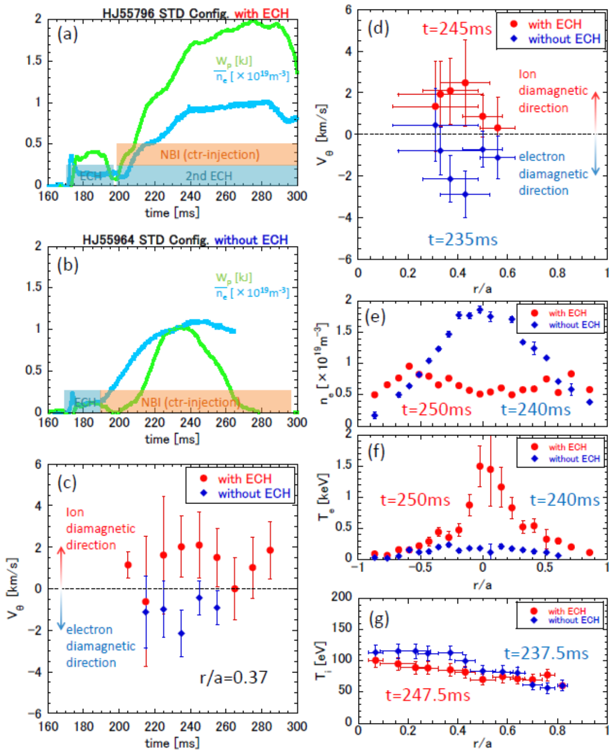

Fig.2. (a) and (b) time evolutions of line averaged electron density and stored energy and timings of ECH and NBI, (c) time evolutions of poloidal flow velocity at r/a=0.37, (d) radial profiles of poloidal flow velocity, (e) radial profile of electron density, (f) radial profile electron temperature, and (g) radial profiles of ion temperature. Red (blue) points indicate the discharge with (without) ECH.

without ECH. The change in the direction of the poloidal flow due to ECH is observed. This experimental observation indicates that the radial electric field is changed its sign from negative (ion root) to positive (electron root). Neoclassical transport analysis is required to understand these phenomena.

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