Measurement of impurity ion temperature using charge exchange recombination spectroscopy in Heliotron J

This paper describes the measurement of the impurity ion temperature using Charge eXchange Recombination Spectroscopy (CXRS) in Heliotron J. The measurable range of the CXRS system has been extended from 0.37 < ρ < 0.79 to 0.07 < ρ < 0.94 with the spatial resolution Δρ ~ ±0.05 by installing newly designed sightlines. The radial profile of the carbon ion temperature was measured in NBI plasmas. The core ion temperature with CXRS is consistent with that measured with a charge exchange neutral particle analyzer.

1. Introduction

In magnetically confined plasmas, the measurement of the radial profile of the plasma pressure and the rotation velocities (v_t and v_p) is indispensable not only for the heat or particle transport analysis but also for the evaluation of the radial electric field. The Charge eXchange Recombination Spectroscopy (CXRS) has been utilized for the measurements of the radial profile of the impurity ion temperature, density and rotation velocity in high temperature fusion plasmas [1]. The ion temperature and the rotation velocity are evaluated from the Doppler broadening and the Doppler shift of the line emission from the Charge eXchange Recombination (CXR) reaction between the fully ionized impurity ions (A^{Z+}) and the neutral beam particles (H^0) as follows:

\[ A^{Z+} + H^0 \rightarrow A^{(Z-1)+} (n = j \rightarrow i) + H^+ + h\nu \]  (1).

In Heliotron J, a CXRS system has been developed, and the ion temperature has been measured in the range of 0.37 < ρ < 0.79 [2], where ρ is the normalized minor radius. We have recently introduced a new objective optical system in order to extend the measurable area. We show initial results of the radial profile measurements of the impurity ion temperature.

2. CXRS system in Heliotron J

Figure 1 shows a schematic of the CXRS system
in Heliotron J, a helical-axis heliotron device with an L=1/m=4 helical coil. Two sets of NBI (co and ctr) for plasma heating are used as diagnostic beams. An emission line of CVI (n=8→7, 529.05 nm) is used for the CXRS measurement since no strong line spectrum is observed near this wavelength and we can use fiber bundles to guide the emission to a spectrometer. Two sets of the 14 sightlines are newly installed for the beam-carbon CXR emission (#3.0 port) and the background emission (#7.0 port). To optimize the spatial resolution of the CXR measurement, the sightlines are chosen in parallel to the magnetic axis by taking into account the region of the neutral beam passing. Figure 2 shows the radial positions of the sightlines as a function of the distance from the pivot point for this system. This optimization enables us to measure the radial profile of the CXR emission in the range of 0.07 < ρ < 0.94 with the spatial resolution of Δρ ~ ±0.05.

The plasma emission is led to a Czerny-Turner monochromator whose focus length is 400 mm, F number is 2.8 and grating is 2160 grooves/mm. A CCD camera (ANDOR DU-897, 512×512 pixels and 16×16 µm) was installed to detect the spectral and spatial profile of the CXR emission.

3. Experiments

Figure 3 shows an example of the radial profile of the carbon ion temperature and its time evolution. The plasma was generated by ECH, and sustained only by NBI from 170 ms to 270 ms. The NBI port-through power was 920 kW in total. As shown in Fig. 3(a), we obtained the ion temperature profile in the range of 0.07 < ρ < 0.83. In the peripheral region ρ > 0.83, however, the intensity of the CXR emission was too low to estimate the ion temperature. The radial profile has a peaked shape, and the temperature reached up to 200 eV at ρ=0.07. Figure 3(b) shows the time evolution of the carbon ion temperature at three radial positions. The bulk (deuterium) ion temperature measured with a Charge eXchange Neutral Particle Analyzer (CX-NPA) is also plotted in the figure. The center carbon ion temperature agrees well with the bulk ion temperature.

4. Summary

We measured the radial profile and time evolution of the carbon ion temperature using the CXRS in Heliotron J. The radial profile measured in the range of 0.07 < ρ < 0.83 has a peaked shape. The ion temperature reaches up to 200 eV at the core, and its time evolution agrees well with the bulk ion temperature measured with the CX-NPA.

References