23P028-P

Measurement of impurity ion temperature using 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による不純物イオン温度分布計測

Takayuki Minami[1], Shinji Kobayashi[2], Hyunyong Lee [1], Shinichiro Kado[3], Tohru Mizuuchi[2], Kazunobu Nagasaki[2], Hiroyuki Okada[2], Takashi Minami[2], Satoshi Yamamoto[2],Shinsuke Ohshima[5], Tomotaka Harada[6], Tasuku Kagawa[1], Kiyofumi Mukai[1], Linge Zang [1], Shohei Arai[1], Hiroaki Yashiro[1], Hiroto Watada[1], Yoshinobu Wada[1], Sadayoshi Murakami[4], Yuji Nakamura[1], Kiyoshi Hanatani[2], Shigeru Konoshima[2], Fumimichi Sano[2]

南　貴之[1], 小林進二[2], H.Y. Lee[1], 門信一郎[3], 水内　亨[2], 長崎百伸[2], 岡田浩之[2], 南　貴司[2], 山本　聡[2], 大島慎介[5], 原田伴誉[6], 香川　輔[1], 向井清史[1], L. Zang[1], 荒井翔平[1], 八代浩彰[1], 和多田泰士[1], 和田善信[1], 村上定義[4], 中村祐司[1], 花谷　清[2], 木島　滋[2], 佐野史道[2]

[1]*Graduate School of Energy Science, Kyoto University, Gokasho, Uji, 611-0011, Japan*
京都大学大学院エネルギー科学研究科 〒611-0011　京都府宇治市五ヶ庄
[2]*Institute of Advanced Energy, Kyoto University, Gokasho, Uji, 611-0011, Japan*
京都大学エネルギー理工学研究所 〒611-0011　京都府宇治市五ヶ庄
[3]*Graduate School of Engineering, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, 113-8656, Japan*
東京大学大学院工学系研究科 〒113-8656　東京都文京区本郷 7-3-1
[4]*Graduate School of Engineering, Kyoto University, Yoshidahontyo, Sakyo-ku, 606-8501, Japan*
京都大学大学院工学研究科 〒606-8501　京都府京都市左京区吉田本町
[5]*Pioneering Research Unit for Next Generation, Kyoto University, Gokasho, Uji, 611-0011, Japan*
京都大学次世代開拓ユニット 〒611-0011　京都府宇治市五ヶ庄
[6]*Undergraduate School of Electrical and Electronic, Faculty of Engineering, Kyoto University, Yoshidahonmachi, Sakyo-ku, 606-8501, Japan*
京都大学工学部電気電子工学科 〒606-8501　京都府京都市左京区吉田本町

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 $0.37 < \rho < 0.79$ to $0.07 < \rho < 0.94$ with the spatial resolution $\Delta\rho \sim \pm 0.05$ 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:

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

In Heliotron J, a CXRS system has been developed, and the ion temperature has been measured in the range of $0.37 < \rho < 0.79$ [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

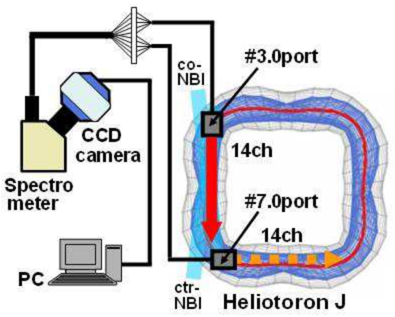

Fig.1. Schematic of CXRS system in Heliotron J

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 $0.07 < \rho < 0.94$ with the spatial resolution of $\Delta\rho \sim \pm 0.05$.

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

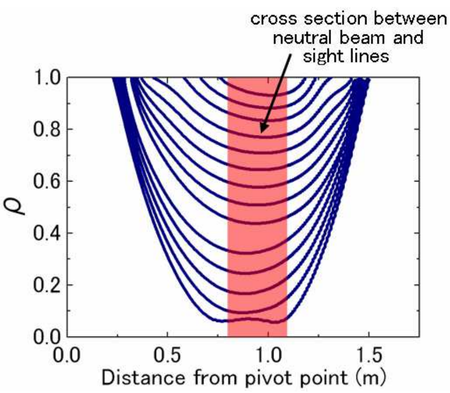

Fig.2. Radial positions of channels

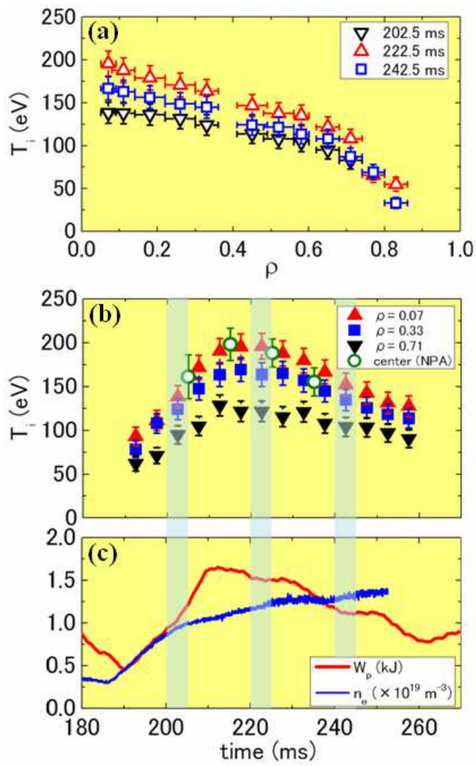

Fig.3. (a) radial profile of T_i, (b) time evolution of T_i at three radial positions, (c) the stored energy W_p and the line-averaged electron density

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 $0.07 < \rho < 0.83$. In the peripheral region $\rho > 0.83$, 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 $0.07 < \rho < 0.83$ 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

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