# 21PB-089

# Density dependence of ion temperature of high-density NBI plasmas in Heliotron J
# ヘリオトロンＪ高密度ＮＢＩプラズマにおけるイオン温度の密度依存性

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This study describes the influence of HIGP to the density dependence and the density dependence of ion temperature. High density plasma experiments have been carried out in Heliotron J NBI plasmas with HIGP (High intensity gas puff). It shows that HIGP could significantly affect the time evolution of carbon ion temperature ($T_i$). A decreasing of $T_i$ during HIGP and a recovering phenomenon after HIGP has been observed. As $T_i$ was determinate by the balance between heating and losing power, and the plasma was primarily heated by NBI heating. It implies that the variation of $\overline{n_e}$ could affect the NBI power absorption and the energy equilibrium between ion and electron.

## 1. Introduction

In magnetically confined fusion plasmas, the measurement of ion temperature ($T_i$) profile with time evolution could provide indispensable information to improve the plasma confinement. With the Supersonic Molecular Beam Injection (SMBI) and High Intensity Gas Puff (HIGP), Heliotron J has achieved a high density and high performance plasma [1]. In this study, we measured the time evolution of carbon ion temperature using Charge eXchange Recombination Spectroscopy (CXRS) system and evaluate the relationship between the electron density and carbon ion temperature in a HIGP fueled plasma.

## 2. CXRS system in Heliotron J

Figure 1 shows a schematic view of parallel CXRS system in Heliotron J. This system measures the emission line of $C^{6+}$ ($\Delta n = 7-8$, $529.05nm$) to estimate the temperature of $C^{6+}$. Two sets of optical fiber (beam and background region) are installed to remove the cold components. The observable range is 0.07 < $\rho$ < 0.94 and radial resolution is $\Delta\rho$ ~ 0.02-0.06 [2-3].

## 3. Experimental results

The density dependence of carbon ion temperature ($T_i$) is investigated in high density plasma with HIGP. As shown in Figure 2 (a), plasma was created by Electron Cyclotron resonance Heating (ECH, t=160-180ms, 70GHz, 331kw). After that plasma was heated by Neutral Beam Injection (NBI). The plasma density had a significant increasing with HIGP (t=220-230ms) fueling. After a short time of decreasing (t=220-235ms), the plasma stored energy ($W_p$) and carbon ion temperature at the core region was increasing again and reached the peak at 255ms.

Figure 3 shows the relationship between $T_i$ and the line averaged density ($\overline{n_e}$). Before 220ms, $T_i$ was keep increasing with the growing up of $\overline{n_e}$. With a high intensity of gas puffing from 220ms to 230ms, $\overline{n_e}$ was significantly increased but $T_i$ was decreased. As shown in Figure 2 (a), the $W_p$ was also declined during HIGP, and $W_p$ could be calculated from the products of $\overline{n_e}$ and $T_i$. The dashed lines in Figure 3 show the constant value of products between $\overline{n_e}$ and $T_i$ which indicates the stored energy of ion. After HIGP, $\overline{n_e}$ reached the top at about 240ms and start decreasing, but $T_i$

was keep on raising and $W_p$ reached the top at about 250ms. At this moment, the plasma reached a steady state with the maximum stored energy. After that, the stored energy started declining with the decaying of plasma.

A recovering phenomenon of $T_i$ after HIGP has been observed. As $T_i$ is determinate by the balance between heating and losing power, the ion energy balance should be investigated. For NBI plasma, the plasma is primarily heated by NBI. The NBI heating power could be absorbed by both ion and electron, and also have energy equilibrium between ion and electron. Therefore it's necessary to calculate the NBI power absorption and the energy equilibrium between ion and electron.

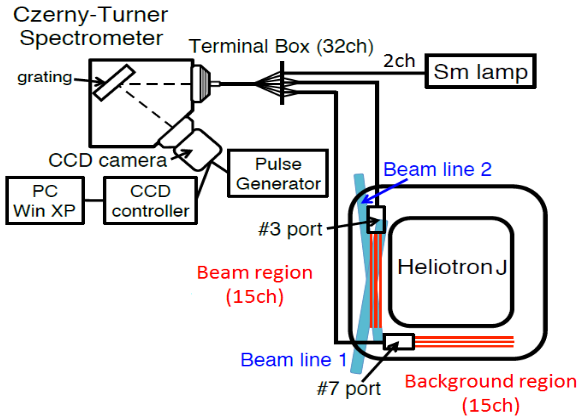


Fig.1. Schematic view of parallel CXRS system in Heliotron J [3]

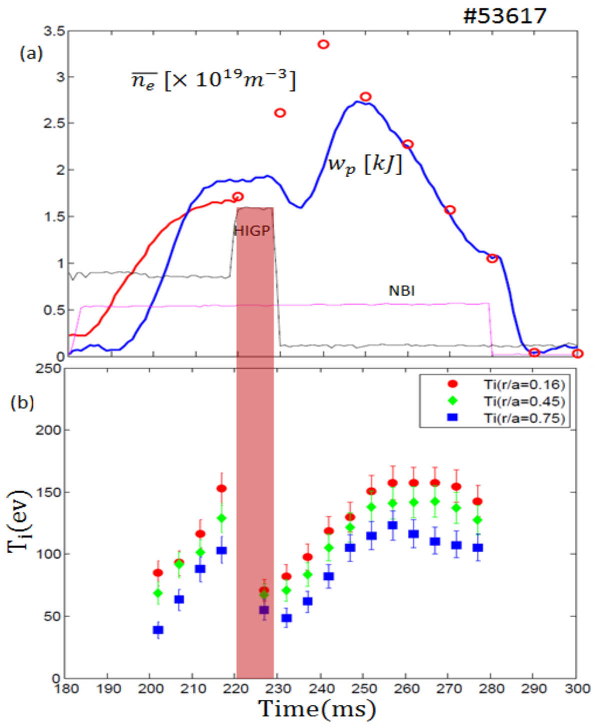


Fig.2. (a) Time evolution of plasma parameters and (b) carbon ion temperature with HIGP

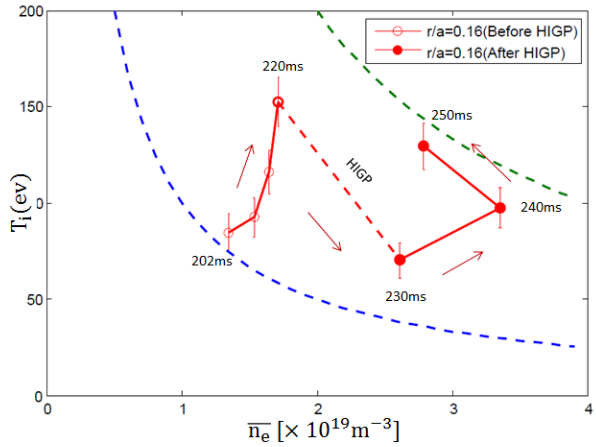


Fig.3. Density dependence of ion temperature with HIGP

## 4. Summary

High density plasma experiments have been carried out in NBI plasmas of Heliotron J with HIGP. The carbon ion temperature and the plasma stored energy significantly decreased during HIGP. After HIGP, the stored energy started to increase again and reached a higher peak than before, and a recovering phenomenon of the ion temperature has been observed. The NBI absorption and energy balance analysis will provide us the confinement characteristics of the high density plasmas by HIGP.


## Acknowledgments

This work was supported by NIFS/NINS under the NIFS Collaborative Research Program (NIFS10KUHL030, NIFS12KUHL050, NIFS14KUHL062, and NIFS12KUHL051).


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