Profile Characteristics of Fuelling Controlled Plasma using the Nd:YAG Laser Thomson Scattering System in Heliotron J


A new YAG-TS system has been developed to measure time evolution of $T_e$ and $n_e$ profiles in Heliotron J with high spatial and temporal resolution. A time evolution of electron temperature and density profiles was measured for the high-density neutral-beam-injection plasma with a high-intensity gas-puff (HIGP) fueling. The profiles reveal that not only large increases of core $n_e$ but also increases of peripheral $T_e$ contribute to the increase of the stored energy after the HIGP by increasing both the core and the peripheral pressures. It was found that HIGP could improve the global thermal confinement especially in the peripheral region.

1. Introduction

Spatial profiles measurement with time evolution of plasma density and temperature provides important information for the fusion plasma. The information is especially indispensable to understand the physics of plasma transport. In Heliotron J, spontaneous transition phenomena to an improved confinement mode have been observed [1]. Heliotron J also achieves high-density and high-performance plasmas with supersonic molecular beam injection [2] and high-intensity gas-puff (HIGP) fuelling [3, 4]. In this respect a high time and spatial resolution Nd:YAG laser Thomson scattering (YAG-TS) system for Heliotron J has been developed to measure the time evolution of electron temperature ($T_e$) and density ($n_e$) profiles [5-7]. The YAG-TS system consists of two Nd:YAG lasers, each of which has pulse energy of 550 mJ, repetition frequency of 50 Hz, and pulse width of 10 ns, a beam dump, and 25 interference polychromators, corresponding to the 25 scattering volumes about 1 cm radial separation along the laser path.

2. Time Evolution Measurement of $T_e$ and $n_e$ Profiles of Fuelling Controlled Plasma

We measured the time evolution of $T_e$ and $n_e$ profiles of high performance plasma with a HIGP, which was fuelled during 10 ms at a fuelling rate several times higher than that for the normal gas. The plasma is initiated by short-pulse electron cyclotron heating (ECH) and is sustained by neutral beam injection (co-NBI) with a port through power of 0.46 MW. Figure 1(a) shows the time evolution of the stored energy and the line-averaged density measured by both the microwave interferometer (curved red line) and the YAG-TS (brown circle) in the HIGP plasma. A rapid increase of $n_e$ is observed and the stored energy starts rising after the increase of $n_e$ in spite of no gas puffing. The line-averaged densities measured by the YAG-TS starts decreasing before the peak timing of the stored energy.

Figure 1(b) and 1(c) show the time traces of the core $T_e(r/a = 0)$, the peripheral $T_e(r/a = 0.6)$, the peaking factor of the $T_e$ and the core $n_e(0)$, the peripheral $n_e(0.6)$, and the peaking factor of the $n_e$ respectively. Figure 1(d) and 1(e) show the $T_e$ and the $n_e$ profiles for three characteristic timings,
before the HIGP ($t = 220$ ms), just after the HIGP ($t = 230$ ms), and the peak timing of the stored energy ($t = 250$ ms). By the effect of the particle supply of the HIGP, the core $n_e$ increases while the peripheral $n_e$ holds, which makes the $n_e$ profiles more peaking. The increase of the line-averaged density after the HIGP is dominated especially by the large increase of the core $n_e$. In terms of the temperature, the core $T_e$ increases up to almost the same value as that before the HIGP. The peripheral $T_e$ increases to the higher value than that before the HIGP. The difference of the change of the rate between the core and the peripheral $T_e$ makes the $T_e$ profiles flatter. As the results of both the increase of the core $n_e$ and the large increase of the peripheral $T_e$, the pressure of whole region increases after the HIGP, which causes the increase of the stored energy. This result suggests that HIGP could improve the global thermal confinement especially in the peripheral.

3. Summary

We developed the YAG-TS system to measure the time evolution of $T_e$ and $n_e$ profiles in Heliotron J with high spatial and temporal resolution. With this system, we measured the time evolution of the profiles of the $T_e$ and the $n_e$ for the high-density plasma with the HIGP fueling. The time evolution of the $T_e$ and the $n_e$ profiles reveals that not only the large increase of the core $n_e$ but also the increase of the peripheral $T_e$ contribute to the increase of the stored energy after the HIGP by increasing both the core and the peripheral pressures.

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References


Fig.1. (a) Time traces of line-averaged density measured by interferometer and YAG-TS, stored energy in plasma, and timings of ECH, NBI, and HIGP. Time traces of (b) $T_e(r/a=0)$, $T_e(r/a=0.6)$, and the peaking factor of $T_e$ and (c) $n_e(r/a=0)$, $n_e(r/a=0.6)$, and the peaking factor of $n_e$. Profiles of (d) $T_e$ and (e) $n_e$ for NBI-sustained plasma at 220, 230, and 250 ms.