§5. Particle Balance Study in Steady-state Operation of Pure Hydrogen Plasma with Central Beam Fueling

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Particle control is one of the most important issues in steady-state operation of magnetically confined fusion plasmas. In this study, the behavior of particle balance was experimentally investigated under the central beam fueling condition in LHD. The working gas used in this study is hydrogen, which would show stronger interaction with the wall than helium, used as the main working gas in the steady-state operation with the ICRF heating in LHD.

In order to sustain a steady-state hydrogen plasma, the neutral beam injector of NBI-BL4 and electron cyclotron heating (ECH) were utilized. The BL4 is a positive-ion-based NBI, and four ion sources are sequentially operated every 40 s. The injection duration with one ion source is 35 s, and the injection interval for 5 s secures to suppress an increase in the residual gas flow from the ion sources into the LHD vacuum vessel when the operating ion source is changed. The port-through power is 0.4 MW with the energy of 25 keV, and the injected beam is modulated to control the beam fueling rate.

Figure 1 shows typical wave forms of a steady-state plasma (shot No. 123678) in this experiment. The duration of the plasma is about 340 s with the density of $0.5 < n_e < 0.9 \times 10^{19}$ m^{-3} and the central electron temperature is about 2 keV. The ECH with the frequencies of 77 GHz and 154 GHz is applied with the total power of about 360 kW for sustaining the discharge. The duty for the beam modulation of BL4 is on/off=0.2s/1.8s. The magnetic axis position is fixed at R_{ax}=3.70m, and the perturbation field to expand the 6-O island is applied using local island diverter coils (1920A). As shown in the figure, it is found that an increase in the density is suppressed during the discharge. For the comparison, time evolution of the plasma density in a dynamic scan of the magnetic axis position (shot No. 123675, R_{ax}=3.61m~3.69m) is also plotted in the 3rd graph in Fig. 1. That indicates that the plasma density increases when the plasma shifts inwardly and vice versa. These results demonstrated that the density control via the application of perturbation field is also effective for sustaining steady-state plasmas as well as the control of magnetic axis position. Response of the plasma density to the NBI modulation is also observed in these discharges. The dynamics of the plasma density responding to the pulsed particle source in the core region will be analyzed for further understanding of the particle balance behavior.

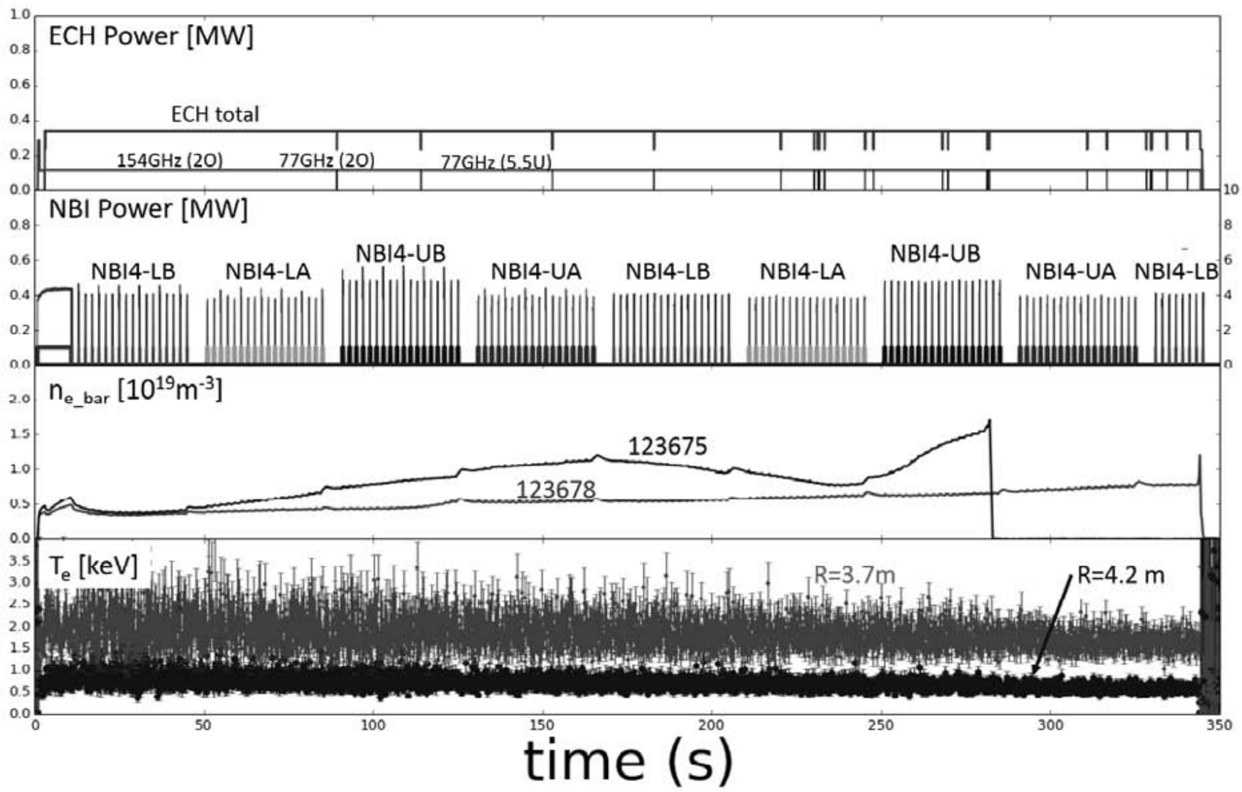

Fig. 1. Typical wave forms of long pulse operation. The 1st graph shows the ECH power launched into the plasma. The 2nd shows the injection power of NBI-BL4. The 3rd shows the line-averaged electron density for the shots of No. 123678 (340-sec duration) and No. 123675 (285-sec duration). The 4th shows the electron temperatures at the central (R=3.656m) and at around the half minor radius (R=4.194m).