§16. High Beta Experiments in LHD

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In previous LHD experiments, the achieved volume averaged beta value has been increased by optimizing magnetic configurations to characteristics of equilibrium, stability and transport as well as an increase in heating power. The beta value of over 5 % has been obtained in B_t < 0.5 T configurations[1]. Recently, we have made experiments at B_t =1 T in order to produce high-beta plasma in low-collisional regime.

The R_{ax} scan experiments in the standard configuration (pitch parameter of helical coil, γ_c = 1.254) with constant electron density suggest that the optimum preset-R_{ax} is 3.56 m for production of high beta plasma. We attempted to increase the beta value by Hydrogen pellet injection and gas-puff in the experiments. The beta value of 4.1 % was achieved by injecting four pellets and maintained for about 0.1 s. Then the central electron temperature and density were 0.9 keV and 6×10^{19} m^{-3}, respectively, and the achieved temperature was about 4.5 times higher than that in high-beta discharge (5.1 %) at B_t = 0.425 T. In the pellet case, the peaked density profile was formed, which induced large Shafranov shift (ΔR ~ 0.44 m). Then strong m/n = 2/1 mode appeared because of steep pressure gradient around the $\iota/2\pi$ = 1/2 resonant surface located at core region.

In the gas-puff discharge, the achieved beta value was 3.4 % and the sustainment of high-beta state depends on the duration time of heating. The central temperature was 1.2 keV at about 4×10^{19} m^{-3}. Figure 1 shows the typical discharge produced by the gas-puff fueling. The plasma was produced at 3.3 s by three tangential NBIs and the beta value was increased at 3.7 s by additional heating due to two perpendicular NBIs and ICRF. The beta value was spontaneously increased at 3.75 s with an increase in electron density, mainly, in peripheral region[2]. The ion saturation current measured at the divertor plate was significantly reduced then, which means that the particle confinement in the periphery was improved although no clear reduction of Hα was found. After the transition, edge MHD instabilities such as m/n = 1/2, 2/3 and so on appeared and were enhanced by formation of the steep pressure gradient, which obviously limits the increase in the beta value. Also the modes were clearly observed in signals of the ion saturation current, Hα and so on.

Figure 2 shows the electron density profiles before (3.733s) and after (3.8s) the transition in Fig.1 discharge. The magnetic axis is located at 3.8 m ((ΔR ~ 0.24 m). Typically, electron density has hollow (or flat) profile in the gas-puff discharge, and the hollow profile is enhanced by increasing the density at R = 4.35-4.8 m after the transition. The electron temperature profile was almost constant before and after transition. The $\iota/2\pi$ = 3/2 and 2 resonant surfaces where the modes were destabilized after the transition are located at R = 3.55 m and 3.64 m, respectively. The HINT2 calculations for plasmas before and after the transition suggest that the increase in the beta value and excitation of the edge MHD modes are due to extension of the region with long connection length of magnetic field line to the outward.

1) Sakakibara, S. et al.: Plasma Phys. Control. Fusion **50** (2008) 124014.
2) Toi, K. et al.: Fusion Sci. Technol. **58** (2010) 61.

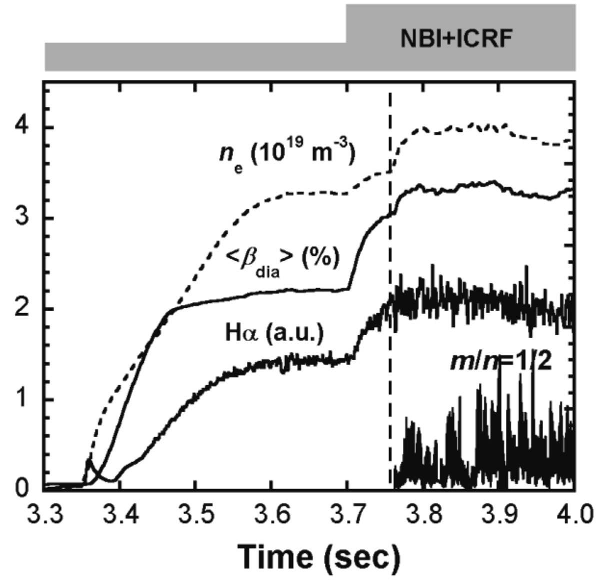

Fig. 1 Typical high-beta discharge produced by Hydrogen gas-puff fueling.

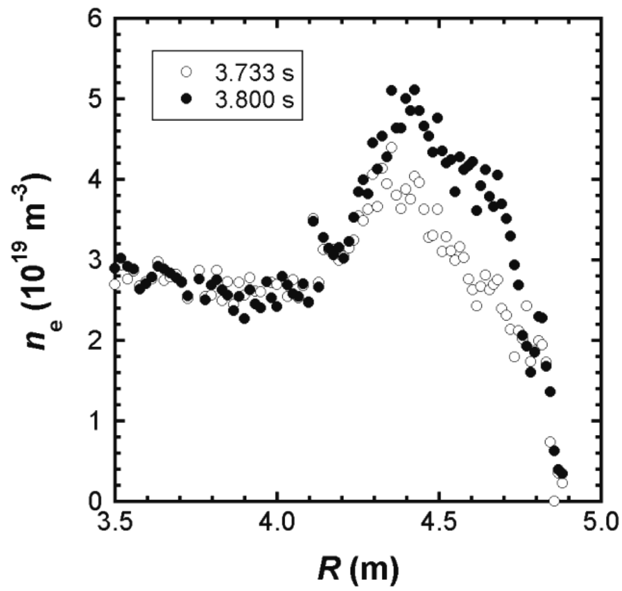

Fig. 2 Electron density profiles at 3.733 and 3.8 s in Fig.1 discharge.