Recent study of the high performance confinement and the high beta plasmas on the Large Helical Devices

K.Y. Watanabe, A. Komori, H. Yamada, K. Kawahata, T. Mutoh, N. Ohyabu, O. Kaneko, S. Imagawa, Y. Nagayama, T. Shimozuma, K. Ida, T. Mito, R. Sakamoto, S. Ohdachi, K. Nagaoka, R, Kumazawa, H. Funaba, M. Kobayashi, S. Masuzaki, O. Mitarai[a], Y. Narusima, S. Sakakibara, M. Sato, M. Yoshinuma, S. Sudo, O. Motojima, and LHD experimental Group

National Institute for Fusion Science,322-6 Oroshi-cho, Toki 509-5292, Japan
[a] Liberal Arts Education Center, Kumamoto Campus, Tokai University, 9-1-1 Toroku, Kumamoto 862-8652, Japan

kiyowata@LHD.nifs.ac.jp

In LHD (Large Helical Device), the experimental and theoretical researches to obtain the knowledge applicable to the fusion reactor are underway. The recent progresses on the plasma performance are summarized as the followings.

The high beta regime has been extended to the volume averaged diamagnetic beta $<\beta_{dia}>$ of 5% mainly by optimizing the magnetic configuration and the increase in the NBI heating power. A quasi-steady state beyond 100 times of the energy confinement time with $<\beta_{dia}> > 4.5\%$ has been demonstrated. Pressure driven instabilities observed in LHD are harmless. An IDB (Internal Diffusion Barrier) scenario, producing peaked pressure profiles by multiple pellet injections, has been also applied to another high beta plasma production. As the highest value of the central beta value, β_{dia}~10% is transiently achieved under $<\beta_{dia}>$ ~3%, which is comparable to that of the standard high beta operation with $<\beta_{dia}>$~5%. The production of the peaked pressure profile has the advantage for the MHD stability because of the large Shafranov shift and the steep pressure gradient and for the high fusion power output because it is proportional to the square of beta value not to the beta value itself.

The operational regime of the high-density plasma with IDB has been extended. The central density was recorded as high as $1\mathrm{x}10^{21}$ m^{-3}. Based on these high-density plasmas with the IDB, a quite different ignition scenario from the tokamak's has been proposed taking the operation scenario in the thermal instability regime into account. There is a progress on the impurity accumulation. It is theoretically and experimentally shown that a typical impurity source, the carbon, is effectively screened in the very edge of the ergodic layer at higher density.

Improvement of ion heat transport has been realized by an upgrade of the ion heating power with a low energy perpendicular NBI. An ion ITB (Internal Transport Barrier), that is a peaked profile of ion temperature, Ti, with a steep gradient in the core region, has been formed and the central Ti of 6.8 keV has been achieved in a hydrogen plasma with the line-averaged electron density of $2\mathrm{x}10^{19}$ m^{-3}. The experimental ion thermal diffusivity significantly decreases to the neoclassical level, indicating a significant reduction of anomalous transport. According to the analysis of neoclassical ambipolar diffusion, the enhancement of the negative radial electric field associated with the Ti increase is predicted, which might lead to the suppression of the anomalous transport. Up to now, the ITB is transiently observed. The maintenance of the stationary ITB structure is one of the future subjects.

In the conference, the related physics understanding and the meaning on the reactor study will be discussed together with the parameter extension.