Progress of Steady State Experiment in LHD

T. Seki, T. Mutoh, R. Kumazawa, K. Saito, H. Kasahara, S. Kubo, T. Shimozuma, Y. Yoshimura, H. Igami, H. Takahashi, N. Ashikawa, S. Masuzaki, M. Tokitani, F. Shimpo, G. Nomura, C. Takahashi, M. Yokota, A. Kato, Y. Takita, S. Kobayashi, Y. Mizuno, S. Ito, H. Okada[a], K. Sakamoto[b], T. Imai[c], T. Kariya[c], R. Minami[c], Y.P. Zhao[d], J.G. Kwak[e], A. Komori, O. Motojima, and LHD Experimental Group

National Institute for Fusion Science,322-6 Oroshi-cho, Toki 509-5292, Japan
[a] Institute of Advanced Energy, Kyoto University, Uji, Kyoto 611-0011, Japan
[b] Japan Atomic Energy Agency, 801-1, Mukoyama, Naka 311-0193, Japan
[c] Plasma Research Center, University of Tsukuba, Tsukuba 305-8577, Japan
[d] Institute of Plasma Physics, Academia Sinica, Hefei 230031, P.R. China
[e] Korea Atomic Energy Research Institute, Daejeon 305-600, Korea Rep.

seki@nifs.ac.jp

Steady state operation using ion cyclotron range of frequencies (ICRF) heating and electron cyclotron heating (ECH) has been carried out on the Large Helical Device (LHD). In ICRF heating scheme, minority ion heating mode is adopted in helium majority and hydrogen minority plasma. The ion heating mechanism works to sustain the plasma. The devising ways for the steady state operation such as magnetic axis sweep and real-time impedance matching are introduced. The operational range was expanded gradually year by year [1]. The maximum pulse length and injected heating energy is 54 min. 28 sec. and 1.6 GJ, respectively. The line-averaged electron density was 0.4×10^{19} m^{-3} and the electron and ion temperature was 1 keV in that shot.

The plasma is terminated by mainly by abrupt density rise and the problem is not easy to be settled. The density rise is caused by influx of metallic impurities. The radiation loss power increases and the electron temperature drops. It occurs frequently when sparks are observed in the vacuum vessel. Frequency of the sparks is related to ion tail formation by the ICRF heating. Removal of a harmful influence causing by the accelerated high-energy ions is important for the ICRF steady state operation. As an alternative heating mode, mode-conversion heating was tried. Electrons are mainly heated by mode-converted ion Bernstein wave in this heating scheme. The plasma discharge more than one minute was achieved by this mode so far.

In the case of ECH discharge, the pulse length of 65 min was achieved by 110 kW of the ECH power using the 84 GHz CW gyrotron [2]. The magnetic field was 1.48 T on the magnetic axis of 3.6 m. The central electron temperature was 1.5 keV and line-averaged electron density was 2×10^{18} m^{-3}. The plasma was maintained as long as the ECH power was injected into the plasma. To achieve the steady state operation improvements of ECH system was important. Water-cooling of the waveguide was strengthened and vacuum system for the evacuated waveguide section was improved. Higher performance plasma operation using the 77 GHz gyrotron will be carried out soon.

The understanding of heating technology and wave and plasma physics for steady state operation is important and useful for other machines and future reactors.

[1] T. Mutoh, et al., J. Plasma Fusion Res. **81** (2005) 229.
[2] Y. Yoshimura, et al., J. Phys.: Conf. Series **25** (2005) 189.