The Large Helical Device (LHD) in Toki, Japan is the largest helical system (stellarator) in the world. It is a $l=2$ heliotron configuration with a divertor. The major radius is 3.6-3.9 m, the minor radius is 0.6 m, and the magnetic field is 3 T. In this period, LHD achieved major advances in performance without deleterious effects from instabilities, or density and impurity buildups.

In 1999, LHD concentrated on ion cyclotron radiofrequency heating (ICRF) using 1.3 MW at 38.47 MHz. Helium gas was used with hydrogen ions as a minority species. When ICRF power was applied to electron cyclotron heating (ECH) generated target plasma, a high-temperature plasma was obtained with nearly constant density ($T_e(0) = 1.6-2.0$ keV, line averaged density $= 5 \times 10^{18} \text{ m}^{-3}$). This plasma was maintained stably for 5 seconds by ICRF power alone without any problems from increased impurities.

With a well-conditioned wall, neutral beam injection (NBI) alone can initiate a plasma with appropriate gas puffing, and heat the plasma without using ECH. This allowed us to operate the discharges at any magnetic field (above $B=0.5$ T) so that we could achieve high-$\beta$ plasmas. At $B=1.3$ T, the beta value estimated from the diamagnetic signal reached 2.4% with pellet injection. The achieved beta value was limited by heating power, not by any kind of MHD instability.

The discharge with the inward shifted configuration exhibits a factor of 1.6 improvement over the ISS95 confinement scaling law and is found to be comparable to those of ELMy H-mode tokamaks. The observed high edge temperature, not seen in the smaller heliotron devices resulted in higher stored energy and hence higher energy confinement. The edge barrier or pedestal forms as the plasma pressure is increased, not through a rapid transition as in tokamak H-mode.

Demonstration of a high-quality, steady-state helical plasma is one of the major goals in the LHD experiment. We installed carbon tile divertor plates, which made long-pulse discharges possible. Two discharges, heated by ICRF (1 MW) and NBI (0.5 MW), lasted more than 1 minute. In both discharges, the electron densities were $1-2 \times 10^{19} \text{ m}^{-3}$ and were controlled by manual gas puffing. The electron temperature maintained around 1-2 keV. The radiation power is less than 20% of the input power and there was no sign of the impurity accumulation.

Fig. 1  Schematic view of LHD.

contact: motojima@LHD.nifs.ac.jp

Fig. 2  Helical structure of LHD plasma in calculation (left) and measurement (right). Ergodic field lines are selected in the plot which emit visible light measured by the camera.