§27. Long Pulse Discharge Sustained by MW Level of ICRF Power in LHD

Seki, T., Mutoh, T., Kumazawa, R., Saito, K., Kasahara, H.

Steady state operation is one of the important missions of LHD. Discharge length of 54 minutes and 28 seconds and total input heating energy of 1.6 GJ were achieved in the former experiment. Averaged total heating power was 490 kW. High power steady state operation is important expressly from engineering point of view. Long pulse discharge sustained injection power more than 1 MW was mainly investigated.

Figure 1 shows the time evolution of plasma parameters in long pulse discharge. Averaged injection powers of ICRF, ECH, and NBI are 894 kW, 90 kW, and 75 kW, respectively. Total heating power is 1059 kW and plasma duration time is 525 sec. Magnetic axis was swept between 3.65 and 3.67 m to distribute the heat load on divertor plates. NBI is injected when magnetic axis moves to outmost. A line averaged electron density is 0.6 x 10^{19} m^{-3} and dropped when NBI is injected. Ion and electron temperature progressed constant and react with NBI injection. At the end of plasma, density increase was not controlled in this shot. In 9th cycle, the maximum pulse length injected more than 1 MW was 285 sec. The pulse length was extended in 10th cycle.

Temperatures on divertor plate kept increasing during the shot. Plates near the ICRF antenna (3-I, 7-I, and 7.5-L ports) reached particularly high temperature. The maximum temperature rise reached almost 500 ºC in 525 sec. operation by measurement using a thermocouple. An IR camera was installed to measure one of the highest temperature plates (3-I port). The temperature at carbon went up to more than 1400 ºC (exceeded the limit of measurement). A CCD camera viewing 7-I divertor observed a hot spot on the plate. These extreme temperature increase is thought to be caused by the accelerated ions at edge plasma region at front of ICRF antenna.

Temperature at ceramic feedthrough continued to rise also. The increase rate was reduced by strengthened cooling compared with the 9th cycle. Further strong cooling by increasing flux of N_2 gas is required for higher power and longer pulse operation.

Figure 2 summarized achieved pulse length and injected ICRF power. In 10th cycle experiment, the experiments using the ICRF power around 1 MW were mainly carried out (solid square). If the power was increased, pulse length tends to be short because influx of iron impurity was frequently happened. All data are in a trend and a breakthrough is indispensable to achieve a higher power and steady state operation.

In 11th cycle, new gyrotron will be available for the experiments. The frequency is 77 GHz and 200 kW will be injected into the plasma in steady state. Stronger electron heating will contribute to steady state operation. Higher density operation and electron heating by mode conversion heating are another key factors for further steady state experiment.

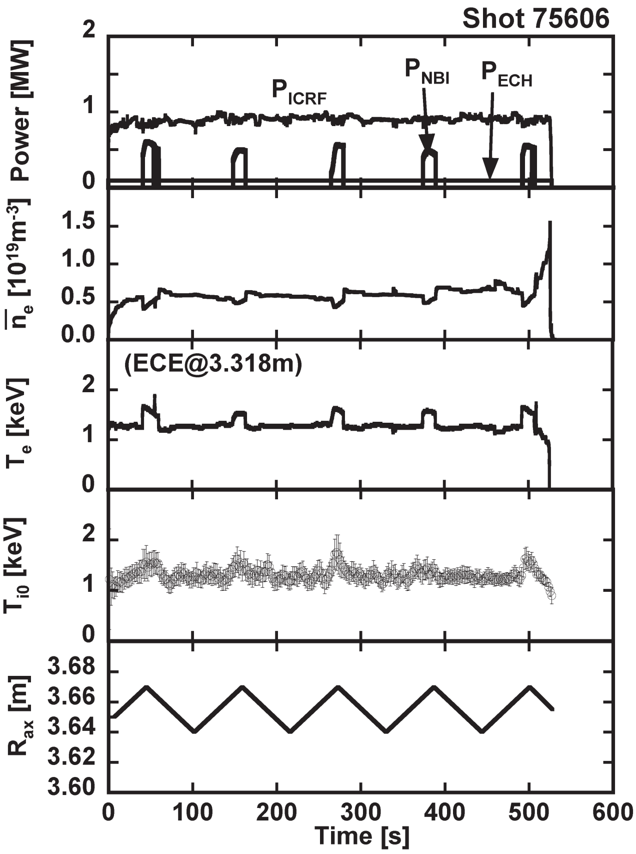

Fig. 1. Time evolution of plasma parameters in the long pulse discharge with high power injection. An injected heating power exceeds 1 MW.

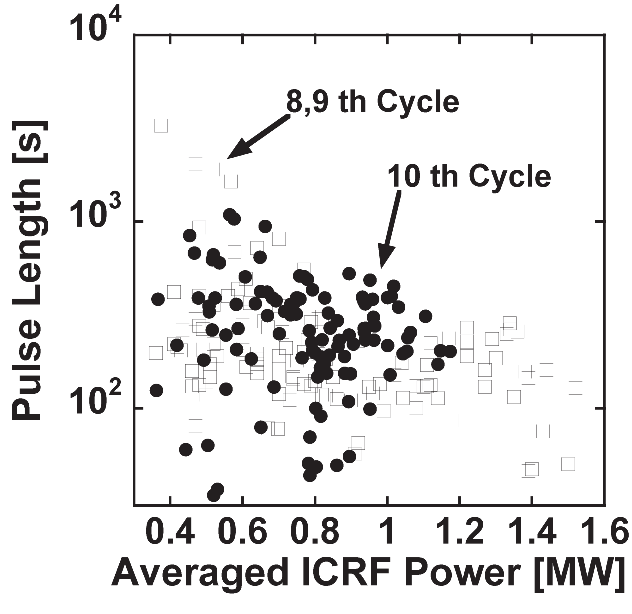

Fig. 2. Pulse length of plasma discharge as a function of an averaged ICRF power.