§1. Development of High Power Plasma Heating and PWI Study Using Steady-sate Discharge

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Steady-state operation (SSO) has been studied on the Large Helical Device (LHD), and the novel long pulse discharge with the plasma duration time τ_d of 54 min, line averaged electron density n_e of 0.4x10^{19} m^{-3}, ion (Ti) and electron temperature (Te) of 1 keV was demonstrated by the hydrogen minority heating regime in helium plasma using radio frequency (RF). High performance plasma with higher density and temperature is requested to investigate the PWI effect on the stead-state condition, and the effective experimental strategy for SSO has been discussed on the collaboration between National Institute for Fusion Science (NIFS) and many universities through a framework of the general collaboration research program in NIFS.

By the developments of particle fueling method, the improvement of stability for high power RF heating system and the mitigation of the local heat load by supplying the average heating power to different toroidal sections, the long-pulse discharge with n_e ~ 1x10^{19} m^{-3}, Ti ~ Te ~ 2 keV and τ_d ~ 48 min was achieved using averaging RF heating power of 1.2 MW with the same heating scenario of the 54 min operation. The ultra-long pulse discharge waveform is shown in Fig. 1, and the electron density is kept constant on the discharge. In order to increase electron density in the SSO, the electron density could not keep constant using the simple proportional method to fuel particles, and the simple method could effectively control the density in the previous long pulse discharge. On the newly adopted real-time gas fueling system, gas-fueling rate was estimated by the difference between target density and line averaged electron density, and the quantity of gas-fueling rate was adequately controlled by the difference on the real-time.

There were three kinds of gas fueling rate in the fueled particles for helium and hydrogen, and hydrogen particle was supplied by the super-sonic gas puffing and frequency modulated gas puffing. However, the hydrogen-fueling rate was much smaller than the quantity of helium-fueling rate. In the helium fueling, the fueling rate was negligible form t ~ 300 sec and to t ~ 1900 sec, and then helium-fueling rate was increased in τ_d > 2000 sec, which was new SSO regime. The new SSO regime was firstly observed at the higher density plasma (n_e ~ 1x10^{19} m^{-3}) with τ_d > 2000 sec, and it seemed to be strongly related with the accumulation of mixed-material, which was caused by the erosion from the surface of carbon divertor plates.

In previous SSO study for the gas fueling include in particle retentions, the saturated particle retention on the long pulse plasma is predicted, but the recovery of gas-fueling rate is an unprospective phenomenon from the former SSO operation in tokamaks and helical plasmas. The study of newly gas-fueling operation regime is important to estimate wall-recycling rate on the long pulse operation like ITER and a fusion reactor, and it will be key role to control particle fueling in it. In order to reveal the new regime, it is necessary to study the PWI, particle balances, high power steady-state heat handling and the demonstration using actual long-pulse plasma, and the collaboration framework between NIFS and universities makes powerful support to understand the phenomena.

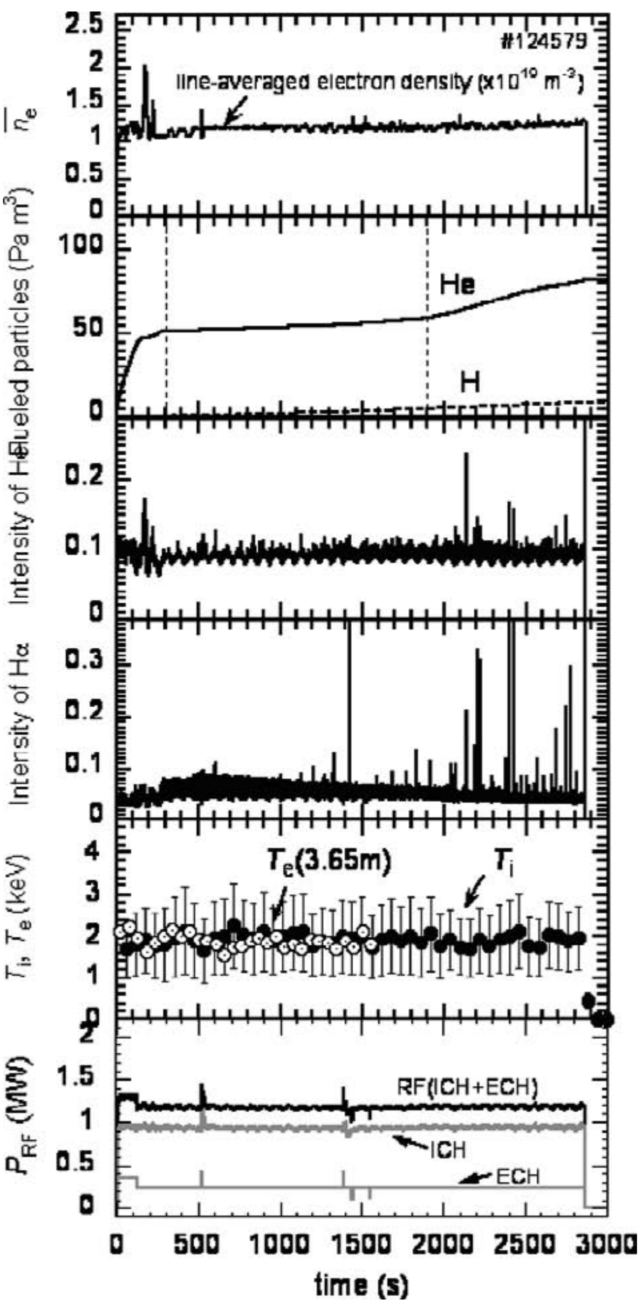

Fig.1 Discharge waveform in various plasma parameters in the 48 min discharge. Many plasma parameters were kept constant on the SSO.