§12. Long Pulse of ICRF Heated Plasma Discharge

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The demonstration of the steady state plasma discharge is one of the main objectives on the LHD project. The final goal of the performance of the steady state discharge is as follows; the fusion triple product is $n_e\tau_E T_{i0}$=1.0x10^{19} m^{-3}keV sec and the duration time is more than 30 minutes with the heating power of 3MW.

Experiments of the long pulse operation were tried at the end of the 3rd and 4th experimental campaigns, using ICRF heating. At the 3th experimental campaign the long pulse discharge with 68 seconds was achieved at the plasma of W_p=110 kJ, n_e=1.0x10^{19} m^{-3}, T_{e0}=2.0 keV, T_i=2.0 keV and τ_E=0.19 sec using ICRF heating power of P_{ICH}=0.8MW. The fusion triple product of $n_e\tau_E T_{i0}$=0.31x10^{19}m^{-3}keVsec.[1] At the 4th experimental campaign the pulse length was extended to 120 seconds at the plasma of n_e=0.8x10^{19} m^{-3}, T_{e0}=1.3 keV and T_i=1.3 keV using ICRF heating power of P_{ICH}=0.4MW as shown in Fig.1. In this long pulse discharge the experimental condition was employed at the optimum, i.e., B=2.75T, R_{ax}=3.6m, γ=1.25 and f=38.47MHz. The fusion triple product was estimated to be $n_e\tau_E T_{i0}$=0.28x10^{19}m^{-3} keVsec by deducing the scaling low of the fusion triple product, i.e., $n_e\tau_E T_{i0}$=0.03 x $n_e(10^{19}m^{-3})^{1.02}P_{ICH}(MW)^{-0.18}$.[1]; because the measurement of the plasma stored energy using a diamagnetic loop was not applicable at such a long pulse discharge plasma.

A review of long pulse discharge experiments at two experimental campaigns is shown in Fig.2; the pulse length (open circles) and the injected energy of ICRF heating (open squares) to the LHD plasma are plotted versus the shot number. The maximum injected energy is 50MJ. So far the phenomena preventing the duration time of the ICRF heated plasma from extending to the longer duration, e.g., 30 minutes have not been observed. They are thought to be a loss of the plasma density control due to the vacuum wall saturation with hydrogen molecules and a local increase in the temperature due to the plasma heat load etc. The long pulse duration time was simply limited by the ICRF heating power source. A long pulse operation of 5,000 seconds with 1.6MW at f=50MHz was achieved by employing a low impedance mode [2]; however a parasitic oscillation of 1.2~1.3GHz is thought to prevent the long pulse RF output at the present frequency of 38.47MHz. To absorb a power of the parasitic oscillation ferrites are installed between the screen grid and the control grid of the tetrode tube of the final amplifier. However the temperature of ferrites was increased even a low RF output power, e.g., 300~400kW for a few minutes, though an air cooling was employed to remove a dissipated power. Now a purified water cooling method is tried to enhance the heat removal from the ferrites. A target of the R&D is an achievement of operations of 0.3MW for 30 minutes and 0.6MW for 5 minutes. At the 5th experimental campaign long pulse operations will be carried out for 30 minutes at the plasma as the same as the 2 minutes discharge as shown in Fig.1 with the injected ICRF heating power of 0.5MW and for 5 minutes at the higher density with 1MW.

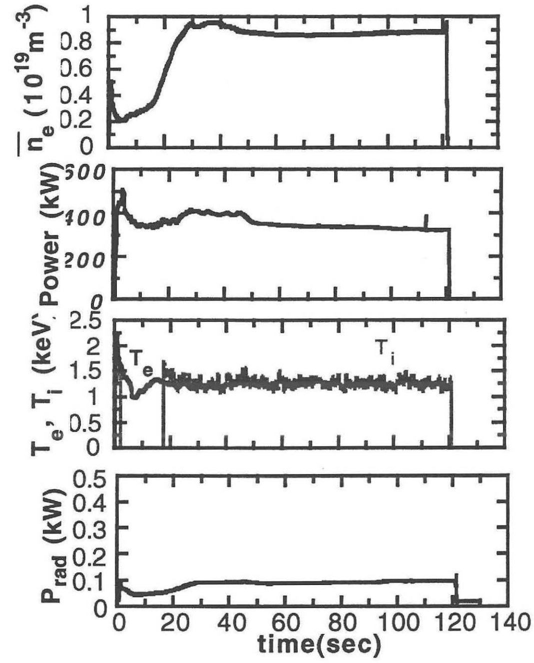

Fig.1 Time evolutions of plasma parameters of 2 minutes discharge.

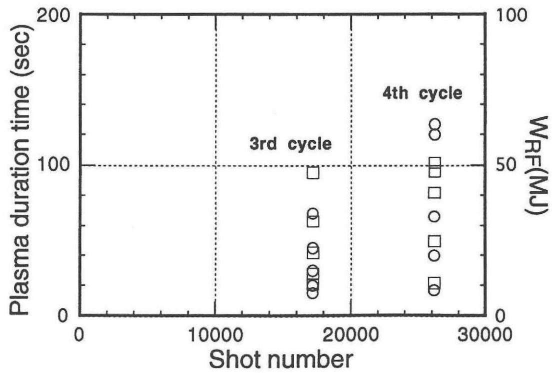

Fig.2 Review of long pulse discharge of ICRF heated plasma.

References

[1] R.Kumazawa et al., Physics of Plasmas, **8** 2139(2001).

[2] T.Seki et al., to be published in Fusion Engineering (2001).