§5. Sustainment of keV-order Stable Plasma by ECH Over One Hour on LHD

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Stable and continuous plasma sustainment is one of the main goals of LHD project. So far long-pulse operation has been tried and a 756 second plasma sustainment was achieved in the 7th experimental campaign in F. Y. 2003. In that case, the pressure inside the evacuated waveguide gradually increased during the power transmission up to the interlock threshold level 1.3 Pa so that the power transmission was terminated. The temperature all over the transmission line was much increased up to 100 degrees by transmission loss.

During the maintenance period between the 7th and 8th campaigns, two major modifications on the transmission line were performed. To enforce evacuation, straight waveguides were replaced by pumpout-tees at eight positions. Each new pumpout-tee was connected to an common evacuated duct or turbo pumps. To remove the transmission loss energy on the waveguides, almost all the surface of the waveguides and their couplings were covered with water cooled thin copper jackets except supported positions.

Previous to a trial of the long pulse discharge, magnetic axis position scanning experiment was performed to search an optimized experimental configuration. Referring to the result of the configuration optimizing experiment shown in Fig. 1, the trial of the CW plasma sustainment was performed with R_{ax}=3.6 m and B_{ax}=1.5 T. For the long pulse discharge, data acquisition settings such as sampling time were changed so that the data could be processed for 3932 seconds (30 ms sampling, 128 kword).

At first, using several shots of duration up to a few hundred seconds, optimized gas flow rate was searched and gradual increase with an increment step of 0.0002 Pam^3/s for every 5 seconds up to 0.003 Pam^3/s was determined. Then the discharge #56068 was started with this gas fueling scenario. Plasma start up was supported by 82.7 GHz power of total 420 kW, 300 ms pulses and the CW power sustained the plasma. Waveforms of ECH power monitor output, gas flow rate, line averaged electron density and electron temperature measured with ECE system are plotted in Fig. 2. Until about 1900 seconds, density was kept nearly constant at 1.5 x10^{18} /m^3 though the gas flow rate was controlled sometimes to compensate gradual decrease of the density.

At about 1900 seconds, gas flow rate was increased for trial of plasma sustainment at higher density. However, increase of gas flow rate up to 0.006 Pam^3/s caused uncontrollable density increase up to 3.2 x10^{18} /m^3 and the flow rate was decreased again. Three more times increasing the density was tried. However at each trial rapid density increase occurred and keeping the density at moderate level could not accomplished with the ECH power of 110 kW.

Excluding those density increases by high-density trials the plasma could be much stable, and except for the limitation on data acquisition the discharge could be continued longer.

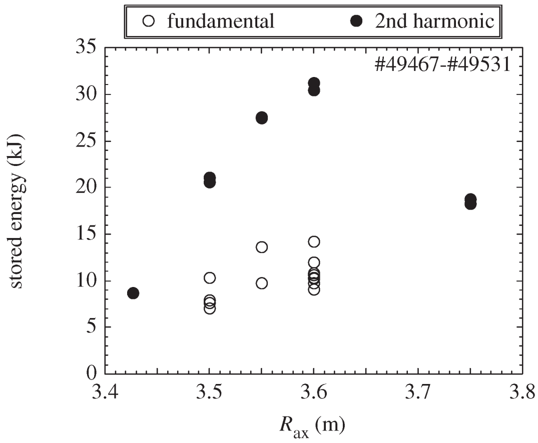

Fig. 1. Result of magnetic axis scanning experiment searching the optimized configuration for CW-ECH experiment. Closed circles denote the maximum stored energy at each magnetic axis position with on-axis 2nd harmonic resonance conditions, and the open circles with higher field conditions.

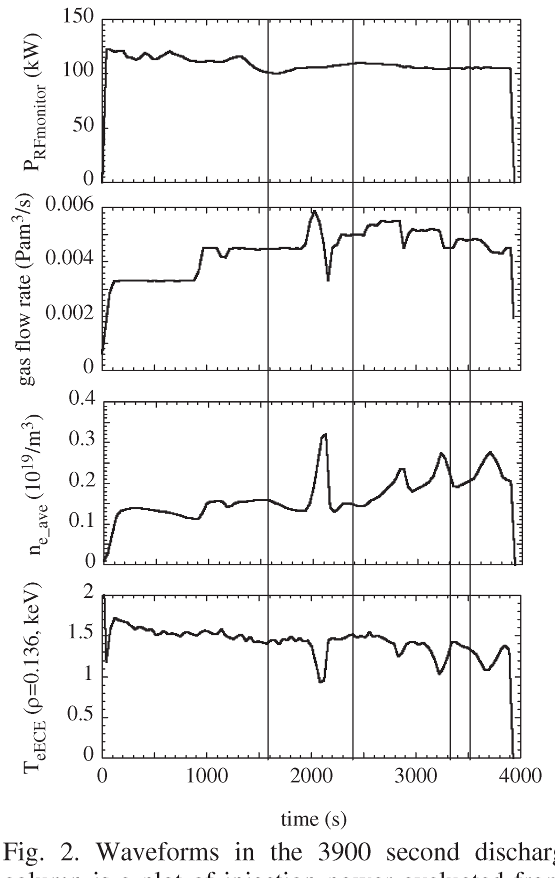

Fig. 2. Waveforms in the 3900 second discharge. Top column is a plot of injection power evaluated from power monitor on a miterbend, the second: gas flow rate, the third: line averaged electron density and the bottom: electron temperature measured with ECE system.