§20. Long Pulse NBI Heating in LHD

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Steady-state operation is one of the main objectives in LHD, and long-pulse NBI heating for several tens of seconds was planned in the second experimental campaign, as the first step towards the steady-state operation [1]. One of two injectors (BL2) had an ability of long-pulse injection up to 35 sec in the second campaign, and the pulse duration will be extended year by year to 30 min by modification of power supplies [2].

One month later after the start of NBI operation in LHD in September, 1998, the pulse duration was extended to 10 sec with an injection power and energy of 1.1 MW and 80 keV, respectively. The pulse duration had been determined by the beam blocking, which was caused by the out-gas from molybdenum protection plates inside the injection port. Repetition of injection for longer than 1 sec was effective for conditioning of the injection port, and 10 sec injection was achieved. In the 80 keV - 1.1 MW - 10 sec injection, an rapid increase in the density and the radiation power was observed at the pulse end although the plasma was almost steady in the first half of the shot. After the following several hundreds of short pulse shots for shorter than 1 sec, a quasi-steady-state plasma was obtained for 21 sec with a reduced injection power of 0.6 MW. The injection energy was 66 keV. Figure 1 shows the time evolution of various plasma parameters in the 66 keV - 0.6 MW - 21 sec shot. The plasma density and temperature are almost steady at 0.3 x 10^{19} m^{-3} in the line-averaged electron density and 1 keV in the near central ion temperature, respectively. The radiation power and the impurity emission line intensities are also steady for 21 sec. At higher densities, relaxation oscillation phenomena were observed at a period of 1 - 3 sec. Figure 2 shows an example of the relaxation oscillation shot for 20 sec. On a visible TV monitor, plasma enlargement and shrinking were observed synchronously on increase and decrease in the electron temperature.

The injector operation including negative ion sources was stable. These results have demonstrated an ability of steady-state operation in superconducting LHD, and 1 MW - 1 min NBI heating will be tried in the third experimental campaign.

References

[1] N. Noda, *et al.*, J. Plasma Fusion Res. SERIES, **1**, 130 (1998).
[2] Y. Takeiri, *et al.*, *ibid.*, 405 (1998).

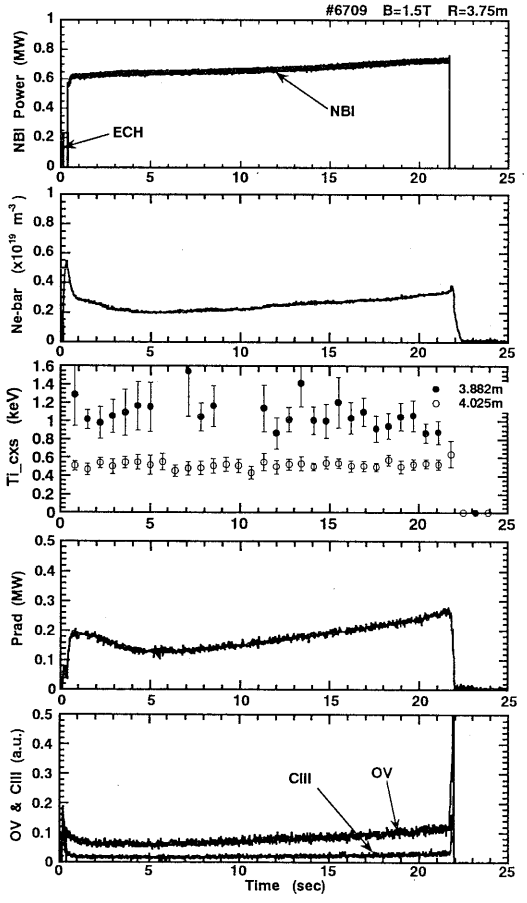

Fig. 1. Time evolution of various plasma parameters in 66 keV - 0.6 MW - 21 sec shot.

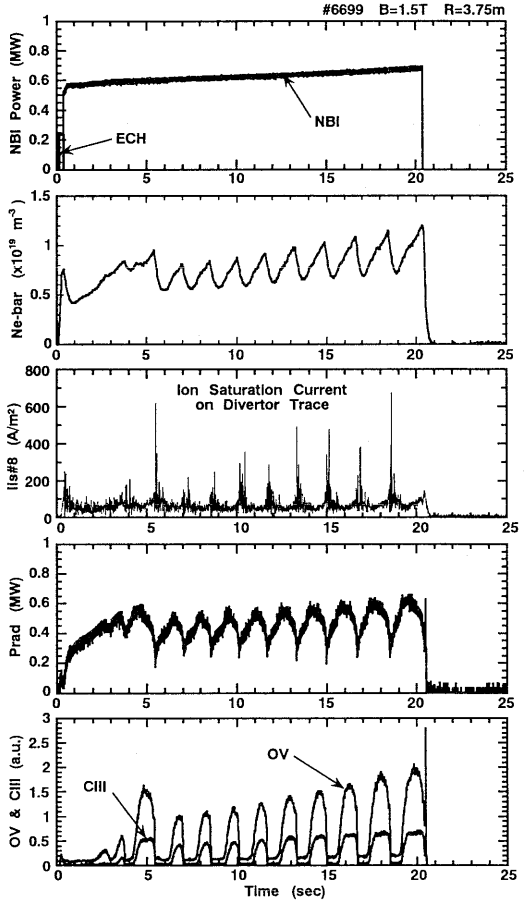

Fig. 2. Time evolution of various plasma parameters in relaxation oscillation shot for 20 sec.