§22. Long Time Discharge Experiments by ECH in LHD

Shimozuma, T., Sato, M., Takita, Y., Ito, S., Noda, N., ECH group and LHD experimental group G1, G2

LHD has external super-conducting magnets for producing a confining magnetic field and can operate continuously in principle. If there are CW (Continuous Waves) power sources to produce plasmas, it can be sustained steadily. We have been developing CW power sources of ECH, i.e. gyrotrons for that purpose.

Requirements for CW ECH power sources are , for example, sufficient cooling of all parts, including an improvement of cooling structures, realization of vacuum barrier windows which can tolerate high power CW transmission, high RF coupling efficiency from gyrotron to wave guide, efficient removal of leak RF and also suppression of X-ray irradiation.

We prepared one CW 84GHz gyrotron (CPI #2R) for long time discharge experiments. This gyrotron could generate 100kW, 95% duty, 2 minutes output power. Figure 1 shows a typical wave form of injected RF. Incident power into LHD was limited within 50kW and 95% duty because of low coupling efficiency from the gyrotron window to the wave guide and also of a shortage of gyrotron aging time. Time duration of the power input was restricted within 2 minutes due to high heat load to MOU (matching optics unit).

The MOU consists of four mirrors, absorbing structure of leaking RF, and shielded box. The shielded box was evacuated to prevent some arcings. The diffracted RF from the mirrors are absorbed by water-flowing Teflon tubings which are wound on the inside walls of the box. Measurement showed that about 33% power of the gyrotron output was diffracted (not coupled to the wave guide) and absorbed by the tubings. This power loss limited the longer period operation.

The experiments was performed at the magnetic field of 1.5T with the magnetic axis of 3.75m, and working gas was helium. Millimeter wave beams were focused on the position of the magnetic axis by a quasi-optical antenna which consists of two focusing and two flat mirrors. Keeping the duty factor of gyrotron operation of 95%, we extended the injection time period to 10 sec., 20 sec., and 2 minutes. During the procedure timing and amount of gas puffing were optimized.

Figure 2 shows a time evolution of some plasma parameters during a 2 minutes discharge by ECH. Helium gas was puffed only within the first 5 seconds. After 5 sec, the plasma looked to be in steady state and the average electron density was kept around 0.3 - 0.5 x 10^{18} m^{-3}. Bolometer signal was also kept constant. Although the visible light emission was weak, the ion temperature measured by the spectroscopy of CV line is estimated to be about 300eV during steady state phase of the discharge.

Hereafter we will strengthen the cooling of MOU, and continue to age the gyrotron. At the next LHD experiment, longer and higher power injection can be expected.

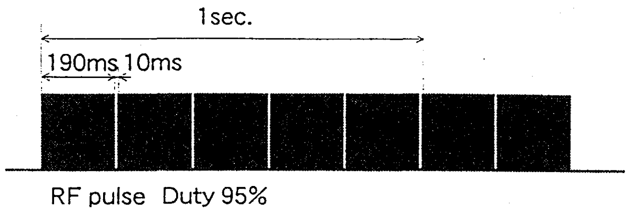

Fig. 1 Typical waveform of injected RF

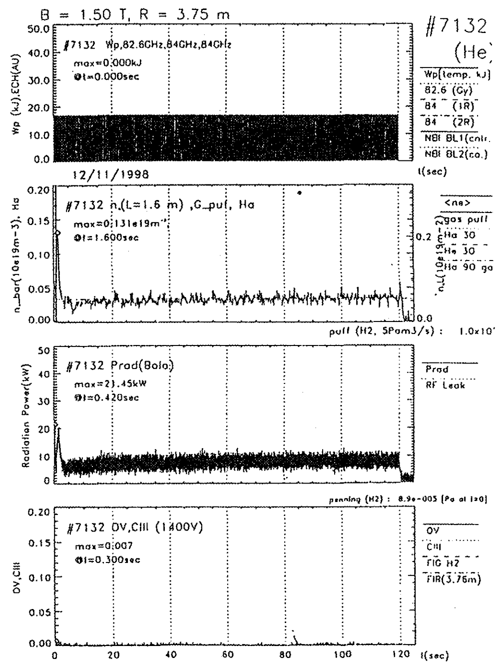

Fig. 2 Time evolution of some plasma parameters during 2 minutes discharge by ECH