§27. Production and Steady State Operation of Non-inductive Current Driven Plasmas by ECRH

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1. Introduction

Electron cyclotron wave (ECW) is useful for local plasma heating, local current drive and plasma production. The locality of the deposition profile into the plasma was made sure in various experiments, for example suppression of neoclassical tearing mode (NTM) and sawteeth stabilization. Moreover as for the plasma production, the availability of ECW was well-known in the field of the plasma processing.

In the field of fusion research, plasma start-up experiments were executed by the combination of ECW with lower hybrid current drive (LHCD) in various tokamak devices (WT-2, WT-3, JIPPT-IIU, PLT). However the available duration of the devices was not enough to reach steady state. In future fusion reactor should be operated without the assistance of the ohmic heating, because the reactor with the installation of ohmic coils is not attractive in the view of the construction cost. This matter should be investigated in superconducting devices, which are free from the limitation of discharge duration.

2. The ECH system

A new ECW system (170GHz, 200kW, 5sec) is installed on the TRIAM-1M tokamak (R=0.8m, a/b=0.12/0.18m), which has 16 superconducting toroidal magnets made of Nb_3Sn to be produced steady toroidal magnetic filed of 11 T on the winding and of 8 T at the center of the plasma chamber. The microwave is generated by a gyrotron as shown in Fig. 1. The output microwave from the gyrotron is coupled to corrugated waveguides by using a matching optical unit (MOU). The output power at the window of the gyrotron is beyond 260 kW and the power at the waveguide is about 200kW. The conversion loss at the MOU is about 15 %. Unfortunately we do not carry out the measurement of total loss of the waveguide now. It is a future work, however the calculation of the loss of the transmission line except MOU is estimated as 2~3%. An injected window to TRIAM-1M is made of diamond and the increment of the temperature during 1 sec pulse is less than 5 °C.

3. Experimental results

The start-up experiments without the assistance of the ohmic heating can be demonstrated by the combination of electron cyclotron heating (ECH:170 GHz) with LHCD (8.2GHz) as shown in Fig. 2. Plasma can be made around fundamental electron cyclotron resonance of injected ECW from 0 sec to 0.3 sec and then LHCD can produce and maintain the plasma current to keep plasma equilibrium for 10 sec. The injection of LHW is delayed from the injection of ECW by 5 ms. The waveform of plasma current is similar to a locus of Harrier airplane, therefore we would like to name this operation "Harrier Tokamak".

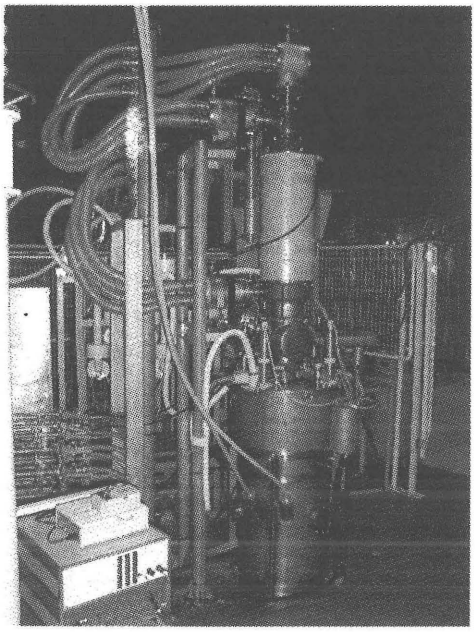

Fig. 1. Photograph of the gyrotron of 170 GHz 200kW 5sec.

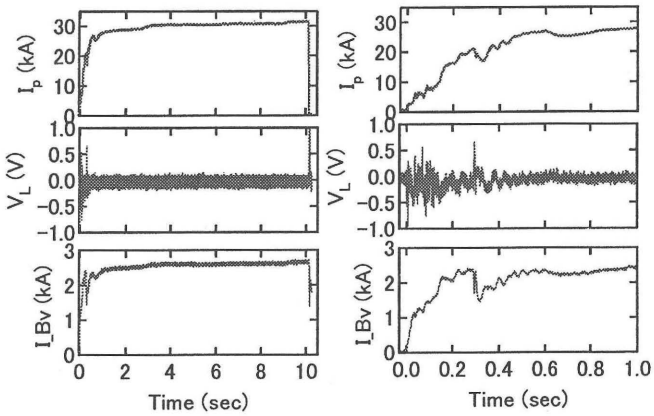

Fig.2. The typical waveforms of the discharge without assistance of the ohmic heating are shown. The left figures show plasma current (top), loop voltage (middle), and current for poloidal field coil (bottom) and the right ones show the details at the beginning of the same discharge. The discharge was made by electron cyclotron wave (170GHz, 150kW, 0-0.3sec) and sustained by lower hybrid current drive (8.2GHz, 115kW).