§55. Collaborative Research on Electron Cyclotron Heating in high-density Plasmas Using the 28GHz High Power Gyrotron System

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Electron Bernstein Wave Heating and Current Drive (EBWH/CD) experiments have been conducted in QUEST. In order to study the EBWH/CD effect, first the high-density plasma should be produced and sustained beyond the cutoff. If a high frequency power source is available for the experiments, accessible density in the ECWH/CD experiments become higher. High frequency 28 GHz system has been considered for the high-density operation. Second harmonic resonance 2 f_{ce} of 28 GHz was located at the inboard side as well as fundamental resonance f_{ce} of 8.2 GHz near the plasma center. The EBWH/CD experiments are planned using 2 frequency range sources of 28 GHz and 8 GHz. The plasma will be initially produced by the 8 GHz system, and then the density will be ramped-up with the 28 GHz system. The 8 GHz EBWH/CD experiments can be conducted in the over dense plasma sustained by the high frequency 28 GHz system.

In this year, the ohmic discharge experiments with the RF injection were conducted to study the EBWH/CD effect in over dense plasmas. RF power was injected into the 30 kA plasmas controlled by feedback regulation of the center solenoid coil current to maintain the constant plasma current. Figure 1 shows time evolutions of the incident RF power, the line-averaged density, the plasma current, and the loop voltage in the experiment. The density was rapidly increased beyond the O-mode cutoff of 0.83 x 10^{18} m^{-3} by the RF injection. 100 kW RF power was totally injected by two 8 GHz RF systems. Density was first increased, and then the plasma current and the loop voltage were changed. The Hard X-ray (HX) intensities were measured with tangential viewing in the forward direction for the current-carrying electrons. The lower energy HX intensity was increased before the higher energy HX intensity was increased. Plasma current was increased due to the high energetic electrons accelerated with the RF injection. Plasma current and the loop voltage were clearly increased and decreased by the RF injection in the plasma current feedback control respectively, indicating the EBWH/CD effects in the over dense plasma.

Collaborative research has been begun with Tsukuba University and NIFS. A 28 GHz CW gyrotron has been developed at Tsukuba University. A conventional high voltage power supply of 50 kV was prepared to control the anode voltage for the triode MIG of the 28 GHz gyrotron. High-speed / high-voltage CW switch system integrating multiple stages of MOSFETs connected in series is prepared to turn on/off the anode voltage and to cut the voltage for the over current detection. Over current detection system of the anode current, and a gyrotron tank with insulators of cathode- anode-electrodes are prepared and tested. Cooling water system is modified to operate the 28 GHz gyrotron system. Figure 2 shows the present setup of the 28 GHz gyrotron system. Supper conducting magnets and the gyrotoron are first installed, their setting position and axes are checked. Matching Optics Unit (MOU) and a transmission line composed of circular corrugated waveguides and a 90-degree miter bend are connected to the system. Oscillating power at the 28 GHz gyrotron is transmitted into the QUEST through a vacuum window using the transmission line. The oscillating test of the gyrotron is conducted with the Kyushu University facilities. A short-pulse dummy-load (DL) is installed after the MOU with and without coupling to the waveguide. A proper oscillating mode is confirmed, and oscillating power is transmitted to the DL by a coupling mirror at the MOU. Operation parameters in the oscillating test with the coupling to the waveguide are as the followings.

Cathode Voltage / Current:	70 kV/ 15A
Anode Voltage / Current:	38 kV/ 0.2mA
Loss power at MOU:	36 kW
Transmitted Power to DL:	311 kW
Oscillating efficiency:	33 %

Although the pulse width of the test is limited at a 100 ms level, long pulse tests for 1 sec will be conducted soon. High power test of a 600 kW level will be also done in next year. In the next year, the high-density operation will be carried out with the high frequency 28 GHz system.

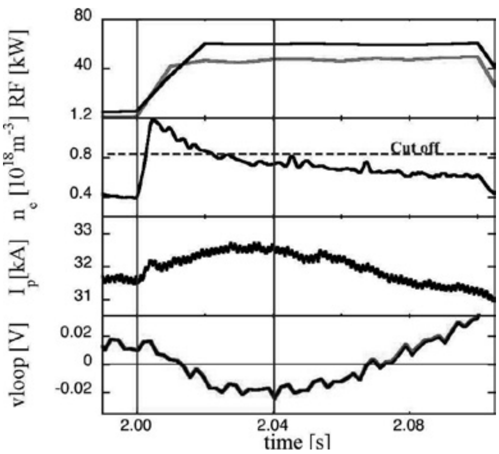

Fig. 1: Time evolutions of incident RF power, line-averaged density, plasma current, and loop voltage in superposed RF injection to the ohmic plasma.

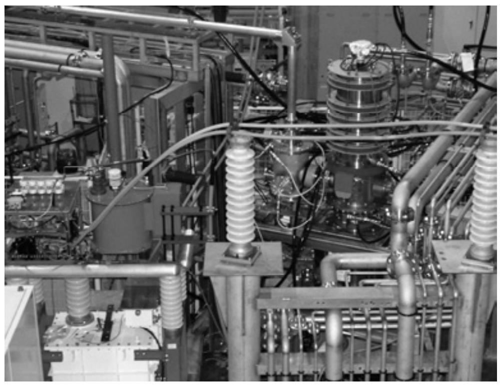

Fig. 2: Present setup of the 28 GHz gyrotron system.