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

Idei, H., Zushi, H., Hanada, K., Nakamura, K., Fujisawa, A., Hasegawa, M. (Kyushu Univ.), Imai, T., Kariya, T., Minami, R., Sakamoto, M., Numakura, T. (Tsukuba Univ.)

Electron Cyclotron / Bernstein Wave Heating and Current Drive (ECWH/CD, EBWH/CD) experiments have been conducted in QUEST. Long pulse discharges with the plasma current of 10 kA and 15 kA were non-inductively attained in the limiter configurations for 37 s and 20 s with only Radio Frequency (RF) power, respectively. The single-null divertor configuration was obtained with the plasma current of 15 kA. The elongation, triangularity, and aspect ratio were 1.53, 0.41 and 1.98 in the RF-sustained plasmas, respectively. The divertor configuration with the high plasma current (~25 kA) was also attained in the 17 s plasma sustainment. Obtained density was typically low (~2×10^{17} m^{-3}), compared to the O-mode cutoff density (~8.3×10^{17} m^{-3}) in these experiments. Effective EBWH/CD experiments in the high-density plasma beyond the cutoff have not been expected in the low- density plasma.

In order to study the EBWH/CD effect, first the high-density plasma should be produced and sustained beyond the cutoff. The high-density operations were conducted in the inboard null configuration. The divertor configurations formed single- and double-null points upper and/or lower for the mid-plane in the QUEST device. In the inboard null configuration, a null point was appeared at the high field side of the QUEST device. The high energetic electrons could be confined with the strong positive *n*-index field. Figure 1(a) shows time evolutions of plasma current and density obtained in this configuration. A series of gas puffing were applied to obtain the high-density plasma. The plasma current first decreased, but the plasma current was remarkably observed in the higher density plasma again. Figure 1(b) shows the obtained plasma current for the line-integrated density at 70 and 100 kW power. The high-density window was not attained in the lower RF incident power.

O-mode cutoff density increases as square of the operating RF frequency. If a high frequency power source is available for the experiments, accessible density in the ECWH/CD experiments become higher. High frequency system has been considered for the high-density operation. Figure 2 shows fundamental and second electron cyclotron resonance frequencies, f_{ce} and $2f_{ce}$ at the magnetic field of B_T=0.25 T, and O-mode cutoff frequencies f_{pe} in various density profiles. The $2f_{ce}$ of 28 GHz was located at the high field side as well as f_{ce} of 8.2 GHz near the plasma center, as shown in Fig.2. The O-mode cutoff density is (~1×10^{19} m^{-3}) for 28 GHz. The EBWH/CD experiments are planned using 2 frequency range sources of 28 GHz and 8.2 GHz. The plasma will be initially produced by the 8.2 GHz system, and then the density will be ramped up with the 28 GHz system. The 8.2 GHz EBWH/CD experiments can be conducted in the over dense plasma sustained by the high frequency 28 GHz system. Collaborative research has been begun with Tsukuba University and NIFS. A 77 GHz CW gyrotron has been successfully developed by collaborative research between Tsukuba University and NIFS for the Large Helical Device experiments. A 28 GHz CW gyrotron has been developed as their research program at Tsukuba University. The 28 GHz gyrotron will be operated for the EBWH/CD experiments with the gyrotron power supply in Kyushu University. Maximum beam voltage and current were -75 kV and 25 A in the Kyushu University power supply. The operating parameter region of the 28 GHz gyrotron was surveyed to operate it with the limitted beam voltage and current in Kyushu University. The power level of 500-600 kW was available within the operating limits. The Tsukuba 28 GHz gyrotron was with a triode MIG gun, while a 170 GHz gyrotron for the previous TRIAM-1M tokamak was with a diode MIG gun. In the operation survey, the maximum anode voltage was 42.5 kV at the -70 kV beam voltage. A conventional high voltage power supply of 50 kV was prepared to control the anode voltage. High-speed / high-voltage CW switch system integrating multiple stages of MOSFETs connected in series is going to be 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 were prepared.

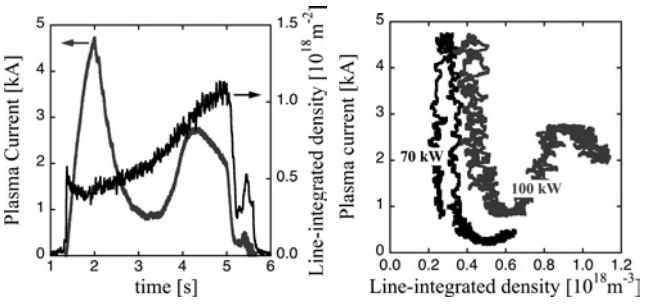

Fig.1: (a) Time evolutions of plasma current and density of the high-density operation in the inboard null configuration. (b) Obtained plasma current for the line-integrated density at 70 and 100 kW power.

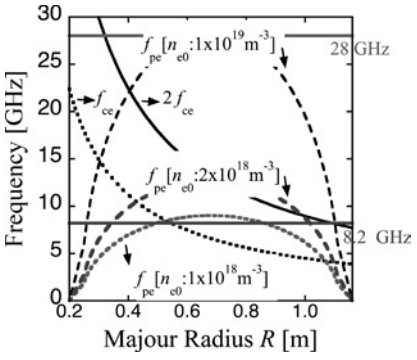

Fig.2: Fundamental and second electron cyclotron resonance frequencies, f_{ce} and $2f_{ce}$ at the magnetic field of B_T=0.25 T, and O-mode cutoff frequencies f_{pe} in various density profiles.