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

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Obtained high-current plasmas with only 28 GHz injection were analyzed with a plasma equilibrium fitting code EFIT. Figure 1(a) shows magnetic flux surfaces analyzed for the 54 kA plasma by the EFIT. Time evolution of plasma shaping parameters was shown in Fig. 1 (b). Large sized- and vertically elongated- plasma was sustained for larger than 1 sec. The small Shafranov-shift Δ less than 0.1 m was observed due to moderate poloidal beta β_p of 0.2. Tangential-viewing Hard X-ray (HX) intensity with 150 keV energy-level was measured for current-carrying forward electrons, while the HX intensity with lower energy-level of 80 keV was observed for the backward electrons.

The 28 GHz system was introduced to attain over-dense plasma for the 8.2 GHz RF injection in the first place. High-density operations were conducted using the 28 GHz system. The 28 GHz RF was superposed for the 8.2 GHz injection. The plasma current was significantly built up to 25 kA by the 28 GHz injection at t = 1.6 sec as shown in Fig. 2 (a). To obtain the high-density plasma, hydrogen gas fueling was applied 4 times. Here differential pressure $\Delta P(t)$ evolution in the hydrogen reservoir tank was plotted in Fig. 2 (b), showing gas-fueling timing. The density was independently increased for the gas timing sometimes. Spontaneous Density Jumps (SDJ) unaccompanied by increment of the Hα intensity were clearly observed. Figure 3 (a) shows electron temperature and density profiles measured by Thomson Scattering (TS) diagnostics at some timing related to SDJ events. Second (2nd) harmonic and fundamental (1st) resonance layers were located at major radii R of 0.32 m and 0.55 m for the 28 GHz and 8.2 GHz injections, respectively. The electron temperatures were high near the 2nd resonance for 28GHz anytime, while it was high near 1st resonance for 8.2 GHz in the low-density plasma before 1st SDJ. Figure 4 (a) shows magnetic flux surfaces analyzed by the EFIT code. Large Shafranov shift was observed due to the large β_p. There should be high bulk electron pressure parts in the outboard although there were no enough TS data points, corresponding inboard high electron pressure parts near 1st resonance layer for 28 GHz. At t = 2.55 sec, core outboard pressure was increased in the over-dense state for 8.2 GHz, while the inboard pressure was rather decreased. If the increased outboard pressure came from electron Bernstein heating effect, corresponding parallel refractive index should be 4 in the electrostatic wave on Doppler-shifted resonance. High energetic HX intensity of 500 keV level was observed in tangential viewing radius R_{tan} of 0.714 m, while the energy was 230 keV level for R_{tan} of 0.341 m, indicating strong synergetic acceleration or heating in the outboard side in the 28 GHz and 8.2 GHz injections. Required pressure for the plasma equilibrium was 400 Pa level, high-energy electron component must be remarkably dominant for the bulk electron pressure of 10 Pa level.

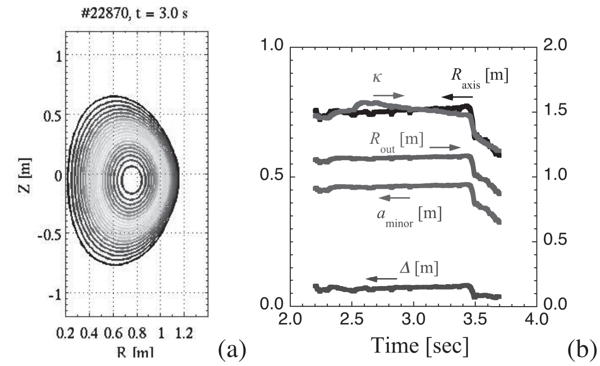

Fig.1. (a): Magnetic flux surfaces analyzed for the 54 kA plasma by EFIT. (b): Time evolution of the plasma shaping parameters.

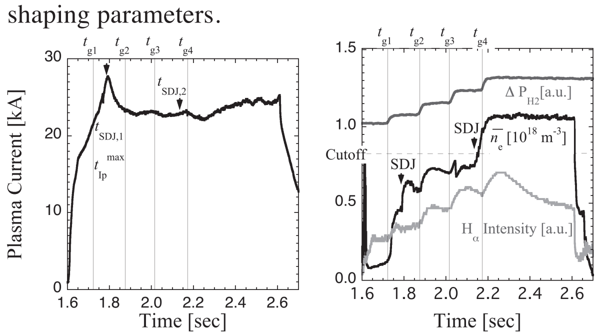

Fig.2. Time evolution of (a): plasma current and (b): hydrogen reservoir tank pressure, line-averaged density and Hα intensity in the 28 GHz and 8.2 GHz injections.

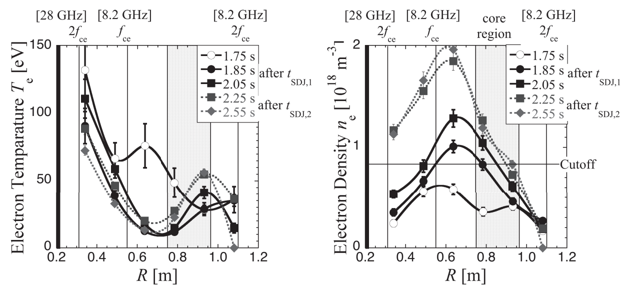

Fig. 3. Electron (a): temperature and (b): density profiles measured by Thomson scattering diagnostics in the 28 GHz and 8.2 GHz injections.

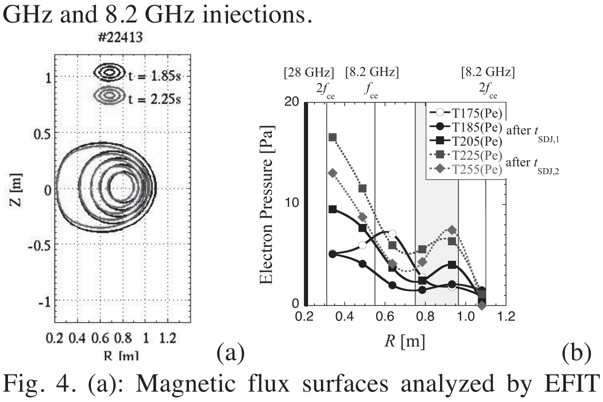

Fig. 4. (a): Magnetic flux surfaces analyzed by EFIT and (b) Electron bulk electron pressure profile in the 28 GHz and 8.2 GHz injections.