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

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Millimeter-wave Electron Cyclotron Heating and Current Drive (ECHCD) experiments have been conducted with the 28 GHz system. Circular corrugated waveguides have been prepared and used for a simple lancer. The launching wave was sufficiently expanded from the waveguide launcher exit with no focusing mirrors. The launching field was linearly polarized as an O-mode polarization at the 2nd harmonic ECHCD scenario in this case. No local ECHCD effects were expected with this system.

The $\lambda/4$ and $\lambda/8$ corrugated reflectors were designed and fabricated to excite arbitrary polarization states. The X-mode 2nd harmonic ECHCD scenario can be conducted in the oblique injection using the polarizer system. A new launcher system with a large focusing mirror has been developed to conduct the local ECHCD experiments on the QUEST. The focusing mirror surface was designed with the developed Kirchhoff integral code, taking phase matching into account between incident and outgoing waves at the mirror reflection. Figures 1 show a schematic of the 28 GHz launcher system and an evaluated beam pattern at the resonance using a 3D electromagnetic simulator. A strongly focused beam with a diameter of ~ 0.01 m was evaluated along the design. The launcher system performances were confirmed at low power test facilities. Figure 2 shows launching angle tests in toroidally oblique injection-control on the parallel refractive indexes of $N_{//}$ from zero (*i.e.* perpendicular injection) to unity (*i.e.* tangential injection). The steering focused beams were well controlled in the oblique injections. Figures 3 show the beam patterns of horizontal and vertical wave-fields of E_x and E_y in the perpendicular injections. The local ECHCD experiments with the polarizer and launcher systems have been begun after their installation of the systems.

For 2nd harmonic ECHCD experiments, the elliptical polarization state was required to excite the desired X-mode wave. In order to confirm the local ECHCD effect, the incident polarization states were controlled to change the ellipticity. The operating window to non-inductive plasma current drive was found on the incident polarization states. Figure 4 shows the time evolution of the plasma current and controlled poloidal field coil current. The 30 kA plasma was started up and ramped up by the 140 kW optimized oblique injection, following the poloidal magnetic field ramp-up. The plasma current still increased up to the end of 28 GHz injection pulse. The long pulse experiments for a few seconds are conducted by the high power injection of 270 kW.

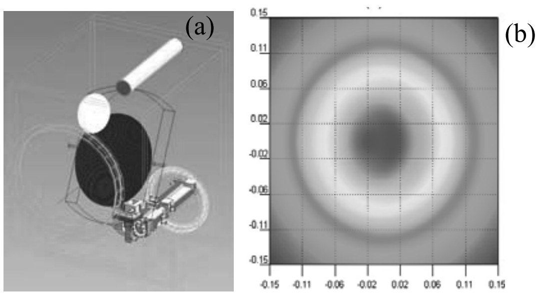

Fig.1 (a): A schematic of the 28 GHz launcher system. The radiated wave from corrugated waveguides was led to the 2nd large focusing mirror by the 1st convex mirror. The 8.56 GHz components in the hybrid launcher system are also shown in the figure. (b): A evaluated beam pattern at the resonance using a 3D electromagnetic simulator. A strongly focused beam with a diameter of ~ 0.01 m was evaluated along the design.

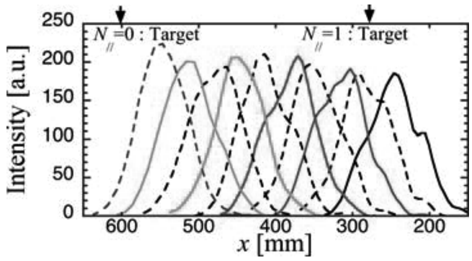

Fig.2: Steering performance tests in toroidally oblique injection-control on the parallel refractive indexes of $N_{//}$ from zero (i.e. perpendicular injection) to unity (i.e. tangential injection).

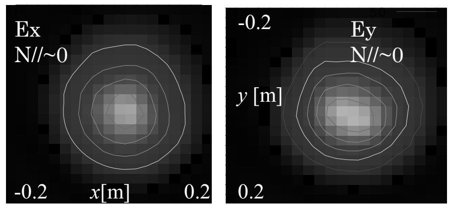

Fig.3: Beam patterns of horizontal and vertical wave-fields of E_x and E_y in the perpendicular injections.

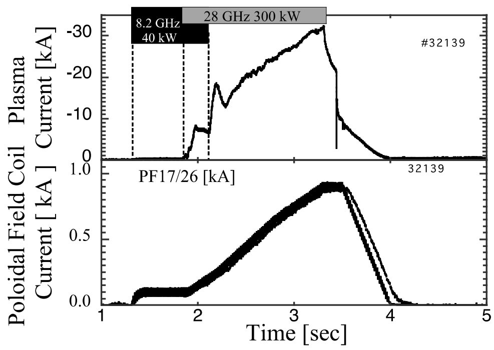

Fig.4: Time evolution of the plasma current and poloidal field coil current. The 30 kA plasma was started up and ramped up by the 140 kW optimized oblique injection, following the poloidal magnetic field ramp-up.