§14. Electron Bernstein Wave Heating through Slow X-B Mode Conversion in CHS

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Compared to the O-X-B process, the slow X-B process can more simply and easily realize mode conversion to Bernstein (B) waves, since the so-called “X-B access window”, is much wider than that for the O-X-B process. When injected through the X-B access window, the slow X-mode EC-waves propagate into the plasmas and are mode converted into the B-waves at the upper hybrid resonance (UHR) layer. The B-waves are absorbed at the Doppler-shifted electron cyclotron resonance, resulting in plasma heating. When injected away from the X-B access window, the X-mode EC-waves suffer right-hand cutoff and cannot heat the plasmas effectively.

The CHS provides a good opportunity to investigate the slow X-B heating scenario experimentally, since due to its two helical coils it has two X-B access windows in a poloidal cross section. In the vertically elongated poloidal cross section, one window is at the inner side of the torus in a position similar to tokamaks, while the other is at the outer side where a wider space is available for installing an elaborate structure such as the movable mirror for beam direction scan, as seen in Fig. 1.

A new plane mirror was installed inside the vacuum vessel between plasma and an outer helical coil. By directing the beam from the existing antenna system to the new mirror, an injection of 54.5 GHz EC-waves from the high-field side became possible. The beam is reflected upward and steered in the toroidal direction by this new mirror. The experimental configuration is schematically drawn in Fig. 1.

Figure 2 shows a typical time evolution of a discharge of the slow X-B heating. An EC-wave power of 275 kW was obliquely injected in three pulses during the discharge at incidence angles of 20 degrees counterclockwise in the toroidal direction and about 50 degrees upward. The wave polarization was set at nearly the X-mode. The first pulse was for plasma generation, and the second and the third ones were applied to the plasmas sustained with 845 kW neutral beam injection (NBI). The plasma stored energy significantly increased with the second and the third injections of ECH power. The central electron temperature increased from about 1.0 to 1.5 keV by the second injection and from about 0.6 to 1.2 keV by the third injection, while the line-average electron density linearly increased during the plasma duration. The increases in the plasma stored energy were then caused by increases in the electron temperature. The electron temperature profiles measured using Thomson scattering measurement during and just before the third ECH power injection are plotted in Fig. 3. It can be clearly seen that the electron heating occurred at the plasma core region, not at the peripheral region where the outer fundamental resonance layer exists.

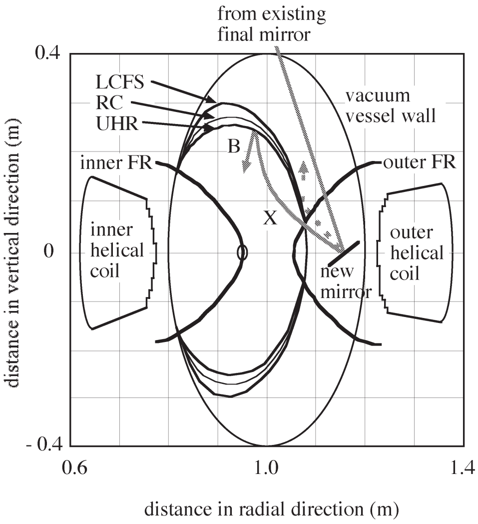

Fig. 1 Configuration for slow X-B heating.

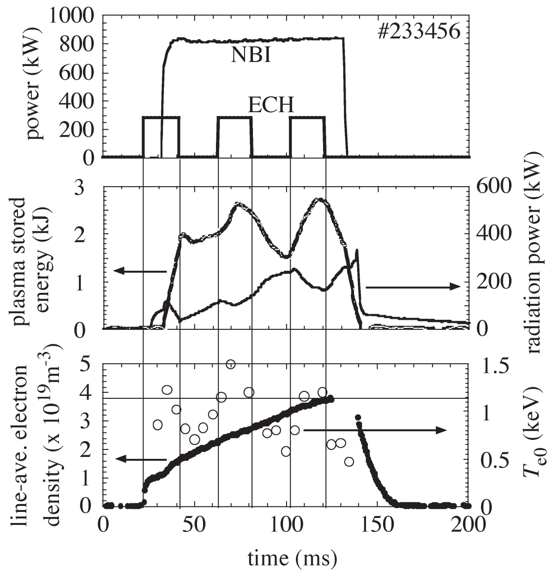

Fig. 2 Waveforms in a discharge with slow X-B heating.

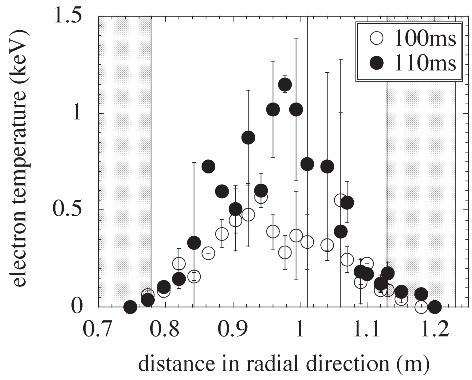

Fig. 3 Electron temperature profiles during and just before slow X-B heating.