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New Results from Heavy Ion Beam Diagnostic on CHS

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Abstract

Static and dynamic behaviors of core plasma potentials in toroidal helical plasmas have been studied by the use of a 200 keV heavy ion beam probe (HIBP) in the Compact Helical System (CHS). Fast time response and local measurements of this diagnostic method have brought about various new insights both on transport and MHD phenomena in toroidal helical plasmas. Outline of this diagnostic instrument and the experimental results are overviewed.

Keywords:

heavy ion beam probe, space potential, radial electric field, plasma confinement, toroidal helical plasma

1. Introduction

A Heavy ion beam probe (HIBP) is a unique diagnostic instrument which can measure local plasma space potential with fast time response in magnetically confined plasmas. However, application of HIBP to helical devices is not so simple as in tokamaks because of full three dimensional trajectories of the probing beam. First application to the helical device has been reported from the ATF torsatron [1], but only for limited discharges mainly with ECH. We have developed a 200 keV HIBP with a new beam trajectory control method (Active Trajectory Control) [2] for the Compact Helical System (CHS). Uniqueness of this HIBP is that both primary and secondary beam trajectories are controlled by the use of two sets of octapole beam deflectors. This method makes full radial scanning possible (from plasma top to bottom edges) and improved accuracy has been achieved in potential measurements with a conventional parallel plate energy analyzer. In this paper, outline of our HIBP and new results introduced by this diagnostic instrument are overviewed. Details of each topics will be discussed in separate papers.

2. A 200 keV HIBP on CHS

CHS is a low-aspect-ratio $l/m=2/8$ Heliotron/Torsatron device with a major radius of 1 m and an average minor radius of 0.2 m. Plasmas are produced and sustained with 53 GHz ECH (two gyrotrons with 700 kW maximum) and neutral beam (two beam lines with 1.7 MW maximum). Figure 1(a) shows a schematic of the 200 keV HIBP on CHS. In actual set up, beam lines of the injector side and the analyzer side are separated toroidally by about 20 degrees because of three dimensional beam trajectories. Observation points are shown in Fig. 1(b) for the typical magnetic configuration of $R_{ax}=92.1$ cm. The observation points shown here are the projections along the field lines, because the real points are distributed both radially and toroidally.

3. Experimental Results

3.1 Static space potential profile [3]

For static radial potential profile measurements, deflector voltages are pre-programmed and scanned

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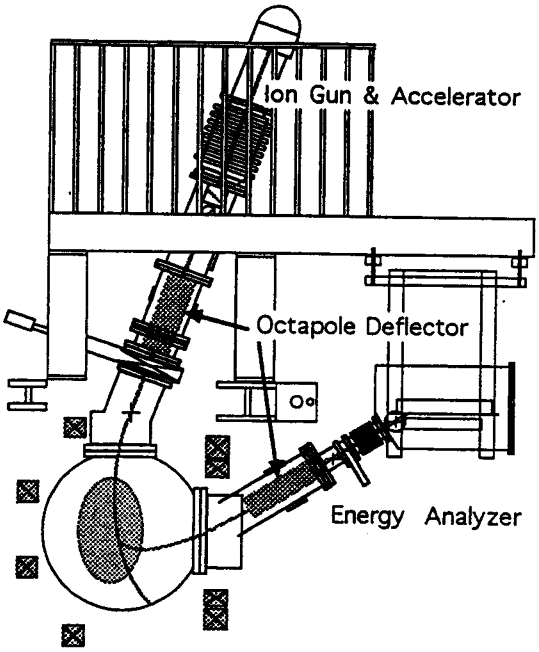

Fig. 1(a) Schematic view of the 200 keV HIBP on CHS.

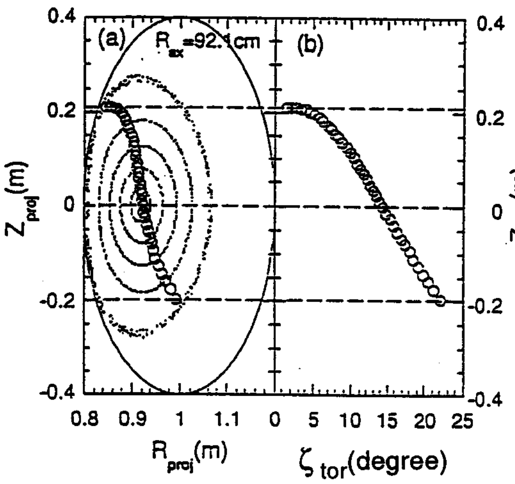

Fig. 1(b) Observation points for the magnetic configuration of R_{ax}=92.1 cm. Observation points distribute both radially and toroidally.

repetitively. High voltage amplifiers for the deflector plates have a slew rate of 180 V/μsec. In normal operation, it takes 4 msec for full radial scanning. Radial electric field profiles are obtained from the observed space potential profiles.

Figure 2 (a) shows radial space potential profiles for typical ECH and NBI plasmas. Space potential is positive everywhere for the low density (n_e=3×10^{12}

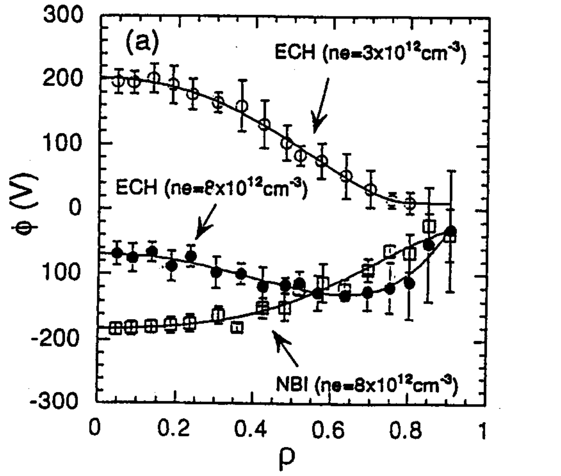

Fig. 2(a) Typical space potential profiles for ECH and NBI plasmas.

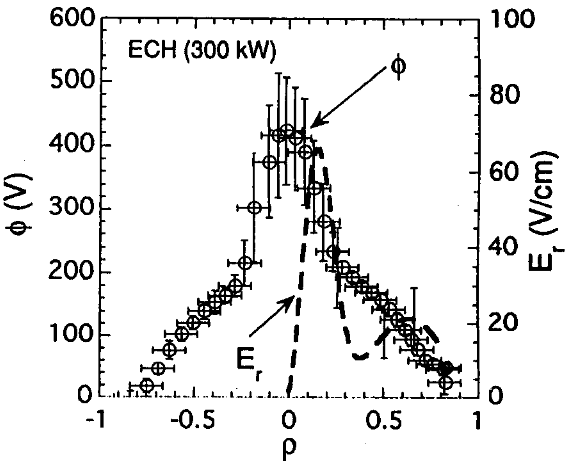

Fig. 2(b) Space potential profile during high power density ECH.

cm^{-3}) high electron temperature ECH (100 kW) plasma and radial electric field is directing outward. When the electron density is increased (n_e=8×10^{12} cm^{-3}) with decreasing electron temperature, the potential drops to negative value but not uniformly in radial positions. The electric filed changes its direction near the edge. In the NBI plasma at the same electron density, space potential shows a negative well and the radial electric field directs inward all over the plasma radius. Those space potential profiles are generally stable in steady states. When the ECH power is increased (300 kW) the electron temperature becomes as high as 1.5–2 keV at low density (n_e=3×10^{12} cm^{-3}) . The space potential in the central region becomes higher and radial electric field as high as 60 V/cm is formed in the core as shown in Fig. 2 (b), although no clear improved confinement is observed. This centrally peaked potential is not always stable.

3.2 Fast transition of radial electric field profile [4]

Dynamic behaviors of space potential profile has been studied during the combined heating of ECH and NBI. A fast transition of radial electric field is observed in the transient phase just after the neutral beam is superposed on ECH target plasma. Figure 3 shows time variation of the space potential at several radial positions. Observation points are fixed with constant deflector voltages to follow such fast change of local space potential. The time resolution is up to 300 kHz, which is determined by the preamplifiers for the detectors. An abrupt change of the space potential at the center is seen at around t=55 msec, while the potential in the outer region shows only gradual change. It indicates that the structure of radial electric field changes in a very short time, of the order of 100 μsec, which is much faster than the energy confinement time of a few msec. In this transient phase, the electron temperature is gradually decreasing mainly due to the increase in electron density, while the ion temperature increases though it is still lower than the electron temperature. This transition is considered to be due to nonlinear dependence of electron and ion radial fluxes on the radial electric field in toroidal helical plasmas.

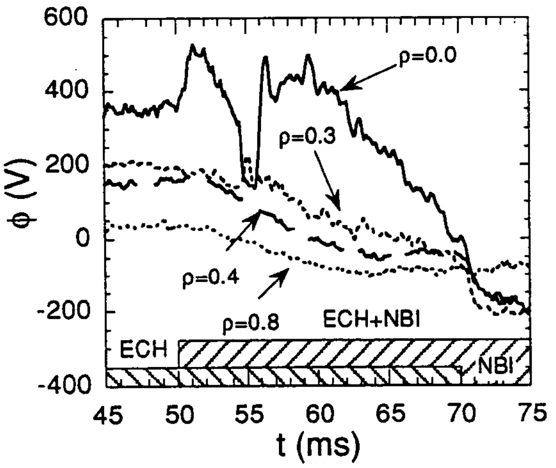

Fig. 3 Fast transition of space potential structure during a combined heating of ECH and NBI.

3.3 Space potential oscillation during MHD activities [5]

Space potential fluctuation has been observed during MHD activities. In low density neutral beam heated plasmas, an $m/n=2/1$ burst mode has been detected with a magnetic probe array. The burst mode grows at the frequency around 40 kHz and abruptly switches to a low frequency (5 kHz) decaying mode. The burst repeats every milliseconds but does not lead to a disruptive phenomena. The HIBP can probe the core region directly. Figure 4 shows a radial amplitude profile of the space potential fluctuation, where a path integral effect is examined and found to be neglected [6]. The potential oscillation is observed only in the growing phase of the burst and the amplitude has a peak of 40 V near the $q=2$ surface. Since the background radial potential profile shows a negative well with the central potential of −200 V, the observed potential oscillation is considered to be mainly due to perturbation of the magnetic flux surface. It is considered that flattening of plasma pressure profile occurs around $q=2$ surface when the high frequency growing mode switches to the low frequency mode. It reduces a driving force for the pressure driven instability and terminates the instability. Then the initial condition recovers and the burst mode repeats. Further study is necessary to confirm such qualitative explanation.

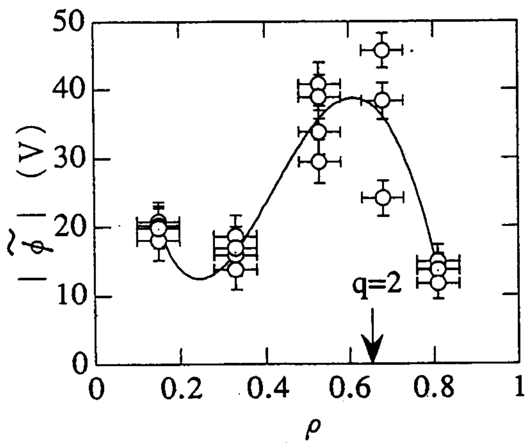

Fig. 4 Radial profiles of space potential fluctuation during the m/n=2/1 MHD burst mode.

4. Conclusion

A heavy ion beam probe has been applied to a low-aspect-ratio Heliotron/Torsatron device CHS. Experimental results from the HIBP have introduced new insights on those behaviors related with radial electric field and space potential fluctuations in toroidal helical plasmas.

References

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