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SPACE POTENTIAL FLUCTUATIONS DURING MHD ACTIVITIES IN THE COMPACT HELICAL SYSTEM (CHS)

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Abstract

Local space potential fluctuations have been measured during MHD activities in a low-beta NBI heated plasma in the Compact Helical System (CHS) by the use of a heavy ion beam probe (HIBP). Two types of MHD modes with accompanying potential oscillations are observed. One appears in periodic bursts with relatively low frequency (< 40 kHz) and large amplitude (20 - 40 volts), and is localized around the $q = 2$ surface (average minor radius $\rho \sim 0.7$). The other appears in continuous and coherent oscillation with higher frequency (105 - 125 kHz) and smaller amplitude (~ 5 volts). This oscillation also has spatial structure. Possible interpretation for the space potential oscillations is presented.

Keywords: Space Potential, Fluctuation, MHD Activity, Heavy Ion Beam Probe, CHS, Interchange Instability

1. INTRODUCTION

Studies on magnetohydrodynamic (MHD) instabilities have been one of the major issues in magnetic confinement fusion researches. Various diagnostic techniques have been applied such as external magnetic probes (Mirnov coils), soft X-ray detector arrays, ECE imaging methods and so on. Those diagnostics have measured mode structures and local density or temperature fluctuations. A heavy ion beam probe can introduce a new parameter, the space potential, for these studies with fast time response in microseconds, which is expected to improve the understanding of MHD phenomena. In this paper, we will present measurements of internal space potential fluctuations during MHD activities in toroidal helical plasmas.

2. EXPERIMENTS

Experiments have been carried out in a low beta neutral beam (NB) heated plasmas in CHS[1]. The major radius R = 0.92 m, the average minor radius a = 0.18 m and the toroidal magnetic field Bt = 0.9 T. Plasmas are produced by ion Bernstein wave (IBW, 7.5 MHz) and then sustained by NB with co-injection (port through power of 0.85 MW). Those are typical conditions where MHD bursts, the strongest MHD instabilities observed so far in CHS, are observed [2].

Figure 1 shows typical discharge parameters; the average electron density, the beam driven toroidal current, a beta value and a Mirnov coil signal. The central electron and ion temperatures, $T_e(0)$ = 350 eV and $T_i(0)$ = 200 eV. respectively. The bursting MHD activities are seen on the Mirnov coil signal. It is noted that the burst mode changes its characteristic during the discharge (t = 87 ms).

Plasma space potential is measured with a 200 keV HIBP [3]. Singly charged cesium ions (primary beam) are injected into the plasma and doubly charged ions (secondary beam) produced by electron impact ionization events are detected with an electrostatic energy analyzer. Data are reported here for two different HIBP beam energies, 71.3 keV (center chord) at which the scan line passes from top to bottom of the plasma through the magnetic axis and 55.9 keV (off-center chord).

3. RESULTS

Figure 2 shows the Mirnov coil and HIBP signals during one burst cycle starting at t = 112 ms. The HIBP signal, the normalized top-bottom difference current on the split plate detectors, is the measure of the space potential at $\rho = 0.4$. The burst has a growing oscillation with decreasing frequencies from 30 to 10 kHz, followed by a low frequency damping oscillation (~ 5 kHz). From the mode analysis using Mirnov coil arrays, the mode is propagating in the ion diamagnetic direction with toroidal and poloidal mode numbers m/n = 2/1 during the growing phase (the 2/1 mode) and in the electron diamagnetic direction fixed to ExB rotation in the damping phase (the ExB mode). The potential oscillation decreases in the latter phase while the magnetic perturbation is larger. Instead the DC potential changes slowly. There is no low frequency damping oscillations in the early phase of the discharge.

Figure 3 shows frequency spectra of the Mirnov coil and HIBP signals during a 16 ms time period that includes the burst in Fig. 2. The bursting mode produces the large power between 0 and 30 kHz in both signals. In addition, the HIBP signal has a clear peak at 115 kHz that is comparable in magnitude to the low frequency peak (the 115 kHz mode). This mode appears rather coherent and continuous, and is observable only in the latter phase of the discharge . It is noted that the HIBP signal is filtered with a break frequency of 100 kHz and there is signal attenuation of a factor 2 at 115 kHz. A small bump is also seen in the Mirnov coil signal around 115 kHz. The frequency response of the Mirnov coil decreases above 50 kHz due to its stainless steel casing and the attenuation at 115 kHz is larger than for the HIBP signal.

In interpreting the HIBP signals (the normalized top-bottom difference) as space potentials, the effect of horizontal injection angle into the energy analyzer [4] and the path integral effect due to the $\partial \mathbf{A}/\partial t$ term of the electric field (**A:** vector potential) in the presence of magnetic fluctuations [5] have been examined, which conclude that those effects are small. Then space potential fluctuations for the burst mode are plotted as a function of a minor radius as shown in Fig. 4. The fluctuation is localized around the $q = 2$ magnetic surface in the 2/1 mode phase with an amplitude of 20 to 40 volts. The change of equilibrium potential profile during one burst cycle is shown in Fig. 5. The negative potential well becomes shallower by about 40 volts in the ExB mode phase. It is also found that the phase relation between the Mirnov coil and the potential signals changes both temporally and spatially.

The timing of the 115 kHz mode is examined by dividing the raw data into 256 μs blocks and Fourier transforming the blocks with averaging over many bursts from several shots (Fig. 6). The time $t = 0$ in the figure is set when the 2/1 mode switches to the ExB mode. The 115 kHz mode damps as the 2/1 mode grows, and then restarts again after a few hundred microseconds. The potential fluctuation is about 5 volts near the half plasma radius and is smaller at the center and the edge. However, the spatial structure changes depending on discharge conditions.

4. DISCUSSION

The potential oscillation during the 2/1 mode can be qualitatively understood if it is an interchange mode. The temporal and spatial phase variation between the Mirnov coil and potential signal is not fully understood yet, but it is probably due to the nonlinear evolution of the instability. The potential oscillation at its maximum during the interchange mode is considered to be dominated by magnetic surface deformation.The maximum displacement can be estimated from the potential profile to be 2-3 cm in average radius. On the other hand, the ExB mode is fixed to the plasma ExB rotation with smaller potential oscillation. In contrast, fluctuations on the HIBP sum signal (total secondary beam current) that are related to density fluctuations remain, although the signal is considered to be contaminated by the path integral effect and is not a pure local value[6]. The density fluctuations are also seen on the HCN interferometer signals with the strongest signal on the chord passing through the q = 2 surface for the m = 2 mode structure. These observation may be an indication of an island formation as was discussed related with HIBP data in TEXT [7].

Different from the burst modes, the 115 kHz mode continues with almost constant amplitude except for a short time interval during the burst mode. A possible explanation for this break is that the 2/1 burst mode alters the plasma equilibrium so that the 115 kHz mode becomes stabilized. The 115 kHz mode is not a precursor to the 2/1 mode, since its amplitude seems fairly constant throughout the cycle. Similar high frequency MHD modes are observed with new magnetic probes in different operational conditions with NB heating [8], but the relation is not yet clear.

5. CONCLUSION

Space potential fluctuations have been measured during bursting MHD activities with a heavy ion beam probe on CHS. A potential oscillation (10 - 30 kHz) is observed in the growing phase of the MHD burst, which is considered to be an m/n = 2/1 interchange instability. When its amplitude reaches a certain level, the mode switches to a low frequency mode fixed to the ExB poloidal rotation (~ 5 kHz). The potential oscillation decreases significantly in this phase. In addition, a rather coherent and continuous high frequency (~ 115 kHz) mode is observed between the MHD bursts. The mode also has a spatial structure depending on discharge conditions. Further study is necessary for understanding the total picture of these MHD modes and their effects on confinement.

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FIGURE CAPTIONS

Figure 1 Typical discharge parameters in which a bursting MHD mode is observed. The mode changes its characteristics at t = 87 ms.

Figure 2 Mirnov coil and HIBP (top-bottom difference current which is a measure of the space potential) signals during a burst cycle.

Figure 3 Autopower spectra of Mirnov coil and HIBP(potential) signals .

Figure 4 Radial structure of the potential oscillation (growing phase of the MHD bursts).

Figure 5 Space potential profiles in the stable state and at the timing of the maximum amplitude of the magnetic fluctuations.

Figure 6 Temporal evolution of the autopower spectra during a burst cycle. The 115 kHz mode terminates as the 2/1 mode grows and restarts again during the low frequency ExB mode phase.

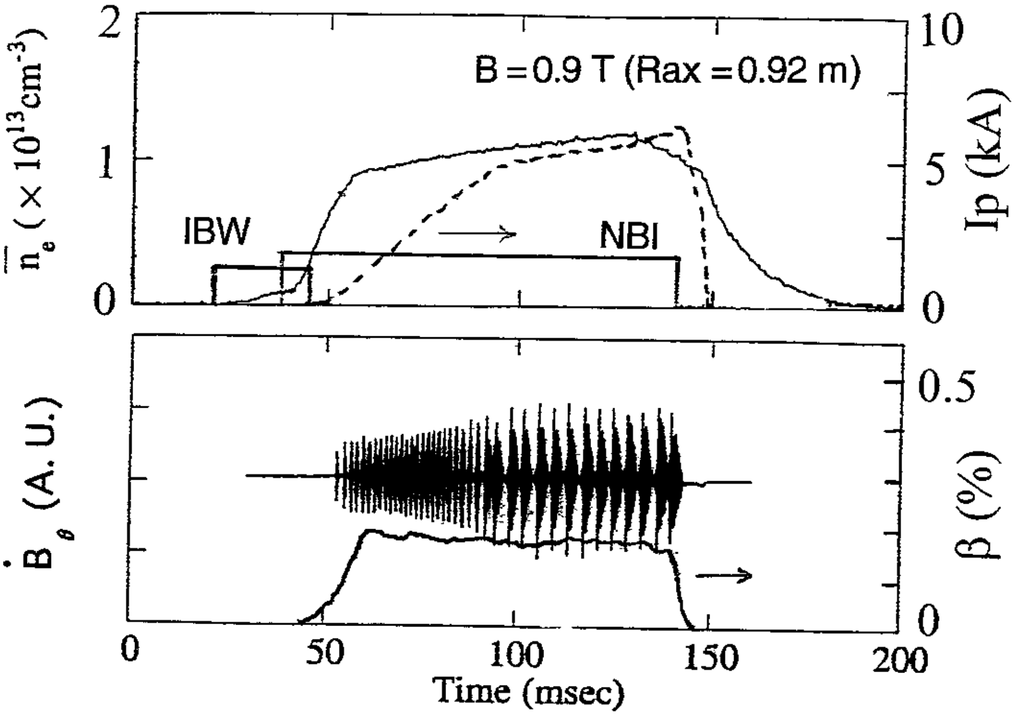


Figure 1

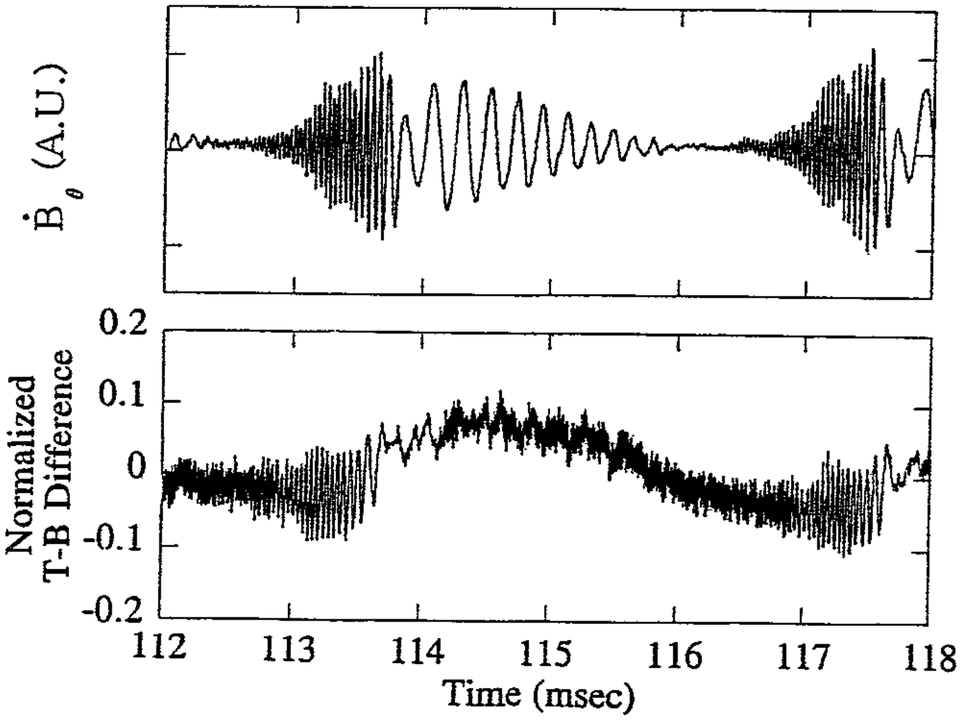
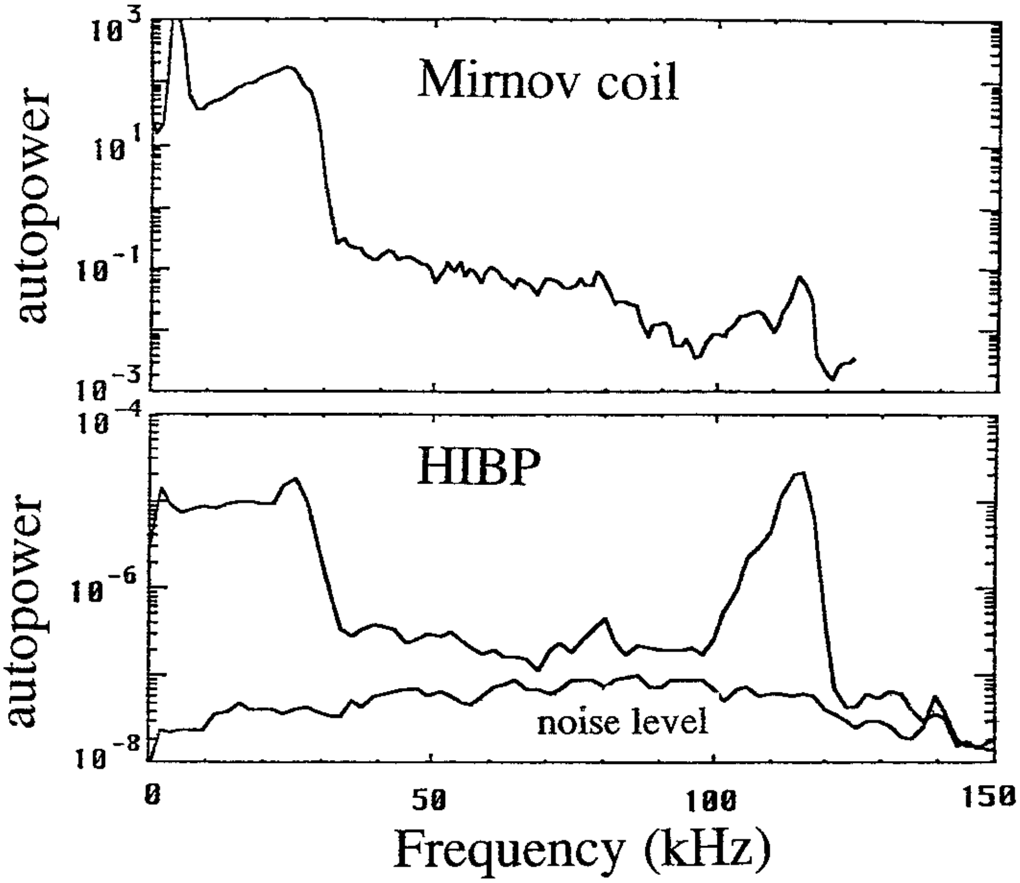


Figure 2



10^3
10^1
10^-1
10^-3
autopower
Mirnov coil
10^-4
10^-6
10^-8
autopower
HIBP
noise level
0
50
100
150
Frequency (kHz)

Figure 3

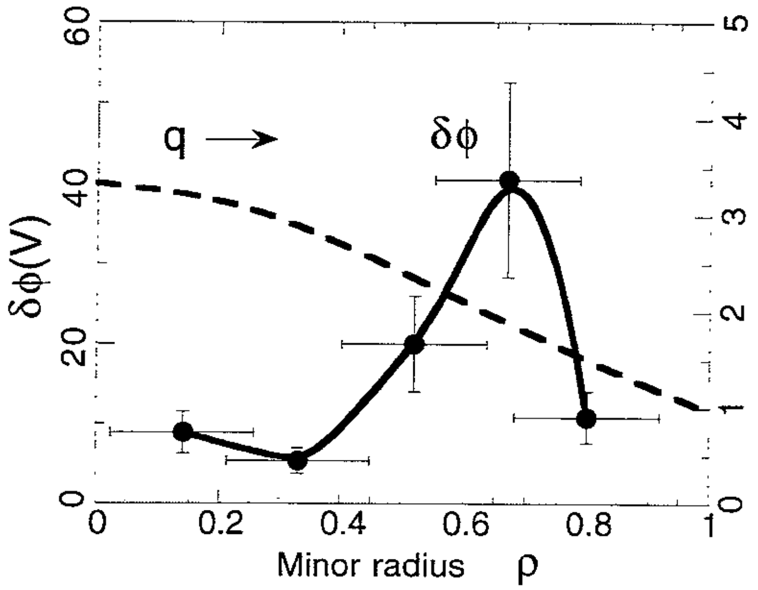


Figure 4

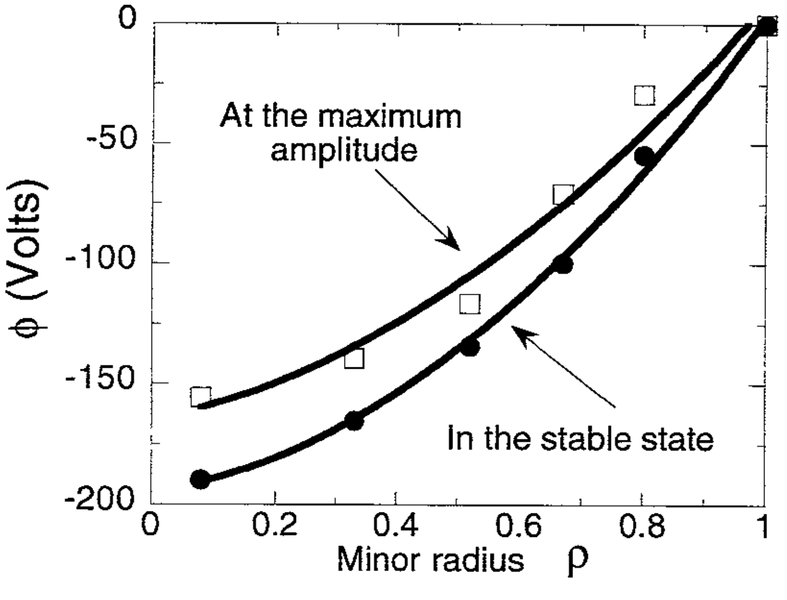


Figure 5

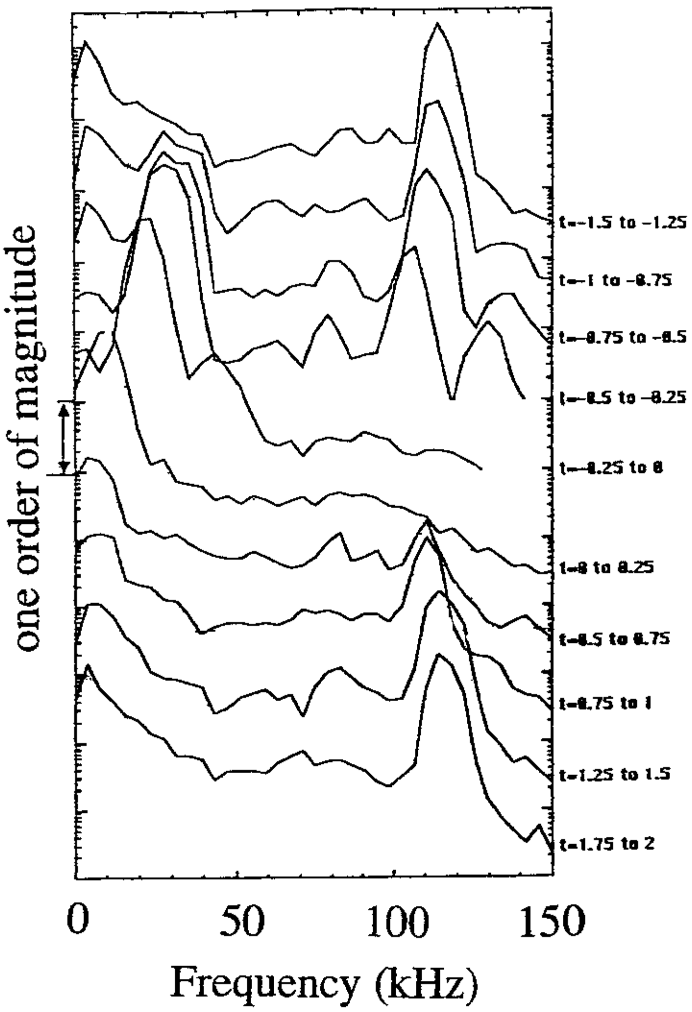

one order of magnitude
t=-1.5 to -1.25
t=-1 to -0.75
t=-0.75 to -0.5
t=-0.5 to -0.25
t=-0.25 to 0
t=0 to 0.25
t=0.5 to 0.75
t=0.75 to 1
t=1.25 to 1.5
t=1.75 to 2
0
50
100
150
Frequency (kHz)

Figure 6

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