§2. Symmetric Electric Field Generation Caused by Loss of High Energy Particles

Ohshima, S., Fujisawa, A., Shimizu, A.,
Nakano, H., CHS Group

One of the most important issues in burning plasma is physics of the alpha particle, which can interact with the plasma and cause the violent instabilities. Such instabilities driven by energetic particles, for example, fishbone, Alfven eigenmodes, energetic particle modes, etc., have been found and studied in many various devices. Here, we have a question whether such instabilities can affect the structure of the electric field in plasma interior or not.

In CHS, a burstic phenomenon like fishbone, which is excited by fast particles, is observed during neutral beam injection heating. This report demonstrates the internal potential measurement of the instability driven by energetic particles, using heavy ion beam probe (HIBP). A typical waveform of the burst in magnetic probe signal is shown in figure 1(a) and (b). The phenomenon has periodic characteristics and accompanies frequency chirping in a cycle of the burst. Obviously, potential at ρ~0.4, measured by HIBP, has good correlation with the magnetic probe signal in fig. 1(c). This instability has structure of m/n=2/1, detected from the magnetic probe array, where m and n imply poloidal and toroidal mode number, respectively. However, the fluctuation of δϕ around the magnetic axis is found to have a symmetric structure, that is, m/n=0/0 from the signals of twin HIBPs separated by 90° in toroidal direction. The phase differences between the signals become zero in chirping phase, as shown in the fitted curve of fig1(c).

Temporal and spatial structure of the instability in a cycle of the bursts is assessed via shot-by-shot measurement of the HIBP. Figure 2 shows the profiles of the potential fluctuation amplitudes and the phase differences to a fixed magnetic probe signal. The amplitude and the phase at a moment are evaluated using wavelet analysis. In the early phase of the burst, the profile has two peaks clearly around ρ~0.6 and plasma core. The former location is corresponding to q=2 rational surface. The fluctuation of the latter peak around the plasma center has structure of m/n=0/0, which is mentioned above. Fluctuation amplitudes of the m=0 and m=2 parts are obtained by evaluating the value of phase differences in fig.2(b), and shown in dotted curves of fig. 2(a). As a burst develops, the symmetric fluctuating structure becomes dominant, and finally forms the zonal structure having Er shear.

One of the possible causes for the symmetric structure is a radial current caused by direct loss of fast particles. The m=2 mode localized at q~2 surface can vary the fast particles, and then, generate the electric field. From neoclassical theory, such current to generate the observed electric field in this experiment is estimated to be sufficient small. Therefore, this is a finding of a new kind of zonal flow, generated by energetic particle driven instability.

In future burning plasma, it is possible that the oscillating flow generated by energetic particle loss would affect the property of plasma confinement.

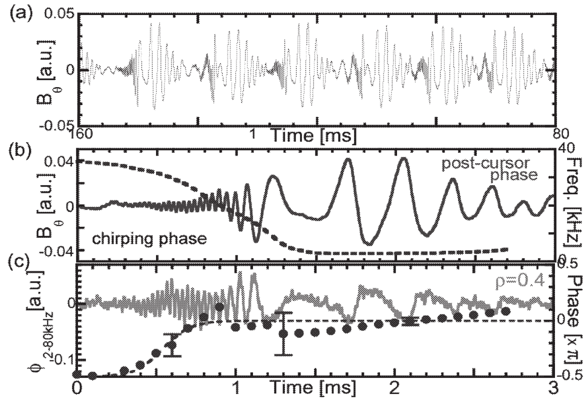

Fig. 1 (a) A series of quasi-periodic bursts measured with a magnetic pick-up coil. (b) Magnetic probe signal and the frequency of the fluctuation(dashed line) in a burst. (c) A potential fluctuation signal of an HIBP at ρ=0.4. The points indicate the phase difference between twin HIBP signals in an identical discharge on another day. Obviously, the mode is changing from n=1 to n=0 property during the chirping phase, as shown from the fitted curve (dotted line).

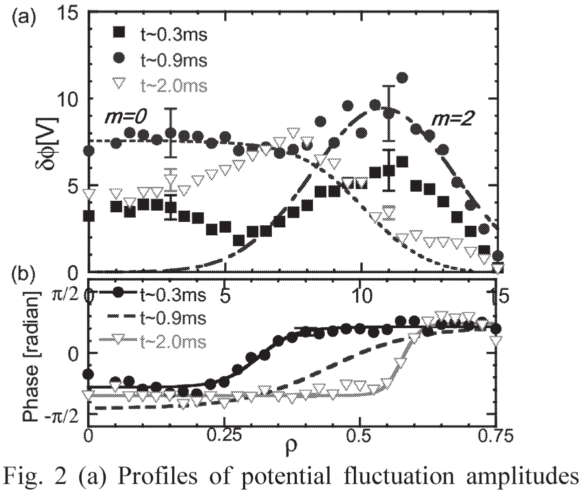

Fig. 2 (a) Profiles of potential fluctuation amplitudes measured with HIBP. Dotted curves indicate the m=0 and m=2 fluctuation component, respectively. (b) Phase differences between potential and magnetic field fluctuation as a function of radius.