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Effect of fast ion driven modes on radial electric field in the Large Helical Device

大型ヘリカル装置における高速イオン励起モードの電場に及ぼす影響

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Electrostatic potential fluctuations associated with fast-ion driven modes are observed by a heavy ion beam probe in LHD plasmas. Characteristics of a mode with the toroidal mode number(n) of 0 are presented. The initial frequency of the n=0 mode is in the range of the predicted GAM frequency, but it is higher than the predicted frequency. Judging from the temperature dependence of the frequency and mode structure (n=0), a candidate of the n=0 mode is energetic-particle driven geodesic acoustic mode(EGAM). When the n=0 mode is excited, other burst of energetic-particle driven mode also occurs simultaneously. In addition that, drop of the averaged electrostatic potential is observed. It may indicate outward flux of fast ions by the excited modes.

1. Introduction

In future nuclear fusion reactor, there is a concern that the energetic-particle driven Alfvén eigenmodes(AEs) will enhance the radial transport of energetic particles such as alpha particles in a D-T reaction and the loss of the energetic particles will deteriorate the performance of the fusion reactors. On the other hands, it is suggested that the radial transport of the energetic particles may form radial electric field(E_r), and may trigger improved confinement of bulk plasmas[1].

Recently, in addition to that, geodesic acoustic mode(GAM) driven by energetic particles has been observed [2-6]. The GAM is a branch of zonal flow and attracts much attention in the area of turbulent-transport study[7] because the zonal flow is considered to be a key phenomena regulating turbulence level.

Therefore, the behaviors of energetic particle modes including the influence on the radial electric field should be investigated in order to predict the performance of nuclear fusion reactors.

In recent LHD experiment, energetic-particle driven modes with the toroidal mode number(n) of zero and with the up-chirping frequency are observed by Mirnov coils and a heavy ion beam probe (HIBP). In this presentation, the electrostatic potential fluctuations associated with the up-chirping n=0 mode are reported. The electrostatic potential drop synchronizing with the excitation of the mode is also presented.

2. Apparatus and experimental condition

In order to measure the electrostatic potential(ϕ), its fluctuations($\tilde{\phi}$) and density fluctuations($\widetilde{n_e}$), HIBP using a gold ion beam is installed on LHD. The temporal and spatial resolution is 2 μs and a few centimeters, respectively. Since the beam energy(E_b) is 1.134 MeV in this experiment and the resolution of the electrostatic potential is $\Delta\phi/E_b$ = 1.6 x 10^{-5}, the potential fluctuation with the amplitude of 18 V or more can be measured. The potential profiles can be measured from the center to the half of the minor radius by scanning the probing beam.

The plasmas are produced and sustained by tangential neutral beam injections (NBIs) in which hydrogen beams with the energy of 170 keV are injected in co and/or counter directions. The line averaged electron density is about 0.1 x 10^{19} (m^{-3}), and the central electron temperature is about 2 keV and it increases to 10 keV by superposition of ECH.

3. Characteristics of fast-ion driven n=0 modes

The spectrogram of the potential fluctuation is shown in Fig.1. The frequency of n=0 mode shifts upward from 60 kHz to 80 kHz with a time constant of a few 10 ms. The time constant, the amount of the frequency shift, repetition frequency changes increase during the superposition of ECH. Since the totoidal mode number is 0 and the frequency tends to relate the electron temperature, a candidate of the n=0 chirping mode is EGAM[4]. However, the frequency of the mode is larger than the predicted GAM frequency (40 kHz and 64 kHz for hydrogen plasmas without and with ECH, respectively).

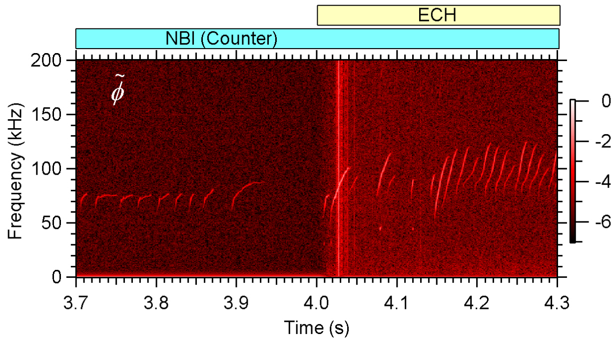

Fig.1 Spectrogram of the electrostatic potential measured by HIBP. The observed position is at the normalized minor radius of about 0.3.

Spatial profiles of the mode can be measured through scanning the probe beams of the HIBP. According to the results, the n=0 mode exists in the central region like the GAM with a constant frequency observed in reversed shear plasmas[6]. The frequency shift does not seem to correlate with the observed position. Thus, it is not attributed to the excitation position. The results may consistent with the hole-and-clump model[8] in which the nonlinear evolution of the hole-and-clump pair in the velocity space causes the frequency shift.

4. Effect of fast-ion driven modes on E_r

Figure 2 indicates a temporal evolution of the averaged electrostatic potential. The potential drops by a few hundred volts when n=0 mode excited. The magnitude of the drop correlates with the amplitude of the mode. Note that other bursts of fast-ion driven modes are also exited in the frequency range from 140 to 200 kHz as shown in Fig.2(c).

Since a drop in the electrostatic potential means that an outward radial current is induced, the drop in Fig.2(a) may indicate outward flux of fast ions by the n=0 mode and/or another fast-ion driven mode. At present, however, a role of each mode is not clarified because the both modes excited simultaneously. The mechanism of the potential drop remains an open question.

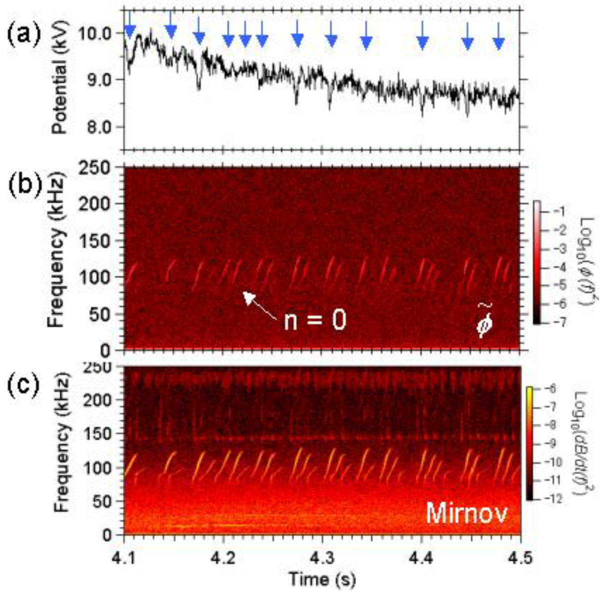

Fig.2 (a)Electrostatic potential at the normalized minor radius of about 0.4. (b) Spectrogram of the potential fluctuation. (c)Spectrogram of magnetic fluctuation measured by a Mirnov coil.

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