§2. Observation of Clump and Hole Formation in the Energetic-ion Spectra by GAM Burst Activities

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The Geodesic Acoustic Mode (GAM) and Zonal Flow (ZF) get more interest recently since they might regulate the level of turbulences. The excitation of GAMs by energetic particles are observed and reported in several magnetically confined plasma devices, such as JET[1], DIIID[2,3] and LHD[4,5].

Recently, changes of energy spectra of fast-ions associated with the up-chirping GAM bursting activities were observed on LHD as shown in Fig.1. Here, counter-NB was injected by NBI#3 at very low density LHD plasmas of $n_e = -4x10^{17}m^{-3}$ during the whole time range shown in the figure. The magnetic axis location of the configuration is R_{ax} .=3.75m and the magnetic field strength is 1.375T at the axis with ordinary magnetic field direction. GAM bursting activities are observed when ECH was applied to the plasma. As shown in the figure, the increase



Fig.1 Typical waveforms of the discharge where the change of ion energy spectra were observed with GAM bursting activities. Waveforms for (a)NB injection energy(solid lines with closed circles), ECH injection power(dashed lines with open circles), (b) Mirnov-coil signal, (c)line averaged electron density(solid lines with closed circles), H_{α} -signal(dashed lines with open circles), Neutral flux signals for (d) 164keV (open circles), 156keV(closed circles), (e) 133keV (open circles), and 112keV(closed circles) are shown.

of neutral flux was observed with the GAM bursts onsets, which are indicated vertical dashed lines in Fig.1, at lower energy channels, i.e., 133- and 112-keV, while the depression was observed at high energy channel(164keV), which is close to the beam injection energy. It must be noted the gray areas shown in the figure indicate the time ranges where the NB break-downs were occurred and large degrease of neutral flux was also observed.

Figure 2 shows the change of energy spectra during the single burst activity. The GAM burst onset is around 4.423s in the figure, thus the spectrum between 4.415s and 4.42s is free from the effect of instability. Fig.2(c) shows the deviation of energy spectra during the GAM activity from the spectra before the activity. As shown in the figure, a clear clump-hole pair was observed in the spectra. As shown in the spectra the hole location was changed ~148keV to ~164keV. At the same time the mode frequency was changed from 79.5kHz to 116kHz. This is consistent with the clump-hole formation theory shown by Berk, et.al.,[6]. Further comparison of the experimental observation to the theory is necessary to confirm the theory.

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Fig.2 (a) Typical wave-form of Mironov coil during GAM activitiy. The GAM onset is around 4.423s. (b) Change of energy spectra and (c) the deviation of the spectra from the original were shown.