§18. Radial Structures of Potential Fluctuations Induced by Energetic-Ion Driven Geodesic Acoustic Modes in Reversed-Shear Plasmas

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In tokamaks, axisymmetric modes having n=0 toroidal mode number destabilized by energetic ions were detected by magnetic probes and other fluctuation diagnostics [1-3]. These n=0 modes are excited in reversed magnetic shear (RS-) plasmas with counter neutral beam injection (NBI) or ICRF heating. The density fluctuations have up-down asymmetry of m=1. These modes are interpreted as energetic-ion (EI) driven geodesic acoustic modes (GAMs) called EGAM[4]. Because of n=0, these modes are destabilized by anisotropy of the velocity distribution function of energetic ions instead of the radial gradient of energetic ion density. These modes are paid much attention because they might affect bulk plasma beneficially such as micro-turbulence regulation and direct bulk ion heating through Landau damping by bulk ions. On LHD, energetic ion driven GAMs were also observed in two types of plasmas: (1) RS-plasmas after several slowing-down times from the turn on of counter NBI[5], and (2) very low density plasmas where the slowing down time is much longer than NBI pulse duration [6].

Measurement of the radial and temporal evolutions of the EI-driven GAM in the above-mentioned RS plasmas was attempted by a heavy ion beam probe (HIBP). The RS plasma is produced with help of generation of large net plasma current driven by counter NBI. This large plasma current leads to large difficulty in tracking of the probe beams. This has been overcome by fine tuning of the trajectories of incident and ejected secondary beams. The potential and its fluctuation measurements have been succeeded in such RS-plasmas by the beam tuning. Figure 1 shows time evolution of plasma current (I_p), bulk ion temperature at the plasma center (T_{io}) and line averaged electron density (<n_e>) in a RS plasma where both reversed shear Alfvén eignmodes (RSAEs) and EI-driven GAM are excited, and couple each other. The spectrograms of magnetic probe (MP) signal and the coherence between the MP signal and the potential fluctuations at the plasma center measured by HIBP are also shown in this figure. As seen from the coherence, the potential fluctuations at r/a~0 are dominated by EI-driven GAM, of which frequency is close to GAM frequency of a bulk plasma. The potential fluctuations were measured at various radial locations for reproducible RS plasma discharges. Near the zero shear layer of the RS plasma (r/a ~ 0.33), the potential fluctuations are induced by both EI driven GAM and RSAE as shown in Fig.2. Around this radial location, the eigenfunction of the GAM overlaps with that of RSAE. This is qualitatively same as the results derived from ECE and magnetic probe signals [5]. Note that the EI-drive GAM for the time window from t=6.8s to t=7.3s differently behaves in Figs.1 and 2. This is caused by ECH applied with different power. As seen from the spectrogram of magnetic probe data in Fig.1, the local minimum of the rotational transform (or local maximum of q: q_{max}) in the RS-configuration of LHD passes 2 and 3. The potential fluctuations of EI-driven GAM gradually increase in time after q_{max} passes 2.

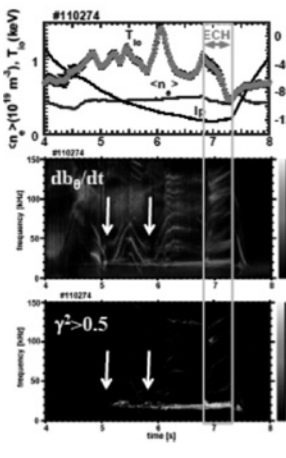

Fig.1 (from top to bottom) Time evolutions of I_p, T_{io} and <n_e> in a RS-plasma with large counter-flowing plasma current, and spectrograms of magnetic probe signal (db_θ/dt)and the coherence between the potential fluctuations at the plasma center (r/a~0)and db_θ/dt.

Interestingly, after q_{max} has passed 3, the central ion temperature T_{io} starts to increase linearly in time for about 200 ms which is longer than global energy confinement time, and suddenly decreases. This time evolution has no clear correlation with the GAM amplitude. The time-averaged plasma potential in the plasma core region decreases in time synchronizing with the T_{io} rise. The spontaneous increase in T_{io} seems to be similar to the triggering event of ITB formation observed in a RS-plasma in DIII-D [7].

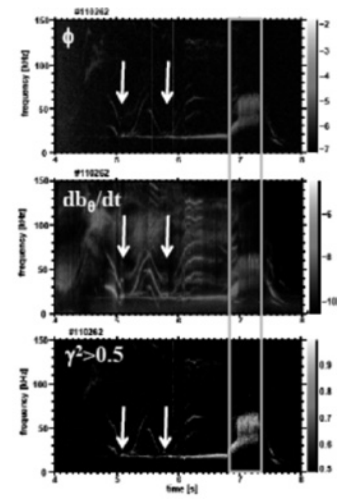

Fig.2 (from top to bottom) Spectrograms of potential signal obtained at r/a ~0.33, magnetic probe signal and the coherence of the two signals.

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