§23. Production of Reversed Magnetic Shear Configuration and Alfvén Eigenmodes in Heliotron J

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The reversed magnetic shear (RS) configuration in tokamak plasmas attracts much attention because it is thought to be a promising candidate scenario for ITER steady state operation. The curvature of the safety factor q ($=2\pi/\iota$) at the zero shear layer $q''(r_o)$ is positive in a tokamak RS plasma, where r_o indicates the radial position of the zero shear layer or $q = q_{min}$ (the local minimum of q). In the RS plasmas, reversed shear Alfvén eigenmodes (RSAEs) are excited by energetic ions having unidirectional upward frequency sweeping, when the q_{min} decreases in time [1]. Moreover, geodesic acoustic modes (GAMs) are sometimes destabilized by energetic ions [2,3]. On the other hand, the RS plasma with the opposite sign ($q''(r_o)$ <0) was generated by counter neural beam current drive (NBCD) in neon doped plasmas of LHD, where RSAEs with characteristic symmetric frequency sweeping, i.e., downward to upward sweeping via the minimum frequency were observed together with energetic ion driven GAM [4]. It should be noted that the time evolution of RSAEs in tokamak and LHD RS configurations gives us very accurate information of q_{min} in tokamaks or q_{max} in LHD. The GAM frequency will also provide information of plasma temperatures and ion mass density. Accordingly, comprehensive understanding of RSAEs and GAMs in tokamak and helical RS plasmas is very important toward a fusion reactor. Heliotron J is a kind of shearless helical systems, and the rotational transform ($\iota/2\pi$) could have several extrema along the minor radius when various non-inductive current drive methods are applied. That is, the configuration having $q''(r_{o1})$>0 and $q''(r_{o2})$<0 may be realized, where r_{o1} and r_{o2} are two zero shear layers away from the magnetic axis.

This bi-directional collaboration program aims at clarifying the characteristics of RSAEs and GAMs in Helioton J with NBCD and/or electron cyclotron current drive (ECCD). The following three operation scenarios were tested on Heliotron J, that is, (Scenario 1) co-NBCD plus electron cyclotron heating (ECH), (Scenario 2) co-NBCD plus counter-ECCD, and (Scenario 3) counter NBCD plus counter-ECCD. On-axis and off-axis (at r/a~0.15) ECCD schemes were tried.

In the Scenario 1, co-NBCD induced net plasma current up to ~0.8 kA. The rotational transform at the plasma center is inferred to increase slightly larger than ~0.52, and to stay ~0.52 near the plasma boundary. The electron density profile is not available. If the profile is broad or slightly hollow, the shear Alfven spectra would have a minimum away from the plasma center. A global Alfvén eigenmode (GAE) can be excited near the off-axis minimum of the spectra in Heliotron-J [5]. Figure 1 shows the spectrograms of beam emission spectroscopy (BES) signals at r/a= 0 to 1.0 every $\delta(r/a)$=0.1 radial separation. A coherent mode of ~80 kHz is clearly identified on the BES signal at r/a=0.6. This mode is strongly localized near the radial location (r/a~0.6). First, we discuss a possibility of GAE as a candidate of the observed mode. The m=2/n=1 GAE frequency is estimated to be ~80 kHz on the assumption of B_t=1.25T, R=1.2m, n_e=0.6x10^{19} m^{-3}, and the density ratio of proton and deuteron=1. Similarly, the frequency of m=4/n=2 is inferred to be ~150 kHz. Two dominant modes of n=1 and 2 are detected in magnetic probe signals. So far, we cannot conclude which of m=2/n=1 and m=4/n=2 modes is dominantly excited. It should be noted that GAE usually has global structure having a broad eigenfunction. Nevertheless, even GAE could localize near the extremum of the shear Alfven spectra as the mode frequency approaches to the extremum [6]. Energetic particle mode (EPM) may be another candidate. EPM can be destabilized in the case that energetic particle drive exceeds damping rate caused by continuum damping. Accordingly, EPM usually exhibits bursting character having rapid frequency chirping due to appreciable nonlinear effects. For lack of information of density and rotational transform profiles, we cannot identify the observed mode as GAE or EPM.

The Scenarios 2 and 3 were also tested, where ECCD was carried out as on-axis and off-axis drives. However, any energetic ion driven modes were not destabilized noticeably in Alfvénic frequency range. The ECCD in low density regime may considerably affect energetic ion pressure profile, and may suppress the destabilization.

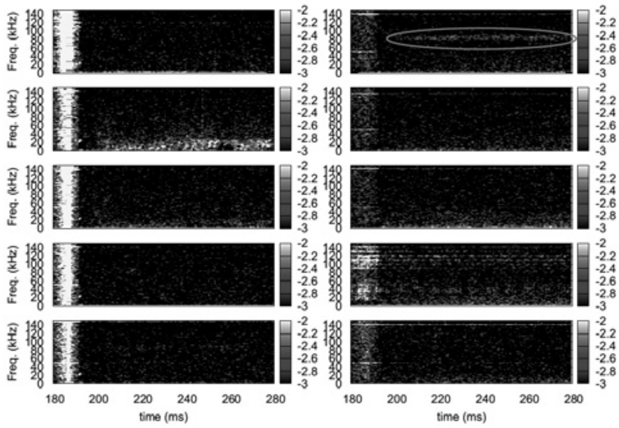

Fig.1 *Spectrograms of BES signals at each sightline from r/a=0, 0.1,…, 1.0 (from top to bottom in the left-hand side frames and top to bottom in the right-hand side ones). The coherent mode is excited around r/a=0.6, which is encircled with an elongated circle.*

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