§24. Production of Reversed Magnetic Shear Configuration and Alfven 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 Alfven eigenmodes (RSAEs) are excited by energetic ions having unidirectional frequency sweeping, that is, upward, 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 were observed for the first time together with energetic ion driven GAM [4]. These results show that characteristics of RSAE are sensitively dependent on $q''(r_o)$. It should ne 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 with various non-inductive current drive methods. That is, the configuration having $q''(r_{o1})>0$ and $q''(r_{o2})<0$ may be realized in Heliotron J, 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 ECCD. The following preparatory experiment has been done with following two operation scenarios: (scenario 1) in NBI heated plasma, the control of $\iota/2\pi$ profile is done by ECCD, and (scenario 2) $\iota/2\pi$ profile control is done by combination of co- and counter NBCD.

In the scenario 1, ECCD was applied to the magnetic configuration of the $\iota/2\pi$-0.52 at the toroidal field strength B_t=1.3T in order to produce the RS plasma and excite RSAEs. However, ECCD induced strong density pump-out in addition to the modification of the $\iota/2\pi$ profile. In this scenario, the Alfven eigenmode studies became very difficult, because both density and the rotational transform profiles would be modified simultaneously. Next, the scenario 2 using co or counter NBCD was tried. In the counter or co NBCD plasmas, no Alfven eigenmode was excited. Then, finite beta plasma was produced by raising plasma beta value using balanced NB heating. Figure 1 shows the spectrogram of magnetic probe signal in thus produced plasma, where the line averaged electron density <ne> is ~1.5×10^{19} m^{-3} and the induced net plasma current is ~1kA. Two types of coherent modes were excited. The frequency starts from ~75 kHz, and decreases down to ~45 kHz. It gradually increases to ~50 kHz with slow decrease in $\langle n_e \rangle$. The time evolution of the frequency has a similar evolution to the expected m/n=2/1 GAE frequency calculated on the assumed time evolutions of the density and $\iota/2\pi$ profiles. The other coherent mode having a constant frequency of ~25 kHz was excited for ~ 10 ms in the middle phase of the discharge. The poloidal mode number is m=4, but n number cannot be derived because of irregular phase differences among magnetic probes.

In this year experimental campaign, any RS plasmas where RSAE and GAM are excited by energetic ions were not produced with NBCD, ECCD or the combination. More experimental trials in other magnetic configurations are required over wide range of electron density in the next year experimental campaign.

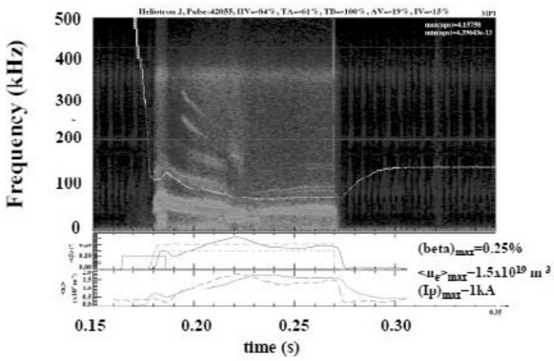

Fig.1 Spectrogram of magnetic probe signal in a plasma heated by balanced NBI in the configuration of $\iota/2\pi$=0.52. The dotted curve in the spectrogram indicates the predicted frequency of m=2/n=1 GAE using assumed time evolution of the electron density and the rotational transform profiles.

[1] H.L. Berk et al., Phys. Rev. Lett. **87**, 185002 (2001).
[2] R. Nazikian et al., Phys. Rev. Lett. **101**, 185001 (2008).
[3] H.L. Berk et al., Nucl. Fusion **46**, S888 (2006).
[4] K. Toi et al., Phys. Rev. Lett. **105**, 145003 (2010).