§11. Role of Plasma Fluctuation for EBW Current Ramp-up at the Electron Cyclotron Harmonics

Zushi, H. (Kyushu Univ.)

Abstract The two dimensional structure of density fluctuations is examined during the current jump phase indicating a change from the open magnetic fields to the closed ones. During the smooth current ramp-up phase the two dimensional contour of the LiI intensity shows vertically alignment, consistent with the magnetic surfaces. At the inflection point in Ip ramp-up the LiI intensity contour becomes flat in the observation regime and then suddenly a steep gradient and higher intensity regime are formed in the vertical direction. This higher intensity corresponds to a burst of LiI waveform. According to these changes in the contour, it is found that within ± 1 ms around the burst of LiI a low frequency coherent wave with a long wavelength rapidly grows. The relations with other signals (magnetic flux and microwave stray power) are discussed with respect to the topological change in the magnetic configuration and mode conversion of the incident electromagnetic waves. [1,2,3]

1. Motivation and Experiments

Since the inner space of the device is limited physically, one of the important issues for spherical tokamak is to ramp-up plasma current by non-inductive methods. Most popular one is a method with electron cyclotron waves ECW. In this method a small vertical field B_z with a positive curvature was superimposed to a toroidal field B_t which corresponded to the cyclotron resonance. The role of B_z on the equilibrium of the plasma in the open magnetic field has been studied and an optimum B_z has been derived by balancing the enhanced end loss along the magnetic filed lines intersecting the chamber and reduced E x B loss by compensating the vertical electric field E induced by the toroidal drift. Density and potential fluctuations have been also affected by this B_z, however, no systematic studied has been done from the view point of the current ramp-up. In the spherical tokamak device CPD (Compact Plasma wall interaction experimental Device), the non-inductive current drive experiments have been performed using electron cyclotron waves at 8.2 GHz and the characteristics of the density fluctuations during the ramp-up phase have been studied, at least a change in characteristics of the fluctuations near the "current jump" will be presented in this report. .

The device parameters of the CPD chamber is as follows; the diameter as well as height is ~ 1.2 m, repectively. The toroidal field B_t corresponds to the cyclotron resonance field at 8.2 GHz. In the present paper the major radius of the fundamental cyclotron resonance is varied from 0.16m to 0.2 m. In the chamber second harmonic resonance position located at the middle, but the third harmonic resonance position is very close to the side wall of the chamber. In order to ramp-up the plasma current vertical magnetic field B_z ~ 50 G at R = 0.2 m with the decay index of ~ 0.046 is added by three sets of poloidal field (PF) coils. Therefore pitch angle of the magnetic filed line is ~ 1-2 degree and the total length of the magnetic field line is an order of ~ 100 m. A set of 8.2 GHz klystrons (8 × 25 kW, CW) is used for ECH. A thermal Li sheet beam is injected from the bottom of the chamber and the 2D images (300×600 mm) of LiI (670.8 nm) intensity for 1 ms are taken at every 40 ms and spatial resolution is 1 mm^2. In addition, the fluctuation measurement is performed by a lithium beam fluctuation spectroscopy LBFS system consists of 50 spatial points, connected to photomultiplier tubes via a fiber bundle (10×10). Fluctuations of LiI intensity, $\tilde{I}_{Li}$, are proportional to the local density fluctuations, $\tilde{n}_e/n_e = \tilde{I}_{Li}/I_{Li}$ .The viewed area is 50 mm×25 mm within the 2D CCD image in an R-Z plane. The radial resolution of each fiber is ~ 5 mm ϕ. Sampling frequency of analog to digital convertor is 300 kHz. Cross correlation and cross power spectrum between each 50 signals are analyzed by fast Fourier transform technique.

2. Conclusion

The 2 D structure of density fluctuations has been measured with LBFS in initial annulus rf plasma which has been produced by ECR at small power. The equi-intensity contour is observed to be aligned along the vertical direction and coherent waves are found to be excited in the low frequency range (1-10 kHz). It should be noted that the vertical field, which is pre-required for ramp-up plasma current, stabilizes these coherent waves. The relative amplitude is reduced by a factor of 2 and the correlation length is reduced < 5 mm. With increasing RF power the plasma expands towards the low field side and driven current increases. The 2D contour of LiI shows a change from vertical alignment to the horizontal one within ± 1 ms around the burst of LiI. The fluctuations at ~ 1 kHz are found to grow rapidly and it correlation length becomes al least more than 50 mm at the current jump.

[1] H.Zushi et al., "Two dimensional density fluctuation measurements during the non-inductive current ramp-up phase in the compact plasma wall interaction experimental device CPD", Plasma Physics and Fusion Technology, 2009 in press

[2] T. Yoshinaga et al., "Physics Study of EC-Excited Current Generation via Current Jump in the Compact Plasma-Wall-Interaction Experimental Device",22nd IAEA FEC EX/W (2008)

[3] T. Ryoukai, H. Zushi et al., "Field line tying and magnetic shear effects of the vertical magnetic field on low frequency density fluctuations in CPD", FPR (2009) in press