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

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Abstract Two dimensional high speed visible light images taken by the fast camera have been studied during the current ramp-up phase using electron cyclotron waves in a simple magnetic configuration with vertical (B_z) and toroidal fields (B_t) in QUEST. Near the outer boundary (source region) of the slab plasma helix-sinusoidal perturbations are exited, whose helix angle and vertical wavelength are consistent with pitch angle and turn distance of the magnetic field lines there. 2D evolution of these helix instabilities are studied as a function of B_z/B_t. Current shows a peak near the optimum B_z/B_t, while the instabilities grow non-linearly with increasing this ratio. Statistical analysis of fluctuating images shows a quadratic relation between kurtosis and the skewness over the wide region and condition [1].

Introduction: In tokamas, RTPs, stellarators, and mirrors there are fundamental similarities in the radial transport, which is characterized by intermitted convection rather than diffusion [1]. This convective nature has been reported to be described by nonlinear evolution of drift or interchange instabilities driven by the pressure gradient or curvature of the magnetic field lines. In QUEST non-inductive current ramp-up phase, identification of initial perturbations, nonlinear evolution of them, triggering process of a blob by steepening the gradient of the profile, and acceleration of the blob along the radial excursion are investigated as a function of B_z/B_t near the outer plasma edge, where $\nabla B \bullet \nabla p > 0$ and the magnetic configuration features open field.

Helix perturbations and statistical feature of the fluctuation

QUEST is a medium sized spherical tokamak device, whose diameter and height are 2.8 and 2 m, respectively. Slab-annual hydrogen plasma was initiated by microwaves of 7 kW at 2.45 GHz using electron cyclotron resonance heating, extended vertically near the resonance layer at R~0.37 m (B_{res}=875 mT), and diffused outward. The radial resolution and framing rate of the image are ~ 10 mm and 20000 frames s^{-1}, respectively. A typical image indicating initial helix-sinusoidal perturbations near the "source region" (left) and a "coherent structure" (right) evolved nonlinearly from initial perturbations are observed as a function of B_z/B_t. Since this value changes the following quantities, the return distance Δ_z ($=2\pi RB_z/B_t$), pitch angle θ ($=\tan^{-1}(B_z/B_t)$) and the length L_c ($=2\pi R2b/\Delta_z$) connected to the walls of a field line in the poloidal plane, initial perturbations are varied. Fairly good agreement of observed one with Δ_z and θ indicates that initial perturbations are excited and extended along the magnetic field lines at the plasma source region. Plasma current (~ 1-3 kA) is driven by Rf injection, however, this level is strictly affected by the high particle recycling level. In addition to this significant effect, these fluctuations play an important role to transport the plasmoid crossing the open magnetic fileds.

Non-linear growth of these fluctuations

In the phase of the non-linearly evolution of the initial perturbation, it is observed that radial gradient or inverse scale length L_p^{-1} ($=I/\nabla_R I$) outside the source region plays an essential role. The steep gradient outside the plasma source region is deformed and a ridge crest propagates as a blob along and crossing the magnetic field lines. With increasing B_z/B_t deformation of the contour of L_p^{-1} becomes even more complex. The observed fluctuations show an intermittent nature, in particular, far from the source region. Statistical analysis of fluctuations on the entire radial region under the experimental conditions (P_{rf} and B_z/B_t) reveals that a simple quadratic relation, $K=1.3S^2+3$, exists between Kurtosis K and the skewness S of the fluctuations in a wide spatial region for various experimental condition. This suggests that fluctuations in the magnetic field obey a simple statistical law.

[1] H. Zushi, et al., 19th PSI (2010)