§15. Observation of Turbulence Propagation at ELM Event in LHD Plasmas

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Radial propagation of micro-scale turbulence has been observed in H-mode plasma experiment with ELM events. The experiments are carried out in the magnetic configuration where the magnetic axis position in the vacuum field is R_{ax}=3.9 m, on-axis magnetic field strength is B_t=0.8 T. In this discharge, the plasma is heated by neutral beam injectors (NBI), in which total power is around 10 MW. H_α signal is a good indicator to notify onset of the ELM event and the ELM frequency is found to be around 70 Hz. These ELM events are considered as a sort of resistive interchange mode from the former study. It makes the loss of about 10 % of stored energy in this analyzing data set. When the ELM events occur, the line integrated electron density drops just inside the last closed flux surface (LCFS) and increases outside. Figure 1 shows the radial profiles of electron density and temperature, which are measured by the Thomson scattering system. Here, two time slices, which are before and after onset of ELM events, are shown. It is clearly observed that there is the pivot point and it locates around at LCFS. Now, the question is that the density at well inside of LCFS (about 10 cm) looks like also dropping, simultaneously. The propagation time scale is faster than the diffusive transit time scale. Some other physics probably play a role of this abrupt loss mechanism. We try to investigate the turbulence effect and pay attention to the happening of the turbulence near the pivot point.

ELM events are self-organized plasma phenomena and we utilize the statistical study by the conditional averaging technique. H_α signal is used as the indicator of ELM events and the onset of ELM events is expressed as t = zero shown in Fig. 2(a). Here, 146 events are used for this analysis. The magnetic fluctuation is observed by Mirnov coils as shown in Fig. 2(b). It shows that the MHD event occurs during very short time (less than 0.5 ms) and it might be a trigger of the turbulence burst. The high frequency density fluctuation amplitude, which has over 100 kHz frequency components, is evaluated by applying a short-time fast Fourier transform (FFT) to multi-channel Doppler reflectometer signal. Contour map of the temporal change of turbulence amplitude versus effective radius is shown in Fig. 2(c). Here, each time window is 64μs and 146 events are ensemble-averaged. Just after the ELM onset, it is observed that rapid increase of turbulence amplitude at 2 cm inside the pivot point. Then, the turbulence front looks like propagate inward direction with a fast time scale.

Also, the envelope of high frequency component of each Doppler reflectometer signal is able to use as the indicator, since it has the information of temporal behavior of turbulence intensity. The front of turbulence burst is travelling from the pivot point radially by a distance several times of ion sound radius (ρ_s~3 mm), propagating inward at a speed ~ 100 m/s. This fast turbulence propagation may cause a drop in density as far as 10 cm inside of the LCFS.

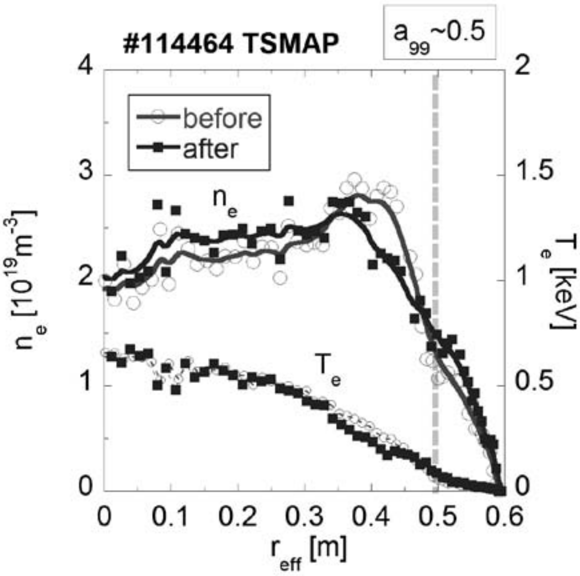

Fig. 1. Radial profiles of electron density and temperature measured by Thomson scattering system before (open circle) and after ELM event (filled square). The effective LCFS is also shown vertical green line (r_{eff}=a_{99}, where 99% of the kinetic energy is confined).

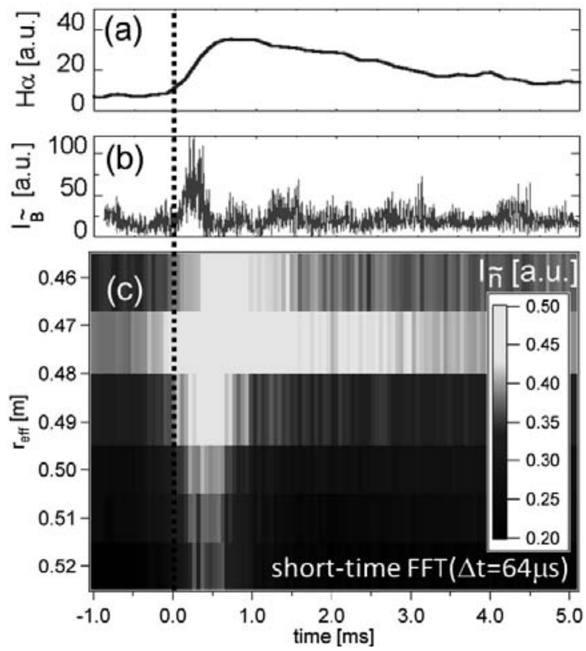

Fig. 2. Time evolutions of the ensemble averaged (a) Hα signal and (b) magnetic fluctuation intensity. (c) Contour map of the change of the high frequency density fluctuation component versus effective radius and time. Each time window is 64μs and ensemble-averaging number is 146.