## §4. Long Range Fluctuations in Quasi-Stationary and Transient Plasmas of LHD

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Recently, low frequency temperature fluctuations with long distance correlation were discovered in LHD [1]. The stationary characteristics of the long-range fluctuations are well understood. The dynamic behavior of long-range fluctuations is discussed here. Changes in the spatiotemporal structure of long-range fluctuation are investigated in the transient phase after the TESPEL injection. The target plasma is produced with neutral beam injection of 2 MW and electron cyclotron resonant heating (ECRH) of 0.8 MW is superimposed at the plasma centre. Typical parameters in this experiment are as follows: a major radius of 3.5 m, an averaged minor radius of 0.6 m, and a magnetic field strength of 2.83 T on the axis, the line-averaged density of $0.4 \times 10^{19}$ $m^{-3}$, central electron temperature $T_e(0)$ of 4 keV. The TESPEL injection induces a cold pulse at the plasma edge. The electron temperature in the edge region decreases due to cold electrons provided by TESPEL ablation, while the core electron temperature begin to increase with 0.1 ms delay. The reduction of core thermal diffusivity after the TESPEL injection was evaluated to be ~10% [2].

The long-range fluctuations are existed in the stationary phase and also during the $T_e$ rise phase. Cross-correlation functions are calculated during the $T_e$ rise phase (t = 2.850–2.858 s) after the TESPEL injection, and compared with that obtained just before the TESPEL injection (t = 2.835–2.843 s). The time window of 8 ms for correlation analysis is chosen to be much less than a rate of change in equilibrium $T_e$ (~ $\tau_E$ ~ 50ms) during the $T_e$ rise phase. Figure 1 demonstrates that the correlation in the central region ($\rho < 0.2$) was clearly reduced, and the region with large correlation (> 0.5) is shrunk from $0 < \rho < 0.6$ to $0.2 < \rho < 0.55$ after the TESPEL injection. Although the fluctuation amplitude is reduced across the plasma radius, a strong correlation is still observed in the region $0.2 < \rho < 0.6$ after the TESPEL injection. On the other hand, the correlation in the central region ($\rho < 0.2$) was reduced in spite of the amplitude, which is reduced but still finite there. This means that the phase relationship is changed and the radial wavenumber of fluctuations, $k_r$ are modified after the TESPEL injection. A time evolution of radial cross-correlation indicates that the change in radial cross-correlation starts with an increase in the central $T_e$ and with a decrease in the averaged fluctuation amplitude within the temporal resolution of 5 ms [3].

Although $T_e$ perturbed by the TESPEL injection turned back after tens of ms, the long-range fluctuation did not return to the former state. The amplitude decreased and correlation length shortened. The total plasma energy was increased ~10% after the TESPEL injection owing to an increase in the density. The change in long-range fluctuation coincides with the change in the plasma state.

Temporal resolution of the change in the radial correlation structure of the long-range modes is determined for the time window of calculation of the radial cross-correlation. The time window of 5 ms is too long to discuss a causal relation between the change in fluctuation structures and the abrupt change in transport after the TESPEL injection. The time window will be shortened by reduction of statistical error associated with thermal noise of ECE measurement. However, the time scale of $T_e$ fluctuation is 0.3–0.7 ms and thus it is difficult to observe the changes of amplitude and/or radial correlation structure within the time scale of 1 ms.

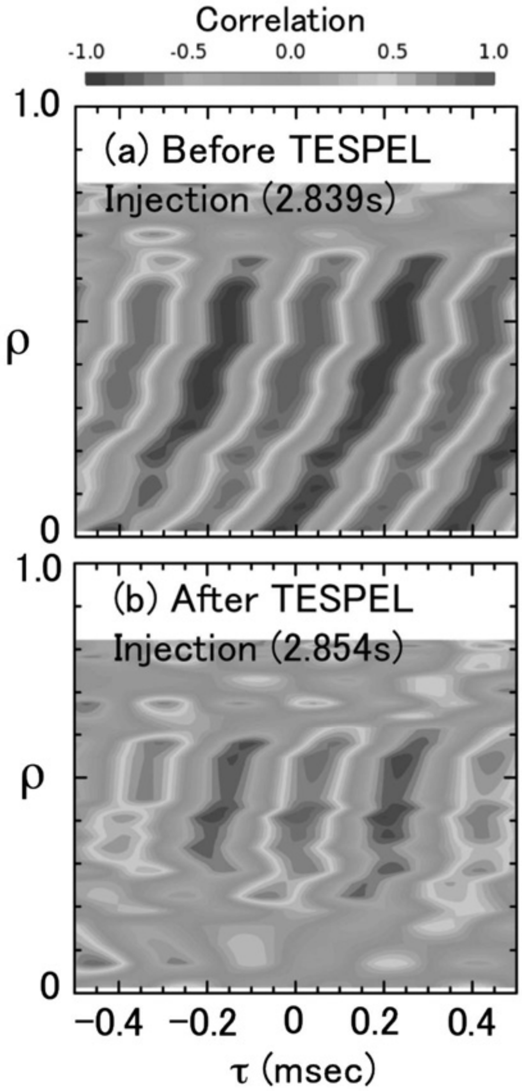


Fig. 1 Contour plot of the cross-correlation function of the low-frequency component (1.5–3.5 kHz) of $T_e$ fluctuation (a) before the TESPEL injection (2.835–2.843 ms) and (b) during $T_e$ rise phase (2.85–2.858 ms) induced by the TESPEL injection.

[1] S. Inagaki et. al., Phys. Rev. Lett. **107**, 115001 (2011)
[2] S. Inagaki, et. al., Plasma Phys. Control. Fusion **52,** 075002 (2010)
[3] S. Inagaki, et. al., Nucl. Fusion **52,** 023022 (2012)