§4. Abrupt Core Temperature Drop in Response to Edge Perturbation on LHD

Inagaki, S., Itoh, S.-I., Yagi, M. (Kyushu Univ.),
Tamura, N., Nagayama, Y., Kawahata, K.,
Fujisawa, A., Itoh, K., Yamada, H.

Magnetically confined toroidal plasmas exhibit various transport dynamics e.g. spontaneous internal transport barriers (ITBs) formation[1)], transition of low to high confinement mode in the edge region and abrupt core-edge interactions. The observed dynamics has different time and space scales. Plasma transport is dominated by turbulence, and thus the exhibited time and space scales of transport dynamics is considered to be resulted from the turbulence-transport interactions. To achieving a predictive capability of turbulence transport, therefore, understanding of the dynamics is crucial.

An abrupt core T_e rise in response to edge colling has been observed in tokamaks and LHD[2)]. At the same time as the non-local T_e rise, a non-local T_e drop is observed. Figure 1(a) indicates time evolution of T_e at different radii in a typical non-local T_e drop discharge. Experiments are carried out with a major radius at the magnetic axis of R_{ax} = 3.5 m and a magnetic field at axis of 2.83T. Typical parameters in this experiment are as following: line averaged density $1 \times 10^{19}\mathrm{m}^{-3}$, central electron temperature up to 1.5 keV, central ion temperature of 1-2 keV, plasma β value of 0.1%, absorbed ECH power of 0.8 MW, deposited neutral beam power of 2 MW. The cold pulse produced in the edge region ($\rho > 0.8$) by a TESPEL injection is strongly reduced in the region of $0.8 < \rho < 0.55$, and thus the cold pulse can not reach the core region. In spite of no direct effects of the cold pulse on ∇T_e and T_e in the central region ($\rho \leq 0.3$), a sudden drop of core T_e is observed. In the recovery phase, T_e in the central region overshoots a steady state value. The transport correlation diagram with respect to core ($\rho = 0.19$) heat flux reveals that the core heat flux has multi-non-local correlations with ∇T_e at three different singular positions as shown in Fig. 1(b). The cross-correlation is defined as $C_{f,g}(\rho_f, \rho_g, \tau) = \langle f(\rho_f, t) g(\rho_g, t+\tau)\rangle / \sqrt{\langle f^2(\rho_f, t)\rangle \langle g^2(\rho_g, t)\rangle}$, here $\langle\rangle$ means temporal average, defined as $\langle h(t)\rangle = (T)^{-1}\int_0^T h(t)dt$, $f = \delta T_e(\rho_f, t)$, $g = \delta T_e(\rho_g, t)$. There is a strong but positive correlations (~ 0.9) with ∇T_e at $\rho = 0.73$ and are middle correlations ($\sim 0.4 - 0.5$) with ∇T_e at $\rho = 0.55, 0.31$. The correlation time of $C_{\delta q_e/n_e, -\delta\nabla T_e}(\rho_{\delta q_e/n_e}, \rho_{\delta\nabla T_e} = 0.73, \tau)$ and $C_{\delta q_e/n_e, -\delta\nabla T_e}(\rho_{\delta q_e/n_e}, \rho_{\delta\nabla T_e} = 0.31, \tau)$ is short (3-4 ms) as shown in Fig. 1(c). On the other hand, $C_{\delta q_e/n_e, -\delta\nabla T_e}(\rho_{\delta q_e/n_e}, \rho_{\delta\nabla T_e} = 0.55, \tau)$ is the 4 times longer (16 ms). Figure 1(d) shows that the ∇T_e at three different singular positions have correlations with heat flux in the wide region ($\rho_{\delta q_e/n_e} \leq \rho_{\delta\nabla T_e}$). There are low order rational surfaces (n/m = 1/2, 2/3, here n/m is toroidal/poloidal mode number) around $\rho = 0.31, 0.52$ and no rational surfaces around $\rho = 0.73$. The pellet injection experiments in RTP[4)] may imply the existence of such a singular position and a dependence of its location on the position of the low order rational surfaces. The non-local T_e drop demonstrates a coexistence of positive and negative non-local correlations. It may be natural that there are multi eigen functions in the global mode concerned with non-local transport. Recently, it has been pointed out that competition among different modes affects the turbulence structure[3)]. The non-local T_e drop is observed in the vicinity of a merging point between the local and non-local transport branches in the flux-gradient diagram.

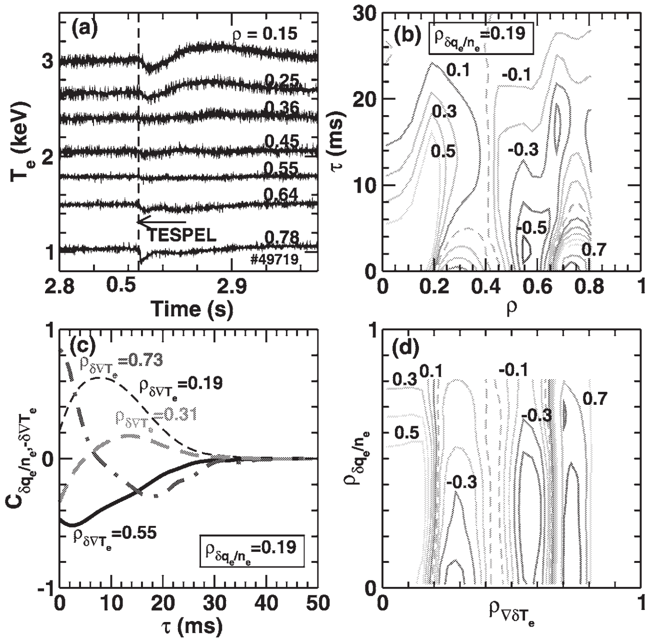

Fig. 1: (a) Typical time evolution of T_e in the non-local T_e drop case, (b) contour maps of the cross-correlation function between δq_e at $\rho = 0.19$ and the 21 $\nabla\delta T_e$ channels, (c) cross-correlation functions at three different singular positions, (d) contour maps of the cross-correlation between the 21 δq_e points and the 21 $\nabla\delta T_e$ points at $\tau = 0$.

1) Takashi S., et. al., Plasma Phys. Control. Fusion (2003) vol.45 pp.1183

2) Tamura N., Inagaki S., et. al., Nucl. Fusion (2007) vol.47 pp.449

3) Itoh S.-I. and Itoh K., Plasma Phys. Control. Fusion (2001) vol.43 pp.1055

4) Hogeweij G.M.D., et. al., Nucl. Fusion (1996) vol.36 pp.535