25F03

Finding the Latent Structure in Large Scale Transport Event
大規模輸送現象により見いだされた電子熱輸送の潜在的構造

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An edge perturbation induced by a trace impurity pellet (TESPEL) injection in LHD evokes a non-local transport phenomenon (large scale transport event, LSTE, such as a core electron temperature rise in response to edge cooling). In order to evaluate how the local heat transport properties change in the LHD plasma with the LSTE, a new transit time distribution analysis is applied. The results show that two large-scale coherent structures in the electron heat transport exist, and are qualitatively different from each other. Therefore the non-local transport phenomenon observed in LHD is evoked by the interaction of those structures.

1. Introduction

Nowadays it is well known that high-temperature turbulent plasmas exhibit a fast and global response (beyond the standard local diffusive paradigm) to a change in plasma parameters at a location. The most famous example of such a response is an abrupt rise of the core electron temperature T_e in response to the edge cooling (so-called “non-local transport phenomenon”) [1]. Unfortunately, although more than 10 years have passed since this kind of large scale transport event (LSTE) was discovered, there is still no rational explanation of the phenomenon. In the recent studies of the LSTE, a spatial interaction of the heat transport has been highlighted [2]. Whatever the reason may be, however, the local heat transport is definitely and strangely changed in the LSTE. So we revisit the investigation of the local heat transport properties (∇T_e) in the LSTE, especially the non-local transport phenomenon for gaining a deeper understanding the heat transport in the strongly turbulent plasmas.

2. Experimental Setup

The edge perturbation experiment with a tracer encapsulated solid pellet (TESPEL) injection is carried out on LHD with the magnetic axis position of R_{ax} = 3.5 m, the average minor radius of a ~ 0.6 m and the magnetic field at the axis of B_{ax} = 2.829 T. The plasma around the time of the edge perturbation is heated continuously by a neutral beam injection (NBI) and an electron cyclotron heating (ECH). The focus of all ECH beams is adjusted near the R_{ax}. A multi-channel heterodyne radiometer is used to track the temporal behavior of the T_e with a high time resolution. More detailed information on the experimental setup can be found in Ref. [3].

3. Typical Example of Large Scale Transport Event in LHD

Figure 1 shows a typical temporal behavior of the T_e measured with the multi-channel heterodyne radiometer at different normalized minor radii in the edge perturbation experiment. As can be easily recognized from Fig. 1, a significant rise of the core

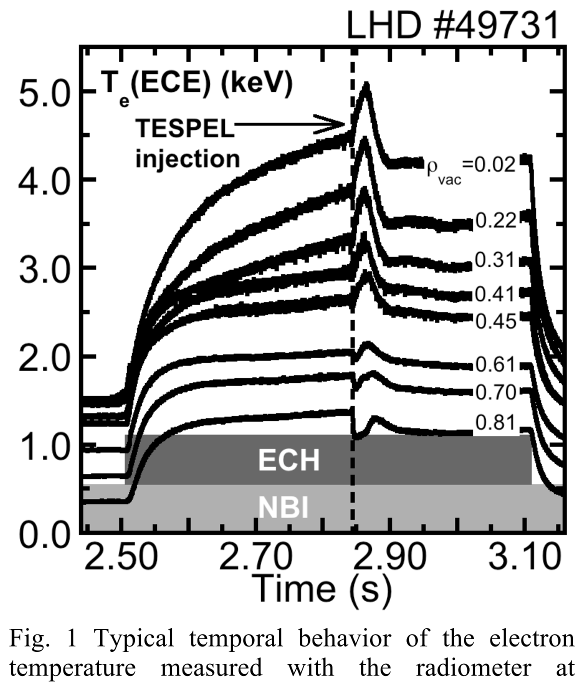

Fig. 1 Typical temporal behavior of the electron temperature measured with the radiometer at different normalized minor radii. The time of the TESPEL injection, which evokes the edge perturbation is indicated as the vertical dashed line.

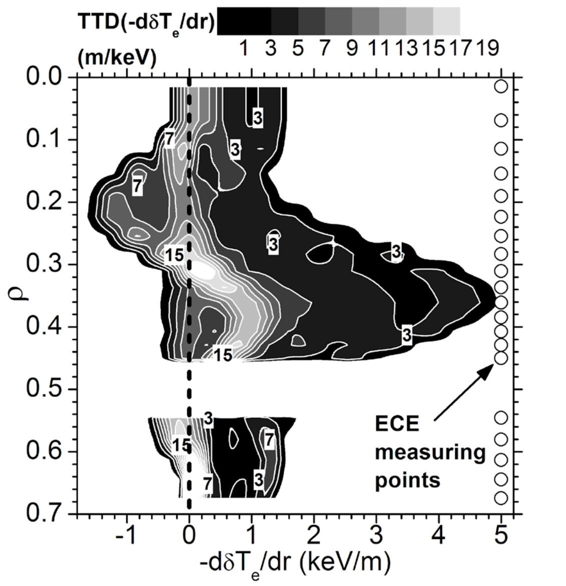

Fig. 2 Contour map of the transit time distribution of the gradient of the perturbed electron temperature for the discharge with the non-local transport phenomenon. In this case, the line-averaged electron density is at 0.7×10^{19} m^{-3}.

T_e takes place in response to the edge cooling accompanying the TESPEL injection. This kind of LSTE is not peculiar to helical plasmas nor to plasmas with an impurity pellet injection, but is a very common characteristic of the magnetically confined toroidal plasmas.

4. Transit Time Distribution Analysis

In order to evaluate how the local heat transport properties change in the LHD plasma with the LSTE, a new transit time distribution (TTD) analysis is applied to the temporal behavior of the T_e gradient. Figure 2 shows a contour map of the TTD of the gradient of the perturbed T_e for the low-density (line-averaged electron density n_{e_bar} = 0.7×10^{19} m^{-3}) plasma with the typical LSTE. As see in Fig. 2, a peak at non-zero displacement of the $-d\delta T_e/dr$ is found to exist over a wide region ($\rho > 0.55$, at least 6 cm wide) in the periphery of the plasma. This peak clearly shows the existence of another transport branch. This branch does not have a stronger attracting force compared with the original branch (at zero point f the $-d\delta T_e/dr$), which can cause the backward transition of the edge electron heat transport. On the other hand, around $\rho = 0.35$ (about 10 cm wide), the TTD is found to has a wide flat region. This demonstrates that various values of the $-d\delta T_e/dr$ can exist despite a lack of another apparent transport branch. It should be noted here that almost no change in the profiles of electron density and heat deposition in the core plasma after the onset of the LSTE. When the value of n_{e_bar} increases to 1.2×10^{19} m^{-3}, no clear rise of the core T_e in response to the edge cooling has been observed. In this case, in the core region, even not the exact same as the case shown in Fig. 2, various values of the $-d\delta T_e/dr$ still can exist despite a lack of another apparent transport branch. On the other hand, in the edge region, the transition to another transport branch disappears. Therefore no core T_e rise in the high-density plasma could be attributed to the disappearance of transition to another transport branch in the edge region.

5. Discussions and Summary

The formation mechanism of such large-scale coherent structures of the electron heat transport remains unclear. One of the candidates for that is a long-range T_e fluctuation, which is very recently discovered in LHD [4]. This long-range T_e fluctuation is defined by the long radial correlation length comparable to the plasma minor radius, the low frequency, 1 ~ 3 kHz, and the ballistic radial propagation speed, ~1 km/s. Interestingly, the time-averaged amplitude of the low-frequency component of the long-range T_e fluctuation has a similar spatial structure to the TTD map in the core region. More detailed discussion on this matter will be done in the conference.

In conclusion, the TTD analysis shows that two large-scale coherent structures in the electron heat transport exist in the LHD plasma exhibiting the non-local transport phenomenon. The non-local transport phenomenon observed in LHD could be attributed to the interaction of those structures.

Acknowledgments

We would like to thank to all of the technical staff of NIFS for their excellent support. This work is supported in part by a Grant-in-Aid for Young Scientists from a Toray scientific foundation, Grant-in-Aids for Young Scientists (A) (23686134) and for Scientific Research (S) (21224014) from JSPS and NIFS grant administrative costs, NIFS11ULHH012.

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