Particle Transport Analyses using Transient MHD Events and Proposal of a New Two-dimensional Diagnostics

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1. introduction

In the last A3 foresight program workshop held in Kagoshima in June 2014, I presented the transport analysis results for the super dense core (SDC) mode in the Large Helical Device (LHD), using the particle pulse propagation induced by the pellet injection [1]. From the time evolution of the local electron density and its profile, i.e., gradient, the diffusion coefficient D and the convective velocity v were derived by using the one-dimensional transport equation. Comparing D in the nested flux surface region and the stochastic region, it was found that the difference of the magnetic topology affects the particle transport. It was also observed that D is further increased by applying resonant magnetic perturbations (RMPs). These results agree well to those expected in the numerical study with the HINT2 code [2]. The particle pulse induced by the pellet injection is useful for the transport analysis, because one can easily estimate the source quantity and can determine the injection timing as he/she wants. However, there exist some disadvantages. For example, its perturbation is sometimes so large that the plasma itself is disturbed by the pellet injection, i.e., diagnostics. Ablation of the pellet during the penetration into the plasma also complicates the analyzing process, since it increases the density along the path. Although another method using, e.g., gas puffing modulation has also been used in many tokamaks and stellarators, it also has similar advantages and disadvantages.

I have recently developed a new particle transport analysis technique using transient MHD phenomena like saw-tooth oscillation and/or core density collapse (CDC) which is ballooning-type instability destabilized in the SDC mode in LHD. If once CDC takes place, it evacuates certain amount of particles from the confinement region to the divertor through edge stochastic region. The CDC itself occurs quite fast, since it is an MHD phenomenon. After the collapse, however, its particle pulse propagates, depending on D and v in the region. The superior thing of this method is that the particle source is originated at the core region, which enables the measurement to be free from taking account of the source in the edge region.

2. Experimental results

Experiments were carried out at the outward shifted configuration at R_{ax} = 3.85 m with B_T = 2 T. The plasma was produced and maintained by the neutral beam injection. The density was increased by the repetitive pellet injection. The line integrated electron densities at various radial positions were measured with a multi-channel CO_2 laser interferometer, where the plasma is vertically elongated. Time trends of main plasma parameters are shown in Fig. 1.

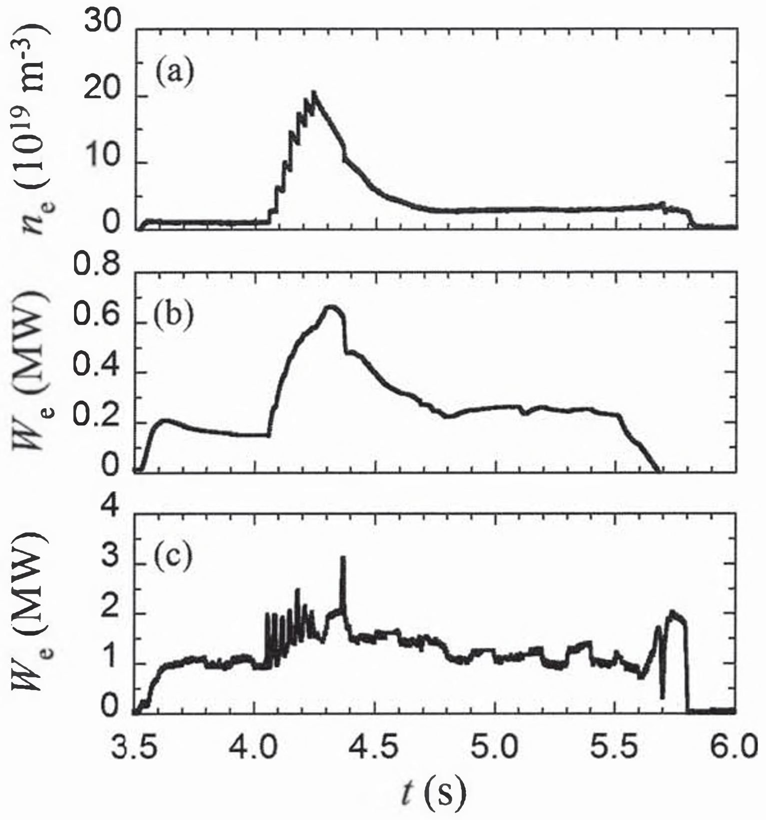

Fig. 1. Time evolution of (a) line averaged density, (b) stored energy and (c) radiated power.

In order to modify the edge stochasticity, RMPs (m/n = 1/1 and 2/1) were applied with the normal conducting RMP coils installed in outside the cryostat of the LHD. The configuration of the RMP coils installed in LHD is depicted in Fig. 2.

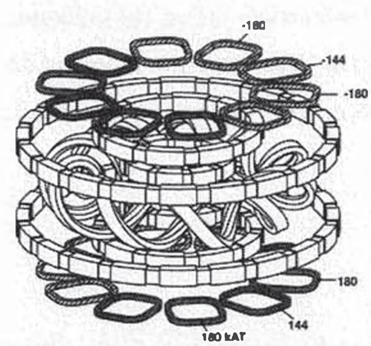

Fig. 2. RMP coils. Each colored group is driven by independent power supply.

Figure 3 shows the time evolution of (a), (c) line averaged electron density at different radial positions and (b), (d) divertor flux measured with Langmuir probes embedded in divertor plates. The left and right columns are from the discharges without and with RMPs, respectively. As seen from Fig. 3 (a) and (c), CDC takes place at t = 4.368 s in both discharges. After the CDC, the particle pulse propagates from the core (r = 4.157 m) to edge (r = 4.228 m) regions and finally reaches the divertor, as shown in Fig. 3. The propagation were compared between different edge stochasticities. It is found that the delay of the propagation observed in the edge region changes when the RMP is applied, as depicted with red closed circles. This result suggests that the particle transport is different in different magnetic topologies. In this experiment, the difference between two discharges was not so clear, since the CDC was too big to keep the original density profile. The CDC broke not only the core region but even the edge region. Optimization of the CDC amplitude is mandatory to see the clear pulse propagation. In addition, higher sampling frequency is required to increase the accuracy of the observation.

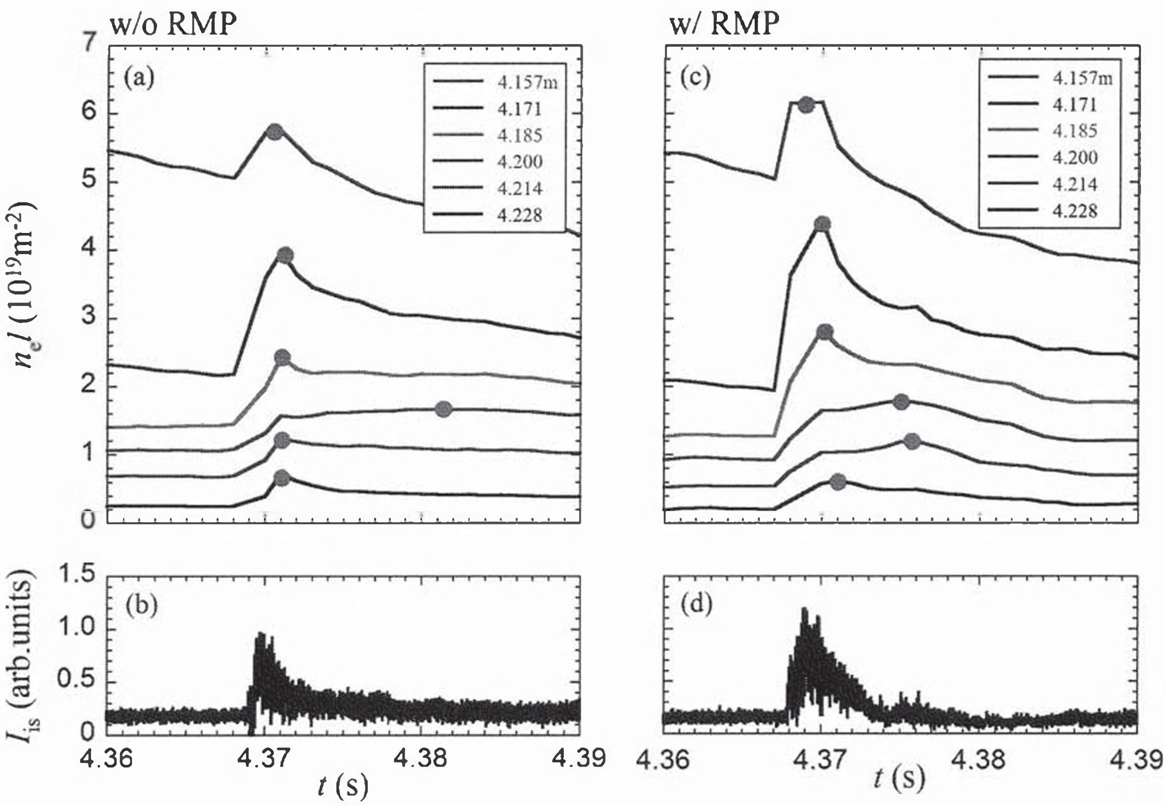

Fig. 3. Time evolution of (a), (c) line averaged electron density at different radial positions and (b), (d) divertor flux measured with Langmuir probes embedded in divertor plates. The left and right columns are from the discharges without and with RMPs, respectively. CDC occurs at t = 4.368 s in both discharges. Closed red circles indicate peak of the density pulse.

3. Proposal of helium beam probe for edge two-dimensional n_e, T_e measurements

I would like to propose a new edge diagnostics, helium beam probe (HeBP), which can measure particle pulses passing through the edge stochastic region two-dimensionally, with high time and spatial resolutions [3].

Using three (667.8, 706.5, 728.1 nm) line emissions from helium atoms in the plasma, edge electron temperature and density can be derived with the collisional-radiative model. For the beam injector, a Laval nozzle with a fast solenoid valve is recommended to produce the collimated beam. Three He I line emission images are spectroscopically detected with an image-intensifier-coupled fast camera behind three interference filters. An image-guide fiber may be necessary to keep the camera away from the high magnetic and/or radiation field region.

A schematic view of the HeBP system is shown in Fig. 4.

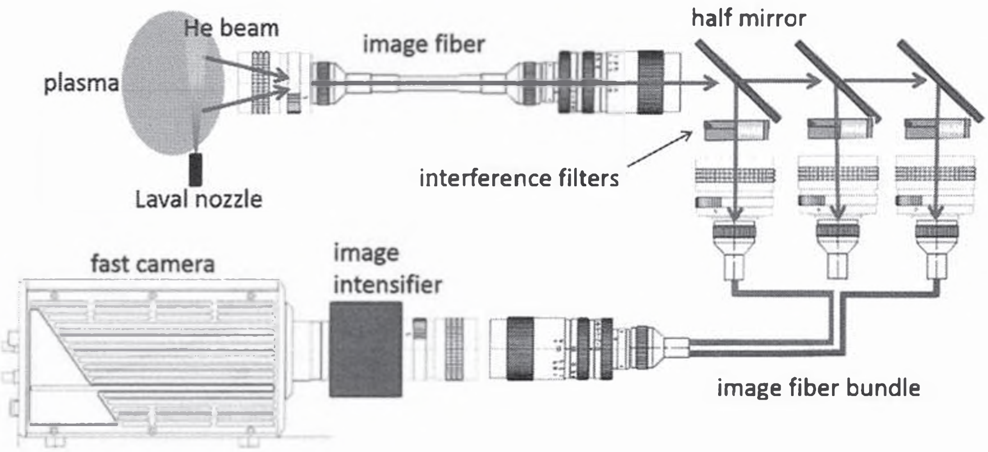

Fig. 4. Schematic of HeBP system.

Acknowledgements

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References

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[2] Y. Suzuki, K. Ida, K. Kamiya et al., "3D plasma response to magnetic field structure in the Large Helical Device", Nuclear Fusion, **53** (2013) 073045-1.

[3] T. Morisaki, et al., "Development of Helium Beam Probe for Edge Plasma Measurements" 39th EPS Conference & 16th Int. Congress on Plasma Physics.