§19. Electron Density Responses Measured with the Divertor Interferometer on LHD

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Divertor detachment is one of preferable operations in future fusion reactors to reduce the heat load to divertor plates. In order to understand physics of a divertor plasma during the detachment, information of the electron density of divertor legs with a high temporal resolution is indispensable.

A millimeter-wave heterodyne interferomerter for the divertor leg plasma in LHD has been operated since the 11th experimental campaign. The millimeter-wave passes through the outer and upper divertor leg in the horizontally elongated plasma cross section at 3-O port. The measured position of the diverter leg is at the middle point between the X-point and the diverter plates. The temporal resolution is 10 μs and the present density resolution is $\pm 2.3\times10^{16}$ m^{-3}, which are enough to measure dynamics of detached plasmas.

Figure 1 shows temporal behaviors of the divertor density during the detachment operations. The detachment occurred at t=2.14 s. While the line averaged electron density along the central chord of the core plasma continued to increase, the density at the divertor leg decreased to about one fifth compared with that at the attach phase. During the detach phase, the spiky density rises which were 3-4 times higher than the base density. They were well correlated with spikes of the H_α emission signal, which was due to radiation belts. This observation implies that the electron density in the radiation belt is rather higher than surrounding. This is consistent with estimation of the density from spectroscopy [1].

Figure 2 shows an expansion of spiky density signals and magnetic probe data. The fluctuation property during the spikes is quite different form that during inter-spikes; small spikes with a time width of several hundreds μs are observed. These are no correlation with the magnetic fluctuation data. The electron density may change with a time constant of several hundreds μs due to recombination and ionization. Other possibility is as follows. In high density and low temperature region with significant neutrals in the radiation belt, the parallel transport along the magnetic field line might be prevented and that enhances charge separation. As a result, the electric field causes $\mathbf{E}\times\mathbf{B}$ drift similar to the mechanism of blob transport.

The relationship between the electron densities at up- and downstream during an outward-shifted detach experiment is shown in Fig.3. In the case of tokamaks, it is well known that n_{ed} is proportional to n_{eu} in the sheath-limited region and to n^3_{eu} in the high recycling region. On the other hand, The downstream density n_{ed} in LHD increases with 1.5-2 power of the upstream density n_{eu}. This result seems to be almost consistent with theoritical analysis that perpendicular transport occurs due to the three-dimensional structure of SOL in LHD: $n_{ed} \propto n^{1.5}_{eu}$ [2].

[1] M. Goto and S. Morita, Plasma Fusion Research **3**, S1042 (2008).
[2] M. Kobayashi et. al., J. Plasma Fusion Res. 85 393 (2009).

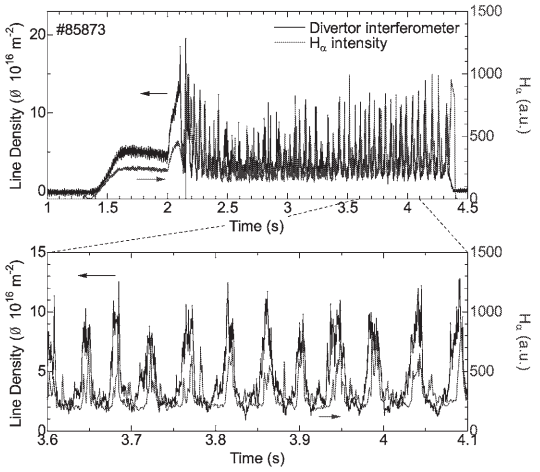

Fig. 1: One example of temporal behavior of the divertor density of self-sustained complete detachment discharge 'Serpens mode'.

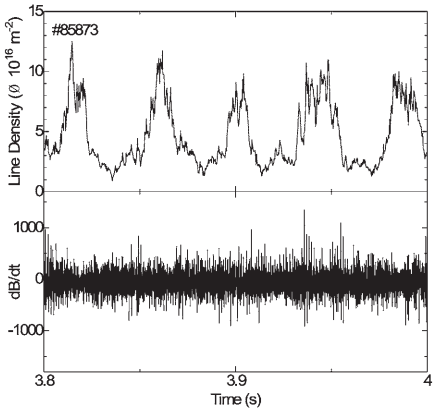

Fig.2: An expansion of spiky signals of the divertor electron density during detachment phase and dB/dt measured with a magnetic probe.

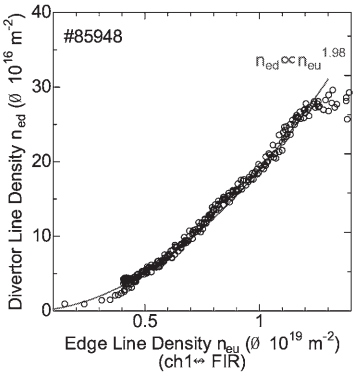

Fig.3: Relationship between the electron densities at upstream (ch1 of the FIR laser interferometer) and downstream (divertor interferometer).