§20. Finite Beta Effect on Plasma Parameters of LHD Divertor Legs

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In the helical plasma experiments such as LHD, interaction between plasma and neutral particle is an important factor for the control of heat and particle of the whole device. However, since the their profile is intrinsically three-dimensional, experimental information is still insufficient. Especially, little information on ion temperature and plasma potential makes it impossible to deduce plasma heat flux. Among the various probe systems in LHD, the hybrid directional Langmuir probe (HDLP)[1] has a unique feature as a thermal probe to measure the heat flux directly and to deduce plasma parameters from it. Figure 1 shows the stroke of HDLP driving system, and it covers not only divertor leg ($z \sim 1600$) but also neighbor area of last closed flux surface (LCFS) ($z < 600$).

We have proposed a new analysis method to deduce time-dependent plasma heat flux from thermocouple data of thermal probes.[2] And by applying it to HDLP data, plasma heat flux evolution of characteristic time longer than 1[s] becomes possible. Figure 2 shows one example of NBI plasma (SN.124355 – 124361). Magnetic configuration is $(R_{ax}, B_t, \gamma_c) = (3.55\text{m}, -1.0\text{T}, 1.2538)$ and high beta plasma is produced. HDLP is set outside of LCFS, and scanned shot by shot. It is expected from the orbit calculation of fast ion produced by NBI that many so-called re-entering ions stay around this area and the heat flux is due to these ions. Since time response of HDLP sensor is limited to be slow, heat flux evolution due to finite beta magnetic configuration change can not be recognized, although heat flux profile and its slow change is shown in this figure.

In order to confirm that heat flux is carried by fast ions, heat flux – bias voltage (Q–V) characteristic data is very important. For thermal ion, Q–V data shows linear dependency and its gradient is given by electron temperature. But more generally Q–V data contains the information on ion energy distribution function, although conventional Langmuir probe would loss such an information. Figure 3 shows preliminary test to obtain Q–V data with HDLP. Plasma discharge (#115940) starts at t=3.3[s], NBI heating lasts till 4.8[s], ECH power terminates at 5.3[s]. HDLP was set at $z = 600$ and plasma minor axis is a little shifted outward ($R_{ax} = 3.60$m) compared with Fig. 2. Although scanning frequency is set to be quite slow, plasma duration time is also small (~ 2s) and no clear Q–V data is obtained. Similar measurement especially for divertor leg plasma will be necessary for next experimental campaign.

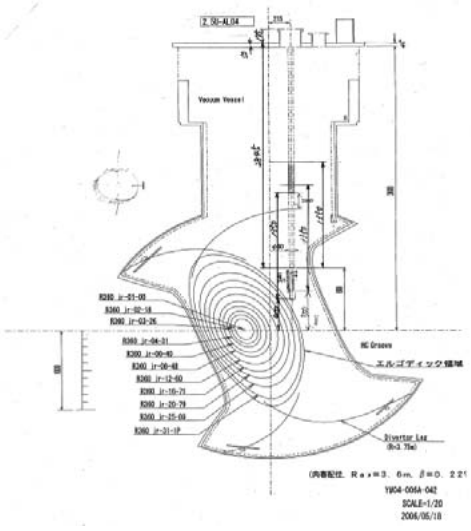

Fig. 1: HDLP setting in LHD vacuum chamber. HDLP can be moved vertically, and it covers not only divertor leg but also neighbor area.

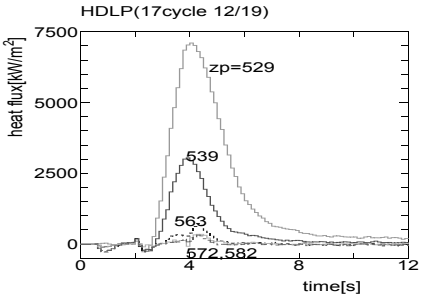

Fig. 2: Estimated heat flux profile near LCFS. Heat flux is mainly carried by fast ions produced with NBI.

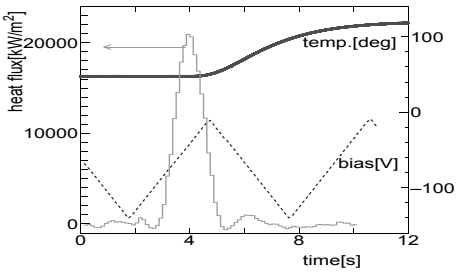

Fig. 3: Effect of probe biasing on the heat flux.

1) K.Nagaoka et al., Rev. Sci. Instr., 79, 10E523 (2008).

2) H.Matsuura *et al.*, Contrib. Plasma Phys. 54, No. 3, 285 — 290 (2014).