§25. Measurement of the Heat Flux Change Due to Confinement Transition in Heliotron J

Matsuura, H. (Osaka Pref. Univ.), Ohshima, S., Hashimoto, K., Okada, H., Mizuuchi, T. (Kyoto Univ.), Nagaoka, K., Mutoh, T.

In order to estimate divertor heat flux q, a simple formula $q = \gamma T_e I_{is}$ has often been used, where T_e is electron temperature and I_{is} is ion saturation current measured with probes. However, relationship between the heat flux and the plasma parameters is much more complicated and heat transition factor γ depends upon many other parameters such as ion temperature, space potential, probe bias voltage, surface reflection coefficient, and so on. Thus, in order to check proposed methods to reduce the divertor heat load, the direct measurement of the heat flux is indispensable. Thermal probe method, in which the heat flux value to the probe tip is evaluated from tip temperature data and steady state heat balance relation, is the most promising, but the time response of thermal probes is rather poor.

Probe tip temperature is monitored with thermocouple(TC), which is connected to the tip. The thermal diffusion time $\tau = L^2/\alpha$ is needed for TC to response after plasma irradiation start, where L is the distance between probe surface and TC connection point and α is thermal diffusivity of probe tip material. Figure 1 shows three temperature response of 14 mm copper plate measured with TC at $x = 1, 2, 10$ mm, where x is the distance from plasma irradiation surface. Plasma irradiation with heat flux of 20MW/m^2 lasts 100 ms. The blue line ($x = 10$ mm) reproduces well the experimental results obtained Hybrid Directional Probe (HDP) at port 7.5. During plasma discharge, no temperature increment is observed and after about 1 s, temperature peak appears. From HDP data, it is impossible to deduce the heat flux change induced by plasma confinement changes or detachment.

As shown by this calculation, if TC is set closer to the surface, temperature response during the irradiation could be measured and time dependent measurement of heat flux would become possible. Of course, TC data analysis of such a probe needs to consider heat pulse propagation in a probe tip. Temperature gradient type thermal probe (GTP) uses two or more TC and gives us heat flux value with relatively simple analysis[1]. For Heliotron J experimental condition, convection heat transfer of residual gas can be neglected.

In 2010FY experiment, a new hybrid probe was constructed and tested with Heliotron J edge plasma (see Fig.2) for the first time. Its body is made of boron nitride (BN) and equipped with four conventional Langmuir probe tips and a copper (Cu) GTP tip. The size of Cu tip is set as small as possible to improve time response. So its fabrication was very difficult task and the setting of GTP tip is possible only along the axial direction of a large probe head. Unfortunately, the whole probe system is driven in the axial direction to the last closed flux surface of Heliotron J plasma and magnetic field lines inside of the last closed surface crosses the side surface of the probe head. So plasma heat flux is hindered by BN head to reach the Cu GTP and S/N ratio is not so good. This situation is similar with those of the so-called ion sensitive probe. For Heliotron J condition, electrons with small gyro radius could not reach GTP and only ion heat flux can be measured.

In order to overcome the this drawback, the new thermal probe applicable to side surface of the hybrid probe body has been developed. Its tip is also made of copper, but only one TC could be equipped. So simple GTP analysis can not be applicable for it. Recently a new analysis model was developed for LHD experiment[2]. It would also reproduce heat flux change of Heliotron J plasma from TC data obtained with this new thermal probe.

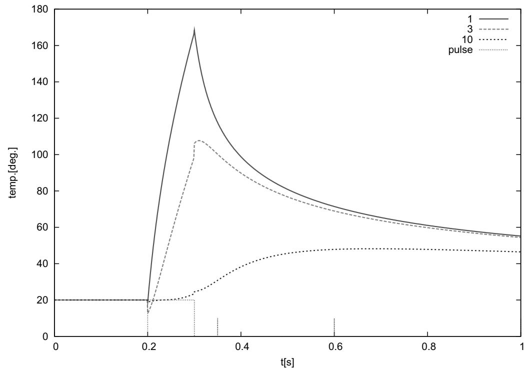

Fig. 1: Model calculation results of probe tip temperature.

Fig. 2: Photo of combined probe with a Cu GTP tip.

1) H.Matsuura *et al.*, Jpn. J. Appl. Phys. (2020) vol.49 08JD03.

2) H.Matsuura *et al.*, Ann. Rep. NIFS, Apr.2010-Mar.2011(2011)48.