§6. Experimental Study on Heat Flux of Divertor Plasma (Measurement of Sheath Heat Flux on the Surface of Gamma 10 Divertor Plates)

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In the GAMMA 10 tandem mirror, high heat-flux generation experiments (E-divertor) with high-power plasma heating systems have been started. In 2011FY experiment, plasma heat flux was estimated with calorimetric method based on Lumped-Heat-Capacity system approximation. From this results, a clear prospect of generating the ITER-grade high heat flux under the good controllability was confirmed. But this method can not give us information on time evolution of heat flux. Moreover, sampling speed of the recorder for thermocouple (TC) data of the calorimeter was too slow to catch the transient heat pulse propagation in the target, and temperature peak value might be underestimated, since the thermal diffusion time of the target is the order of 1[s] for thermal diffusivity of target material (Cu).

From 2012FY experiment, a new calorimeter target was constructed and applied to GAMMA 10 experiment. Figure 1 shows the photo of this calorimeter head. The temperature data is recorded with GL900 (GRAPHTEC Corporation), whose sampling interval is 1[ms]. It takes about a few [s] to to reach the maximum value of the sensor temperature. This is faster by a factor of 10 than old sensors. But large noises are found at the beginning of sampling

Figure 2 shows comparison of raw TC signal for different operating condition.[1)] Shot number #223374 and #223377 are normal discharge data. Both signals agrees well and its change is too fast compared with thermal diffusion time of the target. So it is expected that these noise comes from some system problem, not from incidental events. Large negative spike around 800 [ms] seems to be due to electromagnetic noise of the coil system, since it appears also for #223375 and the coil current for confinement magnetic field is reduced to zero at this timing. On the contrary, large positive jump during plasma discharge (50 – 250 [ms]) vanishes for #223376. This noise comes ether from RF noise of heating system or from large plasma current flowing into the target. Effort to reduce these noise is on going.

From discharge plasma research, it is reported that, even for the same plasma condition, heat flux into solid target may change according to the target material mainly due to ion energy reflection. Figure 3 shows the estimation of energy reflection coefficient R_{iE} as the function of hydrogen ion energy. When ions reach to the target, heat flux must be multiplied by the factor of $(1-R_{iE})$. Considering that ion temperature of GAMMA 10 plasma is several 100 [eV], heat flux measured with Cu would be larger than those with W, since tungsten has large R_{iE} than copper. Preliminary experiment results of 2013FY does not contradict this expectation.

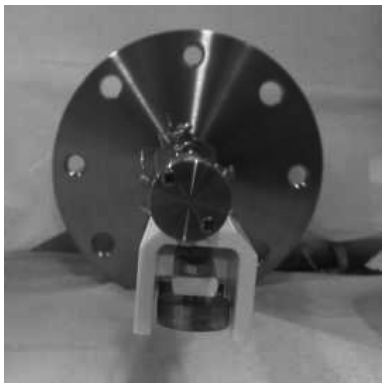

Fig. 1: Constructed calorimeter head.

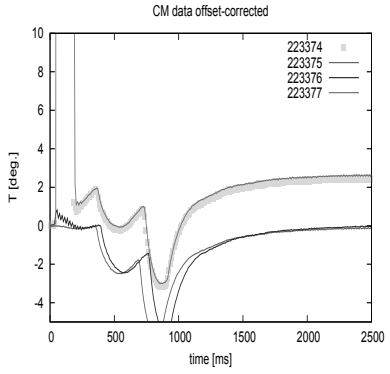

Fig. 2: Fast TC signal noise around GAMMA 10 plasma discharge. Normal discharge (#223374, #223377), only seed plasma without RF heating (#223376), and only magnetic field (#223375).

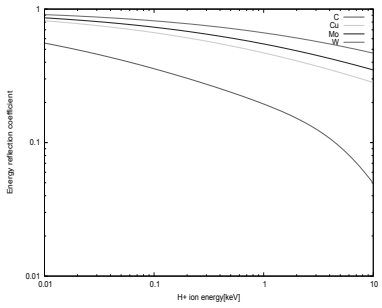

Fig. 3: Ion energy reflection coefficient evaluated with Eckstein's empirical formula.

1) H.Matsuura et al.: Fusion Science and Technology, 63(2013)180-183.