§7. Development of the Monitoring System for Divertor Heat Flux Distribution

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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.

From 2012FY experiment, a calorimeter target was modified to improve the thermocouple (TC) signal response. While TC of the old sensor was connected to backside of the target, TC connection point of this new sensor is moved through the left tube shown in the figure to $x = 2$ mm position apart from the irradiation surface and thermal diffusion time is expected to be smaller than an old one by a factor of 25. But large noises are found at the beginning of sampling, which can be categorize into two types[1]. One is a large positive spike which appears during plasma discharge and disappear in no plasma production shot. So its origin is thought to be ether RF noise of heating system or large plasma current flowing into the target. Another noise is negative pulses seen around $t \sim 700$[ms] and observed even in only magnetic coil operation without plasma production.

From 2013FY experiment, a new calorimeter with two heads made of copper and molybdenum was designed and constructed. Figure 1 shows this twin calorimeter head. Thermocouple setting is the same as the new sensor described above and have fast response

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 2 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. Figure 3 shows radial distribution of heat flux measured by moving the calorimeter system shot by shot. Although two heads are shifted each other, both heat flux has the peak around the mirror axis ($X = 0$ mm) and heat flux measured with copper head is larger than those with molybdenum by about 20 $\sim$ 40 %.

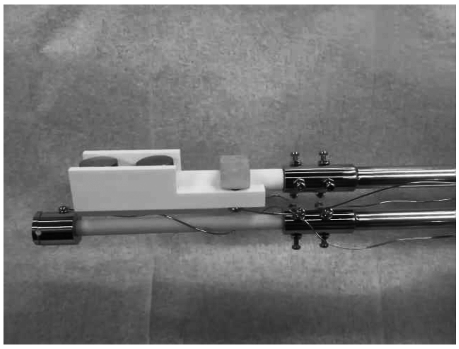

Fig. 1: Twin calorimeter head. One is made of copper and another is of molybdenum.

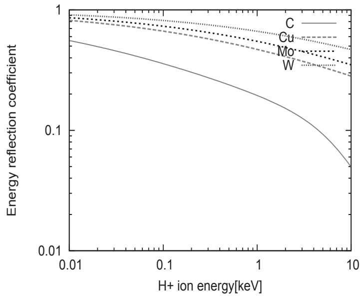

Fig. 2: Ion energy reflection coefficient evaluated with Eckstein's empirical formula.

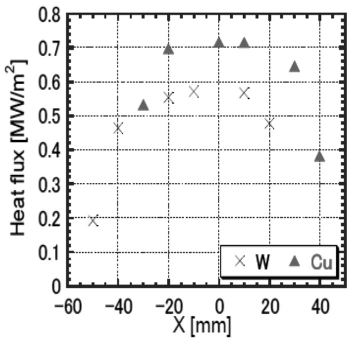

Fig. 3: Radial distribution of heat flux measured with the twin head calorimeter of Fig. 1. (#227796∼227803)

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

2) M.Iwamoto et al.: Plasma and Fusion Research, 9(2014)3402121.