§42-14 Development of in-situ Calibration of Infrared Camera Measurement

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i) Introduction

In the fusion devices such as LHD and ITER, it becomes difficult to calibrate the optics for measurements and to evaluate the emissivities of the plasma facing components by removing the infrared (IR) camera system and the plasma facing components, such as a divertor target, from the devices for calibration. The main objective of this research is to develop the in-situ calibration technique for the IR camera including the transmission of the optics and the emissivities of the plasma facing components.

ii) Research results

The proof-of-principle experiment to evaluate the emissivity changes of the object surfaces for in-situ calibration was performed by irradiating an IR laser on the surfaces.[1, 2] Figure 1 shows the experimental setup. Tungsten samples with the surface-roughnesses (*R*a) of 0.3, 1.0, 2.3 and 5.9 μm were set on a rotating stage in a vacuum chamber and heated up to about 1100˚C with a graphite heater. The tungsten samples were irradiated by an IR laser (wavelength: 3.22 μm, average power: 0.65 mW) and the scattered lights were measured by an IR camera (FLIR SC5200). Angular distributions of the scattered laser light on the surfaces were measured by rotating the samples while keeping the angle of 5˚ between the line of sight of the IR laser and that of the IR camera as shown in Fig.2 a).

Without a laser irradiation, the emissivities of the surfaces of the samples were evaluated at the different wavelengths (3 μm - 5 μm) by measuring the scattered light with the corresponding band-pass filters and the surface temperatures measured by a thermocouple. For each wavelength, the temperature dependence of the emissivity was evaluated at the different surface temperatures (400˚C - 1100˚C). It was found that the emissivity had a week (< 10%) dependence on wavelength and surface temperature. However, the emissivity had a strong dependence on the surface-roughness. It was increased very much from 0.2 to 0.6 with the surface-roughness from 0.3 μm to 5.9 μm roughly. It means that it is important to know the emissivity change due to the erosion and impurity deposition on the surface during the operation in the fusion devices such as LHD and ITER when the temperature is measure with a single band method. On the other hand, the change of the ratio of the emissivity at the wavelength band of 3.35 μm to that at 4.67 μm was less than 10%. This means two color method has an advantage to the single band method.

In the experiments with the IR laser irradiation on the sample surface, scattered light on the surface was observed by the IR camera as shown in Fig. 2 b). The angular distributions of the scattered light on the surfaces with the surface-roughnesses of 1.0 μm, 2.3 μm and 5.9 μm were observed at the surface temperature of 22˚C as shown in Fig. 2 c). The scattered light on the surface with the surface-roughness of 0.3 μm was located around θ_w=0˚. In ITER, the IR camera will observe the divertor target with the angle (θ_w) of -40˚±20˚. Therefore, it will be possible to observe the scattered light in ITER. Detailed procedure how to estimate the change of the emissivity is under developing.

Experiment on LHD was performed to confirm the availably of this method using the IR laser in the large fusion devices. The emission and the scattered light from the tungsten sample installed in the LHD were observed by the IR camera.

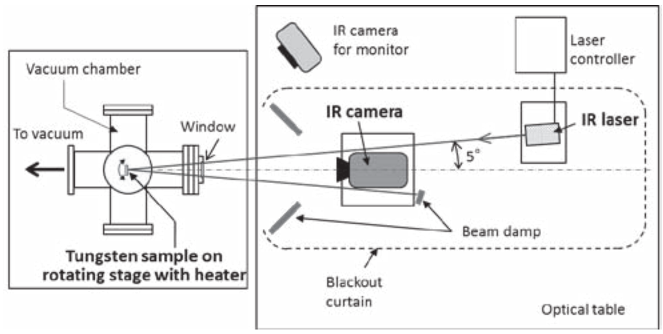

Fig. 1 Experimental setup: Tungsten sample mounted on the rotating stage is set in a vacuum chamber and heated by a graphite heater located just behind the sample. The sample is irradiated by an IR laser and the scattered light on the surface is measured by an IR camera.

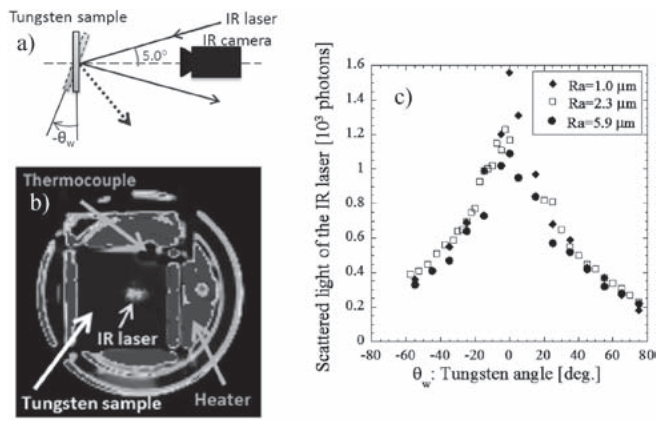

Fig.2 a) Optical arrangement of an IR laser, tungsten sample, IR camera and the rotating angle of θ_w. b) Image of the IR camera for tungsten sample (temperature: 400˚C, Ra: 1.0 μm, θ_w: 0˚). c) Angular distributions of scattered light of the IR laser for samples of surface-roughnesses of *R*a = 1.0 μm, 2.3 μm and 5.9 μm.

1) Takeuchi M. et al.: ICPP 2014, MCF.P25, Sep. 2014, Lisbon, Portugal
2) Takeuchi M. et al.: Plasma 2014, 21pC2-4, Nov. 2014, Niigata, Japan