§42-26 Investigation of the Effect of Plasma Exposure on the Thermal Characteristics of an Imaging Bolometer Foil

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InfraRed imaging Video Bolometer (IRVB) is useful to measure the radiative power from a fusion plasma. This diagnostic has been already applied to LHD and JT-60U. This method is also being applied to KSTAR and possibly to other devices including ITER. Figure 1 shows the schematic of the IRVB principle. In the IRVB using a thin metal foil, the 2D distribution of temperature is formed on the foil. An IR camera measures this distribution. To calculate the plasma radiation, $P_{\rm rad}$, from the temperature on the foil, T, the heat diffusion equation shown in Equation1 should be solved,

$$-\frac{P_{\rm rad}}{kt_{\rm f}l^2}+\frac{\varepsilon\sigma_{\rm SB}\left(T^4-T_0^4\right)}{kt_{\rm f}}+\frac{1}{\kappa}\frac{\partial T}{\partial t}=\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2} \qquad (1).$$

Here, l^2 is foil pixel area, $\sigma_{\rm SB}$ is the Stefan-Boltzmann coefficient and T_0 is background temperature. Then, the foil thickness, $t_{\rm f}$, emissivity, k, and thermal diffusivity, κ, have to be calibrated for each bolometer pixel on the foil. This can be done by comparing the results of a finite element model of the foil with those from calibration experiments using a He-Ne laser. Absolute calibration is essential especially for using multiple IRVBs on LHD to perform 3D tomography on LHD.

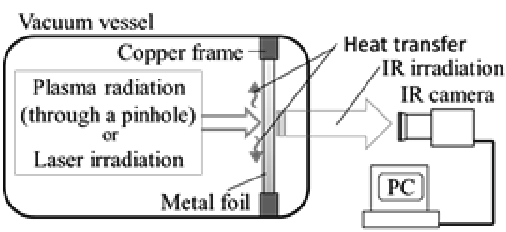

Fig. 1. Schematic of an IRVB principle.

The effects of plasma exposure on these foil characteristics must be also investigated for long-term plasma discharge. We have IRVB foils exposed to plasmas in LHD and other fusion devices. The parameter distribution such as foil thickness before the exposures have been measured. Calibration data for IRVB foils exposed to plasmas in LHD and other fusion devices were taken using the calibration test stand at NIFS. The calibration data were analyzed using the IDL software. The finite element modeling of the foil was done using the ANSYS software. Then, calibration data after the plasma exposure were compared to those before the exposure. In addition, the surface analysis of the foils was done in order to discuss the effects of the plasma exposure. Data is still under analysis and we expect to have results in the coming fiscal year.

The concept design of an in-situ calibration system has been completed[1]. The schematic of the in-situ calibration system is shows in Fig.2. This system was designed to improve the measurement from the viewpoint of the foil calibration especially in the LHD deuterium experiments. A visible laser (JDS Uniphase/ 1145, 632.8 nm × 22.5 mW) is injected to the foil after checking the power and beam profile. A hot mirror (Edmund Optics/ 45° 101 × 127) is used for a periscope system to avoid the damage to the IR camera detector from direct irradiation of X-rays, neutrons, and gammas from the plasma. The hot mirror can transmit the laser light and reflect the IR signal from the foil since it has the transmittance of > 85% for visible light and the reflectance of > 95% for IR signal. Two motorized goniometers (SIGMAKOKI/ GOHTM-40A60, GOHTM-40A75) are applied as a biaxial goniometer with a mirror to scan the laser irradiation position. Here, the distance from the mirror to the foil is assumed to be 1000 mm considering the distance of 600 mm from the IR camera to the foil in the current setting and the thickness of the neutron shield which is still under consideration. In this case, 90 × 70 mm of the foil size correspond to ±2.6° and ±2.0°, respectively, which are in the range of the travel angles of the goniometers ±5° and ±4°. Moreover, the length corresponding to the diagonal of the foil at the vacuum window is 40 mm, which is smaller than the effective diameter of the window, ϕ = 100 mm. Then, laser irradiation points can cover the whole foil area through the vacuum window. These stages can be controlled using LabVIEW software with the positional repeatability of ±0.004° which is equal to the resolution of ±0.1 mm on the foil. This repeatability is sufficiently smaller than the bolometer pixel size of 2.5 mm × 2.5 mm. Therefore, this system can scan the irradiation points with enough accuracy. This system is removable to avoid damage to components from neutron irradiation during plasma experiments since the installation accuracy can be guaranteed using knock pins. We confirmed that the components worked well and this calibration system will be applied in the next LHD experimental campaign.

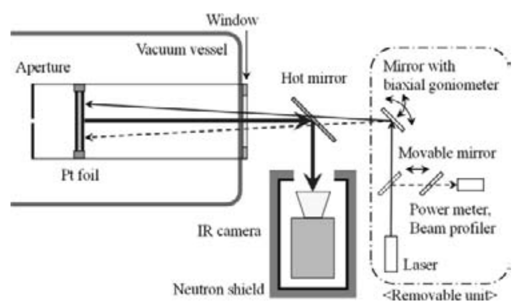

Fig. 2. Schematic of in-situ calibration system for IRVB [1].

1) Mukai, K. et al.: Rev. Sci. Instrum. **85** 11E435 (2014).