§8. Development of In-Situ Calibration System for Foil Detector of Infrared Imaging Video Bolometer in Large Helical Device

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The InfraRed imaging Video Bolometer (IRVB) is a useful diagnostics for the multi-dimensional measurement of plasma radiation profiles. The fundamental schematic of an IRVB is a combination of a pinhole camera and an IR camera. The profiles of the plasma radiation are collimated by an aperture (e.g. 8 mm × 8 mm) in the pinhole camera and are projected onto a thin platinum foil (e.g. 130 mm × 100 mm, t = 2.5 μm) as a two-dimensional temperature distribution. Here, the heat-diffusion effect of the foil must be considered to estimate the radiation profile from the IR image using the two-dimensional heat diffusion equation. Therefore, the local thermal characteristics, emissivity, ε, thermal conductivity, k, foil thickness, t_f, and thermal diffusivity, κ, should be calibrated over all the bolometer pixels (~1,000) on the foil. For the application of IRVB measurement to the neutron environment in fusion plasma devices such as the Large Helical Device (LHD), in-situ calibration of the thermal characteristics of the detector foil is required.

The schematic of the in-situ calibration system has been designed as follows.[1)] A periscope system must be applied to protect the IR camera detector from damage by the direct irradiation of X-rays, neutrons, and gammas from the plasma. A He-Ne laser (JDS Uniphase/ 1145, 632.8 nm × 22.5 mW) as the known radiation power source is injected to the foil. Laser irradiation points can be scanned using a mirror with two motorized goniometers (SIGMAKOKI/ GOHTM-40A60/ GOHTM-40A75), which correspond to the center of the each bolometer pixel. The visible laser can be transmitted to the foil and the IR radiation from the foil can be reflected to the IR camera using a hot mirror (Edmund Optics/ #64-472 45° 101 × 127) since it has a transmittance of > 85% for visible light and a reflectance of > 95% for IR signal.

The plasma side of the foil detector is coated by carbon to increase the absorption of broadband plasma radiation. The opposite (camera) side is also coated to increase the IR signal radiated to the IR camera. The laser must be injected from the camera side of the plasma radiation in this in-situ calibration system. Then, reproducibility and uniformity are required for the carbon coating on both sides. However, the conventional coating method using carbon spray cannot obtain high reproducibility and uniformity. Therefore, a vacuum evaporation technique was introduced in this study.

Small samples of the foil detector were made using the ICF 34 gaskets (ϕ = 16 mm) as the foil frame. The thickness of the platinum foil is 2.5 μm, same as in the LHD plasma experiments. The samples were coated on both sides by the spray or evaporation method. The evaporation coated sample was annealed at 400°C for 30 minutes before coating.

A He-Ne laser (JDS Uniphase/ 1135, 632.8 nm × 10.0 mW) was irradiated to the center of the foil samples in a test vacuum chamber. The IR images observed from opposite side of the laser are shown in Figure 5. Although a non-uniform structure was observed in the case of the spray coating (Fig. 1. (a)), the concentric circular temperature profile was obtained in the case of the vacuum evaporation coating (Fig. 1. (b)). These results indicate that higher reproducibility and uniformity of the coating can be obtained by the vacuum evaporation coating. Therefore, the vacuum evaporation coating technique can be applied for the in-situ calibration system. Moreover, the emissivity was increased from 0.6 to 0.9 using the vacuum evaporation coating by the rough estimation of a radiation pyrometer just after annealing. This result indicates that the S/N ratio of the IRVB measurement will be improved. Then, a high resolution detector will be realized and a large number of bolometer pixels can be obtained which is required for the tomographic reconstruction using many IRVBs.

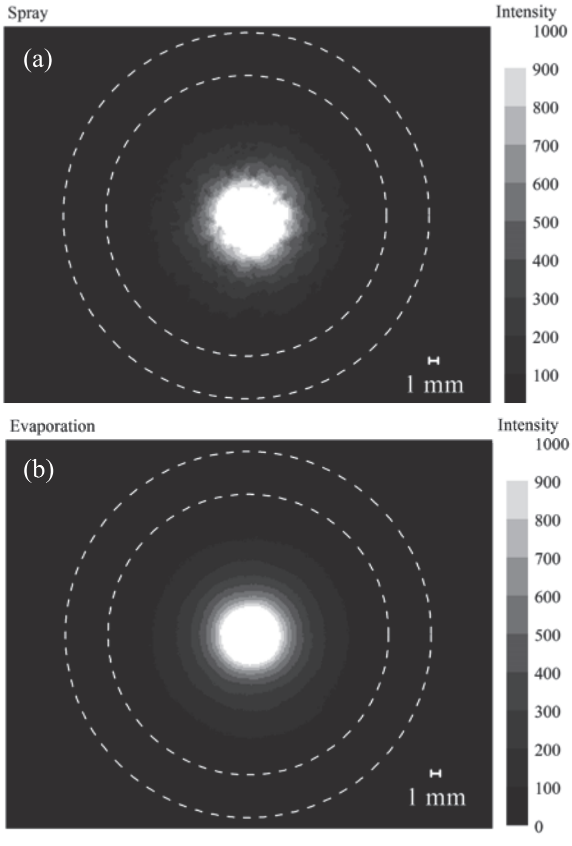

Fig. 1. IR images of (a) spray coated and (b) vacuum evaporation coated samples observed from opposite side of the laser irradiation. Color scale indicates the difference of IR intensity after and before the laser irradiation. Dashed lines show foil holder.

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