§18. Thermal Characteristics of Different Foils for an Imaging Borometer for LHD

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The infrared imaging video bolometer (IRVB) is useful to measure the radiative power from the LHD plasma. This diagnostic already has been applied to LHD and JT-60U. This method will be applied also to KSTAR and possibly ITER. In the bolometer using a thin metal foil, a 2D distribution of temperature is formed on the foil. An IR camera measures this distribution. The temporal and spatial resolution of the measurement depend on the thermal properties such as thermal conductivity and thickness of the foil, as well as radiative power intensity and photon energy. In order to calibrate the imaging bolometer, the spatial distribution of these foil properties must be determined 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 imaging bolometers on LHD to perform 3D tomography on LHD. In this fiscal year, the calibration methods for thermal diffusivity were developed for non-steady state IRVB measurement.

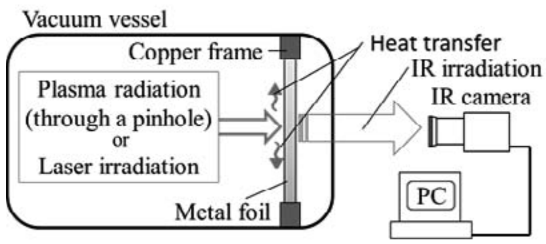

Fig. 1. The schematic of an IRVB principle.

Figure 1 shows the schematic of the IRVB principle. The metal foil absorbs the plasma radiation through an aperture and the resulting temperature distribution on the foil, which is measured by an IR camera, is used to calculate the absorbed radiation. Some spatial non uniformities occur in the physical and thermal parameters of the foil which determine the heat diffusion in the foil. Then, calibration is needed to compensate for these non uniformities in the heat diffusion equation of the metal foil. The parameters are the thickness of metal foil, t_f, the emissivity, ε, and the thermal diffusion coefficient, κ. Here, these parameters are obtained for each bolometer pixel area into which the foil is divided. The time derivative term in the heat diffusion equation was ignored in the previous calibration method. Therefore we investigated the influence of adding the time derivative term. That made the measurement of radiation in shorter time spans possible.

The conventional calibration method[1)] used the following procedure. (a) The laser irradiation of known power is used in the laser experiment instead of the incident plasma radiation. Next, the laser experiment is simulated by an FEM. (b) The effective thickness of the metal foil, t_f, and (c) the effective emissivity are estimated in an iterative calculation by comparing both results of laser experiment and simulation. (d) The processes (b) ~ (c) are replicated to converge to the estimated values.

A new method is established considering the non-steady state term in the heat diffusion equation through the use of t_f and ε from an estimation in steady state. In addition to the above procedure, (e) the temperature decay data on the foil is obtained at non-steady state after the laser irradiation to steady state. The temperature decay is obeyed Eq.1 while τ is the time constant.

$$\mathrm{T} = \Delta\mathrm{T}\left[\exp(-\frac{\sqrt{t}}{\tau})\right] + T_0 \qquad (1)$$

(f) The heat diffusion coefficient κ is estimated in the non-steady state calculation using τ. In this case, the variable parameter used in the FEM in the iterative calculation is the density ρ. (g) The calculation is replicated until the estimated value of ρ converges. Then, κ can be obtained using the equation, κ=*k*/(*c*ρ), where *k* is thermal conductivity and *c* is the thermal capacity.

Figure 2 shows a plot of the time dependence of the temperature at a location with the laser irradiation after it was shuttered. The line shows the decreasing temperature in the experiment, and the triangle symbols show the FEM simulation. Each determined value is about 0.93 of the value of the previous iteration at the selected representative points in the foil, which are at the corner, the edge and the central parts. This suggests that the model has great reproducibility. The time constant τ is obtained from a fit to the decay plot in Eq. 1. After several iterations the FEM time constant converges to the experimental one and then, the density, ρ, is obtained.

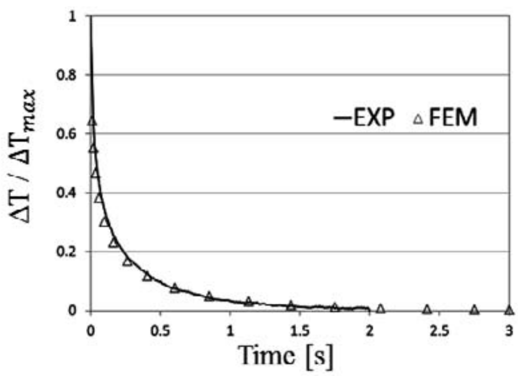

Fig. 2. The decrease of the temperature with time. The line is from the laser experiment, and the square plots from the FEM.

1) Sano, R. et al. : Plasma Fusion Res. **7** (2012) 2405039.