Improvement of the Accuracy of the Imaging Bolometer Foil Laser Calibration

H. ParchamyAraghy, B.J. Peterson, N. Ashikawa, H. Hayashi, H. Kawashima[1], and S. Konoshima[1]

National Institute for Fusion Science,322-6 Oroshi-cho, Toki 509-5292, Japan

[1] Japan Atomic Energy Agency, Naka-shi, Ibaraki-Ken, 311-0193, Japan

An imaging bolometer with a single graphite-coated metal foil is a diagnostic tool for diagnosing plasma radiation from magnetic fusion plasmas. We could obtain the local foil properties (the thermal diffusivity, κ, and the product of the thermal conductivity, k, and the thickness, t_f) of the metal imaging bolometer foil by analyzing the calibration data. For improving the IRVB a Tantalum (Ta) foil is offered due to strength, low neutron cross-section, and high sensitivity, however there is a large discrepancy between the value of the foil thickness from the experimental value and the nominal value. For calibrating of the foil the He-Ne laser beam is focused on 63 various locations which are determined by using the marks on the frame. The parameters of the foil are determined by comparing the measured thermal radiation data from an IR camera (FLIR/SC500) (60 Hz, 320 × 240 pixels, 7.5-13 μm) with the corresponding results of a finite element model.

Keywords: Accuracy, calibration, He-Ne laser beam, improve, imaging, bolometer

.

1. Introduction

The infrared imaging video (IRVB) bolometer with a single graphite-coated metal foil is a diagnostic tool that can act as a broadband absorber of radiation from nearly all spectral regions from of the foil plasma and convert its energy into a measurable temperature rise [1].

The calibration technique of the infrared imaging bolometer foil gives confidence in the measured values of the total radiation power from the plasma, and compensates for non-uniformities in the foil [2, 3]. The local foil properties of the foil such as the thermal diffusivity, κ, and the product of the thermal conductivity, k, and the thickness, t_f, are obtained by the foil calibration for one part on the foil when the foil is heated by the laser power [2]. Tantalum (Ta) is offered for improved sensitivity, foil strength, and lower neutron cross-section compared to the previously used gold foil of the imaging bolometer for the JT-60U tokamak [4].

Here, the improvement of the accuracy of the laser calibration of the imaging bolometer foil is considered.

2. The single graphite-coated metal(Ta and Au)foil

For improving the accuracy of the foil calibration of the imaging bolometer foil a new calibration setup in laboratory (low noise environment) has been designed and set up [4].

A single graphite-coated gold foil with an effective area of 9 × 7 cm^2 and a nominal thickness of 2.5 μm for use in the IRVB of LHD and a single graphite-coated tantalum foil with an effective area of 9 × 7 cm^2 and a nominal thickness of 5 μm for use in the IRVB of JT-60U is used on the calibration setup. Both sides of the foils are blackened with graphite. The blackened sides are heated by a 500 W heat lamp for drying the foils after spraying. The foils that are supported by a copper frame are shown in Fig. 1.

Calibration of the foil was made using a He-Ne laser as a known radiation source to heat the foil. The laser beam (~27 mW) is directed by three mirrors that are positioned by z and x-axis stages, to propagate through a CaF2 window in a chamber that is evacuated by a turbomolecular pump below 10^{-3} Torr and is focused on the foil. The blackbody radiation power from the foil that is heated by the laser beam is detected by an IR camera through a ZnSe window.

The IR camera (FLIR/SC500) with a frame rate of 60 Hz and pixel number of 320 × 240 is a microbolometer detector type that is sensitive to the far infrared wavelength range (7.5-13.0). The IR camera is moved by using a lab-jack (in z direction) and x-axis-stage (in x direction) for providing the thermal images of the foil which is heated by the He-Ne laser beam. In Fig.1, two contour thermal images from the laser spot after focusing on the foil (the center and the edge) resulting from the blackbody radiation from the foil are shown.

author's e-mail: journal@jspf.or.jp

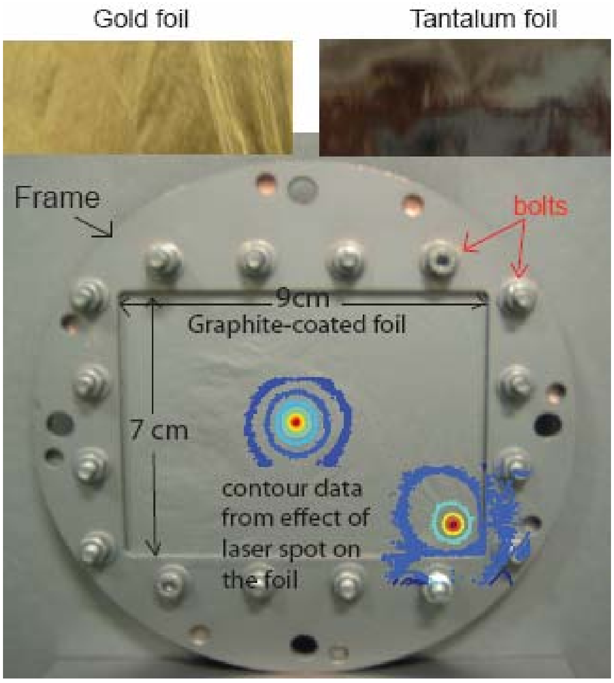

Fig.1 The single graphite-coated (one for Ta and one for Au separately) foil that is supported by a copper frame and temperature contour images from the laser spot after focusing on the foil (center and edge).

3. Improvement of Foil Calibration

The accuracy of the calibration of imaging bolometer foil is improved by using a new calibration setup and a FLIR/SC500 IR camera with a close-up lens at laboratory (low noise environment). This combination provides a spatial resolution of ~ 0.09 mm which is ~ 7 times better than the previous in situ calibration using a different Indigo/Omega IR camera where the spatial resolution of this camera is ~ 0.648 mm. The laser beam is focused on various locations which are determined by using the marks on the frame. Calibration data were taken at 63 (7 × 9) points on the foil. For the foil calibration using a HeNe laser, the laser power is necessary for solving the heat diffusion equation in two dimensions analytically by using the finite element model (FEM). A new model is made by finite element modeling according to the resolution of the FLIR/SC500 camera and the laser beam diameter.

The foil temperature rise was taken from the peak of a 2D Gaussian fitted to the temperature profile from the IR camera. The IR thermal data are averaged over 200 time frames of the steady state data. The FEM is used for solving of the two-dimensional heat diffusion equation with a constant thickness and thermal parameters of the foil and approximately 2000 spatial points assuming a constant temperature at the foil boundary. The FEM used the measured beam profile, fit to a 2-D Gaussian, as the heat source term.

A second order polynominal is fitted to the kt_f (the thermal conductivity is assumed to be constant at the nominal value) and ΔT data from the FEM to find the effective value of the t_f of the foil from the experimental value of ΔT. The variation of t_f from two locations (center and edge) of the gold foil (with nominal value of the foil thickness, t_f = 2.5 μm), and the tantalum foil (with a nominal value of the foil thickness, t_f= 5 μm), is shown in Fig.2.

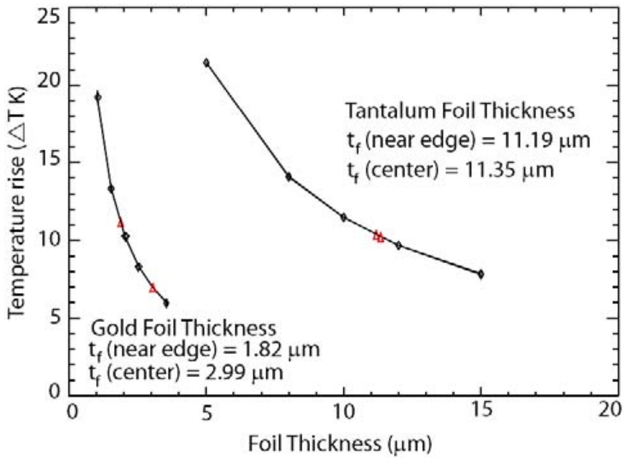

Fig.2 The appropriate value of the product of the kt_f of the (Au and Ta) foil from the experimental value of the ΔT is found from fitting a second order polynominal to the kt_f and the ΔT data from the FEM.

Acknowledgment

The authors are grateful to the support given by the MEXT Grant-in-Aid # 16082207.

References

[1] B. J. Peterson, A. Yu. Kostrioukov, N. Ashikawa, M. Osakabe, and S. Sudo, Rev. Sci. Instrum., vol. 74, 2003 , pp. 2040.

[2] H. Parchamy, B. J. Peterson, et al., Rev. Sci. Instrum. 77, 515 (2006)

[3] H. Parchamy, B. J. Peterson, et al., Plasma Fusion Res. 2, (2007) (in press).

[4] B. J. Peterson, et al., Plasma Fusion Res. 2, (2007) (in press)

[5] H. Parchamy, B. J. Peterson, H. Hayashi, S. Konoshima, N. Ashikawa, and the LHD team, Submitted for publish to IEEE TPS