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Test results of active thermography method for plasma-wall interaction studies on the KTM tokamak

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In November 2019, the physical start-up of KTM tokamak was carried out. One of the main research task of KTM tokamak is study of behavior of first wall candidate materials under influence of high heat flux, which is expected to be in future thermonuclear reactors [Ref.1]. KTM is an aspect ratio A=2, single null divertor configuration, plasma current Ipl=750 кA, toroidal magnetic field Bt=1 T, plasma pulse duration in an ohmic mode τpulse≤1 seconds and up to 5 seconds with 5 MW ion cyclotron resonance additional heating. In the KTM the maximum estimated heat flux value on the divertor plates is expected to be 20 MW/m2, which is corresponds to expected heat load value in ITER [Ref.2].
Currently one of the optimal methods for the surface temperature measurements of first wall materials is noncontact infrared thermometry. It is possible to measure temperature distribution on a surface of research material with high spatial and temporal resolution by using thermographic camera According to physical principle of thermographic camera it is required to set correct body emissivity value to achieve precision temperature measurements.
In international experimental thermonuclear reactor ITER is planned to use metallic first wall made of beryllium and tungsten. In addition, studies of possibility to use lithium as first wall material for TNR and other materials are extensively carried out in the world.
Metallic first wall leads to the problem of precise determination of surface temperature by optical thermometry. This is due to the fact that metals are not black bodies, have low emissivity which in most cases depends on temperature. In addition, emissivity depends on condition of material surface and able to vary with time due to the both surface modification under effect of plasma emission and deposition material dust particle on the surface or, for instance, beryllium particle deposition on divertor plates made of tungsten. In such case, measurement error can achieve dozens of percent, especially in high temperature area.
For the correct thermographic measurements the original method was suggested [Ref.3,4]. This method allows to measure emissivity changes of research material during the plasma influence. The method based on using of IR laser. The method is based on the use of an infrared laser (IR) at the wavelength of the working range of the thermographic camera. Pulse-periodic laser radiation is used directly to determine emissivity changes of the sample during the plasma discharge and the corresponding correction of temperature measurements of the thermographic camera. The use of this method is designed to increase the accuracy of temperature measurements of the surface of the investigated materials with a thermographic camera in a wide temperature range.
The main idea of the proposed method is to use pulsed laser emission projected onto the body surface in the field of view of thermographic camera. Laser emission partially reflects from the surface of the body. It is possible to measure body reflectivity ρ or reflectivity changes by measuring power of reflected emission Wref. Since there is a direct dependence for opaque bodies between the emissivity (emissivity factor) ε and the reflectivity (the reflection coefficient) ρ:
ρ+ε=1, (1)
then when the value of one of the terms changes, for example, with increasing temperature, the second one also proportionally changes. Thus, it is possible to determine the value of the emissivity by controlling the value of body reflectivity
To control the reflection coefficient, it is proposed to apply periodic short pulses of the IR laser with a duration not exceeding one frame exposure and with a maximum repetition frequency ½ of the camera registration frequency. In this case, the laser pulses must be strictly synchronized with the exposure of the frame. Fig. 1 shows the proposed time diagram of the IR camera and laser. As can be seen from Fig. 1, application of such time diagram of the IR camera and IR laser operation, it is possible to measure the emitting power directly both from the body itself Wbody and from emission together with the reflected laser emission Wbody+ref= Wbody+ Wref. At the same time, the maximum effective operating frequency of the camera is reduced by half.

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Depending on the speed of the heating the body surface, the frequency of laser pulses can vary from a peak

equal to half of the maximum frame rate of the IR camera to the necessary minimum to control the heating rate.
Theoretically, the change of reflectivity Δρ can be defined from the change in the power of the reflected laser emission:
Δρ(T_0-T_i)/ρ(T_0) =(W_ref (T_0)-W_ref (T_i))/(W_ref (T_0)), (2)
where,
Wref (T0) –initial reflected laser emission at temperature T0
Wref (Ti) - reflected laser emission at temperature Ti
ρ(T0) –initial reflectivity at temperature T0
Thus, the change of body emissivity coefficient can be determined by measuring the change in the reflection coefficient. Since initially the value of ρ(T0) of the test sample is unknown, it is determined experimentally before plasma experiments.
The paper shows and discusses the results of testing the technique on a plasma beam facility [Ref.5]. Tungsten samples were heated by electron beams. Fig. 2 shows a layout of experiments on the plasma beam facility. During the experiments the samples were heated up to 1200 °C.

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Fig. 3 shows the curves of the relative changes of the reflected laser power radiation and reflectivity for the one of the tungsten samples. The emissivity of the sample determines by the measured temperature of the sample using a thermocouple, in accordance with the method in [Ref.6]. Then reflectance is calculated according to equation (1).

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As can be seen from the data in Fig. 3, there is a fairly close coincidence of the measurement results for the proposed method and for the found values determined using thermocouple readings. Deviation is within the limits of the measurement accuracy.
Thus, testing results of the proposed thermographic method on the plasma beam facility has shown the possibility of using.

References

1 I. L. TAZHIBAYEVA, et al., "KTM Experimental Complex Project Status", Fusion Science and Technology, vol.47, April 2005, p.746 –750.
2 N. Holtkamp, et al. An overview of the ITER project. Fusion Engineering and Design. Volume 82, Issues 5–14, 2007, Pages 427-434. https://doi.org/10.1016/j.fusengdes.2007.03.029.
3 Concept of a new approach in thermographic measurements for plasma-wall interaction studies on KTM tokamak / B. Chektybayev, E. Batyrbekov, M. Skakov, A. Sadykov // Program and Abstracts of 27-th IAEA Fusion Energy Conference, Ahmedabad, India, 22-27 October, 2018.
4 Active thermography method for metallic plasma-facing components temperature measurements in the thermonuclear fusion devices/ B. Chektybayev, E. Batyrbekov, M. Skakov, A. Sadykov // Abstract book of the 3-rd Quantitative InfraRed Thermography Conference Asia, Tokyo, Japan, 1-5 July, 2019.
5 V. Kurnaev, I. Vizgalov, K. Gutorov, T. Tulenbergenov, et al. , Investigation of plasma-surface interaction at plasma beam facilities, Journal of Nuclear Materials, Vol. 463, August 2015, Pages 228-232.
6 ASTM E 1933 –97, "Standard Test Methods for Measuring and Compensating for Emissivity Using Infrared Imaging Radiometers", 962-3 p, (1997).

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