OPTICAL MONITORING THE TEMPERATURE OF OBJECTS IRRADIATED AT AN ELECTRON ACCELERATOR

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A method of remote on-line control of the temperature of objects heated by an electron beam has been developed and researched. The method is based on analysis of object radiation in optical and infrared ranges and determination of temperature using the calibration data. Experimental study of the method was conducted at an accelerator LU-10 KIPT in a mode with electron energy from 8 to 10 MeV and beam power up to 10 kW. To monitor the temperature of the irradiated samples, a Transcend video camera with a matrix of 1.3 MP operating both in visible and infrared spectrum bands was used. The camera calibration in the infrared range was executed by electric heating of a sample at the test bench. Measuring the temperature of the sample was carried out using a Chromel-Kopel thermocouple and digital meter TERA.

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INTRODUCTION

A method of remote on-line control of the temperature of objects heated by an electron beam has been developed and researched. The method is based on analysis of object radiation in optical and infrared ranges and determination of temperature using the calibration data. At that, the system of electron beam visual monitoring [1] (Fig. 1), which had been developed previously, using Transcend video camera with a matrix of 1.3 MP operating both in visible and infrared spectrum bands, was used.

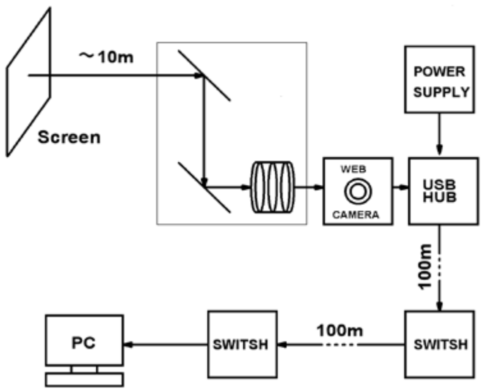

Fig. 1. Block diagram of the system of electron beam image visual monitoring

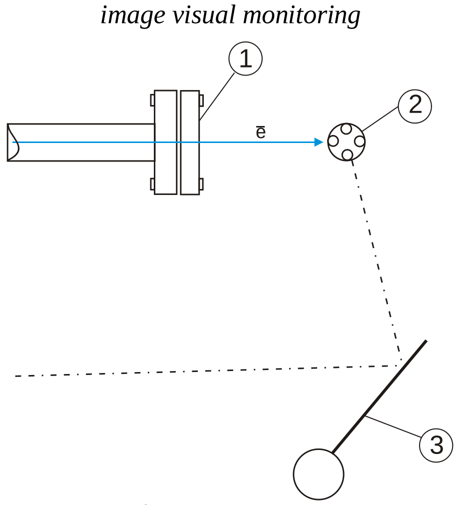

Fig. 2. Location of the object to be radiated at LU-10 output, top view: 1 – scanner output flange; 2 – channels of the radiated camera; 3 – mirror

The additional mirror was used to monitor the process of heating of the object by the electron beam at accelerator bunker LU-10, because the output flange of the beam scanner obstructed the object and it was not visible (Fig. 2).

CAMERA CALIBRATION

The camera calibration in the infrared range was carried out at the test bench by electric heating of the sample. Schematic diagram of the test bench is presented in Fig. 3.

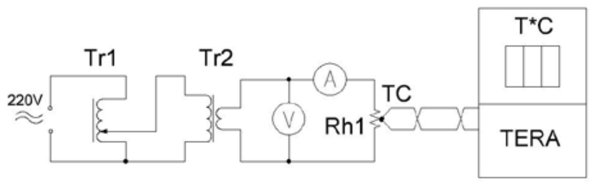

Fig. 3. Schematic diagram of the test bench for calibration

The thin-walled stainless steel tube, indicated in the diagram by Rh1, was used as a calibration sample. The voltage at the ends of the heated sample was changed from 1.7 to 3.5 V; current – from 19 to 33 A using 9 A Latro Tr1. The transformer is manufactured using magnetic core and primary winding 9A Latro, the secondary winding consists of two winding turns of 120 sq. mm cooper wire. Thermocouple TC, connected direct to the input of temperature digital meter TERA, is fixed in the middle of the calibration sample.

Fig. 4. One of the frames of the calibration video recording, left – reflection of the heated object in the mirror, temperature 490.4°

The calibrated camera was focused on the heated sample with the thermocouple attached, as well as the display device of digital meter TERA. Thus a series of frames have been obtained, each of them shows the values of infrared radiation intensity and the related values of the sample temperature. One of these frames is presented in Fig. 4 as an example.

Each frame was processed in program Origin 7.5. Screenshot with the intensity profile of infrared glowing of the sample, reflected in the mirror, is presented in Fig. 5.

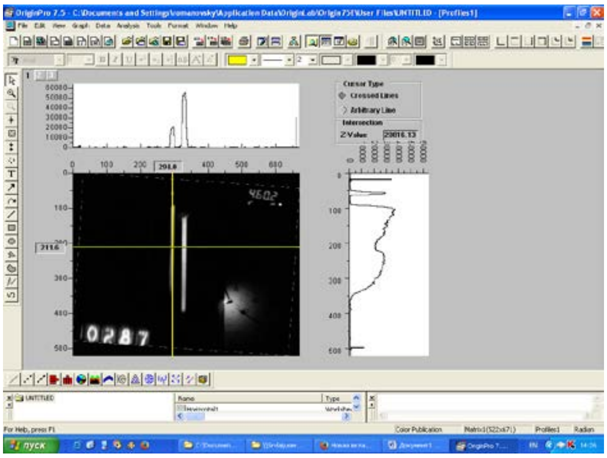

Fig. 5. Profile of intensity of infrared radiation of the calibration sample at the temperature of 460 °C

The minimum value of the intensity corresponds to the thermocouple attachment point. This is the required point for calibration. The calibration curve, shown in Fig. 6 was plotted by several of such points.

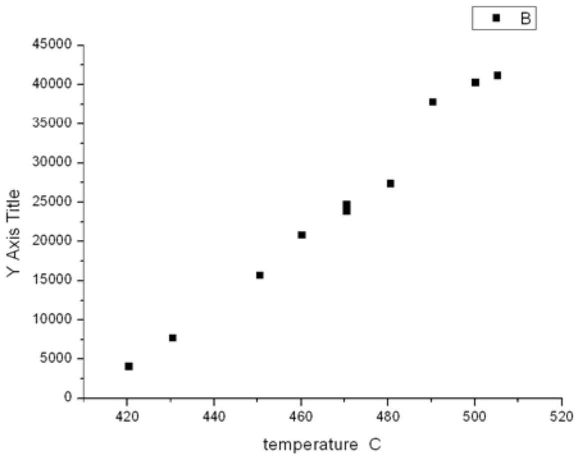

Fig. 6. Calibration curve

THE EXPERIMENT CARRIED OUT AT LU-10 LINAC

The frame from video recording of radiation treatment of the calibration sample at LU-10 linac is presented in Fig. 7. This sample was scanned by the electron beam with energy of 9 MeV, pulse rate of 125 Hz, average current of 0.39 mA, pulse current of 0.92 A, sweep current of 12.2 A.

Processing in Origin 7.5 shows the value of glowing intensity equal to 57789 nominal units (Fig. 8), that corresponds to temperature 540°C.

Fig. 7. Infrared glowing of the sample at LU-10

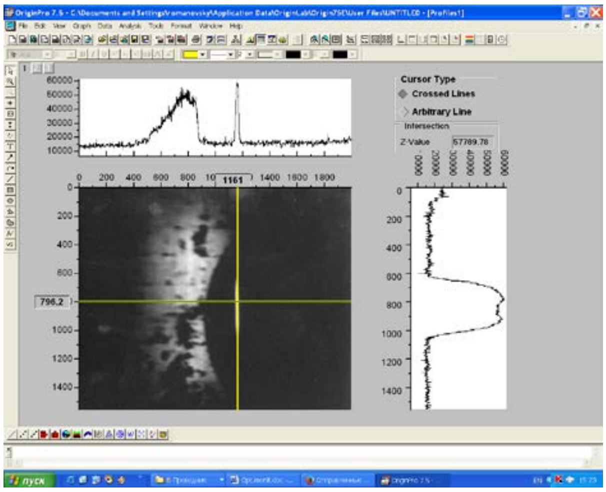

Fig. 8. Profile of infrared glowing of the calibration sample when heated by the electron beam

Besides this experiment the authors used the archive video recording of steel samples radiation treatment in LU-10. It was recorded by the same camera. These hardened steel materials are supposed to be used in nuclear power engineering. Glowing of the calibration sample reflected in the mirror is presented in Fig. 9.

Fig. 9. Infrared glowing of the calibration steel sample reflected in the mirror

After these frames processing in Origin 7.5 we obtained a curve of the temperature distribution on the surface of the sample (Fig. 10).

Using the developed method the temperatures of all six samples were determined from the frames of video recording. These data comply with the calculations of the customer.

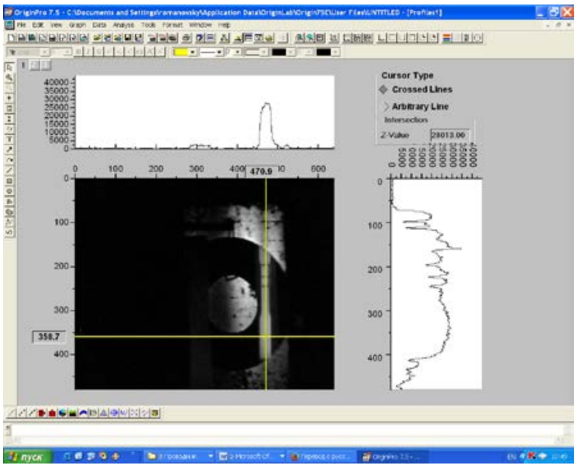

Fig. 10. Profile of sample infrared glowing

CONCLUSIONS

The developed method of remote monitoring enables to obtain in on-line mode 2D the temperature profile of objects surfaces when heated by electron beam. Operability, personnel safety and visibility are the main advantages of this method. This method enables also to monitor the beam current density profile and absorbed dose rate on the surface of objects at the appropriate calibration.

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ОПТИЧЕСКИЙ МОНИТОРИНГ ТЕМПЕРАТУРЫ ОБЪЕКТОВ, ОБЛУЧАЕМЫХ НА УСКОРИТЕЛЕ ЭЛЕКТРОНОВ

В.Н. Борискин, С.К. Романовский, В.А. Момот, Ю.А. Титаренко, Д.В. Титов, В.Л. Уваров, В.А. Шевченко, С.В. Шелепко

Разработан и исследован метод дистанционного on-line-контроля температуры объектов при их нагреве пучком электронов. Метод основан на анализе излучения объектов в оптическом и инфракрасном диапазонах и установлении значения их температуры с использованием калибровочных данных. Экспериментальное исследование метода проведено на ускорителе ЛУ-10 ННЦ ХФТИ при энергии электронов 8…10 МэВ и мощности пучка до 10 кВт. Для мониторинга температуры облучаемых образцов была использована видеокамера Transcend с матрицей 1,3 Мп, работающая как в видимой, так и в ИК-областях спектра. Калибровка показаний видеокамеры в ИК-диапазоне производилась на стенде при нагреве образца электрическим током. Измерение температуры образца производилось с использованием термопары хромель – копель и цифрового измерителя ТЭРА.

ОПТИЧНИЙ МОНІТОРИНГ ТЕМПЕРАТУРИ ОБ'ЄКТІВ, ЩО ОПРОМІНЮЮТЬСЯ НА ПРИСКОРЮВАЧІ ЕЛЕКТРОНІВ

В.М. Борискін, С.К. Романовський, В.О. Момот, Ю.О. Тітаренко, Д.В. Тітов, В.Л. Уваров, В.О. Шевченко, С.В. Шелепко

Розроблений і досліджений метод дистанційного on-line-контролю температури об'єктів при їх нагріві пучком електронів. Метод заснований на аналізі випромінювання об'єктів в оптичному і інфрачервоному діапазонах і встановлено значення їх температури з використанням калібрувальних даних. Експериментальне дослідження методу проведене на прискорювачі ЛУ-10 ННЦ ХФТІ при енергії електронів 8…10 МеВ і потужності пучка до 10 кВт. Для моніторингу температури опромінюваних зразків була використана відеокамера Transcend з матрицею 1,3 Мп, що працює як у видимій, так і в ІЧ-областях спектра. Калібрування відеокамери в ІЧ-діапазоні вироблялося на стенді при нагріві зразка електричним струмом. Вимір температури зразка проведено з використанням термопари хром ель – копель і цифрового вимірника ТЕРА.