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LABORATORY TECHNIQUES

A System for Brightness Pyrometry of Objects via a Water Streak

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Abstract—A television pyrometric system for video observation and temperature measurements of incandescent objects via a 100-mm-thick water streak was developed. The factors affecting the visualization process were experimentally investigated. The error of temperature measurements was evaluated and its values were no greater than 7% in the range of 814–1400°C.

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Water streaks fulfilling various functions are widely used today in engineering and modern high-temperature technologies. Along with underwater welding and electroerosion cutting processes, liquid cooling systems based on distilled or process water [1] are predominantly used in many high-temperature electrothermal plants (ETPs).

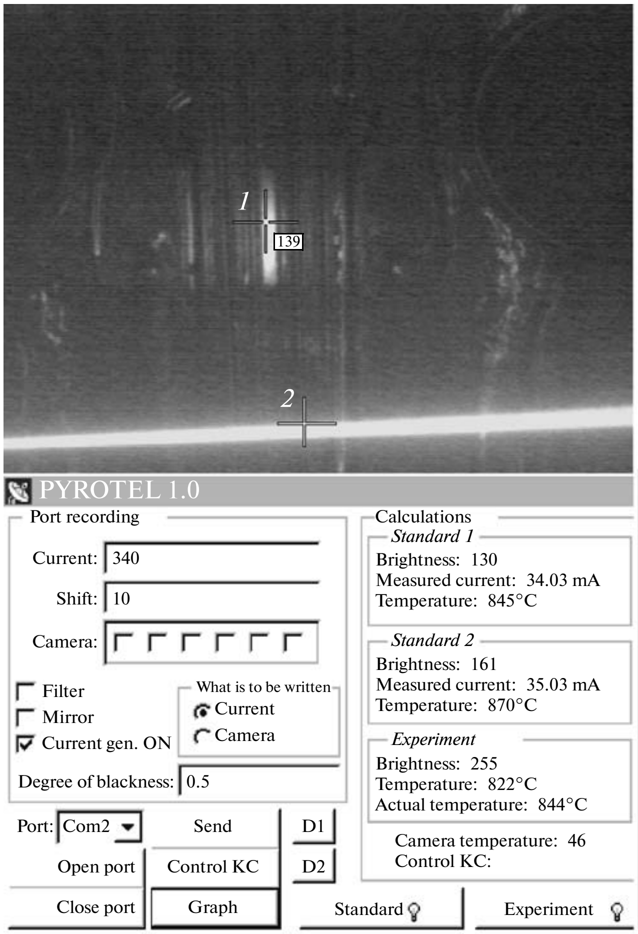
Thus, ETPs with induction heating and water-cooled quartz reactors transparent to visible light are used in production of electronic components, e.g., in growing crystals and epitaxial layers of some semiconductor materials [2]. These features of the ETP design offer a chance to monitor the state of the incandescent reactor fittings and measure their temperature [3, 4]. Water is known to be an absorbing medium for IR radiation, and it is this fact that rules out the possibility of using IR and thermal imagers [5, 6] that are widely available in the market. In this paper, we present results of investigations aimed at designing a television pyrometric system (TPS) for visualizing and measuring the temperature of incandescent objects via a water streak.

The experiments were carried out on a laboratory bench comprising a TPS, optical cells (with 10-, 50-, and 100-mm-thick flat streaks) filled with process water, and an object of investigation. A multimeter with a thermocouple temperature sensor (ТХА), a luxmeter (Ю-88), and a viewing device (ВП23В102) were the auxiliary equipment used in the measurements. A tungsten strip heater (a reference СИ10-300 lamp with a known calibration characteristic) acted as the incandescent object. During the experiments, the maximum distance between the input objective of the TPS and the cell was ~1 m, and the cell-to-reference lamp distance did not exceed ~0.5 m.

The TPS prototype is based on an industrial television (TV) camera with 1/3″ monochrome photosensitive CCD having $580(V) \times 500(H)$ elements, in which it was possible to specify the speed of the electronic shutter (from 1/100 to 1/10000 s), the nonlinearity factor of the TV camera's light-signal characteristic $\gamma = 1$, the limit on the white level, and a fixed gain. The selective filter permitted the changing of the brightness temperature at effective wavelength $\lambda = 655$ nm. In addition, a controller unit for controlling the pyrometric lamp and the TV camera, as well as a personal computer with a video capture card was included in the TPS. The PYROTEL 1.0 program was developed; it was used to support data exchange with a remote computer, determine the brightness of the user-specified point on a video image, calculate the brightness temperature and the actual temperature, and execute operations of adjustment and system calibration.

It is known that visualization of various objects in a water medium and measurement of their geometrical characteristics are distinguished by certain specific features attributable to absorption and scattering of luminous energy, to phase transformations, etc. [7]. The experimental investigations have allowed us to reveal the following features, apart from those mentioned above, in video observations of the incandescent tungsten strip via water streaks: (1) repeated reflection from the interphase boundary and, therefore, occurrence of flare spots and redistribution of the recorded brightness contrast of the object; (2) the lens effect dependent on the water streak shape; and (3) formation of schlieren lenses by gas beads falling in the camera's field of view and by convective flows originating near the walls of the cell [8]. In addition, heating of the photodetector array by the background and under the influence of the scattering magnetic field of the heater (the inductor) is an important factor affecting the methodological error of measurements.

To minimize the measurement error, a new method for measuring the brightness temperature has been proposed and tested. This method involves operation in two modes [9]: (1) video observation and measurement of the brightness temperature of the object and (2) calibration using a built-in brightness temperature calibrator based on a ТРВ 800-1400 pyrometric lamp.



Experimental measurement of the incandescent tungsten strip temperature via a water streak using the TPS (flat streak thickness, 100 mm; $T_{strip} = 1000°C$; $T_{amb} = 25°C$; and illuminance, $E = 40$ lx): (*1*) tungsten strip of the lamp and (*2*) filament of the reference source of the brightness temperature.

The system was switched to the calibration mode when certain characteristics of the electronic section went beyond the permissible limits. The transparency of the water in the streak, the current temperature of the photodetector array, and the background exposure were taken into account when performing the initial calibration of the pyrometer.

An example of visualization and measurement of the tungsten strip temperature using the TPS is shown in the figure, and the measured brightness temperatures and the relative error of measurements are presented in the table. Analyzing the results of laboratory investigations, we noticed the occurrence of repeated reflections and flare spots, which, naturally, had an effect both on the process of incandescent tungsten strip visualization and on the accuracy in measuring the brightness temperature (an increase in the relative error with an increase in the temperature of the strip).

In conclusion, let us present the main results of our study. As shown in our experiments, repeated reflection of light and the lens effects are the most significant factors that locally affect the process of visualization and temperature measurement of an incandescent object.

The proposed method for measuring the brightness temperature offers a chance, along with improvement of the measurement accuracy, to increase the life time of the reference source of the brightness temperature and extend the technological potential of the television pyrometer.

Results of experimental investigations of the TPS functional capabilities (streak thickness, 50 mm; $T_{amb} = 25°C$; illuminance, $E = 40$ lx)

Strip temperature, °C	T_{av}, °C	Error, %
814	805.4	1
900	863.8	4
1000	932.4	6
1100	1028.8	6.4
1400	1486.8	6.2

REFERENCES

1. Sokunov, B.A. and Grobova, L.S., *Elektrotermicheskie ustanovki* (Electrical Installations), Yekaterinburg: GOU VPO UGTU-UPI, 2004.
2. Godisov, O.N., Kalitovskii, A.K., Safronov, A.Yu., et al., *Fiz. Tekh. Poluprovodn. (St.-Petersburg)*, 2002, vol. 36, no. 12, p. 1484 [*Semiconductors* (Engl. Transl.), vol. 36, no. 12, p. 1398].
3. Rainova, Yu.P., Antonenko, K.I., Petsol'dt, I., et al., Abstracts of Papers, *VIII Rossiiskaya Nauchno-tekh. konf. "Datchiki i preobrazovateli informatsii sistem izmereniya, kontrolya i upravleniya"* (VIII Russ. Sci. and Tech. Conf. "Sensors and Data Converters of Measuring, Monitoring, and Control Systems"), Moscow, 1996, p. 112.
4. Karachinov, V.A., Il'in, S.V., and Karachinov, D.V., *Pis'ma Zh. Tekh. Fiz.*, 2005, vol. 31, no. 11, p. 1.
5. Gaidukevich, Yu.Ch., Domarenok, N.I., and Dostanko, A.P., et al., *Elektronnaya Promyshlennost*, 1987, no. 3, p. 59.
6. Porev, V.A., *Tekhnicheskaya Diagnostika i Nerazrushayushchii Kontrol'*, 2002, no. 4, p. 36.
7. Martynov, V.L., Abstracts of Papers, *XIV Nauchno-tekh. konf. "Sovremennoe televidenie"* (XIV Sci. and Tech. Conf. "Modern Television"), Moscow, 2004, p. 120.
8. Karachinov, V.A., Il'in, S.V., and Toritsin, S.B., *Vestnik NovGU im. Ya. Mudrogo, Ser. Tekh. Nauki*, 2003, no. 23, p. 86.
9. Toritsin, S.B. and Karachinov, V.A., RF Patent No. 2247338, 2005.