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PHYSICAL INSTRUMENTS FOR ECOLOGY, MEDICINE, AND BIOLOGY

A Multi-element Thermal Imaging System Based on an Uncooled Bolometric Array

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Abstract—A thermal imaging system based on a commercial uncooled microbolometric array of 384 × 288 elements has been developed and produced. The temperature and spatial resolutions of the system are <0.08°C and 0.96 mrad, respectively. The system has been designed to monitor the technical state of thermal power industry objects. Owing to the "open architecture" and the modular structure of the hardware and software, the system can be adapted for any thermal diagnostic task.

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Thermal imaging is a high-efficiency method for monitoring the technical state of thermal power industry objects, which has found wide application in developed countries. It is based on remote measurement of temperature fields on surfaces of buildings and heat pipelines, as well as thermal and electric power equipment. These fields contain information on heat exchange processes of inside and outside objects, nonuniformities in the thermal and physical properties of barriers, the quality of thermal insulation, defects in equipments, etc.

A wide range of commercial thermal imaging systems produced, mainly, by foreign countries, is available on the market. Nevertheless, for enterprises of the Russian and Ukrainian heat power industries, the possibility of carrying out regular thermal imaging inspection is limited, on the one side, by the high price of such a system and, on the other, by the absence of special software in these systems, which would allow not only the obtaining of thermal maps of surfaces, but also prompt quantitative estimation of the thermal losses, the parameters of safety constructions, the characteristics of thermal insulation, and other parameters in comparison with the requirements of standards. It is impossible to introduce these auxiliary functions into the software of serially produced thermal imaging systems, which do not allow access for changing and updating their hardware and software. Therefore, to perform specific or nonstandard tasks, special thermal imaging devices or "open architecture" systems are currently developed throughout the world [1]. The state of the art of domestically produced thermal imaging systems that can be used as a basis for developing systems flexibly adaptable to each specific diagnostic task is mainly limited by single-element devices or systems based on cooled linear arrays or small-format arrays, e.g., IRTIS-2000 single-element systems (OOO IRTIS, Russia) [2], TK-1 (Ukraine) [3, 4], and systems based on multielement small-format cooled receivers (Ukraine) [5]. The advantage of these systems is in the availability of its hardware and software, i.e., the possibility of not only manufacturing an instrument optimally adapted for a specific task, but also of easily upgrading it during operation for a new task. The necessity of mechanical scanning and the use of liquid nitrogen for cooling the receivers are the drawbacks of all the above systems. This essentially limits their field of application and can be attributed to the requirements for their costs and the absence of the technology for producing high-quality large-format uncooled bolometric arrays in Russia and Ukraine.

Today, some firms specializing in manufacturing electron-optical devices have offered for free sale a number of original equipment manufacturer (OEM) IR modules composed of uncooled arrays of large-format IR detectors, which have minimum electronic equipment for production of video signals in either format and are intended for use as a basis in designing thermal imaging systems with necessary parameters.

In this paper, we describe a thermal imaging system developed on the basis of an IR112 uncooled IR module (ULIS, France). This module contains an uncooled focal plane array (FPA) of bolometric detectors, which is made from amorphous silicon with a format of 384 × 288 pixels [6] and bonded to a standard readout integrated circuit (ROIC), and a digital preprocessor used for preliminary processing of the signal, in particular, for equalizing the sensitivity of pixels in the array. Owing to the high parameters of detected radiation conversion and the high spatial resolution (the dimensions of a pixel in the array are 35 × 35 μm), the small size, and the presence of the user's digital

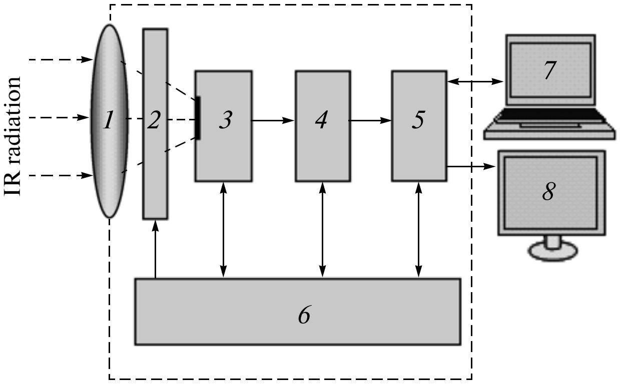


Fig. 1. Block diagram of the thermal imaging system: (*1*) objective lens, (*2*) reference emitter, (*3*) IR112 module, (*4*) signal processor, (*5*) interface module, (*6*) electronic unit, (*7*) PC (PDA), and (*8*) TV monitor.

Fig. 2. External appearance of the thermal imaging system with a standard objective lens.

output, to the connector of which all the data and synchronization signals needed for further upgrading are applied, this module is an ideal basis for designing complete high quality systems capable of forming images with a frequency of up to 50 Hz.

In our thermal imaging system, the IR112 module was complemented with necessary optical elements and electronic units, and original software was developed in accordance with the specific features of this task. The functional diagram of the designed system is shown in Fig. 1.

Germanium objective lens *1* is used to focus IR radiation in the focal plane of the IR112 module array *3*. The system design allows the use of several replaceable objective lenses depending on the specific features of each particular task of thermal diagnostics. Thus, in addition to the standard germanium objective lens with a 40-mm focal length, which is mainly used to observe closely spaced objects, a seven-lens germanium zoom lens with double optical magnification was specially designed for high-quality thermal imaging of heat-power engineering objects from a large distance. This zoom lens has a focal length of 36.2–72.7 mm, a lens aperture of 1.0 : 1.4, and a field of view of 33–16.5°.

ADSP2188 digital signal processor *4* is linked with the user connector of the IR112 module and used for further processing of the signals from the detector array elements in the digital form. In particular, it performs buffering of picture frames in the chip of the static random-access memory (RAM) with a capacity of 512 Kbyte, online averaging of picture frames to improve the sensitivity, and frame-by-frame data transfer to interface electronic module *5*.

The interface module is based on an FT245R chip, which is a converter of digital data in parallel 8-bit code into a serial code, and is used to form and transmit a digital data flow to a personal computer (PC) or a personal digital assistant (PDA) at a rate of 12 Mbit/s in accordance with the USB 1.1/2.0 specification. An additional static RAM with a capacity of 256 Kbyte is used in the interface module to match the rates of picture frame formation and its transfer over the USB channel. The interface module also has a composite video output for connecting TV monitor *8*.

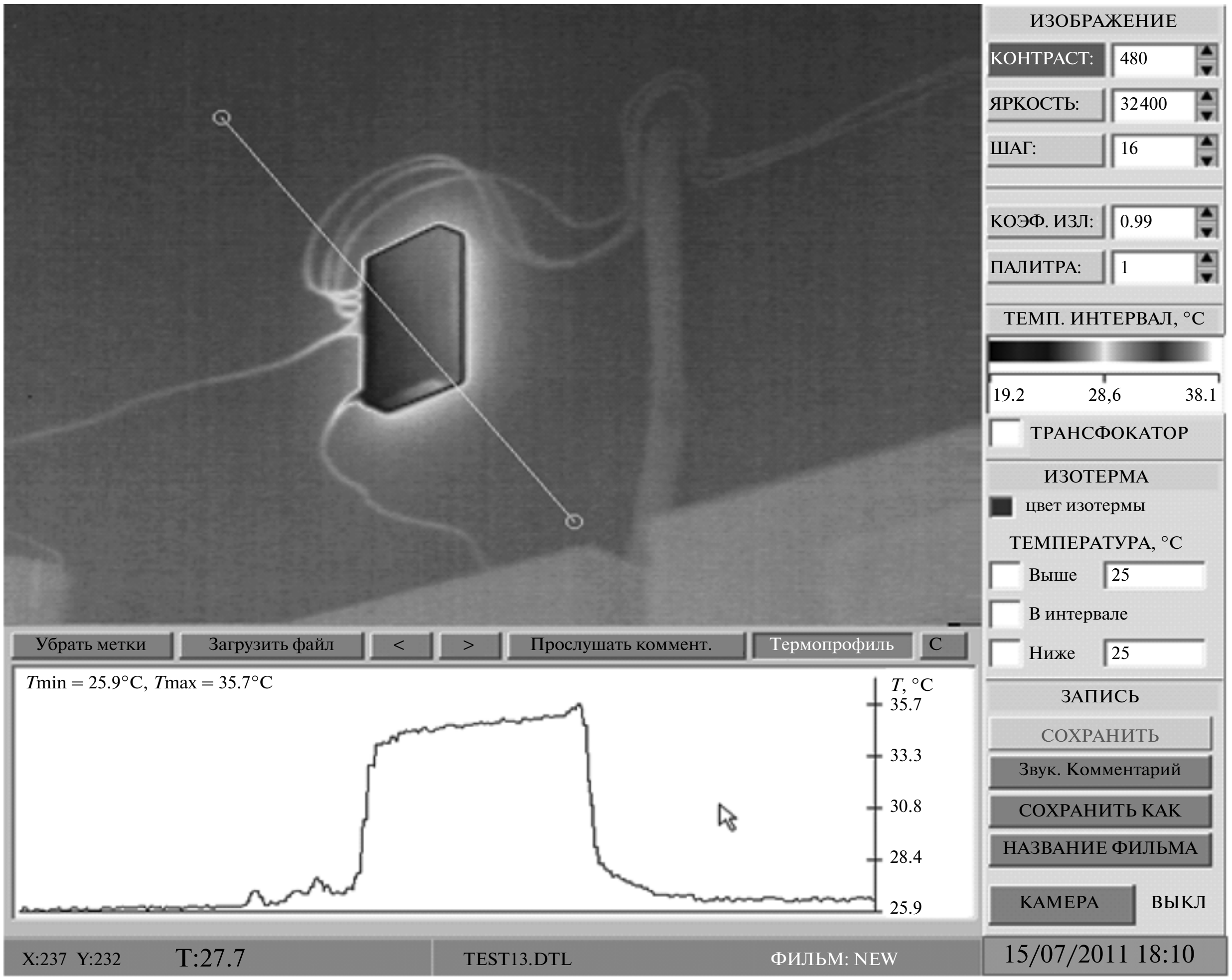
Reference emitter *2* in the form of a metal blind with an electromagnetic drive is used for temperature calibration of the measuring channel in the thermal imaging system. The blind has a known emissivity (≈0.98), and its temperature is monitored by a semiconductor microthermometer. The digital code corresponding to the blind temperature is produced by an auxiliary 10-bit analog-to-digital converter and is transmitted to the PC (PDA) together with the other information on each picture frame. At the instant of calibrations, the blind covers the field of view of the array so that the electric signal from each pixel is proportional only to the radiant power from the surface of the blind.

Interactions and synchronization of individual thermal imaging system units and generation of events from the actuators are effected by the digital logic of auxiliary electronic unit *6*.

The key parameters of the developed system equipped with a standard objective lens are as follows: receiver type, FPA with 384 × 288 pixels; receiver temperature control, uncooled receiver; spectral range, 8–14 μm; field of view (a standard objective lens), 21° (in a horizontal plane) × 16° (in a vertical plane); angular resolution, 0.94 mrad; frame-repetition rate, 10 Hz (USB) and 30 Hz (TV); temperature resolution at 30°C, <0.08°C; range of measurable temperatures, from –20 to +300°C; temperature measurement accuracy, ±2%; and dimensions, 150 × 100 × 105 mm.

The external appearance of the system is shown in Fig. 2.

Visualization of a thermal image on the PC or PDA monitor and control of the video unit are effected via the user interfaces of the original software developed in the pocket programming language (PPL) for the Win-



КОНТРАСТ: 480
ЯРКОСТЬ: 32400
ШАГ: 16
КОЭФ. ИЗЛ: 0.99
ПАЛИТРА: 1
ТЕМП. ИНТЕРВАЛ, °C 19.2 28,6 38.1
☐ ТРАНСФОКАТОР
ИЗОТЕРМА ■ цвет изотермы
☐ Выше 25
☐ В интервале
☐ Ниже 25
Tmin = 25.9°C, Tmax = 35.7°C
X:237 Y:232 T:27.7 TEST13.DTL ФИЛЬМ: NEW 15/07/2011 18:10

Fig. 3. Main page of the interface for Windows XP.

dows XP operating system (Fig. 3) and for the Windows Mobile operating system.

The software embodies the modular design. As a result, the set of functions of the user interface can be easily extended or changed, depending on the specific task of thermal diagnostics. The software package implements a wide variety of basic functions: visualizing the thermal image on the PC or PDA monitor in colors of the selected color box, selecting the active color box (black and white colors or eight color boxes), controlling the brightness and contrast of a thermal image, indicating the temperature in an arbitrary segment of the thermal image, constructing thermal profiles in any cross section, plotting isothermal lines, saving thermal images and sound comments to the hard disk, viewing stored thermal image files and listening to the sound comments, copying graphic data to the clipboard to prepare reports, etc. The software package also performs a number of auxiliary functions for thermal analysis of heat-power engineering objects: measuring the heat transfer coefficient, thermal resistance, specific and total heat losses, etc.

Though the thermal imaging system sample has been designed for use in heat-power engineering, the modular structure of its hardware and software allows one to change the system parameters and the program blocks; connect the system to the other equipment, creating thereby a common interface; etc. Thanks to this design, the developed thermal imaging system can be adapted for solving any thermal diagnostic task, in particular, in medical and research applications.

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REFERENCES

1. Yefremenko, V., Gordiyenko, E., Shustakova, G., et al., *Rev. Sci. Instrum.*, 2009, vol. 80, p. 056104.
2. Vinogradov, V.I., Veretenov, I.S., Slezko, V.N., et al., *Funkts. Diagnos.*, 2005, no. 3, p. 72.
3. Shustakova, G.V., *Mir Tekhn. Tekhnol.*, 2006, no. 2(51), p. 50.
4. Gordienko, E.Yu., Fomenko, Yu.V., Shustakova, G.V., and Efimova, G.S., in *Sb. dokladov BMIT-2009 (Biomeditsinskie informatsionnye tekhnologii v okhrane zdorov'ya)* (Proc. BMIT-2009 (Biomedical Information Technologies in Health Protection), Kiev: Inst. Kibernetiki, 2009, p. 185.
5. Sizov, F.F., Bekhtir O.V., Bilevich E.O., et al., *Nauka Innov.*, 2005, vol. 1, no. 3, p. 22.
6. Tissot, J.L., Durand, F., Garret, Th., et al., *Proc. SPIE,* 2010, vol. 7660.