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Pyroelectric USB-joulemeters of pulsed laser radiation

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Abstract. The general arrangement, principle of operation and basic parameters of pyroelectric USB-meters of energy of pulsed laser radiation have been described. A smart head of the meter converts the signal from the pyroelectric sensor and immediately transfers it to PC using a high-speed USB 2.0 connection. The device consists of two circuit panels located in the common package. The pyroelectric sensitive element and preamplifier are mounted on the sensor panel. Output of the preamplifier is connected with input of the preliminary digital processing panel. The meter is connected with host computer that performs further processing, storage and monitoring of data. Sensor panel can be produced in two modifications, dependently on the pulse energy. Sensitive elements on the base of $LiNbO_3$ or $LiTaO_3$ with absorbing coatings are used for measuring the low-energy pulses, whereas the transparent sensitive elements with a small intrinsic absorption is used for measurements of high-energy radiation pulses. The pulse rate and pulse energy can vary from single pulses up to 2 kHz and from 0.1 μJ up to 0.5 J, respectively.

Keywords: laser, impulse radiation, joulemeter, detector, pyroelectric.

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1. Introduction

In what follows, there is a brief description of PC-compatible measuring devices for diagnostic of laser radiation elaborated at the Institute of Physics, NAS of Ukraine – pyroelectric joulemeters. Pyroelectric detectors of radiation combine nonselectivity peculiar to thermal detectors and high operation speed which in some cases is equal to that of photoelectric detectors, and exceed photoelectric detectors by temporal and temperature stability and range of linearity [1-3]. All of this gives rise to interest in development of devices based on the pyroelectric radiation detectors.

2. Structure and operation of device

The distinctive feature of proposed devices is the absence of the separate module for processing and displaying the results of measurements. The basic block of devices is a Smart Measuring Head (SMH). It consists of two circuit panels: analog and digital ones, located in the common unified package. Block diagram of energy meter is presented in Fig. 1. Pyroelectric sensitive element and preamplifier are mounted on the sensor panel. Output of the preamplifier is connected with input of analog-to-digital converter (ADC). ADC, microcontroller and attendant electronics are mounted on the preliminary digital processing panel (Fig. 2). When a radiation flux falls on the pyroelectric sensitive element, it generates electric signal with a magnitude proportional to the energy of radiation pulse. The PC-compatible software records calibration data and device's functioning parameters, controls operating modes of device, calculates and visualizes the measurement state and results. There is no need for addition power supply and cooling, because SMH probe is powered through the USB port on computer.

Two types of energy meters with significantly different sensitive elements are proposed.

1. USB Radiation Energy Meter VEP-1 designed for measurement of small energies both of single and repetitive (up to 2000 pps) pulses coherent and non-coherent radiation in a wide spectral range of wavelengths (0.2…12 μm) with thin sensitive element of absorptive type, which is covered by front and rear electrodes and black coating.

2. USB Radiation Energy Meter VEP-9P designed for measurement of high energies with transparent sensitive element: the beam pulses pass through the pyrometer sensitive element without beam cut-off and obtrusion. In this case, the energy/power of a pulsed or Q-switched laser can be real-time monitored without work interruption since there is no significant quantitative or qualitative change in the laser beam.

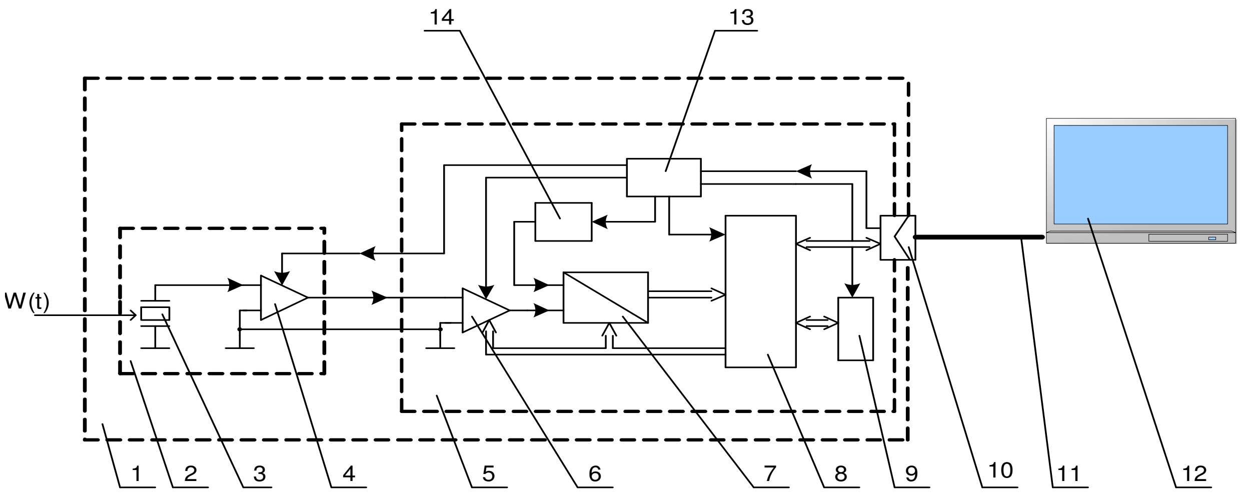

Fig. 1. Block diagram of energy meter: *1* – energy meter, *2* – sensor panel, *3* – pyroelectric sensitive element, *4* – preamplifier, *5* – preliminary digital processing panel, *6* – instrumental amplifier, *7* – ADC, *8* – microcontroller, *9* – interface RS-232, *10* – USB interface connector, *11* – cable, *12* – computer, *13* – voltage converter, *14* – reference voltage source.

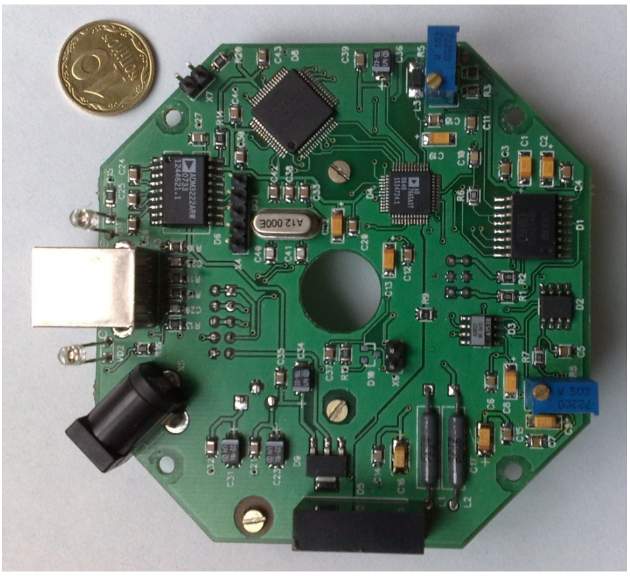

Fig. 2. Outlook of the digital processing panel.

Outlook of pyroelectric USB energy meter of laser radiation VEP is shown in Fig. 3.

3. User's interface description

Operation of the device is based on the program that works on the platform of personal computer (PC) and provides a multiwindow graphic interface of measuring instrument. It consists of main window **Measurement** and some supplementary ones.

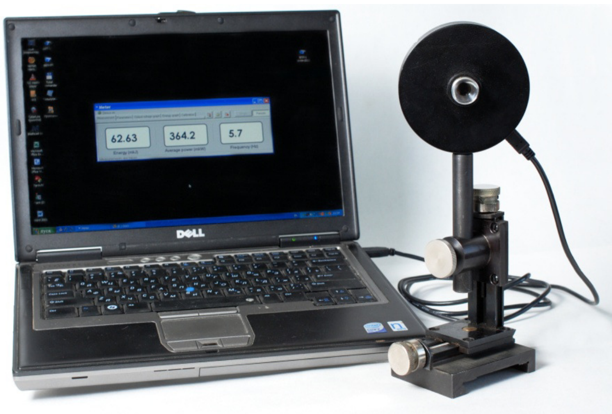

Fig. 3. Outlook of pyroelectric USB energy meter of pulsed laser radiation.

A general view of window **Measurement** is shown in Fig. 4. The indication panel *1* of link state with measuring instrument displays information concerning the connection of PC with the measuring instrument via USB interface. Switchboard panel of the active window *2* has five bookmarks for window reswitching, three buttons for recording process control and for energy graph displaying and two buttons for switching on the measurement regime (**[Single], [Periodic]**). Text messages panel *5* displays text messages that characterize measuring process that is performed at the moment:

— "Measurement is performed";
— "Saturation is reached ";
— "Time of time-out is finished".

The panels *6* to *8* display values of energy pulse, values of pulse repetition frequency, and values of average power of pulse sequence, respectively.

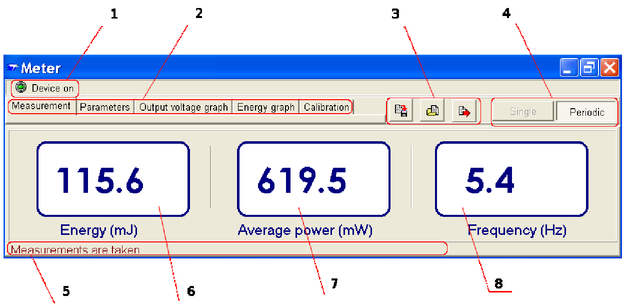

Fig. 4. Window "**Measurement**": *1* – indication panel of link state with measuring instrument, *2* – switchboard panel of active window, *3* – buttons of file operations, *4* – buttons of measuring mode "Single – Periodic" activation, *5* – panel of text messages, *6* – values of pulse energy panel, *7* – average power of pulses sequence panel, *8* – pulses repetition frequency panel.

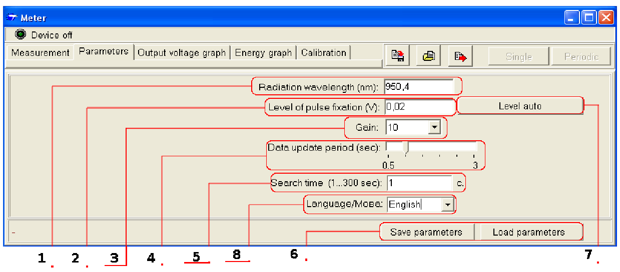

Fig. 5. Window "**Parameters**": *1* – input panel for value of radiation source wavelength, *2* – input panel for pulse fixation level, *3* – panel for regulating the gain of instrumental amplifier, *4* – panel for control of data update period, *5* – input panel for search time (time-out) values, *6* – buttons for saving and downloading parameters, *7* – button for automatic determination of pulse fixation level, *8* – language panel.

The window **Parameters** (Fig. 5) is designed for setting the values of parameters of this measurement session and for input these values into the measuring instrument before it's starting. Being inputted or adjusted, values of measuring parameters are downloading to the measuring instrument. Downloading the parameters is performed after pressing the button **[Load parameters]**.

Output voltage graph window (Fig. 6) is auxiliary one, and it is used for precise determination of pulse fixation level or for control of measuring instrument functioning. The output voltage graph is displaying in this window only in unitary measurement regime (by pressing the button **[Single]**). The window of **Energy graph** is used for function visualization of values change of energy emission pulse against time. A general view of window **Energy graph** is shown in Fig. 7, where the time deviations of energy of periodic laser pulse sequence under some technological process are depicted.

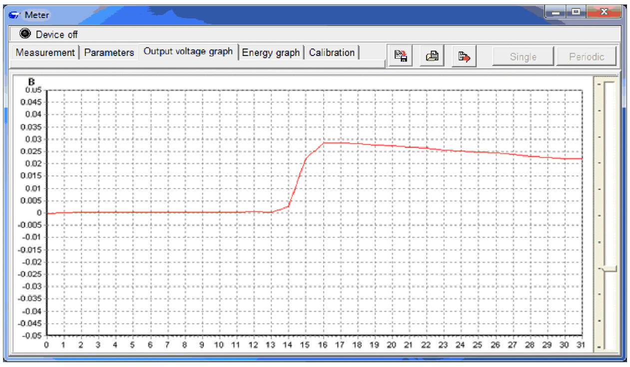

Fig. 6. "**Output voltage graph**" window.

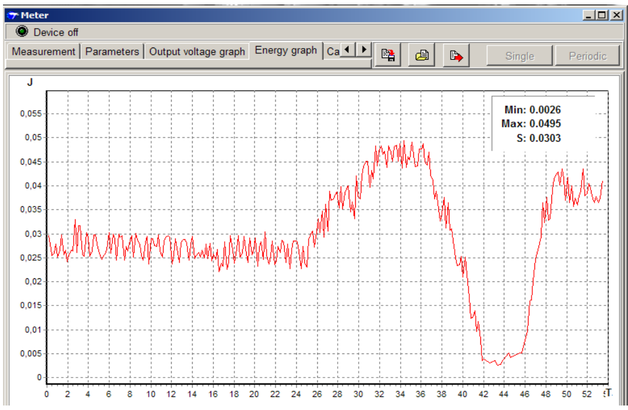

Fig. 7. "**Energy graph**" window.

Upper right corner of graph has a panel that displays the following points:

- Min – minimum value of energy fixed sequence;
- Max – maximum value of energy during the fixed sequence;
- S – value of mean square deviation of energy in percentage.

For recording the dependence of instantaneous energy of sequence pulsed radiation from time, before starting the measurement, it is necessary to open file in desired folder by using the file operation button **[Save to file]** (left button among of three file operation buttons). Immediately after pressing this button, the window **Save as** opens. Accumulated in the file data of dependence instantaneous values of energy from time can be exported in the form of Microsoft Excel file.

Some disadvantage of measuring by this method based on the analog-digital conversion of signal is connected with fixation of its values in separate discrete moments of time. It doesn't allow to define accurately the moment of short pulse appearance and moment when it reaches the maximum level, which leads to decreasing accuracy of measurements. In our devices, we propose improvement of measuring method, which can eliminate this problem [4, 5].

Main parameters of Radiation Energy Meters are presented in Table.

Table. Main parameters of radiation energy meters.

Parameter	VEP-1	VEP-9P
Type of sensitive element	adsorptive	transparent
Wavelength range, μm	0.2…12.0	0.35…4.5
Energy range, J	$1\cdot10^{-6}…2.5\cdot10^{-3}$	$2.5\cdot10^{-3}…5\cdot10^{-1}$
Energy resolution, J	10^{-7}	10^{-4}
Max energy density (under pulse duration > 45 ns), J/cm^2	$1.5\cdot10^{-2}$	2.5
Max repetition rate, Hz	2000	
Max pulse duration, s	10^{-5}	
Sensitive element aperture, mm	10	
Power consumption, W	0.5 (via USB interface)	
Device size (diameter×height), mm	∅100×60	

Devices were tested in the National Scientific Center "Institute of Metrology" and admitted to application as working means of measuring technique.

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