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DEVELOPMENT OF A SOFTWARE AND TECHNICAL COMPLEX FOR A TWO-CHANNEL DETECTING SYSTEM FOR CONTINUOUS REGISTRATION OF X-RAY AND GAMMA RADIATION

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A compact spectrometric tract and software for work as part of a two-channel detecting system for continuous registration of X-ray and gamma radiation in a wide range of energies have been developed. The complex is designed to work with silicon planar uncooled detectors. The software allows you to process information from each spectrometric channel and provide information in the form of a integrated spectrum. The design of the detecting module, which combines low-energy and high-energy detectors in one housing has been developed.

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INTRODUCTION

Gamma radiation spectrometers made of high purity germanium are widely used for nuclear physics experiments. Having a very high energy resolution, they have essential disadvantages, such as large structure, heavy weight, high cost and need to use liquid nitrogen [1, 2]. To solve tasks that do not require such a high energy resolution, a software and technical complex has been developed to create a compact two-channel detecting system for continuous registration of X-ray and gamma radiation based on silicon detectors.

The developed complex can perform registration of X-ray and gamma radiation in a wide range of energies – from 5 keV to 1.0 MeV.

The use of a silicon PIN detector with a thickness of 300 µm as a detector allows you to reliably and with high energy resolution register radiation in the energy range from 5 to 100 keV. The advantages of the PIN detector are the low energy required to create an electron-hole pair, high stopping power, the most sophisticated technology of silicon detectors manufacturing, high radiation resistance and the ability to work in magnetic fields and in a vacuum. However, at energies above 50 keV, the efficiency of using silicon PIN photodiodes significantly decreases. Radiation with an energy of more than 50 keV is more efficient to register with the help of complex detection systems, which consist of a scintillator and a photodetector, as which a silicon PIN photodiode is used.

Thus, for the development of the complex, two detector modules were used: the first – low-energy detector, for registration radiation in the range of 5…50 keV based on a silicon PIN detector, the second – high-energy detector, for registration radiation in the range of 0.05…1.0 MeV based on scintillator CsI(Tl) and a silicon PIN detector [3]. The design of the detecting module, which combines the two specified types of detectors in one housing, has also been developed.

1. ELECTRONICS OF THE COMPLEX

The complex consists of a two-channel detecting module and a spectrometer containing two identical channels for processing signals coming from the detectors.

Schematics of the charge-sensitive preamplifier (CSP) and the shaper amplifier are described in [4]. Formation time constant are chosen to be 1 µs for a low-energy detector and 6 µs for a high-energy detector. As an analog-to-digital converter (ADC), a classic Wilkinson ADC with a filling frequency of 150 MHz is used. The structural diagram of the spectrometer is presented in Fig. 1.

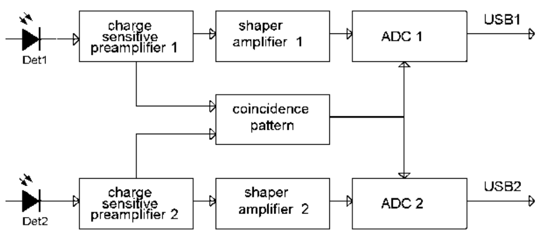

Fig. 1. Structural diagram of the spectrometer

The detection system can work in coincident mode. This mode is activated by software, the ADC can be started by a signal at its input or by an external strobing signal (in this case, from the scheme of coincident).

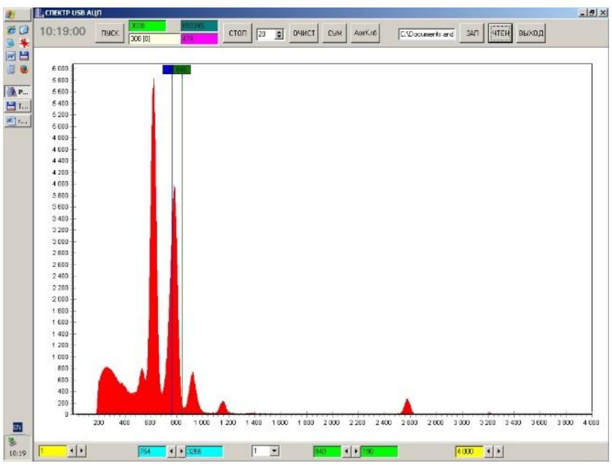

Fig. 2. Low-energy spectrum ^{241}Am, energy resolution 1.16 keV

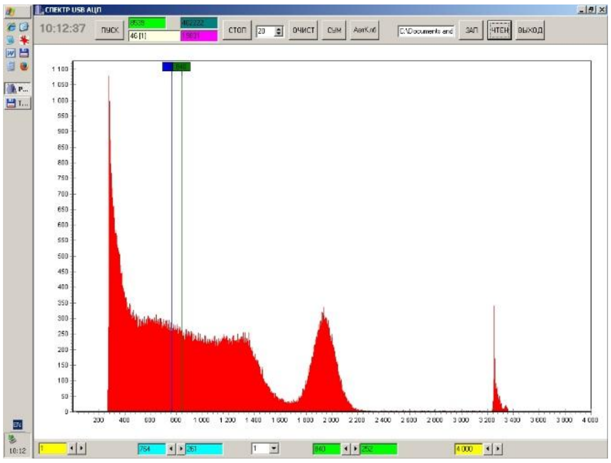

Fig. 3. High-energy spectrum of ^{137}Cs, energy resolution 65.5 keV

Structurally, CSP are made using SMD components and placed in the detection block. The measurement channels of the spectrometer were set individually for each channel. Examples of the obtained spectra are shown in Figs. 2 and 3.

2. SOFTWARE OF THE COMPLEX

Each spectrometric ADC is connected to a computer via a USB interface using the FT245 circuit. The ADC is powered by the USB interface, which allows you to build portable measuring systems. Control commands and data are exchanged through the USB interface. The ADC is designed for searching and selecting pulses generated by electronics. Amplitudes of incoming pulses are transformed into a digital code and the spectrum is accumulated in accordance with these amplitudes. The spectrometric ADC is equipped with a large-capacity incremental memory device.

The ADC executes commands to start and stop operation, commands to set and use the trigger threshold, read and clear incremental memory through the appropriate driver and a set of interface programs. The conversion to ADC can start in the mode of automatic start from the front edge of the incoming pulse or in the mode of synchronization with an external trigger signal.

When starting the program for processing the information coming from the two-channel detecting system, a number of parameters necessary during operation are loaded from the configuration file of the spectrometer. The software performs simultaneous measurement and accumulation of two spectra and their processing.

The program in the computer controls the setting of the thresholds of the ADC, the start and stop of spectrum accumulation, and the cleaning of the internal memory of the ADC. The spectra are periodically read from the internal memory of the ADC, processed and displayed on the monitor screen in the specified form. It is possible to set the duration of the exposure of a set of spectra and stop after the specified time.

It is possible to process the received spectra and compensate the differences in the spectra obtained when working in the measuring channels.

The received spectra are saved in files on the computer disk, previously recorded spectra can be loaded into the program for viewing and processing.

When spectra are loaded from disk, the corresponding parameters of the spectrum are also loaded from the file. The set of spectra can be continued after stopping or loading spectra from a file on disk.

The spectrum measurement program works in an interactive mode using control buttons and information output windows.

The main window of the spectrum measurement program is conditionally divided into three panels: the spectrum set control panel, the spectrum display panel and the display control panel.

In the upper part of the window there is a control panel for a set of spectra. On it there are control buttons, fields for outputting information about the progress of the spectrum set, and windows controlling the ADC threshold. The control buttons allow you to start, continue and stop the set of spectra. In addition, there are buttons for cleaning the spectrum, express processing, calibration, and writing/reading spectra to files on the disk.

In the central part of the program window there is a spectrum display panel. On this panel, obtained spectra are displayed cyclically. The scale of the display changes automatically as the spectrum is set. Markers are displayed on the spectrum display panel, highlighting the processing area.

In the lower part of the program window, under the spectrum display panel, there is a spectrum display control panel. The position of the markers on the spectra display panel is displayed and set here. On the display control panel there are buttons for controlling the display of spectra on the display panel. Any of the spectra or their combination can be displayed on the screen.

Also, any part of the spectrum can be highlighted and enlarged on the spectrum display panel.

In addition, there are buttons that allow to correct differences in the characteristics of the measuring channels. Differences in measurement channels may be caused by differences in the offset of the zero reference position and the gain factor for each set of preamplifiers, shapers and ADCs used in these channels.

To correct the offset of the position of the zero reference of one channel relative to the other, the possibility of shifting one spectrum relative to the other is provided. For such a shift, it is possible to use the position of the control channels in the spectra or the position of the control peaks of the spectra of the measured isotopes or radiations.

To correct the gain coefficients in the channels, it is possible to recalculate the width of the spectrum channels when displayed on the screen. This operation can be performed if there are several control channels in the measured spectra, the position of which must be matched.

A difference in the efficiency of registration in the measurement channels can be observed, which is determined by the difference in the counts in the control channels in the spectra. To compensate these differences, it is possible to increase proportionally the number of counts on all spectrum channels.

Interesting areas of the spectrum can be subjected to additional processing. On the area marked with markers, the calculation is carried out with the determination of the background, the search for the peak and the determination of its parameters with the approximation of the given function. At the same time, the parameters of the found peak are calculated taking into account the previously performed energy calibrations.

Thus, the program interface allows to control the progress of the spectrum measurement, display the required information in the required form in the appropriate windows and panels, correct the obtained spectra, obtain the characteristics of the selected peaks on the spectrum, save and load the measured spectra to disk in specified files for further processing.

An example of combining two spectra on the energy scale is presented in Fig. 4.

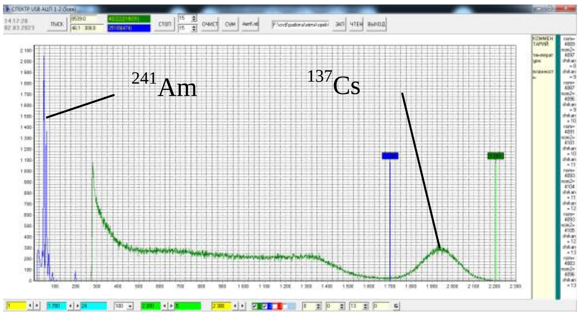

Fig. 4. An example of combining two spectra, radiation sources – ^{241}Am, ^{137}Cs

3. DETECTING MODULE DESIGN

The design of the complex detecting module for the two-channel spectrometer was developed on the basis of two developed by the NSC KIPT bare silicon planar uncooled detectors with an active area of (2x2) mm^2 and a CsI(Tl) scintillator.

A schematic drawing of the detector module is shown in Fig. 5. The detectors, the scintillator and the hole in the collimator are located along one axis that passes through the center of the inlet window of the housing.

The high-energy detector, which consists of a silicon planar detector and a scintillator glued to the active area of the detector. It is mounted on the first dielectric sitall board, which is fixed to the base of the housing. Scintillator is wrapped with a reflective film. A lead collimator surrounds the scintillator and detector on all sides.

The low-energy detector is mounted above the scintillator on a second sitall board, which is fixed to the collimator. In order to reduce the amount of module construction materials on the path of the detected radiation, the second sitall board has a hole opposite the active area of the detector.

The housing and base of the detector module are made of aluminum. The housing has holes for mounting the module on the spectrometer housing. To ensure the tightness of the housing, the inlet window is closed with aluminum foil of 7 um thick.

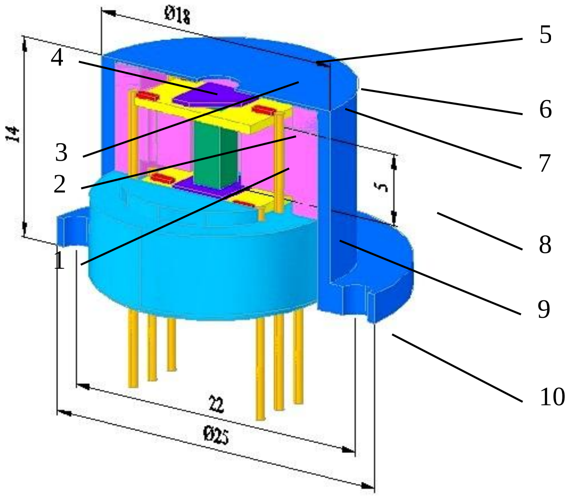

Fig. 5. Schematic drawing of two-channel detecting module: 1 – high-energy silicon detector; 2 – scintillator; 3 – low-energy silicon detector; 4 – collimator; 5 – inlet window; 6 – intermediate terminals; 7 – sitall board; 8 – housing; 9 – base of the housing; 10 – external terminals

The electrical connection of silicon detectors with CSP is made using intermediate terminals, which are fixed on sitall boards, aluminum wire jumpers with a diameter of 25 μm and external wires of MGTF 0.12. Aluminum wire jumpers connect the pads of the silicon detectors to the intermediate terminals using ultrasonic bonding and the external wires connect the intermediate terminals with CSP by soldering. Materials for gluing and bonding are given in [5].

An analysis of the characteristics of silicon planar uncooled detectors and inorganic scintillators was carried out for the production of research samples of the two-channel spectrometer.

The preparation of technological equipment and materials was carried out, the modes of detecting modules test samples manufacturing were determined (gluing the detector and scintillator, microwire bonding, sealing of the housing, heat treatment, etc).

Research samples of single-channel detector modules were made, the design of which is given in [6]. The equipment presented in [7] was used for their manufacture.

CONCLUSIONS

The electrical circuit of the charge-sensitive preamplifier and shaper amplifier using SMD components for continuous spectrometric registration of X-ray and gamma radiation was developed.

The design of a research sample of the detecting module for spectrometric registration of X-ray and gamma radiation based on silicon photosensors developed by the NSC KIPT and a CsI(Tl) scintillator was developed.

An analysis of the characteristics of silicon uncooled detectors and inorganic scintillators for use in the construction of a two-channel spectrometer was performed.

Preparation of technological equipment and materials was carried out, production modes of research samples of detecting modules were determined, and research samples of single-channel modules were made.

Studies of spectrometric characteristics of the manufactured research samples in the energy range of energies from 60 keV to 0.662 MeV, with ^{137}Cs and ^{241}Am radiation sources carried out.

Studies have shown the operability of the developed design of the two-channel detecting system and satisfactory results of energy resolution.

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РОЗРОБКА ПРОГРАМНО-ТЕХНІЧНОГО КОМПЛЕКСУ ДЛЯ ДВОКАНАЛЬНОЇ ДЕТЕКТУЮЧОЇ СИСТЕМИ БЕЗПЕРЕРВНОЇ РЕЄСТРАЦІЇ РЕНТГЕНІВСЬКОГО ТА ГАММА-ВИПРОМІНЮВАННЯ

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Розроблено малогабаритний спектрометричний тракт та програмне забезпечення для роботи у складі двоканальної детектуючої системи безперервної реєстрації рентгенівського та гамма-випромінювання у широкому інтервалі енергій. Комплекс розрахований на роботу з кремнієвими планарними неохолоджуваними детекторами. Програмне забезпечення дозволяє проводити обробку інформації від кожного спектрометричного каналу та подавати інформацію у вигляді єдиного спектра. Розроблено конструкцію детектуючого модуля, який об′єднує в одному корпусі низькоенергетичний і високоенергетичний детектори.