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МЕТОДИКА ФИЗИЧЕСКОГО ЭКСПЕРИМЕНТА

AUTOMATION SYSTEM FOR MEASUREMENT OF GAMMA-RAY SPECTRA OF INDUCED ACTIVITY FOR MULTI-ELEMENT HIGH-VOLUME NEUTRON ACTIVATION ANALYSIS AT THE IBR-2 REACTOR OF FLNP AT JINR

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The automation system for measurement of induced activity of gamma-ray spectra for multi-element high-volume neutron activation analysis (NAA) was designed, developed and implemented at the IBR-2 reactor at the Frank Laboratory of Neutron Physics. The system consists of three devices of automatic sample changers for three Canberra HPGe detector-based gamma spectrometry systems. Each sample changer consists of two-axis linear positioning module M202A by DriveSet company and disk with 45 slots for containers with samples. Control of automatic sample changer is performed by the Xemo S360U controller by Systec company. Positioning accuracy can reach 0.1 mm. Special software performs automatic changing of samples and measurement of gamma-spectra at constant interaction with the NAA database.

На реакторе ИБР-2 разработана, создана и внедрена автоматическая система измерения гамма-спектров наведенной активности для проведения многоэлементного массового нейтронного активационного анализа (НАА). Система состоит из трех устройств автоматической смены образцов, трех спектрометров на базе HPGe-детекторов с блоками спектрометрической аппаратуры фирмы «Canberra» и оригинального управляющего программного обеспечения. Каждое устройство смены образцов состоит из двухкоординатного модуля линейного перемещения M202A фирмы «DriveSet» и диска с 45 ячейками для контейнеров с образцами. Управление устройством автоматической смены образцов осуществляется с помощью контроллера Xemo S360U фирмы «Systec». Точность позиционирования может достигать 0,1 мм. Специальное программное обеспечение осуществляет автоматическую смену образцов и измерение гамма-спектров при постоянном взаимодействии с базой данных НАА.

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INTRODUCTION

Neutron activation analysis (NAA) is one of the most advanced analytical techniques widely used in geology, biology, medicine, environmental sciences and material science both for fundamental and applied research [1].

Instrumental neutron activation analysis (INAA), conducted at the pulsed fast IBR-2 reactor, is characterized by the stable conditions for analysis where a high neutron flux density

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in the entire energy range (thermal, epithermal and fast) greatly improves the selectivity and sensitivity of NAA.

Creation of modern semiconductor detectors with a high resolution, as well as personal computers, has significantly improved the technical level of INAA along with the methods of processing of spectrometric information. Methods of INAA are associated with absolute and relative methods [2], k_0-method [3], cyclic method and the method of Compton suppression [4]. NAA based on the comparator method fulfills the requirement of a primary ratio method with metrological fundamentals including the measurement equation, the evaluation and quantization of all sources of uncertainty and the aspects of traceability [5].

Within the framework of international research programs NAA of large numbers of samples is carried out worldwide. It requires organization of labeling, storage and registration of all operations with analyzed samples, measurements and processing of the spectra, as well as systematization of results.

Thus, at the present stage of the NAA development, its automation at facilities operating at the research reactors in terms of multi-element high-volume analysis becomes a priority task. It has two aspects: creation of devices and systems for the automation of analysis (hardware) and the development of computer technology and software, both for hardware control and treatment of analytical data. It should be noted that despite the fact that the creation of automation systems for NAA can be regarded as an essential stage in the development of the method, the progress in this direction is very slow [6–9].

Currently (2012–2015), the IAEA Coordinated Research Program «Development of an Integrated Approach to Routine Automation of Neutron Activation Analysis» focuses its efforts on a unified approach to automation of the NAA process in different countries [10]. In the framework of this program the hardware and software for a comprehensive automation of NAA at the IBR-2 reactor have started to be developed [11, 12]. This paper describes the present status of this development, the hardware and software for automation of measurements of gamma-ray spectra of induced activity.

AUTOMATION SYSTEM FOR MEASUREMENT OF GAMMA-RAY SPECTRA OF INDUCED ACTIVITY

Fundamental and applied research using NAA has been conducted at the pulsed fast IBR-2 reactor for more than four decades. The radioanalytical complex includes a pneumatic system that operates for a large amount of environmental and technological samples in numerous national and international projects. In such circumstances the necessity to automate the procedure of analyses and data processing, as well as of registration of samples and organization of interexchange of information, is a very high priority.

The block diagram of the automation system for measurement of gamma-ray spectra of induced activity for multi-element high-volume NAA is shown in Fig. 1.

The system consists of three HPGe detectors with spectrometric electronics, three sample changers and the original control software. Each sample changer consists of two-axis linear positioning module M202A by DriveSet (DriveSet.de) company and disk with 45 slots for containers with samples (Fig. 2).

Each linear positioning module is fixed with the additional aluminum construction above two metal tables with adjustable feet. On one of the tables a rotating disk to hold the samples

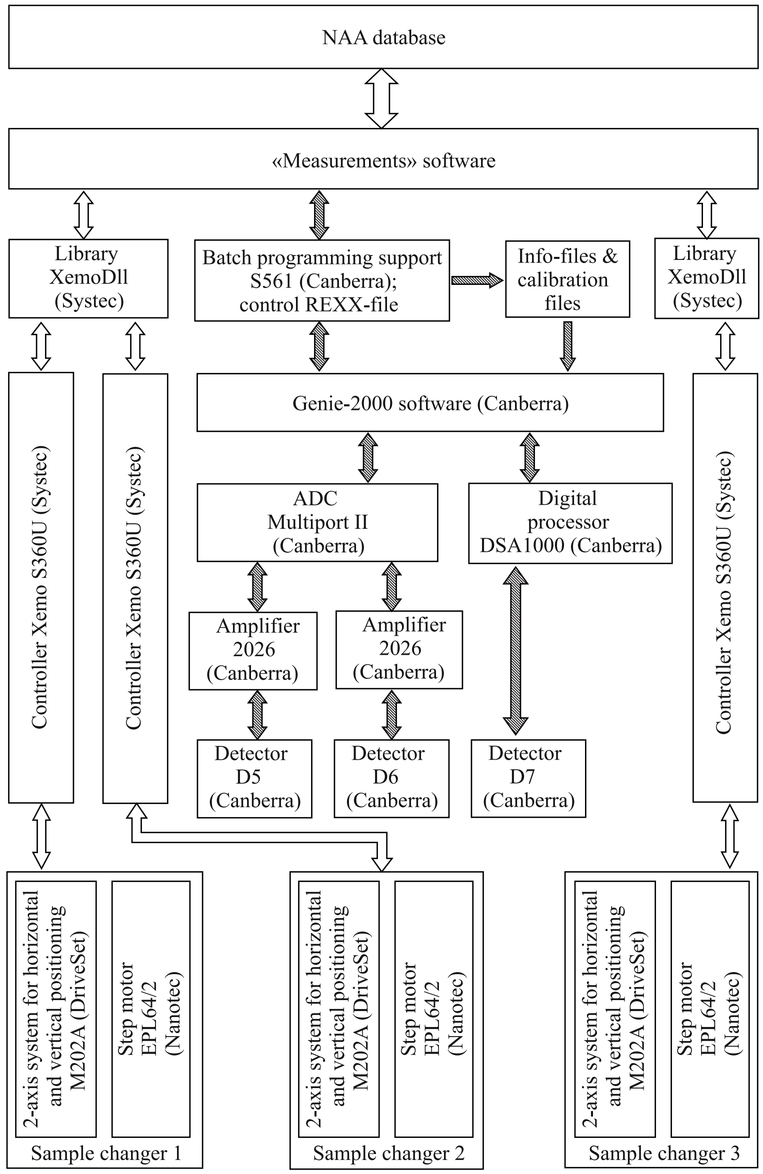

Fig. 1. The block diagram of automatic system of spectra measurement

is installed, while under another table a dewar with the detector is placed, the head is above the surface of the table. The disk with samples, as well as the detector, are surrounded with the shielding.

The disk is rotated by a step motor EPL64/2 with a two-way shaft by Nanotec (nanotech.com) company. On one side of the motor its shaft is connected with the shaft of the disk by means of a coupling, while on the other side, an incremental encoder is mounted on

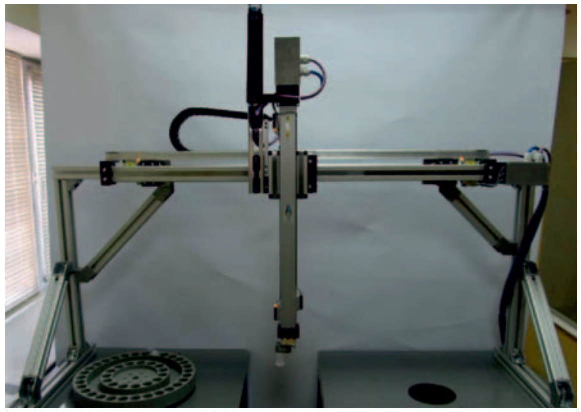

Fig. 2. General view of the sample changer

a shaft, which controls the selection of the cell with a sample. The initial cell in the disk is determined by an electromagnetic sensor. Positioning accuracy of the disc can reach 0.01°.

The movement of containers from the disk to the detector and back is carried by a device M202A manufactured by DriveSet company. It comprises horizontal and vertical linear positioning modules. Each axis is made of high-strength aluminum profile with integrated hardened steel rods. A carriage with the precision guide rollers moves along the track. The carriage of each module moves by means of the trapezoidal screw thread, which is rotated by a step motor. The brake for the vertical axis is not needed because of the self-locking trapezoidal thread. Each axis is provided with two ends and one reference sensor, as well as a linear incremental encoder, which allows the determination of the position of the carriage. The end sensors exclude the possibility of damage of the devices while movement to the physical boundaries of the axes. Reference sensors allow one to specify the initial positions of the modules. Positioning accuracy can reach 0.1 mm. Maximum speed of movement along both axes is up to 0.08 m/s and acceleration is up to 1 m/s^2 with a maximum load is 1 kg. The maximum vertical movement for this module is 400 mm and the horizontal one is 800 mm. Harnesses are laid into movable cable channels.

The sample changer is fixed on the table surfaces by means of Bosch Rexroth module profile system.

The special spring-pressed grab is used to capture the container from the disk (Fig. 3).

Control of linear positioning module M202A and disc with samples is provided by the Xemo S360U controller by Systec (systec.de) company. Each sample changer uses its own controller. Each controller can control up to four axes. All controllers are connected to the PC via USB ports. Each container selected from the disk is moved to the detector and is held above it during the measurement of the spectrum. The spectra are measured in one of the three fixed height positions above the detector. Control of the container position during the measurement of the spectra is performed by incremental encoders. After completion of the measurement the container is returned to the same location of the disk which then rotates for selection of the next sample.

An original «Measurements» software was specially designed to automate measurements of gamma-spectra of induced activity by Genie-2000, to control the sample changers and

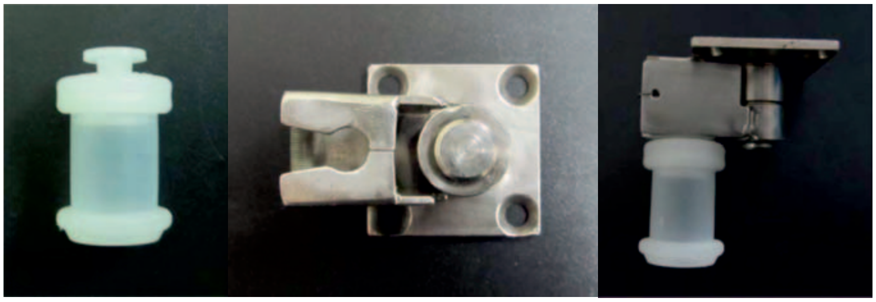

Fig. 3. Device to catch the container

for the exchange of the information with the NAA database [12] both in automatic and semi-automatic modes.

The program is written in Visual Basic. The XemoDll library by Systec company was used to create a program module to control the sample changers. Interaction with the Genie-2000 program is performed by means of a dynamically generated program using the REXX programming language (REstructured eXtended eXecutor — «restructured extended executor») in the Batch Support Tools S561 for Genie-2000. The Structured Query Language (SQL) is used to work with the database.

The program allows minimizing human involvement in routine long-term measurements of the spectra of the induced activity. The simultaneous measurements are conducted at three detectors as required by the mass analysis of samples. The program interface is shown in Fig. 4.

Before starting the measurement cycle, one must specify files containing the lists of samples to be measured or create these lists using the program. Then, one makes sure that the relevant samples on the disk of the sample changer equate with the list of samples. After the start, the automatic measurement of gamma-ray spectra, recording of the spectra on a computer disk and change of samples will go on. During the operation, a permanent exchange of information with the NAA database takes place. All the information required for processing of the spectra in accordance with the name of a measured sample is read automatically from the NAA database with the corresponding information files and recorded in the spectrum. These include: batch code and code of the sample to be measured, measurement type, date and time of the beginning of irradiation, date and time of the end of irradiation, the weight of the sample, the sample height above the detector and the name of the experimenter. Depending on the number of the detector used in the measurements, the program automatically finds the necessary energy and efficiency calibration files for the selected position of a sample above the detector and records the calibrations in the spectra.

For visualization of information, the program automatically finds the file with areas of interest and displays them in the window of Genie-2000. Areas of interest are graphical peak intervals found by the program while spectra are being processed. File numbers with the spectra and related information (date of measurement, the experimenter's name) are automatically saved in the NAA database.

The Genie-2000 program with an additional interactive peak fitting module S506 is used for processing of the spectra obtained. These treatment results are stored in a file with the values of the activities of identified isotopes in the sample and the minimal detectable activity of these isotopes.

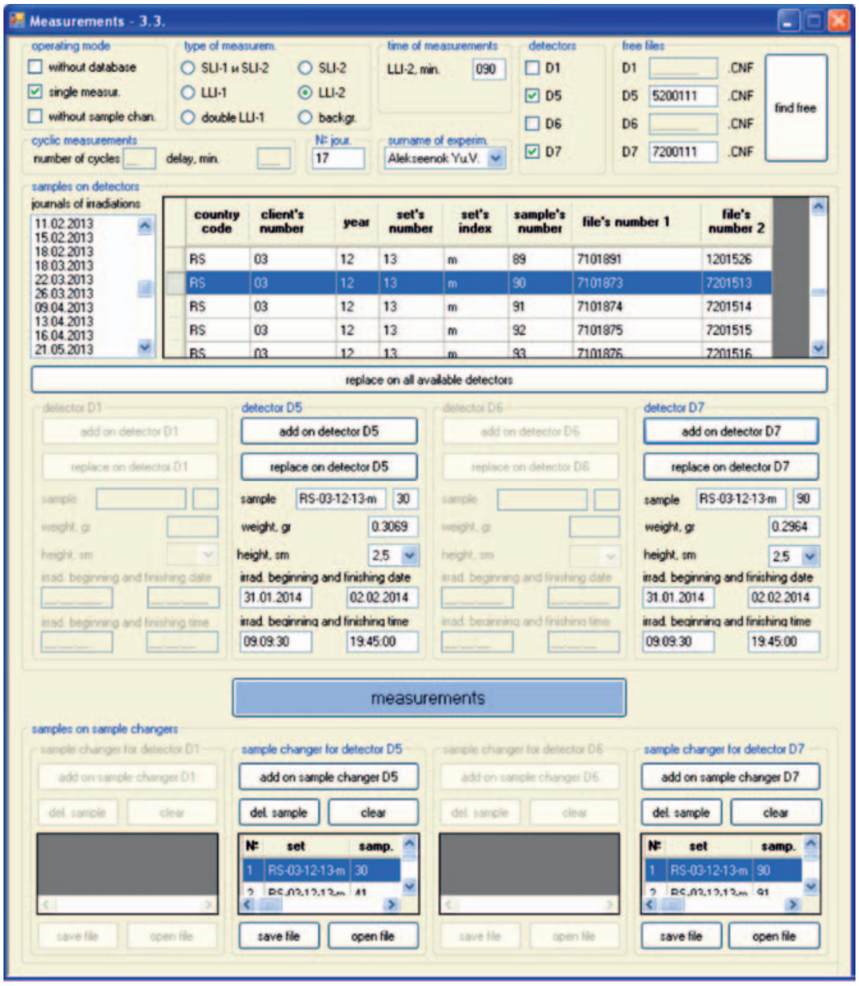

Fig. 4. Interface of the «Measurements» program

Calculation of elemental concentrations in the samples is performed by a relative method using the «Concentration» program [11]. The values of the calculated concentrations of elements with uncertainties of calculations and minimal detectable concentrations for the given experimental conditions are stored in the NAA database.

CONCLUSION

A system was developed for measuring gamma-ray spectra for a set of samples that allows one to automate the process of measurement for multi-element high-volume NAA at the IBR-2 reactor. The automated system is designed to conduct analyses of large sets of samples, to process large amounts of data, to increase productivity of analyses, to improve quality of results, to decrease the number of human errors, and to minimize human involvement in routine processes of measurements of spectra.

The created software has a user-friendly interface, both in the Russian and English languages. Automation of the system was tested and successfully operates when performing scientific research and international projects.

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