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NEW ANALOG ELECTRONICS FOR THE NEW CHALLENGES IN THE SYNTHESIS OF SUPERHEAVY ELEMENTS

V. G. Subbotin [a], *A. M. Zubareva* [a], *A. A. Voinov* [a, 1], *A. N. Zubarev* [a], *L. Schlattauer* [b]

[a] Joint Institute for Nuclear Research, Dubna

[b] Palacky University, Olomouc, Czech Republic

A new series of experiments aimed at the synthesis and study of decay properties of the most neutron-deficient isotopes of element Fl ($Z = 114$) and of the heaviest isotopes of 118 element is planned at the DGFRS (FLNR, JINR). An appropriate registering system is to be implemented to transfer spectrometric data from double-sided silicon strip detector (DSSD). New analog modules were designed that allow one to simplify existing multichannel measurement system and to improve the real-time method of "active correlations" in search for the rare events of SHE formation and decay. The main features of the new modules — the 16-channel charge-sensitive preamplifier, the 16-channel analog multiplexer and the 1.25 MSPS 12-bit Parallel ADC — are presented.

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INTRODUCTION

Significant success in the synthesis and decay properties studying of the superheavy nuclei ($Z \sim 114$ and $N = 184$) was achieved at the FLNR, JINR (Dubna, Russia) during the last 15 years [1]. Six new superheavy elements with $Z = 113-118$ and more than 50 new isotopes with $Z = 104-118$ were observed for the first time at the Dubna Gas-Filled Recoil Separator (DGFRS) in irradiations of the targets of ^{233,238}U, ^{237}Np, ^{242,244}Pu, ^{243}Am, ^{245,248}Cm, ^{249}Bk and ^{249}Cf with accelerated ^{48}Ca ions beam delivered by U-400 cyclotron.

All of these new nuclei were detected using an array of position-sensitive Si strip detectors in the focal plane of the DGFRS. For this purpose we first applied a 12-strip single-sided Si strip detector (SSSD), and later a similar 32-strip detector (two 16-strip wafers), both from Canberra NV. Appropriate registering systems were designed and applied for the measurement of energy, position and time information from reaction products implanted into the detector and from their subsequent alpha decay or spontaneous fission [2, 3].

The next step in exploring this "island of stability" of the superheavy nuclei could be study of new isotopes at the very edge of the new SHE region. For example, in irradiation of ^{239}Pu, ^{240}Pu targets with ^{48}Ca beam one could observe formation and decay of very light isotopes ^{284,285}Fl [4]. The heaviest isotopes of element 118, ^{295}118 and ^{296}118 [5], could be produced in the reactions with targets of $^{249-251}$Cf.

[1] E-mail: voinov@jinr.ru

NEW FOCAL-PLANE DETECTOR ARRAY AT THE DGFRS

The array of detectors at the DGFRS has been modified to improve the position resolution of recorded signals and to reduce accordingly the probability of observing sequences of random events that imitate decay chains of implanted nuclei. New detection system includes 0.3-mm-thick double-sided silicon strip detector (DSSD) manufactured by Micron Semiconductor Ltd. This large DSSD has 1-mm-wide strips, 48 at the front side and 128 at the back side, equal to 6144 pixels of 1 mm^2 in one silicon wafer (to compare with 240 and 960 individual cells of formerly used 12-strip and 32-strip detectors, respectively). Such a high pixilation enables one to achieve superior position resolution for registering recoil-correlated decay sequences and thus reducing number of potential random events. This detector of implanted recoils was surrounded by six side Si detectors (MICRON), each 500 μm thick with an active area of 65 by 120 mm without position sensitivity. This new Si-detector array has been designed, assembled, commissioned off-line and provided by the Oak Ridge National Laboratory.

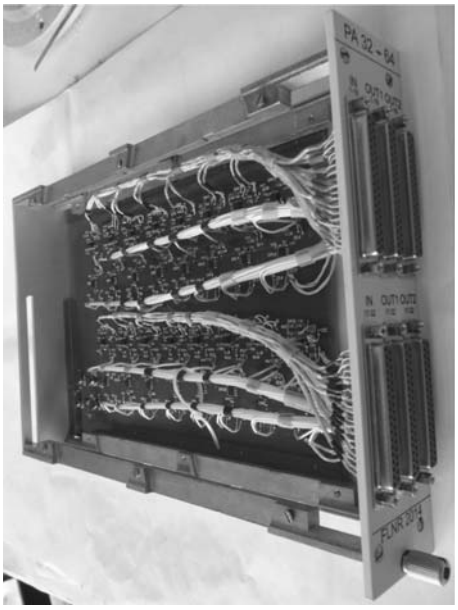

Fig. 1. PA32-64 — 32-input splitter-amplifier module

Signals from all the detectors are processed using MESYTEC linear-logarithmic preamplifiers [6]. Further, analog signals from preamplifiers were split into two independent measurement branches. Special analog splitter-amplifier PA32-64 (Fig. 1) was designed by DGFRS group as 4M CAMAC module to provide sharing of every spectroscopic channel between two measuring branches. The transfer factor from input to output is 1.1. For better precision and stability, precision resistors with a tolerance of 0.1% and low temperature coefficient of 25 ppm/°C were used in gain circuits. Every module splits 32 input signals into two independent output 32-channel streams. First 32 outputs go to analog registering system of the DGFRS similar to that used in previous experiments [7]; the other 32 outputs, to 50 Ω inputs of digital system based on XIA PIXIE-16 modules provided by ORNL [8]. Thus, all the spectroscopic signals from focal-plane detectors (48 plus 128 from DSSD, plus 6 from side SSSD and one from rear detector used in “VETO-mode”) together with signals from “START” and “STOP” multiwire proportional chambers were processed simultaneously by two different (“analog” CAMAC based and “digital” PIXIE-16 based) registering systems.

DESIGN OF NEW ELECTRONIC MODULES

With the aim of improving energy resolution of the individual spectroscopy channels, a new 16-channel charge-sensitive preamplifier PA-16 (Fig. 2) was designed and tested by DGFRS group. This should have good stability and linearity in a wide particle energy range from 1 up to 250 MeV. For this purpose, we chose dual operational amplifier AD8066 (Fast-FET, 250 MHz) by Analog Devices with low-noise input FET transistor BF861 (by Phillips) and high-speed voltage feedback [9]. For calibrating individual channels with external generator, the CMOS low-voltage 16-channel ADG706 multiplexer [9] was applied in de-multiplexing mode. It switched the input pulse from the precision spectroscopic pulse generator to one of the 16 outputs with a number chosen by address code preset in special logical module UPOG (detailed description of the method in [10]). The main characteristics are presented below in Tables 1 and 2.

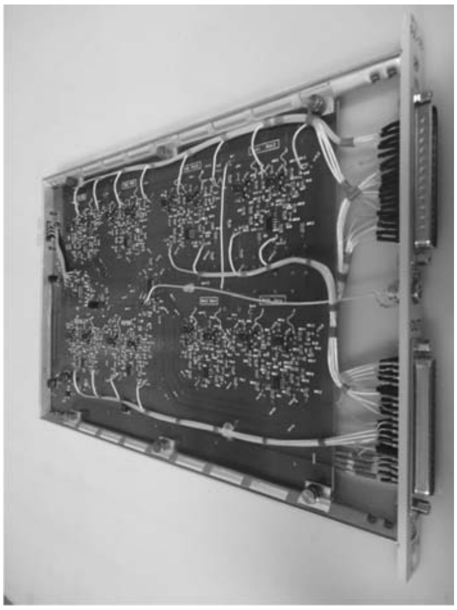

Fig. 2. 16-channel charge-sensitive preamplifier with autocalibration mode

Another development of the operating "analog" registering system is associated with attempts to reduce the total system "dead-time" of data recording and to optimize the method ("active-correlation method") of the on-line search for "recoil–alpha-particle" or "recoil–SF" correlations when performing the experiments on synthesis and study of the SHE.

Application of this method [11] developed in DGFRS research group allows one to stop the ion beam from the cyclotron after detecting "candidate" correlation within energy and time intervals corresponding to decays of parent and/or daughter nuclei in the same position on detector. Thus, the beam-associated background of various nature in the separator's focal plane is strongly reduced.

Table 1

Input/output polarity	Inverted
Energy sensitivity (Si), mV/MeV	8
Noise output performance	See Table 2
Negative feedback constant MΩ/pF	10/5.6
Power supply, mA +6 V −6 V	 200 110

Table 2. **Noise perfomance measured for PA-16 using the ORTEC 575A spectroscopy amplifier set at 1.5 μs, near-Gaussian shaping**

C_{sourse}, pF	Noise, keV (FWHM, Si)	Rise time, ns
0	5	26
70	10.5	30
132	14	40
175	16	60
225	17.5	90

Experimental data characterizing the incoming events in the “analog” CAMAC-based registering system are recorded after spectroscopic signals from 48 front strips, and 128 rear strips of the DSSD are processed by measuring SAR ADC. Every ADC is working in combination with a 16-channel analog multiplexer (MUX) that reduces the total number of the measuring channels and gives the code number of the working strip like in [2]. Thus, we can measure the particle energy and its position in focal-plane detector’s area using three couples of MUX-ADC for serving the 48 front strips of DSSD and eight MUX-ADC couples for serving the 128 rear strips. In fact, we measure the energy of the detected particle in the DSSD twice (using separate ADCs for signals from front and rear detectors). In CAMAC-based registering system the total “dead-time” can be reduced if the conversion time of each ADC is short enough and the number of ADCs to be read in CAMAC cycle is minimum (yet, without loss of experimental data). With this aim in view, a new fast analog multiplexer and a new 12-bit ADC were designed (0.8-μs conversion time, compare with 40 μs in [12]). On the other hand, a new system for determining coordinate of detected particles from 128 rear strips was proposed and constructed. It consists of four individual modules CD32-5 that produce binary code “1 strip of 32” each and primary register PKK-05 producing final code “1 of 128 strips”. Every coder CD32-5 has 32 spectroscopic inputs with adjustable amplitude threshold from 30 to 300 mV. The scheme AD8564 [9] works as fast trigger and gives TTL-compatible signal to priority coder (realized in programmable logical array on EPM7128SLC-15N from ALTERA Corp.) if an input signal exceeds the preset threshold level. At the output each module gives the logical 5-bit code corresponding to the launched channel, one of thirty two. Special module — “pre-register” PKK-05 — reads these 5-bit binary codes from four modules and sums these into a single 7-bit code. This binary 7-bit code is transmitted to CAMAC input register to be read by crate-controller (Fig. 3). In this way we minimize the number of modules to be read in CAMAC cycle from eight to one and get the digital address of the strip with the detected event. Thus, the total “dead-time” is reduced by about 10 μs. Further improvement can be made with developing new spectroscopic amplifiers with lower shaping time of signals.

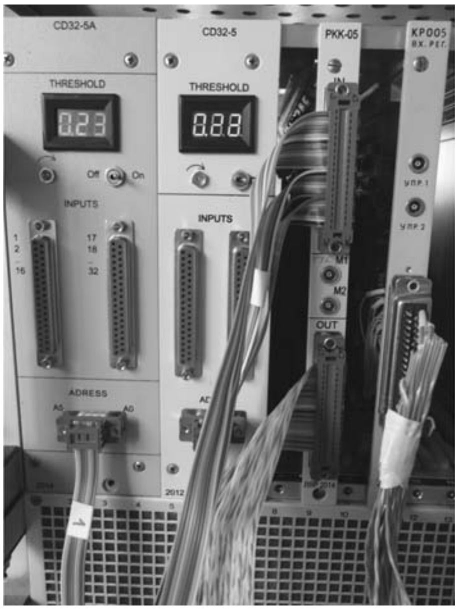

Fig. 3. CD32-5 and PKK-05

CONCLUSIONS

• Two independent registering systems (“digital” and “analog”) are implemented in the new experiments on synthesis of SHE with new DSSD array.

• The new 16-channel spectrometric charge-sensitive preamplifier with an energy resolution of 5 keV is designed and tested to be further used in the DSSD-based measuring system.

• The new fast serial approximation ADC and 16-input Multiplexer are manufactured to process signals from the front DSSD 48 strips.

• The new system for coding the strip number for 128 rear strips is manufactured.

• The new modules should be built into the new measuring system and tested in the experiment with the aim of obtaining better energy resolution and shorter "dead-time".

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