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# ONLINE MONITORING SYSTEM OF ACCELERATOR ELECTRON BEAM ENERGY

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*Abstract*

A necessity for online measurement of the output electron energy arises during start-up, adjustment or operation of an accelerator. For this purpose, there has been developed a system, allowing an online monitoring of energy spectrum accelerated electrons simultaneously with measuring of average beam current. This system is meant for reconstruction of the accelerated electron energy spectrum in the energy range from 1 to 10 MeV at the average beam current from 20 to 150 µA.

The system is based on an absorbing filter method and consists of an assembly, absorbing the accelerated electron beam, and a measuring system.

The developed system tests on the electron accelerator have proved the possibility for its application to monitor electron beam energy in real time.

## INTRODUCTION

A number of linear resonance electron accelerators functions in RFNC-VNIIEF. Among these are such accelerators as LU 10 20 [1] and LU-7-2 [2]. These accelerators are meant for generation of intense electron beams and bremsstrahlung and research the radiation hardness of instruments and materials by the means of generating such radiation.

Measurement of the output electron energy is required both during start-up, adjustment or study of accelerator properties, as well as during physical experiments, requiring precise testing of output beam energy. To supply operability and universality (including a capability for application in different accelerators), it was decided to use an absorbing filter method for measurement of the beam energy. As a result, there has been developed a system for measuring beam parameters, consisting of a measuring assembly and a monitoring system. The developed system is portable, compact, and it helps to organize online measurements of accelerated electron beam spectral response inany accelerator with the energy from 1 to 10 MeV in the shortest time

## OUTPUT BEAM ENERGY MEASUREMENT USING ABSORBING FILTER METHOD

The simplest way to resolve the problem of measuring the beam energy is to use a method of electron absorption in matter. For aluminum the energy dependence on free path Is of the form [3]:

$$R = 0.412 \cdot W_k^n, \quad \text{for } 0.01 \le W_k \le 3 \text{ МэВ} \quad (1)$$
$$R = 0.53 \cdot W_k - 0.106, \text{ for } 3 \le W_k \le 10 \text{ МэВ}$$

Where R – free path of electrons in aluminum, g/cm$^2$;
$W_k$ – kinetic energy, MeV;

$$n = 1.265 - 0.0954 \cdot \ln W_k.$$

One can obtain a full energy response of an accelerated electron beam by restoring energy electron spectrum from current distributions, measured in absorbing assembly plates. A measuring absorbing assembly was developed for this purpose. It represents a set of 20 insulated from each other current-conducting plates of size 100x100 mm and thickness from 0.15 to 1 mm with air gap between plates 2 mm. Appearance of the assembly is shown in Fig. 1.

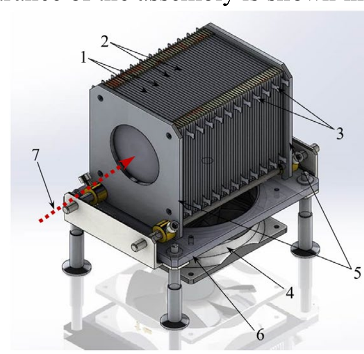


Figure 1: Measuring assembly, 1 - Aluminum plates; 2 - insulation between plates; 3 - leads for current measurement; 4 - fan; 5 - strengthening flanges; 6 - supporting frame; 7 - beam axis direction.

Spectral response of the assembly was calculated in the program C-007 [4] by Monte-Carlo method in the energy range from 1 to 10 MeV in increments of 0.5 MeV. Calculation results are given in Fig. 2.

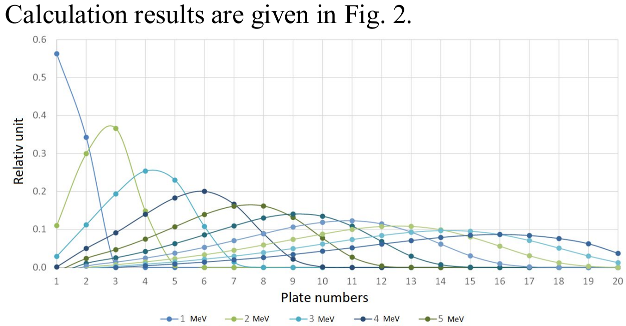


Figure 2: Spectral response of 20 plates assembly.

## ENERGY SPECTRUM RECONSTRUCTION PROGRAM REVIEW

To reconstruct the accelerated electron beam spectrum from current distributions over measuring assembly plates, one should solve the system of 20 equations (number of plates) with 19 variables (values of plate current intensities at different beam energies – 1, 1.5, 2, …, 10 MeV). The system in a matrix notation is of the form:

$$\boldsymbol{A} \cdot \boldsymbol{X} = \boldsymbol{B}, \quad (2)$$

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To solve the combined algebraic linear equations (CALE) (2) a method of least squares (MLS) has been selected. Solution of the given equation system may contain negative values, which do not satisfy us. Thus, the restriction – $X \geq 0$ was additionally imposed on solutions. Realization of such an algorithm was proposed in paper [5] and applied in developed computer program "Spektr".

The program code is implemented in language C++. The main program window (Fig. 3) is separated into two sections. The left region is meant for visualization of calculated and measured current values, as well as for current distribution output, corresponding to the found energy spectrum. A spectrum and an average beam energy value are presented in the right region.

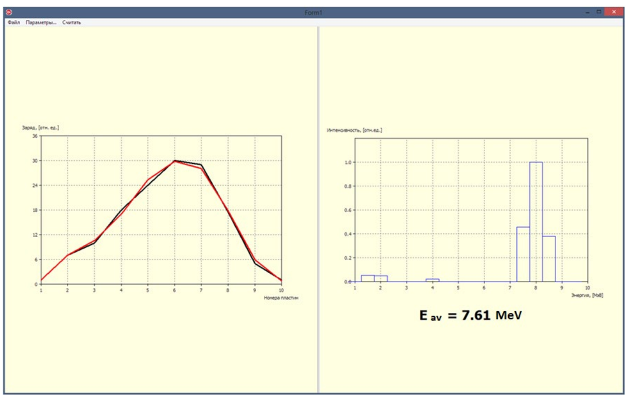


Figure 3: Main window of program "Spektr".

## CURRENT MEASUREMENT DESIGN USING ASSEMBLY

When the accelerated electron beam is passing through a detector, a charge is accumulating in the detector plates. The charge accumulated in the detector plates flows down to the ground through a ripple integrating RC-filter, consisting of a resistor and a capacitor. Registered voltages on resistors of each RC-filter arrive at the inputs of a multi-channel a-d converter. Further digitized signals arrive at the inputs the inputs of a multichannel controller, and then the combined signal from the controller output is delivered to the personal computer input. Measurement design for an electron current with the aid of measuring assembly is given in Fig. 4.

## RESULTS OF CURRENT MEASUREMENTS AND ENERGY SPECTRUM RESTORATION

Measurement run of accelerated electron beam energy response was conducted using the developed measuring assembly.

Figure 5 shows plate current distributions, normalized to maximal values, obtained at different settings of input accelerator parameters and restored energy spectra corresponding to them. Accelerator settings were changing in such a way, that the maximum current value was in plates with different numbers. According to spectra diagrams one can say that when maximum current is shifted towards plates with a higher number, the average electron energy grows.

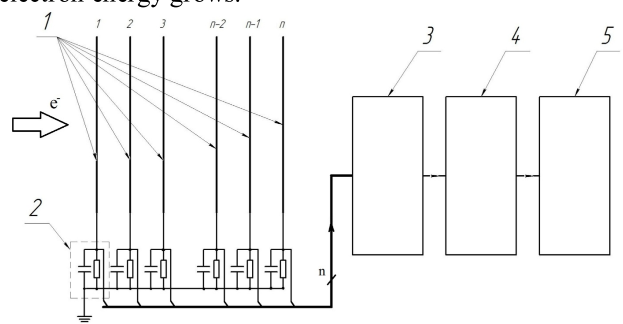


Figure 4: Electron current measuring circuit using the measuring assembly. 1 – electro-conductive absorbers; 2 – ripple integrating RC-filter; 3 – a-d converter; 4 – controller; 5 – personal computer with software.

The most interesting thing was comparison of spectrum, measured by the method of absorbing filters with spectrum, obtained with the aid of magnet spectrometer, namely a scanning magnet. Fig. 6 red line shows a spectrum, measured with the aid of the magnet spectrometer. The histogram reports absorbing filter method measurement results.

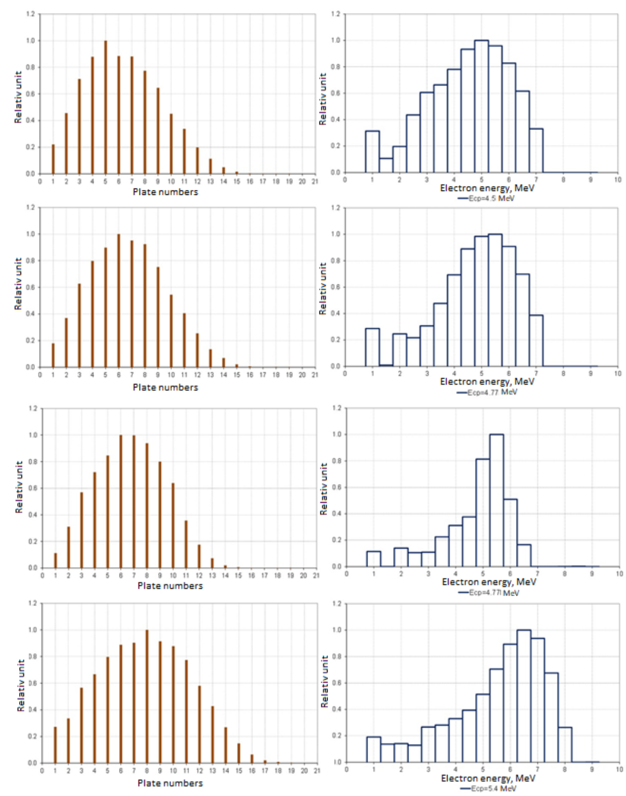


Figure 5: Distribution of currents over plates (left column) and corresponding restored energy spectra (right column)

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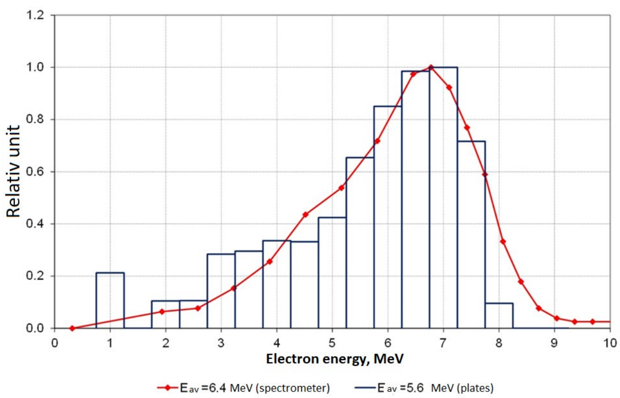


Figure 6: Electron energy spectrum, obtained with the aid of magnet spectrometer and by absorbing filter method.

## CONCLUSION

Experimental sample of monitoring system of output electron beam energy was developed and tested.

The following works were performed:

–express control method of output electron beam energy was developed;

– measuring assembly structure was developed;

–calculation of current distribution over the assembly plates at different electron beam energies was carried out;

– the computer program meant for the energy spectrum restoration by distribution of currents in the measuring assembly plates was developed;

– the monitoring system of output energy was developed;

– the energy monitoring system was tested on the accelerator.

From the result obtained it can be concluded, that application of the beam energy monitoring system for operational measurement of accelerated electron beam energy spectrum in the real time mode is possible.

Patent license №2707270 for invention of «Charged particles spectrometer» became a result of the work on development of output electron beam energy monitoring system.

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