ISBN: 978-3-95450-197-7 doi:10.18429/JACoW-RUPAC2018-THPSC33

# RADIATION INSTALLATION AND ACCELERATOR UELV-10-10-C-70 BEAM PARAMETERS CONTROL, MANAGEMENT AND REGISTRATION SYSTEM

P. A. Bystrov, Yu. S. Pavlov, A. A. Kozlov, IPCE RAS, 199071 Moscow, Russia
I. Yu. Yakupov, A. V. Prokopenko, MEPhI, 115409 Moscow, Russia
N. E. Rozanov, MRTI RAS, 117519 Moscow, Russia

*Abstract*

The design of radiation technological installation operation parameters recording system for accelerator UELV-10-10-S-70 is presented. Proposed the design of the sensor, which makes possible roughly evaluate the energy spectrum of accelerator beam. Solutions are proposed for data transfer from the accelerator equipment to the computer for former analysis and recording data in journal, as well as preventing supernumerary situations.

## INTRODUCTION

Irradiation of medical products on radiation installations based on electron beam requires a careful, responsible approach. To increase the quality of irradiation, continuous monitoring of the installation operation is necessary. The design of the system for monitoring and recording parameters of a radiation-technological installation at IPCE RAS was presented earlier [1]. The developed monitoring system is able to collect data in real time with number of sensors, perform its analysis and registration, inform about errors and emergency situations. System uses a simple solution for collecting and transferring data from sensors to a computer, which traditionally remains a bottleneck in technology.

An important task remains to develop a sensor able to determine the parameters of the accelerator beam, such as pulse current and energy spectrum and transfer them to recording system in real time. Various methods, based on simple equipment, for determining the energy spectrum of accelerator beam, which can be used for continuous monitoring without interrupting the production process, were proposed [2].

This paper concerns developing a technique for evaluating the beam energy spectrum of an industrial accelerator UELV-10-10-S-70 by methods based on standard equipment, which does not interrupt the process of irradiation on accelerator. For this problem, the beam spectrum sensor based on the Faraday cup is proposed, using the control system. The sensor measures the current of the part of the deflected beam. It uses that part of the beam which is not utilized in standard accelerator operation.. The measurement accuracy can be increased by using long-term collecting and mathematical post processing of the collected data.

The method is simulated using the "Beam Scanning" code. A computational model is being developed for processing the results of measurements in these methods, using the computer code "Beam Scanning".

## MATERIALS AND METHODS

Irradiation center at IPCE RAS is based on radiation-technological installation with electron accelerator UELV-10-10-S-70 which is mounted in radiation-safe bunker and designed to perform irradiation by electron beam with electron energy up to 8 MeV, beam power up to 10 kW.

Figure 1: Radiation installation at IPCE RAS center.

Radiation-technological installation consists of linear electron traveling wave accelerator with beam scanning system attached to it and circular conveyer, which moves objects before the output window of accelerator, one meter far from output window. The conveyer with boxes and accelerator with beam scanning system of this installation are presented on Fig. 1. Installation is used in different research, technological and commercial applications. Installation has an open beam, which makes possible to work with the beam using different instruments.

To collect information about installation operation and to control the process of irradiation, recording system was implemented. This system consists of measurement and signal conversion blocks for collecting the following data: the data on conveyer movement, the data on conveyer motor power supply and the data on deflection magnet beam scanning system power supply. In current version of the system the data about the conveyor movement, scanning system deflecting magnet current and accelerator

ISBN: 978-3-95450-197-7 doi:10.18429/JACoW-RUPAC2018-THPSC33

state is collected, using sensors and controller similar to well-known “Arduino”, and sent onto computer through USB port for further analysis. The system is presented on Fig. 2.

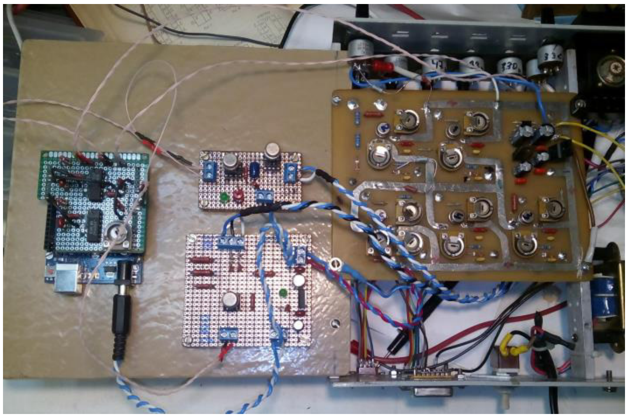

Figure 2: Control system.

To collect information about beam, the Faraday cup, presented on Fig. 3 is proposed as a sensor. Positioning the Faraday cup under conveyer of installation [3] makes possible to analyze the flow of deflected and scattered beam at that point. The flow changes according to deflecting magnet field and depends on beam energy spectrum. Using collimating slots, mounted in front of the cylinder inlet, it is possible to achieve capturing the flow of a particular direction, deflected at a particular angle.

Figure 3: Faraday cup.

Faraday cup is connected to pulse integration system, which helps to accumulate the beam current, collected by the sensor. Then data is transferred to microcontroller.

For the preparation of the experiments carried out a computer calculation. To simulate the sensor operation at experimental conditions, the computer code "BEAM SCANNING" [4-8] was used. “BEAM SCANNING” can be used in different applications with electron beam and irradiated objects on industrial sterilization installations. Simulation allows to determine the beam electron current, captured by metallic irradiated objects. This helps to propose the optimal method of sensor positioning and to develop sensor design The calculation can be performed to study the method of further analysis, required to obtain the energy spectrum.

## RESULTS OF SIMULATION

To find out a beam energy spectrum thee magnet analyzer is proposed, based on a magnet of working beam scanning system [9-10]. Using a beam, propagated under the conveyer of installation at large deflection angles, it is possible to separate its part, which propagates by straight lines form the centre of the magnet, collect it into a Faraday cup and measure the collected current. The angle of beam deflection, magnetic field and electron energy are connected by a simple approximate equation:

$$\alpha \approx \frac{h_M B_M ec}{\varepsilon},$$

where $\varepsilon$ is the electron energy, $h_M$ is the length of magnet field area by Z axis, $B_M$ is the magnetic field, $e$ is the electron charge, $c$ – light velocity.

From this formula we see, that energy depends linearly of magnetic field with given angle of deflection. Since the cylinder inlet has a noticeable diameter, there is a range of angles $\Delta\alpha$ , in which particles are collected by a cup. We can derive:

$$d\varepsilon \approx \frac{-h_M B_M ec}{\alpha^2} d\alpha$$

This means that collected energy range linearly depends on angular inlet size and magnetic field. To model the situation using code “Beam Scanning” we create a rectangular area of magnetic field, given beam spectrum and cylinder with collimating holes, which models the Faraday cup. In model we use a beam, containing only the electrons of energies 1, 3 and 5 MeV in equal parts of beam current. Each scanning period magnetic field increases, and electrons, first of 1 MeV, then 3 MeV and then 5MeV are captured. This can be seen on waveform from cup, shown on Fig. 4, displaying the current from cylinder. First we suppose, that there is no output foil at accelerator exit.

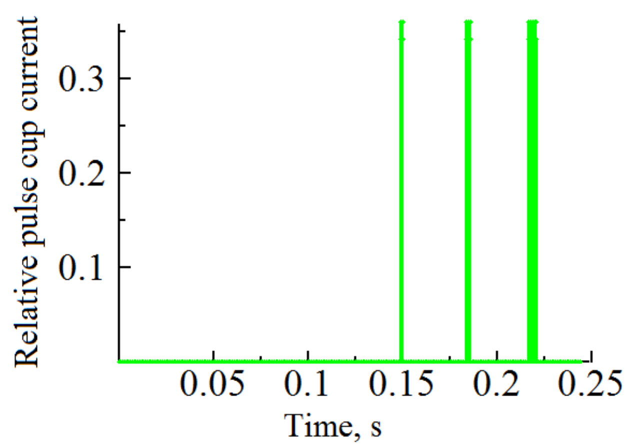


Figure 4: Waveform from cup on one period of scanning, $B_M$ linearly depends on time; in this simulation output foil is absent.

The figure shows, that current is captured well, but with an increase in energy, the number of beam pulses trapped

ISBN: 978-3-95450-197-7 doi:10.18429/JACoW-RUPAC2018-THPSC33

by the cylinder increases. If we add an output foil to our model, that causes the beam scattering, then waveform of cylinder is more difficult to study. The waveform of model with foil is presented on Fig. 5. In this model, the total current drops by two orders of magnitude, measured curve displays essential increase of relative current at high energies, while all currents are relatively equal. Three peaks of energies can be seen, but vaveform do not represent the beam spectrum.

Using this method to restore a spectrum, we should carry out a complex mathematical processing of an incorrect problem. From this study we can note, that obtaining beam spectrum is difficult task, and only rough evaluation is possible.

To proceed with the problem we can try to separate the captured electron beam into parts, depending of different depth of penetration using insulated aluminum plate pack at the cylinder bottom [11]. This will require accurate measurement of currents from each plate, using integrating circuits and signal accumulation.

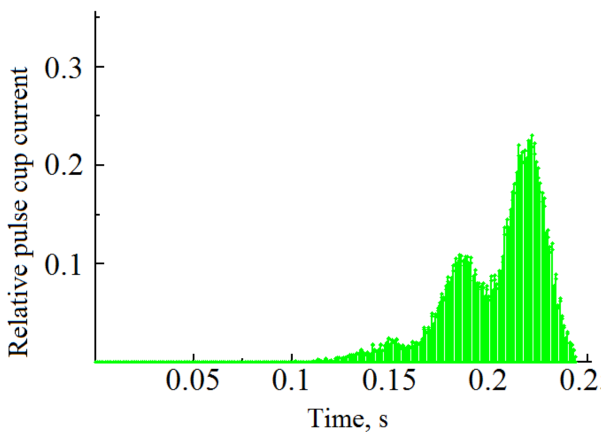


Figure 5: Waveform from cup on one period of scanning, $B_M$ linearly depends on time; in this simulation output foil of 50 μm is used.

## CONCLUSION

A device has been developed for controlling and recording the parameters of the radiation installation, a simple method for collecting and transmitting data to a computer has been proposed.

The developed version of the system collects data on the movement of the conveyor and the current parameters of the deflecting magnet of the scanning system. A sensor is proposed for a constant, coarse estimate of the electron beam spectrum. For this purpose, indirect methods were used, in particular, a measurement method based on a magnetic analyzer of a scanning system.

A simulation was performed using a model of standard Faraday cup with collimating slots. The simulation results showed that method requires a complicated mathematical calculations and accurate measurements to efficiently obtain a spectrum, so the further development of the sensor is required.

## REFERENCES

[1] Bystrov P. A., Pavlov Yu. S. Development of the control system for the operation of the industrial accelerator UELV-10-10-c-70 / Proceedings of the IV International Conference Laser, Plasma Research and Technology - LaPlaz 2018. — Moscow, 2018. — V. 1. — p. 393–394.

[2] Bystrov P. A., Pavlov Yu. S., Yakupov I.Yu. Development of a technique for measuring the energy spectrum of an industrial accelerator beam UELV-10-10-c-70 / Proceedings of the IV International Conference Laser, Plasma Research and Technology - LaPlaz 2018. — Moscow, 2018. — V. 1. — p. 395–396.

[3] P. A. Bystrov, A. V. Prokopenko, Yu. S. Pavlov, O. V. Suvorova, and I. Yu. Yakupov. Improving the efficiency of using an electron beam in the radiation center at IPCE RAS / Radiation technologies in agriculture and food industry: status and prospects,. Obninsk. — FSBI VNIIRAE. — 2018. — p 136–140

[4] Bystrov P. A., Rozanov N. E. Methodology and the computer code "BEAM SCANNING" for calculation of processes in scanning system of the electron beam / Nuclear physics and engineering. — 2011. — V. 4. — Number 4. — p.355-358.

[5] Bystrov P. A. Applying the computer code beam scanning for obtaining the electron beam energy spectrum and monitoring the beam scanning system with a faraday cup and edge current sensors. / Problems of Atomic Science and Technology. — 2014. — Issue 3. —p. 193-196.

[6] Bystrov P. A. Sterilization Installation Electron Beam Dynamics Optimization / 2014 20th International Workshop on Beam Dynamics and Optimization (Bdo) — 2014. — p. 36-37.

[7] Bystrov P. A., Rozanov N. E. The model of the irradiation of a three-dimensional object by the electron beam in the sterilization installation with the local radiation shielding / Problems of Atomic Science and Technology. — 2014. — Issue 3. —p. 128-133.

[8] P.A. Bystrov and N.E. Rozanov, The methodology and the computer code BEAM SCANNING for calculating the processes in the scanning system of electron beam with a broad energy spectrum / Problems of atomic science and technology, Kharkov Institute of Physics and Technology, Ukraine. — 2012. — No 4. —p. 87-91.

[9] Alexeev M. A., Bystrov P. A., Rozanov N. E. Simulation of the process of measuring the energy spectrum of an electron beam by the magnetic analyzer on the basis of a scanning system of a sterilization installation. / Nuclear Physics and Engineering. — 2013. — Vol. 4. — No 4. — p. 361-364.

[10] Alexeev M. A., Bystrov P. A., Rozanov N. E. Computer simulation of the electron beam energy spectrum measurement by the magnetic analyzer method based on scanning system of the sterilization installation. / RuPAC 2012 Contributions to the Proceedings - 23rd Russian Particle Accelerator Conference

[11] Kudinov V.V., Smirnov V.V. A Practical Method for Evaluating the Electron Spectrum Based on the Processing of Electron Passage Curves in an Aluminum Absorber // Scientific session MEPhI-2015. In the collection of annotations. M.: MEPhI, 2015. - Vol. 2 - P.206