

SUBSYSTEM FOR CONTROL OF ISOTOPE PRODUCTION WITH LINEAR ELECTRON ACCELERATOR

*S.P.Karasyov, R.I. Pomatsalyuk, V.A. Shevchenko, I.N. Shlyakhov,
A.Eh. Tennishev, V.L. Uvarov*

*National Science Center "Kharkov Institute of Physics and Technology"
61108, Kharkov, Ukraine
uvarov@kipt.kharkov.ua*

One of advanced ways of isotope production for medicine is using of bremsstrahlung of the electron accelerator [1]. Therewith, this technology requires development of special target units, that can be operated under high radiation energy flow (up to 10 kW and more) and absorbed dose up to 10^{10} Gy. The conditions of high efficiency of the nuclide production and an isotope purity of them define requirements to the control and diagnostic systems. In this report the high-current LINAC subsystem for diagnostic and monitoring the basic technological parameters of isotope production (energy flux of bremsstrahlung photons and absorbed dose in the target, target activity, temperature and consumption of water cooling the converter and target) is described. The parallel printer port (LPT) of the personal computer is proposed to use as an interface with the measurement channels.

PACS number: 07.05.Bx

1 INTRODUCTION

The main method of isotope production today is the nuclear reactions initiated by heavy particles (basically neutrons and protons), generated in the reactors and accelerators. While the cross-sections of these reactions are considerably higher than photonuclear ones, but a charged particle interacting with the target loses the energy very fast and leaves a resonance region. Therefore an efficiency of the isotopes production (rate of isotope nuclei generation per unit of the beam power) on heavy particle accelerators is not very high [2]. In case of reactors the problem is a large amount of the radioactive waste created along with useful isotope production. For example, if 1 Ci of the ^{99}Mo (parent isotope of $^{99\text{m}}\text{Tc}$ – the general nuclide using in medicine diagnostic) is produced using the reactor then up to 50 Ci of long-lived waste is produced too [3]. So, taking into account a constant increase of isotope applying in medicine, a creation of ecological safety technologies of their production becomes more and more actual.

A bremsstrahlung of the electron accelerator can be used for production of isotope series for biophysical and medical purpose [4]. In this case, although the specific activity of a produced isotope is relatively not so high ($\leq 1\text{Ci/g}$), the efficiency of their generation is considerably higher than in the case of using heavy charged particles and neutrons [5]. Additionally, an isotope production with using the electron accelerator is considerably lesser in respect to concurrent production of radioactive isotopes than other technologies.

2 TECHNOLOGY OF ISOTOPE PRODUCTION ON THE ELECTRON ACCELERATOR

The schematic diagram of the setup for isotope production using (γ, n) and (γ, p) reactions with a solid target is shown in Fig. 1. The electron beam passes through an accelerating structure AS, swings in line by a scanning electromagnet SM and outputs to atmosphere through

an exit window. The sweep length and electron energy are defined by the measurement channel with magneto-inductive sensor SBPM [6]. Output beam is directed to the target unit TE that includes: bremsstrahlung converter C, target T and ionization chamber IC.

The converter presents aluminum case that has two Ta-plates with thickness 1.2mm each (for an electron energy in the range 20...30 MeV). The target T consists of a set of the treated plates containing the initial isotope and enclosed in an Al-casing. Running water continuously cools down the converter plates and target plates.

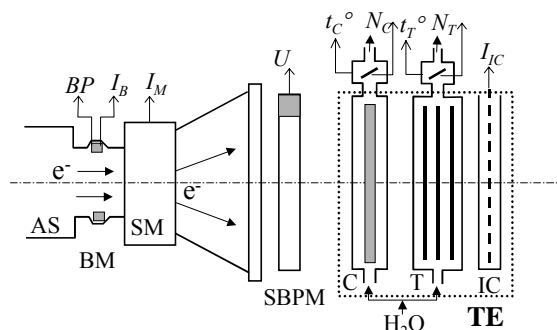


Fig. 1. Schematic diagram of the setup for isotope production with the electron accelerator.

A control subsystem of the target unit monitors continuously the water temperature at the converter (t_C) and the target (t_T) output and output value of water consumption N_C and N_T in these units. The copper thermistors are used as temperature sensors, and the turbine converters are used as water consumption sensors [6].

3 OPERATION CONTROL OF BREMSSTRAHLUNG AND TARGET ACTIVITY

3.1. The technological measurement channel for metrological accompaniment of the radionuclide production process using the electron accelerator is devel-

oped. It controls the following parameters:

- bremsstrahlung energy flux,
- absorbed dose rate and absorbed dose of bremsstrahlung in the target,
- target activity,
- converter and target cooling water temperature and its consumption.

3.2. For the continuous monitoring and control of bremsstrahlung parameters a sensor low disturbing a radiation field is needed. Considering above-mentioned circumstances, the plane-parallel wide-aperture ionization chamber IC with a sensitive region size 220x550 mm was developed and constructed as a measurement probe. The chamber is made from aluminum and its effective thickness is 0.6 g/sm² [7].

The choice of geometrical parameters of the IC is defined by conditions of bremsstrahlung generation (BR). The BR in modern electron accelerators is produced by conversion of the initial high-power electron beam (10 kW). Since such beam swings into the line before output to the atmosphere, this defines increasing of a geometrical size both in initial electron beam and bremsstrahlung too.

3.3. The automate system for input and signal processing from the ionization chamber, temperature channel and water flowmeter is constructed (Fig. 2). The system is modularized and has four measurement channels.

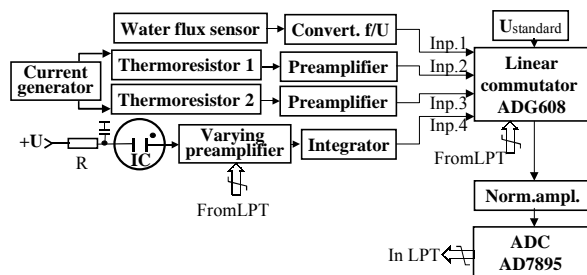


Fig. 2. Block-diagram of the control-measurement channel using LPT-port.

The power supply +250 V with a stability about 10⁻³% is developed for a chamber feed that works in the current mode. The load of the chamber IC is the measurement resistor R. A potential from this resistor (that is proportional to the amount of energy stream through the chamber or absorbed dose rate of bremsstrahlung in point of its interaction with an irradiated object) goes to the input of the preamplifier. The latter is an inverter with various gain coefficients and made using the analog IC AD711. From the output of the preamplifier the amplified signal goes to the integrator with a time constant $\tau \approx 1.5$ sec, that is much more than the period of the accelerator pulse rate and beam scanning. In other words, the signal at the integrator output is proportional to the IC current, averaged over the period τ . Then the signal going to the input of the linear commutator is controlled by the computer.

The beam is turned off in the mode of activity measurement and the tract of activity measurement is connected to the ionization chamber. This tract is similar to the measurement tract of absorbed radiation dose rate

and a difference is only the preamplifier gain. The changing of the preamplifier gain is provided by the resistor connection to the feedback of the preamplifier through the commutator controlled by the computer.

The temperature tract consists of two identical channels that make measurement of temperature water, cooling converter and target. The copper thermistors with a resistance $R_0 = 50 \Omega$ are used as the primary sensors and connected as is shown in Fig. 2. The preamplifiers of DC current use analog IC type of AD623 and have gain $\sim 10^3$. The current generator has stability better than 10⁻⁴ %. A signal from the preamplifier output is going to the linear commutator and digitized by 12-bits ADC. The accuracy of measurement is about 0.01⁰C with noted channel parameters.

3.4. The standard water flowmeter TIIP-10-1-1B was chosen as primary probe for the water consumption measurement. An output voltage (that is proportional to the water flow in system) from the flowmeter is applied to the input of the linear commutator.

From the commutator the signal goes to the input of the buffer amplifier, that is made as non-inverting voltage amplifier with a high input impedance and then signal goes to the ADC input. The selection of the measurement channel is controlled by commands from the computer.

In the course of system operation the following parameters are measured and output to the display:

- 1 – bremsstrahlung energy flux,
- 2 – absorbed dose of bremsstrahlung in the target,
- 3 – target activity,
- 4 – time of target exposure,
- 5 – temperature and consumption of cooling water.

After achievement of target activity preset, the system generates a control signal for beam accelerator switch off.

4 INTERFACE BETWEEN CONTROL SYSTEM AND COMPUTER

A traditional use of known standards like IEEE-488, CAMAC is unreasonably expensive and in many cases controller interface cards are not supported by modern personal computers (P-II, P-III) because of the high CPU speed and mode Plug and Play.

The parallel printer port (LPT) is proposed to use as an alternative variant of the interface between the measurement equipment and personal computer. This port is supported by all IBM personal computers and does not require building of additional interfaces.

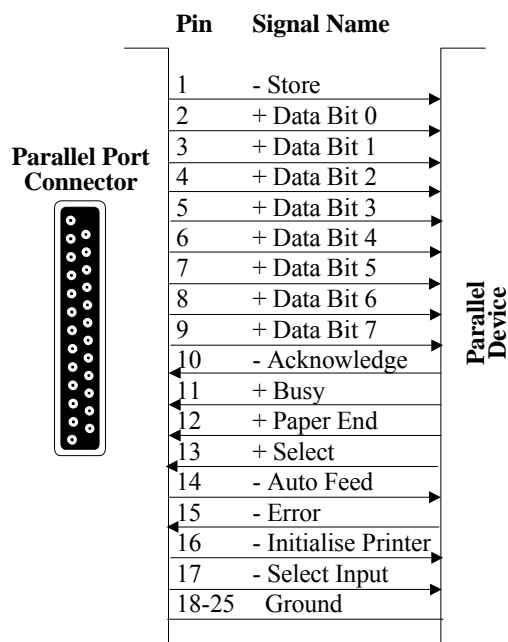
Three registers (Fig. 3) control a printer port in the computer. 12 lines are used for the data sending to the printer and printer control as output and 5 lines are used as an input for the data sending to the computer.

5 ACKNOWLEDGMENTS

Work is supported by STCU under contract N 2185.

REFERENCES

1. M.H. Mac Gregor. *Linear Accelerators as Radioisotope Producers*. Nucleonics.
2. M.C.Lagunas-Solar et al. Cyclotron Production of Molybdenum-99 via Proton-Induced Uranium-238 Fission // *Trans. Amer. Nucl. Soc.* 1996, v. 74, p. 134-135.
3. W.van Z. Villiers. *Proc. Nucl. and Hazardous Waste Managem. Inter. Topical Meet.* 14-18 Aug. 1994, Atlanta, USA, p. 2190-2192.
4. N.P.Dikiy, A.N.Dovbnya, S.V.Maryokhin, V.L.Uvarov. On Production Efficiency of Medical & Biophysical Isotopes Using the Electron Accelerator // *Problems of Atomic Science and Technology. Issue: Nuclear-Physics Research* (34). 1999, v. 3, p. 91.
5. R.G.Bennett et al. A System of ^{99m}Tc Production Based on Distributed Electron Accelerators and Thermal Separation // *Nucl. Technol.* 1999, v. 126, p. 102-121.
6. V.L.Uvarov, V.N.Boriskin, S.P.Karasyov et al. Electron Linac Controlling Subsystem for Isotopes Production Technologies // *Proc. of Workshop on Personal Computer and Particle Accelerator Controls PCaPAC 2000*, Oct. 9-12, 2000, DEZY, Hamburg, Germany, p. 127.
7. A.A.Butenko, S.P.Karasyov, R.I.Pomatsalyuk et al. Technological Measuring Channel for Bremsstrahlung Monitoring // *Problems of Atomic Science and Technology. Issue: Nuclear-Physics Research* (35). 1999, v. 4, p. 49.



**All outputs are generated by software;
all inputs are real-time (nonlatched) signals**

Fig. 3. Signals assignment of the LPT-port.

This number of lines is enough for the control measurement system and acceptance of data from it. The use of a serial ADC AD7895 allows to provide data stream rate up to 120kbod, that is sufficiently for the systems with low and medium data stream rates.

Because a modern printer port uses a bidirectional data bus, it allows to use the parallel ADC and increase the exchange data rate about up to 10 times.

The drivers for system control were written with the high-level language Pascal, that allows to simplify programming significantly without lose of the response speed.