INSTRUMENT BASE OF SYSTEMS FOR DIAGNOSTICS AND TRANSPORTATION OF PROTON AND NEUTRON BEAMS FOR RADIATION TESTING OF ELECTRONICS AT THE 1 GeV SYNCHROCYCLOTRON OF PNPI

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1. Introduction

The widespread use of semiconductor products of microelectronics as an element base of space electronic systems has made the problem of assessing and predicting the levels of failures of elements and assemblies to the radiation effects of outer space relevant. The requirements for these tests are due to the fact that in modern devices manufactured using micron and submicron technologies, new effects of radiation exposure have arisen associated with ionization effects and structural damage to products under the action of individual high-energy particles, the so-called single radiation effects, or single event effects.

Over the past 20 years, failures and breakdowns under the action of individual protons and neutrons have been studied at PNPI in the operation of various highly integrated products: memory elements, transistors, charge coupled devices (CCD) matrices. In this direction, PNPI actively cooperates with many organizations and enterprises in Russia.

Below is given a description of the instrumental base of the systems for diagnostics and transportation of proton and neutron beams, which are part of the stands for radiation tests, developed at PNPI in cooperation with the Institute of Space Instrumentation (Roscosmos), a branch of the United Rocket and Space Corporation [1].

2. Transportation system

The transportation system ensures the delivery of the proton beam from the output window of the accelerator to the workstations. The transportation system includes:

- Dispensing magnet SP-40 – for output to the required path;
- Correction magnets – to shift the proton beam vertically and horizontally;
- Collimators – to change the beam emittance;
- Magnetic lenses – for focusing and defocusing the proton beam;
- Absorber of variable thickness (0–530 mm) – for changing the beam energy in the range of 60–1 000 MeV [2].

The diagram of the proton beam transportation paths to the irradiation workstations is shown in Fig. 1.

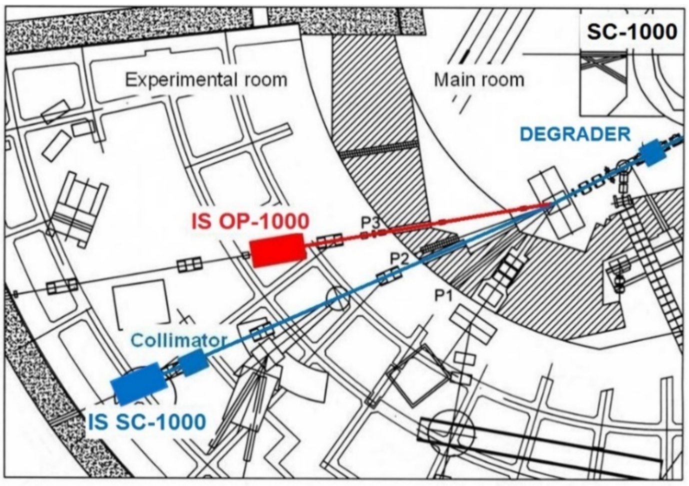

Fig. 1. Diagram of proton beam transport paths: P2 – protons with an energy of 1 000 MeV; P3 – protons with a variable energy of 60–1 000 MeV

The automated control system for setting and stabilizing the current in the magnetic elements is responsible for regulating the current in the magnets (Fig. 2). For output to the working path, an appropriate magnetic field is installed in the distributing magnet SP-40, which is located at the output wall of the “Main Hall”.

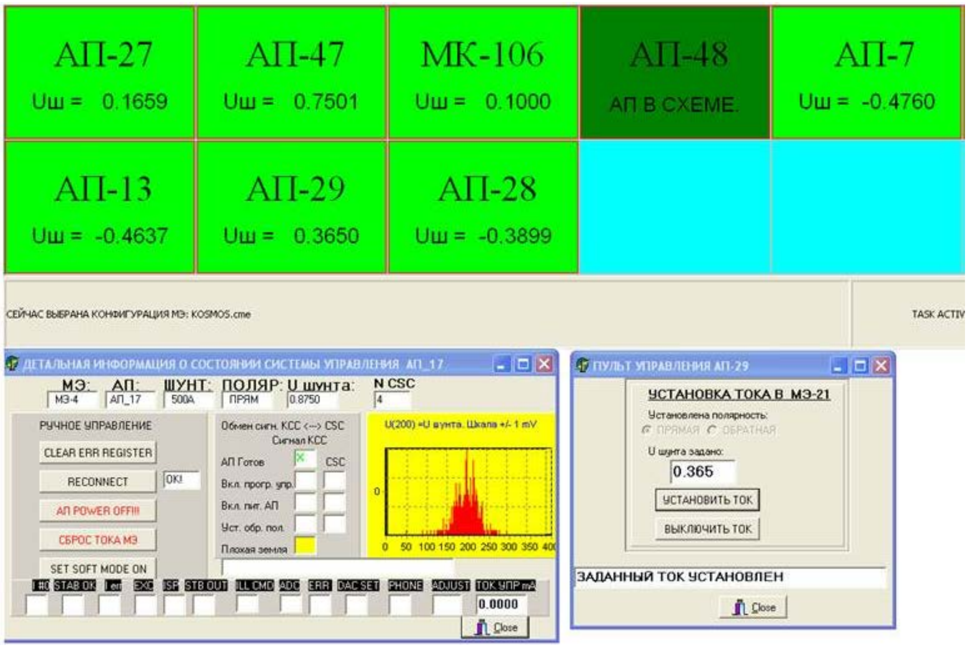

Fig. 2. Interface of the automated control system of the current in the magnetic elements

The fields in the main magnet E-9 of the synchrocyclotron and in the distributing magnet SP-40 are set and controlled by nuclear magnetic resonance (NMR) magnetometers, which makes it possible to reproduce the beam output with good accuracy (Fig. 3).

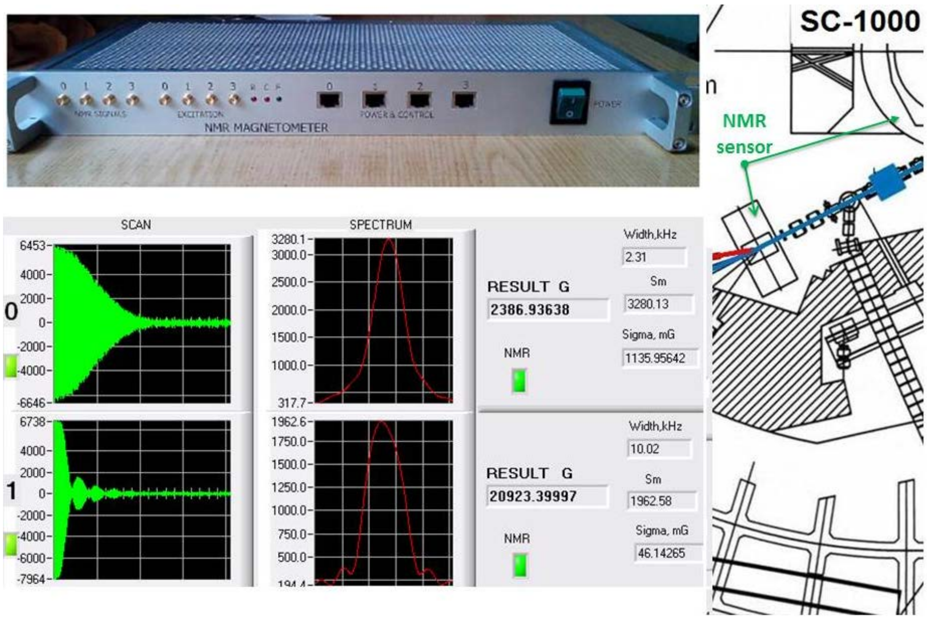

Fig. 3. Nuclear magnetic resonance magnetometer, its interface and location

The variable thickness absorber allows remote adjustment of the absorber thickness by placing a set of copper cylinders in the beam path (Fig. 4).

Fig. 4. The variable thickness absorber

3. Diagnostic system

The diagnostic system provides control of beam parameters and consists of the following tools:

- Two-channel semiconductor profilometer to determine the width of the beam and its centre of gravity;
- Scintillation profilometer with CCD-matrix – to obtain a proton beam profile with a resolution of 512 × 512 points;
- Two-section ionization chamber for online monitoring of the intensity of the proton flux [3];
- Fission ionization chamber to determine the intensity of the neutron flux;
- Two-axis position-sensitive multiwire proportional counter to obtain the distribution of neutrons in the beam.

A two-section ionization chamber design is shown in Fig. 5.

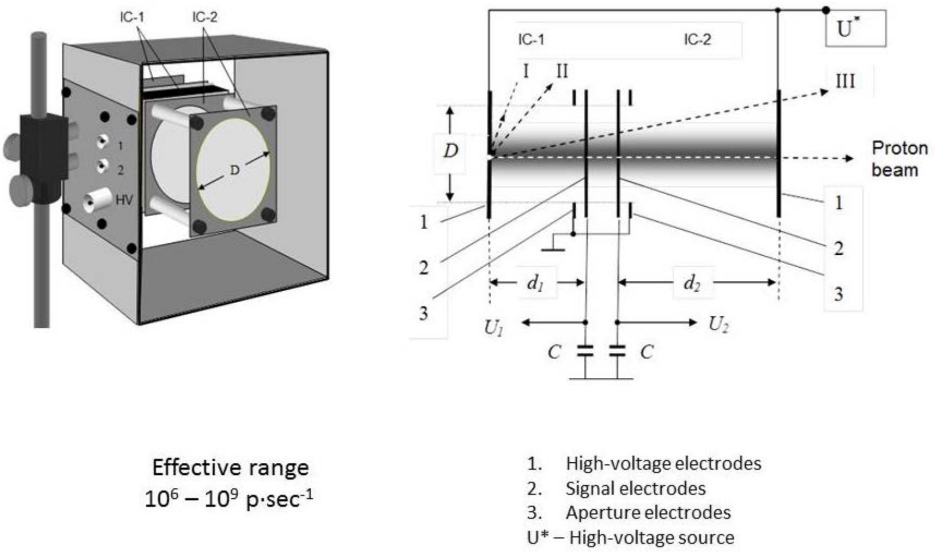

Fig. 5. Two-section ionization chamber design

The results of measuring the beam width and particle distribution density are shown in Fig. 6.

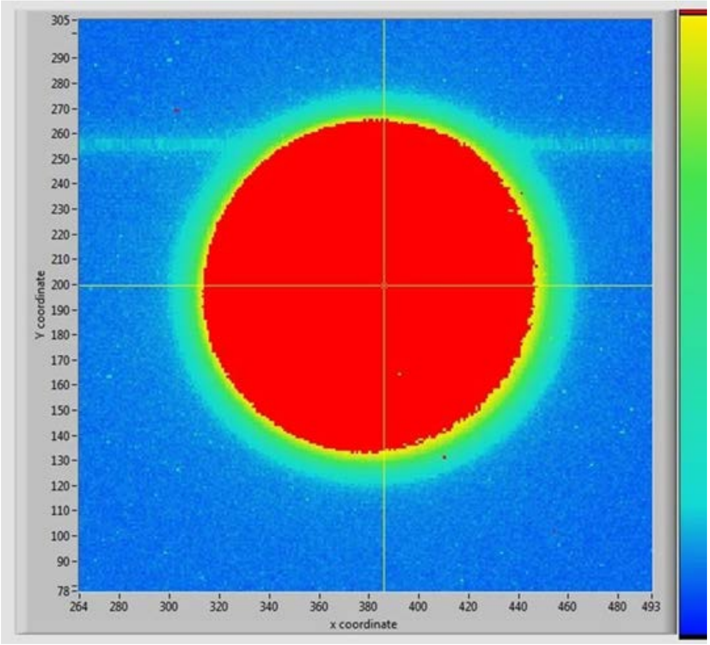

Fig. 6. The result of the work of a scintillation profilometer with a CCD-matrix to find the particle distribution density in the beam

4. Conclusion

The PNPI centre is equipped with all necessary systems of beams diagnostics and transportation to a target. These systems allow changing the shape, energy and direction of the proton beam, as well as measuring the profile and intensity of proton and neutron beams. There is also an instrument to vary the temperature of exemplars in a wide range.

The combination of these systems provides the necessary beam parameters for testing electronic components in proton beams with a variable energy of 60–1 000 MeV and in an atmospheric neutron beam with a wide energy range (1–1 000 MeV).

References

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2. E.M. Ivanov, G.F. Mikheev, V.S. Anashin, An Automated Moderator of the Proton Beam of the Synchrocyclotron – a Degrader: Utility Model Patent No. 181147; Priority 03.30.2018.
3. D.A. Amerkanov, G.I. Gorkin, E.M. Ivanov *et al.*, PTE **3**, 11 (2016).