

OBTAINMENT OF 5 mA 2 MeV PROTON BEAM IN THE VACUUM INSULATION TANDEM ACCELERATOR*

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Abstract

In BINP the neutron source for BNCT based on proton accelerator was designed and built. It is necessary for the therapy to ensure a stable proton beam current of not less than 3 mA with energy 2 MeV. During the injection of negative hydrogen ion beam into the accelerator the unwanted charged particles are produced, affecting the stability of beam parameters. The article describes methods of suppression of undesirable charged particles and the results of experiments.

INTRODUCTION

Boron-neutron capture therapy (BNCT) [1] is a promising method of malignant tumours treatment. For implementation the technique in clinical practice the accelerator based compact epithermal neutron sources with energy of protons from 2 to 3 MeV and a current at least of 3 mA are required. To solve this problem in BINP a new type of particle accelerator was proposed and developed – vacuum insulation tandem accelerator. In the accelerator construction the high rate of acceleration of ions and the insulator placed remote from acceleration channel are implemented [2]. After reducing of dark current to an acceptable level [3], optimizing of injection of negative hydrogen ion beam into the accelerator [4] and optimizing of stripping gas target [5], the proton beam current increased from initial values of approximately 140 μ A [6] to a value 1.6 mA [7], stable over time more than hour. While explaining the causes of the current limitation in the acceleration channel a significant flow of electrons and the counter-flow of positive ions generated in the accelerating channel and in the stripping target were detected and measured [8]. The paper describes details of further modernization of the accelerator and presents experimental results on the suppression of unwanted fluxes of charged particles and increasing proton beam current.

EXPERIMENTAL RESULTS

Scheme of the vacuum insulation tandem accelerator is shown at Fig. 1. Negative hydrogen ion beam with an energy of 23 keV and current of 6 mA leaves the source 1, after that it is rotated in magnetic field at an angle of 15°, focused by a pair of magnetic lenses 2, injected into the accelerator and accelerated to an energy of 1 MeV. In the gas (argon) stripping target 7 mounted inside the high-voltage electrode 6, negative hydrogen ions are converted into protons, which are accelerated to an energy of 2 MeV

by the same potential. To the high-voltage 6 and five intermediate electrodes 5 the potential is supplied from a high voltage power supply (sectional rectifier) 9 (most of the source is not shown) through the insulator with resistive divider 8. Turbo molecular pumps 10 installed in the ion source chamber and in the output of the accelerator, and a cryogenic pump 4 through the blinds in high-voltage electrodes provide vacuum pumping.

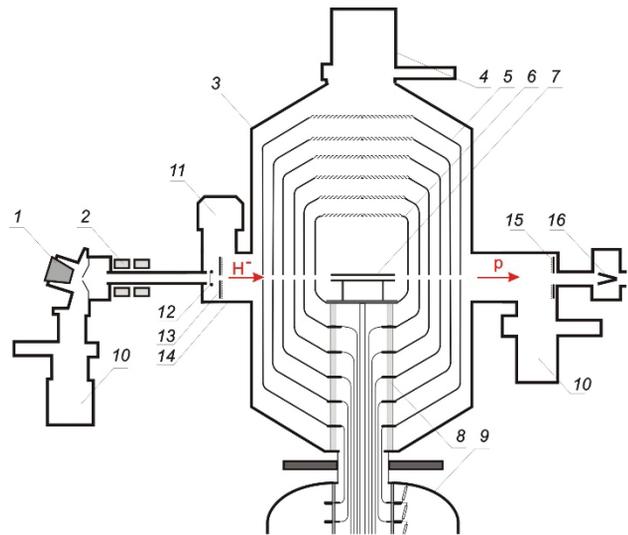


Figure 1: Vacuum insulation tandem accelerator. 1 - negative hydrogen ion source, 2 - magnetic lenses, 3 - accelerator, 4 - cryogenic pump, 5 - intermediate electrodes, 6 - high-voltage electrode, 7 - gas stripping target, 8 - insulator, 9 - high voltage power supply, 10 - turbo molecular pump, 11 - cryogenic pump, 12 - ring, 13 - metal cooled aperture and detector with a grid, 14 - input vacuum volume, 15 - detector with a grid, 16 - Faraday cup. The arrows indicate the direction of the negative hydrogen ion beam (H^-) and protons (p).

Modernization of the accelerator was as follows. The water-cooled metal diaphragm 13 with a 20 mm hole with possibility of centring along the beam axis was installed in the vacuum chamber 14 at the accelerator input. That aperture is considered to reduce the flow of gas and ultraviolet from the source of negative hydrogen ions in the accelerating channel. At the upper flange of input vacuum volume through the slide valve DN 250 the cryopump On-Board 250F (CTI-Cryogenics, USA) 11 was installed. This should improve the vacuum conditions in the beam-transporting channel and in the accelerating channel. In front of the cooled diaphragm a metal ring 12 was installed. Negative potential applied on this ring should suppress the flow of electrons that accompany the beam of negative

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hydrogen ions. Surface of cooled aperture 13 was covered by the wired tantalum grid for suppressing the secondary electrons produced by irradiation of metal surface by positive ions. Between the grid and the diaphragm an insulated metal plate for current measurement was placed. In addition, on the surface of the vacuum chamber at the output of the accelerator the similar grid and plate 15 were installed.

Fig. 2a shows that when voltage is applied to the grid at the entrance of the accelerator, bremsstrahlung dose rate (caused by the absorption of electrons in the metal, accelerated to 1 MeV [9]) is significantly reduced. Presented at Fig. 2b the current-voltage characteristic of the detector at the entrance of the accelerator indicates that the coefficient of secondary electron emission formed under the influence of positive ions is ~ 10 (high secondary electron emission coefficient is typical for many-electron atoms and ions with energies above 100 keV [10]).

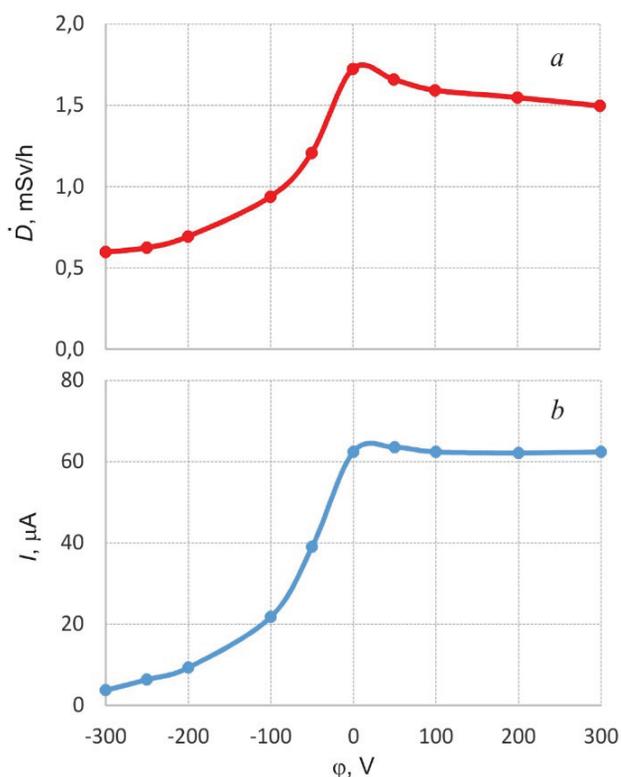


Figure 2: Dependence of the gamma radiation dose rate D (a) and current on the detector mounted at the accelerator input from grid potential ϕ (b).

After installation of the diaphragm, the cryogenic pump, rings and grids it was achieved a significant reduction of unwanted flows of charged particles. In particular, the flow of electrons accelerated to full voltage was reduced 20 times to a value of about 0.5% of the ion beam current. Suppression of undesired flows of charged particles in the accelerator improved accelerator operation resistant to breakdowns of the total voltage and significantly increased the proton beam current. Fig. 3 shows the oscillograms of current and energy of the proton beam. Measured by

Faraday cup (16 in Fig. 1) proton beam current for one hour exceeds 5 mA, the average value is $5,120 \pm 0,060$ mA, max value is 5.327 mA.

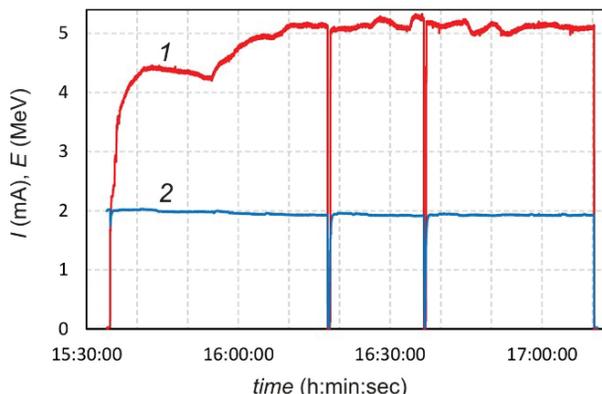


Figure 3: Proton beam current I (1) and energy E (2) oscillograms.

CONCLUSION

As a result of the modernization of the accelerator flows of undesired charged particles was effectively suppressed. It is allowed to reduce the level of gamma radiation from accelerator and increase proton beam current up to 5 mA. Obtaining of a stationary proton beam with a current of 5 mA has actually solved a problem of neutron source for BNCT - irradiating of a lithium target by this beam provides the desired flux of epithermal neutrons.

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