THREE-FOLD INCREASE OF THE PROTON BEAM CURRENT IN THE VACUUM INSULATION TANDEM ACCELERATOR

I. Shchudlo†, S. Taskaev, D. Kasatov, V. Dokutovich, A. Makarov, I. Sorokin, Ya. Kolesnikov, E. Sokolova, A. Kuznetsov,Yu. Ostreinov,Budker Institute of Nuclear phisics SB RAS, Novosibirsk, Russia

Abstract

Supression of undesired flow of electrons and positive ions formed in the beam line in the vacuum insulation tandem accelerator allowed us to increase accelerated proton beam current with an energy of 2 MeV to more than 5 mA. The paper describes details of the accelerator modernization, experimental results of studies of undesired charged particles suppression and measured parameters of the accelerated high current proton beam.

INTRODUCTION

At present boron-neutron capture therapy (BNCT)[1] is expected to be a promising method of malignant tumours treatment. For implementation the technique in clinical practice 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 wasproposed and developed – vacuum insulation tandem accelerator.In the accelerator construction the highrate of acceleration of ions and the insulator placed remote from acceleration channelare 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 140µA[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 furthermodernization of 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 figure 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. At the high-voltage 6 and five intermediate electrodes 5 of accelerator the potential is supplied from a high voltage power supply (sectional rectifier) *9*(most of the source is not shown) through the insulatorwith resistive divider *8*. Turbo molecular pumps *10* installed in the ion source and in the output of the accelerator, and a cryogenic pump *4* through the blinds in high-voltage electrodes provide vacuum pumping.

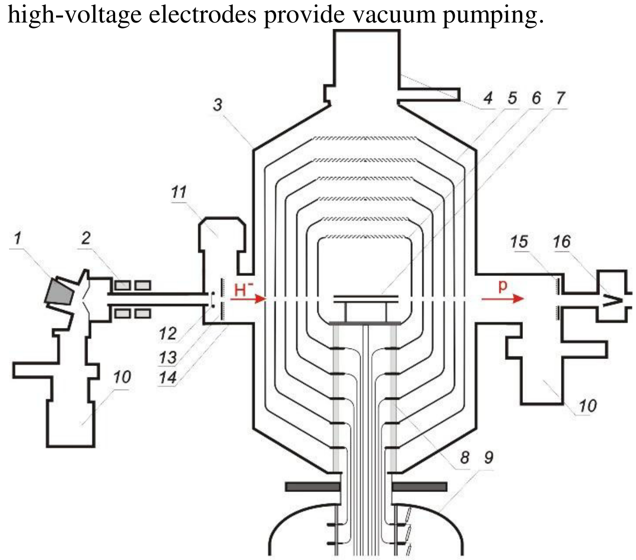

Figure 1: Vacuum insulation tandem accelerator.*1* - negative hydrogen ion source, *2* - magnetic lenses, *3* - accelerator, *4* - cryogenic pump, *5* - intermediate electrodes,*6* - high-voltage electrode,*7* - gas stripping target,*8*– insulator,*9* - high voltage power supply, *10* - turbo molecular 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. Before thecooled diaphragm a metal ring*12* was installed.Negative potential, appliedonthis ringshould supress the flow of electronsthat accompanythe beamof negative hydrogen ions. Surface of cooled aperture *13* was covered by the wired tantalum grid for supressing the secondary electrons produced by irradiation of metal surface by positive ions. Between the grid and the diaphragm insulated metal plate for current measurement was placed. In addition,onthe surfaceof the vacuum chamberat the exit unit ofthe accelerator similar gridand disc*15*were installed.

Figure 2a shows that when voltageis 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 figure 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 characteristic for many-electron atoms and ions with energies above 100 keV[10].

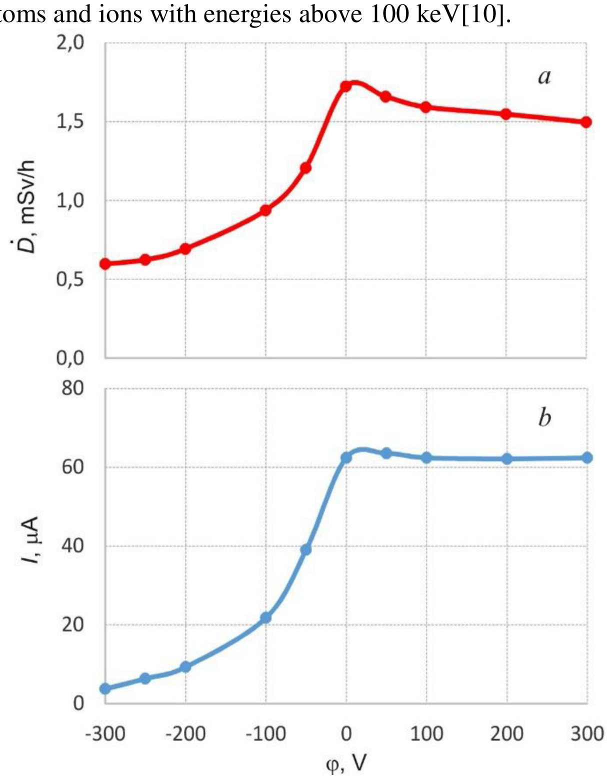

Figure 2: Dependence of the gamma radiation dose rate*D* (*a*) and current on the detector mounted at the accelerator entrance from grid potential of φ (*b*).

After installation of the diaphragm, the cryogenic pump, rings and grid it was achieved a significant reduction of unwanted flows of charged particles. In particular, the flow of electrons accelerated to full voltagewas 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 the 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 ± 0,060 mA, max value is 5.327 mA.

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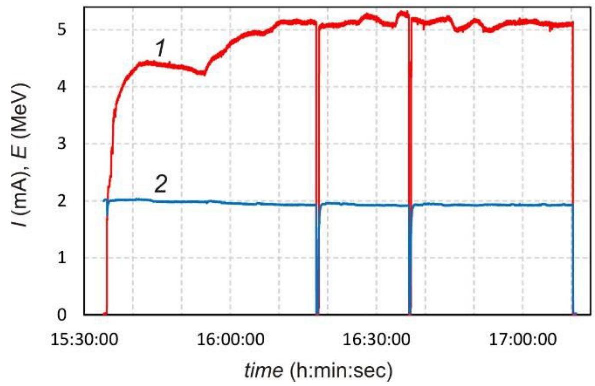

Figure 3:Current *I* (*1*) and energy *E* (*2*) oscillogram of the proton beam.

CONCLUSION

Obtainingof 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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