THE STUDY OF THE ELECTRICAL STRENGTH OF SELECTED INSULATORS WITH A DIFFERENT SHAPE OF THE SURFACE

Ya.A. Kolesnikov#, A.A. Gmyrya, D.A. Kasatov, A.M. Koshkarev, A.S. Kuznetsov, A.N. Makarov, E.O. Sokolova, I.N. Sorokin, I.M. Shchudlo, S.Yu. Taskaev, Budker Institute of Nuclear Physics, SB RAS, Novosibirsk, 630090 Russia

Abstract

In the BINP SB RAS was proposed and created a source of epithermal neutrons for BNCT. The proton beam obtained on a tandem accelerator with vacuum insulation. Sectionalized demountable feed through insulator is an integral part of the accelerator. Voltage from the high voltage source distributed to the electrodes via resistive divider. Because of the small amount of current (hundreds of microamperes) flowing through the divider, dark currents that occur in the accelerating gaps, can significantly affect the uniform distribution of the potential along the accelerating channel, and, consequently, on the beam transportation. Therefore there is a need to change the design of the feed through insulator which will allow to set potentials at the electrodes directly from the high voltage rectifier sections.

To study the feasibility of such changes has been designed and built an experimental stand, in which a single insulator with double height subjected to the same conditions as in accelerator. On the experimental stand was studied electrical strength of ceramic and polycarbonate insulators with a different shape of the surface. The paper presents the results of experimental studies of insulators. Their application will get rid of the voltage divider inside the feed through insulator and realize the scheme which allows to set potential on the electrode gaps directly from the rectifier section. This will increase the operating voltage of the accelerator and its reliability.

INTRODUCTION

In 1998, for high-current proton beams BINP proposed a new type of accelerator - tandem accelerator with vacuum insulation. At present, on the accelerator neutron source there were conducted various experiments for the development of Boron Neutron Capture Therapy (BNCT) [1]. The principle of BNCT technique is simple and elegant: a boron-containing agent is injected in patient's blood, and then part of the body with tumor is irradiated with neutrons. During the nuclear reaction $n(^{10}B, ^{7}Li)\alpha + \gamma$ most of the energy (84%) is allocated within $3 \div 10$ µm, which matches with the size of the mammalian cells. Illustration of BNCT idea is presented in Figure 1.

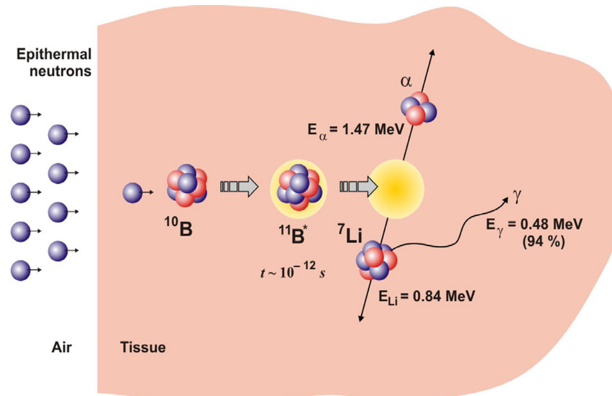

Figure 1: Principle of BNCT.

DESIGN OF THE ACCELERATOR

Figure 2 presents the scheme of the tandem accelerator with vacuum insulation. The outgoing beam from the source of negative hydrogen ions *1* with 23 keV energy and 5 mA current is rotated by 15° in a magnetic field , focused by a pair of magnetic lenses *2*, injected into the accelerator and accelerated up to 1 MeV. In the argon stripping target *7*, mounted inside the high voltage electrode *5*, negative hydrogen ions are converted into protons. Then protons are accelerated by the same potential 1 MV up to 2 MeV. The potential at the high voltage electrode *5* and five intermediate electrodes *6* of accelerator supplied from the high voltage source *10* using a feedthrough insulator *9*, wherein the ohmic divider is installed. Pumping of the gas is maintaining by turbo-molecular pumps *8* installed on the ion source chamber and at the exit of the accelerator, and a cryogenic pump *4* via jalousies [2].

Accelerator produces a stationary proton beam with 2 MeV energy and 5 mA maximum current with 0.1% high energy monochromaticity and 0.5% current stability [3]. On the accelerator the generation of neutrons is achieved and the effect of neutron radiation on cell cultures is studied [4]. For the therapy it is necessary to increase the voltage up to 1.15 MV and is desirably to increase proton beam current to the value 10 mA.

Figure 3 shows one of the main elements of the accelerator – sectioned assembled feedthrough insulator using which voltage from the high voltage rectifier is applied to the central electrode and the intermediate electrodes.

#i.kolesnikov@g.nsu.ru

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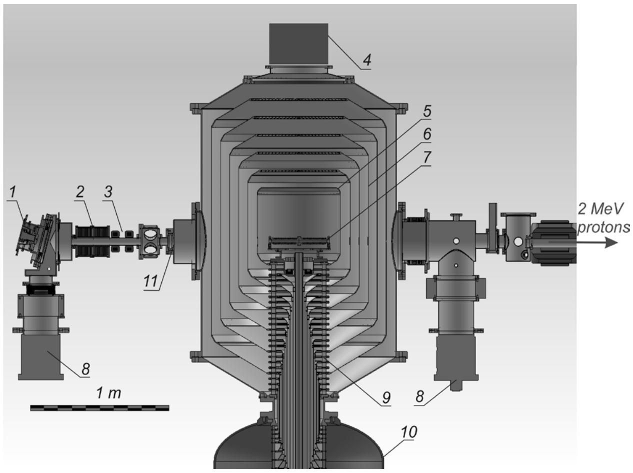

Figure 2: Tandem accelerator with vacuum insulation: *1* - source of negative hydrogen ions, *2* - magnetic lenses, *3* - correctors, *4* - cryogenic pump, *5* - high voltage electrode, *6* - intermediate electrodes, *7* - the gas stripping target, *8* - turbo molecular pump, *9* – feedthrough insulator, *10* – high voltage source, *11* - inlet diaphragm.

The insulator is situated outside of the beam accelerating channel. The insulator consists of two parts - a SF_6 gas-filled (bottom) part, and vacuum (top) part.

The top part of the feedthrough insulator assembled from 24 circular glass insulators, vacuum-tightly fastened together with intermediate electrodes through the rubber seals. Height of the glass rings is 35 mm.

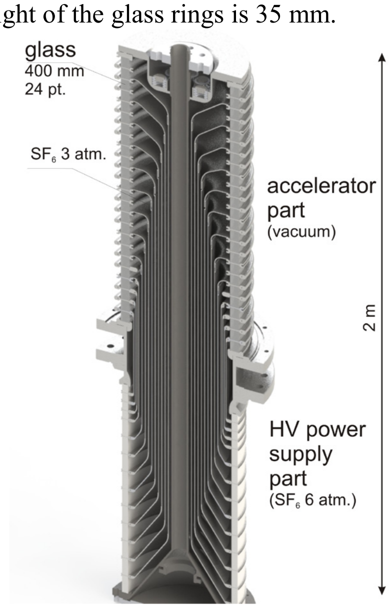

Figure: 3: Scheme of the high-voltage feedthrough insulator.

The bottom gas part of the feedthrough insulator, located in the tank of high-voltage rectifier, consists of 14 ceramic rings glued with their electrodes. The height of the ceramic rings are 30 and 60 mm. The diameter of the ceramic rings as the diameter of the glass rings is about 400 mm.

The potential distribution on the electrodes is set by a resistive divider located inside the top and outside of the bottom part of the feedthrough insulator using a system of inner coaxial cylinders, connecting the electrodes with the equal potential gas and vacuum parts of the feedthrough insulator.

The potential distribution on the electrodes of the vacuum insulator, which are not electrically connected with the coaxial tubes is set by resistors, located inside the vacuum part of the feedthrough insulator.

Dark currents in the accelerating gaps can significantly affect on the uniform distribution of the potential in the accelerating gaps, and, consequently, on the beam transportation, due to the use of low power voltage divider and low value of the current (hundreds of microamperes), flowing through the divider.

EXPERIMENTAL STAND

The aim of experiments was to study the electrical strength of the double-heighted (73 mm) insulators, made of different materials (polycarbonate and ceramics), and various outer surface shapes (ribbed and smooth) an experimental stand was created (Figure 4).

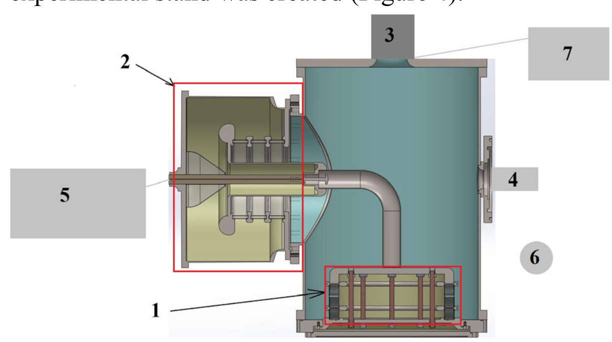

Figure 4: The scheme of the experiment: *1* - test module, *2* - high voltage input, *3* – turbomolecular pump, *4* - vacuum gauge, *5* - high voltage source, 6 – spherical dosimeter, 7 - backing pump.

Test module *1*, which contains an insulator, situated inside the vacuum volume. Voltage on insulator is put on by high voltage source 5 through the input *2*. Vacuum system *3, 4* and *7* provides necessary conditions as in vacuum insulated tandem accelerator.

The major aim of experiments is to study the electrical strength of insulators and possibility of one hour exposure without breakdowns at 100 kV.

RESULTS OF EXPERIMENTS

The first training session of smooth ceramic insulator have been running for 3 hours and ended at 105 kV. During this time there were about 220 breakdowns, more than half of which were in the range from 83 to 95 kV. Subsequent training gives as a result exposure over 1.5 hour of the insulator at a voltage of 100 kV (corresponding to the electric field strength of 13.7 kV/cm).

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A month later, a second experiment was conducted with the insulator. Raising the voltage to 104 kV lasted 20 minutes, as shown in Figure 5. It is 9 times faster than the first training. Considering the time of voltage rise, insulator stood for about an hour without breakdowns. Voltage rise rate was 1 kV/min. At each step power of X-ray radiation dose increased, and by the end of minute fell to 0.5 µSv/h. This is shown in Figure 6.

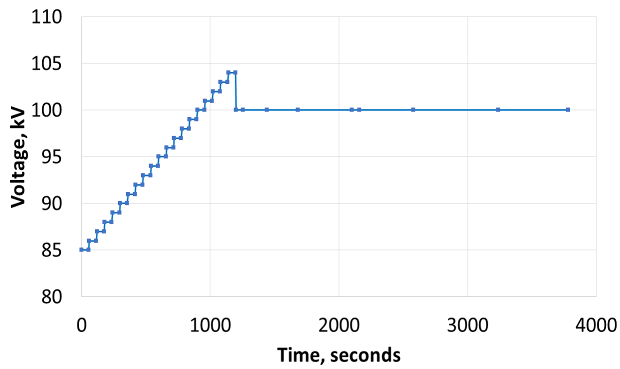

Figure 5: The dependence of voltage from time while training and exposuring of smooth ceramic insulator at 100 kV voltage.

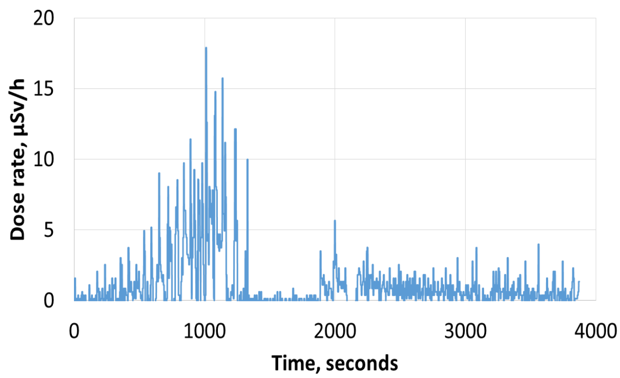

Figure 6: The dependence of the dose rate from time while training and exposuring smooth ceramic insulator at 100 kV voltage.

The second series of experiments has been carried out with a ribbed ceramic insulator. In 40 minutes of training voltage raised up to 83.2 kV. After a 40-minute of break in 15 minutes 100 kV was achieved. Next training gave 110 kV on insulator in 20 minutes. Insulator stood for 80 minutes without breakdowns at a voltage of 100 ÷ 105 kV. This is shown in Figure 7.

The third series of experiments has been conducted for ribbed polycarbonate insulator. The first training session was held to 105 kV for 30 minutes. Figure 8 shows decreasing of radiation over time while exposuring of the insulator at a voltage of 100 kV during an hour. Also, the vacuum level in these experiments was 10 times higher, than in experiments with ceramic insulators.

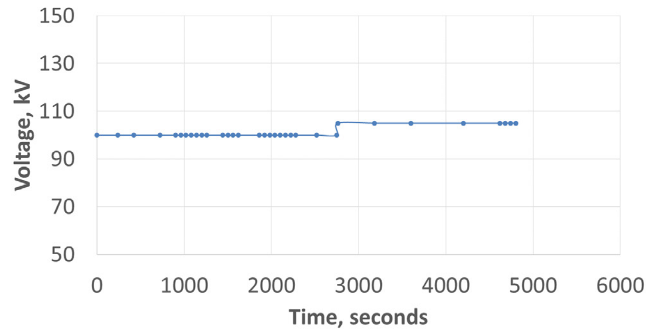

Figure 7: The dependence of voltage from time for training and exposure of ribbed ceramic insulator at 100÷105 kV voltage.

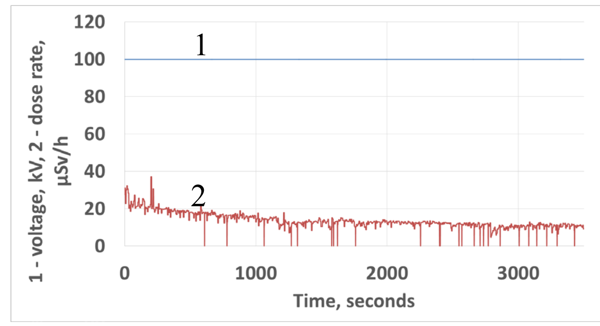

Figure 8: The dependence of the voltage and dose rate from time while training and exposuring ribbed polycarbonate insulator at 100 kV voltage.

CONCLUSION

Experiments showed, that the best double-height insulator for a tandem accelerator is ceramic insulator with a ribbed outer surface, because its reliability higher, than reliability of others insulators.

Polycarbonate insulators with ribbed inner surface can be used in new scheme of feedthrough insulator also, but then it should be upgraded the vacuum pumping.

ACKNOWLEDGMENT

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