A Facility for BNCT on the KG-2.5 High Current Accelerator of Cockroft-Walton Type at IPPE

A. Glotov[1], S. Bazhal[1], M. Bokhovko[1], O. Kononov[1], V. Kononov[1], B. Fursov[1], I. Gulidov[2], Yu. Mardynsky[2], A. Sysoev[2], G. Silvestrov[3]

[1]*A.I. Leypunsky Inst. Phys. and Power Engineering, Obninsk, Russia*
[2] *Medical Radiology Research Center, Obninsk, Russia*
[3]*G.I. Budker Inst. Nucl. Phys., Novosibirsk, Russia*

Abstract

Activities on the creation of the specialized neutron source for the fast neutron– and boron neutron capture therapy (BNCT) for treating of cancer patients are reported. 2.5 MV high current accelerator of protons and deuterons is used as a basis for this activity. The equipment necessary for the neutron therapy as well as for clinical experiments (these experiments are scheduled to be started in 2004) is developed.

Status of the KG-2.5 accelerator

The KG-2.5 accelerator operating at Institute for Physics and Power Engineering in Obninsk is a direct current machine of Cockroft-Walton type. It can produce intensive proton and deuteron beams with energy up to 2.5 MeV has high reliability and power reserve. The accelerator was designed and manufactured at Efremov D.V. Scientific Research Institute of Electrophysical Apparatus (St.-Petersburg) in 1970 [1]. It is used for many years in research on nuclear physics.

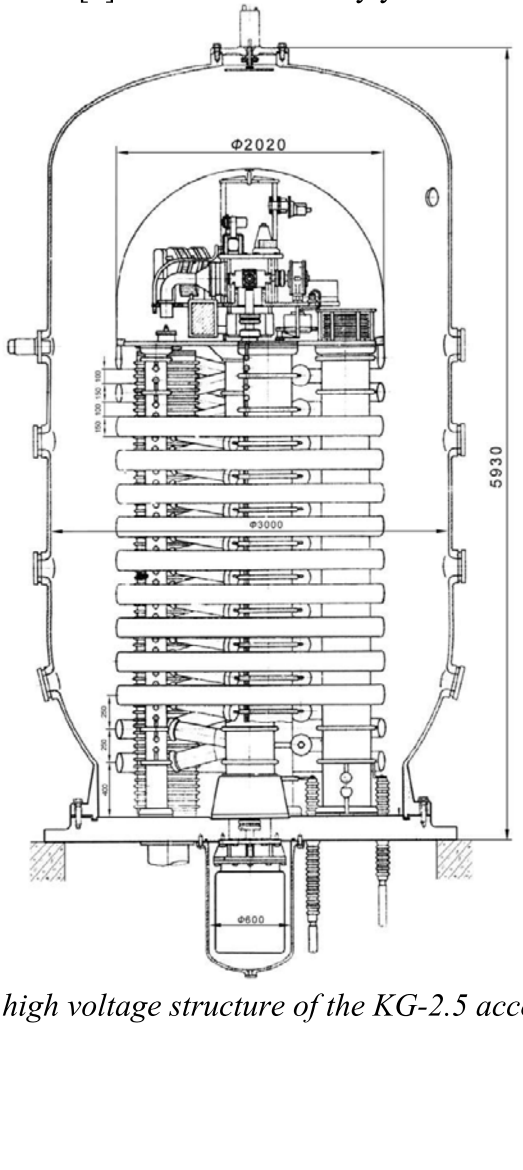

Fig.1 A high voltage structure of the KG-2.5 accelerator.

A feature of this accelerator is the design of the high-voltage cascade generator, based on a variety of Cocroft-Walton voltage multiplier. The generator was design and manufactured under supervision of B.I. Albertinsky. The high voltage power supply, the accelerating tube and the ion source are housed inside the accelerator tank filled by the N_2/CO_2 gas insulating mixture under pressure of 0,8 MPa (Fig. 1).

A uniform field accelerating tube is used in the machine to accelerate charged particles. The accelerating tube consists of two units. The units are made of porcelain insulating rings. Aperture of the tube varies at the beginning part of the first unit, which has the length of 550 mm. Diameter of the electrode aperture in that part is gradually reduced from 150 mm to 60 mm. The rest electrodes of the tube has the aperture of 60 mm. Permanent magnets are applied to suppressed electron loading in the tube channel.

Ion source at this accelerator is installed inside the high-voltage terminal. At present time the RF ion source producing the beam current up to 2 mA is used

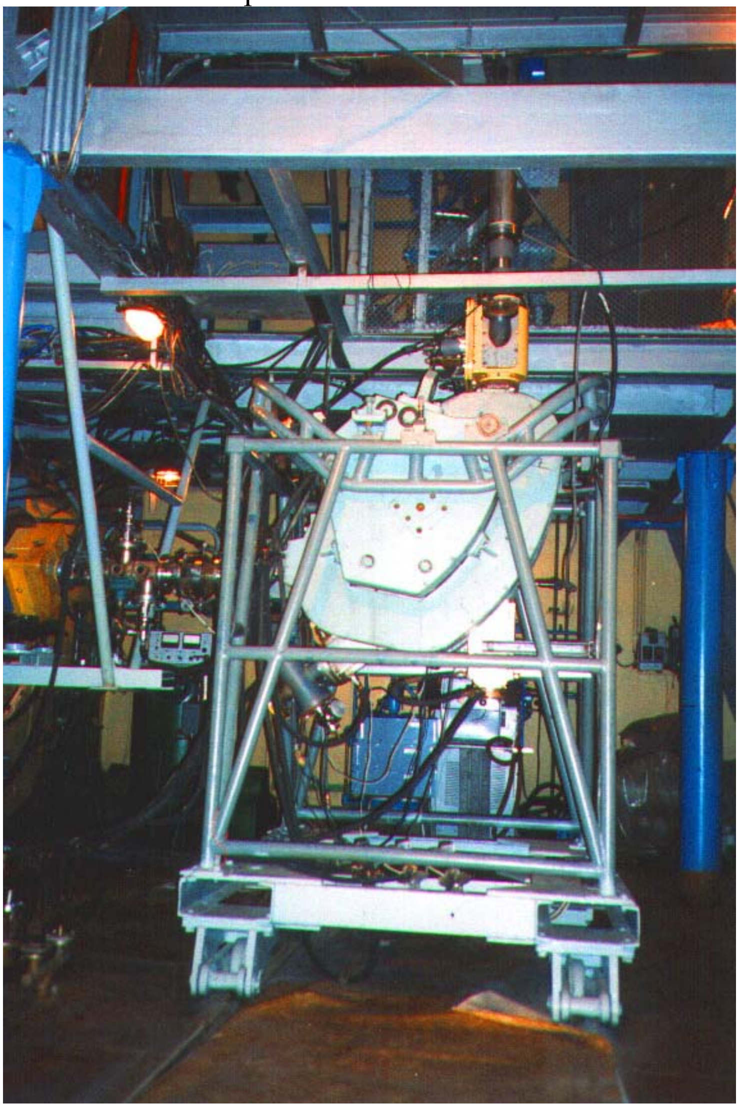

Fig.2 Electromagnet mass-analyzer.

The cascade generator is a twelve-fold symmetrical voltage multiplier circuit. Two charge transporting columns and a filtering column are assembled of high-voltage capacitors and selenium rectifiers. To limit short circuit current the capacitors are provided with protecting metal resistors. The cascade generator is provided with twelve compensating inductive elements positioned between the charge transporting columns. The circuit elements mentioned above are assembled inside a high-voltage column, provided with the gradient hoops, resistor voltage divider and high-voltage terminal For the cascade generator to be fed, a frequency converter with a working frequency of 8 kHz and output power of 100 kW as well as two oil filled step-up transformers of 50 kVA maximum power are used. The transformers are installed outside the accelerator tank. The accelerator has power reserve sufficient for the ion beam current to be increased.

The accelerator is equipped with a vacuum system, beam line, magnetic analyzer (Fig. 2) as well as with devices necessary for the beam focusing and control. An effective system for the gas cooling of the equipment installed inside the accelerator tank is used. A multiple-loop system of energy stabilizing is applied at the accelerator. This system provides the energy stability of 0.1 %.

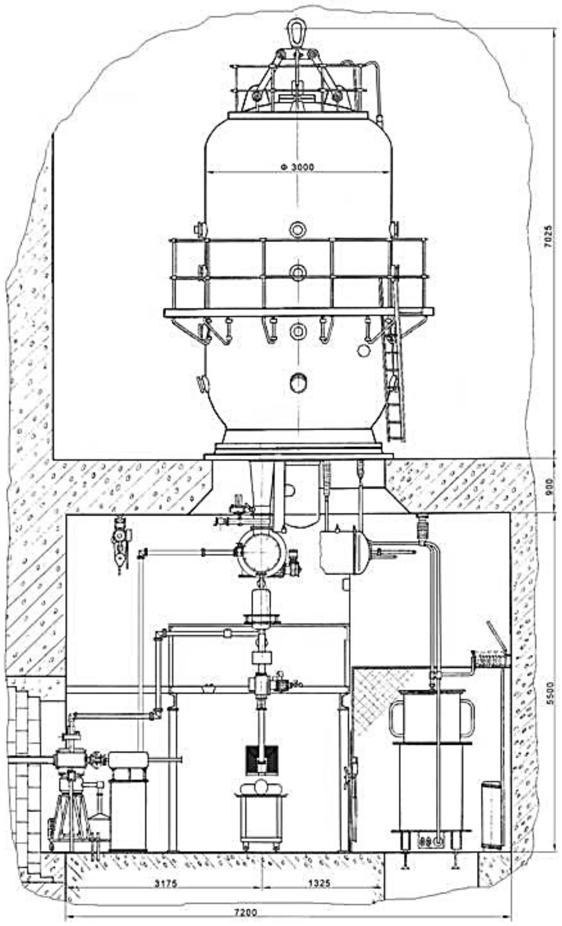

Fig.3 Layout of the accelerator under running with unsepareted beam focused at the beryllium target.

Plans for upgrading of the accelerator

Two operational regimes of the KG-2.5 accelerator will be realized for the therapy of oncological diseases. Under the first regime the beryllium or lithium target is installed under “straight”, unsepareted ion beam (Fig. 3). The beam current is of about 5 mA for that regime. To running with the unsepareted beam the magnetic analyzer is rolled off by the railway releasing the room for the target device and the patient’s cabin. Under the second regime (Fig.4) the lithium target is disposed in the horizontal part of the ion beam line. This regime requires that the energy of the proton beam of about 5 mA is kept near threshold of the Li(p,n) reaction.

Under application of the thick beryllium target neutrons of 0,5-6 MeV are generated in exothermal $^{9}Be(d,n)^{10}B$ reaction. However, application of the deuteron beam with energy of 1.8-1.5 MeV provides maximum neutron yield in energy range of 1-2 MeV. Angular distribution of the neutrons is anisotropic with maximum yield of (3.8-6.8) 10^{11} $(mA\cdot sr)^{-1}$ at 0 degree.

Therapeutic neutron beam is shaped by the shield and collimator assembly (iron and polyethylene) which has thickness of about 0.5÷0.7 m. Under deuteron current of 4 mA neutron flux density at the output of the collimator will be of $6\cdot10^{8}$ $см^{-2}$, that is twice more than the flux density of the therapeutic beam from the BR-10 reactor, which has been successful used for 20 years by medical stuff of MRRC for the neutron therapy.

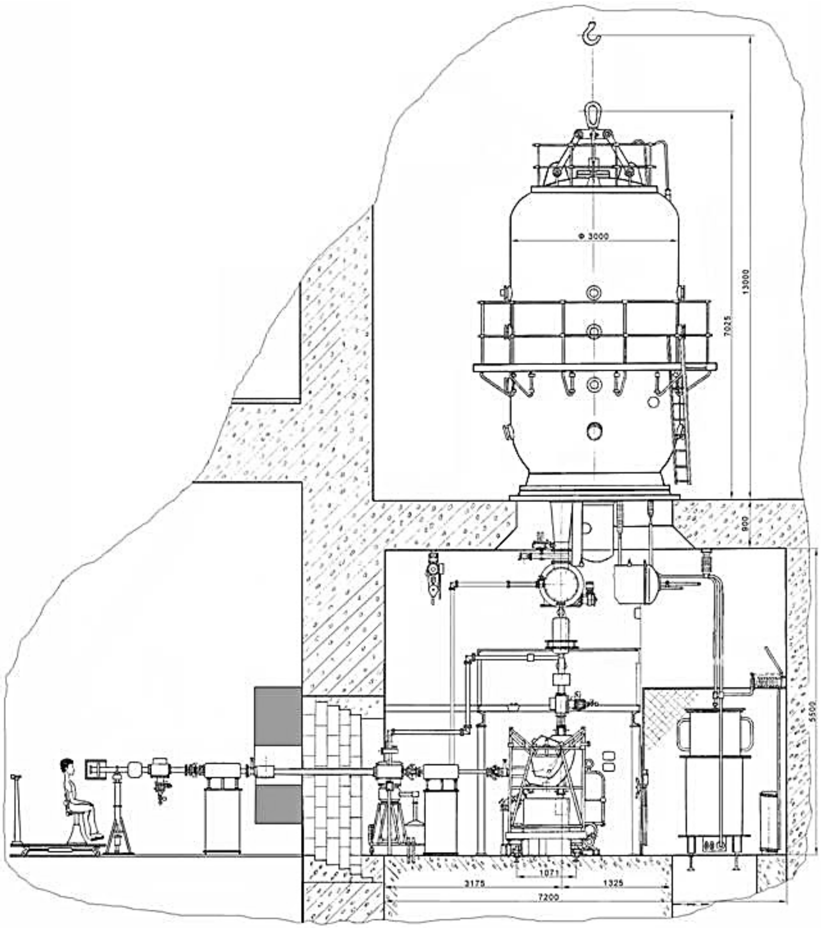

Fig.4 Layout of the accelerator under running with the separated beam in the horizontal part of the beam line and the lithium target installed.

Under proton beam of 2,4 MeV, neutrons generated from thick lithium target ($^7Li(p,n)^7Be$ reaction) will have continuous energy spectra with maximum energy of about 0,7 MeV. This source could be used for both the neutron therapy and the BNCT. At the FNT mode polyethylene shielding and collimator should be used. At the BNCT mode the beam shaping assembly consisting of heavy water or another material (e.g. Al AlF_3) should be used. Photon-equivalent dose rate is about of 1 $Gy \cdot min^{-1}$ for proton current of 4 mA. This rate makes possible to apply BNCT for brain tumors at the accelerator.

To realize the operational regimes mentioned above the main unit and systems of the KG 2.5 accelerator are now under development. The existing RF ion source will be replaced by the new, more intensive one. The high voltage power supply based on a cascade voltage multiplier circuit will be upgraded. Essential improvements of the vacuum system are planned.To solve the problem of beam acceleration and transport for the intensive ion beam at the accelerator the work aimed at development of the ion optical elements and their experimental study is carried out. Electromagnet quadrupole lens will be mounted in the vertical beam line downstream the accelerator. The lens is necessary to focus unsepareted beam at the “straight” target or to transport the intensive ion beam through the magnetic analyzer. The similar lenses will be installed in the horizontal part of the beam line to focus separated proton beam. A switching magnet following the magnet analyzer will spread the beam among three beam lines. The central one of those three beam lines will be utilized to run with the lithium target for the BNCT applications.

References

1. B. Albertinski, I. Kurizina, O. Nikonov, O. Ovchinnikov, “HV cascade generator for 2 MeVaccelerators”,PTE, 43 – 46, 1971, №3,