INITIAL HIGH VOLTAGE TESTS AND BEAM INJECTION EXPERIMENTS ON BINP PROTON TANDEM-ACCELERATOR.*

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Abstract

The results of the tandem commissioning as initial high voltage tests and beam injection experiments on BINP proton tandem-accelerator are given. The accelerator is intended to be used in facilities generating resonant gamma rays for explosives detection and epithermal neutrons for boron neutron-capture therapy of brain tumors. A magnetically coupled DC voltage multiplier derived from an industrial ELV-type electron accelerator is used as a high voltage source for the accelerator. A dc high-current negative ion source has been developed for injection into the tandem. In the tandem accelerator there is set of nested potential electrodes with openings which form a channel for accelerating the negative hydrogen ion beam and subsequently accelerating the proton beam after stripping in the gas target. The electrodes are connected to a high voltage feedthrough insulator to which required potentials are applied from the high voltage power supply by means of a resistor voltage divider.

INTRODUCTION

The Nuclear Resonant Absorption (NRA) method for explosives detection is based on the resonant absorption by ^{14}N of 9.17 MeV gammas produced using $^{13}C(p,\gamma)^{14}N$ reaction [1]. The chosen reaction uses a proton beam at 1.75 MeV energy.

Neutron generation for neutron capture therapy is carried out by directing the proton beam onto a lithium target and using the reaction $^7Li(p,n)^7Be$.

The most efficient operating mode is at a proton energy of 1.915 MeV [2].

In both the generation of resonant gamma rays for explosives detection and the production of epithermal neutrons for boron neutron-capture therapy of brain tumors, very stable energy in the range of (1.7 – 2.5) MeV and very high current in the range of 10s of milliamperes are needed.

TANDEM – ACCELERATOR DESIGN AND CONSTRUCTION

The unique feature of the Vacuum Insulated Tandem Accelerator (VITA) is that it uses vacuum insulation instead of the conventional scheme of previous tandems in which two ceramic insulated accelerating columns with a charge-exchange target in between are located inside a pressurized insulating gas environment. The prospect of high current (a few tens milliamperes) accelerator design according to the conventional scheme is limited by two basic disadvantages — the necessity of pumping the gas of the charge-exchange target through the accelerating columns and the inevitable current of secondary electrons and ions produced by passage of the high current beam, which leads to charge buildup and subsequent voltage breakdown on the inner surfaces of high voltage electrodes and ceramic insulators.

Fig. 1 shows the construction of VITA, developed at BINP, using the sectionalized rectifier, 1, from an industrial ELV-type electron accelerator as a powerful and reliable source of high voltage.

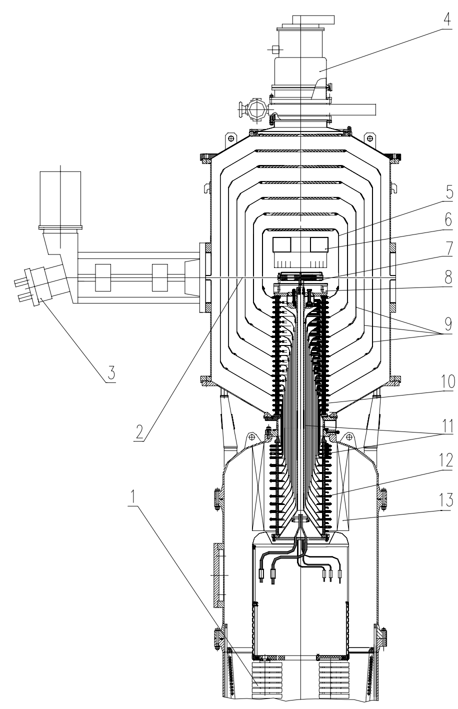

Figure 1: Vacuum insulation tandem accelerator.

The source of negative hydrogen ions 3 [3] injects the beam into the VITA low energy beam tract (Fig. 2). After one half energy acceleration and charge-exchange process of negative hydrogen ion into proton inside the charge-exchange tube, 7, (Fig.3) in the center of high-voltage electrode, 5, (Fig.4) has oc-

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curred, a proton beam is formed at the outlet of the tandem.

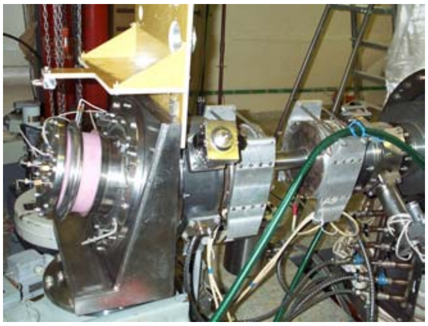

Figure 2: The H^- ion source and low energy beam tract.

Figure 3: The pipe of charge-exchange target and volume of target`s control systems.

Figure 4: The high-voltage electrode of tandem.

The high voltage electrode is surrounded by a nested system of coaxial potential shields, 9, (Fig.5), providing a homogeneous distribution of the potential and preventing the full voltage effect.

The high-voltage feedthrough, 10, (Fig.6) transfers the output of the high-voltage power supply, 1, from the high voltage source tank into the vacuum tank. The high voltage tank is pressurized with seven atmospheres of SF_6 insulating gas. The feedthrough is located far from the region of passage of the accelerated beam, region 2.

The high-voltage electrode, which encloses the gas stripper target, is located on the vacuum side, 8, of the feedthrough. It attaches to a metal flange that is pressure sealed by a tightening pipe that passes along the common axis of the feedthrough and connects to another metal flange located on the gas pressurized end of the insulator.

Figure 5: The set of different potential shields.

Figure 6: The high-voltage feedthrough.

On the gas pressurized end, the metal flange connects to the high-voltage source. The pressurized gas part of the feedthrough, 12, (placed in SF_6) is made of ceramic rings separated by metal rings to establish a uniform potential distribution. The vacuum part of the insulator is made of glass rings, separated by metal rings. The inside of the feedthrough is maintained under a few atmosphere of SF_6 gas pressure. A coaxial series of thin wall pipes, 11, of various lengths are located inside the feedthrough to connect the respective metal rings of different potential on the gas part of the insulator and its vacuum part. The voltage is applied to these rings from the resistive divider, 13, providing a uniform distribution of potential along the insulator length. Vacuum pumping is carried out by a cryogenic pump, 4, (Fig.7).

Coaxial round holes for the beam passage are cut in the walls of vacuum tank, the high-voltage electrode and in the coaxial shields. The thin-wall shields placed along the equipotential surfaces of the electrostatic field hardly contribute to the beam focusing.

Figure 7: Vacuum tank and cryogenic pump.

The low energy beam focusing in this system is provided by axisymmetric lenses: one electrostatic (input hole of the first accelerating gap) and two magnet lenses (Fig.2), placed before input aperture. Fig.8 shows computer simulations of the beam envelope for 40 mA, 10 mA and 1 mA H^- beams with 1 eV initial ions cross energy and a high voltage electrode potential of 1 MV.

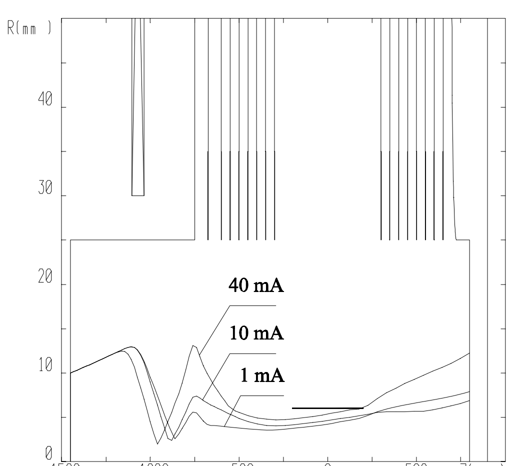

Figure 8: Example of computer simulation envelope results for some H^- beams.

An analysis of the application of different charge-exchange target gases was made and argon gas target was chosen for use. The charge-exchange target is a pipe with an inner hole of 10 mm diameter and ~ 400 mm length. Argon gas leaks in the center of the pipe. Systems for controlling gas flow of the gas stripper target, and processing data from the charge exchange tube thermocouples are located in the space designated as 6 in Fig.3.

RESULTS AND DISCUSSIONS

The injection unit, which includes the flange H^- source and low energy beam line, was successfully tested on a special test-bed before assembly of the tandem. A beam of 25 keV, 4 mA negative hydrogen ions was transmitted from the source and focused to the target at the distance of 1.2 meters. The beam cross-section of elliptic shape with semimajor axis of 2.3 cm and semiminor axis of 1.3 cm was measured at the distance of 0.85 meters, in accordance with calculated beam envelope curve.

Presently, the VITA is undergoing commissioning. The vacuum and pressure tests are completed and the design value of electric potential of all high voltage components in the gas pressurized tank and the tandem vacuum tank were achieved at voltage up to 1 MV.

Nuclear reaction C^{12} (p,γ) $N^{13}(\beta^+)C^{13}$ was used for beam energy and current testing. This reaction has resonances at 0.457 MeV and 1.698 MeV of proton energy. Prompt 2.36 MeV resonant quanta and annihilation quanta from decay of N^{13} was registered in the experiment. Doubled of proton energy because charge-exchange process was observed in the measurements.

CONCLUSIONS

This high efficiency, high current tandem accelerator will greatly improve the likelihood that VITA will become a useful proton source for the method of detection of chemical explosives, as well as a useful method of boron neutron-capture therapy of brain tumors.

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