Vacuum insulation tandem accelerator for NCT

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Summary

Novel 2.5 MeV, 40 mA tandem accelerator is presented and discussed. Results of work of ion source and choice of ion optical channel and charge-exchange target are shown. Results of experiments on study of high voltage durability of 45 mm vacuum gap with large square electrodes and determination of dependence of autoemission current on electric field intensity are reported.

Introduction

2.5 MeV tandem accelerator is one of the main elements of proposed neutron therapy facility [1]. The main idea of tandem accelerator is providing high rate acceleration of high current hydrogen negative ions by special geometry of potential electrodes with vacuum insulation.

Fig. 1 shows the construction of vacuum insulation tandem accelerator developed at BINP, as a base of neutron source, using the sectionalized rectifier from industrial ELV-type electron accelerator, as a powerful source of high voltage. Negative hydrogen ion beam is injected into electrostatic tandem accelerator with vacuum insulation. After charge-exchange of negative hydrogen ion in proton inside charge-exchange tube in the center of high-voltage electrode, a proton beam is formed at the outlet of the tandem, which is accelerated to double voltage of high-voltage electrode.

The following work and experiments necessary for construction of the accelerator were performed during 2000-2002:

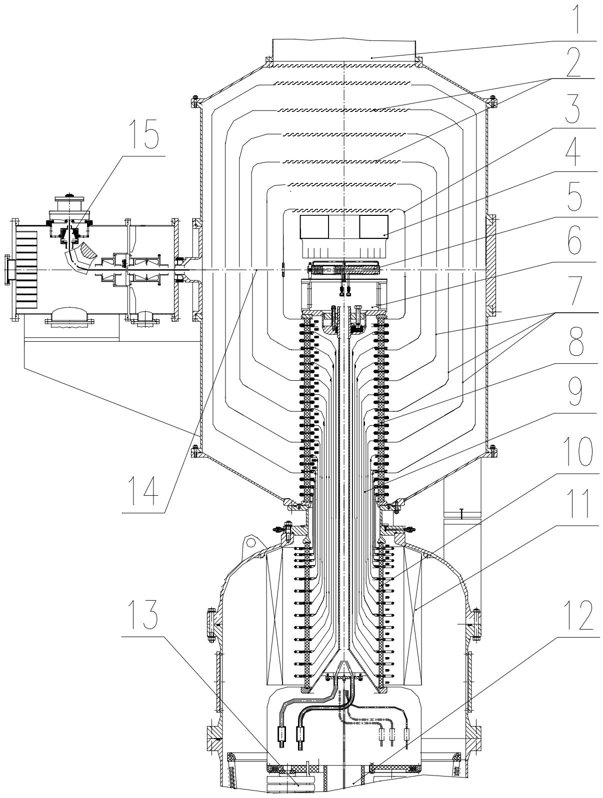

Fig. 1. Scheme of vacuum insulation tandem accelerator. 1 – orifice for pumping, 2 – profiled covers of electrodes, 3 – high voltage electrode, 4 – pump, 5 – charge-exchange target, 6 – letting-to-gas system, 7 – interim electrodes, 8 – vacuum part of high voltage through-pass insulator, 9 – metal tubes, 10 – gas part of high voltage through-pass insulator, 11 – potential divider, 12 – dielectric tube, 13 – high voltage rectifier, 14 – beam line, 15 – negative hydrogen ions source.

Results

At test desk available, dc H^- ion beam of 9.5 mA was obtained with negative ion source having Penning geometry electrodes. Under 5 mA the normalized emittance measured was 0.3 π mm mrad.

Computer simulation of transport of a dense beam is carried out taking account of space charge and emittance of the beam. It showed two ways of transporting the dc beam of negative hydrogen ions from ion source to the accelerator: the one using axisymmetric lens and another using magnetic lens. Despite high power consumption the letter is recommended for use, as it allows transporting fully compensated beam; and as it is capable of choosing the position without changing the channel construction. Two schemes of coordinated leading the negative hydrogen ion beam of 25 keV in the tandem accelerator were examined, that are “strict” (by use strong magnetic lens and beam overfocusing at the entrance to accelerator) and "soft" introduction (without beam overfocusing, with increased first gap and more fluent increase of electric field tension in the tandem accelerator). Since both of the schemes have merits and demerits and both have only slight difference in ion-optical channel design, the recommended solution is the one providing a possibility to experimentally check both "soft” and “strict” beam focusing. Optimal geometry of magnetic screen providing minimum aberrations introduced by lens and absence of saturation effects was determined. Magnetic lens as a folding solenoid with outer water cooling was designed. As a result, there are two constructions of ion-optical channel of the tandem accelerator for the H^- beam with the initial protons energy of 25 keV and current of 10 mA: with “soft” and “strict” focusing of the beam [2].

An analysis of different types of charge-exchange target had been made [3]. A gas target was chosen for use. Following gas charge-exchange targets were assigned to be used: i) argon gas target with outer pumping; ii) argon gas target with recycling turbo-molecular pumping inside the high voltage electrode; iii) gas target with gas freezing on the nitrogen trap inside the high voltage electrode. Charge-exchange target, cryogen pump-out system, system for transporting target gas, liquid and gas nitrogen under the high voltage electrode potential were manufactured.

It is know [4] that breakdown of millimeter vacuum gaps with 10 J energy released results in drop of voltage durability of vacuum gap. A set of experiments on study of high voltage durability of 45 mm vacuum gap with large square electrodes was carry out on 0.6 MeV tandem-accelerator. To clear up the effect of stored energy on electric durability of hifh-voltage vacuum gap, one added cascade generator capacity (≈ 400 pF) and special energy storage capacity (≈ 700 pF). The results of experiments showed that storage energy of 50 J released at breakdown did not result in detraining of 45 mm vacuum gap.

Dependence of autoemission current on electric field intensity in high voltage gap was measured. Current density was determined to be $1.7 \cdot 10^{-7}$ A m^{-2} at field intensity 33 kV cm^{-1} and to increase sharply at field intensity higher than 70 kV cm^{-1}.

The results of experiments allowed to determine high voltage and energetic parameters of 2.5 MeV accelerator. The tank diameter was determined to be 1400 mm, high voltage electrode diameter — 600 mm.

Electrostatic intensity at accelerating gap is 32 kV/cm. The high voltage electrode is surrounded by system of different potential shields providing homogeneous distribution of potential and preventing full voltage effects. Energy storage in vacuum gap is lower than 20 J. It is determined that overvoltages on the rest vacuum gaps and insulators are permissible at ELV breakdown at full power or breakdown of one of vacuum gaps. Therefore, there is no need to mount a compensating capacity divider from high voltage condensers with low reliability, that increases significantly the tandem's reliability.

2.5 MeV tandem accelerator is under construction now in a 3-layered protected bunker with necessary infrastructure. Mechanic and mounting works at sectionized rectifier were finished at its working place, it was started-up and operating voltage of 1.25 MV was obtained. Design drawings for high voltage through-pass insulator, for high voltage electrodes of rectifier and accelerator, and for the accelerator were prepared. Insulators and electrodes of high voltage through-pass insulator, and vacuum tank for the accelerator were manufactured. Electrodes for rectifier and accelerator are under manufacturing.

Conclusions

The work and experiments performed allowed to determine parameters of the novel 2.5 MeV, 40 mA tandem accelerator and to start its manufacturing.

References

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