Accelerator based neutron source for neutron capture therapy

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Summary
A conception of novel accelerator based neutron source for neutron-capture therapy at hospital appropriate for commercial use is presented and discussed. Design features of facility components are discussed. The possibility of stabilization of proton energy is considered. At proton energy of 2.5 MeV the neutron beam production for NCT use after moderation is also considered.

Introduction
Accelerator source of epithermal neutrons for the hospital-based boron neutron capture therapy was proposed [1] and presented on previous NCT Symposium [2]. Results of realization of this project are presented here.
Kinematically collimated neutrons are produced via near-threshold ^{7}Li(p,n)^{7}Be reaction at proton energies of 1.9 MeV. Dc accelerator current of tens of milliamperes allows to provide therapeutically useful beams with treatment times of tens of minutes. The basic components of the facility are: a hydrogen negative ion source, an electrostatic tandem accelerator with vacuum insulation, a sectioned rectifier, and a thin lithium neutron generating target on the surface of molybdenum disk cooled by liquid metal heat carrier.
Possible variant of neutron source arrangement is performed at Fig.1. Negative hydrogen ion beam is injected into electrostatic tandem accelerator with vacuum isolation. After charge-exchange of negative hydrogen ion to 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. Neutron generation is proposed to be carried out by dropping an intensive proton beam onto lithium target using ^{7}Li(p,n)^{7}Be threshold reaction.

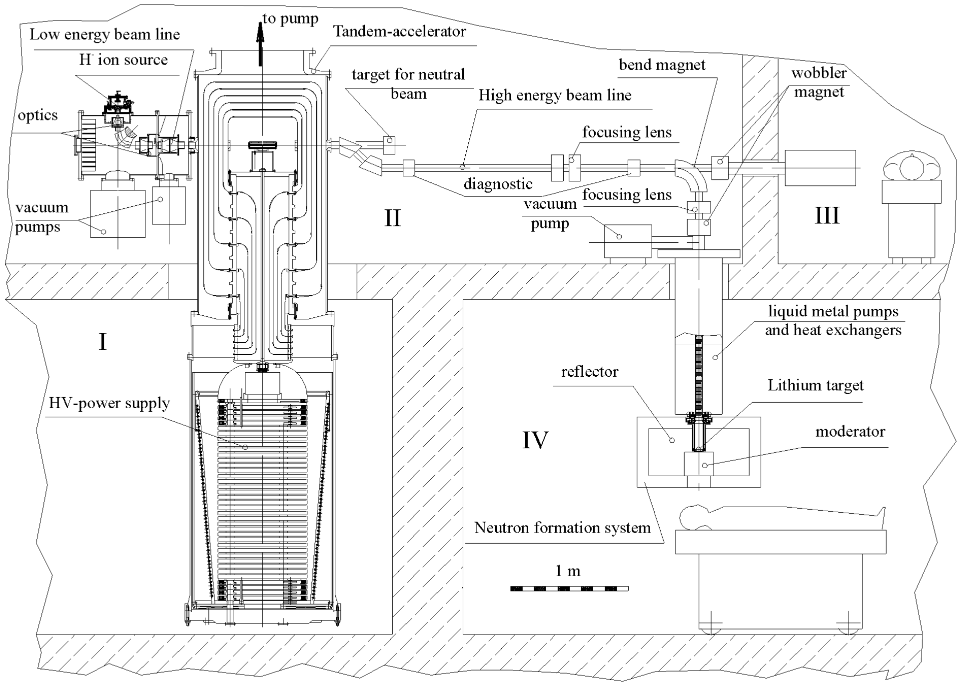

Fig. 1. Possible variant of neutron source.

Results

At test desk available, dc H^- ion beam of 9.5 mA was obtained with negative ion source having Penning geometry electrodes [3]. The value obtained for the normalized emittance 0.3 π mm mrad meets the requirements.

Development of tandem surface plasma source of H^- ions was continued to obtain dc 40 mA H^- ion beam with small emittance, high gas efficiency and low attendant electron current [4].

Computer simulation of transport of a dense beam is carried out taking account of space charge and emittance of the beam [5, 6]. 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. 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). 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 [5].
An analysis of application of different charge-exchange targets has been made. Three variants of gas stripping target were chosen for further development and realization [7]: 1). Argon gas target with external pumping. This target is attractive by the lack of dissociation effects. 2). Argon gas target with turbo-molecular pump in immediate vicinity and with recirculation. It allows to weaken requirements on beam transportation and improve gas conditions. 3). Target with cryogenic nitrogen pump in immediate vicinity. It also allows to weaken requirements on beam transportation, but its use is accompanied by many effects which require experimental testing.
A set of experiments on study of high voltage durability of vacuum gap with large square electrodes were finished on available 0.6 MeV tandem-accelerator [6]. The results allowed to determine high voltage and energetic parameters of 2.5 MeV accelerator. 2.5 MeV vacuum insulation tandem accelerator is under construction now in a 3-layered protected bunker (Fig. 2 - 3). Mechanic and mounting works at sectionized rectifier were finished, it was started-up and operating voltage was obtained (Fig. 2).

Fig. 2. High voltage power supply.

Fig. 3. Accelerator tank.

Slow loop of stabilization of high voltage was adjusted and tested in course of secionized rectifier testing. The signal of the measuring divider was determined to be supported with necessary accuracy of 0.1 %. In obtaining proton beam, instead of the signal from the measuring divider, a signal from energy analyzer of associated atoms may be given, which is proportional to energy of accelerated protons. A system of active suppress of high voltage rectifier pulse was developed with several kilohertz band to provide necessary stability of accelerating voltage better than 0.1 % [9].

Various neutron producing targets have been worked [8]. The first specimen of neutron production target with liquid metal heat carrier was made. Thermal mode of the stationary target was investigated using electron beam up to tens of kW and both water and liquid metal cooling systems [8].

Spatial-energy distribution of source neutrons and attendant γ, and spatial distribution of the absorbed doze and optimization of physical shield under calculation.

Conclusions

Accelerator based neutron source for neutron-capture therapy at hospital appropriate for commercial use is under construction now [10]. We are planing to complete the source and to obtain neutron beam for therapeutic use.

References

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