Test experiments for ion beam injection at the prototype of electrostatic tandem accelerator

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Introduction

In the framework of the development of high-current electrostatic tandem accelerator with vacuum insulation [1] an experimental test stand is being built and experiments are planned for ion beam acceleration at a single-gap prototype of the tandem. The previous experiments [2] with the prototype proved an electric strength of accelerating gap in a static mode, i.e., without the beam. The objectives of the planned experiments therefore are the following:

- Study of behavior of vacuum accelerating gap of the prototype with a passage of ion beam, over a wide range of values of electric field strength in the gap and beam current.
- Study of issues concerning the matched introduction of low-energy ion beam into the high-voltage accelerating gap and shaping of the beam for transporting through a gas stripping pipe with 10 mm diameter.
- Testing of some diagnostics of the low-energy ion beam.

The key feature of the planned experiments with the prototype is the use of a proton beam instead of H^- beam, as this is provided for the full-scale tandem accelerator. The sign of ion charge does not have the determining value for the tasks named above, but obtaining of proton beams presents less difficulties in comparison with H^-.

Experimental layout

Major elements of the experimental test stand are shown in the figure 1. An ion source (1) is joined to a buffer vacuum volume (3) through an angle adjustment device (2). The buffer volume is evacuated with a turbomolecular pump (4) down to the pressure less then $1 \cdot 10^{-5}$ Torr. From the opposite side of the buffer volume an ion beam pipe (stainless steel tube with 50 mm inner diameter) with diagnostic module (5) and axial magnetic lens (6) are placed. The pipe is joined to the vacuum tank (7) of the prototype through a gate valve. The beam parameters (emittance, profile and total current) can be measured with the removable probes, mounted in the diagnostic module.

The ion injector DINA-4A [3], designed and constructed at BINP, is employed as the proton source. This is the reliable and convenient in the use instrument, which works in a repetitive pulse mode. The injector with a power supply unit was tested on a test bench and its stable work was proved with the following parameters of the proton beam (table 1):

The space charge of the beam is completely compensated at the exit from the injector. A smaller beam with required parameters is cut out from the entire beam with the aid of two limiting diaphragms, the first one is positioned directly at the the injector outlet and the second diaphragm is located near the place where the ion beam pipe is joined to the buffer volume. The beam is focused by an axial magnetic lens, then it is accelerated across vacuum high-voltage gap of the tandem prototype and passes through a round opening with diameter of 25 mm into the inner electrode (8 at fig. 1), where it can be registered.

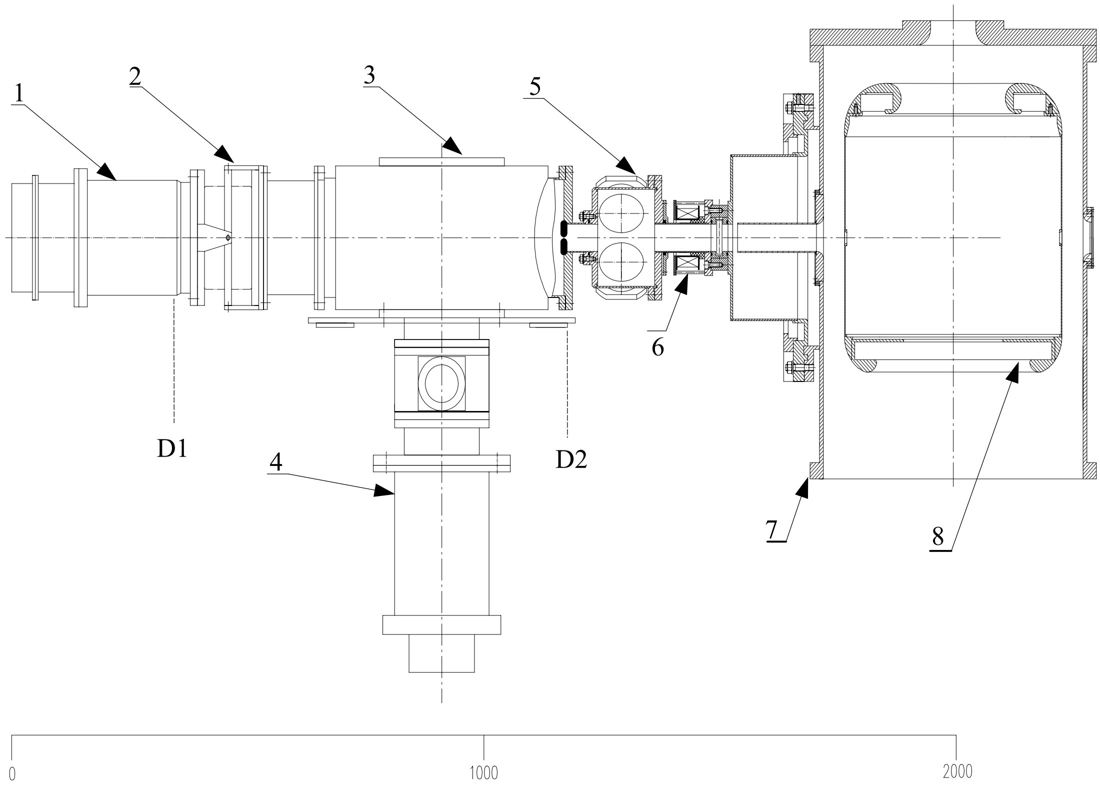

Fig. 1. Schematic of the experimental setup. Positions of beam limiting diaphragms are designated as D1 and D2, respectively.

Table 1.

Energy of protons, keV	13
Beam diameter, mm	40
Proton current density, mA/cm^2	80
Pulse duration, μs	100 (*)
Repetition rate, s^{-1}	0.1
Beam angular divergence, rad	$2 \cdot 10^{-2}$ or less

(*) - it can be lengthened to 200 μs with the appropriate power supply.

A matched introduction of the beam into the prototype of tandem accelerator is numerically modelled using the SAM [4] and the BEAM [5] codes. It was assumed that the beam space charge compensation vanishes at the entrance to the accelerator gap (after the point of raising the potential in the gap higher than 10 eV). The calculated beam envelopes for different values of current are shown in the figure 2. The computations show that proton beam with the current up to 60 mA can be accelerated without losses on the edge of electrode opening and a parallel beam is formed past the opening, accepted to the introduction into a gas stripping pipe.

As it follows from the calculations, the magnetic lens current should be about 20 A at 880 turns in the solenoid coil. It was shown, that there is no need for ferromagnetic shell. Also there is no need for forced cooling because of pulsed operation of the lens.

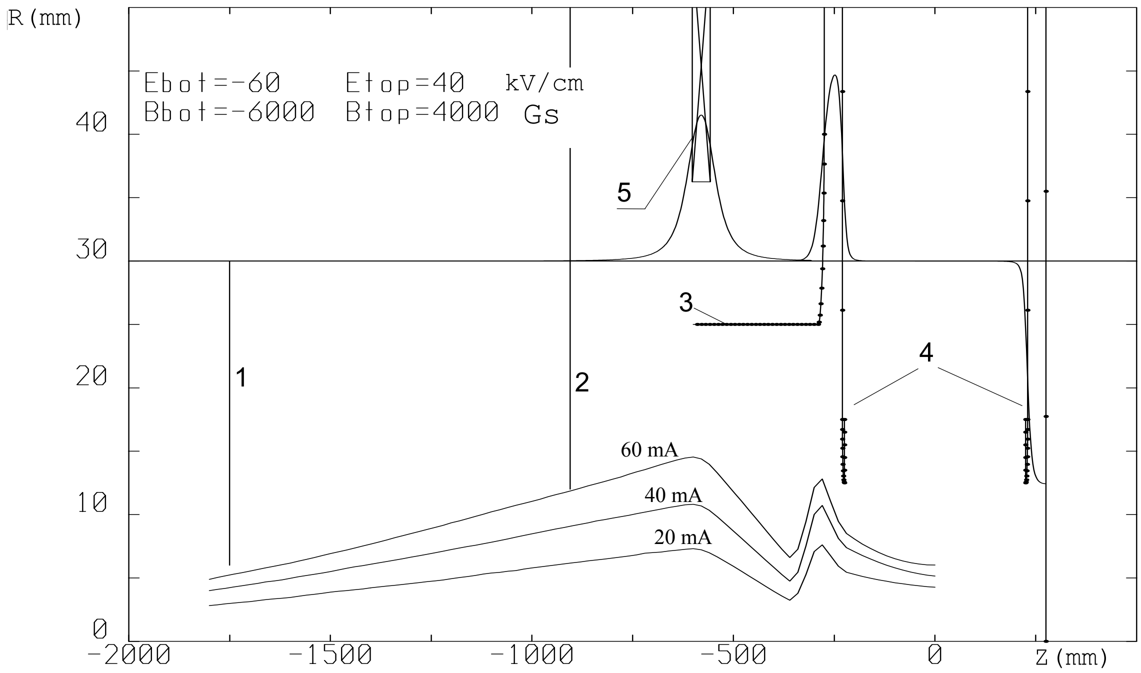

Fig. 2. Envelope of the 12 keV, 60 mA proton beam. 1, 2 – limiting diaphragms; 3 – beam pipe and vacuum tank; 4 – high-voltage electrode; 5 – magnetic lens.

Summary

The scheme of test experiment is elaborated for ion beam acceleration at the prototype of tandem accelerator with vacuum insulation.

Ion beam source was prepared and ion beam line is designed and constructed.

References

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