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He^{+} ION SOURCE FOR THE NICA INJECTION COMPLEX

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Abstract

A mono-ion source of single-charged helium of high intensity has been created to confirm the declared parameters of Heavy Ion Linear Accelerator (HILAC) [1, 2] and for the injection into superconducting synchrotron (SC) Booster during the first run.

The paper presents the design of the He^{+} ion source, test bench for the TOF measurements and acceleration beam developed at VBLHEP, JINR. The results of the tests of the source are presented. During the tests the intense beams of ions 50 mA of He^{+} were produced.

HELIUM ION SOURCE

For designing helium ion source the proton ion sources described in [3, 4] were taken as a prototype. Ion source with cold magnetron cathode and magnetic plasma compression consists of the two basic parts: plasma generator, system of ions extraction and beam formation. There are three basic space may be attributed to plasma generator: space of auxiliary discharge between magnetron cathode and magnetron anode, space of the main discharge between magnetron cathode and anode, and area of plasma expansion (see Fig. 1).

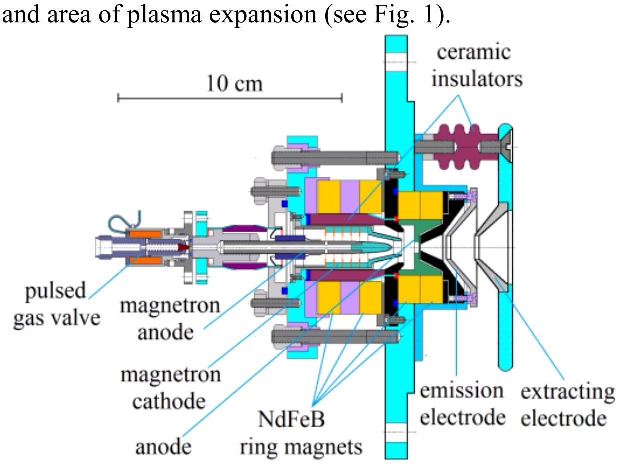

Figure 1: Helium ion source design.

The entire cathode block is placed in a longitudinal magnetic field (see Fig. 2). The magnetic field is organized using four ring neodymium magnets. Two of them with consistent polarity form a longitudinal field in the region of the magnetron cathode. The next two magnets with opposite polarity create a strong non-uniform magnetic field that compresses the plasma into a 1 mm emission hole.

From the region of magnetic compression, the plasma enters the expander and expands in it. A concave plasma boundary (meniscus) is formed, which forms an ejected beam. Extraction of ions from the plasma is carried out by applying a pulsed voltage of up to -40 kV to the extracting electrode.

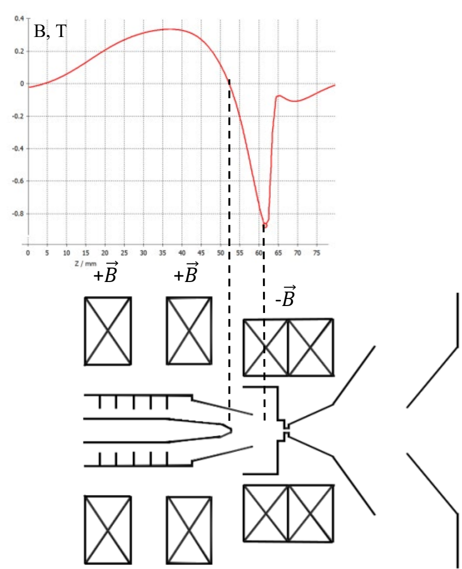

Figure 2: Equivalent diagram and graph of the magnetic field distribution along the axis.

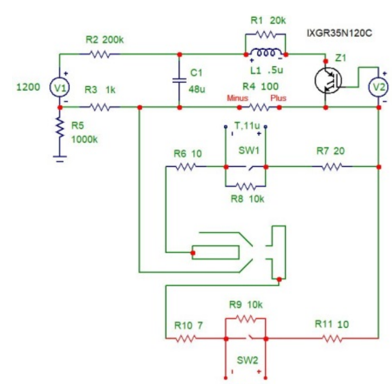

Figure 3: Scheme discharge modulator.

Gas system provides pulsed gas injection into space of magnetron discharge. Pulsed voltage up to 1 kV in the gaps between magnetron anode and magnetron cathode,

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and between magnetron cathode and anode was provided with the generator of HV pulses (see Fig. 3).

The auxiliary discharge current in the magnetron region at a voltage of about 450 V reached 3 A. The current of the main discharge, contracted by the magnetic field, reached 15 A (see Fig. 4).

The combustion mode of the main discharge was easily reconfigured by changing either the value of the ballast resistance in the power circuit, or the amount of working gas supplied to the volume of the gas-discharge chamber in portions using an electromagnetic valve.

The ion source operates in a pulsed mode with a repetition rate of 0.25 to 1 Hz and a pulse duration of up to 100 μs.

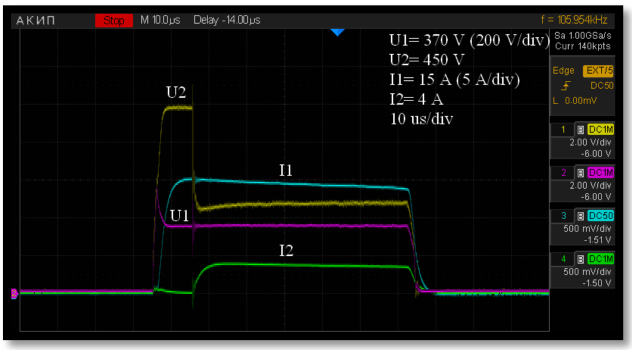

Figure 4: Oscillograms of voltage and current in auxiliary (U_2, I_2) and main discharges (U_1, I_1).

TEST BENCH FOR TOF STUDIES

For test bench extraction voltage was supplied with the pulsed transformer and applied to the terminal whereas extraction electrode had a ground potential. Test bench for the TOF studies had three Faraday cups, beam modulation electrode and drift space ~1.8 m (see Figs. 5 and 6). The total ion current was estimated with the signal from FC1 and the value observed was up to 50 mA. There was the aperture 8 mm diameter in the bottom of the FC1 for the beam passing. About 25 cm behind the extracting electrode Faraday cup 2 and beam modulation electrode mounted together in one assembly could be placed manually on the beam way. The signals registered by Faraday cup 1 and Faraday cup 2 were used for the source tuning.

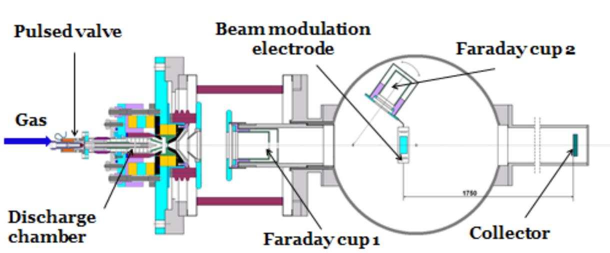

Figure 5: Test bench layout for the TOF measurements.

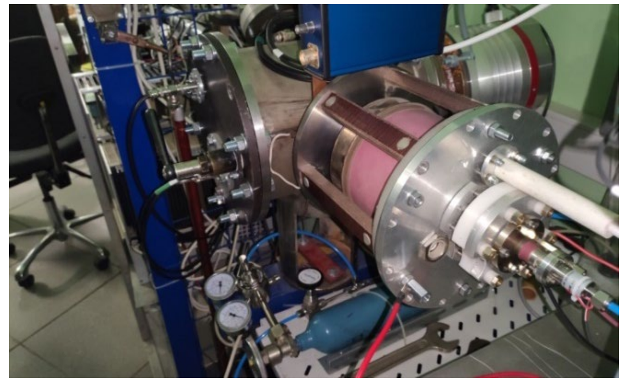

Figure 6: Helium ion source at the test bench.

For the beam modulation the 1 kV pulses 50 ns duration were applied to the electrode. Collector's signals were registered to obtain TOF spectrum. He^+ ions were the main species in the beam produced. Traces of impurities of carbon, oxygen and nitrogen were observed also (see Fig. 7).

The emissivity of the source, at a main discharge current of ~ 10 A, is about 50 mA He^+. The proportion of hydrogen, hydrocarbons, nitrogen and oxygen is reduced by training the source. In the process of improving the parameters of the source, the fraction of He^+ 90% was reached. He^{2+} ions are absent.

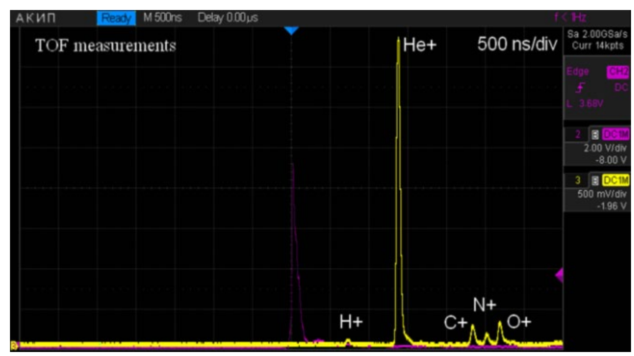

Figure 7: TOF spectrum obtained at the test bench for the helium ion source.

FORMATION THE BEAMS He^+ WITH THE LEBT

To provide with the He^+ beams the first run of the SC Booster helium ion source was placed on the HV terminal and fixed to the LEBT of HILAC (see Fig. 8). Beam was formed by two focusing electrode with the ability to adjust the duration of the ion beam in the range of 3 - 15 μs and accelerated in electrostatic tube up to RFQ input energy 17 keV/u. Two solenoids were used for beam focusing at the RFQ input. Steerers bend the beam in vertical and horizontal planes if needed (see Fig. 9).

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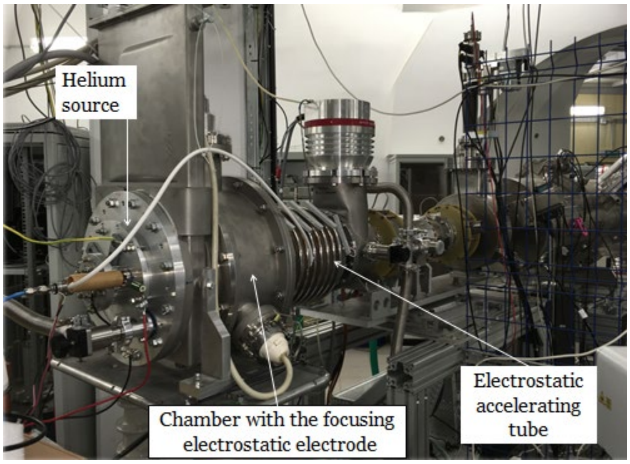

Figure 8: Helium ion source on the HV terminal fixed to the LEBT.

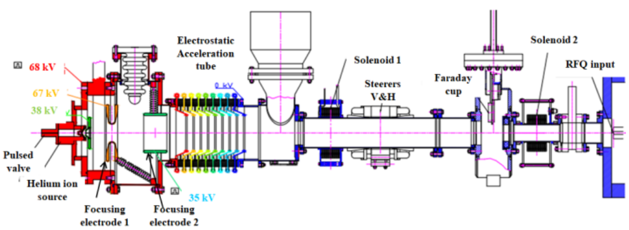

Figure 9: LEBT layout.

Pulse transformer provided HV terminal with electrical pulsed potential up to 100 kV of amplitude at the 200 us of the total pulse duration. To match the He^+ beam energy to RFQ input energy the value 68 kV of electrical potential was provided at the terminal during accelerating run. Beam intensity up to 25 mA at the injection point into RFQ was varied by solenoids (see Fig. 10).

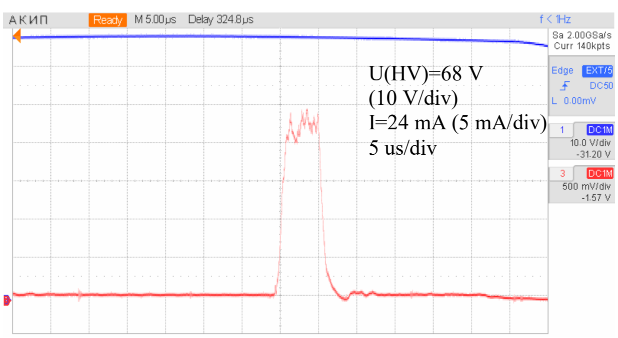

Figure 10: Signal Faraday Cup at LEBT (red), signal from divider of the HV pulsed transformer (blue).

CONCLUSION

To confirm the HILAC parameters, a need arose for a source of singly charged helium. A compact, lightweight, economical (gas flow) ion source with a cold magnetron cathode and magnetic plasma compression at the emission hole is created. A new ion source requires fewer power sources than a duoplasmotron. He^+ source does not need cathode glow power sources and electromagnet power sources due to the use of a cold cathode and permanent ring magnets.

Ion source produced the beams He^+ with current up to 50 mA was developed and used for Booster commissioning successfully.

The results of the work of the source at the stand with beams of protons, deuterium were also obtained.

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