CHARACTERISTICS OF A HEAVY ION INJECTOR Z/A≥1/3 BASED ON LASER-PLASMA ION SOURCE

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SCHEMATIC DIAGRAM OF THE HIGH CURRENT ION INJECTOR

Schematic diagram of the high current heavy ion I-4 (ITEP) is shown on Fig. 1. It consists of two-modules CO_2 pulsed laser generator 1 which radiation is transported by copper mirrors 2 to the entrance tube of the vacuum chamber 3 that has the internal diameter of 350 mm. Then the laser beam is focused to the cylinder target 4 with the spherical lens. The target with the diameter of 130 mm rotates around the geometrical axis and shifts up and down during operation to avoid a crater formation in the target material. The laser beam falls on the target angularly (30º) but the surface normal coincides with the time of flight tube axis and laser plasma expansion direction. The extraction system consists of three electrodes: positive 5, negative 6 and grounded (interelectrodes distances are 40 and 20 mm, accordingly). Positive extraction electrode is situated at the distance 1680 mm from the target. Its passage opening of 40 mm is closed by the grid. Einzel lens 7 is used to match the ion beam with the RFQ section 8 entrance.

The RFQ section main characteristics are frequency – 81.36 MHz, z/A≥1/3, injection energy – 0.02 MeV/u, output energy – 1.6 MeV/u, maximum ion current – 100 mA. The system operates in repetition rate mode up to 0.2 Hz.

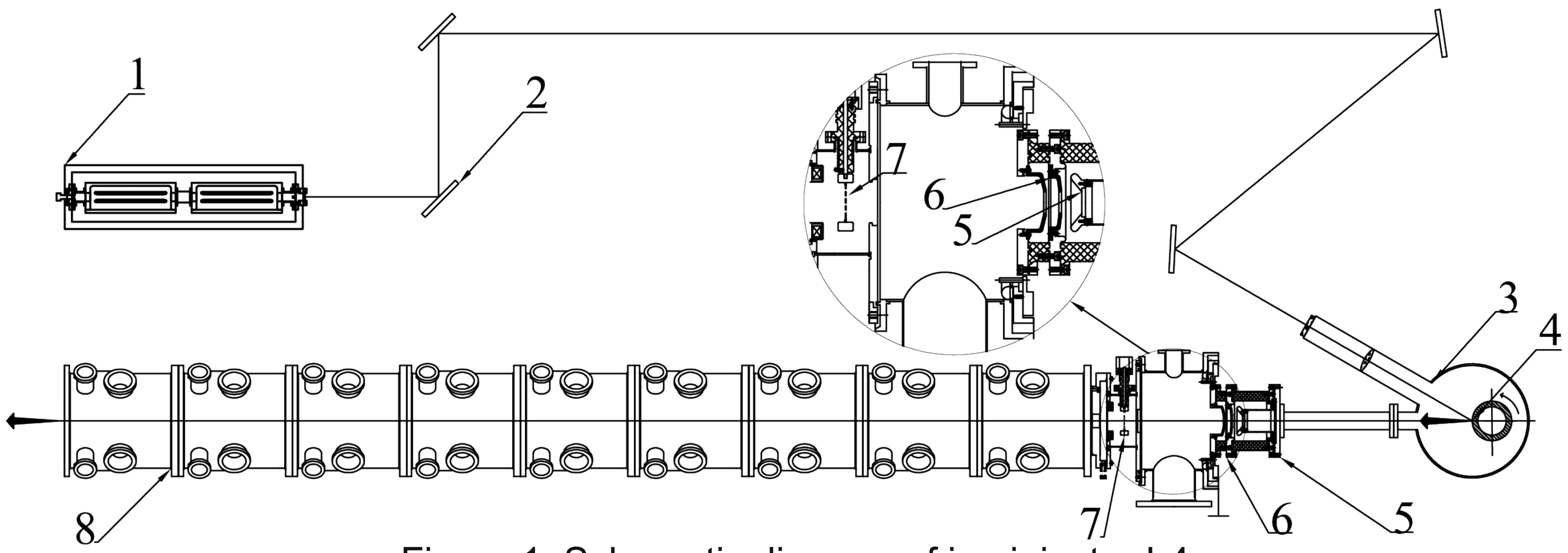

Figure 1. Schematic diagram of ion injector I-4.

CHARACTERISTICS OF LASER AND ION BEAMS

CO_2 laser oscillator [1] operates at a high level of the specific energy deposition into a self-sustained discharge . It provides laser beam with high quality of spatial and temporal characteristics:

- pulse energy – 7 J,
- peak power – 105 MW,
- FWHM duration – 30 ns,
- Beam divergence – close to diffraction limit.

These parameters have good reproducibility in long term operation.

Flat mirrors allow transporting the laser beam up to the input window of the vacuum chamber. Then laser radiation is focused on the target surface by spherical lenses with different focal length to vary power density in the range of $8\cdot10^{10}\div8\cdot10^{11}$ W/cm². A typical shape of the spatial distribution of the energy density in the focal spot is close to Gaussian and lies in the interval 200 ÷ 600 μm.

The time-of-flight technique is used in investigations of ion component from the laser plasma plume. Recording the parameters of a plasma stream using an electrostatic analyzer allows reconstructing the charge composition, the energy spectrum of ions, and the partial currents for particles of different charge states. The energy resolution ΔE/E of the instrument achieved is estimated as $\Delta E/E \approx 8 \times 10^{-4}$ [2]. The 143EM secondary electron multiplier with one-electron response time of 3 ns was used as the particle detector. The results are shown on Fig. 2 a,b.

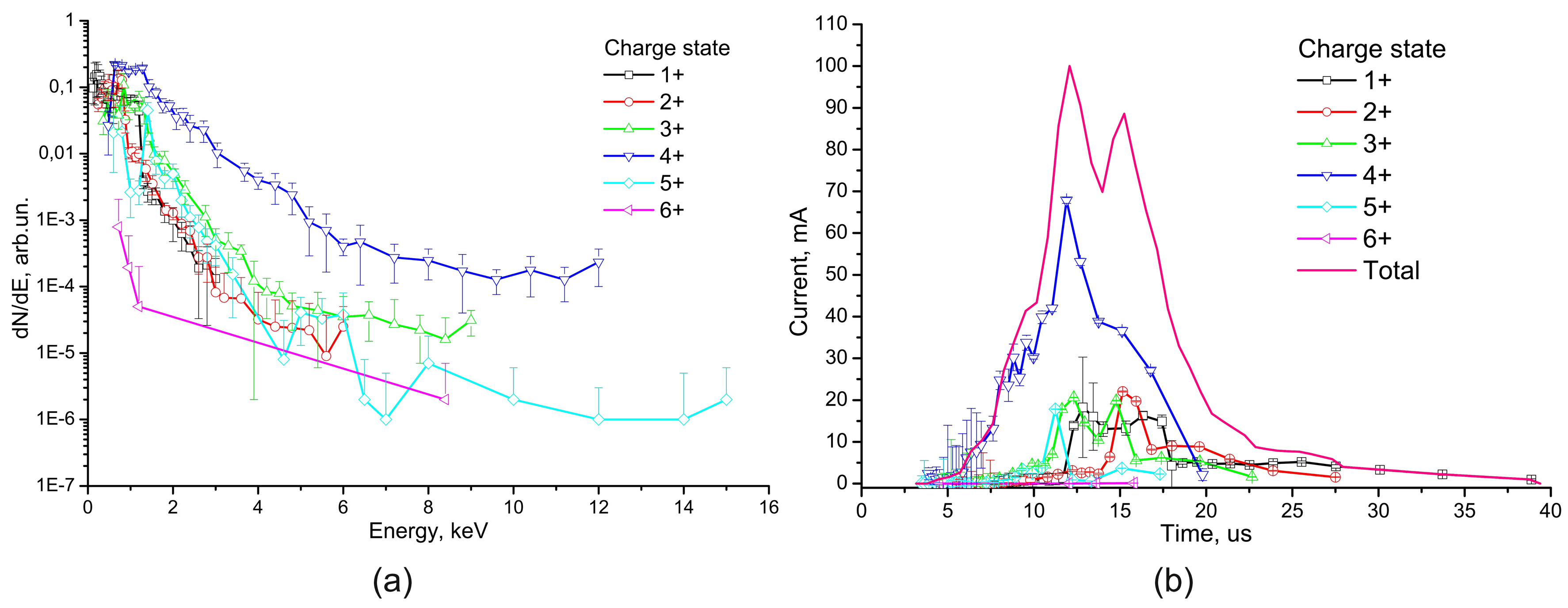

FIGURE 2. Energy spectra (a) and partial currents (b) of carbon for drift length 1680 mm

Beam extraction system consists of three electrodes. The positive electrode has a grid (transparency: 90%, cell dimensions: 0.5x0.5 mm) and a diaphragm installed. To match C^{4+} ion beam energy into the RFQ the positive electrode has to be at +60 kV potential relative to ground. Extraction voltage is increased by the negative electrode. Ion beam current was measured by a Faraday cup placed behind the ground electrode of the extraction. +1.5 kV potential was applied to the cup to suppress secondary electron emission.

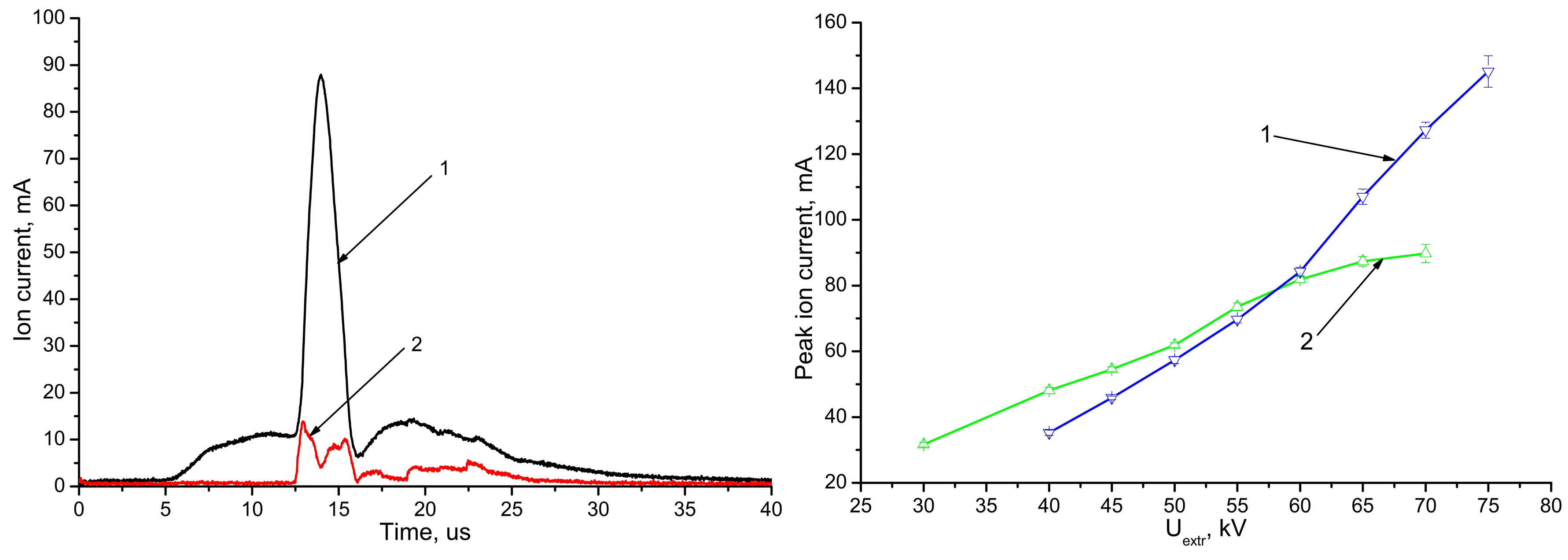

FIGURE 3. Total (a) ion current (1) and its standard deviation (2). Peak ion current versus extraction voltage (b) for 20 mm (1) and 15mm (2) positive electrode aperture.

Fig. 3 (a) shows the averaged ion current signal (a) and its deviation (b). Extraction voltage was 70 kV (+60 kV and -10 kV), aperture of the positive electrode was 15 mm. Zero time is the front of the laser pulse. Fig. 3 (b) shows extracted ion current versus voltage applied to the extraction gap for 20mm and 15 mm apertures of the positive electrode. Wider aperture prevents complete extraction of ions, therefore it was decreased to 15 mm.

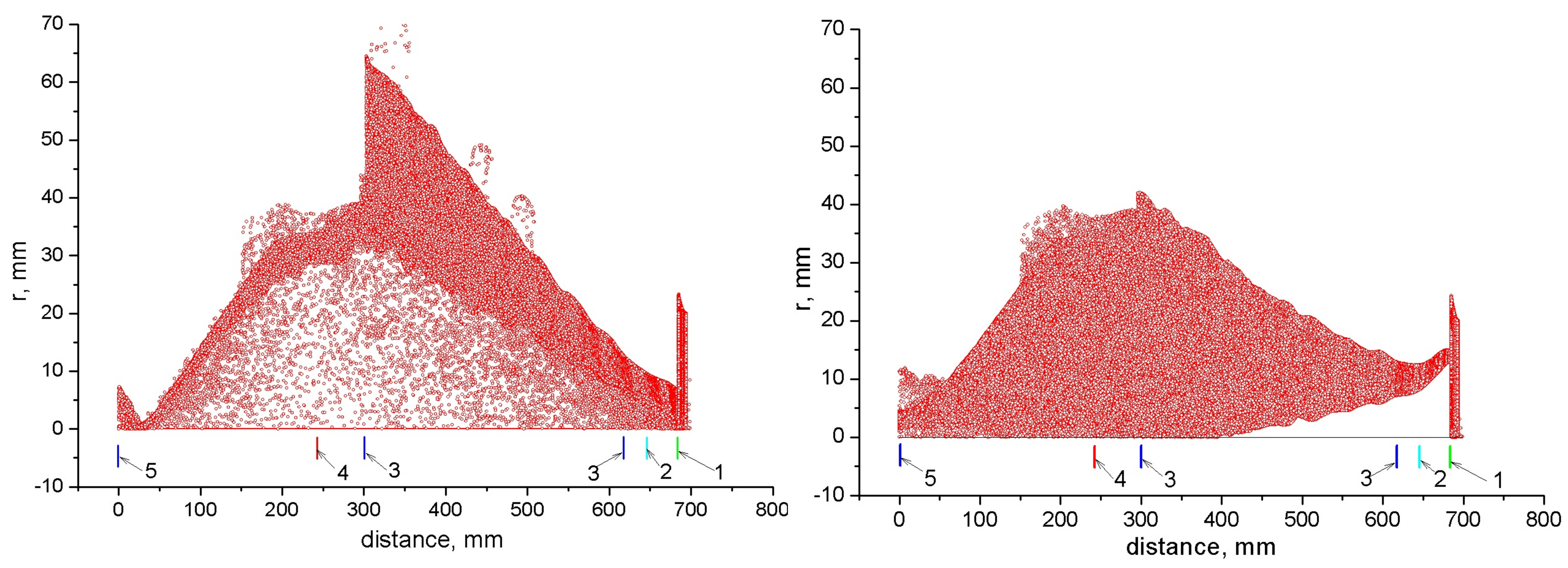

FIGURE 4. Numerical simulation of solid (a) and hollow (b) carbon ion beam transporting. 1 – positive electrode, 2 – negative electrode, 3 – ground electrode and flange, 4 – Enzel lens, 5 – RFQ input.

Measurements of phase parameters of extracted carbon ion beam were carried out. The "pepper-pot" technique with CCD-camera was used [3]. Measured emittance values of the total ion current are about 520 π mm mrad along y-axis and 560 π mm mrad along x-axis. Time resolved emittance measurements to obtain the data corresponding time interval of maximum fraction of C^{4+} are planned.

The code described in [4] was applied for simulation of low energy ion beam transporting through the Einzel lens to the input of the RFQ. Calculations were based on experimental data and conducted for solid (Fig. 4(a)) and hollow (Fig.4 (b)) beams extracted from equal area. Transmission values are 15% and 80% respectively.

REFERENCES

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