AVERAGE PROTON BEAM CURRENT INCREASING AT THE MMFL INJECTOR

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The most essential results on the MMF Linac Injector beam current increase are given. The problem is solving in two ways: 1) reconstructing of the optics at the input part of the accelerating tube; 2) pulse repetition rate magnification. Possibility of the pulse current increase with the emittance growth being limited is studied. The emittance and phase density of the beam at the exit of the accelerating tube are presented. The experimental data are compared with the numerical calculations. Preliminary results on the injector transition to the 100 Hz repetition rate are given.

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Results of the intense beam formation at the Moscow Meson Facility Linac (MMFL**)** comprising the injector [1,2] accelerating tube (AT) grid-free optical system are given. The injector provides a pulsed beam at the input of the LEBT channel settled 2 m downstream the AT beam forming part. The channel input aperture is 54 mm. Till now the AT long-focus optics has been delivered using lenses with the grid at the ion source (IS) extracting electrode and at the intermediate electrode dividing AT into 2 parts**.** During long-term beam shifting in the MMFL injector both grids proved to be stable up to 1 mA average beam current. Normalized emittance was 0.17…0.24 π·cm·mrad depending on the IS regime and AT optical conditions (here and after the emittance is given for the beam core containing 63% of a total beam current).

The limited thermo-resistance of the extracting electrode grid has resulted in the 30% emittance deterioration after 200h beam operation. Necessity of beam current increase up to 2 mA with the pulse repetition rate being doubled to 100 Hz and of emittance decrease (RFQ cavity at the entrance of MMFL has an acceptance of 0.35π·cm·mrad) demanded the grid-free optics.

The improved AT configuration is shown in Fig.1. Two diaphragm diameters have been tested: - 80 and 100 mm. The accelerating gap between electrodes 5 and 6 was decreased to 120 mm. This gap being the input aperture of the lens provides principal focusing to the LEBT entrance. The electrode 6 inlet has a diameter 70 mm. Since November 2002 modified AT is successfully in use.

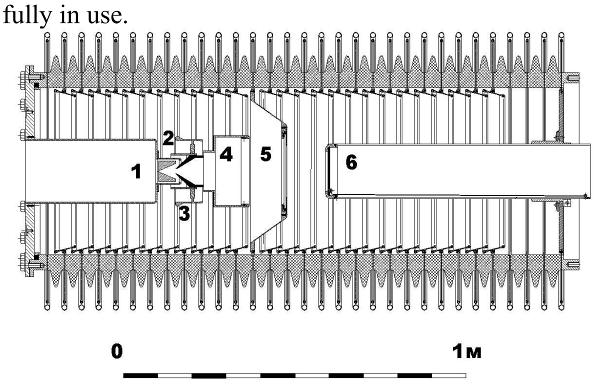

Fig.1. Proton injector accelerating tube
1 – duoplasmatron, 2 – expander,
3 – extractor electrode, 4 – focusing electrode,
5 – electrode with ∅100mm diaphragm,
6 – grounded electrode with the ∅ 70mm diaphragm

The current transformer monitor is installed 1560 mm downstream diaphragm 6. Immediately after it the emittance measurement device used for IS mode optimization [3] is placed.

In summer 2002 the grid-free extraction system with conical electrodes was installed, see Fig.2,a.

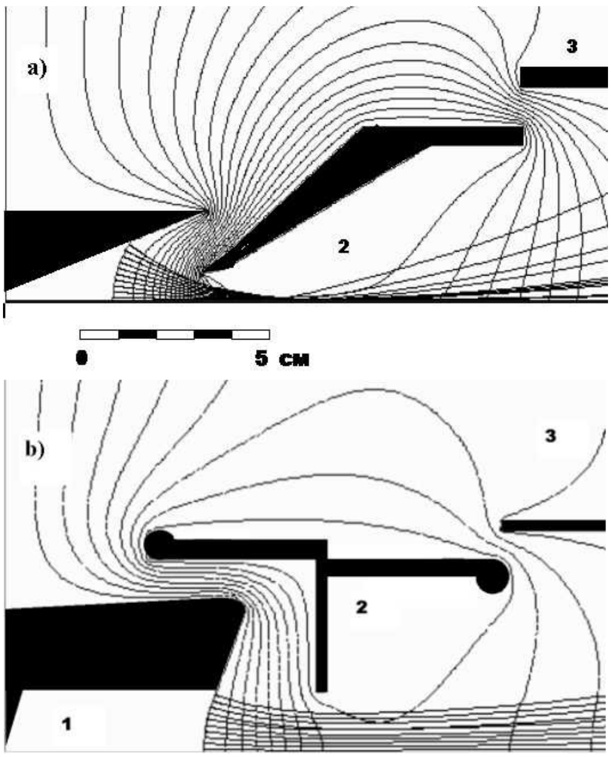

Fig.2. Extraction system simulations:
a - conical electrodes, 100 mA pulse current, 35 kV extractor voltage;
b - cylinder expander, Pierce optics, plate expander, 120 mA pulse current, 35 kV extractor voltage;
1 – expander; 2 – extractor; 3 – focusing electrode

The extracting electrode aperture diameter is 14 mm. The expander is made from mild steel. Since September 2002 till April 2003 such a system has been successfully used during 1600 h beam run with a pulse ion current up to 100 mA, pulse duration 190 μs and repetition rate 50 Hz. When the pulse current being 100 mA the best emittance value of 0,16π·cm·mrad was measured (see Fig.3). The maximum achieved current was 110 mA.

At the end of April 2003 the extraction system with the cylinder expander, Pierce geometry and the ∅ 30 mm plate electrode (see Fig.2,b) was put into AT. It permits to get the maximum pulse current up to 145 mA. With 120 mA current the emittance of 0.11 π·cm·mrad was measured (see Fig.4).

The beam forming system has been optimized for the maximum of current at the first LEBT beam current transformer (BCT). The values of measured currents are: 115 mA at the injector output, 100 mA at the first LEBT BCT and 60 mA at BCT after the analyzing magnet.

The injector operation mode was as follows: IS arc current – 36 A, extractor voltage – 35 kV, focusing voltage – 21, 76 and 324 kV were applied to the first and second parts of AT respectively, hydrogen flux through the IS was about 250 cc/hour.

Comparison of two extraction systems mentioned above is shown in Fig.2. Simulation of particle trajectories was carried out with a zero transverse velocity spread. In the case of conical electrodes (Fig.2,a**)** the beam enters the AT space strongly converging. This results in significant emittance distortion.

With the plate extractor (Fig.2,b) the beam at the beginning of AT space is practically parallel. It has larger radius and may be better focalized when passing through the AT.

Preliminary tests of the injector with the 100 Hz repetition rate to the double average current have been carried out. Recently 400 kV power supply is capable to provide 160 µs flat-top pulse. The top of the pulse falls down strongly at greater pulse duration due to the chokes saturation in the multi-cascade discriminator [4]. The pulse current of 95 mA corresponding to the 1.5 mA average current has been achieved with 160 µs pulse and 50 Hz repetition rate. Some modification of 400 kV power supply will be done to get 200 µs pulse duration.

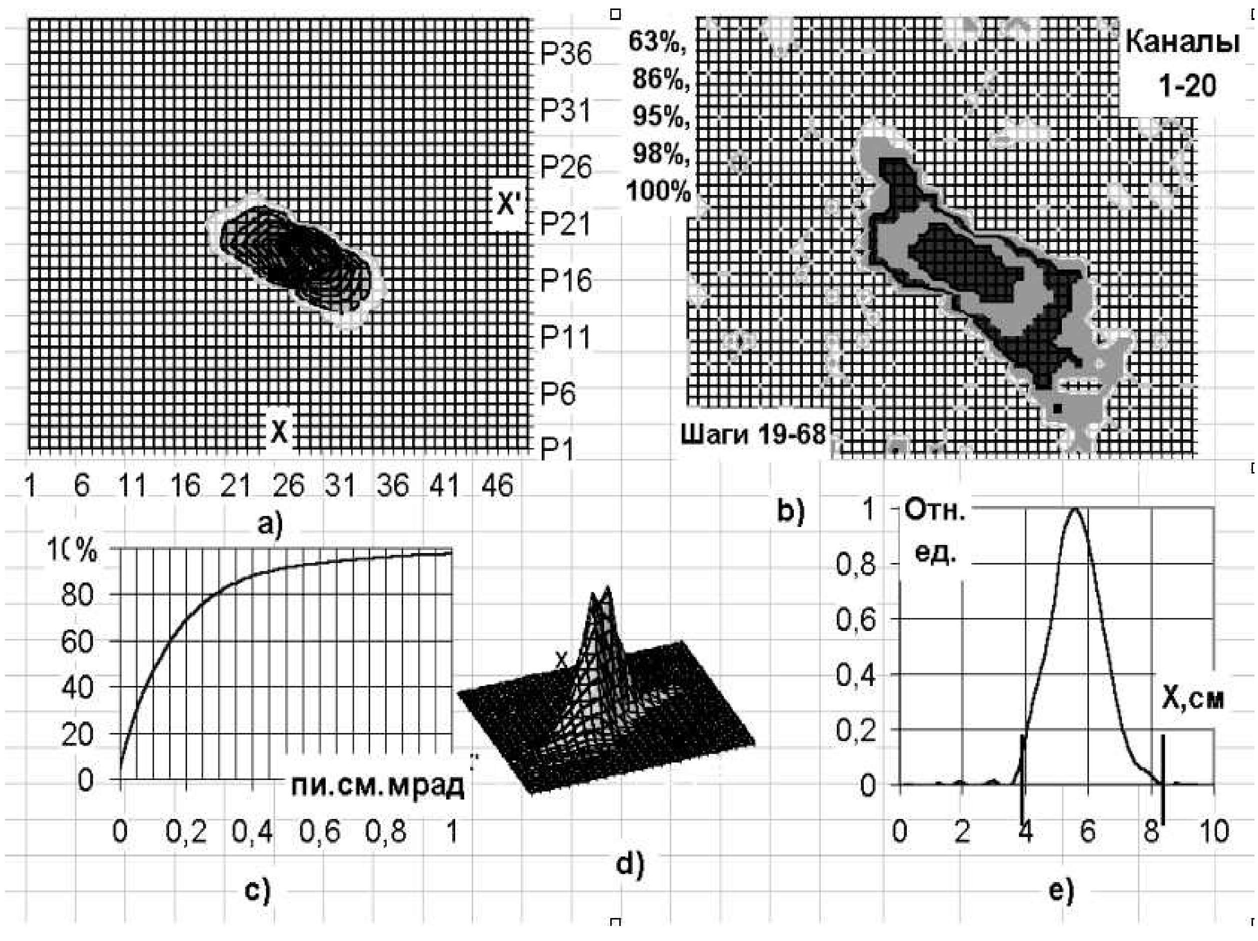

Fig.3. Emittance of the mA pulse current using the conical extraction system. Scale factors: X – 2mm, X' – 4mrad,
a - lines of the constant phase density for 1, 10, 20, ……, 80, 90% of maximum density;
d - phase space domains containing 63, 86, 95, 98, 100% of the beam;
d – beam current fraction vs. limited emittance; c - phase density as a function of X, X';
e - beam profile

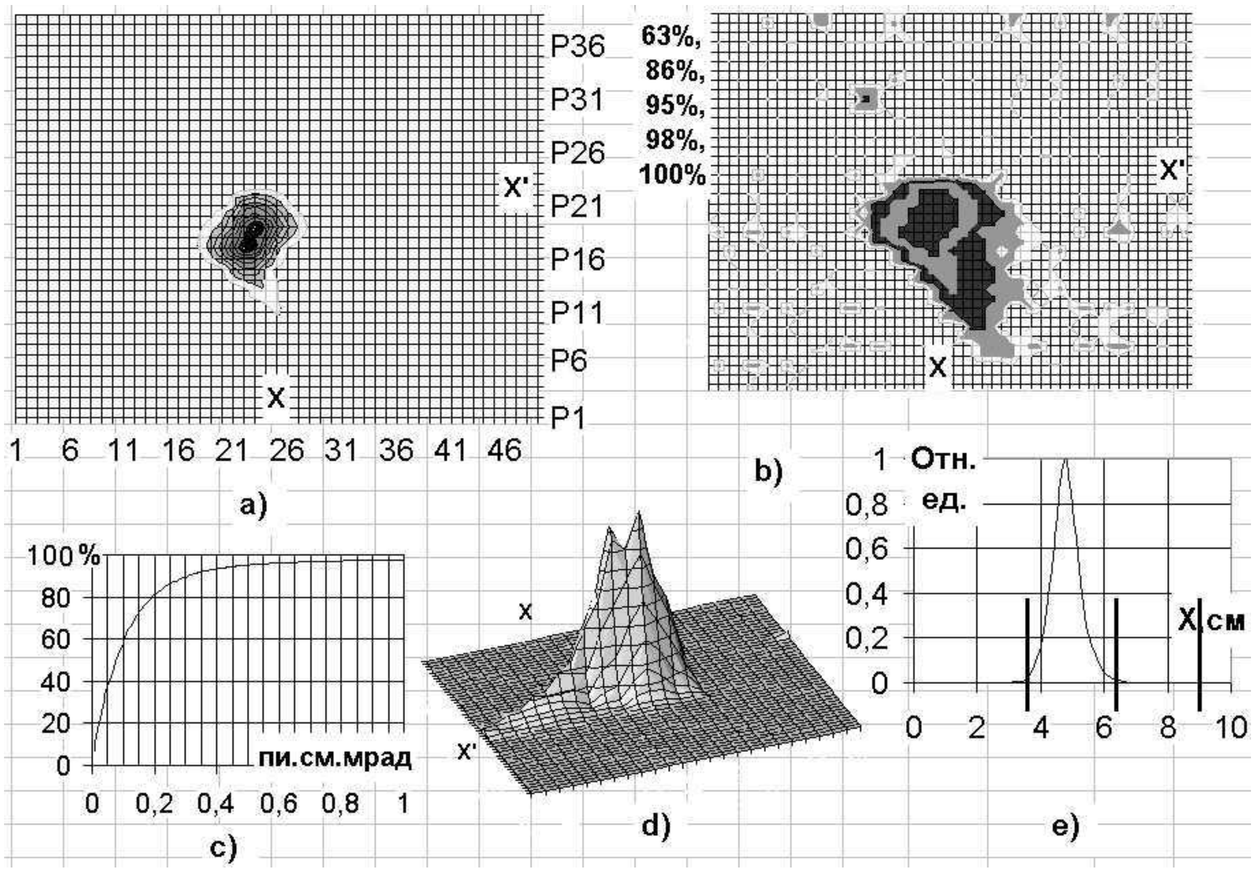

Fig.4. Emittance of 120mA pulse current using the Pierce extraction system

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ПОВЫШЕНИЕ СРЕДНЕГО ТОКА ПУЧКА ПРОТОНОВ ИНЖЕКТОРА ЛУ ММФ

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Приведены основные результаты работ по увеличению среднего тока пучка инжектора ЛУ ММФ. Рассматриваются два пути повышения среднего тока - реконструкция системы формирования пучка на начальном участке ускорительной трубки и увеличение рабочей частоты следования импульсов. Исследованы режимы, обеспечивающие увеличение импульсного тока пучка при ограниченном росте эмиттанса. Представлены данные об эмиттансе и фазовой плотности пучка сразу после ускорительной трубки. Экспериментальные результаты сравниваются с результатами численного моделирования пучка. Дано описание подготовительных работ по переводу инжектора на частоту повторения импульсов 100 Гц.

ПІДВИЩЕННЯ СЕРЕДНЬОГО СТРУМУ ПУЧКА ПРОТОНІВ ІНЖЕКТОРА ЛП ММФ

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Приведено основні результати робіт зі збільшення середнього струму пучка інжектора ЛП ММФ. Розглядаються два шляхи підвищення середнього струму - реконструкція системи формування пучка на початковій ділянці прискорювальної трубки і збільшення робочої частоти проходження імпульсів. Досліджено режими, що забезпечують збільшення імпульсного струму пучка при обмеженому зростанні еміттансу. Представлено дані про еміттанс і фазової густини пучка після прискорювальної трубки. Експериментальні результати порівнюються з результатами чисельного моделювання пучка. Дано опис підготовчих робіт з переведення інжектора на частоту повторення імпульсів 100 Гц.