Beam Extraction System for Industrial Electron Accelerator ILU-14

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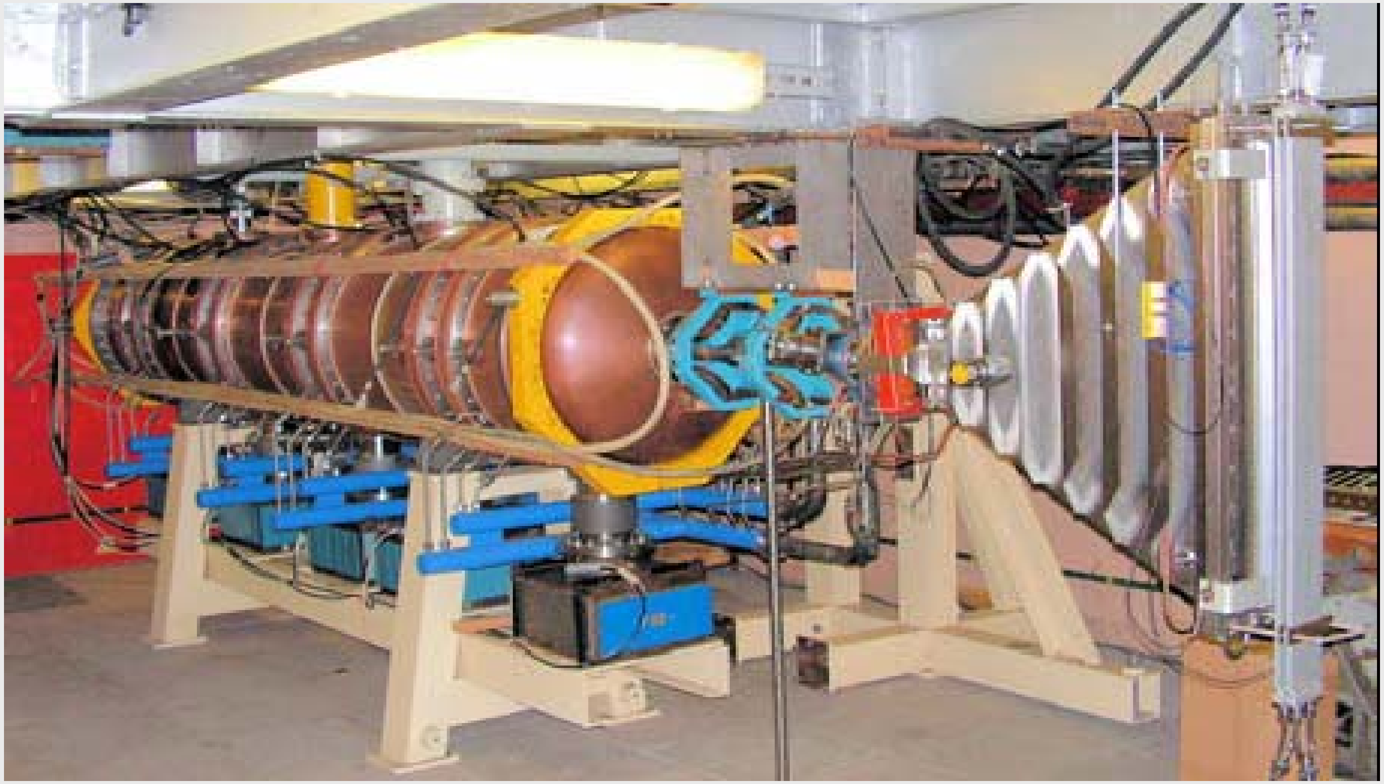
Industrial accelerator ILU-14

- Currently there is heightened interest to radiation technologies used bremsstrahlung because of its high penetration power.

- New powerful (up to 100 kW) industrial linear electron accelerator ILU-14 with energy 7.5 ÷ 10 MeV was developed. Operation frequency of this accelerator is 176 Mhz, overall efficiency is 26%.

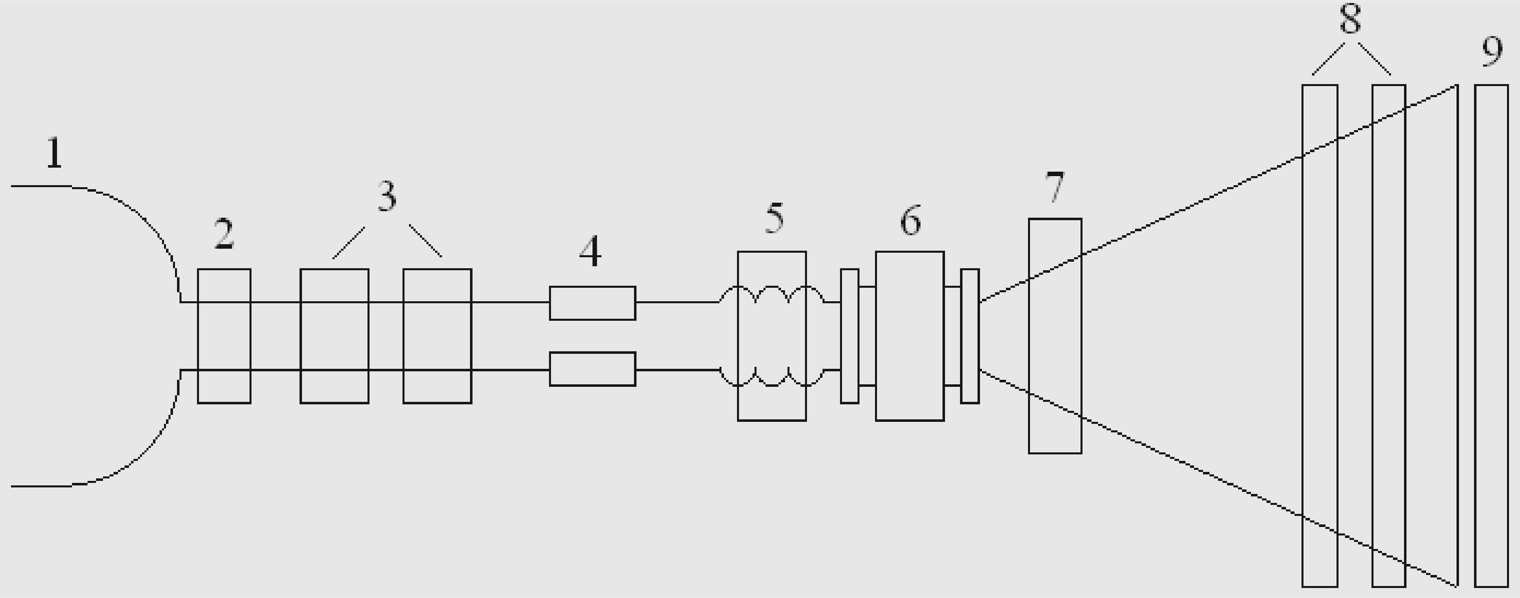
- The test results: electron energy – 10 Mev, beam power – 60 kW.

Prototype accelerating structure with scanning system



Requirements for the new scanning system: admissible dose nonuniformity in radiation zone is of no more than ± 5% along the scanning length up to 1m.

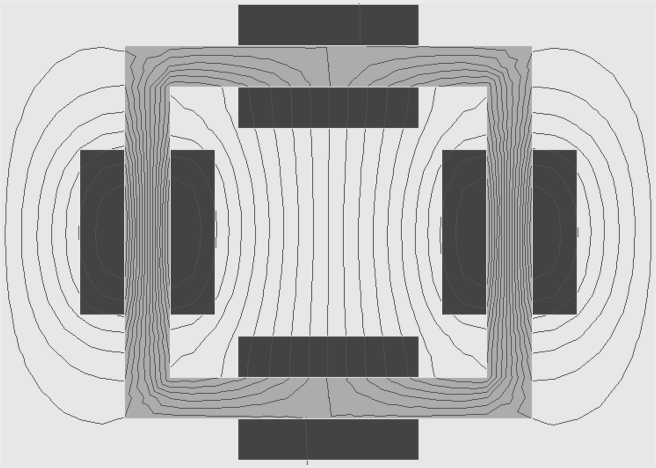
Block-diagram of beam output system



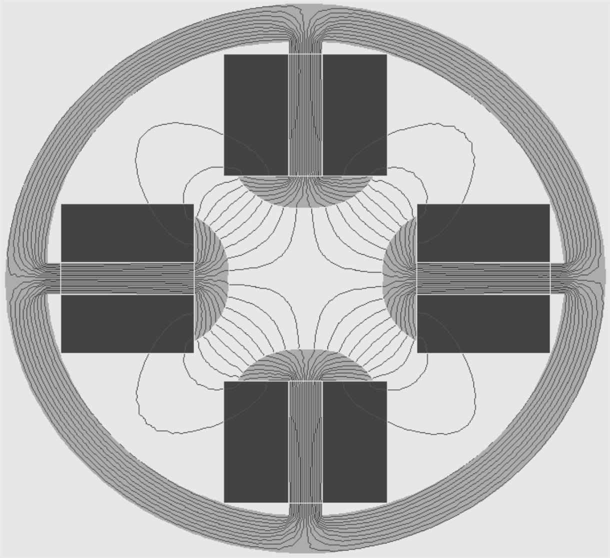
1 – accelerating structure, 2 – control magnet, 3 – quadrupole doublet, 4 – diaphragm, 5 – bellows unit with correction system of scanning field, 6 – scanning chamber with scanning electromagnet, 7 – transverse beam scanning system, 8 – Panovsky lenses, 9 – converter.

Beam forming system

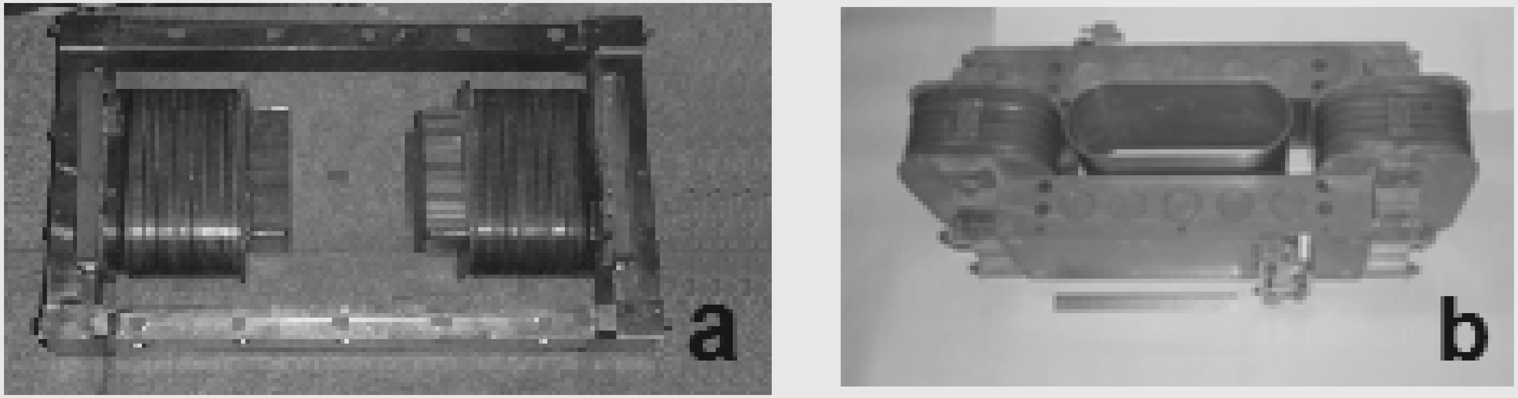
- To control beam position after the exit of accelerating structure with respect to the central axis of the output channel the directing magnet was entered. There is two-coordinate corrector of electron trajectories in the range ± 5 cm.



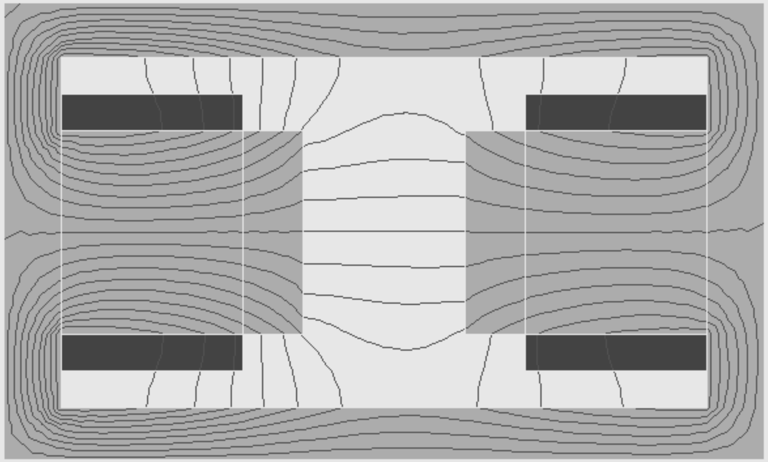
- To achieve the necessary beam size during adjustment of the accelerator without beam scanning the quadrupole doublet was installed.



- Choice of scanning device is determined by the specification of the beam extraction system as a whole.
- Scanning electromagnets with poles are twice more effective on magnetic field value at the same number of ampere-turns.



Scanning electromagnets with poles (a) and without poles (b)



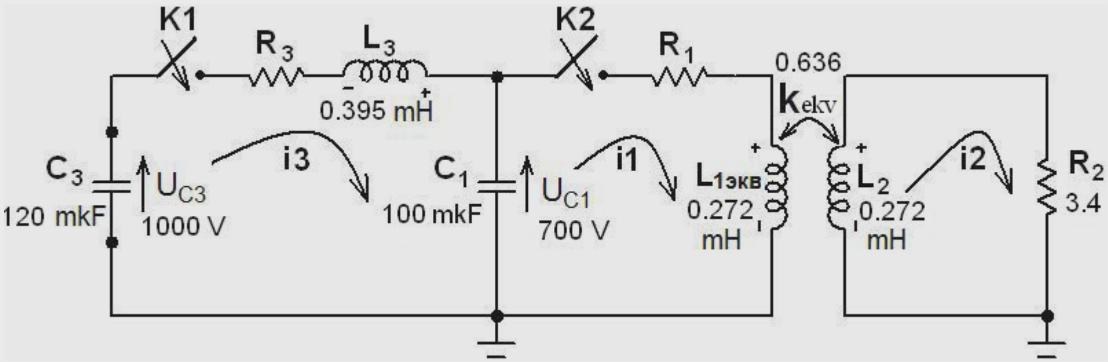
Number of the electromagnet ampere-turns is 10000, magnetic field amplitude is 1kGs, maximal supply current is 300 A.

Influence of the scanning chamber metal shield

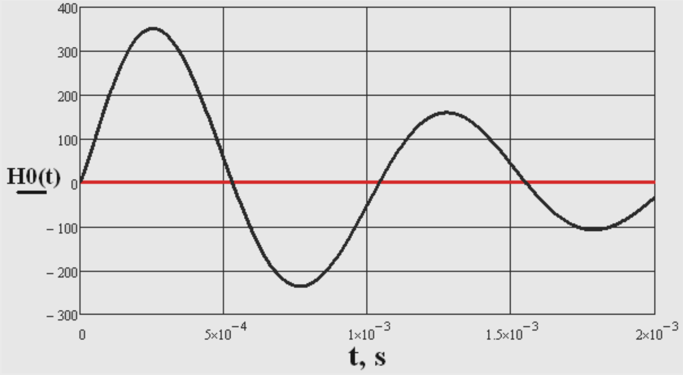
- Magnetic field in the vacuum part of scanning chamber H0(t) is the superposition of the scanning electromagnet effecting field H1(t) and field which excited by induced currents at the metal shield of the scanning chamber:

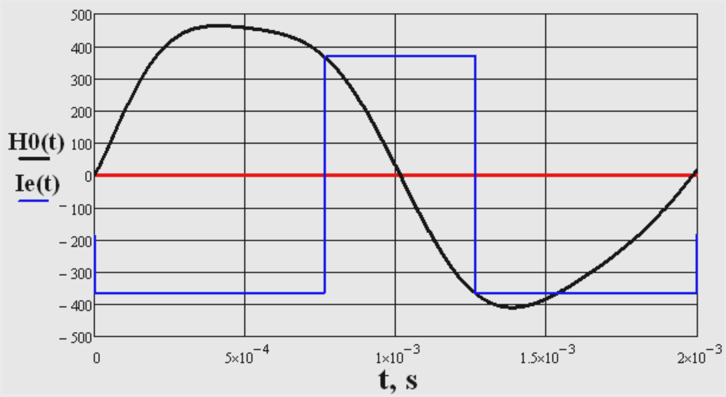
$H1(t) = \frac{L}{R} \cdot \frac{dH0}{dt} + H0(t),$ where L and R – inductance and active resistance of the metal shield.

- There is magnetic field damping in the vacuum through ohmic resistance of the scanning chamber metal shield.

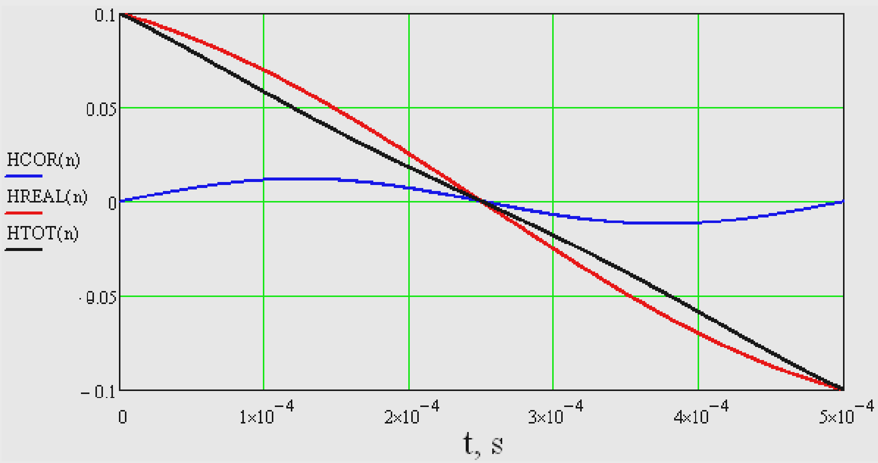


- Insertion of the additional correcting circuit in the scheme of the electromagnet power supply allows to compensate this effect.



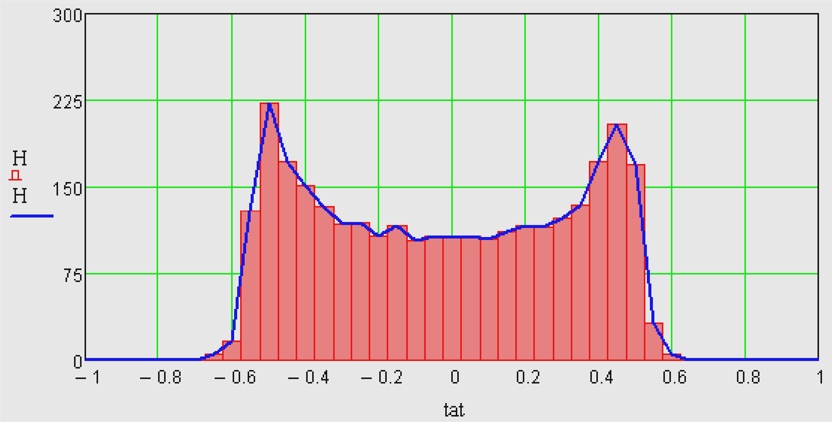


Correction of scanning field



Forms of the scanning and correcting fields during beam pulse.

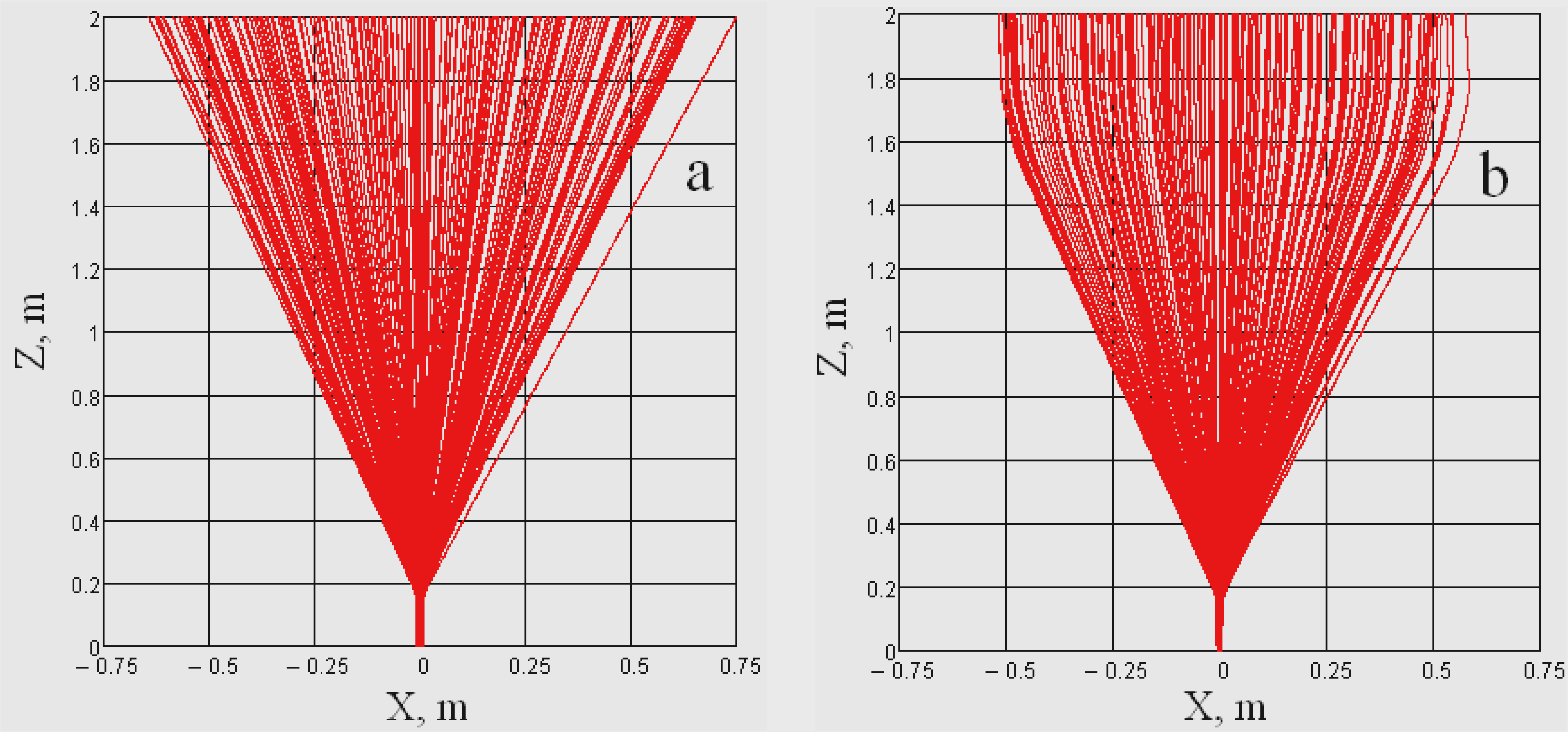
- The beam current density at edges of the bell foil increases. So to achieve the dose uniformity speed of the beam scanning should be raised to edges of the foil.
- Insertion of an additional correcting field leads to equalization of beam scanning speeds along the bell extraction window.



Histogram of the output beam current density

Histogram of the output beam current density after correction.

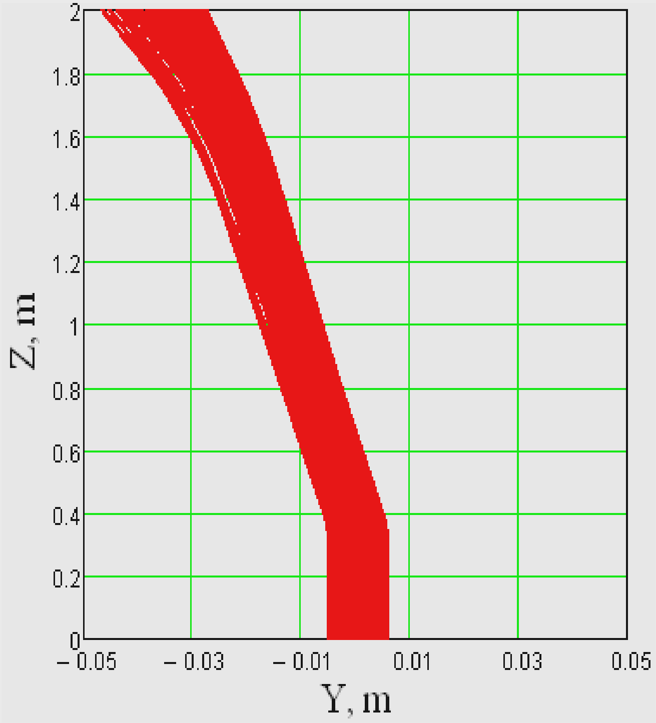
- To receive on the bell foil a beam with identical angular characteristics installation of additional turning devices is necessary.
- The Panovsky lens (a flat quadrupole lens) allows to turn beam on all length of the bell. It is produced in the form of two rectangular plates with windings evenly reeled up on all length.

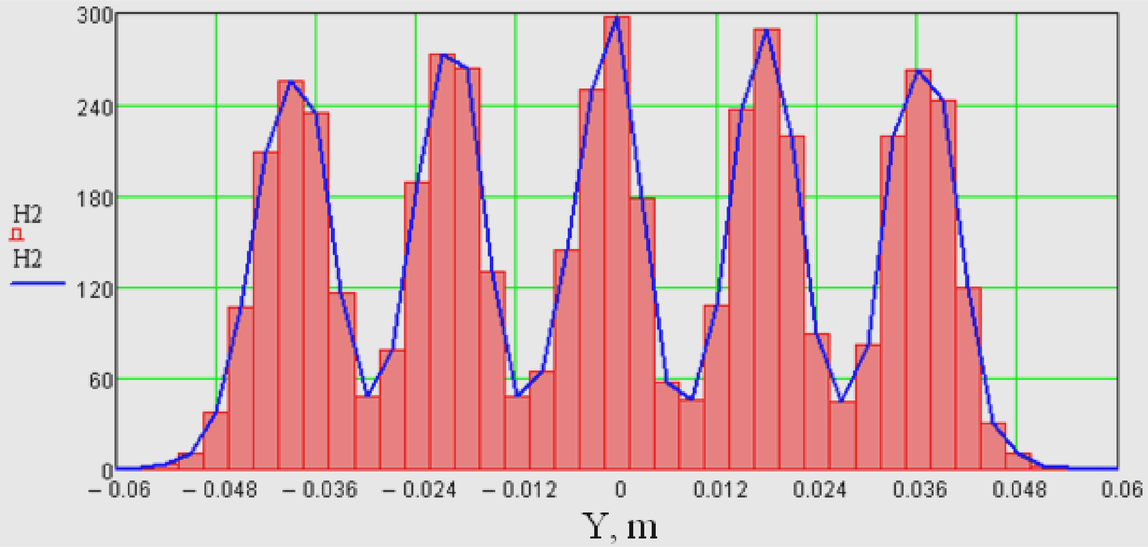


Trajectories of scanning beam without (a) and with using of Panovsky lenses (b).

Horizontal scanning system

For some types of radiation processing the mode of so-called line scanning of the beam can be demanded. In this mode the bunch is serially scanned for all length of a final window, both on the bell center, and for its edges (in the cross-section direction). Electronic trajectories of the beam and also the histogram of output beam current density across a bell are shown on figures.





Parameters of extraction system electromagnets

Element name	Iron section, mm2	Number of coil turns	Maximal current, A	Resistance of windings, Ohm*	Magnetic field amplitude	Loss power, Wt
Directing magnet (channels X, Y)	10×100	200	6	0.24	0.01 T	10×2
Focusing quadrupole	20×100	200	6	0.6	0.25 T/m	22
Defocusing quadrupole	20×100	200	6	0.6	0.25 T/m	22
System of scanning field correction	30×100	30	40	$8 \cdot 10^{-3}$	0.012 T	4
Scanning electromagnet	30×100	30	300	$8 \cdot 10^{-3}$	0.11 T	100
Horizontal scanning	10×100	170	6	0.6	0.01 T	22
Panovsky lens	25×100	170	10	2.6	0.1 T/m	260

* Calculation values.

Industrial Electron Accelerator ILU-14

RESULTS

- The scanning system of the beam with energy up to 10 MEV is produced and tested. The received nonuniformity of the dose field in radiation zone was ±10%.

- To improve radiation quality (dose uniformity) and obtain competitive advantages the correcting system of a scanning magnetic field was designed. Consequently, nonuniformity of the surface dose will be reduced to ±5%.

- This system will be tested within projects of sterilizing complexes at FMBC of A.I.Burnazyan (Moscow) and “Park of Nuclear Technologies” (Kurchatov, Kazakhstan).

THANK YOU FOR ATTENTION!