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UPGRATED THE EXTRACTION DEVICE OF FOCUSED ELECTRON BEAM INTO THE ATMOSPHERE.

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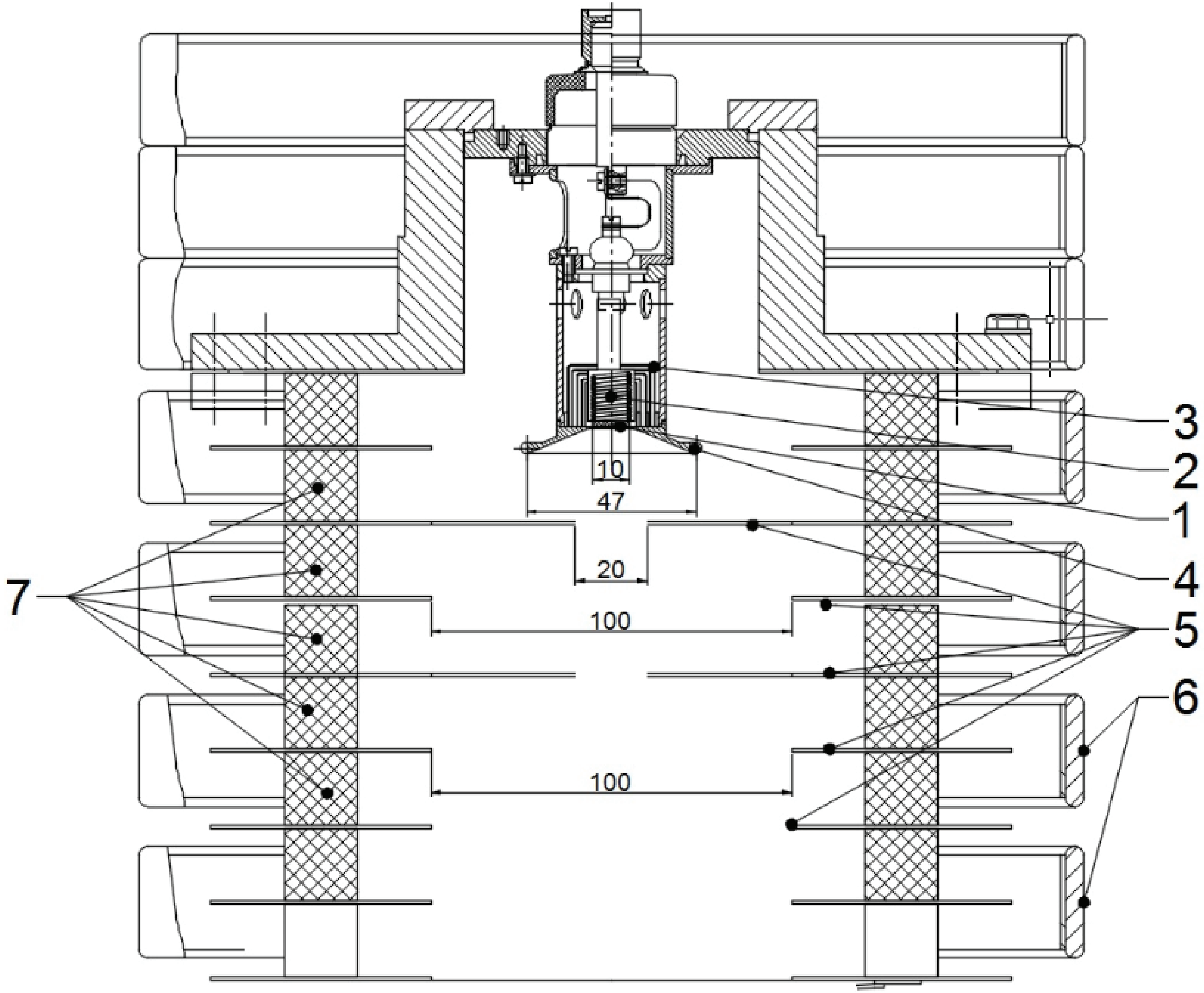
ACCELERATORS ELV

Large aperture accelerating tube design

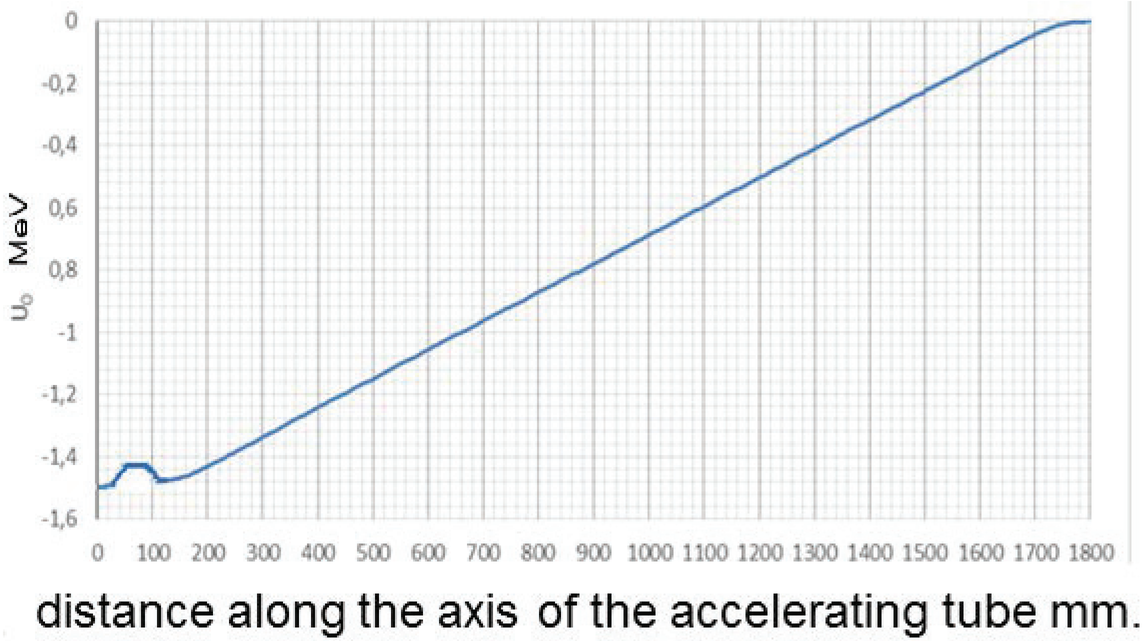


Cathode part of the accelerating tube
1 - cathode; 2 - cathode heater; 3 - heat shields; 4 - cathode electrode; 5 - accelerating tube electrodes; 6 - shielding rings; 7 - ceramic insulator

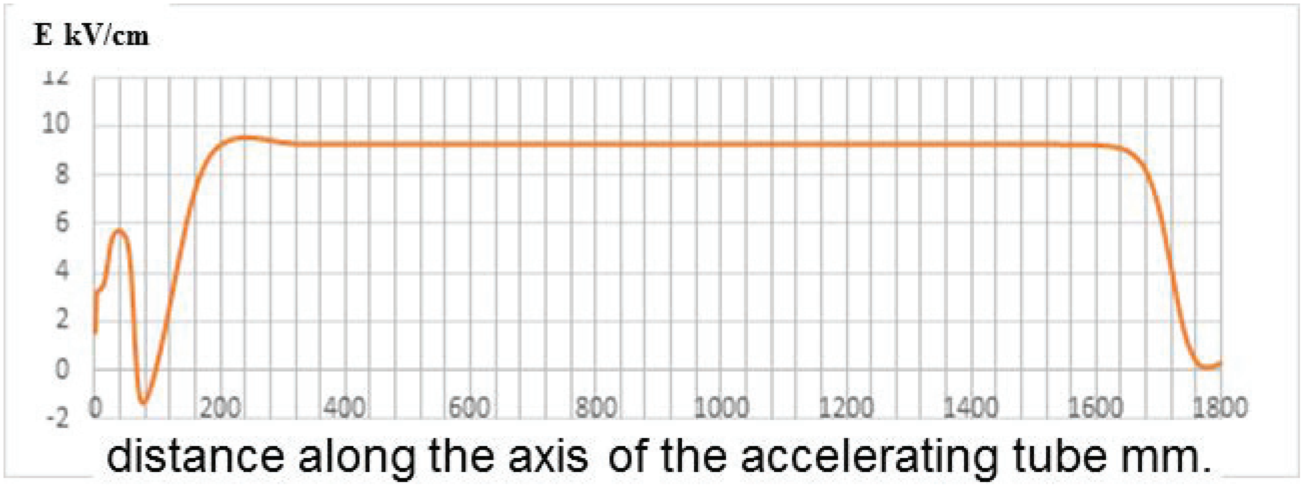
Factors affecting the beam size and its angular divergence at the exit from the accelerating tube.

1. Longitudinal electric field: carries out the main focusing of the beam;
2. Influence of the magnetic field of heating coil (the beam acquires an azimuthal momentum $P\varphi 0$);
3. The space charge of the beam;
4. The ripples of the accelerating voltage;
5. Aberrations of electromagnetic lenses. They also affect the optimal hole size in the outlet diaphragms;
6. Transverse component of the magnetic field of the primary and secondary windings, which leads to oscillations of the beam, and leads to the need to increase the holes in the diaphragms.

Distribution of potential (a) and electric field (b) along the axis of the accelerating tube



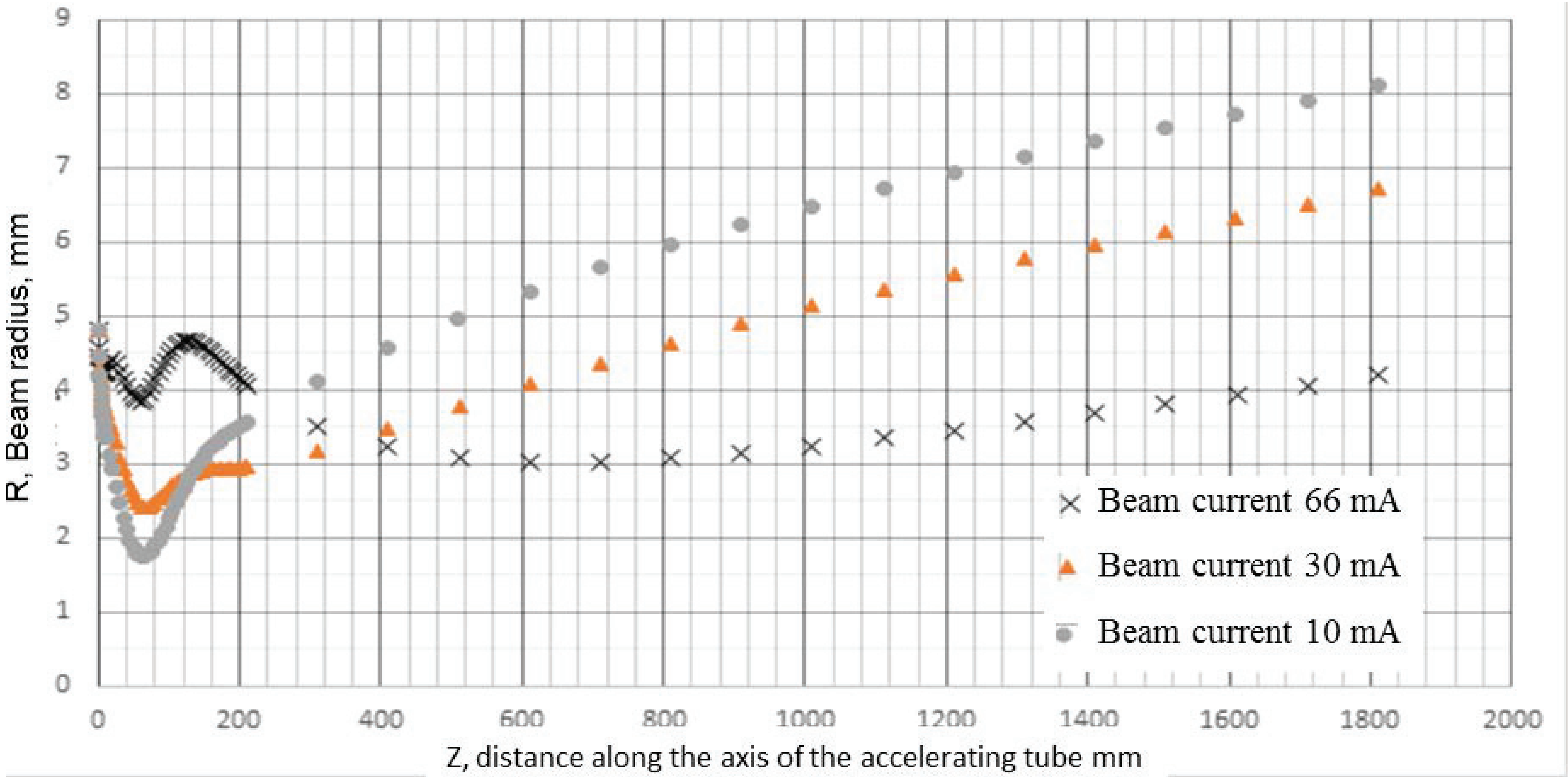
(a)



(b)

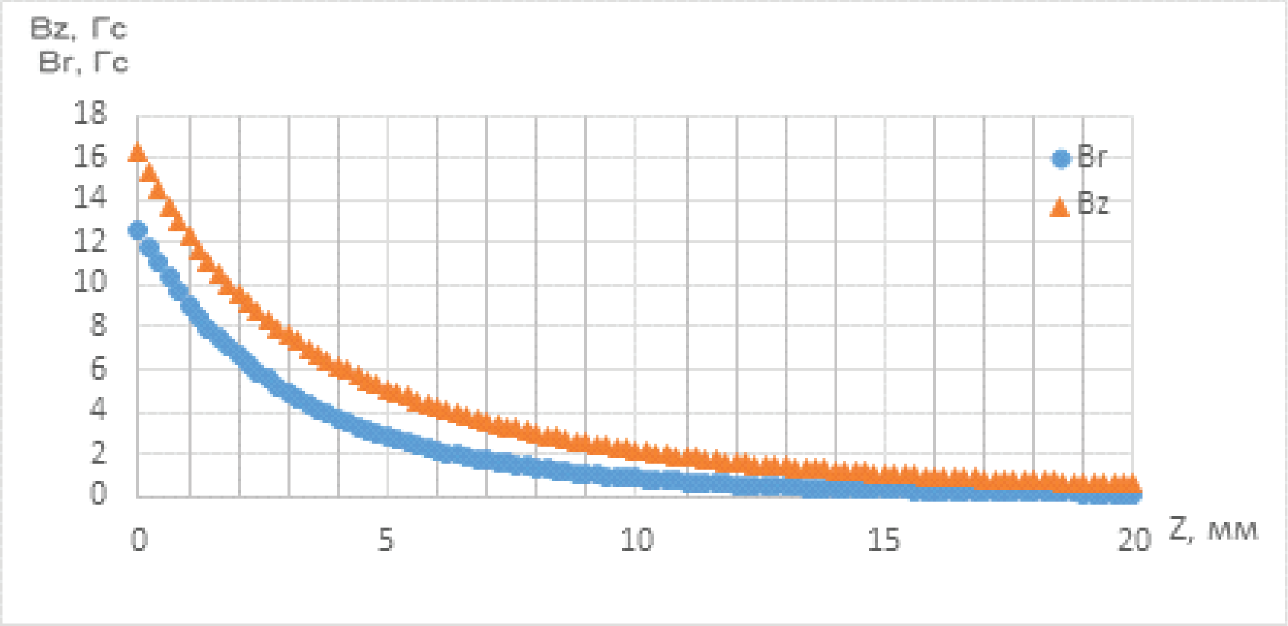
The potential and electrical field distributions near cathode prevent the exchange ion-electron processing and improve the accelerating tube operation stability.

Calculated beam envelopes

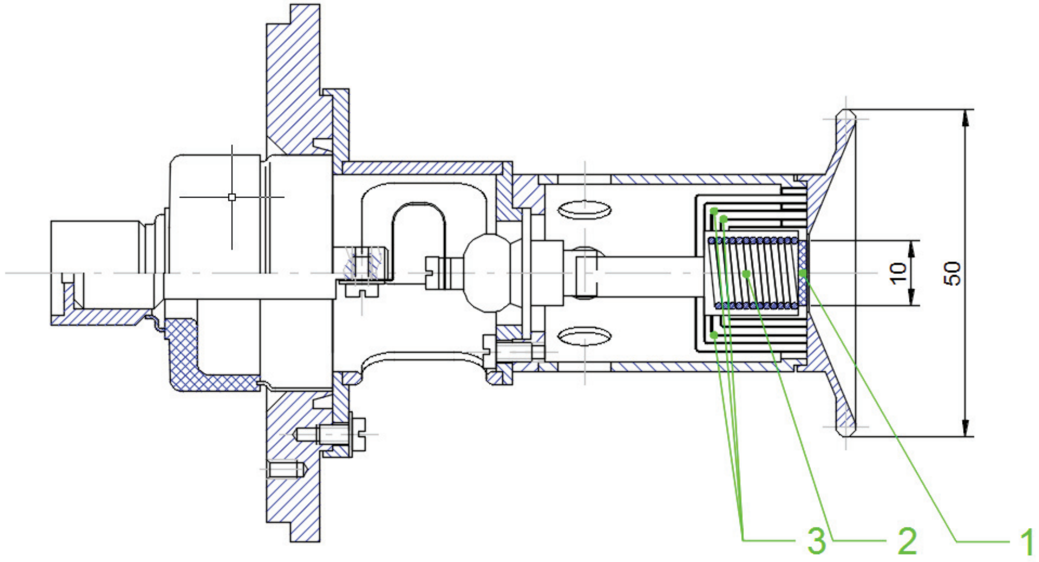


The envelopes for different beam currents at an energy of 1.5 MeV, the length of the accelerating tube is 1800 mm

Influence of the magnetic field from the heating coil.



Electron injector heater coil magnetic field. Coordinate z = 0 corresponds to the emitting surface of the tablet.



Injector with near-cathode electrode in Pierce geometry. 1-Cathode LaB6; 2-heating coil; 3- Heat shields.

Because of the magnetic field of the heating coil, the electron acquires an azimuthal momentum Pφ0 of about 4.4 Gs cm. With a trajectory radius of 5 mm, the angular momentum is obtained 2,2 Gs·cm². $\Delta r_{min} = \frac{1}{2} \cdot F \frac{P_{\phi 0} r}{P_0}$, P_0 – momentum of electrons, F- is the focal length of the lens , $P_{\phi 0} r$- , is the angular momentum.

The minimum focused beam radius Δr_{min} is approximately 0.3 mm.

Influence of the emittance associated with the cathode temperature.

The value of the temperature emittance, $\varepsilon_T = \frac{d_k \cdot \Delta P_k}{P_0} = d_k \cdot \alpha_{k,}\ (\alpha_k = \frac{\Delta P_k}{P_0})$, where d_k is the diameter of the cathode, ΔP_k is the spread of transverse momenta due to the temperature of the cathode, and P_0 is the final momentum of electrons. The divergence of the beam in the crossover at its total energy after the lens is equal to $\frac{d_л}{f_л}$; where $d_л$ is the diameter of the beam at the entrance to the lens, and $f_л$ is the focal length of the lens, therefore $d_{min} = \frac{\varepsilon_T \cdot f_л}{d_л}$. With $d_л$ = 10 mm, $f_л$= 180 mm and $\varepsilon_T = 3\ 10^{-3}$ rad mm, we have dmin ≈ 0.05 mm. This value is negligible.

Influence ripples of the accelerating voltage on the beam diameter.

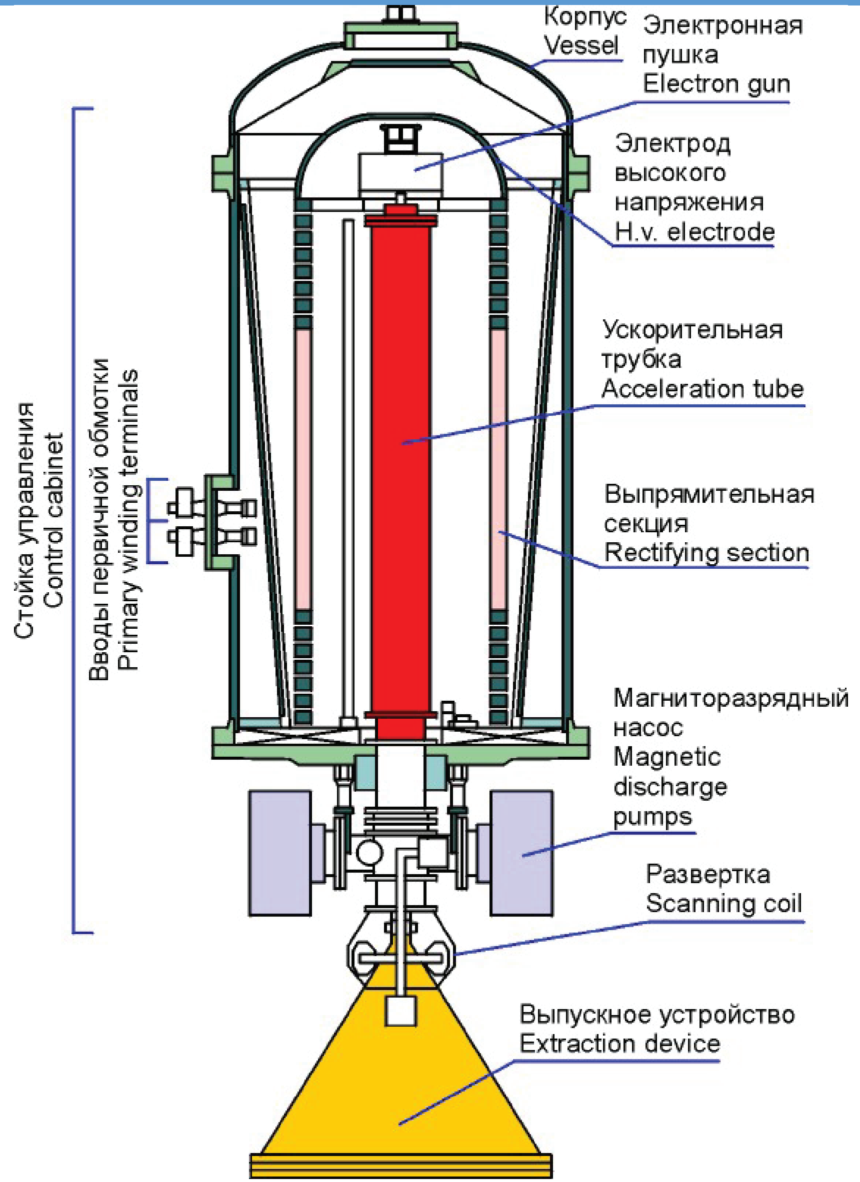
The ripples of the accelerating voltage in this electron accelerator were initially assumed to be 5%. The energy ripple causes the focal length of the lens to change with the pulsation frequency, which leads to an increase in the beam diameter in the crossover.

$$d_{min} = d_{Линзы} \frac{\Delta f}{f}$$

Where dmin is the minimum diameter of the focused beam cm, dlens is the diameter of the beam at the entrance to the lens, which is 10 mm,

At an energy of 1.5 MeV, $\frac{\Delta f}{f} \sim \frac{\Delta U}{U}$ then, at an energy ripple of $5 \bullet 10^{-2}$, the effective beam diameter in the first diaphragm at the exit from the outlet will be ≈ 0.5 mm.

Influence of the transverse component of the magnetic field of the primary and secondary windings of the transformer.



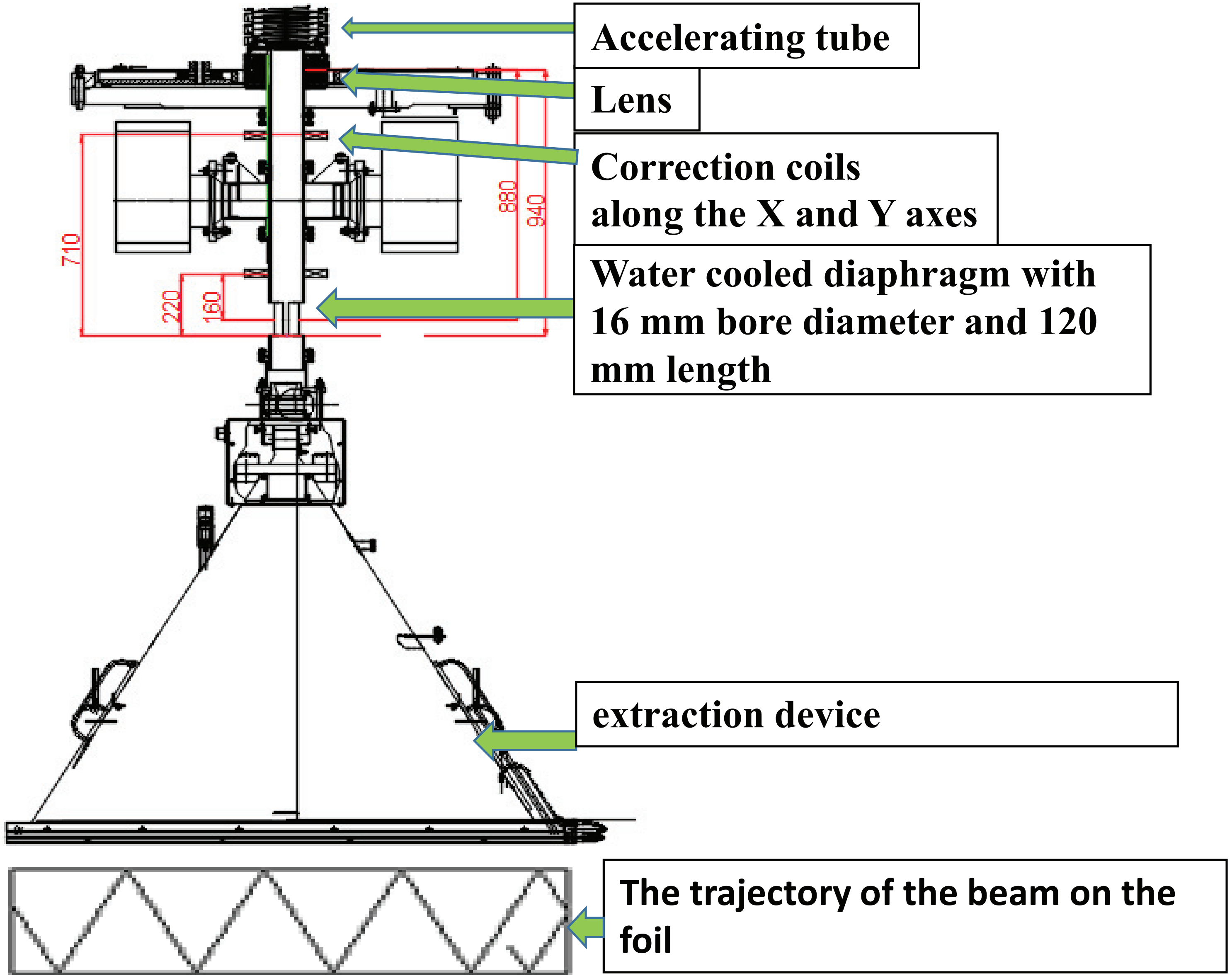
The tube, which is located inside the high-voltage rectifier and the primary winding, is penetrated by a transverse magnetic field associated with the tilt or misalignment of the accelerating tube and the primary or secondary windings of the transformer. Its value can reach $B^{\perp} = 0.2$ G. This leads to the appearance of variable angles Δα at the exit from the accelerating tube.

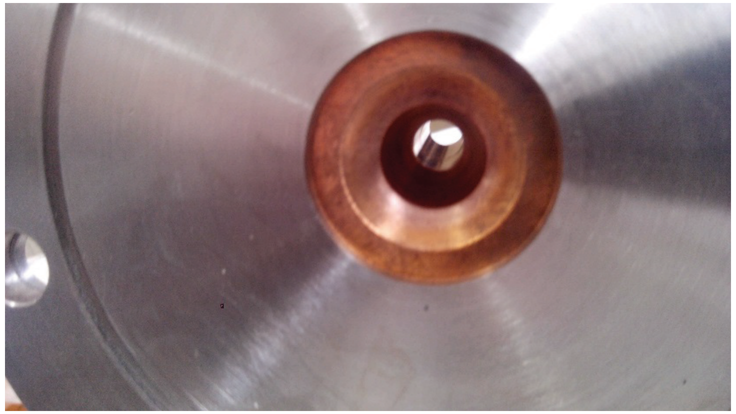
$$\Delta\alpha = \frac{B_{\perp} \cdot L_{mp}}{B\rho_0} = \frac{0.2 \cdot 180}{6,5 \cdot 1000} = 5.5 \cdot 10^{-3}$$

Where is the transverse magnetic field of the primary winding, $L_{тр}$ is the length of the accelerating tube, which is 1800 mm, B · ρ0 is the electron momentum, which is $6.5 \cdot 10^3$ G · cm for a beam energy of 1.5 MeV

$\Delta dmin = f_Л \cdot \Delta\alpha$. Where $f_л$ is the focal length of the lens 180 mm. In our case, the oscillations of the beam in the output diaphragm will be $\Delta dmin \approx 5 \cdot 10^{-3} \cdot 18 = 9 \cdot 10^{-2}$ cm.=0,9 mm

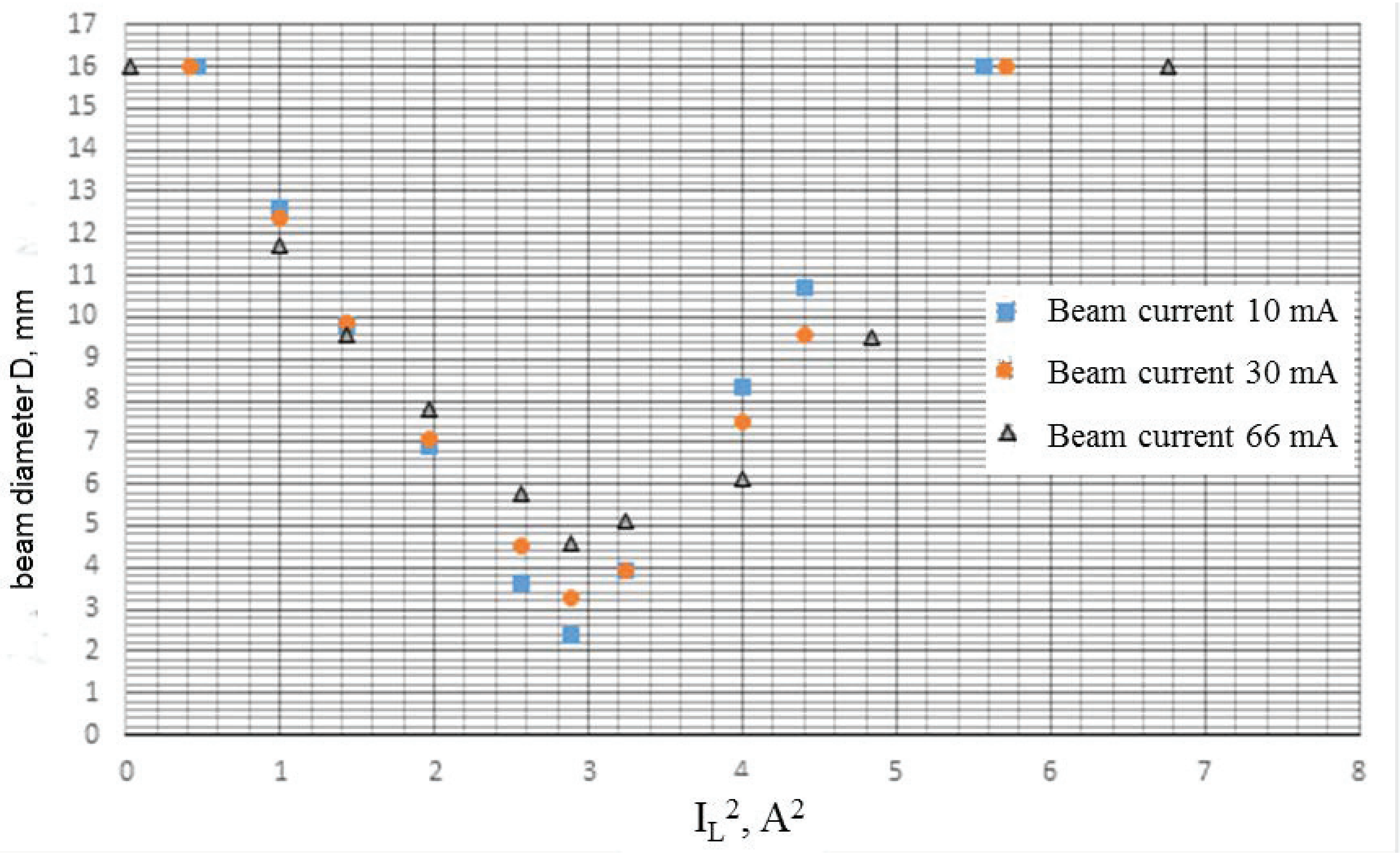
Stand for measuring the beam diameter.



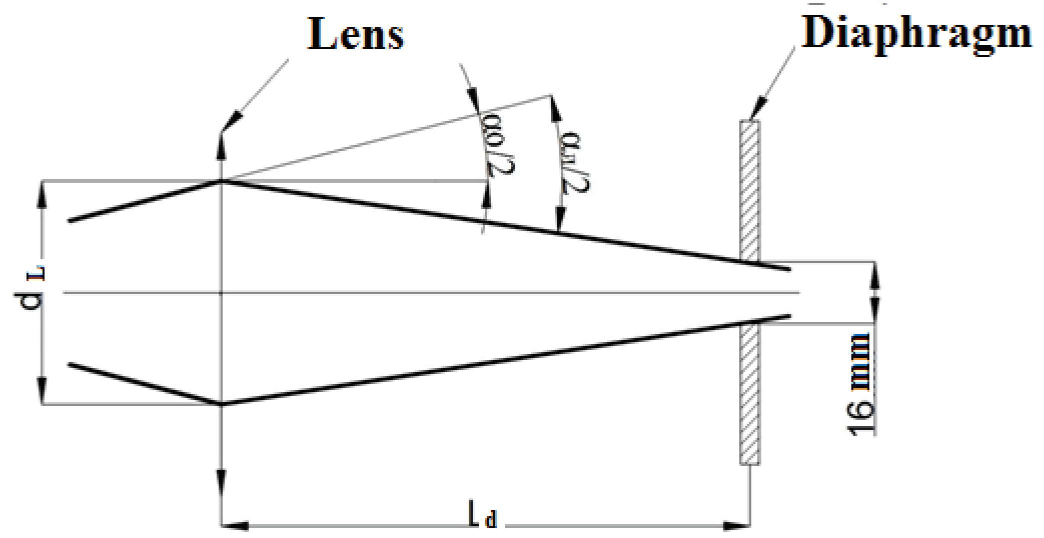


Water cooled diaphragm with 16 mm bore diameter and 120 mm length

Dependence of the beam size in the diaphragm on the focusing lens current at an energy of 1.5 MeV



Determination of the beam parameters in the focal lens.



d_L - is the diameter of the beam in the lens. Д - measuring diaphragm with a hole diameter of 16 mm. $D_{пуч}$ -is the beam diameter in the diaphragm, L_d -is the distance from the lens to the diaphragm, which is 940 mm

$$D_{Beam} = d_L - (\alpha_L - \alpha_0) L_D \quad (1)$$

α_0 -is the angle of divergence or convergence of the beam at the entrance to the lens;

$\alpha_L = d_L / f_L$

Focal length of an electromagnetic lens.

$$f_L = \frac{4(B\rho)^2}{I_L^2 \cdot \int B_{1A}^2 \cdot dl}$$

Bρ - electron momentum at the exit from the accelerating tube G · cm; $I_л$ is the current of the electromagnetic lens A. $\int B_{1A}^2 dl$- integral of the magnetic field strength for an electromagnetic lens.

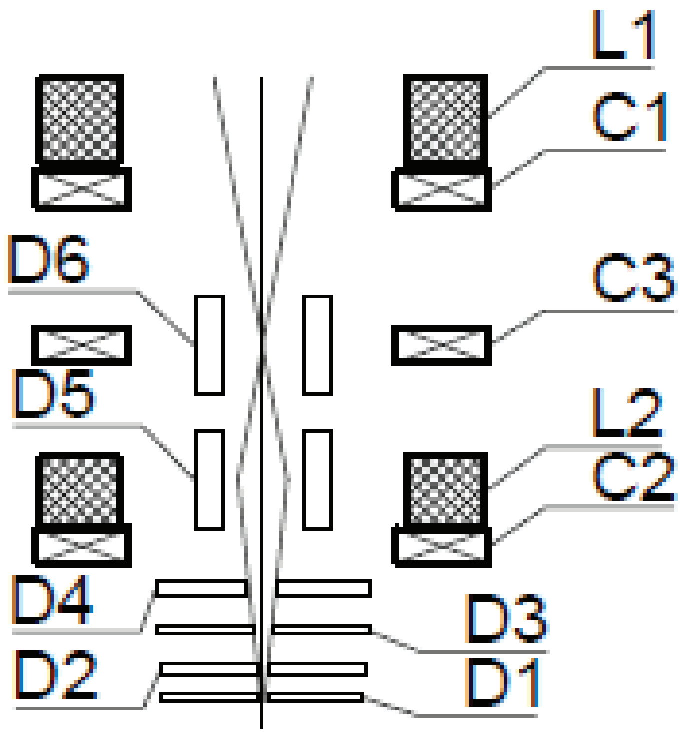
$$D_{beam} = d_L + \alpha_0 L_D - \frac{d_L \cdot L_D \cdot I_L^2 \cdot \int B^2 \cdot dl}{4(B\rho)^2} \quad (2)$$

$$d_L = \frac{\Delta(D_{beam})}{\Delta(I_L^2)} \cdot \frac{4(B\rho)^2}{(\int B^2 \cdot dl) \cdot L_D} \quad (3)$$

$$\alpha_0 = \frac{d_L}{L_D} - \alpha_L = \frac{d_L}{L_D} - \frac{d_L}{f_L} = d_L \cdot \frac{f_L - L_D}{L_D \cdot f_L} \quad (4)$$

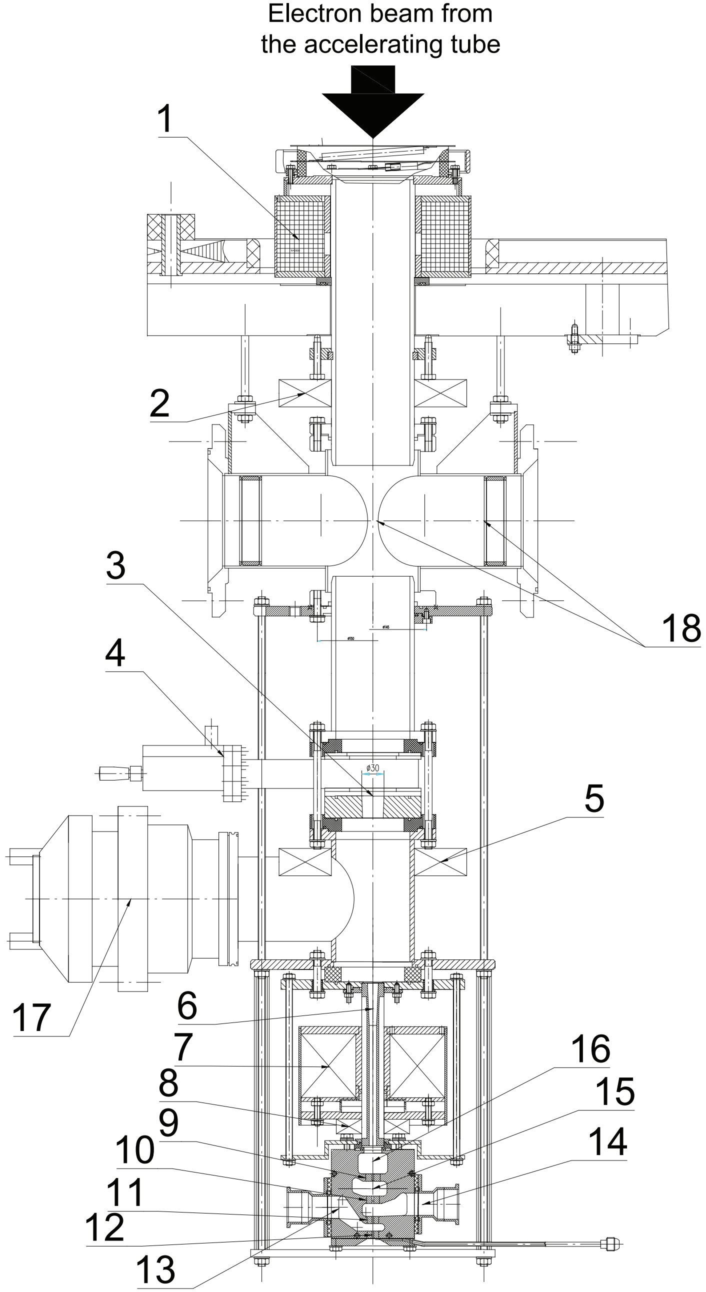
The beam diameter at the exit from the accelerating tube is $d_л$=9-15 mm. The divergence of the beam at the exit from the accelerating tube $\alpha_0 = 7 \cdot 10^{-3}$ rad.

Optical diagram of the extractions device



L1 - focusing lens at the exit from the accelerating tube; L2 - focusing lens, which focuses the electron beam into the diaphragm D1, with a focal length of 180 mm; C1, C2, C3, - correction coils; D1 - diaphragm of the first stage with a hole diameter of 2 mm, D2 - diaphragm of the second stage with a hole diameter of 2,5 mm; D3 - diaphragm of the third stage with a hole diameter of 3,5 mm; D4 - fourth stage diaphragm with a hole diameter of 4 mm; D5 - a diaphragm in the form of a pipe with a hole diameter of 10 mm and a length; D6 - 6th stage diaphragm with a hole diameter of 7mm .

The extraction device of focused electron beam into the atmosphere.



1 - Upper lens L1; 2 - upper correctors C1; 3 - water-cooled diaphragm with a hole diameter of 7mm D6; 4- Gate valve; 5- average correctors C2; 6 - water-cooled diaphragm with a hole diameter of 10mm D5; 7 - Lower lens L2; 8- lower correctors C3; 9- diaphragm with a hole diameter of 4 mm D4; 10- diaphragm with a hole diameter of 3.5 mm D3: 11- diaphragm with a hole diameter of 2.5 mm D2; 12 - diaphragm with a hole 2 mm in diameter; 13 - the first stage of pumping (pump AVZ-90); 14 - the second stage of pumping (pump AVZ-90); 15 - the third stage of pumping(pump RUTS ZJ-150+AVZ-20); 16 - fourth stage (turbomolecular pump NVT-450); 17 - fifth stage (turbomolecular pump NVT-450); 18 - sixth stage (two pumps NMD-0.4).

The extraction device of focused electron beam into the atmosphere

Accelerator parameters: Energy 1.4 MeV, Beam current 50 mA, Beam power 70 kW. The beam diameter at the exit from the extraction device is 2,5 mm.

Thank you for attention