ELECTRON GUN FOR TECHNOLOGICAL LINEAR ACCELERATOR

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The work is purposed to the design of diode electron gun for powerful technologic electron linac and to experimental investigations of the beam parameters at the gun exit. The gun feature is the quick cathode replacement. This is very impotent for operating of the accelerator. The gun optics and beam parameters were calculated using the EGUN code. Beam parameters were investigated as at the special test stand so as a component of the linac injector. The gun produces the beam current of 2 A at the anode voltage 25 kV. Measured beam parameters correspond to calculated results.

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1. INTRODUCTION

In the general case any technological electron accelerator has to comply with following requirements:

- compactness;
- low power consumption;
- operation and service flexibility;
- long-time beam supply.

The last one is defined by a beam source quality.

Modern linear technological electron accelerators, generally, are assembled with one accelerating structure and low-voltage electron source. This comes from one simple reason. Application of low-voltage electron sources permits an accelerator to be more compact and adaptable to technological processes. The linear accelerator facility KUT [1] that is applied for technological purposes represents such class of accelerators. It includes following main subsystems: injector system, disk-loaded accelerating structure, beam scanning and extraction system and feedback systems. The injector system [2] uses a low-voltage diode electron gun. The injector also includes: buncher, accelerating cavity, two axial-symmetric lenses and beam current monitor. It is capable to produce electron beam with energy of 0.5 to 0.6 MeV at the exit.

One of units determining the accelerator long-term operation is an electron gun. An idealized electron gun for a technologic accelerator has to meet high cathode emission capability, low filament power and good accessibility. The present paper is purposed to experimental investigations of a low-voltage electron gun for technological accelerators.

2. ELECTRON GUN DESIGN

Initial parameters used to design the electron gun for the technologic accelerator are defined, in particular, by performances of the injector, which the gun will operate in. In this context the gun was designed to injectors similar to the KUT injector. Taking into account the injector operating experience the gun has to be able to produce a beam pulse current about 2 A at the anode voltage 25 kV. Besides, for optimal beam transit through the focusing and bunching systems of the injector and reducing the space charge force influence on electron bunch shaping it is necessary to provide certain beam performances at the injector input. In particular, beam waist should to be sited a near the injector input and beam size in the waist should be about 7 mm. It is desirable that the particle density should be increased to the beam circumscription.

From the technological point of view the gun should be sufficiently compact and provide a short time for maintenance in the accelerator facility. It is assumed here the cathode replacement. Obviously, some gun details have to correspond to structural details of the injector. Investigations showed that the required beam parameters could be obtained by using the input injector flange as an anode. This materially simplifies the gun design and makes it possible for short-term maintenance.

Gun optic calculations and electron beam simulations were carried out with using the EGUN code [3]. The cathode lifetime depends, in particular, on the cathode load value. Therefore, a flat cathode with 14 mm a diameter was chosen. This gives a rather low value of the cathode load (about 1.5 A/cm^2). Calculations of the focusing electrode geometry were paid great attention because of the specifying beam parameters.

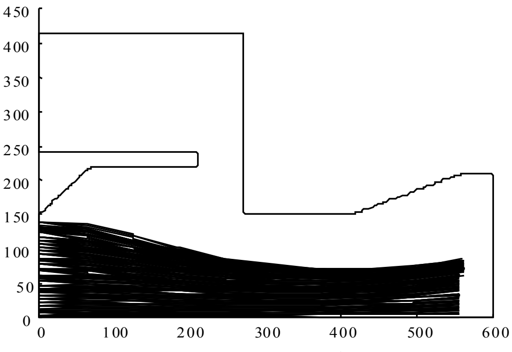

Fig. 1. *EGUN simulation.*

Simulation results showed that the gun could produce electron beam with specified parameters. Beam current density at the gun exit increases with beam radius increasing because of aberration of the gun optic

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system. The calculated normalized beam emittance (4σ) is 31 π mm mrad. Fig. 1 demonstrates the gun electron-optic system geometry and particle traces simulation.

Being based on simulation results the gun assembly was designed. Structurally it represents a high-voltage insulator 3 (see Fig. 2) having flange junction 4 to join with anode 5. Flange junction 1,2 of the cathode-heating unit with the insulator makes it possible for the cathode 6 replacement without focusing electrode displacing. In this procedure the cathode-heating unit design ensures the required cathode position relative to the focusing electrode. Having the supplementary cathode-heating unit the procedure of the cathode replacement can be time minimized up to several minutes. The emitter replacement in the cathode-heating unit can feather be done independently of operating of the accelerator. Such design of the cathode-heating unit makes it possible, if necessary, changing of the gun electron-optic system.

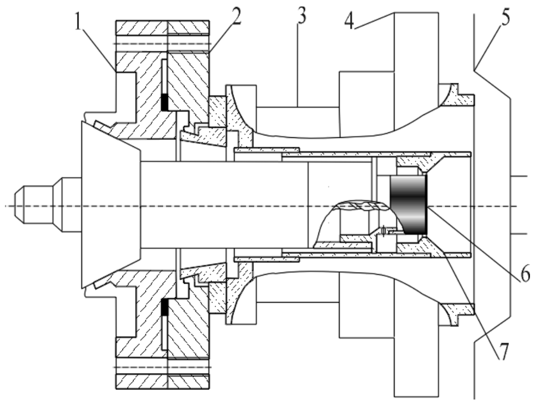

Fig. 2. *Gun Assembly.*

The flat dispenser tungsten emitter with barium-aluminate impregnation and surface cover with the Os-Ir-Al film [4] is used as a cathode. The last one enables to decrease the cathode temperature that increases its lifetime. The feature of such a cathode is the low filament power. The gun design makes it possible using of BaNi cathodes [5], which have more low operating temperature.

3. EXPERIMENTAL LAYOUT

Experimental tests were carried out at the special test setup. The gun was fed from the modulator which was similar to the modulator KUT equipped with. It provides high voltage and filament voltage smooth tuning in limits of 11 – 25 kV and 1.5 – 8 V, respectively. The high voltage pulse duration is adjusted from 1 to 4 μs with the pulse repetition rate from 1 to 300 p.p.s. The modulator has a high-voltage divider and a beam current transformer to control the high-voltage pulse magnitude and cathode current, respectively. The section movable beam monitor was designed for measurements of the transverse beam distribution and the beam emittance. It consists of 32 copper strips having thickness of 0.25 mm. The strips are placed perpendicular to the beam axis and are insulated by mica strips having thickness of 0.25 mm. Thus, the strip arrangement period is up 0.5 mm. For measurements of beam distribution and beam size in different cross sections the monitor movement is provided along the beam axis in wide limits. The monitor position is controlled accurate to 0.1 mm. During tests the signals from monitor were measured with a multichanell data processing system [6]. The section beam monitor is connected with the system via the electronic switchbox. The data processing system has A/D converters with 50 ns time resolution what enables one to indicate pulse signals quite accurate.

Oilless vacuum system enables to keep vacuum at the 10^{-6} torr that is one order less of critical value, which the cathode poisoning can occur.

4. TEST RESULTS

The designed gun was tested in two steps. During the first step there was investigated the operation of the gun electron-optic system, its ability to produce the electron beam with required parameters. The behavior of anode current with anode voltage and the beam spatial distribution were measured at different distances of the monitor from the anode plane. These measurements were carried out in one pulse per second repetition rate mode with the high-voltage pulse duration 4 μs.

Results of the gun current-voltage characteristic measurements confirm the electron emission presence which follows the "3/2" law. This points at the sufficient emission capacity of the cathode. As Fig. 3 indicates this is correct at the maximum monitor position (*l*=99 mm) from the cathode plane. At the minimum monitor position (*l*=17 mm) from the cathode plane some displacement to the linearity is observed. This is explained by distortions of electric field distribution in the gun caused by the beam monitor close position. This hypothesis was confirmed by computer simulation.

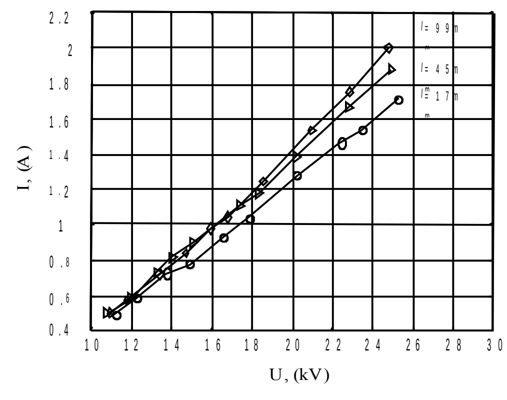

Fig. 3. *Volt-current dependences.*

Fig. 4 indicates integral transverse beam profile measured at the position *l*=17 mm and processed by the data processing system. Such transverse profile features a beam the density of which increases to the circumference. This corresponds to calculated results.

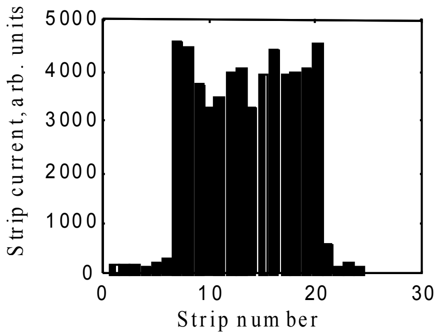

Fig. 4. *Beam profile.*

The possibility to measure the beam profile in three different positions made it possible experimental defining of the emittance. The beam divergence and its emittance measurements showed well computing and experiment coordination. This follows from the beam envelope graph processed in Cartesian coordinates (Fig. 5). Solid line is the envelope calculated from the particle traces simulation. Dash line is the experimental one processed by the data processing system. According to calculated and experimental results the beam crossover position is at 30 cm from the cathode plane.

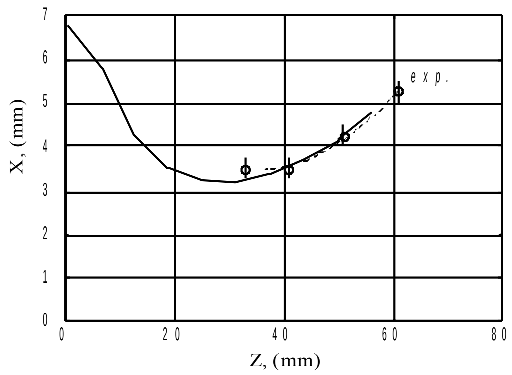

Fig. 5. *Beam envelope.*

The gun as a component of the injector was tested during the second step. The electron beam transit through the injector and the gun working capacity depending on repetition rate was investigated. The injector had following operating mode: anode voltage – 25 kV, pulse current – 2 A, high-voltage pulse duration – 4 μs and repetition frequency up to 300 p.p.s. The volt-ampere characteristics were measured using the passive beam current transformer with the transform coefficient 0.5 A/V. The test results indicates the gun volt-ampere dependence agrees in fact with the line l=99 mm (see Fig. 3). A sensible change in the gun operating was not observed with repetition frequency increasing. The electron beam transit through the injector is 93% and does not change in fact with the repetition frequency increasing. The main experimental parameters of the gun are summarized in Table.

Gun parameters

Parameter	Calc.	Exp.
Anode voltage, kV	25	25
Current, A	1,98	1.7 – 2
Perveance, $A/A^{3/2}\cdot 10^{-6}$	0,51	0,42 – 0,52
Size in crossover, mm	7.1	7.5
ε_n , π·mm mrad	31	30

5. CONCLUSION

Thus, as a result of the research work and experimental tests a new electron gun design for technologic electron accelerators was developed. The electron gun prototype passed tests to satisfaction and can operate in linear electron accelerators applied for technologic purposes.

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