MULTY-BEAM ELECTRON GUN FOR ELIT-3A

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Abstract.

To improve performance reliability of the ELIT-3A installation a new 19-beam electron gun with total diameter of the cathode 46 mm has been developed, constructed, and put into operation. Parameters of the accelerator are:

– current 50 A;
– electron energy 1.65 MeV;
– pulse duration 11 µsec.

During operation the multy-beam gun showed some essential advantages, namely:

– the flow of electrons on electrodes is decreased considerably, that in turn has reduced number of break-downs in accelerating tube by order;
– life-time of the gun is extended minimum 5 times due to lessening of the cathode current density;
– new calculated optics allowed one to reduce the number of focusing magnetic lenses in the tube to single one compared to three required before.

Being in exploitation for more than 5500 hours the gun reveals almost better emission characteristics than at the beginning. In the paper one can find more detailed description of the gun itself as well as results of experiment at ELIT.

INTRODUCTION

The existing in Budker Institute of Nuclear Physics, Novosibirsk, electron accelerator ELIT–3A produces the beam 1.65 MeV of energy, 50 A, and 11 mksec duration for supplying high frequency generator Gyrocon, that feeds high frequency linear accelerator with energy up to 50 MeV.

The high voltage for ELIT–3A accelerator is supplied by Tesla transformer with a couple coefficient 0.6 and a correction of the pulse top by third harmonic. Oscillograms of a current pulse and a voltage one of the accelerator are presented in Figure 1. The lower half-wave is the accelerating voltage.

The accelerating tube made of glass LK-5 rings 30 mm of width and outer diameter 320 mm. It comprises of four identical parts assembling with three permanent magnets between them. The tube accelerating electrodes are produced from stainless steel and are sealed with Indium and rubber by Plexiglas sticks. The fourth electromagnetic lens is situated at the tube exit to match the beam with Gyrocon entrance [1], [2].

To produce an electron beam, a gun with emitter made of LaB₆ 30 mm in diameter, indirect heating and current intercepting control grid was used. The cathode current density was 10-11 A/cm². The life-time of the cathode in the accelerator achieved 1000-1200 hours. But that gun had two main disadvantages:

– electrons reflected of the grid gain great additional angles to beam trajectories and being landed on insulator of the accelerator tube caused breakdowns along the tube regularly; that in turn led to ion bombardment of the cathode and destruction of the latter accordingly;
– the type of used vacuum seal of the gun during operation tended to fatigue of copper, the gasket made of, and came to SF₆ leaking into the tube that poisoned the cathode.

To enhance the situation a new multy-cathode electron gun with thick non-intercepting current control grid on a conflat seal has been constructed. The new gun has the cathode of a bigger diameter, the integral emitting area of 19 myrocathodes comprises 8.2 cm², that is 1.64 times more than 5 cm² of an actually working one of the previous gun. That in turn decreases current density to 6.2 A/cm² and operating temperature of the cathode from 1620ºC to 1580ºC, which reduces evaporation rate 2.6 times. If we take into account that we overheated the previous cathode due to non-perfect vacuum condition, the difference in temperature could reach 100ºC or 9 times for evaporation rate.

![Figure 1: Channel 1: ELIT current. Channel 2: ELIT voltage.](image-url)
SIMULATIONS
Several steps have been performed to compute the ELIT-3A optics by developed in BINP simulating code SAM. Considering our previous reach experience [3] the following gun parameters have been chosen:
- electron current density on the cathode;
- cathode diameter;
- number of microcathodes.
At first, an electrostatic calculation of existing accelerating tube was made to estimate electric field and grid potential. Then, we studied a behavior of an electron beam for single sell at cathode–grid area. And the last step was to compute the beam envelope in the accelerating tube with magnetic lenses starting from the grid surface with initial energy equal to grid voltage and the current value estimated previously. One of the beam envelopes is shown in Figure 2. All of this seemingly laboring procedure, because we had to use 2D program for computing essentially 3D system. Nevertheless, it allowed us:
- to calculate exact electron current from the gun;
- to estimate required magnetic lenses fields;
- to simplify beam transportation system cutting number of magnetic lenses in transportation system from three to one;
- to reduce electron current on the insulator and electrodes of the accelerating tube.

Figure 2: Beam envelope in the accelerating tube.

GUN CONSTRUCTION
The electron gun consists of a cathode, a forming electrode, a heater, and a control grid. All parts are mounted on a flange. The cathode comprises graphite matrix 46 mm in diameter with 114 mm of curvature into which 19 microcathodes are inserted. The parameters of the latter are:
- emitter material $\text{LaB}_6$;
- diameter 7.4 mm;
- microcathode curvature 16 mm.
The cathode heater is bifilar spiral made of tantalum tape 5 mm width, 0.5 mm of thickness, and integral area of 40 cm$^2$. The accuracy all microcathodes are heated with, is better than 20 degree. The heater is mounted on bars passed through thermal shields. There is also tantalum electrode fixed on the cathode surface, which is forming electrode and a heat shield at the same time.
The control grid from molybdenum is 4 mm of thickness and is fixed on focusing electrode sleeve, which is mounted on 3 insulators removed outside of the gun flange. The cathode–grid distance is 10 mm. During operation 19 holes in the grid are accurately aligned with microcathodes. To cut off the current, a voltage of about 500 V is enough. At 28 kV on the grid the electron current is 50 A. The heating power required is 650-680 W. The picture of the new gun, as well as the old one, are shown in Figure 3.

![Figure 3: New assembled multy-beam gun and its cathode unit (front) and old gun with its cathode unit (back).](image)

RESULTS
On 10.05.2004 the multy-beam gun was operating for 5400 hours, from which more than 4400 hours supplying 900 J per pulse. The loss of electrons decreased from 2% to 0.2%. During the first 3000 hours number of brake-downs reduced more than order and comprised one brake-down during 15-20 hours only. Later on these parameters slightly degraded but they still remain better, that those for a previous gun.

REFERENCES