200 KEV PULSE ELECTRON BEAM SOURCE FOR THE VEPP-5 INJECTION COMPLEX

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Abstract

The pulsed electron beam source on voltage 200 kV and current 10 A with half-height pulse duration 3 ns is described. The gun is based on the dispenser cathode with 20 mm diameter. The current control is performed by means of molybdenum grid with the cell size 0.4x0.4 mm and optical transparency of about 0.7. The numerical optimization of cathode-grid unit is carried out. The experimental results obtained are in good agreement with project parameters.

INTRODUCTION

At Budker Institute of Nuclear Physics SB RAS a construction of the VEPP-5 injection complex is continued. Electron bunches for the preinjector are formed by the electron gun operating at the stable mode of 200kV, 2A current amplitude and 50 Hz repetition rate [1]. The oxide cathode-grid unit diameter 12.5 mm (used in GS-34B valve) is used as electrons emitter. This cathode does not provide a required current and also is not durable enough. To provide the complex project parameters an electron gun with parameters listed below was designed.

Electron energy	200 keV
Bunch current amplitude	10 A
Pulse duration	2-3 ns
Pulse repetition rate	50 Hz
Beam emittance less than	0.01 π cm rad
The cathode life-time more than	10^4hours

The results of the cathode-grid unit numerical optimization and the electron-optical channel of the gun calculation are described in the paper. The results of the electron source tests and the plans for the future are also presented.

ELECTRON SOURCE DESIGN

The electron source design is shown in Fig.2. Accelerating tube (12) along with gun control unit (GCU) (13) installed on it, pulse transformer (PT) (3) and modulator parts (IGBT module (1) and primary storage unit (14)) are placed in common SF6 filled tank (2) under pressure 0.17 MPa. In a design like this all modulator pulse elements are shielded by metal tank, therefore, electromagnetic striking is reduced to minimum [2]. The high voltage pulse former is based on the resonant charge of secondary capacitance through the step up pulse transformer and subsequent discharge to the primary storage capacitance back. The pulse former circuit is presented in Fig.2.

An electron-optical system of the gun is described in [3]. The cathode-grid unit with focusing electrode is assembled on the flange as one separate unit (5). To decrease the breakdown influence on the GCU reliability the scheme with "grounded" grid is utilized. A dispenser

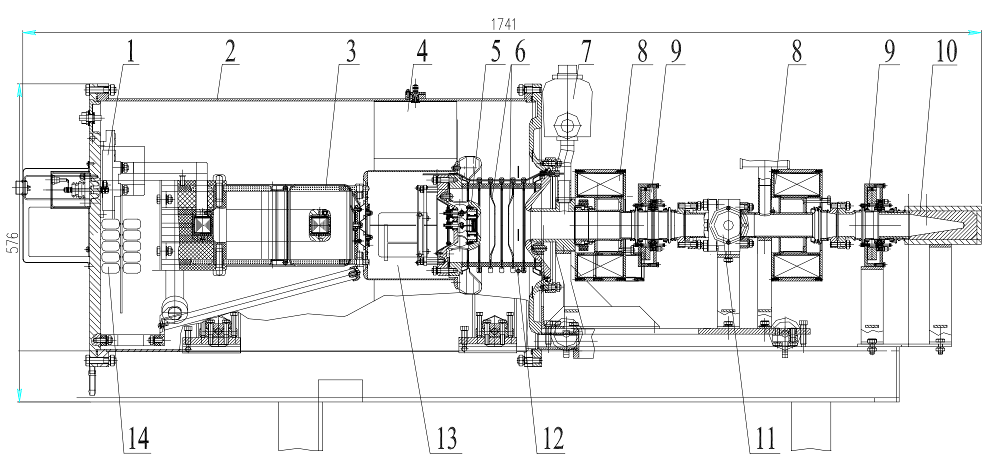

Figure 1: 200 kV gun and pulse modulator design. 1 – IGBT module, 2 – SF6 filled tank, 3 – PT, 4 – capacitive divider, 5 – cathode-grid unit with focusing electrode, 6 – electrodes, 7 – ion pump, 8 – magnetic lenses, 9 – beam current resistive monitors, 10 – collector, 11 – gate, 12 – accelerating tube, 13 – gun control unit, 14 – primary circuit capacitive storage unit.

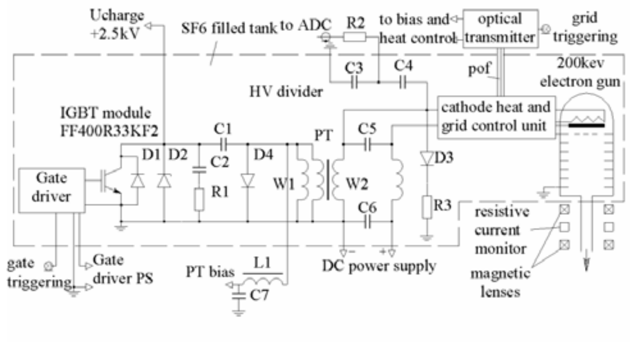

Figure 2: Pulse former circuit.

spherical cathode unit 20mm in diameter produced in “Thorium” is used as an electron emitter. The cathode allows 4–5 disassemblies of the gun and exposure on the air without its emission degradation. The control grid has spherical radius 100 mm, cell size 0.4x0.4 mm, width of crosspieces 0.06 mm and is made of 100mkm molybdenum. The initial distance between grid and cathode is equal to 0.5 mm. However, a cathode-grid gap short-circuit was appeared at the cathode heating and as a result, the gap was increased up to 0.8 mm. The accelerating tube consists of 6 welded alumino-oxide ceramic 22HS rings with outer and inner diameters 150 mm and 135 mm respectively. The accelerating electrodes, which along with the focusing one and anode are forming the electron-optical system (EOS) are fixed into the tube electrode recesses.

The primary storage capacitance is charged from special charging unit which allowed to stabilize output voltage with precision better than ±0.25%. The specially designed compact gun pulser (13 on fig.2) generates voltage pulses for the gun current control. To disable current and regulate extraction voltage the unit forms constant bias voltage on the cathode. The same unit supplies the cathode filament. Pulse former triggering is realized using plastic optic fiber cables. The double secondary winding of the PT is used to supply the GCU.

THE GUN OPTICS OPTIMIZATION

The cathode-grid unit low current emission measurements show that the unit perveance is changed at the heating voltage variation, that is a thermal change of the cathode-grid gap is observed. Fig.3 shows the experimental dependence of the cathode-grid unit perveance on the filament heat power at the “cold” cathode-grid gap 0.8 mm. The effective gap calculated from the law of “3/2th” for the plane diode based on measured perveance values is shown at the same figure. If one suggests the thermal shift of the gap is caused by the grid central part deformation than the minimum distance between the cathode and the grid would be even less. The calculation of the volt-amps diagram of the diode with the spherical cathode (R=100 mm), spherical anode with the variable curvature radius and 0.8 mm gap at the edge gives the values of effective and minimum gaps relating to the perveance and filament power values (fig.3). Thus,

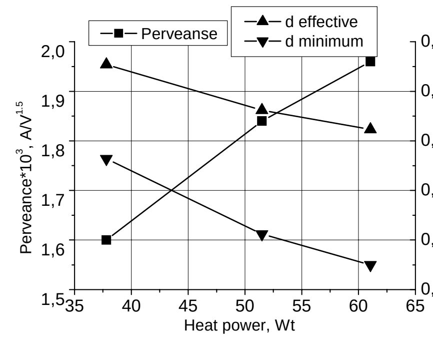

Figure 3: The Perveance and the cathode-grid gap dependence on the filament power at the “cold” gap 0.8 mm.

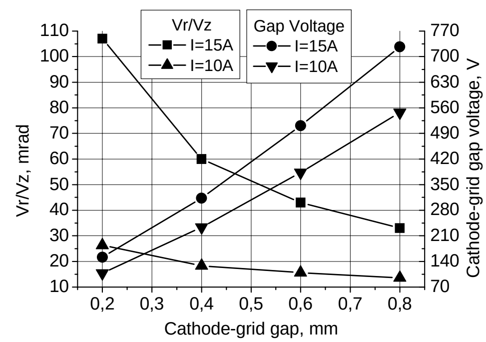

Figure 4: The transversal velocities and the cathode-grid voltage dependence on the gap value.

the thermal deformation of the grid central part could be up to 0.32 mm. It, perhaps, was the cause of the cathode-grid unit short-circuit. Besides, the cathode-grid gap’s nonuniformity leads to the current density nonuniformity from the cathode surface. That could be a cause of the cathode central part early exhausting. The molybdenum grid with shaping of greater radius or plane at all was proposed to apply for excluding above mentioned phenomenon. At the heating such grid would deform in the central part setting approximately an equal gap at the whole cathode surface. Taking into account the temperature shift of the grid central part 0.3 mm, the cathode arch radius R=100 mm and the cathode-grid gap at the edge 0.5 mm the grid spherical radius would be 250 mm.

The operational cathode-grid gap choice is defined mainly by pulse former parameters and the beam emittance requirements. The cathode-grid unit and the gun EOS calculation have been made by UltraSAM computer code[4] in electrostatic approximation. For the calculation of the separate cell of the grid an axisymmetric model of the rectangular cell with equal area was utilized. The full amount of such cells is about 2000. The maximum relative variation of the transverse electron velocity at the grid plane and the accelerating cathode-grid voltage necessary for gaining of the beam current 10 A and 15 A as function of cathode-grid gap are

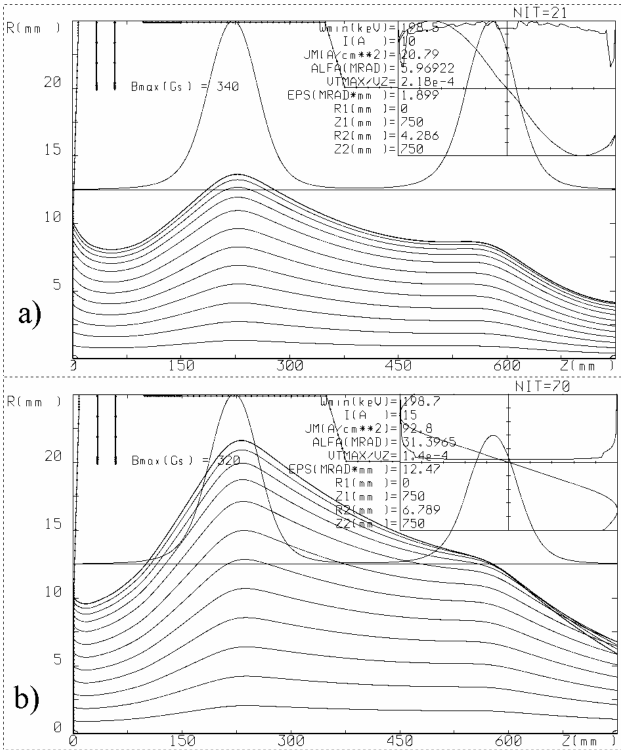

Figure 5: The EOS calculation results for the beam current 10 A (a) and 15 A (b) (the magnetic field distribution along the axis, electron beam trajectories, in the up right corner – the current density distribution and the beam phase-space image after 2nd lense).

presented in fig.4. The dependences show the electron transverse velocities, especially at the gaps <0.4 mm, is essentially increased at the beam current 15 A. For the beam current 10 A the gap choice is mainly defined by the ability of forming the short voltage pulses on the cathode-grid gap.

The gun EOS simulation from the grid surface to the collector was made at the gun current 10 A and 15 A and initial electrons energy 0.3 kV and 0.4 kV respectively (fig.5 a,b). It is obvious the beam emittance at the gun output is less than required value. Taking into account electrons initial velocities concerned with electrons thermal motion, the cathode surface roughness and the grid influence emittance is increased up to 4 mm mrad at the beam current 10 A and up to 15 mm mrad at the current 15 A.

A substantial parameter affecting on the quality of beam bunching is the beam pulse duration. This value must not exceed a half of operational wave length of subharmonic buncher, that is, the pulse duration measured at the bottom should be less than 2.8 ns. Therefore, for delta-shaped pulse rise and fall times should be less than 1.4 ns. The load impedance: cathode-grid leads capacitance and inductance and its resistance influences on the forming such short pulse. The cathode-grid unit capacitance and inductance measured values are the following L=20 nH, C=20 pF (the capacitance is weakly depends on the cathode-grid gap). Thus, the time constant of this circuit is $\tau_1 = \pi\sqrt{LC} \approx 2$ ns. Besides, the rate of rise of the cathode-grid voltage is restricted by the $L - R_{load}$ circuit with the time constant $\tau_2 = 3L/R_{load}$. At the load resistance less than 30 Ohm this time constant become more than 2 ns that is it appreciably affects on pulse forming. Thus to generate the control pulse of required duration (~2.8 ns) it is necessary to form shorter pulse (<2 ns) with the amplitude greater than required. Taking into account aforesaid and ability of generating of nanosecond pulses with amplitude up to 1 kV the cathode-grid gap was chosen 0.5 mm.

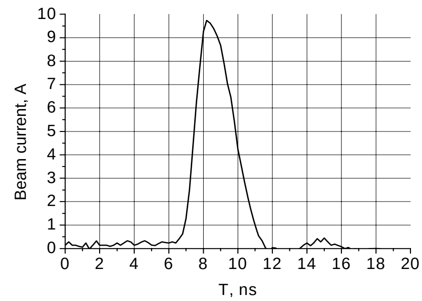

Figure 6: The shape of current pulse at the 1st current monitor.

CONCLUSIONS

By the present day the current pulse of amplitude 9.7 A and duration 2.4 ns (halfheight) and ~4.5 ns (measured at the bottom) at the electrons energy 190 kV has been obtained at the gun with the cathode-grid gap 0.8 mm (in “cold” condition. It is proposed to rebuild the control pulse former for decreasing the duration down to required value and to change the cathode-grid unit to the similar but with the plane grid and with the gap 0.5 m.

REFFERENCES

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