High perveance electron gun for the electron cooling system

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Abstract

The cooling time in the electron cooling system is inversely proportional to the beam current. To obtain high current of the electron beam the control electrode of the gun is provided with a positive potential and an electrostatic trap for secondary electrons appears inside the electron gun. This leads to a decrease in the gun perveance. To avoid this problem, the adiabatic high perveance electron gun with the clearing control electrode is designed in JINR (J. Bosser, Y. Korotaev, I. Meshkov, E. Syresin et al., Nucl. Instr. and Meth. A 391 (1996) 103. Yu. Korotaev, I. Meshkov, A. Sidorin, A. Smirnov, E. Syresin, The generation of electron beams with perveance of \(3 \times 10^3 \mu A/V^{1/2}\), Proceedings of SCHEF'99). The clearing control electrode has a transverse electric field, which clears secondary electrons. Computer simulations of the potential map were made with RELAX3D computer code (C.J. Kost, F.W. Jones, RELAX3D User's Guide and References Manual). © 2000 Elsevier Science B.V. All rights reserved.

1. The scheme of the electron gun

The generation of intensive electron beams with low temperature of particles is a well-known problem in the electron cooling method. Presently a large number of electron cooling systems are equipped with electron gun with an adiabatic optics [1–6]. The electron gun has a flat cathode, Pierce electrode, control electrode and anode (Fig. 1). Due to the action of the control electrode this gun helps to change the beam current without changing the electron energy.

When the gun operates in a regime of high perveance, the control electrode has positive potential versus the ground. It initiates the storage of secondary electrons, generated in collisions of primary beam electrons with residual gas atoms. This process leads to limitation of the beam current generated by the gun.

2. Pulsed clearing of secondary electrons

To avoid this effect, a pulse generator (the so-called “blower”) is used. The “blower” brings periodically the control electrode potential to the ground, which opens the electron trap and cleans the space inside the control electrode. The peculiarity of the “blower” pulses is its unsymmetrical form.

The energy of the secondary electrons, accelerated onto the front slope of the pulse is described by the formula

\[ E_t \propto \frac{U_{se}}{t_1} t_{osc}, \]
where \( U_{ce} \) is the voltage on the control electrode, \( t_1 \) the duration of the front slope of pulse, and \( t_{osc} \) the time of the electrons oscillations in positive potential region. The energy that the electrons loses on the back slope of the pulse is

\[
E_b \propto \frac{U_{ce}}{t_2} t_{osc} \frac{t_2}{t_{||}},
\]

where \( t_2 \) is the duration of the back slope of pulse, \( t_{||} \) the travel time of the secondary electrons between the gun and collector. If \( E_t > E_b = t_1 < t_{||} \), then the secondary electrons leave the gun.

3. The results of the experiments

The experiments on the Test Bench have shown that the gun perveance does not depend on the control electrode potential when it is negative. For the positive control electrode potential the “blower” pulse repetition frequency depends on residual gas pressure and has to be high enough to provide the designed value of the gun perveance (Fig. 2)

\[
T_{\text{blower}}(s) = \frac{1}{[10^9 P(\text{Torr})], \, 8 \times 10^{-9} < P < 5 \times 10^{-6} \, \text{Torr}}
\]

In the LEAR experiments the boundary value of the gun perveance had the same dependence on the positive potential of the control electrode when the gun perveance was reduced (Fig. 3).

The problems of using the “blower” are the reduction of the gun perveance and its pulse mode of operation.

4. The electron gun with clearing control electrode

To resolve the problem of gun perveance reduction the electron gun with a clearing control electrode was proposed [7]. The design of new gun is very similar to “Parkhomchuk trap” used for neutralisation of electron beam space charge [8,9]. The clearing control electrode consists of two plates.
Each plate has its own potential. The difference of potentials produces a transverse electric field. Secondary electrons drift in the crossed electric and magnetic fields to the high-resistance glass, which was placed between plates (Fig. 4).

The potential map for the electron gun with clearing control electrode was calculated with RELAX3D computer code. The potential map in vertical plane of the gun and potential map of the cross-section near the region of the clearing electrode are presented (Figs. 5 and 6). The calculations of the dynamics of the beam are in progress now.

The first experiments with a prototype of the gun showed that using the clearing control electrode helps to avoid the problem of the gun perveance reduction. The gun perveance is not varied with positive potential of grid anode (Fig. 7). In these experiments one plate of the clearing control electrode had ground potential. The beam perveance

![Fig. 4. The scheme of electron gun with clearing control electrode.](image)

![Fig. 5. The potential map for the gun with clearing control electrode (R-S plate).](image)
achieved a value $P_{\text{beam}} = 6.5 \mu\text{A}/V^{3/2}$ at electron energy 2.5 keV and beam current 830 mA.

The new electron gun with clearing control electrode is under construction in JINR and the first experiments with it are scheduled.

5. Conclusions

The electron gun with clearing control electrode gives some advantages for electron cooling systems: clearing of the secondary electron inside the gun helps to avoid the gun perveance reduction problem.

Acknowledgements

This work was supported by the Russian Foundation for Basic Research (Grant 99-02-17716) and INTAS (Grant 96-0966).

References


