THE ELECTRON GUN WITH VARIABLE BEAM PROFILE FOR OPTIMIZATION OF ELECTRON COOLING

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Abstract

Considerable losses of ions appear during an electron cooling of intensive ion beams. These are recombination losses and the losses arisen due to the instability development of the cooled beam. To avoid these effects the usage of hollow electron beams was proposed. The electron beam density in central part can be decreased at many times without reduction of the cooling rate of the whole ion beam. So the recombination losses in the core of the stored ion beam can be reduced and the intensive ion beam interacts with low intensive electron beam that can decrease undesirable coherent oscillations. The electron gun with variable beam profile was designed for CSR cooler (IMP, China). Variation of the sign of the control electrode potential permits to change the beam profile from disk to ring in the cross-section. The gun parameters were calculated using UltraSAM code. The results of microperveance and electron beam profile measurements are presented. Thin tungsten wire was used for the electron beam profile measurements. The results are in good agreement with the calculations.

1 INTRODUCTION

An electron cooling is used for an improvement of the ion beam parameters in storage rings [1,2]. The method is based on the usage of a cold electron beam moving together with an ion beam with the velocity equal to the velocity of ions on the common with the ion beam direct part of orbit. Collisions of ions with electrons lead to losses of the chaotic movement energy of ions.

At cooling of intensive ion beams it was found out that there is strong recombination of cooled to the low temperature ions with an electron beam. This recombination leads to the considerable losses of the stored beam. Moreover, exceeding cooling causes the development of the transversal instability, that also leads to the beam losses. One of the most probable causes of the development of this instability is the space charge fluctuation.

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To avoid these effects the usage of hollow electron beams for cooling was proposed in [2,3]. The electron beam density decrease in central part, where cooled ions accumulate (see Fig. 1, [3]), leads to considerable decrease in recombination losses with keeping the cooling rate of the whole ion beam (because cooling rate drops rapidly with the decrease of the oscillation amplitude). The electron gun with a control electrode was designed to produce hollow electron beams. By varying the potential of this electrode it is possible to obtain on the gun output the beam with parabolic, flat or hollow profile.

2 THE ELECTRON GUN

The electron gun under consideration is shown on Fig. 2. By digits on the figure are marked: 1 – cathode, 2 – forming electrode, 3 – control electrode, 4 – anode. The gun is immersed into the longitudinal magnetic field of 700-1000 Gs. Convex oxide cathode Ø29 mm is used. The control electrode is situated near the cathode edge, so its potential strictly influences on the emission from this area. The potential of the forming electrode is equal to the cathode potential; the purpose of this electrode is to dump exceeding emission from the cathode edge.

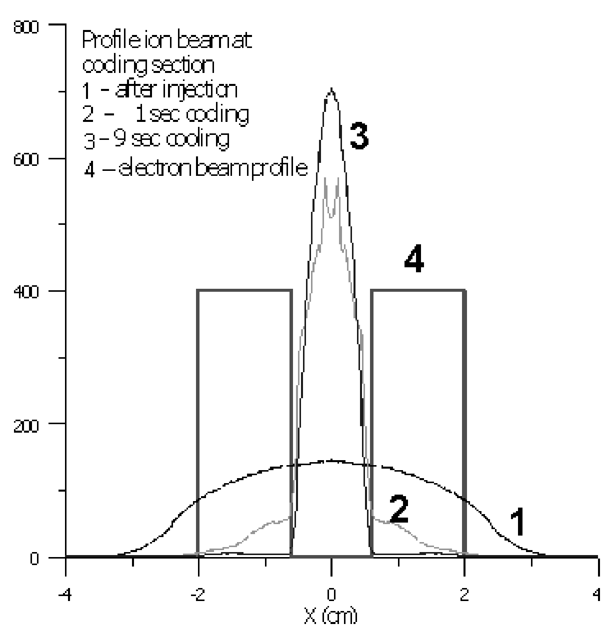

Figure 1: The behaviour of the ion beam profile in cooling section with hollow electron beam.

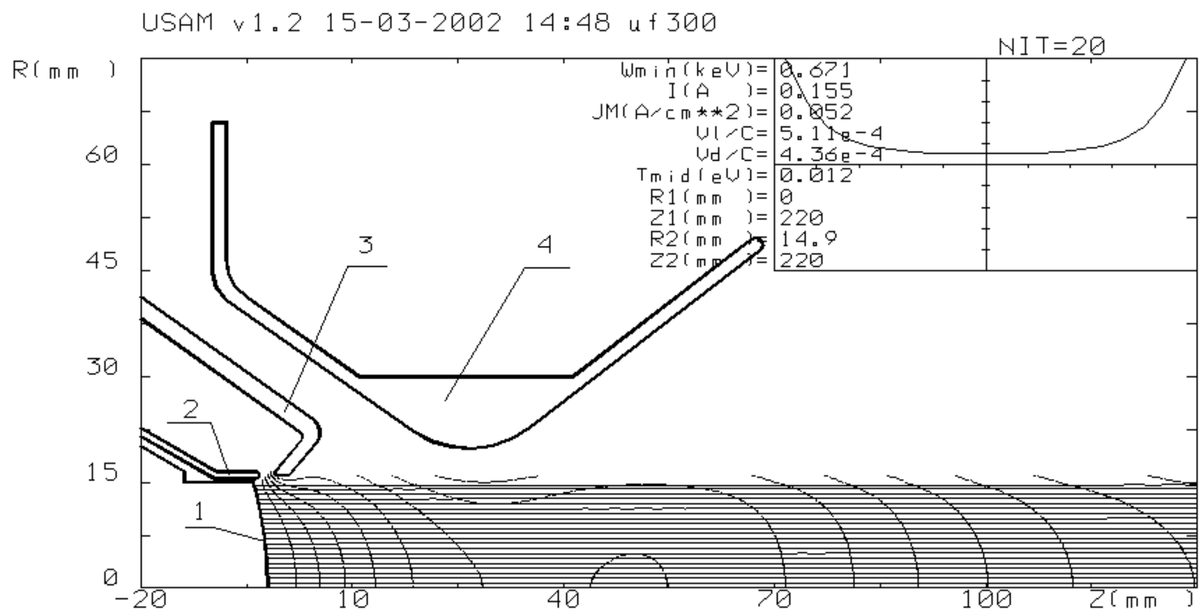

Figure 2: Geometry of electron gun with variable beam profile: 1 – cathode, 2 – forming electrode, 3 – control electrode, 4 – anode; equipotentials, trajectories and beam profile on the gun output.

3 THE MEASUREMENT OF VOLTAMPER CHARACTERISTIC OF THE GUN

The measured and calculated by UltraSAM code [4] perveance of the electron gun versus the control electrode potential is shown on Fig. 3. The control electrode potential is normalised to the anode potential. The gun output current is increased with rise of the control potential till $U_{control}/U_{anode} \approx 0.7$. The formation of a virtual cathode takes place in this point. The control electrode potential causes so much current that it cannot pass over the anode due to the sagging of potential and part of it reflects back (see Fig. 4). After that the gun output current remains constant regardless of the further growth of the control electrode potential, the position of the virtual cathode is only moving.

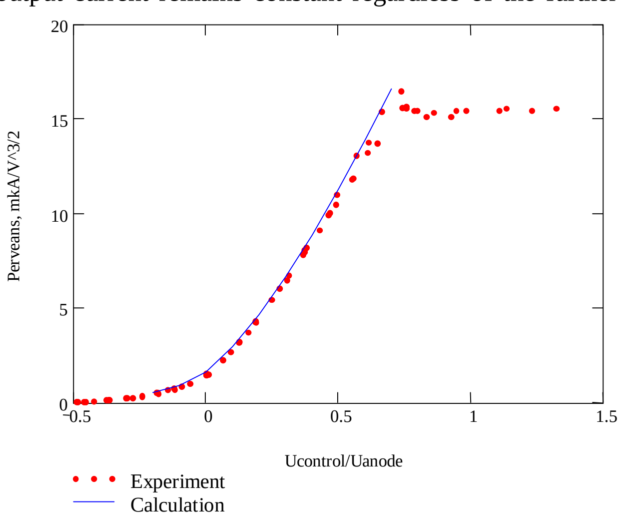

Figure 3: The perveance of the electron gun as the function of the control electrode potential normalised to the anode potential.

4 MEASUREMENTS OF ELECTRON BEAM PROFILE

The thin tungsten wire Ø20 µm is used for electron beam profile measurements. The deposited current was measured during the movement of the wire in transverse to the beam direction. The beam profiles were restored using these data. The measured and calculated by UltraSAM code profiles corresponded to different values of the control electrode potential are shown on Fig. 5.

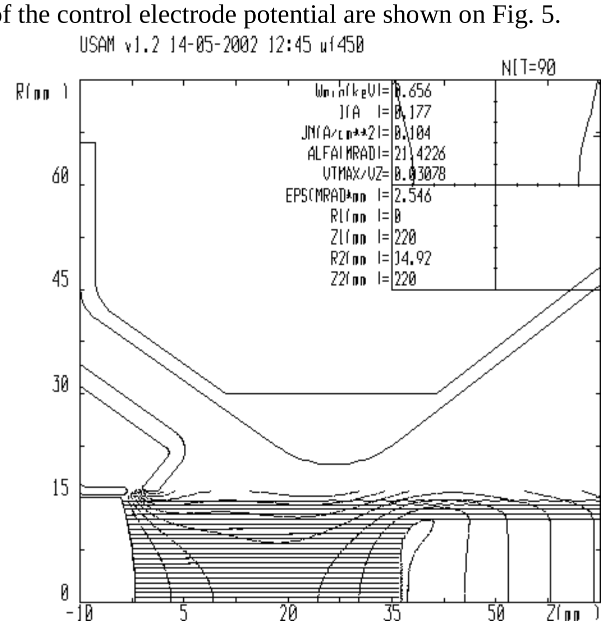

Figure 4: Equipotentials, trajectories and beam profile on the gun output in the presence of virtual cathode.

The current density distribution in the beam has also been found by registration of the light radiation, which appears when the beam heats the wire. The calibration of the signal to the heating power value was done by the heating of the wire by direct current. To find the current density distribution the wire was moving in transverse to the beam direction. The electron beam profiles at different potentials of control electrode obtained using this method are shown on Fig. 6. On the figure one can see how the beam profile transforms from parabolic to flat, than to hollow.

5 CONCLUSION

The testing of electron gun with variable beam profile shows the good agreement of calculated and measured characteristics. Such electron gun will be used in the electron cooling installation CSR (IMR, China) and will reduce the losses in stored ion beam by control of its sizes and density.

6 REFERENCES

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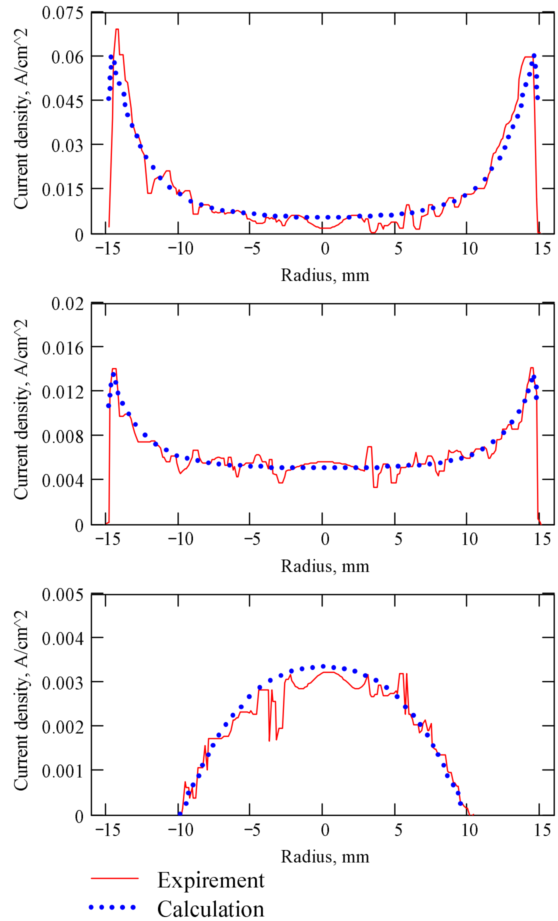

Figure 5: Calculated and measured beam profiles at control electrode potential Uc = +300V, +100V, -100V and anode potential Ua=500V.

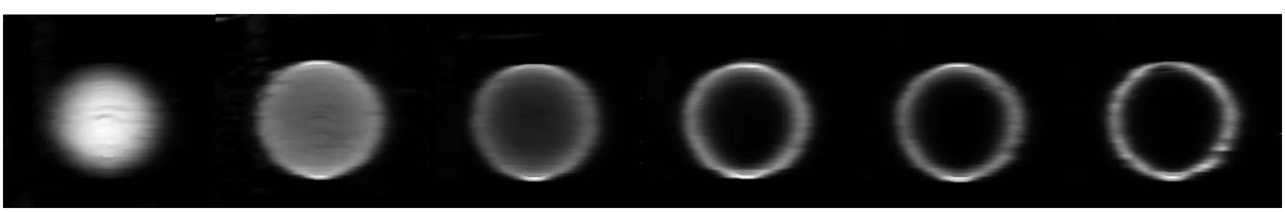

Figure 6: Electron beam profiles at control electrode potential Uc = 0V, +100V, +200V, +350V, +400V, +600V and anode potential Ua=500V.