CONTROLLING THE BEAM OF THE MAGNETRON GUN WITH A SECONDARY-EMISSION CATHODE BY MEANS OF A MAGNETIC FIELD OF THE SOLENOID AND PERMANENT RING-SHAPED MAGNETS

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Abstract

The report is concerned with the possibility of monitoring the parameters of the beam in the magnetron gun with a secondary-emission cathode by using magnetic fields of permanent ring-shaped magnets. The measured magnetic-field distributions of permanent magnets are presented. Consideration has been given to the possibility of controlling the beam current and size on the Faraday cup. The experimental results are reported.

INTRODUCTION

During the recent years the investigations on the electron beam production and application were carried using magnetron guns with a secondary-emission cathodes [1-2]. The operating principle of these guns is based on the back bombardment of a cathode with primary electrons, the secondary electron accumulation in the crossed electric and magnetic fields, the electron cloud formation near the cathode and the electron beam forming at the gun exit. Distribution of electric and magnetic fields determines the electron cloud density and size that is related with electron trajectories in the anode-cathode gap. It is suggested in [3] to change the magnetic field distribution in order to create near the cathode, along its full axis, a magnetic trap were the electron accumulation will takes place for the beam current be increased. The proposed magnetic trap should have a little length to decrease the magnetic field distortion and to improve the beam transport. On the other hand, the change in the magnetic field distribution leads also to the change in the transverse sizes of an annular beam, as well as, to the current redistribution in the anode-cathode gap. In the paper the authors consider a possibility of controlling the beam parameters (beam current and its transverse sizes) and beam production conditions in the magnetron gun with a secondary-emission cathode using the magnetic fields of a solenoid and permanent ring-shaped magnets.

EXPERIMENTAL DEVICE

The experimental device (fig.1) comprises the following main units: feeding high-voltage pulse generator 1; electron gun with a secondary-emission cathode C and anode A in the crossed fields, placed in vacuum chamber 3; solenoid 4 which creates a longitudinal magnetic field; target assembly with a Faraday cup (FC); computer-aided measuring system 6 for measuring the beam parameters; synchronizer 7.

The voltage pulse of generate has a special shape, i.e. the voltage surge with an amplitude to 190 kV (surge decrease duration is □0.8 □s) for electron cloud formation, the flat-top pulse amplitude is up to 150 kV, pulse duration is ~15 □s and the pulse repetition rate is 2 Hz.

The electron beam is produced in the magnetron gun having the following parameters: cathode diameter of 40 mm, internal diameter of 78 mm, cathode length of 85 mm, anode length of 140 mm, cathode material is copper, anode material is stainless steel. The magnetron gun is placed in the vacuum volume 3 (pressure of □10-6 Torr).

The magnetic field for electron beam production and transport is created by solenoid 4. The amplitude and the longitudinal distribution of the magnetic field can be changed by varying the current value in the solenoid sections.

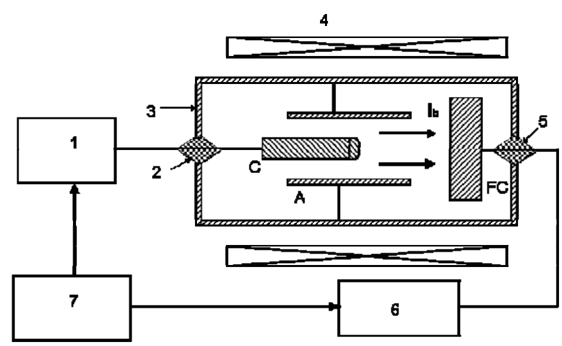

Figure 1: Schematic view of the accelerator.

1 – pulse generator, 2, 5 – insulator, 3 - vacuum chamber, 4 - solenoid, 6 – computer-aided measuring system, 7 – synchronizer, C – cathode, A – anode, FC – Faraday cup..

The measurement results on the parameters of pulse voltage, beam current at the Faraday cylinder and their stability were processed by means of the computer-aided measuring system 6. The measurement error is 1…2%.

EXPERIMENTAL RESULTS AND DISCUSSION

The paper presents the measurement results on the distribution of magnetic fields created by a solenoid and permanent magnets, as well as, the results on the control of the beam current and its sizes.

The magnetic field was measured and the ratio of currents in the solenoid coils was calculated in order to create a magnetic trap near the cathode surface. An inhomogeneous magnetic field along the magnetron gun was created by means of two different current ratios in the solenoid coils (Fig.2). The region of the inhomogeneous magnetic field extends almost for 10 cm from the beginning of the cathode entry into the anode, the field decrease takes place at a distance of ~ 2-3 cm from the cathode end. The axial magnetic field distortion (dip) is ~4…5% and the magnetic field is smoothly decreasing and increasing.

The investigations on the electron beam formation in the magnetron gun with a secondary-emission cathode were carried out using the magnetic field distribution obtained. The experiments were made using the magnetron gun (aluminium cathode diameter of 78 mm, anode diameter of 78 mm) with distribution of a distorted magnetic field (amplitude of ~ 940 Oe, field dip of ~ 50 Oe) (Fig.1, curve 1) at a cathode voltage of ~ 32 kV. They have shown that the magnetron gun forms an electron beam with a current of ~33 A and an anode current at a level of ~0.08 A …0.1 A.

Under the same experimental conditions, in the case of a magnetic field without a dip, being weakly increasing on the cathode and decreasing in the channel of beam transport to the Faraday cup, at a cathode voltage of ~33 kV, the magnetron gun forms an electron beam with a current of ~24A, and an anode current at a level of ~0.15A. At a cathode voltage of ~36 kV the current onto the Faraday cup were ~38A and ~30A, respectively.

The above-given results show that the use of an inhomogeneous magnetic field, on the most part of the magnetron gun length, permitted to increase the electron beam output current by ~25%. However, the beam transport in the first case was going in the homogeneous field, and in the second case it was in the decreasing field, that can effect on the output parameters of the electron beam. Nevertheless, the beam current has been slightly changed, probably, on account of the fact that the magnetic trap has a significant length and is not situated in the optimum cathode region.

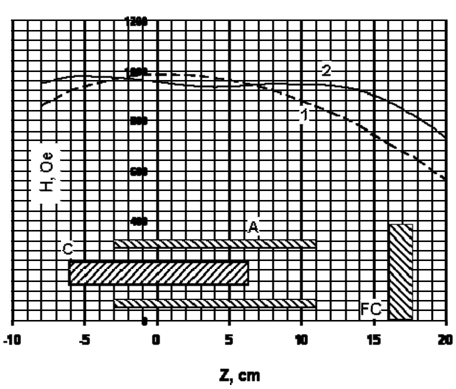

Figure 2: Distribution of magnetic fields and arrangement of the gun components. 1- magnetic field distribution for the common case of beam production. 2- magnetic field distribution in the case of magnetic field formation and beam production.

The measurements of electron beam sizes on the aluminium target situated in the Faraday cup region were carried out.

In Fig.3 represented are distributions of longitudinal and transversal magnetic fields along the system axis for two cases of the beam transport. In the first case (curve 1) the magnetic field longitudinal component decreases in the direction to the Faraday cup. In the second case (curves 2) the magnetic field longitudinal component smoothly increases in the direction to the Faraday cap.

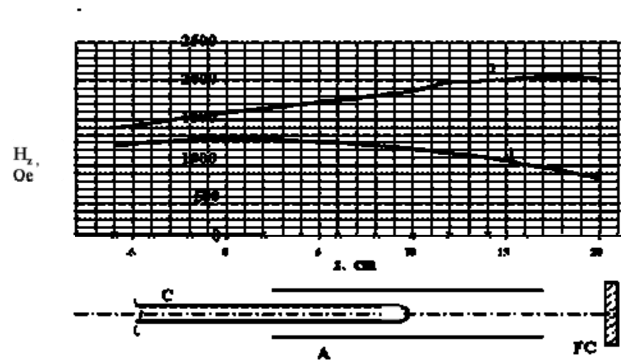

Figure 3: Distribution of the magnetic field longitudinal component Hz and arrangement of the gun components along the system axis z. C – cathode, A – magnetron gun anode, FC – Faraday cup.

At a cathode voltage of 50 kV and with the decreasing magnetic field the magnetron gun forms an electron beam having the current of 50 A and the outer diameter of 55 m and the wall thickness of ~3mm. In the case of magnetic field increase the beam current was decreasing down to ~25A, and the outer diameter was decreasing down to 38 mm with a wall thickness less than 2mm.

The beam prints for these two cases obtained on the one and the same target are shown in Fig.4.

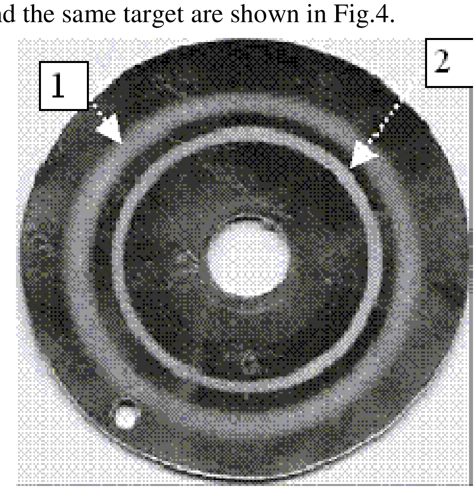

Figure 4: Beam prints.

It is seen from the figure that the electron beam thickness for two magnetic field distributions has different values that is important for irradiation of different targets.

To create the magnetic trap of a little length it is intended to use the magnetic fields of permanent ring-shaped NeFeB magnets placed into the secondary-emission cathode. The transverse and longitudinal components of the magnetic field were measured on the outer side (by the radius) of the ring having the sizes: outer diameter of 31 mm, internal diameter of 19 mm and the thickness of 3 mm. Measurements were performed at a distance of 4 mm, 6 mm and 8mm from the external radial ring surface. The obtained distributions of the longitudinal and radial components in the axial direction are represented in Fig.5 and 6. It is seen that the extension of magnetic field being changing, and, consequently, the magnetic trap length, is ~1 cm. The width of the zone of magnetic field decrease and increase is ~ 10…15 by the level of 0.5.

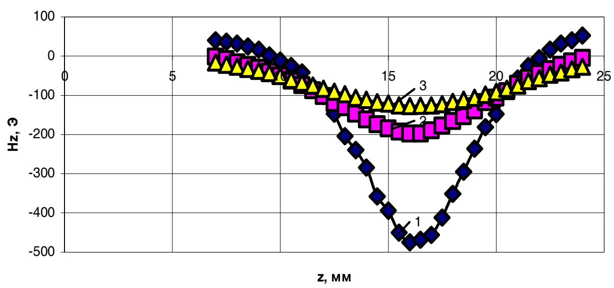

Figure 5: Hz versus z and Δr. 1 – Δr =4 mm; 2 – Δr =6 mm; 3 – Δr =8 mm.

The results show that the field amplitude is changing nonlinearly with the change of the distance from the outer ring surface, for example, at a distance of 4 mm the field is ~500 Oe, and at a distance of 8 mm it is ~ 160 Oe.

It should be noted that the local magnetic field decrease can be located not in the cathode middle but at its end, where the beam is accelerated and extracted from the anode. Then the thickness of the electron layer and, hence, of the electron beam may be increased, that is sometimes necessary during irradiation of different targets.

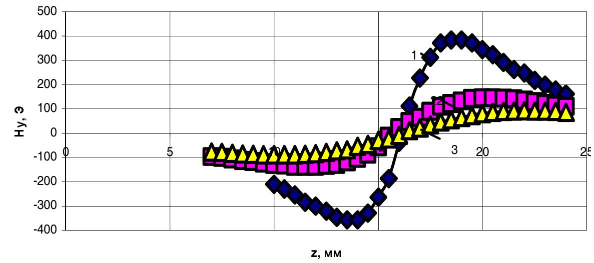

Figure 6: Hr versus z and Δr. 1 – Δr =4 mm; 2 – Δr =6 mm; 3 – Δr =8 mm.

The works were carried out to develop a magnetron gun with a magnetic trap using the ring-shaped magnet. The estimates show that when the trap with a magnetic field dip of ~10% and a magnetic field producing the electron bream of ~1500…1600 Oe is used, one should use a cathode of ~40…45 mm in diameter at a voltage of ~100…130 kV, the anode diameter of ~ 80 mm.

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