MODES OF ELECTRON BEAM GENERATION IN A MAGNETRON DIODE WITH A SECONDARY-EMISSION CATHODE

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Abstract

Modes of electron beam generation and parameters were investigated using a magnetron injection gun with a secondary-emission cathode depending on the magnetic field value and distribution. The experiments demonstrated that in such a source one can perform the modes of generation with an axial current, axial and anode currents, and only anode current. For the first time it has been shown that the electron current direction in the magnetron gun can be varied from axial to radial one.

INTRODUCTION

In the present work the investigation on the influence of the magnetic field amplitude and distribution on the modes of electron flux generation and direction in the magnetron gun has been carried out.

EXPERIMENTAL SETUP AND RESEARCH METHODS

Experiments to investigate the beam parameters were performed at the setup schematically shown in Fig.1.

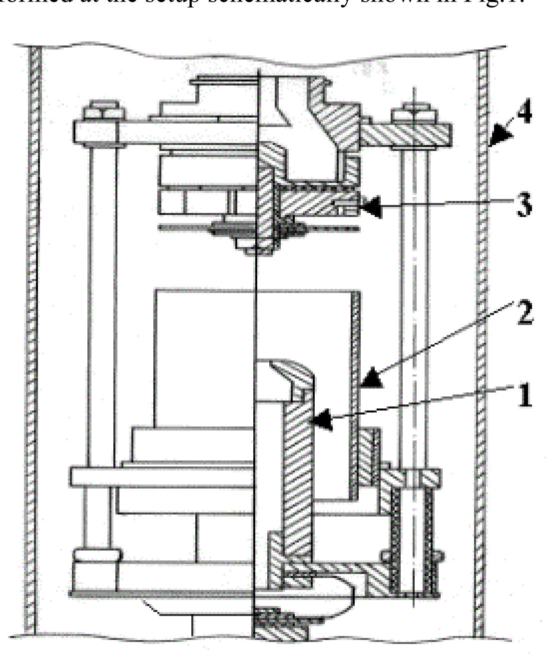

Figure 1: Schematic of the experimental setup. 1 - cathode,2 - anode, 3 - Faraday cup, 4 - vacuum chamber.

A specially shaped voltage pulse with a peak at the top from a pulse modulator [1] was applied to the gun cathode, its anode was connected to the ground via a resistor R3. The overshoot amplitude is adjusted within 60 ... 100 kV, the amplitude of the flat part of the pulse was 20... 55 kV, the overshoot falloff duration was ~ 0.3 μs, the pulse duration at half-height was ~ 8μs, the pulse repetition rate ranged from 10 to 20 Hz (curve 2 in Fig.2).

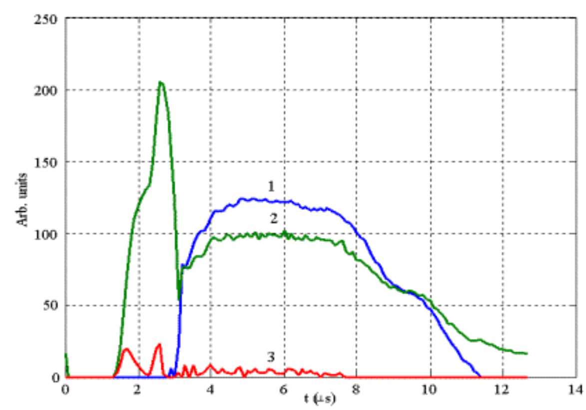

Figure 2: Pulses of voltage (2), beam current (1) and anode current (3), Along the vertical: 1 - 0.4 A/div,2 - 0.5 kV/div, 3 - 0.04 A/div.

The studies were made on the magnetron gun of a coaxial construction which had a cathode, 40 mm in diameter and 70 mm in length; an anode, 70 mm in internal diameter and 140 mm in length; cathode material was copper, anode material was steel. The magnetron gun was placed in the vacuum chamber, where a vacuum of ~ 10^{-6} Torr was maintained. The magnetic field for beam generation and transport was created by the solenoid (consisting of 4 sections with which the magnetic field could be adjusted by varying the current value in the sections of the solenoid). The solenoid was energized by the constant-current source.

The studies of beam parameters were performed by means of a 8-channel sectionalized Faraday cup and a computer-assisted measuring system [2]. The pulses from each of Faraday cup sections come to the matched attenuator unit, which allows to match the signal amplitudes for a further convesion and processing in the ADC and PC. The pulsed signals are registered in steps of 50 ns or 100 ns simultaneously in 12 channels in the digital form. The system provides processing of 32 pulses following one after the other. The measurement error is within 1 to 2 %. Measurements were taken of the beam current from each of 8 segments of the Faraday cup, of the cathode voltage and the anode current. These parameters were measured at the given temporal points and were averaged over 16 pulses following one after the other. Then the computer processing of results was

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performed and we have calculated: the total beam current, the coefficients of maximum deviation of current/voltage pulse heights from the average value. the coefficient of the azimuthal beam homogeneity, the distribution of a full charge of beams from the Faraday cups, the relative distribution of beam currents during the pulse.

The transverse beam dimensions were measured by obtaining prints on the aluminium target, the prints being made separately for each mode of beam generation (cathode voltage and magnetic field of a given value were maintained in every series of measurements).

EXPERIMENTAL RESULTS AND DISCUSSION

The experiments have shown that the electron beam direction in the gun can be varied (along the gun axis or perpendicular to it - on the radius), by adjusting the amplitude and distribution of the longitudinal magnetic field. In this case, several modes of electron beam generation are realized: open (when practically all the electron current is going along the gun axis to the Fraday cup), closed (when the electron current is going perpedicularly to the gun axis - on the radius to the anode) and intermediate.

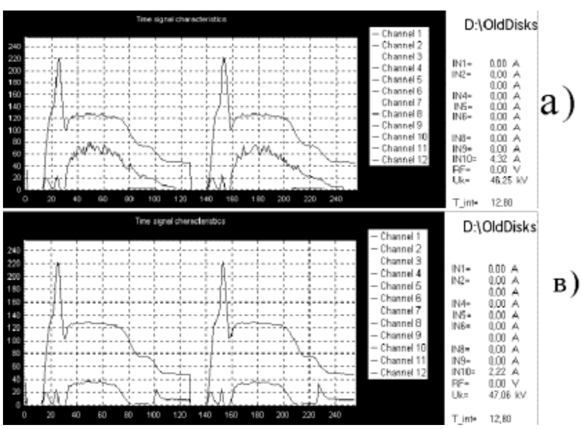

Figure 3: Oscillograms for the closed mode of magnetron gun operation. a) in the rising magnetic field; b) in the falling magnetic field.

In the open regime at a cathode magnetic field strength of ~1300 Oe, cathode voltage of 50 kV, the Faraday cup beam current equals to 50 A, the anode current is ≤ 1% of the beam current (curve 2 in Fig.2). In the case of the magnetic

field increase in the cathode region up to 1800 Oe, the anode current was decreasing down to the value of an order of several milliamperes that is due to the enhancement of the electron flux magnetic isolation.

In the course of experiments the existence of the closed mode of magnetron gun operation (magnetron mode) has been found. In this case the electron current was going to the anode, the secondary-emission multiplication of electron being retained (see Fig.3). This mode was attained by reducing the magnetic field H in the cathode region down to the Hell field value of 1.1 ... 1.2 order $(H_H=6.72U^{1/2}[r_a)1 - r_c^2/r_a^2)]^{-1}$, where **U** is the cathode voltage **V**, $\mathbf{r_c}$ and $\mathbf{r_a}$ (cm) are the cathode and anode radii, respectively. At a voltage of 45 kV the Hell field is ~600 Oe).

The closed mode of magnetron gun operation is realized with two magnetic field distributions - rising and fallling. In the rising magnetic field, at a cathode voltage of ~ 45 kV and a cathode magnetic field of ~850 Oe, the current to the anode is ~10A, and the current to the Faraday cup is ~1A.

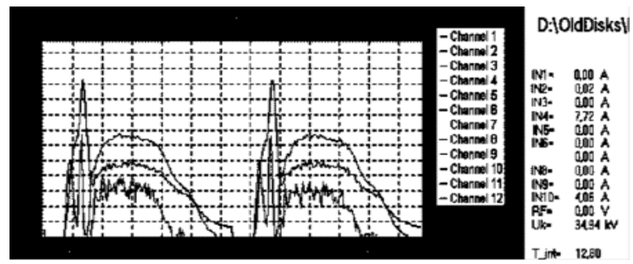

Figure 4: Oscillograms for the borderland mode of magnetron gun operation

In the falling field from the cathode to the Faraday cup decreasing down to ~450 Oe, at a cathode voltage of `700 Oe, the current to the anode is ~5 A, and the current to the Faraday cup is practically absent. The oscillograms for these cases are presented in Fig.4. In the intermediate mode (when the current goes to the Faraday cup and to the anode too) with a cathode magnetic field strength of ~750 Oe and at the Faraday cup of ~1200 Oe, the direct beam current was ~5 A, and the anode current was ~7 A.

The beam current and the anode current could be adjusted by varying the magnetic field distribution along the axis of the gun.

CONCLUSIONS

Investigations on the electron beam generation were carried out in the magnetron gun with the secondary-emission cathode. At a different magnetic field distribution in the gun, the open and closed modes of electron beam generation were obtained experimentally, and the beam parameters in these modes were investigated.

REFERENCES

[1]. Dovbnya A.N., Reshetnyak N.G., Romas’ko V.P. et al. “Pulse Modulators for Feeding Powerful Microwave Devices Based on Magnetron Guns with Secondary-Emission Cathodes” PAC2001, Chicago, June 2001, p.3759.

[2]. Ayzatsky N.I., Boriskin V.N., Dovbnya N.A. et al. “Investigation on the parameters of electron beams in multicathode secondary-emission source” RUPAC2002, Obninsk, Russia, October 2002, p.91.