The Advanced Designs of Magnetrons with Improvement Output Characteristics

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Abstract: *This paper presents the experimental and theoretical investigations of the two constructions of the magnetrons: the low-voltage X and Ku ranges magnetrons with two RF outputs of energy and the cold secondary emission cathode magnetron with ancillary side cold cathode. It is shown that the electronic frequency tuning in the magnetrons with two RF output can be obtained in the range more than 200 MHz. The electronic control of the frequency tuning from pulse to pulse is performed by the microwave switch on basis the p-i-n diodes. By using the computer modeling, the features of secondary emission multiplication mechanism of the electron beam at the front and droop of anode voltage pulses are shown. The prospects for developing such magnetrons and expansion of areas of their application are discussed.*

Keywords: magnetron; cold cathode; field emission; secondary electron emission; RF output; magnetron gun; frequency tuning; frequency control

Introduction

The recent investigations denote the growing interest concerning to the magnetron generators. These researches are performed for improving their spectral characteristics and developing the novel modes of work including the quick frequency tuning (adjustment of frequency) and the frequency synchronization as well as increasing the life time of the magnetron due to the use of the cold metal cathodes.
This paper presents the results of theoretical and experimental researches of the magnetrons which allow to realize the electronic frequency tuning mode and implement a stable launching of the magnetron with the cold cathodes.

The Two RF Output Magnetron

For the implementation of frequency tuning from pulse to pulse there was used the device on basis of the magnetron with two RF outputs of energy [1]. The functional diagram of this device is shown in Fig. 1.
In order to realize the pulsed operation of the magnetron was used modulator. His operation is synchronized with the source of control pulses which controls by the microwave switch.
Fig. 2 shows the experimental V-I characteristic, tuning frequency curves and changing the output power of the magnetron with two RF outputs in the range of tuning frequencies.

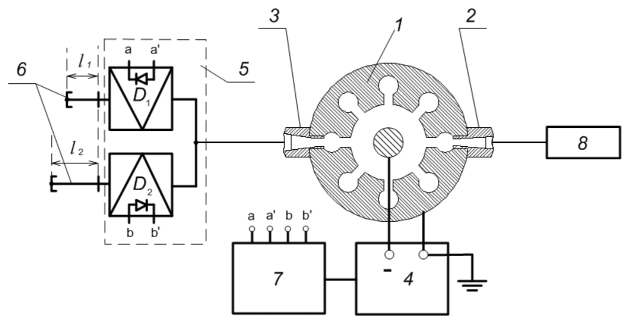
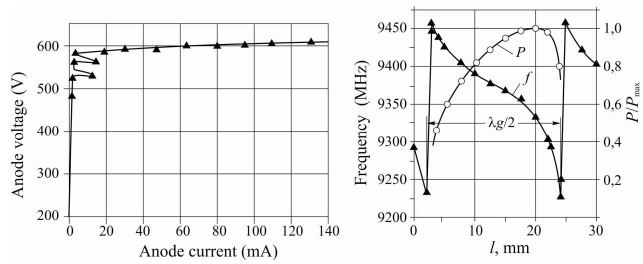


Figure 1. Functional diagram of the device for frequency tuning from pulse to pulse on basis of the magnetron with two RF outputs of energy: 1 – magnetron with two RF outputs; 2 – active RF output; 3 – reactive RF output; 4 – pulsed power supply (modulator); 5 - diode switch of RF signal; 6 - shorted waveguide segments of various lengths l_1 and l_2; 7 – source of synchronized pulses controlling by the diodes D1 and D2; 8 – matched load



(a) (b)

Figure 2. Experimental V-I characteristic, the curve of frequency tuning and changing the output power level in the magnetron with two RF outputs

For operating the magnetron in the pulsed mode is selected the operating point on the V-I characteristic which is corresponded to 600 V and 0.065 A. The pulse width of the anode voltage is 16 ms and filling factor ~ 40. The difference in frequency between the signals is more 90 MHz. The control pulse width which need for operating the microwave switch is equal of 600 microseconds.
The possible application of the magnetron with two RF outputs can be realized in the lighting system on basis of the electrodeless sulfur lamp with microwave pumping (see Fig. 3) [2]. In this case an application of the second RF output allows adjustment of the tuning frequency up to 3%.

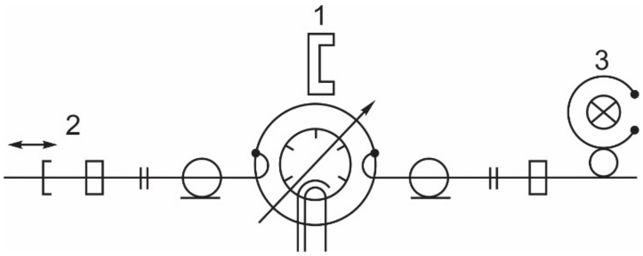


Figure 3. Diagram of the lighting system includes the magnetron (1) with two RF outputs, one of which is connected with the waveguide short (2) and the second – the resonator (3) in which is placed the bulb lamp.

The Magnetron with Cold Start

The functional diagram of the cold secondary emission magnetron using cold start is presented in Fig. 4. As shown in Fig. 4, the magnetron using a cold start consists of the magnetron gun containing the ancillary side cold cathode and the resonant anode block with the internal cold metal secondary-emission cathode. For an excitation of the magnetron it is necessary to form the initial tubular electron beam using the ancillary side cold cathode.

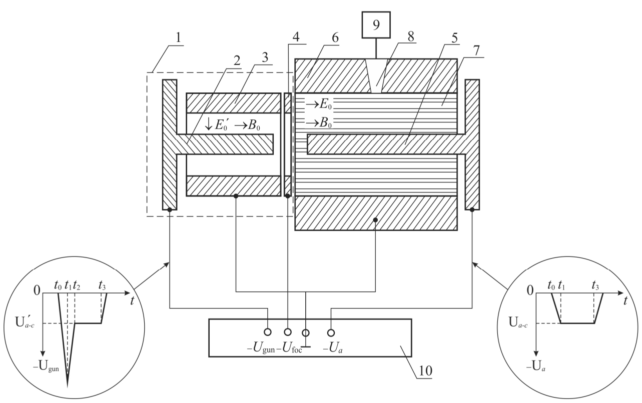
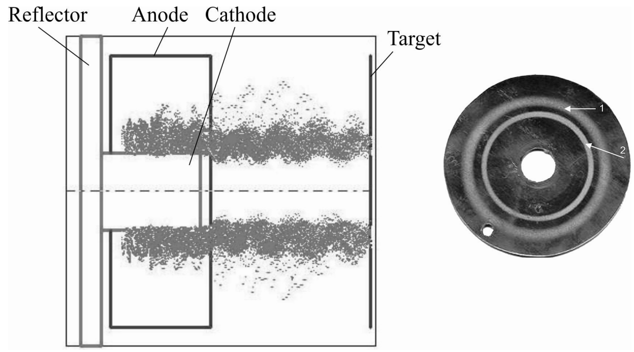


Figure 4. Functional diagram of the cold secondary emission cathode magnetron with ancillary side cold cathode: 1 – magnetron gun; 2 – ancillary side cold cathode; 3 – smooth anode; 4 – second anode; 5 – cold secondary emission cathode; 6 – anode resonant structure; 7 – resonators; 8 – RF output; 9 – matched load; 10 – power supply

The functional diagram includes a power supply (modulator) which forms a periodic sequence of high-voltage pulses. The oscillograms of high-voltage pulses are shown in Fig. 4. As is seen, a distinctive feature of the high-voltage pulse fed to the magnetron gun cathode is availability of voltage falling portion on its front (a portion having negative slope).

Figs. 5 and 6 show results of the computer modeling and the experimental data concerning the formation of the tubular electron beam by the magnetron gun.

For creating a mathematical model of the magnetron gun we used the 3-D quasi-static approximation. The computer modeling of secondary-emission multiplication process is carried out by FDTD method with application of the PIC Method. The geometry of the magnetron gun is in Table 1. As a result, there was developed the code that is called 3D-BMS [3].



(a) (b)

Figure 5. The steady-state tubular electron beam (a) and the electron beam imprints on the Al target (b) (in the space between anodes in Fig. 4) obtained for cases of decreasing (1) and increasing (2) magnetic field

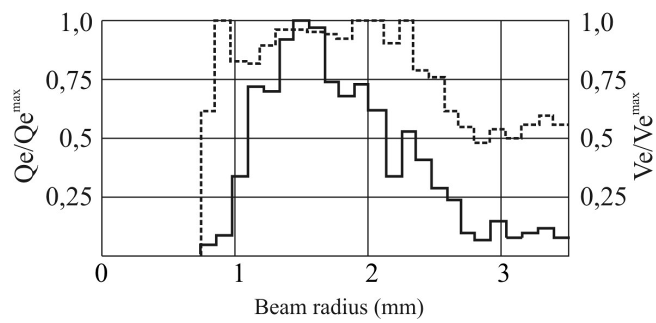


Figure 6. Radial distributions of averaged space charge values (solid curve) and axial component of particle velocity (dotted curve) in the target plane

Table 1. Parameters of the magnetron gun

Cathode radius (mm)	Anode radius (mm)	Cathode length (mm)	Anode length (mm)	Distance cathode - second anode (mm)
1,0	3.5	5.0	9.2	4.6

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