ABSTRACTS

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# COMPUTER MODELLING OF THE ELECTRON-WAVE INTERACTION IN COMBINED MAGNETRON

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*Abstract* — The classical magnetron generators are the most-used among the crossed-field tubes [1]. Having high efficiency, low operating voltages as well as low weight, volume and cost the magnetrons are competitive tubes in the aggregate of the given parameters. Upgrading of requirements to the output parameters of the classical magnetrons as well as complication of their operating modes allowed the researchers to design new types of the magnetrons: coaxial and inverted coaxial magnetrons [2]. These tubes have a different constructional features, but the similar mechanism of an electron-wave interaction. The base of the such mechanism is the interaction a re-entrant electronic beam with electromagnetic field of the resonant delay line (traditional classical crossed-field systems). On the other hand there are the electron- wave systems in which have place the interaction of the two re-entrant electronic beams with electromagnetic field of a resonant delay line (non-traditional systems) [3,4]. Among the tubes of this type are the combined magnetron [5].

In this paper the theoretical and experimental investigation results of the physical processes in the combined magnetron are discussed.

The interaction space of the combined magnetron is shown in Fig. 1. The combined magnetron consist of internal and external cathodes between which there is a resonant delay line (Fig. 1, b). As result we have two-stage generator in which the first stage (internal interaction space) is the classical magnetron and the second stage (external interaction space) is the inverted magnetron. The experimental results investigation of a magnetic field distribution and of a resonant delay line are presented in Fig. 2 and 3. Fig. 2 shows the variation of magnetic field in the different points along axial direction of the magnetron. It is to be noted that in the combined magnetron there was used the samarium-cobalt magnets and poles of the usual type from the classical magnetron.

In order to define of the delay ratio of the electromagnetic wave in the interaction space we used the results of the experimental measures of the phase-shift diagram of the resonant delay line (Fig. 3). The operating point corresponds the case when $\varphi = \pi$ ($\pi$-mode).

The computer modelling of interaction between electronic beams and electromagnetic field is carried out by particle-in-cell (PIC)-method [6]. The electron-wave interaction processes are considered in three-dimensional, quasi-

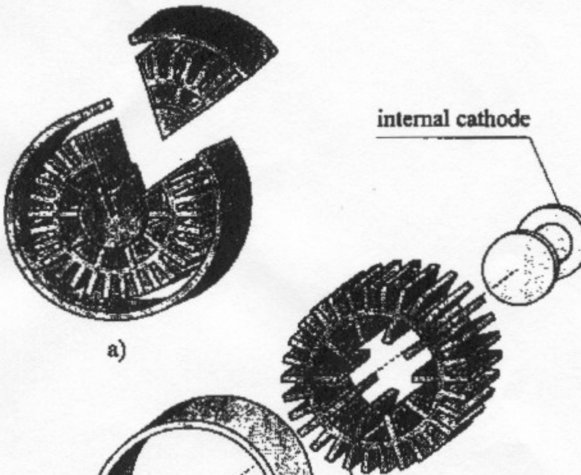


Fig. 1 General view of non-traditional magnetron (a), components his design (b)

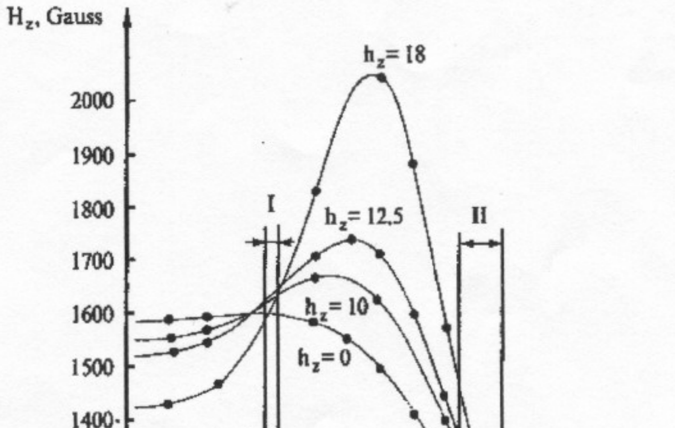


Fig. 1 Distribution of a magnetic field

*periodic, non-relativistic and single-mode (π-mode) approximations.* The mathematical model of the combined magnetron can be presented as self-consistent set of equations including the motion equations (for the electronic beams in the internal and external interaction spaces), excitation equations (for an electromagnetic field) and Poisson's equation (for analysis of

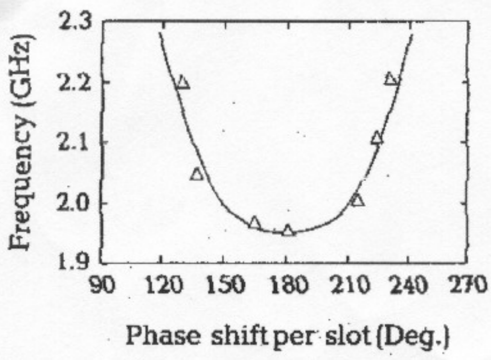


Fig. 3 Dispersion diagram associated with the fundamental pass band

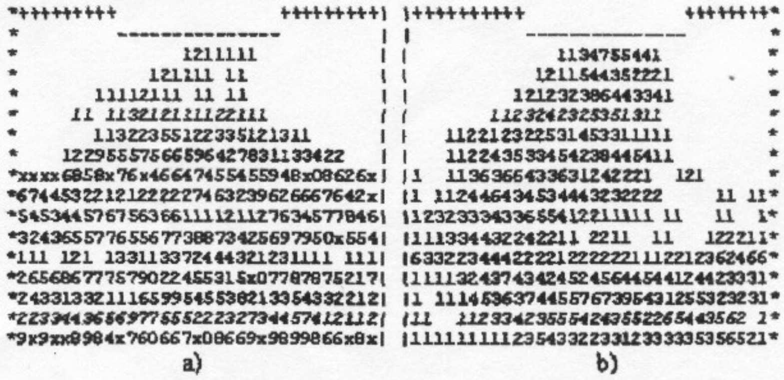


Fig. 4 Space-charge distributions in the one-wavelength cell for external (a) and internal (b) interaction spaces of the combined magnetron

a space charge). Was developed up a program on base of these equations, which is called CICM_3D. The code is realized in algorithmical language Fortran-90 and is adapted for OS Windows 98 and NT.

*Figs. 4 - 6 shows the results of computer modelling. Fig. 4 shows comparison of space-charge distributions in the* one-wavelength cell for external (a) and internal (b) interaction spaces of the combined magnetron. These distributions corresponds the high-voltage part of V-I characteristic.

Figs. 5 and 6 show energy *(a) and angular (b) distributions of* the primary electrons bombarding of the internal and external cathodes, respectively. The anode voltages correspond to the low-voltage (1 - $U_a$ = *10.5 kV*) and high-voltage (2 - $U_a$ = *11.1 kV*) parts of V-I *characteristic. For comparison the* variation of the secondary emission ratio σ versus energy of the primary particles is shown in Fig. 6. The internal and external cathodes impact angles by the back-bombarding electrons is determined as $\alpha_c = arctg\ (v_\varphi / v_r)$, where $v_{\varphi, r}$ are the φ and r - components of electrons *velocity.*

The result of the computer *modelling of the energy* characteristics (output power) showed that the inserting of the external interaction space of the combined magnetron allows *additionally increasing the output* power of the tube by the factor 4.7.

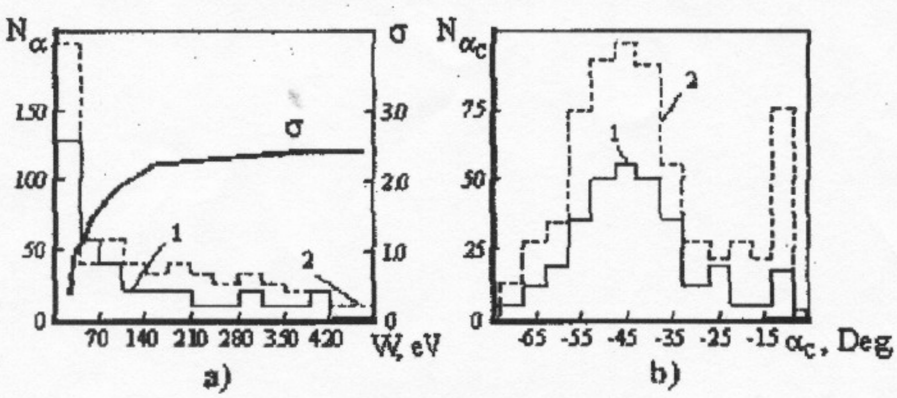


Fig. 5 Energy (a) and angular (b) distributions of the primary electrons in the internal interaction space

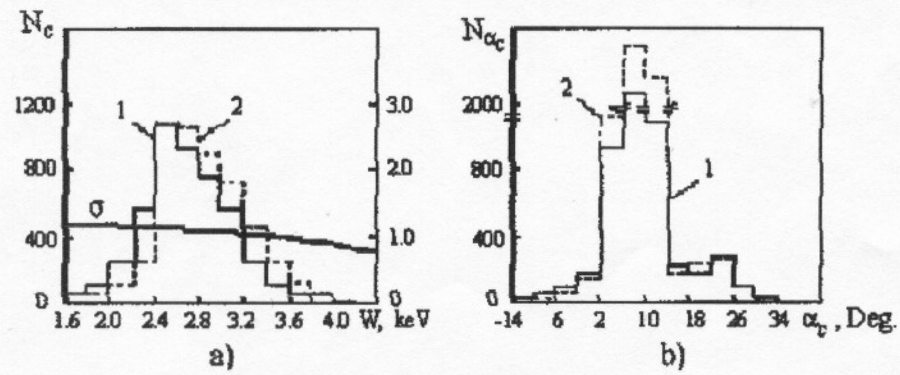


*Fig. 6 Energy (a) and angular (b) distributions of the primary electrons in the external interaction space*

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