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Cavity Resonator With Electrostatic Focusing

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In this article we consider the possibility of using a single lens to modulate the speed of the electron beam. It is shown that the use of a single lens as a modulator in speed does not affect the value of the coefficient of interaction with the electron flux field lens.

Keywords: Modulation, lens, electron beam.

The beams of electrons and ions are among the most common objects in science and technology. Thir application is extremely wide and diverse, and covers such important areas of modern science and technology as a mass - spectrometry, electron microscopy, microwave - technology, plasma physics, solid state physics, chemistry, medicine, and others[1-5]. Therefore, the problem of formation of corpuscular streams, management, their transportation (focus) using stationary electromagnetic fields are among the most fundamental and urgent problems of physical electronics. Under the transport of charged particles in static electron-optical systems of such particles is understood the focus when the form of the particle beam over time remains unchanged. The dynamic mass spectrometers and instruments for the study of fast processes transportation means “delivery” unsteady flow of ions (electrons) with minimal loss from the ion source to the collector. In devices such as ultra-high frequency klystron this means focusing phase (phase stability) electrons[6-8].

Explore Importance of the Problem

Design and creation of a variety of physical devices in the action based on the principle of focusing beams of charged particles are closely related to the elaboration of theoretical methods for studying the dynamics of charged particles in electromagnetic fields. In connection with the qualitative changes of modern electron-optical problems, the classical methods of theoretical research largely lost their community. These changes are due to the fact that, firstly, in recent years more and more attention is paid to studies using charged particle beams of fast processes, the speed of which is comparable with the transit time of particles in the system[9-11]. This information about the object is obtained using essentially unsteady flow of charged particles, which requires taking into account their time of flight. Secondly, there is a growing role of electronic mirrors, lenses cathode used in the static electron-optical of the system, electron-optical theory which can not rely on classical paraxial approximation, which is the basis of the known theoretical methods. Third, the more urgent

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becomes the problem of application of electron-optical elements in the dynamic electron-optical systems to improve their analytical performance.

In microwave electronics for calculating and creating powerful amplifiers and oscillators pay great attention to the formation of powerful electronic stream of various configurations and transportation over long distances. Theory of the formation of electron beams of high intensity subject of a number of theoretical studies. There are ways of transporting electron fluxes in the klystron microwave tubes with a mechanism of interaction between the input and output resonators by various static electric and magnetic fields [14-16, 20]. The need for these fields is caused by the influence of the space charge and Coulomb repulsion forces of the space charge on the electron trajectories. As a rule, the focusing action of electric and magnetic fields are carried out in a drift space of microwave devices.

Method (Calculation part)

In this article we consider the possibility of using a single lens to modulate the speed of the electron beam. Consider a three-electrode single lens with a long focal length, where in the electrodes are composed of three coaxial flat diaphragms arranged at an equal distance s from each other, parallel to each other (Drawing 1).

The axial distribution of the electrostatic potential can be represented as [18].

$$\Phi(z) = \Phi_0\left(1 - \frac{\chi^2}{1+\left(\frac{z-s}{d}\right)^2}\right) \quad ...(1)$$

The origin is compatible with the plane of the middle electrode, and the axis is the axis of symmetry of the system. Assume that a single lens end electrodes supplied with alternating voltage frequency, amplitude

$$U = U_m \sin\omega t \quad ...(2)$$

It is denoted by the moment of passing through the center of some electronic medium electrode lens. Then, neglecting the small change in velocity of the electron inside the lens, you can write:

...(3)

The total kinetic energy of the electron, the logged-in lens with an initial velocity

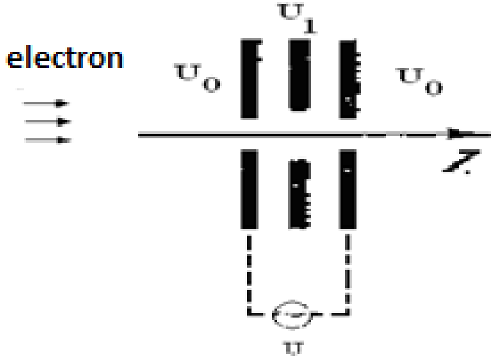


Fig. 1. Connecting the microwave field to the electrodes of a single lens for the modulation of the electron beam velocity

$$\vartheta_0 = \sqrt{\frac{2e\Phi_0}{m}} \quad ...(4)$$

Output value of the lens has:

$$t = t_0 + \frac{z}{\vartheta_0} W = e\Phi_0 + \Delta W \quad ...(5)$$

where in the kinetic energy of the increment can be represented as follows:

$$\Delta W = \frac{eU_m}{2s}\left[\int_{-s}^{s}\sin\left(\omega t_0 + \frac{\omega z}{\vartheta_0}\right)dz + \frac{2s}{\Phi_0}\int_{-s}^{s}\Phi'(z)\sin\left(\omega t_0 - \frac{\omega z}{\vartheta_0}\right)dz\right] ...(6)$$

The prime denotes differentiation with respect to coordinate. After integration increment of the kinetic energy can be represented as:

$$\Delta W = eU_m\left[M - \frac{\omega}{\vartheta_0}\chi^2 I_1(z)\right]\sin\omega t_0 + \chi^2\left[-\sin\frac{\theta}{2} + \frac{\omega}{\vartheta_0}\chi^2 I_2(z)\right]\cos\omega t_0 \quad (7)$$

Here we have introduced the following notation:

$$I_1(z) = \int_{-s}^{s} f(z)\sin\frac{\omega z}{\vartheta_0}dz, \quad ...(8)$$

$$I_2(z) = \int_{-s}^{s} f(z)\cos\frac{\omega z}{\vartheta_0}dz, \quad ...(9)$$

$$f(z) = \left[1 + \left(\frac{z}{d}\right)^2\right]^{-1} \qquad ...(10)$$

Value $\theta = \frac{2\omega s}{\vartheta_0}$ characterizes the unperturbed transit angle of electrons through the lens and is designated by the coefficient of the interaction of the electron beam with the field of a single lens

$$M = \frac{\sin \theta/2}{\theta/2} \qquad ...(11)$$

RESULTS

The calculations show that the integral vanishes, ie, use a single lens as a modulator in speed does not affect the flow rate of interaction with the electron field lens. Secondly, because of the small half angle of the unperturbed flight, when the condition

$$s = \int_{-s}^{s} f(z) \cos \frac{\omega z}{\vartheta_0} dz \qquad ...(12)$$

preserved sine law of change of kinetic energy increment

$$\Delta W = eMU_m \sin \omega t_0 \qquad ...(13)$$

Then, given the small amplitude alternating voltage compared with the potential of a single electrode on the outer lens, the electron velocity at the exit of the lens can be represented as follows:

$$\vartheta \approx \vartheta_0 \left(1 + \frac{MU_m}{2\Phi_0} \sin \omega t_0\right) \qquad ...(14)$$

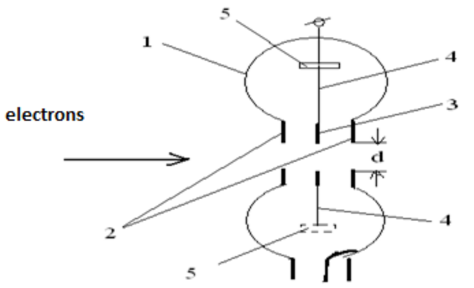
Thus, application of a single lens as the modulator of an electronic stream on speed practically doesn't change the size of coefficient of interaction of an electronic stream with a lens field, however existence of an average electrode gives the chance to organize volume focusing of an electronic stream in the vertical direction.

In the volume resonator the role of the concentrated capacity plays flat clearance a type of plane-parallel grids in the center of the resonator, a role of the concentrated inductance - the toroidal surface forming one round with the developed surface. In the microwave oven devices with the klistronny mechanism of interaction as input and output devices volume resonators are used. Capacity of the entrance resonator is under high positive potential mainly electric high-frequency field is concentrated in the same place. Under the influence of this high-frequency field the electronic stream is modulated on speed further being transformed to modulation on density in drift space of the microwave oven the device and in the output resonator remove energy of the modulated electronic stream at entry into the output resonator in the braking mode of electric field[17-19].

Lack of the entrance resonator described above is: first, existence of grids, being a mechanical barrier on the way of a stream of electrons; secondly, saggings of equipotential surfaces near grids have the disseminating effect on electrons. These factors reduce the size of convection current, thereby lower the power of the microwave oven of the device. Therefore in traditional schemes of such microwave ovens of devices there is a need of use of various transporting systems for drift space: systems of a uniform or non-uniform magnetic field, system of uniform or non-uniform electric field[12-13].

The positive technical result is reached by that instead of the capacity consisting of two parallel grids where high-frequency electric field is concentrated the single lens consisting of three diaphragms is used.

In drawing 2 the design of the offered device [3] is presented. This device represents the toroidal resonator (1) in which in the field of concentration of high-frequency electric field the single lens consisting of three diaphragms with round openings of equal diameter at which extreme electrodes (2) are under the identical high accelerating potential on the same electrodes is installed move high-frequency electric field. The average diaphragm (3) is established by means of the thin carrying-out threads (4) passed through the cuts (5) parallel to lines of current located opposite on toroid surfaces, on it the potential different from the accelerating potentials given on extreme diaphragms moves[21].



1. Corpus resonator, 2, 3- single lens, 4- the thin carrying-out threads diaphragm 3, potential different from the accelerating diaphragm 2, passed through the cuts 5 toroidal resonator

Fig. 2. The volume resonator with electrostatic focusing

CONCLUSION

The device works as follows. The electronic stream accelerated by the accelerating potential, passing area of high-frequency electric field, it is modulated on speed, being transformed to modulation on density in drift space. Clots of electrons, coming to the output resonator in a phase of the braking mode of a high-frequency field, give the energy. Set of three diaphragms is a single lens which focal length is regulated by the potential of an average diaphragm. The volume resonator of the offered design can carry out at the same time a role of the modulator of electrons on speed on the one hand, and the transporting system in drift space with another and the stream of clots of electrons can be focused on a surface of an entrance window of the output resonator. The volume resonator with electrostatic focusing promotes increase of power of the microwave oven of devices of klistronny type at the expense of increase in convection current.

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