MODIFICATION OF THE PIERCE INSTABILITY OF THE ELECTRON FLOW IN A DIODE WITH AN EXTERNAL ELECTROMAGNETIC ACTION

O. G. Melezhik A. V. Pashchenko, S. S. Romanov, I. M. Shapoval[*]
National Science Center "Kharkov Institute of Physics and Technology", 61108, Kharkov, Ukraine
(Received July 1, 2014)

The stability of electron flow passage through the diode with a neutralized space charge has been investigated on the basis of the first-order approximation for hydrodynamic and Maxwell equations. Classification of solutions to the equations was developed in accordance with the magnitude and nature (potential or eddy) of the electric field arising at the diode cathode. The stability regions for these states have been found. It is shown that the presence of external electromagnetic action makes the stability region narrower than that predicted by Pierce.

PACS: 03.65.Pm, 03.65.Ge, 61.80.Mk

1. INTRODUCTION

It has been demonstrated by V. Bursian and V. Pavlov [1] that with injection of an electron flow into a planar diode, the flow density can be increased only to a certain value, called the Bursian-Pavlov limit. An excess of this limit gives rise to instability, which leads to the appearance of a virtual cathode (VC) and to realization of the effects associated with it. One of these effects is the reflection of a greater part of the electron flow incident on the VC. This means that the current that can be passed through the planar diode is determined by the Bursian-Pavlov limit. The limit has its quantification. The electron flow state in the short-circuited diode is given by the Bursian-Pavlov parameter

$$q = \frac{\omega_0^2 l^2}{v_0^2}\,, \tag{1}$$

$$\omega_0^2 = \frac{4\pi e^2 n_0}{m}\,, \tag{2}$$

where l is the diode length, v_0 and n_0 are, respectively, the velocity and density of electrons at the input of the diode. The Bursian-Pavlov limit corresponds to the value

$$q_B = \frac{16}{9}\,. \tag{3}$$

This limit occurs to be a natural power limiter of the electronic devices being developed. In due time, various methods were tried to increase the density of the electron flow passing through the diode. The proposal to use the phenomenon of potential well neutralization of the electron beam by ions belongs to Pierce [2]. Pierce has shown that at a complete space charge compensation of the electrons in the absence of external action, the limit determining the electron flow passage increases up to

$$q_P = \pi^2\,. \tag{4}$$

This limit stems from the occurrence of the "Pierce instability" in the compensated electron flow. So, at the same electron flow parameters at the anode input, and at the same diode length in case of space charge compensation, the ultimate current density increases Λ times, where

$$\Lambda = \frac{q_P}{q_B} = \frac{9}{16}\pi^2 \approx 6\,, \tag{5}$$

The present paper deals with the electron flow passage through the diode with a compensated space charge for both the case of absence of total diode current disturbances, considered by Pierce, and the case of presence of these disturbances. The solution to the problem of electron flow passage through the mentioned diode is of both the applied and methodological importance. The thing is that the state of this electron flow is only one of the possible electron flow states in the diode, which is noted for the compensated space charge and, therefore, is most amenable for theoretical description and physical interpretation. The two will be presented below.

2. THE DIODE WITH A COMPENSATED SPACE CHARGE

The diode with a compensated space charge [2] is defined as a diode with the electrodes being at the same potential, in which the space charge of the electron flow is compensated by stationary ions. The electron

[*]Corresponding author E-mail address: shapoval@kipt.kharkov.ua

flow in the diode is described by the equation of electron motion and by the Maxwell equations. In the description of the electron flow motion, for reasons of v/c smallness, we shall neglect the Lorentz force compared with the electric field strength. This makes it possible to avoid finding the self-magnetic field and to describe the electron flow in terms of the velocity, density and the electric field. The equation of motion, the Maxwell equation for the electric field and the equations of continuity form the set of equations to describe the electron flow in the diode. As in ref [2], we consider the problem in the one-dimensional approximation. Then the set of equations takes the form

$$\frac{\partial v}{\partial t} + v\frac{\partial v}{\partial z} = -\frac{e}{m}E\,, \qquad (6)$$
$$\frac{\partial n}{\partial t} + v\frac{\partial nv}{\partial z} = 0\,, \qquad (7)$$
$$\frac{\partial E}{\partial z} = -4\pi e(n_i - n_e)\,, \qquad (8)$$

where n_i and n_e- are the densities of ions and electrons, respectively. The dimensionless values for the density n, velocity v, coordinate z and time t are the characteristic flow parameters at the input to the diode. These are n_0, v_0, the diode gap length l, and the transit time l/v_0. We shall investigate the stability of ion-compensated electron flow passage through the drift space. For this purpose we find the solution of the equations in the zeroth- order and first approximations. Each of the parameters v, n, E will be represented as a sum of the solutions of zero- and first approximations:

$$f(\zeta,t) = f^0(\zeta) + \tilde{f}(\zeta,t)\,, \qquad (9)$$

where $\zeta = z/l$. The time dependence of deviation values from zero-order approximations will be sought as

$$\tilde{f}(\zeta,t) = \tilde{\psi}(\zeta)e^{-i\omega t}\,. \qquad (10)$$

The deviations from stationary values are considered to be small, and from Eqs.(6)-(8) we obtain the linearized set of equations:

$$-i\omega\tilde{v} + \frac{d\tilde{v}}{d\zeta} = -\tilde{E}\,, \qquad (11)$$
$$-i\omega\tilde{n} + \frac{d\tilde{n}}{d\zeta} + \frac{d\tilde{v}}{d\zeta} = 0\,, \qquad (12)$$
$$\frac{d\tilde{E}}{d\zeta} = -q\tilde{n}\,. \qquad (13)$$

Before finding the solutions to the equations of the zero-order and first approximations, we shall discuss the potential distribution in the diode (Fig.1).

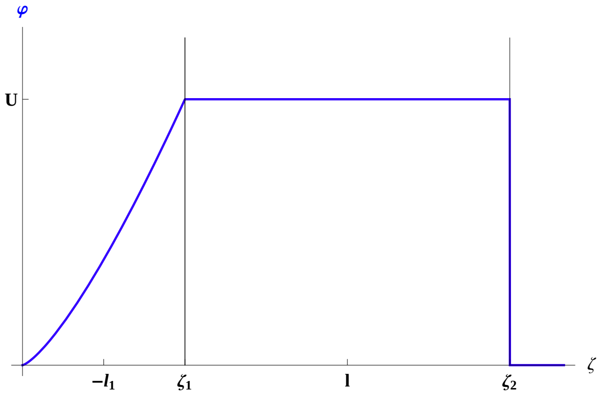


Fig.1. *Diode with the inlet N_1 (at $z = 0$) and outlet N_2 (at $z = 1$) grids, and the cathode at $z = -l_1$ (l_1 is the cathode gap length)*

The potential φ is dimensionless due to mv_0^2/e. In the cathode-grid N_1 gap, in the presence of the cathode emission the potential increases by the Child-Langmuir-Boguslavsky law and provides the potential U transferred by the external circuit from grid N_1 to grid N_2. The potential sag caused by the electron flow in the drift space is eliminated by ions. As a result, the stationary distribution of the potential in the drift space of the diode takes on the uniform shape. Then, the stationary solution of the set (6) - (8) is written as

$$v^0(\zeta) = 1\,; \quad n^0(\zeta) = 1\,; \quad E^0(\zeta) = 0\,; \quad \varphi^0(\zeta) = 1\,. \qquad (14)$$

Equations (11-13) form a system of ordinary linear differential equations of first order with constant coefficients. Its solution is given by

$$\tilde{v}(\zeta) = D_1 e^{i(\sqrt{q}+\omega)\zeta} + D_2 e^{-i(\sqrt{q}-\omega)\zeta} + C\frac{i\omega}{q-\omega^2}\,, \qquad (15)$$
$$\tilde{n}(\zeta) = -D_1(1+\frac{\omega}{\sqrt{q}})e^{i(\sqrt{q}+\omega)\zeta} - D_2(1-\frac{\omega}{\sqrt{q}})e^{-i(\sqrt{q}-\omega)\zeta}\,, \qquad (16)$$
$$\tilde{E}(\zeta) = -D_1(i\sqrt{q})e^{i(\sqrt{q}+\omega)\zeta} + D_2(i\sqrt{q})e^{-i(\sqrt{q}-\omega)\zeta} - C\frac{\omega^2}{q-\omega^2}\,, \qquad (17)$$

where D_1, D_2, C are the integration constants. The solutions (15) - (18) must satisfy the boundary conditions:

$$\tilde{v}(0) = 0\,, \tilde{n}(0) = 0\,. \qquad (18)$$

Conditions (18) are caused by the requirement that the electron flow should not bring in any external disturbance in the diode at frequency ω. The conditions lead to the following equations for D_1, D_2, C:

$$D_1 + D_2 + C\frac{i\omega}{q-\omega^2} = 0\,, \qquad (19)$$
$$D_1(1+\frac{\omega}{\sqrt{q}}) + D_2(1-\frac{\omega}{\sqrt{q}}) = 0\,. \qquad (20)$$

The electric field in the diode arises self-consistently with the coordinate distributions of densities and velocities; therefore, it can neither by itself nor through Eq.(15) give the missing condition on D_1, D_2, C. The equation corresponding to this condition can be derived from the boundary conditions on the scalar potential $\tilde{\varphi}$. In accordance with the determination of the potential $\tilde{\varphi}$, the equations for its finding and the type of boundary conditions, which the potential must satisfy, we consider below some problems, which describe the electron flow passage through the diode.

3. SOLUTIONS CLASSIFICATION

The constant C occurring in the solution of (15)- (17) represents the electric field value on grid N_1 (Fig.1) from the diode side. This conclusion follows from (18) and formula

$$\tilde{E} = \frac{iq}{\omega}(\tilde{n} + \tilde{v}) + C\,. \tag{21}$$

Formula (21) was derived from the set (11) - (13) as a result of substitution and integration. Since it is impossible to assign the electric field at the beginning of the diode gap as the electron flow propagates in the diode, the investigation of the flow passage through the diode must be continued until finding the electric potential, which governs the electron flow motion. In this case, one uses the definition of the electric field by means of the potential

$$\tilde{E}(\zeta) = -\frac{\partial \tilde{\varphi}(\zeta)}{\partial \zeta}\,. \tag{22}$$

The electric field in this formula is the potential field. Below we consider several cases concerning the nature of the constant C: a) C is of potential; b) C is of eddy and c) constant C is of mixed nature.

3a. The Pierce problem ($C = 0$)

In ref. [2] Pierce has considered the electron flow passage through the diode, where the space charge is compensated by stationary ions, assuming that there is no total current disturbance in the circuit. The assumption that this disturbance is zero leads inevitably to the requirement that in formulas (15)-(18) we should have

$$C = 0\,. \tag{23}$$

Indeed, from the definition of the total current it follows that the disturbance is proportional to

$$\tilde{J} \sim \frac{\partial \tilde{E}}{\partial t} - 4\pi e(\tilde{v} + \tilde{n})\,. \tag{24}$$

Writing expression (24) in terms of dimensional variables and taking into account that by definition $\tilde{E}(\zeta, t) = \tilde{\Psi}(\zeta)e^{-i\omega t}$ we draw the conclusion that the right side of (24) and the left side of (21) are equal, this just proving the conclusion about the fulfillment of equality (27). Hence, at zero disturbance of the total current the electric field is written as

$$\tilde{E}(\zeta) = -D_1(i\sqrt{q})e^{i(\sqrt{q}+\omega)\zeta} + D_2(i\sqrt{q})e^{-i(\sqrt{q}-\omega)\zeta}\,. \tag{25}$$

Using the definition (17) and taking into account that

$$\tilde{\varphi}(0) = 0\,, \qquad \tilde{\varphi}(1) = 0 \tag{26}$$

we obtain the expression for $\tilde{\varphi}(\zeta)$:

$$\tilde{\varphi}(\zeta) = \frac{D_1\sqrt{q}}{\omega + \sqrt{q}}(e^{i(\omega+\sqrt{q})\zeta} - 1) - \\ -\frac{D_2\sqrt{q}}{\omega - \sqrt{q}}(e^{i(\omega-\sqrt{q})\zeta} - 1) \tag{27}$$

and the condition for D_1 and D_2:

$$D_1(\omega-\sqrt{q})(e^{i(\omega+\sqrt{q})}-1) - D_2(\omega+\sqrt{q})(e^{i(\omega-\sqrt{q})}-1) = 0\,. \tag{28}$$

Besides, the coefficients D_1 and D_2 must meet the conditions

$$D_1 + D_2 = 0 \tag{29}$$

and

$$D_1(\omega + \sqrt{q}) - D_2(\omega + \sqrt{q}) = 0\,, \tag{30}$$

that follow from (15) at $C = 0$ and (20). The three-equation system ((28)-(30)) for the two unknowns D_1 and D_2 is the over determined system and can be fulfilled only for certain values of ω and $\sqrt{q}$. It is just the equalities follow: from Eq.(30) by condition (29)

$$\omega = 0 \tag{31}$$

and from Eq.(28)

$$\sqrt{q} = n\pi\,. \tag{32}$$

Thus, it appears that the mode with the zero disturbance of the total current is possible only at some assigned values of the parameter $\sqrt{q}$ ($\sqrt{q} = n\pi$).

3b. The potential case, Pierce's instability

In this case, the electric field in formula (21) is determined by expression (26), so that after integration of Eq.(26) and fulfillment of conditions (21) we obtain that the potential disturbance is equal to

$$\tilde{\varphi}(\zeta) = D_1\frac{\sqrt{q}}{\omega + \sqrt{q}}(e^{i(\omega+\sqrt{q})\zeta} - 1) - \\ -D_2\frac{\sqrt{q}}{\omega - \sqrt{q}}(e^{i(\omega-\sqrt{q})\zeta} - 1) - C\frac{\omega^2}{\omega^2 - q}\zeta \tag{33}$$

and the equation for the coefficients takes the form:

$$D_1\frac{\sqrt{q}}{\omega + \sqrt{q}}(e^{i(\omega+\sqrt{q})} - 1) - \\ -D_2\frac{\sqrt{q}}{\omega - \sqrt{q}}(e^{i(\omega-\sqrt{q})} - 1) - C\frac{\omega^2}{\omega^2 - q} = 0\,. \tag{34}$$

Equation (34), considered together with Eqs.(19) and (20), leads to the dispersion equation (DE):

$$(\omega - \sqrt{q})^2(e^{i(\omega+\sqrt{q})} - 1) - (\omega + \sqrt{q})^2 \times \\ \times(e^{i(\omega-\sqrt{q})} - 1) + 2i\frac{\omega^2}{\sqrt{q}}\omega^2 - q = 0\,. \tag{35}$$

It is evident from Eq.(35) that in the case under consideration, oscillations with the frequency

$$\omega = \pm\sqrt{q} \tag{36}$$

can be excited in the diode. ω is the complex frequency, i.e.,

$$\omega = P + iQ \tag{37}$$

where P is the oscillation frequency, and Q is the increment at $Q > 0$ and is the decrement at $Q < 0$. From (36) and (37) it follows that the solution (36) presents steady-state sinusoidal oscillations with the frequency

$$P = \pm\sqrt{q} \tag{38}$$

and the increment

$$Q = 0\,. \tag{39}$$

The dispersion equation (35)can be written as:

$$e^{\beta}[(K^2 - \beta^2)\sin(K) + 2K\beta\cos(K))] - \\ -2K\beta + \frac{\beta^2}{K}(K^2 + \beta^2) = 0\,, \tag{40}$$

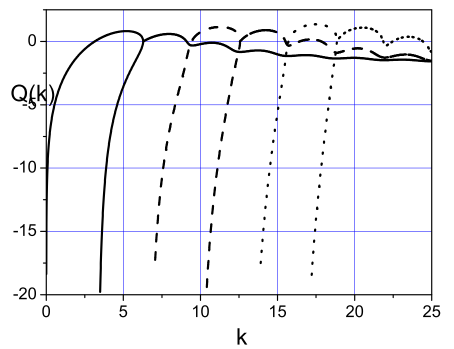
where

$$K = \sqrt{q} \tag{41}$$

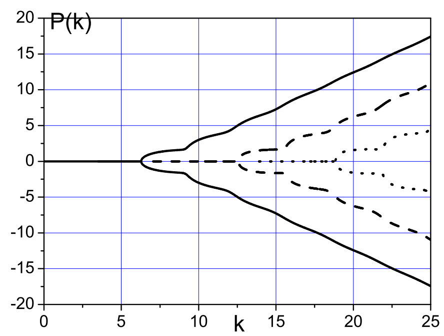
and

$$\beta = i\omega = -Q + iP\,. \tag{42}$$

The solution of Eq.(40) is presented in Figs.2,a,b; 3a,b by two families of curves.



a



b

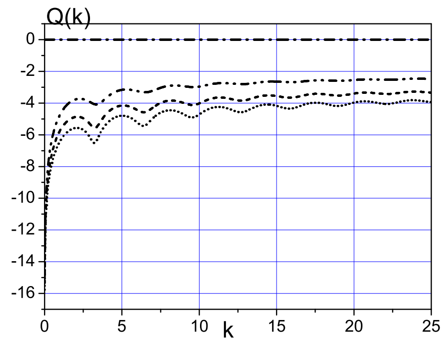
Fig.2. *The solution family A of equation (33) for the case of potential C: top - a) decrement, bottom - b) oscillation frequency*

The first family of curves (Figs.2,a and 2,b) is composed of nearly periodic structures having the points $K = 2n\pi$ as their centers. Each structure consists of two curves for Q tends to the $-\infty$ and having the vertical straight lines $K_1 = 2(n-1)\pi$ and $K_2 = (2n-1)\pi$ as their asymptotes. These curves cross at point $K = 2n\pi$ at $Q = 0$. To the left of the point, one of the curves becomes positive, so the process, corresponding to it, becomes unstable ($Q > 0$). These curves are in accordance with $P = 0$ (Fig.2); so they give the decrement or the increment of the aperiodic process. To the right of the point $K = 2n\pi$, the solution for β becomes complex-conjugate, the curves for Q merge and give the increment of the excited periodical process. It can be seen from Fig.2 that to the right of point $K = 2n\pi$, apart from the solution $P = 0$ that relates to the neighboring structure with the center at $K = 2(n+1)\pi$, two solutions appear for the frequency P, which characterize the arising periodical instability.

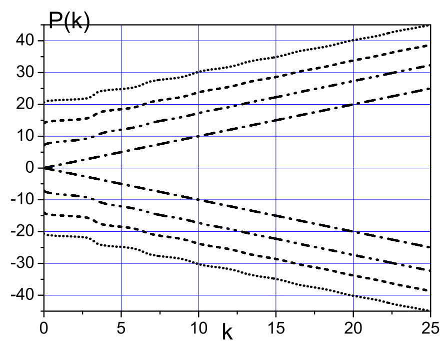
The solution of Eq.(40) at $K = 2n\pi + \alpha$, $|\alpha| << 1$ has the form :

$$\beta = \frac{n\pi}{3} - \alpha \pm (-\alpha(6 + (1 + \frac{2}{n\pi})\alpha))^{1/2}\,. \tag{43}$$

Since by definition we have $\beta = -Q + iP$, it is evident that to the left of the point $K = 2n\pi$, i.e., at $\alpha < 0$, there are two solutions for Q: one solution is positive, and the other is negative. This is in agreement with the above given treatment and with Fig.3,a. For the right neighborhood of point $K = 2n\pi$, i.e., at $\alpha > 0$, formula (43) gives two complex-conjugate solutions. This means that in this neighborhood two new solutions appear for P: one is positive, and the other is negative (Fig.2,b). Of special interest is the solution of Eq.(40) for the region $0 < K < 2\pi$. Fig.2,a suggests the conclusion that in this region only aperiodical process ($P = 0$) is possible; and Fig.2b shows that this process splits at $K < \pi$, since $Q < 0$, and increases at $K > 0$, since $Q > 0$. This is just the Pierce instability. Figs. 3,a and 3,b show the straight lines for $Q = 0$ and $P = \pm K$, which represent a stable current transport through the diode. In this case the current amplitude changes with time harmonically at the dimensionless frequency $P = K$. Besides, Figs. 3,a and 3,b show the curves of one more family. They characterize the damped oscillations ($Q < 0$, $P \neq 0$); so, these oscillations cannot be excited in the diode. Figs. 3,a,b show the straight lines for $Q = 0$ and $P = \pm K$ that correspond to the solutions (38) and (39).



a



b

Fig.3. *Solution family B of equations (40) for the case of the potential C: top- a) decrement, bottom- b) oscillation frequency*

3c. The eddy case

In this case the constant C must be excluded from expressions (17) and (31) for the electric field. And yet, the terms comprising this constant should be taken into account in (15) and (16) for $\tilde{n}$ and $\tilde{v}$, and also, in (19) and (20); so, as the final result, the expressions for $\tilde{E}$ contain the terms with C. Having done all the things, as suggested above, we obtain:

$$\tilde{E}(\zeta) = -D_1(i\sqrt{q})e^{i(\omega+\sqrt{q})\zeta} + D_2(i\sqrt{q})e^{i(\omega-\sqrt{q})\zeta} + \\ + \frac{q}{\omega^2 - q}C\,, \qquad (44)$$

$$\tilde{\varphi}(\zeta) = D_1\frac{\sqrt{q}}{\omega+\sqrt{q}}(e^{i(\omega+\sqrt{q})\zeta} - 1) - \\ D_2\frac{\sqrt{q}}{\omega-\sqrt{q}}(e^{i(\omega-\sqrt{q})\zeta} - 1) - \frac{q}{\omega^2 - q}C\zeta\,. \qquad (45)$$

The condition $\tilde{\varphi}(1) = 0$ leads to the equation:

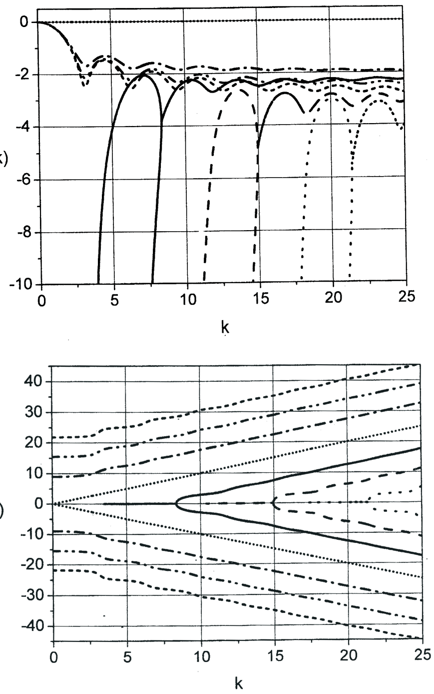
$$D_1(\omega - \sqrt{q})(e^{i(\omega+\sqrt{q}} - 1) - \\ -D_2(\omega + \sqrt{q})(e^{i(\omega-\sqrt{q})} - 1) - C\sqrt{q} = 0\,. \qquad (46)$$

This equation, together with Eqs.(19) and (20), permits the derivation of the dispersion equation for the case under consideration. The DE has the form:

$$(\omega - \sqrt{q})^2(e^{i(\omega+\sqrt{q})} - 1) - (\omega + \sqrt{q})^2 \times \\ \times(e^{i(\omega-\sqrt{q})} - 1) + 2i\sqrt{q}(\omega^2 - q) = 0\,. \qquad (47)$$

(40) Using the definitions (41) and (42) for β and K, Eq. (47) can be written as:

$$e^{\beta}[(K^2 - \beta^2)\sin(K) + 2K\beta\cos(K))] - \\ -2K\beta + K(K^2 + \beta^2) = 0\,. \qquad (48)$$



a

b

Fig.4. *a – Decrement (increment) of oscillations for the case of eddy C; b – Oscillation frequency for the case of eddy C*

The analysis and the plots in Figs. 4,a, 4,b show that Eq.(40) has no unstable growing solutions. This means that in the case, where C is the eddy constant, the diode is in a steady state.

3d. The mixed case. Pierce's instability modification

In this case, the constant C is equal to

$$C = C_1 + C_2\,, \qquad (49)$$

where C_1 and C_2 are, respectively, the potential and eddy parts of the constant C. Using the parameter η that describes the contribution, which the potential constituent gives to C, formula (49) can be written in the following form:

$$C_1 = \eta C\,. \qquad (50)$$

Finding the corresponding potential and carrying out, as before, the procedure of deriving the dispersion equation, we obtain the equation, which differs from Eqs.(40) and (48) by the last component. It has the form

$$\frac{1}{K}[(\beta^2 + K^2\eta - K^2](\beta^2 + K^2)\,. \qquad (51)$$

It is obvious that the DE derived at η=1 goes over into Eq.(40), while at η=0 it changes to Eq.(48).

The decrease in the parameter η provides the transition from DE (40), which gives rise to Pierce's instability, to DE (48), at which a steady electron flow passage through the diode is realized.

The evolution of solution of the DE with component (51) is presented in Figs.5,a-f. At $0 < \eta < 1$, a new solution appears, which has a vertical asymptote $K = 0$ and crosses the abscissa axis in the interval $0 < K < \pi$, thereby reducing the region of electron flow stability in the diode. At $\eta \to 1$, this region extends up to $K = \pi$.

From formulae (48),(51) at Q=0 we have the relationship:

$$\eta = 1 - Sin(G)/G\,, \qquad (52)$$

where G is the electron flow stability boundary.

The graph of the parameter G against η, obtained from equality (52), is presented in Fig.6, which shows the extension of the electron flow stability region at a relatively decreased role of the external electromagnetic action, i.e., the parameter η. The value of G for this region is equal to the highest value of the parameter K, starting from which Q becomes positive. It can be seen that Pierce's parameter K reaches the π value only at η=1, i.e., in the absence of external electromagnetic action.

Physically, the decrease of the electron flow stability region with an increase in the external eddy action is due to the fact that the amplitude of the velocity disturbance (formula (15)) grows, whereas the stabilizing effect due to maintaining electrode potential disturbances at a zero level (formula (26)) is attributed only to the potential disturbance C_1.

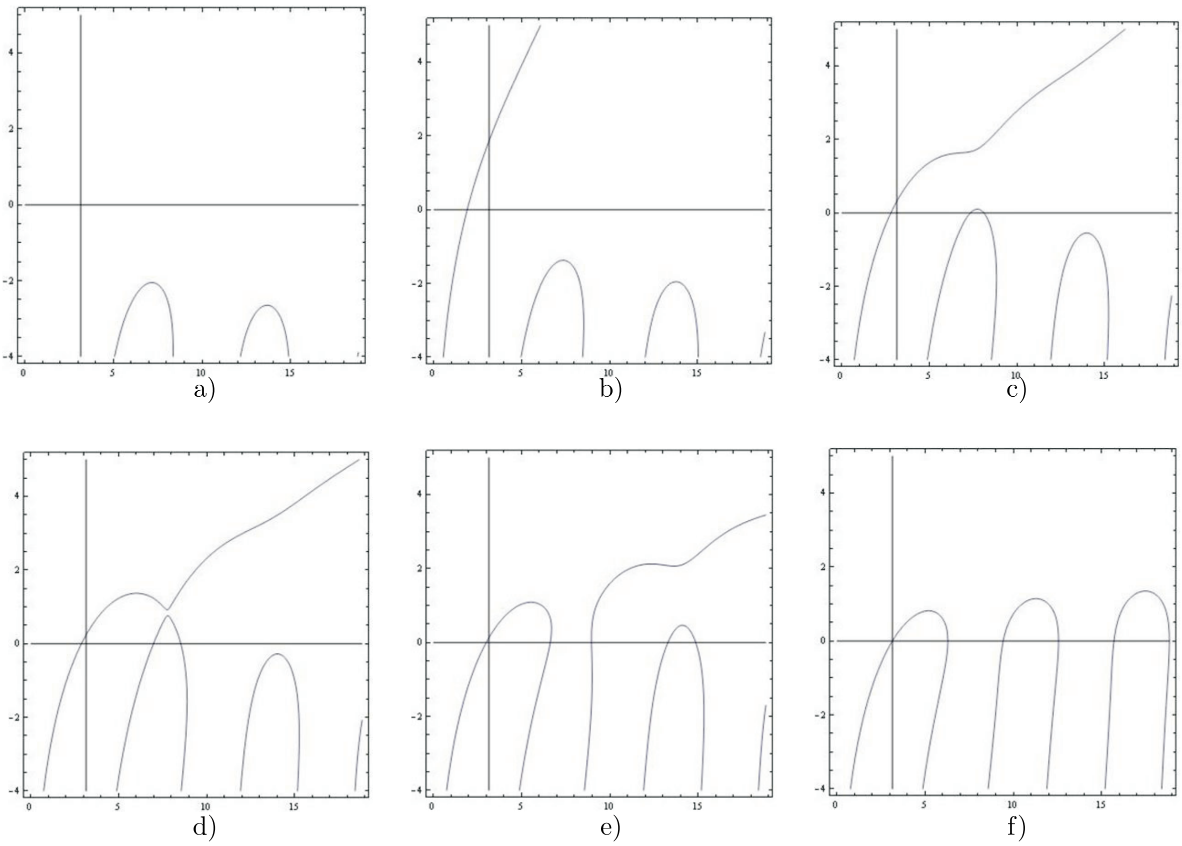


Fig.5. *Increments (decrements) of aperiodical oscillations in the diode: a) η=0; b) η=0.5; c) η=0.881; d) η=0.9085; e) η=0.95; f) η=1.*

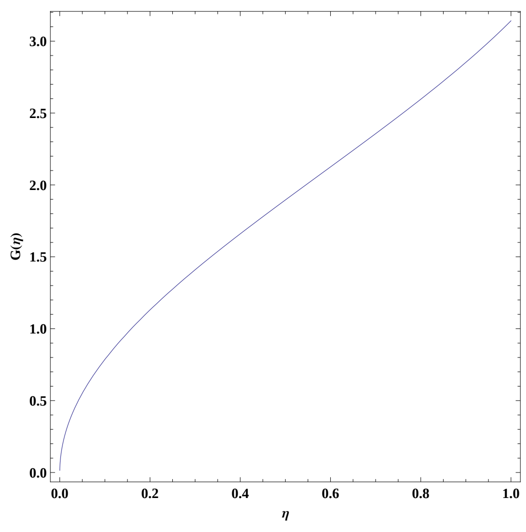


Fig.6. *Pierce's parameter G as a function of η*

4. CONCLUSIONS

The paper has been concerned with the stability of the electron flow passing through the diode with a compensated space charge under an external electromagnetic action.

Classification of electron flow states in the diode has been developed in accordance with the magnitude (zero or nonzero) and nature (potential, eddy or mixed) of the electric field, which arises at the input electrode from the diode gap-side, and is assigned by the constant C. Consideration has been given to the cases, where the electron flow passage takes place without total current disturbances (Pierce's problem). Corresponding dispersion equations have been derived and solved for the case, where the constant C is potential. It has been demonstrated that in this case a stable electron flow passage through the diode takes place until the Pierce's parameter equal to π is reached. As soon as the Pierce parameter exceeds the π value, the Pierce's instability takes place.

In the states with the eddy electric field at the diode input, there is no instability at any values of the Pierce parameter.

It has been shown that for the case, where the constant C is of mixed type, there appears a new solution, which modifies the Pierce instability and reduces the electron flow stability region in the diode.

With a decreasing contribution from the eddy constituent of the constant C, arising in the diode due to the external electromagnetic action, the stability region extends up to the Pierce parameter equal to π. This means, in particular, that in the experimental conditions even an insignificant influence of the external electromagnetic signal can cause an essential reduction in the limiting density of the electron flow passing through the diode.

ACKNOWLEDGEMENTS

The authors are thankful to V. I. Karas' and V. I. Maslov for their interest in the work and useful comments.

References

1. V.R. Bursian, V.I. Pavlov. About a particular case of the space charge effect on the electron flow passage in a vacuum. //*Zhurnal Rus. Fiz.-Khim. Obshchestva.* 1923, v. 55, p. 71-80 (In Russian).

2. J. Pierce. Limiting stable current in electron beams in the presence of ions // *J. Appl. Phys.* 1944, v. 15, p. 721.

МОДИФИКАЦИЯ НЕУСТОЙЧИВОСТИ ПИРСА ПРИ ВНЕШНЕМ ЭЛЕКТРОМАГНИТНОМ ВЛИЯНИИ НА ЭЛЕКТРОННЫЙ ПОТОК В ДИОДЕ

А. Г. Мележик, А. В. Пащенко, С. С. Романов, И. М. Шаповал

На основе решения системы гидродинамических уравнений и уравнений Максвелла в первом приближении изучена устойчивость прохождения электронного потока через диод с компенсированным объёмным зарядом. Проведена классификация решений уравнений в соответствии с величиной и характером (потенциальное или вихревое) электрического поля, возникающего на катоде диода. Найдены области устойчивости этих состояний. Показано, что наличие внешнего электромагнитного воздействия сужает область устойчивости по сравнению с предсказанной Пирсом.

МОДИФІКАЦІЯ НЕСТІЙКОСТІ ПІРСА ПРИ ЗОВНІШНЬОМУ ЕЛЕКТРОМАГНІТНОМУ ВПЛИВІ НА ЕЛЕКТРОННИЙ ПОТІК У ДІОДІ

О. Г. Мележик, А. В. Пащенко, С. С. Романов, І. М. Шаповал

На основі розв'язання системи перших наближень гідродинамічних рівнянь та рівнянь Максвела вивчена стійкість проходження електронного потоку через діод з компенсованим об'ємним зарядом. Проведена класифікація рішень рівнянь у відповідності з величиною та характером (потенційне або вихрове) електричного поля, що виникає на катоді діода. Найдено області стійкості цих станів. Показано, що наявність зовнішнього електромагнітного впливу звужує область стійкості порівняно з передбаченою Пірсом.