EXCITATION AND PROPERTIES OF SOLITARY PERTURBATIONS IN ELECTRON BEAM IN ACCELERATOR

V.I.Lapshin, V.I.Maslov, I.V.Tkachenko*
NSC Kharkov Institute of Physics and Technology, * Kharkov National University,
Kharkov 61108, Ukraine. E-mail: vmaslov@kipt.kharkov.ua

1 INTRODUCTION

If the wall of the accelerator has finite conductivity, then the penetration of electron beam's field, propagating along the wall, into the wall is possible and the excitation of volume charge perturbation, δq, is also possible in the wall. That is the interaction of electron beam with the wall is possible. We consider the possibility of non-linear perturbation excitation in electron beam due to this interaction with the wall.

2 EXCITATION OF NONLINEAR PERTURBATIONS IN AN ELECTRON BEAM DUE TO DISSIPATIVE INSTABILITY DEVELOPMENT AT INTERACTION OF BEAM AND WALL WITH FINITE CONDUCTIVITY

The perturbation of volume charge of the wall is described by the following equation

$$\partial_t \delta q = \sigma \partial_z E \qquad (1)$$

Here σ is the conductivity of the wall. The Poisson's equation for the longitudinal component of electric field in long wave approximation is of following type

$$\partial_z E = -4\pi(e\delta n_b + R\delta q) \qquad (2)$$

Here δn_b is the perturbation of the beam density, R is a small parameter or geometrical factor, taking into account the skin depth and radial spatial distance between the beam and conducting wall. From (1), (2) equations of a continuity and motion for beam electrons one can obtain dispersion relation for high-frequency perturbations with frequency ω and wave vector k:

$$1 - \omega_b^2/(\omega - kV_b)^2 - i4\pi\sigma R/\omega = 0 \qquad (3)$$

Here ω_b is the plasma frequency of the electron beam, and V_b is its velocity. From (3) it follows that maximum growth rate of amplitude $\gamma_L \approx (\pi\sigma R\omega_b)^{1/2}$ have perturbations with wave vector $k \approx \omega_b/V_b$.

With amplitude growth excited perturbations become non-linear. We consider a limiting case, when perturbations are transformed in chain of short perturbations. We investigate the excitation of such short solitary perturbation on non-adiabatic stage of its evolution. In other words, the approach is considered, when during the time of perturbation excitation the beam electrons are shifted relatively to perturbation on a distance, not exceeding of its width.

In this approximation from a kinetic equation for beam electrons and Poisson's equation it is possible to derive similarly [1] equation for spatial distribution of a quasistationary electrical potential $\varphi(t,z)$ of perturbation

$$(\partial_z\phi)^2 \approx (\phi_o - \phi)\phi^2/6 \qquad (4)$$

Here $E= -\partial_z\varphi$, $\phi=e\varphi/T$, T is the electron beam temperature, ϕ_o is the amplitude of perturbation.

Taking into account of nonstationary terms in a kinetic equation for beam electrons one can obtain for the correction to density of beam electrons, δn_{bt} , proportional to $\partial_t\phi_o$, expression

$$\partial_z\delta n_{bt} \approx \partial_t\phi[1/z - z + (2z^2 - 1)\phi_o/6z]V_{th}\sqrt{2} \qquad (5)$$

Here V_{th} is the thermal velocity of beam electrons, $z=(V_s-V_b)/V_{th}\sqrt{2}$. Similarly [1] one can obtain that the velocity of the solitary perturbation is approximately equal $V_s \approx V_b - 1.32V_{th}$.

Taking into account of electron beam interaction with perturbation of charge density in the wall from (2) one can derive

$$e\,\delta n_{bt} \approx -R\delta q \qquad (6)$$

From (1), (5), (6) an equation follows, describing the excitation of perturbation. In the case not so small amplitudes it has a kind

$$\partial_\tau\phi_o\partial_\tau\phi \approx 8\sqrt{2}\partial^3_y\phi \qquad (7)$$

Here $y = z/r_b$, $r_b = (T/4\pi n_b e^2)^{1/2}$, $\tau = t\gamma_L$. The solution of equation (7) we search as

$$\phi(y, \tau) = \phi_o(\tau)\mu[y - \int_{-\infty}^{\tau} d\tau_o\delta V_s(\phi_o(\tau_o))] \qquad (8)$$

δV_s is the change of soliton velocity, appeared as a result of its interaction with environment, $\mu(y)$ is the Spatial distribution of a soliton potential, described by equation(4). From (4), (7), (8) one can obtain following expression for the growth rate of excitation of solitary perturbation

$$\gamma \approx (\gamma_L/3)\phi_o^{1/4}\,[2/(\sqrt{3}-1)]^{1/2} \qquad (9)$$

Thus, the possibility of non-linear perturbation formation in an electron beam as a result of its interaction with a wall of final conductivity is considered. The formation of perturbations in electron beam was observed in [2].

REFERENCES

[1]. H.Schamel. Phys. Rep. 1986. V. 140. N 3. P.163-191.
[2]. L.K.Spentzouris, P.L.Colestock, F.Ostiguy. PAC. 1995.