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PROPERTIES OF SOLITARY ELECTRIC POTENTIAL HUMP IN ELECTRON PLASMA

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The properties of collective electric trap for electrons of charged beam are investigated theoretically. This electron beam propagates along magnetic field in cylindrical tube. It is shown that part of beam electrons are trapped in the system.

In this paper the properties of collective electric trap for electrons of charged beam are investigated theoretically. This electron beam propagates with velocity V_b along magnetic field in conducting cylinder. It has been shown that part of the beam's electrons may be tarpped by selfconsistently formed electric potential hump. This hump keeps these electrons inside the conducting cylinder. The dependence of width of electric trap on amplitude of its electric field is investigated.

In magnetized, electron-plasma-filled conducting tube slow solitary structure may exist [1, 2]. During time interval of electron beam injection into a conducting tube an electric potential hump, $\varphi(z)$, is formed due to the dissipative instability or Pierce instability development with maximum growth rate $\gamma \approx V_b/L$. Here L is the length of the system. This potential hump can be transformed into a solitary perturbation on nonlinear stage of instability development. This potential hump could trap fraction of beam electrons during the time of potential hump formation. This paper is concerned with the properties of this kind potential solitary structure. We consider the case of the strong external longitudinal magnetic field, $H_o \to \infty$. Then the electron dynamics is one-dimensional. We choose the initial perturbation in the form of electric potential hump of small amplitude and of width Δz smaller than the system length. In the case of small soliton amplitude, φ_o ($<< T_e$, here T_e is the electron temperature), from the Vlasov equation one can obtain the expression for the velocity distribution function of electrons. Integrating the latter over velocities, one can derive the expression for the electron density perturbation in the second order of $\phi_o = e\varphi_o/T_e$

$$\partial_z \delta n = \partial_t \phi[y + (1-2y^2)(1-R(y))/y] + \partial_z \phi R(y) + \phi \partial_z \phi[1 - y^2 + (1.5 - y^2)(R(y) - 1)], \quad (1)$$

$$R(y) = 1 + (y/\sqrt{\pi}) \int_{-\infty}^{\infty} dt \exp(-t^2)/(t-y),$$

$$y = (V_b - V_o)/V_{th}\sqrt{2}$$

Here V_o, φ are the velocity and potential of the soliton. Substituting (1) in the Poisson equation, one can derive the KdV evolution equation

$$\partial_t \phi[y + (1-2y^2)(1-R(y))/y] + \partial_z \phi R(y) + \phi \partial_z \phi[1 - y^2 + (1.5 - y^2)(R(y) - 1)] - \partial_{zzz}\phi = 0 \quad (2)$$

From (2) one can obtain the equation describing the space distribution of the potential:

$$(\partial_z \phi)^2 = \phi^2 R(y) - [1 + (2y^2 - 3)R(y)]\phi^3/6 \quad (3)$$

From (3) and $\partial_z \phi|_{\phi=\phi_o} = 0$ the expression for $R(y)$ and V_o follows (similarly to [3])

$$R(y) \approx \phi_o/6, \quad V_b - V_o \approx 1.32 V_{th} \quad (4)$$

From (4) one can see that, if beam velocity is close to $1.32V_{th}$, the potential hump is approximately fixed.

We determine roughly the soliton width from (3), (4):

$$\Delta z = (48 T_e/e\varphi_o)^{1/2} \quad (5)$$

The soliton is the "hole" in the electron phase space.

In the case of large amplitudes, $e\varphi_o/T_e > 1$, from the Vlasov equation one can have the expression for the velocity distribution function of plasma electrons (without electrons trapped by a soliton field) $f = f_o[(u^2 - 2e\varphi/m)^{1/2} + V_o \mathrm{sign}(u)]$ for $|u| = |V - V_o| > (2e\varphi/m)^{1/2}$. Here f_o is the Maxwellian distribution function. Thus one can derive the equation for the soliton shape

$$(\partial_z \phi)^2 = -\phi + (2/\sqrt{\pi})^{1/2} \int_{-\infty}^{\infty} dt\, (t-y)^2 \exp(-t^2)\{[1 + \phi/(y-t)^2]^{1/2} - 1\} \quad (6)$$

From (6) the expression for the soliton width follows

$$\Delta z = [2e\phi_o/T_e(\sqrt{2} - 1)]^{1/2} \quad (7)$$

From (7) one can conclude that the soliton width increases with ϕ_o . Hence, taking into account the trapped electrons is important. We assume for their density distribution the following expression $n_{tr}(z) = n_{tro} \exp[e\phi(z)/T_{tr}]$. Here T_{tr} is the effective temperature of trapped electrons. Using last expression one can obtain similarly to (7) that the width of soliton increases with amplitude growing.

These properties of soliton and its amplitude dependences were observed in experiments and numerical simulations [1].

Similar electron trap has been observed in [4].

References

1. I.P.Lynov et al. // *Physica Scripta*, (20). 1979, p.328.
2. H.Tanaka et al. // *Proc. of 9th Int. Conf. On Plasma Physics. Toki.* 1998.
3. H.Schamel // *Plasma Physics*, (14). 1972, p.905.
4. I.K.Tarasov // *VANT*, 1998.