ABOUT BEHAVIOR OF ELECTRONS AND IONS IN THE ACCELERATING INTERVAL

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Abstract

The behavior of the electron-ion ensemble in accelerating gap. Hot electrons are described by the distribution function, which is a solution of the collisionless kinetic equation, which depends not only on the integrals of motion. For a description of cold ions used hydrodynamic equations. The possibility of excess ions ion-acoustic velocity. The equation that determines the relative density of the ions in the case of closed phase trajectories characterizing the dependence of the field on the coordinate

INTRODUCTION

To study the actual recovery process of heavy ions from the plasma carried out a large number of studies on the review of the process models. In [1] it was shown that the plasma leaving the ions at velocities exceeding the ion-sound velocity. Because in the real world, the electron temperature substantially greater than the temperature of the ion number of accelerated ions is exponentially small. Note, however, the work [2], to study the acceleration of a thin ion beam. In this paper we show that the ion velocity can exceed the speed of ion-sound when changing the beam radius .. In [3] studied the state of the accelerated flow of cold ions in resting, in general, the hot-electron cloud. In particular, in [3], the transition layer system "plasma-vacuum" is infinitely large. In all these works the electron current is zero. In [4] studied the equilibrium state of the system in the presence of a nonzero electron current by using hydrodynamic description of electrons. The paper [5] examines the state of the ion flux in the layer of electrons moving in a direction perpendicular to the flow of electrons. In this work, the maximum energy which can acquire ions in a layer equal to the temperature of electrons, whereas in the conditions of [4], the energy can exceed the electron temperature. problems are also considered in [6] studied in the present work.

FORMULATION OF THE PROBLEM

We shall describe the ensemble of collisionless kinetic equation for electrons and ions to describe the hydrodynamic equations, assuming for the sake of simplicity, one-dimensional problem. For electrons, the kinetic equation is:

$$\frac{p}{m}\frac{\partial f}{\partial x}+e\frac{d\Phi}{dx}\frac{\partial f}{\partial p}=0, \qquad (1)$$

where m - the mass of the electron, $-e$ the charge, Φ - the potential, x - coordinate, p - momentum, $f(x,p)$ - particle distribution function.

Let us put

$$f=\sigma\left(p-\sqrt{2m(C_0+e\Phi)}\right)\Psi(H). \qquad (2)$$

Here $\sigma(x)$ - Heaviside function., $C_0>-e\Phi(x)$ for any x. Expression (2) determines non-zero fluid of electrons: $\Gamma_e=\int\limits_{\sqrt{2m(C_0+e\Phi)}}^{\infty}\frac{p}{m}\Psi(H)dp=\int\limits_{C_0}^{\infty}dH\Psi(H)$. In the case of exponential distribution $\Gamma_e=\kappa_0 T\exp\left(-\frac{C_0}{T}\right)$. The electron density in this case is expressed as follows:

$$n_e=\kappa_0\sqrt{\frac{\pi mT}{2}}\exp\left(\frac{e\Phi}{T}\right)\left(1-erf\left(\sqrt{\frac{C_0+e\Phi}{T}}\right)\right) \qquad (3)$$

Here $erf(x)=\frac{2}{\sqrt{\pi}}\int\limits_0^x\exp(-y^2)dy$ - error integral.

The role of the factor $\sigma\left(p-\sqrt{2m(C_0+e\Phi)}\right)$ in the expression (2) is significant - the one hand, the particle density varies view, on the other - particle current is not zero. Using the hydrodynamic description of one-dimensional flow of cold ions, it is easy to obtain $n_i=\frac{\Gamma_i}{\upsilon_i}=\frac{n_{i0}\upsilon_0}{\sqrt{\frac{M\upsilon_0^2}{2}+e\Phi}}$

Here M - ion mass.

Put the fluid density as: $\Gamma_i=n_{0i}\upsilon_0$, n_{0i} - initial ion density, υ_0 - initial ion velocity. If we introduce the dimensionless potential $u=\frac{e\Phi}{T}$ and to identify the ion-sound velocity $\upsilon_s=\sqrt{\frac{2T}{M}}$, the ion density becomes:

$$n_i=\frac{n_{i0}\upsilon_0}{\upsilon_s\sqrt{\frac{\upsilon_0^2}{\upsilon_s^2}-u}}$$

Let $n_{0e}=\kappa_0\sqrt{\frac{\pi mT}{2}}$

We introduce the dimensionless variables: $t=\frac{x}{l_0}$, $l_0=\sqrt{\frac{T}{4\pi e^2 n_{0e}}}$, $\frac{C_0}{T}=\zeta_0$. Then the Poisson equation becomes:

$$\frac{d^2u}{dt^2}=\exp(u(t))\left(1-erf\sqrt{\zeta_0+u}\right)-\frac{\nu_i}{\sqrt{\frac{\upsilon_0^2}{\upsilon_s^2}-u(t)}} \qquad (4)$$

Here $\nu_i=\frac{n_{0i}}{n_{0e}}\frac{\upsilon_0}{\upsilon_s}$.

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Equation solution.

Equation (4) has integral looking as:

$$\frac{\dot u^2}{2}=\exp(u)-\exp(u)\,erf\sqrt{\zeta_0+u}+$$

$$\frac{2}{\sqrt{\pi}}\exp(-\zeta_0)\sqrt{\zeta_0+u}+2\nu_i\sqrt{\frac{\upsilon_0^2}{\upsilon_s^2}-u}+C_*. \qquad (5)$$

Consider solutions (5), characterized by closed phase trajectories $\dot u(u)$ - dependence field from the potential. There should be two points where $\dot u$ vanishes. If $\dot u(-4)=0$, then $0=e^{-4}+2\nu_i\sqrt{\frac{\upsilon_0^2}{\upsilon_s^2}+4}+C_*$, and if $\dot u\left(\frac{\upsilon_0^2}{\upsilon_s^2}\right)=0$, then

$$0=\exp\left(\frac{\upsilon_0^2}{\upsilon_s^2}\right)\left(1-erf\left(\sqrt{4+\left(\frac{\upsilon_0^2}{\upsilon_s^2}\right)}\right)\right)+\frac{2}{\sqrt{\pi}}e^{-4}\sqrt{4+\left(\frac{\upsilon_0^2}{\upsilon_s^2}\right)}+C_*$$

From these equations, it follows that the ion density, characterized by a quantity ν_i is not arbitrary. Given that $\nu_i=\frac{n_{0i}}{n_{0e}}\frac{\upsilon_0}{\upsilon_s}$ we have a system of three equations for $C_*,\nu_i,\frac{\upsilon_0}{\upsilon_s}$. When $\frac{n_{0i}}{n_{0e}}=1$ we get the equation:

$$\exp\left(\nu_i^2\right)\left(1-erf\sqrt{4+\nu_i^2}\right)+\frac{2}{\sqrt{\pi}}\exp(-4)\sqrt{4+\nu_i^2}$$

$$=\exp(-4)+2\nu_i\sqrt{4+\nu_i^2}. \qquad (6)$$

Solving (6) we obtain:

$$\nu_i\cong 0.007=\frac{\upsilon_0}{\upsilon_s},\ C_*\cong -0.046316.$$

At Fig.1. phase trajectory $\dot u(u)$ is shown. Trajectory has closed character – ions are accelerated from initial point where $u=-4$ to the point where $u=0.4\cdot 10^{-4}$.

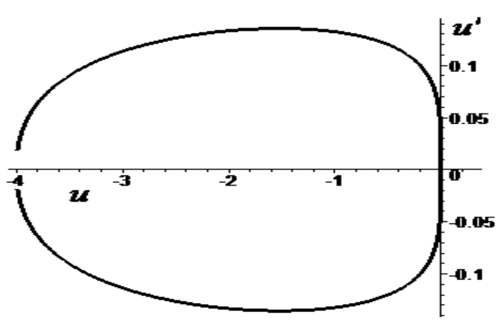

Figure 1: phase trajectory $\dot u(u)$.

It is possible, then, to build a relationship of ion density on the coordinate (Fig.2.).

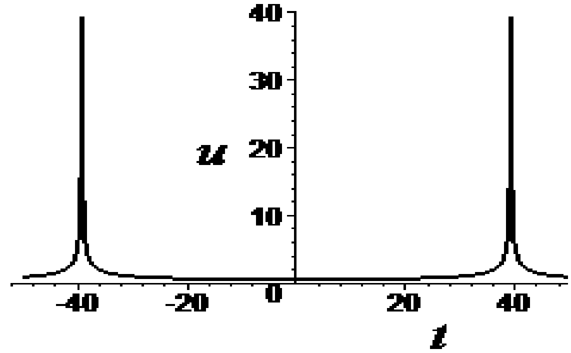

Figure 2: The dependence of ion density on the coordinate At certain points there is a maximum ion density. At these points, the ions have a minimum speed, the maximum speed - the points where the ion density is minimal.

At Fig. 3 - the dependence of the electron velocity on potential.

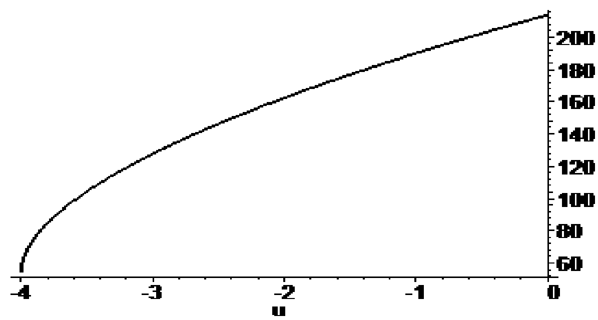

Figure 3: The dependence of electron velocity on potential.

The average hydrodynamic energy of the electrons increases with increasing potential, whereas the energy of the ions decreases when moving in the opposite direction.

CONCLUSION

Thus, in work it is shown that in case of acceleration of ions in a stream of hot electrons at a certain ratio for density of ions a phase trajectory - dependence of the field on potential - has the closed character

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