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A QUASINEUTRAL EXPANSION OF PLASMA BUNCH INTO VACUUM: BEYOND THE "PLASMA APPROXIMATION"*

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"The plasma approximation" is known to be applicable to low-frequency and steady-state phenomenon, popular among plasma scientists in various fields [1]. Sometimes more appropriable term is used here "the plasma condition" [2], i.e. the number of electrons in a Debye sphere is large enough to effect charge shielding. But the utilizing it leads to inconsistencies in the equation of motion and prevents a proper, field-theoretic treatment of a condensed matter in the plasma state. This circumstance takes place due to the fact that if the plasma reaches a quasi-neutral state $n_e \approx n_i$, its space charge is approximately equal to zero $\rho \approx 0$. According to Poisson equation this leads to $\boldsymbol{E} = 0$. But the "plasma approximation" states that $\boldsymbol{E} \neq 0$ and the electric field can be found elsewise [1]. Such a separation of the initially consistent solution of plasma and field equations in the most cases leads to ambiguous multivalued interpretation of the electric field definition. That is the main methodological drawback of the "plasma approximation".

One of the fundamental problems where the "plasma approximation" seems to be the most appropriate choice is the problem of a spatially inhomogeneous quasi-neutral bunch expansion of dense plasma into a vacuum gap. The process in this case is essentially nonstationary. It is accompanied by considerable cooling of electrons and therefore the study of this process requires special approaches. The analytical investigations of this problem have been carried out both in terms of phenomenological hydrodynamic [4] and kinetic models [5].

This paper is aimed to clarify the details of a two-component plasma bunch expansion into free space by numerically solving the system of Poisson-Vlasov equations. Its main purpose is to show the features of this process without using the "plasma approximation". For simplicity, but without loss of generality, we solve the problem of plasma expansion in a one-dimensional Cartesian spatial configuration. The calculation results are compared with the exact solutions of the Vlasov equations with the "plasma approximation" taken from paper [5].

REFERENCES

[1] F. F. Chen, Introduction to Plasma Physics and Controlled Fusion: Springer, 1984, ISBN 0306413329

[2] K. Nishikawa and M. Wakatani, Plasma Physics: Basic Theory with Fusion Applications: Springer, 2000

[3] A.V. Gurevich, L.V. Pariskaya, and L. P. Pitaievskii, "Self-similar motion of rarefied plasma," Sov. Phys. JETP 22, 449, 1966

[4] C. Sack and H. Schamel, "Plasma expansion into vacuum — A hydrodynamic approach," Physics Reports, vol. 156, no. 6, pp. 311–395, Dec. 1987.

[5] D. S. Dorozhkina and V. E. Semenov, "Exact Solution of Vlasov Equations for Quasineutral Expansion of Plasma Bunch into Vacuum," Physical Review Letters, vol. 81, no. 13, pp. 2691–2694, Sep. 1998.

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