Investigation of thermodynamic properties of quasi-two-dimensional dissipative systems with Yukawa interaction

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Laboratory dusty plasma represents a good experimental model for testing the existing phenomenological models in the theory of liquid state, as well as for creating new models. One of important questions of the statistical theory of the liquid state is prediction of the thermodynamic behavior of coupled systems depending on the character of interparticle interaction.

The best-known model for pair interaction of dust particles in plasma is based on the screened potential of Yukawa type: $\phi(r) = (Ze)^2 \exp(-r/\lambda)/r$, where r is the distance, λ is the screening length. In case of isotropic pair interaction potential $\phi \equiv \phi(r)$, physical properties of simple liquids, e.g. pressure P and energy density U, are completely determined by the pair correlation function $g(r)$ [1]. Note that if both *thermal* $P = P(T,n,\phi,g)$ and *calorific* $U = U(T,n,\phi,g)$ equations of state are known, it is possible to find all the thermodynamic characteristics with the help of general thermodynamic relationships.

The most calculations of physical properties of dusty structures in plasma are performed either for three-dimensional Yukawa systems or for pure two-dimensional systems, with neglect of the dissipation of particles' energy, which is caused by collisions with the neutral particles of the buffer gas. Here we present the results of numerical study of thermodynamic properties for dissipative systems of macroparticles in a single dust layer trapped in an external electric field.

As a result of numerical simulations, the correlation functions g(r) were obtained. Together with the given potential of Yukawa type $\phi(r)$, they were used to analyze the thermodynamic properties of the structures under study, namely, to calculate $P(T,n,\phi,g)$, $U(T,n,\phi,g)$, χ_T and the value of reduced heat capacity $C_V = (\partial U/\partial T)_V$. In this work, we propose the approximations of $P/(Tn)$ and U/T that are in a better agreement with the results of numerical simulations than approximations proposed in literature.

In contrast to 3d- systems we have found that there are two singular points for all characteristics of 2-d Yukawa systems under study. First of them (for $\Gamma^* \sim$ 67-70) may be related to the liquid-to-hexatic phase transitions, second ($\Gamma^* \sim$ 100-110) is the crystallization point of analyzed systems in a solid with the hexagonal lattice (hexatic-to-solid phase transitions).

References

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