PHASE TRANSITIONS IN DUSTY PLASMA SYSTEMS OF RF-DISCHARGE

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Dusty plasma (consisting of electrons, ions, neutral gas and solid macro-particles of micron sizes) is a good experimental model for studying of phase transitions in non-ideal systems, because, owing to their size, dust particles may be videofilmed that significantly simplifies the use of direct diagnostic methods. Dusty plasma is ubiquitous in nature (in space, in planetary atmospheres etc.) and often appears in a number of technological processes (for example, in semiconductor's processing). Quasi two-dimensional (2D) dust structures, which consist of from 1 to ~ 10 dust layers, are typical for plasma of radio frequency (RF-) discharge.

According to the Kosterlitz-Thouless-Halperin-Nelson-Young (KTHNY) theory based on unbinding of topological defects (dislocations and disclinations), the 2D system supports two ordered solid phases with the same packing symmetry [1-3]. In the first of them both positional order and bond orientation have long-range. The second (so called hexatic phase) has the short-range positional order and the quasi-long-range bond orientation. Thus, the transitions from the solid to the liquid occur with the formation of intermediate hexatic phase. It often occurs that by melting of a quasi-two-dimensional structure in dusty plasma of RF discharge the collective rotational excitations of dust take place [4-5], which is one of the features of formation of hexatic phase, as it was described in KTHNY theory.

It is known that the weakening rate of the pair correlation function $g(l)$ peaks g^s characterizes the phase state of a 2-d system. Usually, the following approximations are used to estimate this rate [6]:

exponential

$$g^s = 1 + (g_{\max} - 1)\exp\left[-\mu(l - l_{\max})/l_p\right], \qquad (1)$$

power-law

$$g^s = 1 + (g_{\max} - 1)\left(1 + (l - l_{\max})/l_p\right)^{-\eta} \qquad (2)$$

Numerical simulations of quasi-two dimensional dissipative dusty plasma systems have shown [7], that the accuracy of the exponential approximation is about 5% for $\Gamma^* \leq 15$. For Γ^*

from ~25 to ~150, the mean-square error of the exponential approximation grows from ~10% to ~150%, accordingly. And the parameters of these approximations practically don't change (η =1.6, μ = 0.6) for 153 > Γ^* > 110. The parameters μ and η of approximations (1) and (2), obtained in [7], are shown in Fig. 1. For the increasing Γ^* (Γ^* > 165), the weakening of the pair correlation function peaks g^s can be described [6] by the following power-law approximation:

$$g^s \propto \left(l/l_p\right)^{-\eta}, \qquad (3)$$

with η<1/3 for all the peaks of $g(l)$, excluding the very first one.

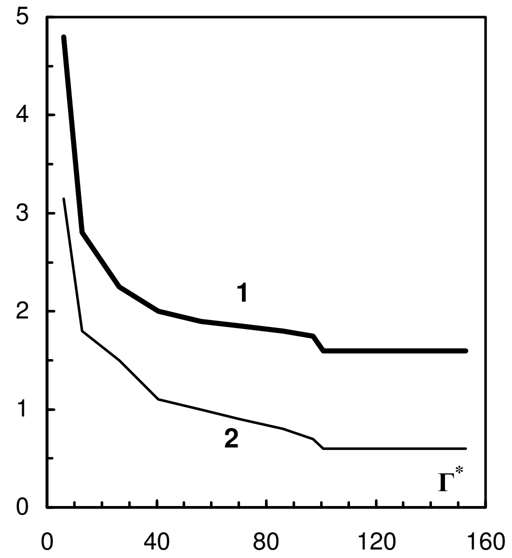
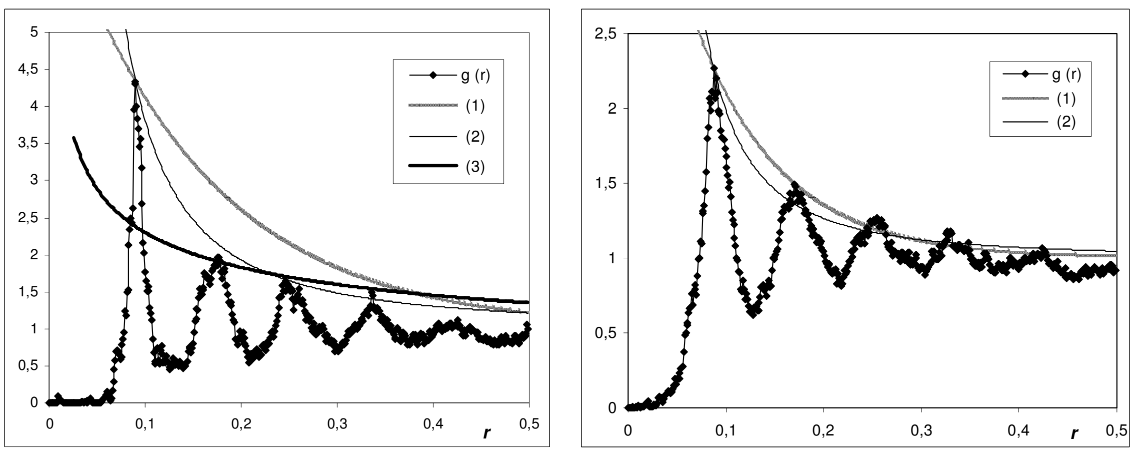


FIGURE 1. The coefficients of power-law η (**1**) and exponential μ (**2**) approximation of the weakening of pair correlation function versus Γ^* parameter [7].



(a) **(b)**

FIGURE 2. Pair correlation functions for dusty subsystems with (a) Γ^* = 205 and (b) Γ^* = 55 (line + markers). Dotted line corresponds to the exponential approximation (1), thin line – to the power-law approximation (2), and the bold line – to the power-law approximation (3).

In this work, we considered the quasi-2D systems, where the areas with different phase states (dusty liquid and dusty crystal) coexist. We analysed the experiments carried out in RF discharge in argon; the pressure of the buffer gas was 2..16 Pa. The grains of 5.5 μm in diameter were used. The effective coupling parameters Γ^* of dusty systems under study varied from 20 to 250. We have found the pair correlation functions of these areas of dusty subsystem. Then their slopes were analysed and compared with the numerical results.

An example of such comparison is presented in Fig. 2, where part (a) corresponds to the more correlated part of a dust structure, and part (b) – to the less correlated one. It can be easily seen that the exponential approximation (1) with numerically obtained parameter μ doesn't work in case of a dusty crystal, and the error is quite large. As for the power-law approximation (2) and exponential (3), they quite well describe the slopes of pair correlation functions within the range of experimental error for both parts of the dusty subsystem.

In Fig. 3 are presented the results of comparison of experimental results with the numerical predictions. It can be easily seen that the exponential approximation (1) with the parameters obtained in numerical simulation satisfactorily describe the systems with small Γ^* ($\Gamma^* < 50$), the approximation (3) is applicable for the systems with $\Gamma^* > 150$, and the power-law approximation (2) can be used with an adequate accuracy for all Γ^* investigated. Nevertheless, it seems that the values of approximation parameters μ and η could somehow be corrected for the systems under study.

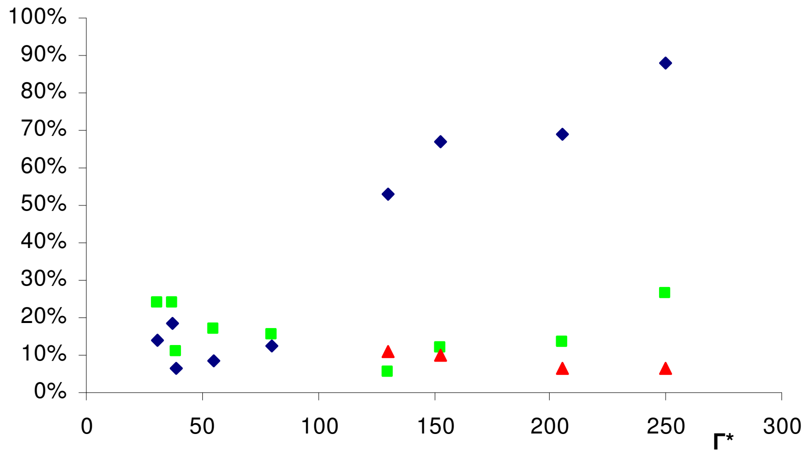


FIGURE 3. The error of the approximations: ◆ - exponential (1), ■ - power-law (2), ▲ - exponential (3). The values of parameters μ and η of these approximations were taken from the results of numerical simulation [7].

Acknowledgements

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