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The Modern Information Technologies and Visualization Methods for Analysis of Computer Simulation Results for Complex Plasma

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Abstract. In this paper we present a software package based on modern information technologies that allows rapid analysis and visualization of the properties of complex plasmas. The properties of plasma are simulated by two means. First of all, we have applied the molecular dynamics simulation method which numerically solves the equations of motions for plasma particles. Secondly, we calculate microscopic properties of plasma by using the Boltzmann equation with additional relations, initial and boundary conditions.

AMS subject classifications: 68N19, 68U20, 68U35

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1 Introduction

Scientific visualization is becoming a key ingredient of research, development, and discoveries in numerous fields of science and technology. Scientific visualization systems help not only to represent the results of calculations, but also to integrate and analyze the results of calculations and experiments accumulated earlier [1, 2].

At the present time the study of the complex plasma properties is not only of fundamental interest, but it also has various important technological applications. It is known that as a result of computer simulation we obtain many complicated graphical dependencies. During design engineering of real technological projects it is necessary to imagine

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complicated processes in complex plasma. In this connection the role of visualization methods for analysis of processes in complex plasma is important.

In the present work two types of plasmas have been considered: in the first part the semiclassical dense plasma with a density of particles $10^{21}-10^{24}cm^{-3}$ and temperature 10^4-5*10^5K is discussed. In the second part the dusty plasma with electron and ion densities $n_i \approx n_e \sim 10^7-10^9cm^{-3}$, and the density of dust particles may vary in a wide range $n_d \sim (10^3-10^8)cm^{-3}$ which arises in the DC and RF gas discharges is studied. Such plasma occurs in many natural phenomena, laboratory facilities, and the implementation of various technological processes. In both cases the plasma is strongly coupled (non-ideal), i.e. when the electrostatic interaction energy of the particles is comparable to their average thermal energy. It means that in order to determine physical properties of plasma different approximation theories, in particular, the perturbation theory could not be applied due to the absence of a small parameter in the system. In this connection, the computer simulation methods of the plasma properties based on numerical solutions of the equations of motions for the particles (MD method), Boltzmann equation, etc. are widely used. The difference between these methods from each other is that in the first case, for simulation of microscopic and transport properties of the plasma it is necessary to know the interaction potential between particles in the system, in the second one the collision integrals are needed in terms of the corresponding scattering cross sections of the plasma particles. The application of these methods imposes definite limitations, in particular, we investigate the semiclassical plasma which consists of classical ions and degenerate electrons. It is supposed for applying of the Boltzmann model the background plasma is sufficiently rarefied, therefore, it is possible to use the known model particle scattering cross sections of the system. In addition, there are specified limitations relating to the applicability of interaction models between plasma particles, which are discussed in detail in [3–5].

We have developed the program software "PLASMA" using object-oriented programming environment Delphi7 and graphics library OpenGL, which includes two large software packages: "Simulation of properties of two-component plasma on the basis of molecular dynamics method" and "Characteristics of discharge and dusty plasma in DC glow discharge".

The first information system includes the program software allowing the investigation of two-component plasma on the basis of computer methods of molecular dynamics and visually track the movement of the particles. The second information system includes the program software allowing obtaining the values of axial and radial distributions of dusty plasma parameters in discharge tube at different parameters on the basis of the Boltzmann equation.

The program package includes system, instrumental and applied software. The choice of programming language was based on such criteria as the rate of the application development, the possibility of building a friendly and reliable interface, the possibility of including databases by means of language itself, for realization process simulation functions, widened mathematical apparatus, effective compilation, availability of the system