Electron trapping in ultra-cold plasma cloud

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In the present work, we have dedicated the study of trapping electrons in a cloud of ultra-cold plasma using molecular dynamic simulation. The simple case was studied using only a Coulomb potential as source of interaction. The forces have been calculated using a hierarchical tree code that allows the increase in velocity of computation compared to conventional methods in molecular dynamics. In this case, we have performed the simulations after the ionization of the cloud of cold atoms since we are interested only to the expansion of the particles. During the expansion, we have observed the effect of trapping, and the quasi equilibrium of the particles like the Thomas-Fermi quasi-equilibrium found in the literature.

1. Introduction

Ultra-cold neutral plasmas have become an attractive topic of study in the recent years. They are produced by photo-ionizing laser-cooled cloud of atoms near the ionization threshold [1, 2]. In these systems, the temperature of the electrons can vary in the range of 1K to 1000K, while the ion temperature can be around 100μK to 1K [3].

The evolution of an ultra-cold neutral plasma can be divided into three different stages. The first stage is characterized by the equilibration of the electrons. The second stage is the equilibration of the ions. The last stage is the expansion of the plasma.

During the expansion of the plasma, free electrons scape from the cloud creating an imbalance of charge due to excess of ions that create a small electric field that trap the remaining electrons.

In the present contribution, we tried to show using molecular dynamics simulations, that the effect of electron trapping in an ultra-cold neutral plasma, lead to a model like the known Thomas-Fermi model for heavy atomic systems [4].

2. Numerical Method

In this work, we have used classical molecular dynamics to simulate the dynamics of the ultra-cold plasma after ionization. The Coulomb force in this simulation is calculated using the interaction between the particles using the hierarchical tree method. This method increases the velocity of the simulation and scales as N log(N). Allowing us to increase the number of particles compared to the classical method of pair-wise the interaction.

A reduced ion-electron mass ratio m_i/m_e =100 is applied to reduce the time cost of the simulation, and we have used 50000 electrons and 50000 ions as the number of particle to simulate. We set the initial density with a Gaussian profile, which is common found in experiments. The positions of all particles are initialized randomly. The velocities are defined randomly with Gaussian distribution, in sense the initial temperature of the electrons is $T_e(0)$ = 10K and the initial temperature of the ions is $T_i(0)$ = 0K.

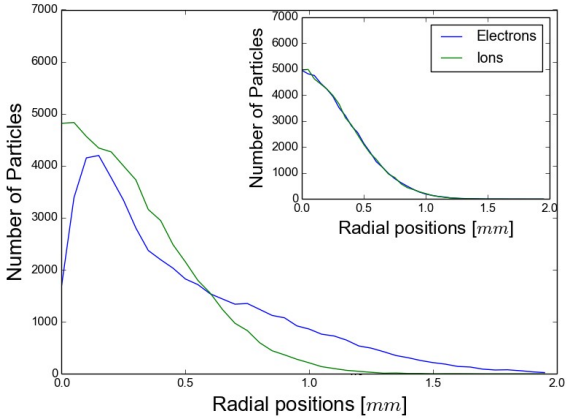

Figure 1. The results of the simulation that computes the number of particles in a radial distribution. Insight figure shows the initial distribution of the particles. The main figure, shows the evolution and the trapping of the electrons after 20 ω^{-1}_{pe}.

3. References

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