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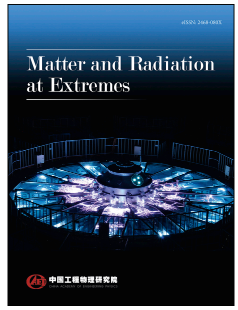

Relaxation of non-isothermal hot dense plasma parameters

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The relaxation of temperature, coupling parameters, the excess part of equation of state, and the correlation energy of the non-isothermal hot dense plasmas are considered on the basis of the method of effective interaction potentials. The electron-ion effective interaction potential for the hot dense plasma is discussed. The accuracy of description of the dense plasma properties by the effective electron-ion interaction potential is demonstrated by the agreement of the derived quantities like stopping power and transport coefficients calculated using our methodology with the results of the finite-temperature Kohn-Sham density-functional theory molecular dynamics, and orbital-free molecular dynamics results as well as with the data obtained using other theoretical approaches.

I. INTRODUCTION

Dense plasma is a subject of active experimental and theoretical investigations due to its importance to the inertial confinement fusion. The dense plasma forms in the experiments on heavy ion driven fusion [1–3], experiments at the National Ignition Facility [4], and magnetized Z-pinch experiments at Sandia [5]. To obtain a thermonuclear reaction in the above-mentioned facilities, the comprehensive study of transport properties and relaxation time of the temperature of dense plasma is required. During compression of a target by the flow of high-energy particles, the non-isothermal plasma with different temperatures of electrons and ions is created. Therefore, it is especially important to study relaxation time of electrons and ions. The temperature equalizes much faster within electronic and ionic subsystems than between electrons and ions. This is due to a large difference between masses of an ion and an electron. Computer simulation can answer many questions and, therefore, becomes the main theoretical method.

Programs for simulation and calculation of inertial confinement fusion targets are extremely complex and need a lot of computation time. The complexity of calculations is caused by a large number of different physical processes: temperature relaxation, change of thermodynamic properties, energy absorption, stopping power, etc. In fact the description of one or more of these processes is already quite complicated.

One of the methods which allows fast calculation of the physical properties of isothermal plasmas is the method of effective interaction potentials. This method [8–30] can provide possibility of fast and accurate calculations of temperature relaxation time, stopping power, and transport coefficients of dense plasmas.

In this approach, the screening (collective) and quantum diffraction effects are absorbed into an effective screened potential Φ:

$$\Phi_{\alpha\beta}(\boldsymbol{r}) = \int \frac{\mathrm{d}^3 k}{2\pi^2} \frac{\phi_{\alpha\beta}(r)}{\epsilon(\boldsymbol{k},\omega)} \mathrm{e}^{\mathrm{i}\boldsymbol{k}\cdot\boldsymbol{r}} \quad , \tag{1}$$

where $\phi_{\alpha\beta}(r)$ is the pair interaction potential, and $\epsilon(\boldsymbol{k},\omega)$ is the dielectric function. Further, we consider the static case $\omega = 0$.

The simplest model describing screened point-like charge potential is a Yukawa potential:

$$\Phi_{\mathrm{Y}}(r; n, T) = \frac{Q_1 Q_2}{r}\, \mathrm{e}^{-k_{\mathrm{Y}} r}, \tag{2}$$

with the familiar inverse Yukawa screening length, k_{Y}.

Yukawa potential (2) can be derived using Thomas-Fermi model [25], or long wavelength limit of the polarization (response) function in random phase approximation (RPA) . Recently, screened ion potential taking into account the Kirzhnits first order gradient correction to the noninteracting free energy density function was obtained by Akbari-Moghanjoughi [26] for zero temperature limit on the basis of the quantum hydrodynamic theory and at the finite temperature by Stanton and Murillo (S-M) in the framework of the orbital-free density functional theory (OFDFT) [25].

Analysis of the available analytical formulas for the screened ion potential has been performed by Moldabekov et al. [27]. In Refs. [9, 25–27, 32–35], the ion potential (ion-ion interaction potential) in the static limit which takes into account the quantum non-locality (diffraction) effect caused by electrons was considered. Dynamically screened potentials in classical, quantum as well as relativistic systems were analyzed in Refs. [17, 36–41].

In this paper, we present results for stopping power, transport coefficients, and temperature relaxation obtained using the effective interaction potential between electrons and ions in dense plasmas. The effective potential is derived using the long wavelength expansion of the polarization function and quantum potential which takes

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