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THE INFLUENCE OF THE COLLECTIVE EFFECTS IN PLASMA, BEHIND SIMPLE CUT-OFF

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Abstract. The modeling of plasma behavior from mid up to strong non-ideality, e.g. plasma with a dominant Coulomb interaction is of interest. The micro field is strongly dependent on a form of used pseudo-potential. It is important to have in mind that the plasma behavior is considered as a variation to the main form of a potential. It was obvious from previous papers that the pseudo-potentials used in solid state physics, e.g. ab-initio ones, could be used successfully in describing of a dense plasma. Here we present the candidates potentials calculated with ab-initio method that should be analyzed in order to be used for describing a dense plasma. As a result, after studying of the potentials, it is expected to have a method of introducing a more complex atoms and ions in existing plasma model.

1. THEORETICAL REMARKS

In the dense plasma the inter-particle Coulomb interaction becomes dominant over the thermal kinetic energy (Fortov et al. 2006). In such conditions a coupled system of particles behaves partially like a crystal. The simplified version, for hydrogen case, of non-ideality parameter Γ is given by

$$\Gamma = \frac{E_p}{E_k} = \frac{e^2}{kTr_{WS}} \sim e^2 N_e^{1/3} \beta, \qquad \beta = 1/kT, \qquad r_{WS} = \left(\frac{3}{4\pi N_e}\right)^{1/3}. \tag{1}$$

The plasma interaction, cut-off Coulomb potential, was used successfully previously, see for example Dimitrijević, et al (2018), Srećković, et al. (2018), Mihajlov, et al. (2015), Ignjatović, et al. (2009). Although the expected plasma influence should be governed in the far field concerning a ionic core radius, it is expected to have a strong influence of the form of a ab-initio yielded pseudopotential. The area of interest in Hydrogen model is in range of $0.1 \leq \Gamma \leq 1.5$, while for other species the thourough investigation of model behavior is needed.

2. THE PSEUDO-POTENTIAL

The describing plasma depends of two parts, the atom/ion content, as well as plasma influence. While the plasma influence is described as a collective phenomena, the atom and ion influence is described with the help of pseudo-potential. The idea of describing a complex atom dense plasma as well as describing of complex atom mixtures plasma arises. The atom and ion influence should be described by the ionic core of the adequate complex atom and ion, while the plasma influence is described with the collective phenomena modeling.

Since the slow processes could be described as a pseudo-static ones, they could be included in a potential. The influence of ions could be described directly as a sort of crystaline structure. It processes a smallest inter-ionic distance so the emitter could feel a averaged potential of several layers of ions.

Besides mentioned approach, there are several ab-initio calculations that are potential candidates for generating a pseudo-potentials capable for being used in dense plasma modeling. Our choice was ATOM, the program originally written by Sverre Froyen at the University of California at Berkeley, and now maintained by Alberto Garcia.

It is expected that presented approach of pseudo static ionic content in plasma could also enable a inclusion of more complex atom and ion plasma models. A first step the comparison of exact model for Hydrogen with previously used Opium code generated one as well as ATOM generated should be carried out.

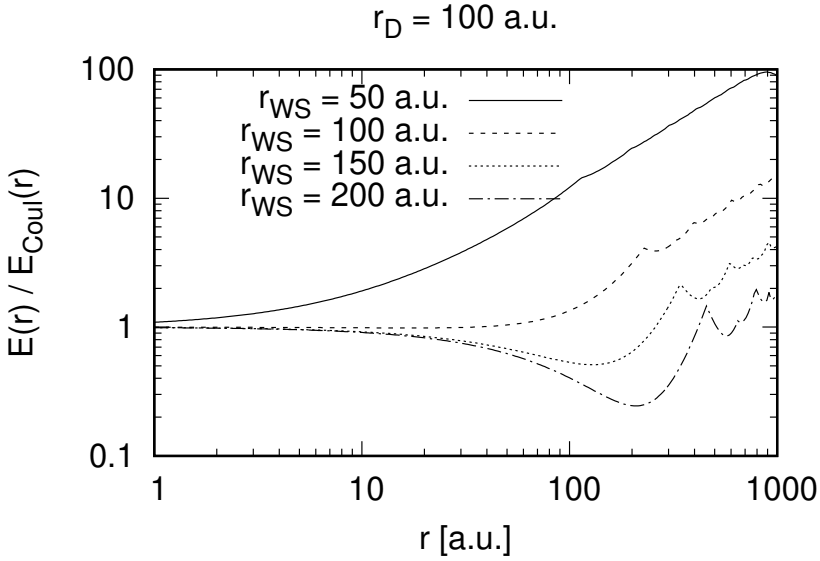

Figure 1: Dependence on ion density

3. RESULTS AND CONCLUSIONS

As a first step approach was to model the behavior of ionic collective phenomena as simple as possible and to have insight of influence of various processes.

The screening is modeled as a Debye one, although it is known that this kind of screening model does not describe a behavior of dense plasma completely, it posses a analytical form and could be easily included within analyzed model.

As a first model analysis a sensitivity on ion density is shown in Figure 1. Here it could be concluded that more dense ionic content is, faster it converges towards the constant value, e.g. it becames a constant slope in the right part of a graph with larhe r. From this it could be concluded that the cut-off model describes well a plasma of high densities.

From Figure 2 it becames obvious that if more intense screening is more separate ion influence is even in a case of plasma of high densities. The cut-off is not capable to adequately describe a plasma with high screening.

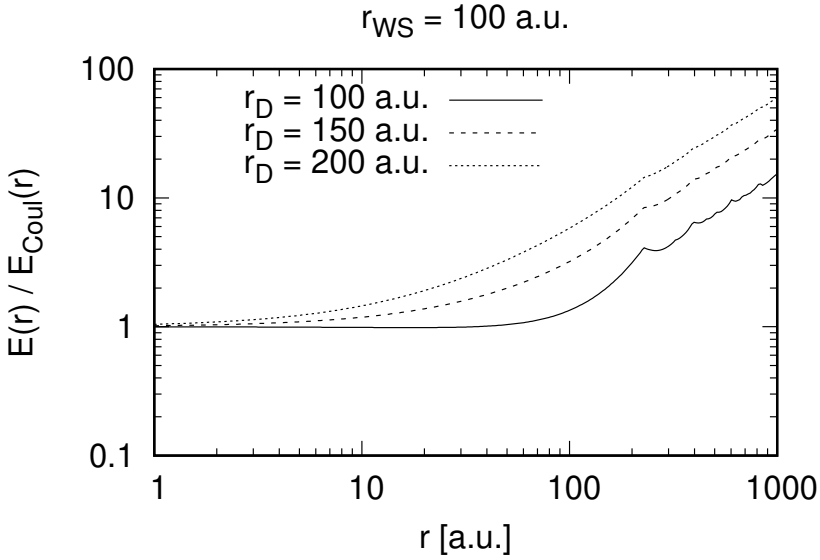

Figure 2: Dependence on screening length

From Figure 3 the influence on size of modeled pseudo crystal is shown. The behavior for single layer and 2 layer model is presented, the validity of describing is good up until a strongest local maximum in a area of $r \gg r_c$. The figure is more illustrative, since in every case of modelling it is necessary to have a prior investigation of adequate model size. The computing time depends strongly on number of layers.

The idea of inclusion of calculations of collective phenomena of ionic content is a inclusion of ionic processes directly in pseudo-potential. From the shown it could be deduced that this approach could lead to applicable results, capable of describing a plasma behavior more precisely than a cut-off model with the usage of non extensive computing power facilities, e.g. it could be available to model a desired plasma behavior on demand.

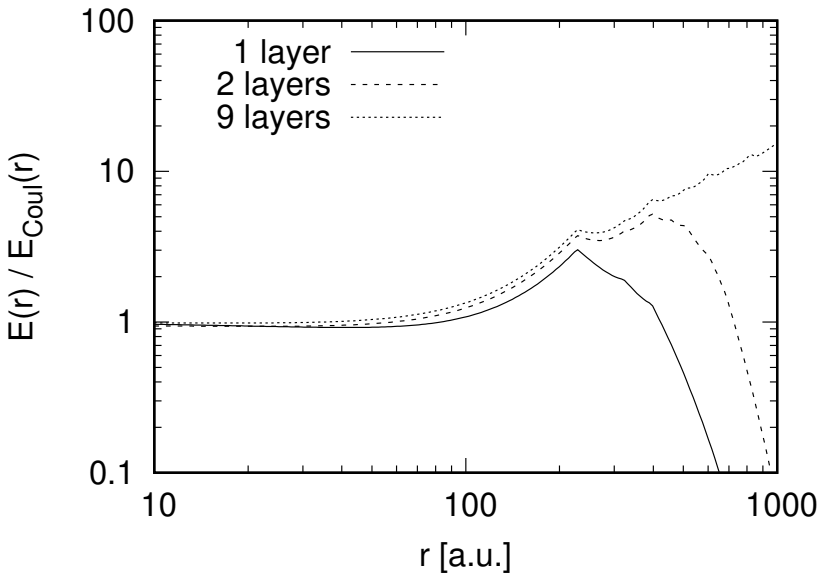

Figure 3: Dependence on number of layers

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