Stopping power of electron gas

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The polarizational stopping power of heavy ions in fully ionized plasmas is described by the Lindhard formula [1]:

$$\left[-\frac{dE}{dx}\right]^{pol}=\frac{2\left(Z_p e\right)^2}{\pi v^2}\int_0^{\infty}\frac{dk}{k}\int_0^{kv}\omega^2\left(-\mathrm{Im}\left[\frac{\varepsilon^{-1}(k,\omega)}{\omega}\right]\right)d\omega,$$

whose high-velocity asymptotic form was found by Bohr, Bethe, and Larkin [2]:

$$\left[-\frac{dE}{dx}\right]^{pol}_{v\to\infty}\cong\left(\frac{Z_p e\omega_p}{v}\right)^2\ln\left[\frac{2m_e v^2}{\hbar\omega_p}\right].$$

The plasma inverse dielectric function (IDF), $\varepsilon^{-1}(k,\omega)$, was determined in [3] within the moment approach [4], complemented by some physical observations in terms of two characteristic frequencies ω_1 and ω_2, which are the ratios of the frequency power moments of the IDF imaginary part, in the following form:

$$\varepsilon^{-1}(k,\omega)=1+\frac{\omega_p^2\left(\sqrt{2}\omega_1\omega+i\omega_2^2\right)}{\sqrt{2}\omega_1\omega\left(\omega^2-\omega_2^2\right)+i\omega_2^2\left(\omega^2-\omega_1^2\right)}.$$

The frequencies ω_1 and ω_2 can be rigorously evaluated using the static structure factor (SSF) of the system. Nevertheless, here we employ the following interpolating expressions [5,6]:

$$\omega_1^2=\omega_1^2(k)=\omega_p^2\left(1+k^2k_D^{-2}+k^4k_q^{-4}\right),\qquad \omega_2^2=\omega_2^2(k)=\omega_p^2\left(1+\frac{\left\langle v_e^2\right\rangle k^2}{\omega_p^2}-\frac{v_{\mathrm{int}}^2k^2}{\omega_p^2}\right),$$

The interpolation and fitting parameters introduced are chosen as follows:

$$v_{int}^2=-\frac{4}{15}\frac{\Gamma^{3/2}}{\beta m_e}\left(\frac{-0.9052}{\sqrt{0.6322+\Gamma}}+\frac{0.27243}{1+\Gamma}\right),\ \Gamma=\beta e^2/a,\ k_q^4=12r_s/a^4,\ r_s=a/a_B,$$

a and a_B are the Wigner-Seitz and Bohr radii, respectively, $\beta=1/(k_BT)$, k_D^{-1} is the Debye radius, k_B stands for the Boltzmann constant with T being the plasma temperature.

The numerical results obtained for the energy losses of heavy ions moving in an electron gas are found in good agreement with the PIC simulation data [7].

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