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Self-similar expansion of finite-size non-quasi-neutral plasmas

MASAKATSU MURAKAMI, Institute of Laser Engineering, MIKHAIL BASKO, Institute of Theoretical and Experimental Physics — A new self-similar solution is presented which describes non-relativistic expansion of a finite plasma mass into vacuum. It is the first analytical solution which treats the effect of charge separation in a fully consistent way and allows a self- consistent determination of the position of the ion front and of the maximum energy of accelerated ions. The solution exists only when the ratio $\Lambda = R/\lambda_D$ of the plasma scale length R to the Debye length λ_D is invariant, i.e. under the condition $T_e(t) \propto [n_e(t)]^{1-2/\nu}$, where $\nu = 1$, 2, and 3 corresponds, respectively, to the planar, cylindrical, and spherical geometries. For $\Lambda \gg 1$ the position of the ion front and the maximum energy $\mathcal{E}_{i,max}$ of accelerated ions are calculated analytically: in particular, for $\nu = 3$ one finds $\mathcal{E}_{i,max} = 2ZT_{e0}W(\Lambda^2/2)$, where T_{e0} is the initial electron temperature, Z is the ion charge, and W is the Lambert W-function. It is argued that, when properly formulated, the results for $\mathcal{E}_{i,max}$ can be applied more generally than the self-similar solution itself.

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