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 $\lambda_D$ is invariant, i.e. under the condition $T_e(t) \propto [n_e(t)]^{1-2/\nu}$, where $\nu = 1, 2, \text{ and } 3$ corresponds, respectively, to the planar, cylindrical, and spherical geometries. For $\Lambda \gg 1$ the position of the ion front and the maximum energy $E_{i,max}$ of accelerated ions are calculated analytically: in particular, for $\nu = 3$ one finds $E_{i,max} = 2ZT_{e0}W(\Lambda^2/2)$, 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 $E_{i,max}$ can be applied more generally than the self-similar solution itself.