THEORY OF ION BEAM PULSE NEUTRALIZATION BY A BACKGROUND PLASMA IN A SOLENOIDAL MAGNETIC FIELD*

Igor D. Kaganovich, Edward A. Startsev and Ronald C. Davidson, Plasma Physics Laboratory, Princeton University, Princeton, NJ 08543, USA

Dale Welch, Mission Research Corporation, Albuquerque, NM, 87110-3946, USA

Ion beam pulse propagation through a background plasma in a solenoidal magnetic field has been studied analytically. The neutralization of the ion beam pulse current by the plasma has been calculated using a fluid description for the electrons. This study is an extension of our previous studies of beam neutralization without an applied magnetic field [1,2]. The high solenoidal magnetic field inhibits radial electron transport, and the electrons move primarily along the magnetic lines. For high-intensity ion beam pulses propagating through a background plasma with pulse duration much longer than the electron plasma period, the quasineutrality condition holds, $n_e = n_p + n_b$, where n_e is the electron density, n_b is the ion density of the ion beam pulse, and n_p is the ion density of the background ions (assumed unperturbed by the beam). For one-dimensional electron motion, the charge density continuity equation $\partial\rho/\partial t + \nabla\cdot\mathbf{j} = 0$ combined with the quasineutrality condition $[\rho = e(n_p + n_b - n_e) = 0]$ yields $\mathbf{j} = \mathbf{0}$. Therefore, in the limit of a strong solenoidal magnetic field, the beam current is completely neutralized. Analytical studies show that the solenoidal magnetic field starts to influence the radial electron motion if $\omega_{ce} \gtrsim \omega_{pe}\beta$, (where $\omega_{ce} = eB/m_e c$ is the electron gyrofrequency, ω_{pe} is the electron plasma frequency, and $\beta = V_b/c$ is the ion beam velocity relative to the speed of light). The condition already holds for relatively small magnetic fields; for example, for a $100MeV$ Ne^+ $1kA$ ion beam ($\beta = 0.1$) and plasma density of $10^{11}cm^{-3}$, B corresponds to a magnetic field of $100G$.

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