Nonlinear processes during the interaction of the petawatt laser pulse with plasma in the presence of external magnetic field

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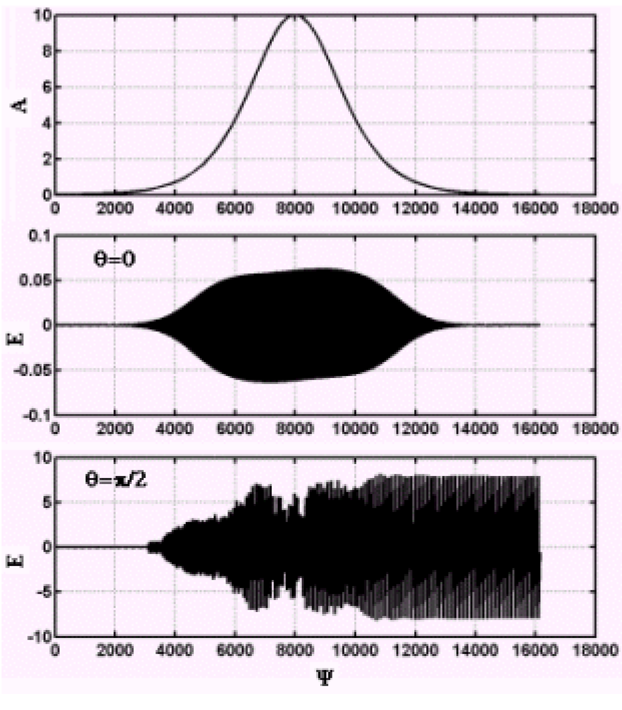
In this report we investigate the generation of an electrostatic wake field and electron acceleration in this field by intense laser pulse propagating in a plasma in the presence of external magnetic field. It is shown that if we do not take into account the change in the laser pulse wave amplitude (approximation of the constant laser pulse wave field), it is possible by switching to Lagrangian variables to reduce the system of equations describing excitation of the wake field and electron acceleration to a simplified system of ODE, which can be easily integrated. This makes possible to find the energy, transferred to electron oscillations in the wake field for different angles between the direction of laser pulse propagation and magnetic field.

The stability of laser pulse propagating with an arbitrary angle to the external magnetic field towards excitation of parametric and decay instabilities with involvement of upper hybrid and lower hybrid waves is investigated as well. Equations describing these instabilities are derived and growth rates are found analytically for a small amplitude wake filed and with the help of numerical calculations in the case of the finite wake field amplitude.



The results of the study can be applied to the problems of laser z-pinch plasma interactions. The focus is on plasma and laser parameters that are readily accessible experimentally, i.e. $1 < B < 100$ MG, $10^{18} < I < 10^{21}$ W/cm^2 and pulse duration 0.1 – 10 ps. This will help guide the development of ultra-intense laser-plasma interaction experiments at the Nevada Terawatt Facility at UNR.

These figures illustrate propagation of long laser pulse L=2000c/ω and $E_0 = 10 mc\omega e^{-1}$ along ($\theta = 0$) and perpendicular ($\theta = \pi/2$) to the external magnetic field in a plasma with parameters $\omega_p/\omega = 0.5$ and $\omega_B/\omega = 0.33$. The high amplitude wake oscillation $E(\psi)$ in the case of perpendicular propagation corresponds to parametrically excited wave under the resonance condition $\omega \approx 2\sqrt{\omega_p^2 + \omega_B^2}$. Here ω, ω_p and ω_B are the wave frequency, Langmuir frequency and electron gyrofrequency respectively, and the laser pulse shape stays unchanged: $E(t,x) = E_0 \cosh^{-2}(\psi c/\omega L)\sin\psi$, $\psi = \omega(t - x/c)$.