Anisotropic effects due the nonlinear inverse bremsstrahlung absorption on the dispersion relation of electron plasma waves

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The nonlinear inverse bremsstrahlung absorption (NLIBA) of intense electromagnetic waves in homogeneous plasmas may have significant impact on many physical phenomena through modifications of the electron distribution function (EDF). These modifications depends on the relevant parameter \( \alpha = \frac{v_0^2}{v_t^2} \), where \( v_0 \) is the quiver velocity and \( v_t \) is the electron thermal velocity. We address in this work the effects of the NLIBA on electron plasma waves (EPW).

It is well known that for a perturbed electric field such as \( \delta E \propto \exp(-i\omega t + ikx) \) where \( \omega \) et \( k \) are the frequency and wavenumber of the EPW, the dispersion relation of the EPW can be derived from the perturbed Vlasov and Poisson equations to get, \( \omega^2 = \omega_p^2 + \Gamma k^2 v_t^2 \) and the damping rate, \( \gamma = \frac{\pi}{2\sqrt{2}} \frac{\omega^3}{\omega_p^2} \frac{d\tilde{F}}{dx} (x = \xi) \) where \( \tilde{F}(\tilde{v}, \alpha) \) is the normalized reduced anisotropic EDF and \( \Gamma = 12\sqrt{2} \int_0^\infty x^2 \tilde{F}(x) \) is the polytropic index which depends on \( \alpha \). For \( \alpha \ll 1 \), the plasma is Maxwellian and one recovers the classical results of Bohm et Gross and Landau, \( \Gamma_{\text{Max}} = 3 \) and \( \frac{\gamma_{\text{Max}}}{\omega} = -\left( \frac{\pi}{8} \frac{\omega_p^3}{k^2 v_t^2} \right) \exp \left( -\frac{\omega^2}{2k^2 v_t^2} \right) \). Solving numerically the Fokker-Planck equation for homogeneous plasmas in presence of strong laser field we calculated the EDF \( \tilde{F}(\tilde{v}, \alpha) \) which presents strong temperature anisotropy induced by NLIBA. As a consequence we found strong modification in the dispersion relation of the EPW. For \( \alpha = 1 \) and \( \alpha = 2 \) the polytropic index is 1.6 and 2.6 times greater than in the case of a Maxwellian plasma. The anisotropy effects affect also the damping of the EPW. In particular, within the frequency range where these waves are weakly damped, i.e., \( \xi = \frac{\omega}{\sqrt{2}kv_t} \gg 1 \), we found that the damping is significantly greater for large \( \alpha \). In particular for \( \frac{kv_t}{\omega} = 0.15 \) one obtains \( \frac{\gamma}{\omega} = 1.46 \times 10^{-5} \) instead of \( \frac{\gamma_{\text{Max}}}{\omega} = 4.6 \times 10^{-8} \) for Maxwellian plasmas. These changes in dispersion and damping of EPW, especially if \( \alpha > 1 \), should amend the thresholds and the growth rates of parametric instabilities which involve the EPW.