NONLOCAL PROPERTIES OF PONDEROMOTIVE FORCE IN TIGHTLY FOCUSED HIGH INTENSITY LASER FIELDS

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In recent years, ultra-short high-power lasers in the range of 10^{22} W/cm^2 have been developed and opened up various applications such as fast ignition-based laser fusion, compact accelerators and high-intensity X-ray/neutron sources. In order to realize such high intensities, the reduction of the pulse width and/or the spot size is necessary. In such spatially localized laser fields, the *ponderomotive force* (light pressure) exists inevitably and plays an important role in the particle dynamics.

The ponderomotive force has been investigated by using the averaging method to the equation of motion and represented as the force proportional to the field gradient which is treated as the first order perturbation to the uniform field. However, as the laser field is tightly focused, higher order perturbations such as the spatial curvature of the laser field amplitude become important.

In order to investigate such higher-order effects, we analyze the relativistic particle motion in a non-uniform high intensity laser field by using the noncanonical Lie perturbation theory [1]. This theory is based on the perturbation theory of phase space Lagrangian, and has been successfully introduced in the gyro-kinetic formalism in describing magnetically-confined fusion plasmas [2] and in the relativistic orbit analyses of an electron beam in free-electron lasers [3, 4] and a particle in high intensity laser fields [5]. The method is found to be efficient and powerful in determining the particle motions systematically keeping the Hamiltonian structure.

Based on the above approach, we derived an equation system describing the relativistic ponderomotive force and the related particle dynamics, in which the influence of the laser field curvature has been included. This work corresponds to the nonlocal extension of the conventional ponderomotive force. Specifically, the particle is found to exhibit a *betatron-like oscillation* with a long period characterized by the curvature of the laser field amplitude.

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