Poster number APR-13-25

N. Iwata and Y. Kishimoto（Kyoto University）

Higher order nonlocal effects of the relativistic ponderomotive force in high power lasers

【Introduction】 The ponderomotive force, which corresponds to the light pressure, plays an essential role in determining the interaction between high intensity lasers and plasmas, providing a basis of important phenomena such as wake field generation and self focusing of the laser light. The ponderomotive force has been derived by applying the averaging method to the equation of motion, and explained as an averaged force proportional to the gradient of the laser field amplitude. This results from the first order approximation with respect to the expansion parameter ε (the ratio of the particle excursion length to the scale length of the gradient of the laser field amplitude). Charged particles irradiated by spatially-localized short pulse lasers are expelled from the interaction region readily due to the strong ponderomotive force, especially when the intensity reaches to the relativistic regime, >10^{18}W/cm^2. Thus, in order to keep long time scale interaction, designing the laser field patterns up to fine scales and controlling the interaction are of importance. In such a case, the higher-order ponderomotive force in the order of ε^n $(n \geqq 2)$ have to be taken into account to determine the particle dynamics.

【Method】 Here, in order to explore a theory that precisely describe the ponderomotive force including the higher-order nonlocal effects, we introduce the noncanonical Lie perturbation method. Since the method is based on the variational principle in noncanonical phase space coordinate, the Hamiltonian structure is maintained rigorously up to higher orders.

【Results and Discussion】 By properly choosing coordinate transformations and gauge functions, we successfully obtained an oscillation-center equation of motion describing the relativistic ponderomotive force up to the third order of ε. The equation involves new terms represented by second and third spatial derivatives of the laser field amplitude, so that the ponderomotive force depends not only on the local field gradient, but also on the curvature and its derivative. The formula is applied to study the particle motion in laser fields with shallow convex and concave field patterns in the transverse direction. The higher order ponderomotive force is found to play a leading role regulating the oscillation center dynamics, which causes difference in the interaction time for the convex field, and the frequency shift of the betatron motion for the concave field.

【Conclusion and Plan】 The higher-order terms obtained in this study become effective in describing particle dynamics in extreme and/or complicated field structure. The new formula can be used to propose the design of the laser field structure which is suitable for keeping the interaction and dynamics (e.g. betatron frequency) for a long time scale by controlling the higher derivatives of the field pattern.