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Novel Hamiltonian method for collective dynamics analysis of an intense charged particle beam propagating through a periodic focusing quadrupole lattice[1]

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Identifying regimes for quiescent propagation of intense beams over long distances has been a major challenge in accelerator research. In particular, the development of systematic theoretical approaches that are able to treat self-consistently the applied oscillating force and the nonlinear self-field force of the beam simultaneously has been a major challenge of modern beam physics. Recently, a powerful new Hamiltonian averaging technique has been developed, which incorporated both the applied periodic focusing force and the self-field force of the beam. Typically, it is advantageous to eliminate fast oscillations from formalism and describe complex beam particle motion in a new non-oscillating coordinates. Standard Hamiltonian techniques are cumbersome due to use of mixed oscillating and non-oscillating independent variables. Newly developed technique is specially designed to avoid use of oscillating variables. The method is analogous to the Lie transform methods in using only non-oscillating variables. At the same time the new approach retains the advantages of simplicity of Hamiltonian methods. Making use of this new method equations determining the average self-field potential for general boundary conditions has been obtained for the first time by taking into account the average contribution of the charges induced on the boundary. For intense beams the boundary effects can be very important because they strongly affect the average self-fields experienced by the beam particles. For example, it has been shown that in the case of cylindrical conducting boundary the average self-field potential acquires an octupole component, which results in the average motion of some beam particles being non-integrable and their trajectories chaotic. This chaotic behavior of the beam particles may significantly change the nature of Landau damping (growth) of collective excitations supported by an intense charged particle beam.

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