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Numerical Simulation and Analytical Study of Efficient Weakly Nonlinear Plasma Wakefield Injector for PETRA IV and Plasma Wakefield Collider

Our group studies high-efficiency acceleration of charged particle beams in the plasma wakefield experimentally and by numerical simulation (see [1]-[9]). The most impressive experimental results [1] until now in electron accelerating by a wakefield, excited in a plasma, have been achieved using capillary-generated plasma. Plasma-wakefield acceleration provides high accelerating gradients [1,10], promises compact accelerators of high-brightness and high-energy electron beams. Applications of plasma-wakefield accelerators, in particular, particle free-electron lasers (see [11]) and colliders demand low energy spread beams, their small emittance, high current of accelerated bunches, large transformer ratio and high-efficiency operation. Achievement of these requires plateau formation on both the accelerating field for witness-bunch and the decelerating fields for driver-bunch. As it is known plateau formation is possible by controlled beam loading with careful shaping current profile and beam charge selection. We will demonstrate by numerical simulation by PIC code such optimal beam loading in a weakly nonlinear electron-driven plasma accelerators. Beams for plasma accelerator are prepared with RF linear accelerator with high beam quality.
In the blowout regime the hose instability can appear [12]. Earlier investigations [13]-[14] show that the instability is essentially suppressed if the focusing force is inhomogeneous along the bubble, and radial inhomogeneity can be additional effect. The problem of the instability can be solved in weakly nonlinear regime. In weakly nonlinear regime throughout the areas of the driver and witness bunches the focusing force is inhomogeneous. Radial inhomogeneity of residual plasma electron distribution also leads to bunch stabilization. We will present results of analytical investigation and numerical simulation of hose instability suppression in plasma wakefield accelerator driven by electron bunch in the weakly nonlinear regime.

Another problem for which the usage of the weakly nonlinear regime will be useful is that for the transition between the accelerating cells, the injection of witness requires placing it in the maximum of the accelerating field of the bubble with plateau formation, and in the case of a weakly nonlinear regime this will be achieved.

Specific areas of interest are:
- optimal beam loading for the self-consistent distributions of a decelerating wakefield of plateau type for a driver-bunch and an accelerating wakefield of plateau type for a witness-bunch during all time of acceleration in the weakly nonlinear regime;
- control of optimal field shape (by loading effect), accelerating electron bunch in plasma wakefield in the weakly nonlinear regime;
- obtaining long electron witness-bunch of good quality (due to loading effect) in plasma wakefield accelerator at high transformer ratio in the weakly nonlinear regime.

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Special Qualifications

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