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Hose instability suppression by bunch anharmonic oscillations in weakly non-linear regime in wakefield accelerator

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Acceleration by plasma wakefield accelerators enables compact sources of high-brightness relativistic electron bunches. Applications like free electron lasers and particle colliders require high efficiency and low energy spread, achievable in the blowout regime, where the radial wake force is linear and independent of the longitudinal coordinate over much of the wakefield bubble. However, this regime introduces hose instability due to harmonic oscillations of electrons in the bunch. Studies show that anharmonic oscillations, caused by inhomogeneous focusing force along the wakefield bubble, suppress this instability. In the weakly nonlinear regime, where some plasma electrons remain in the bubble, their inhomogeneous density widens the stability region. Radial inhomogeneity in the residual plasma electron distribution further leads to anharmonicity of oscillations, stabilizing the bunch. We evaluated the oscillation period and found that the large radial and longitudinal gradients of the focusing force in the driver and witness bunch regions satisfy stochastic stabilization conditions. This enhances the stability of both bunches.

Footnotes

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