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Energy-conserving theory of strongly nonlinear plasma wakefields

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We present a self-consistent model of plasma wakefields in the strongly nonlinear (”bubble” or “blowout”) regime based on the energy conservation law [1]. In this regime, a spherical plasma cavity (a bubble) devoid of plasma electrons is driven by a short intense laser pulse or a high-current electron bunch. The strong longitudinal fields of the bubble (which propagates with almost the speed of light through the plasma) are fit for accelerating electrons to very high energies. Using the energy conservation approach, we derive a new equation for the boundary of the bubble. Compared to previous models [2], the equation does not rely on additional parameters. At the same time, as the comparison to 3D particle-in-cell simulations shows, it describes the structure of the bubble and the fields in it more accurately, especially in the limit of a small bubble size. Based on the new model, we also develop a self-consistent description of the bubble excitation by an electron driver which makes it possible to calculate the structure of the driven wakefield based only on the parameters of the driver.

[1] A. Golovanov et al. Phys. Rev. Lett. 130, 105001 (2023)
[2] W. Lu et al. Phys. Rev. Lett. 96, 165002 (2006)

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