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Beam loading and betatron radiation from a bubble in a deep plasma channel

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We develop an analytical model for beam loading in a bubble generated by a short laser pulse or a relativistic electron bunch in radially inhomogeneous plasma. The influence of a flat-top accelerated electron bunch on the bubble shape is described. The conversion efficiency from the fields of the bubble to the electrons is calculated and the optimal values of bunch charge and its position relative to the bubble that result in the efficiency of nearly 100% are derived. The bunch profile needed to produce a homogeneous accelerating field is also calculated. Betatron radiation from a bubble in a deep plasma channel is studied. The radiation spectrum is calculated. Our results are applied to deep plasma channels with various radial density profiles, namely a profile with the power-law dependence on the radial coordinate and a step-like profile for a hollow channel. We also discuss different approximations for the general theory of nonlinear wakefields in a radially inhomogeneous plasma and their applicability conditions. The model predictions are verified by 3D PIC simulations.

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