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Transverse envelope dynamics of beam slices in a uniform charged ellipsoidal model of the plasma bubble regime

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We consider a relativistic witness electron bunch propagating in an ionized gas background of opposite charge, a simplified configuration similar to the one produced in a capillary discharge where a plasma oscillation has been excited by a driving pulse. We assume in the nonlinear regime, the plasma electrons behind the driver are completely expelled and an ellipsoidal cavity filled with ions is formed. It is justified that the fields are linear in both longitudinal and transverse directions, at least in the region of interest for particle acceleration, as the one produced by a uniform ion distribution within a uniformly charged ellipsoidal distribution. The fields produced by the ions and experienced by a witness electron beam are purely electrostatic, being the ions at rest in the laboratory frame on the time scale of interest and it can be represented with the field distribution produced by a 3D charged ellipsoidal. The energy spread and emittance degradation has been studied by slicing the bunch in an array of cylinders and solving envelope equations for each bunch slice. The properties of transverse envelope and emittance oscillations and energy spread degradation have been analyzed together with the related matching conditions for optimal transport and acceleration.

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