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Emittance preservation in a single PWFA-LC stage using adiabatic plasma density ramp matching sections in the presence of ion motion

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Plasma based acceleration (PBA) is being considered as a building block for a future linear collider (LC). In PBA a short pulse laser or particle beam creates a wakefield and a witness particle beam is accelerated in the wakefield. As the witness beam is accelerated its energy spread must be small and its emittance must be preserved. In some designs the witness beam parameters required by a linear collider are expected to trigger background ion motion which can lead to nonlinear focusing forces which vary along the witness beam. This can lead to emittance growth of the witness beam. To mitigate this, we propose to use an adiabatic plasma density ramp as a matching section. We match the witness beam to the low density plasma entrance, where the beam initially has a large matched spot size so the ion motion effects are relatively small. As the beam propagates in the plasma upramp (downramp), it is adiabatically focused (defocused) and its distribution evolves slowly towards an equilibrium distribution including the effects of the adiabatically changing ion motion. We present simulation results using QPAD which is a quasi-3D quasi-static PIC code based on the workflow of QuickPIC. Simulation results show that this method can reduce the projected emittance growth of a 25GeV, 0.1um emittance witness beam to only ~3% within a single stage, which includes adiabatic matching sections at both the entrance and exit. The trade-off among the length of the plasma density ramp, the adiabaticity of the plasma density ramp, and the plasma density at the entrance is also discussed. This is an important issue for later accelerating stages when the witness beam has an even higher energy.

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