Positron acceleration in plasma waves driven by non-neutral fireball beams

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Plasma-based positron acceleration is a long-standing challenge to the advanced accelerators community in the pathway to a compact electron-positron collider. Due to the electron and ion mass discrepancy, non-linear plasma waves are not symmetric concerning the acceleration of positive or negative charged particles; the ion column behind the plasma wave driver is focusing for electrons and defocusing for positrons. Possible solutions typically rely on changing the plasma or driver profile to drive topologically shaped plasma waves. Some of the most prominent solutions rely on hollow laser beams [1] or electrons beams [2] as drivers of the wakefield structure.

One concept that has recently drawn attention in the context of plasma micro-instabilities is the fireball beam [3], which consists of spatial overlap between an electron and a positron beam. This work shows that standard Gaussian, non-neutral fireball beams in certain conditions evolve self-consistently to a hollow shape electron beam with the positron beam focused on-axis, thus enabling the conditions for stable positron acceleration studied in [1, 2].

We use theory and particle-in-cell simulations to describe the physics behind the hollow beam formation. We also demonstrate stable positron acceleration with the scheme, perform a systematic tolerances study, and show the analogous system with a laser replacing the electron beam.

References

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