Plasma-based acceleration for non-relativistic particles

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In these past years, the study of plasma-based accelerators has been of great interest as they provide a route to more compact, ecological yet powerful accelerators. Currently established acceleration methods, such as Laser Wake Field Acceleration [1] and Plasma Wake Field Acceleration [2], are only applicable to particles whose velocities are close to the speed of light (relativistic particles). Heavier particles, e.g. muons, are thus excluded from the acceleration mechanism, because they are produced with non-relativistic velocities, even though these particles could particularly benefit from plasma acceleration since conventional acceleration techniques are not fast enough to accelerate them before their decay [3]. State-of-the-art techniques to sculpt the spatio-temporal spectrum of electromagnetic wave-packets leading to pulses with arbitrary group velocities have been recently developed [4]. These pulses can drive superluminal ionization fronts, and are promising drivers for plasma acceleration, being able for example to circumvent dephasing. At the same time, they can propagate with a subluminal group velocity, making them suitable candidates to drive acceleration wakes for heavier particles.

In this work, we propose a plasma-based acceleration technique for non-ultra-relativistic particles using pulses with non-relativistic group velocities, and discuss the role of the evolution of these pulses in a plasma on the acceleration. We first investigated the acceleration using an external field with a non-relativistic group velocity analytically and in 2D particle-in-cell simulations using OSIRIS [5]. Subsequently, we investigated the evolution and wakefield properties using optical space-time wave-packet drivers, traveling with group velocities smaller than the speed of light. We have found that these pulses are able to drive plasma wakes that travel slower than the speed of light. However, they are prone to plasma instabilities, e.g. Raman scattering. We discuss the onset and potential mitigation strategies for these instabilities.

References

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