Multi-GeV Direct Laser Acceleration of positrons in a plasma channel

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The maximum energy electron-positron colliders can achieve is limited by their size and cost. Plasma accelerators are known to sustain accelerating fields which are orders of magnitudes higher than those in conventional radio-frequency accelerators. They are expected to provide relativistic beams in shorter distances and at a reduced cost. It was first demonstrated experimentally that a wakefield can simultaneously accelerate and focus positrons when it is driven by a single, long positron beam [1]. On the other hand, numerical simulation brought forward other ways to build wakefields suited for positron acceleration, either using a Laguerre-Gaussian laser pulse [2] or a hollow electron beam [3]. The aforementioned schemes are designed to provide an energy boost of 5-10 GeVs to positrons exiting a conventional accelerator.
A recent numerical investigation suggests a way to both create and accelerate positrons in an even more compact setup [4]. It relies on the 90-degree interaction of a multi-PW laser with a GeV-class electron beam. Positrons are created via the multi-photon Breit-Wheeler process and are then accelerated in vacuum by the strong laser ponderomotive force to a few GeVs.

In this work, we suggest a new scheme where positrons are both created and accelerated to a few GeVs in an all-optical, mm-scale setup using a plasma channel. We conducted a set of Particle-In-Cell simulations with the quasi-3D version of the particle-in-cell code Osiris, which incorporates synchrotron gamma-ray emission and Breit-Wheeler pair production processes. In our setup, a multi-PW intense laser propagates in a mm-long pre-formed plasma channel. Under adequate conditions, a strong electron current is sustained along the channel central axis and generates long-range fields that form a guiding structure for particles with a positive charge. Positrons are created at the laser focus during the interaction with a perpendicularly propagating gamma-ray beam. This setup fosters Direct Laser Acceleration of positrons to multi-GeV energies.

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References

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