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Laser polarization control of ionization-injected electron beams and x-ray radiation in laser wakefield accelerators

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The generation of very high energetic electron beams from the Laser Wakefield Accelerators (LWFA) has become a very active field of research since last four decades, which now strives for continuous improvement of the achievable maximum energy, stability, and beam quality. In order to improving the electron beam quality it is in particular very crucial to understand how the various injection mechanisms affect the final electron beam properties. Ionization injection is a routinely employed injection mechanism in which electrons are ionized typically from the K-shell of an admixed high-Z injector gas species. Photoelectrons generated at the peak of the driver laser field eventually get trapped to the accelerating wakefield structure [1]. Here, we present the impact of injector gas species, and we also capture the effect laser polarization on the electrons generated via optical ionization-injection of a high-Z gas doped in a pre-ionized plasma in LWFA. Our systematic study has been conducted by performing a large number of full-scale 3D particle-in-cell (PIC) simulations using the code SMILEI [2] in the nonlinear bubble regime of LWFA. It has been found that depending on the polarization state of the ionizing laser, the injected electrons' transverse phase space distributions are modified due to the presence of a nonzero transverse momentum gain via above threshold ionization (ATI) process, owing to the conservation of the transverse momentum.

This polarization dependent ATI momentum controls the entire beam dynamics during the acceleration process and eventually affects the trapped beam charge, its transverse emittance and the energy spectra [3, 4], hence the final beam quality.

We also show how the laser polarization can also be employed to adjust the polarization properties (Stoke's parameters) of the betatron x-ray radiation emitted from the accelerating electron beams performing betatron oscillations inside the bubble during the acceleration process [4].

References:

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