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Self-injection process in laser-wakefield accelerator driven by CO_2 laser pulses

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The study of laser wakefield acceleration (LWFA) using long wavelength infrared laser drivers is a promising path for future laser-driven electron accelerators when compared to traditional near-infrared laser drivers operating at $0.8 - 1\ \mu$m central wavelength [1,2]. For a fixed laser intensity I, lasers with longer wavelengths λ have larger ponderomotive potential ($\propto I\,\lambda^2$). Stronger wakes can be generated at relatively low laser intensities by using a long wavelength laser driver (i.e. $\lambda = 9.2\ \mu$m CO_2 laser) due to its very large ponderomotive potential. LWFA driven by CO_2 laser may have significant advantages to applications requiring compact and industrially robust accelerators and radiation sources.

In this work, we use particle-in-cell (PIC) simulations to investigate the self-injection process in CO_2 laser-driven wakefield acceleration for various laser and plasma parameters in the blowout regime. PIC code FBPIC [3] is used to extend the results obtained in [1] to model the interaction of a sub-picosecond CO_2 laser pulse with wavelength $\lambda = 9.2\ \mu$m and pre-ionized uniform plasma with a_0 ranging between 2 and 5. We have explored a wide range of parameters like pulse durations, laser amplitudes, spot size, and plasma densities to determine the self-injection mechanisms through bubble evolution. The accelerating bubble structure of LWFA is dynamic and highly sensitive to the local laser and plasma properties. It can expand and contract as it responds to the evolution of the laser and plasma fields. We report a parameter range that suppresses self-injection in fully blown-out bubbles which is an essential requirement in the experiments of controlled injection in LWFA.

References

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