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Kinetic modelling of autoresonant beat-wave excitation of plasma waves

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We use particle-in-cell simulations performed with Smilei to investigate the autoresonant wakefield excitation. The kinetic simulation reveals significant fluid nonlinearities of the laser self-consistent evolution occur under high plasma density, invalidating the fluid model of quasi-static approximation. However, when considering low underdense plasma, a remarkable agreement emerges between the fluid model and kinetic simulation results. In this regime, the frequency chirp offers effective control over wave amplitude and self-injection of particles. Optimal laser and plasma parameters are identified for amplifying the wakefield to the point of wave-breaking, enabling acceleration of particles via a high-gradient electric field, and ∼30 pC charge of the high-energy (∼ 250 MeV) electrons is expected to be obtained over ∼ 3.5 mm acceleration length. This versatile and efficient acceleration scheme holds promise for a wide range of applications, from tens to hundreds of MeV energies, making it worthy of investigation as a potentially attractive option for various industrial and medical applications.

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