Femtosecond probing of plasma wakefields and observation of a plasma wake echo using a relativistic electron bunch

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The instantaneous longitudinal and transverse field structures of a microscopic, highly transient, laser-excited relativistic plasma wake is captured with femtosecond resolution. This is done by using the high-energy ultrashort electron bunch generated from a laser wakefield accelerator as a probe as firstly proposed in [1]. Furthermore, we have probed the structure of wakefields in a density gradient for the first time. By recording the temporal evolution of the plasma wake wavelength in a density upramp, an echo, i.e., the recurrence of the plasma wake is observed. It is found that after the laser driver has passed, the local wake wavelength first increases with time until it eventually tends to infinity, then it begins to shorten and the phase velocity of the wake reverses its direction. In a density downramp, the wake wavelength monotonically decreases as a function of time until it can eventually be damped by wave-particle interactions [2]. Both the existence of wake echo in a density upramp and its absence in a density downramp are theoretically explained and confirmed in particle-in-cell simulations.

References

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