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Control of electron injection in laser wakefield acceleration with external magnetic fields

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It is shown that external magnetic fields at tens of tesla can provide additional control of electron injection in laser wakefield acceleration (LWFA). In the first case, we consider ionization injection assisted by a transverse magnetic field. Both the electron trapping condition and the wakefield structure are changed significantly by the magnetic field such that injection occurs over a shorter distance and at an enhanced rate. Furthermore, beam loading is compensated for as a result of the trapezoidal-shaped longitudinal charge density profile of injected electrons. These lead to a reduction in the energy spread and an enhancement of both the charge and final peak energy of the electron beam.

In the second case, we consider density downramp injection assisted by a longitudinal magnetic field. The magnetic field dynamically induces an expanding hole in the electron density distribution at the rear of the wake bubble, which reduces the peak electron velocity in its vicinity. Electron injection is suppressed when the electron velocity drops below the phase velocity. This enables the start and end of electron injection to be independently controlled, allowing the generation of sub-femtosecond electron bunches with peak currents of a few kilo-Ampere.

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