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Terahertz-driven compression for femtosecond bunching and laser-electron temporal locking of relativistic electron beams.

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We demonstrate the application of THz-frequency acceleration in the control of the chirp of an electron beam supplied by an RF linac injector. An ultrafast Ti:Sapphire laser drives the THz source, enabling a direct link between laser and electron beam timing and temporal-locking between laser and electron bunch arrival time. The accelerating structures high drive frequency results in a high temporal gradient of the accelerating field. The resulting strong chirp allows compression of the injected bunches to the few-femtosecond level.
Experimentally, multi-cycle THz is generated through optical rectification of wafer-stack periodically poled lithium niobate sources. A sub-picosecond electron bunch interacted with the ~20 MeV/m gradient accelerating THz field, in a velocity-matched dielectric-lined waveguide. Compression of the experimental observed electron time-energy phase space with a modelled magnetic chicane demonstrates a compression factor of over 20, providing bunch durations <20 femtoseconds. The compressed electron-bunch arrival time is correlated with the THz drive laser, and sub-20fs temporal locking between drive laser and compressed electron beam is shown to be achievable even with the energy and time jitter present in RF accelerator, despite the >100 fs RF-laser time jitter. The techniques demonstrate a route to external injection of RF-injector into high-gradient plasma accelerators.

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