Abstract for an Invited Paper
for the DPP05 Meeting of
The American Physical Society

Characterization of femtosecond electron bunches from a laser-wakefield accelerator using THz radiation[1]

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We report on the temporal characterization of laser-plasma-produced electron bunches, indicating ultra-short sub-50 fs charge structure. In the LOASIS laboratory at LBNL, the electron bunches are produced through the interaction of an intense ($> 10^{19}$ Wcm^{-2}) laser pulse with an underdense ($\simeq 10^{19}$ cm^{-3}) Helium plasma. The femtosecond multi-nanoCoulomb bunches have relativistic energies, with a 100% energy spread. As the bunch exits the plasma-vacuum interface, coherent transition radiation is emitted. Since the electron bunch is still dense and compact at the emission interface, the coherent spectrum of the intense radiation pulse covers the THz regime. Spectral and temporal measurements on the THz pulse are performed and correlated to the temporal properties of the electron bunch. Detection techniques such as Michelson interferometry, semiconductor switching, and electro-optic sampling are applied. The latter technique, where the THz electric field versus time is mapped out, provides detailed temporal structure of the radiation pulse, and by inference the electron bunch. The measurements indicate that THz radiation is emitted by a skewed bunch with a sub-50 fs rise time and a $\simeq$600 fs tail (half-width-at-half-maximum), which is consistent with ballistic debunching of 100%-energy-spread beams during propagation. The electro-optic time resolution of the method was limited by the crystal properties. The Michelson interferometry and semiconductor switching experiments confirmed the femtosecond nature of the electron bunches. The electro-optic measurement also demonstrates shot-to-shot stability of the laser-wakefield accelerator (LWFA) as well as femtosecond synchronization between the electron bunch and the probe beam. This highlights the applicability of the LWFA in pump-probe experiments, where synchronized emission of x-rays, gamma rays, THz waves, NIR beams, and electron bunches is available. This work is supported by DoE under contract DE-AC02-05CH11231.

[1]In collaboration with C. B. Schroeder, C. V. Filip, Cs. Tóth, C. G. R. Geddes, G. Fubiani, R. Huber, R. A. Kaindl, E. Esarey, and W. P. Leemans