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Ultrafast terahertz generation and spectroscopy for accelerator diagnostics

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The generation of strong terahertz (THz) radiation has recently drawn considerable attention owing to the potential for intense THz excitation spectroscopy, nonlinear THz optics, as well as biomedical and security imaging. For these applications, THz field strength of MV/cm (or several microjoule under single-cycle, diffraction-limited focusing) is required. Such field strength can be obtained currently at electron accelerator facilities such as linacs, synchrotrons, and free electron lasers, as well as at laser-plasma accelerators, where all mediate highly relativistic electrons. Surprisingly, non-relativistic electrons can also generate intense coherent THz radiation. Recently, high-energy (>5 microjoule), super-broadband (>75 THz) THz radiation has been produced via ultrafast two-color photoionization [1]. In this scheme, a femtosecond laser's fundamental and its second harmonic pulses are mixed in a gas to generate a directional electron current on the time scale of sub-50 fs with simultaneous THz radiation in the far field. Another important THz application is diagnosing the temporal profiles of relativistic electron beams. As a noninvasive method, the longitudinal profile can be characterized from field-induced birefringence in an electro-optic crystal in the vicinity of the electron beam. To monitor the bunch profiles in real time, a chirped optical pulse can be used to map out the charge field onto the probe spectrum. Here, the temporal resolution, previously limited by the chirp, can be greatly improved with an in-line spectral interferometric algorithm [2]. The diagnostic can also provide 2D spatio-temporal imaging of ultrashort electron bunches in real time. Another single-shot diagnostic recently developed is an echelon-assisted spatial encoding method [3] which can provide a >10 ps time window with ∼25 fs temporal step sizes, with many advantages over other single-shot THz diagnostics.

[1] K. Y. Kim *et al.*, Nature Photon. **2**, 605 (2008)
[2] K. Y. Kim *et al.*, Appl. Phys. Lett. **88**, 041123 (2006)
[3] K. Y. Kim *et al.*, Opt. Lett. **32**, 1968 (2007).