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Femtosecond time-resolved dynamics of fast electrons in relativistic laser-foil interactions

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Fast electron generation and transport in ultrashort intense laser-plasma interactions are essential processes for the laser energy deposition, generation of ultrafast radiation sources, ion acceleration, fast ignition approach for inertial fusion energy, etc. Diagnostics of the spatial, spectral characteristics of the fast electrons have been widely carried out. However, precisely measuring the dynamic of the fast electrons is quite challenge since time-resolution as high as femtosecond scale is needed. In this talk femtosecond time-resolved, real-time measurements of the temporal characteristics and dynamics of fast electron beams in thin solids driven by relativistic intense laser pulses will be presented, using the self-induced terahertz (THz) transition radiation. To measure the ultrabroadband THz radiation from solid targets, a single-shot THz autocorrelator free of Electro-optical crystals has been developed [1]. Thanks to the high time-resolution of the autocorrelator, it is found that the duration of the fast electron beams is comparable to that of the driving laser pulse. The fast electron recirculation in the foil, where electrons are trapped inside the self-generated electrostatic potential and rebound back and forth around the thin foil for hundreds of femtoseconds, is directed visualized. The results should be much helpful for understanding and controlling the fast electron dynamics, and further manipulating laser-driven secondary particle and radiation sources.

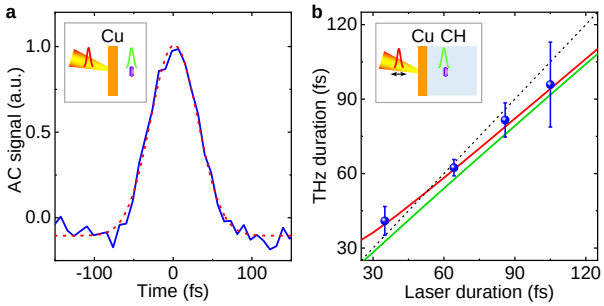

Figure 1 Visualization of fast electron bunch duration. a, Autocorrelation interferogram (blue solid) measured at the 20-μm thick copper (Cu) foil irradiated by a 35-fs ultraintense laser pulse, and fit with a Gaussian function (dashed red). b, THz duration as a function of laser pulse duration for the 10-μm thick Cu foil backed with a 100-μm thick plastic (CH) layer. Blue circles are experimental data. Vertical error bars are a combination of the shot-to-shot fluctuations in the experiment and the uncertainty of Gaussian fitting to the measured AC signal. Red and green curves show numerical calculation results, respectively, with and without considering the electron bunch transverse size.

References

[1] F. Z. Sun, G. Q. Liao, H. Y. Lei, T. Z. Wang, Y. Y. Wei, D. Wang, H. Chen, F. Liu, Y. T. Li, and J. Zhang, A non-collinear autocorrelator for single-shot characterization of ultrabroadband terahertz pulses, Rev. Sci. Instrum. 93, 123003 (2022)