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Ultrashort pulse X-ray absorption spectroscopy using laser-plasma accelerators

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Laser-plasma accelerators now regularly achieve GeV electron energies in laboratory-scale facilities, enabling new research opportunities. One significant application is the generation of ultrashort (few femtoseconds) X-rays through betatron electron oscillations. These broadband pulses are ideal for X-ray absorption spectroscopy (XAS), particularly XANES (X-ray Absorption Near Edge Structure) and EXAFS (Extended X-ray Absorption Fine Structure) spectroscopy, which provide valuable insights into the temperature and structure of a samples electronic and ionic distributions simultaneously.
Current multi-100 TW laser systems can achieve single-shot XAS measurements, with $> 10^6$ photons/eV per shot [1], in the few to 10 keV range. It is predicted that PW class systems will increase this flux by an order of magnitude, and the photon energies to >100 keV, allowing high-Z elements to be probed. Given that these high-flux, broadband, femtosecond X-ray sources can be synchronised with other high-power lasers, this offers new possibilities for studying ultrafast energetic processes. Moreover, increasing repetition rate demonstrates the potential for developing high-quality laboratory-scale XAS facilities, reducing dependence on large-scale synchrotrons.

[1] B. Kettle *et al.* Communications Physics 7, 247 (2024).

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