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Cascaded hard X-ray self-seeded free-electron laser at megahertz repetition rate

Wednesday 4 June 2025 14:00 (30 minutes)

High-resolution X-ray spectroscopy in the sub-nanosecond to femtosecond time range requires ultrashort X-ray pulses and a spectral X-ray flux considerably larger than that presently available. X-ray free-electron laser (XFEL) radiation from hard X-ray self-seeding (HXRSS) setups has been demonstrated in the past and offers the necessary peak flux properties. So far, these systems could not provide high repetition rates enabling a high average flux. We report the results for a cascaded HXRSS system installed at the European XFEL, currently the only operating high-repetition-rate hard X-ray XFEL facility worldwide. A high repetition rate, combined with HXRSS, allows the generation of millijoule-level pulses in the photon energy range of 6–14 keV with a bandwidth of around 1 eV (corresponding to about 1 mJ eV−1 peak spectral density) at the rate of ten trains per second, each train including hundreds of pulses arriving at a megahertz repetition rate. At 2.25 MHz repetition rate and photon energies in the 6–7 keV range, we observed and characterized the heat-load effects on the HXRSS crystals, substantially altering the spectra of subsequent X-ray pulses. We demonstrated that our cascaded self-seeding scheme reduces this detrimental effect to below the detection level. This opens up exciting new possibilities in a wide range of scientific fields employing ultrafast X-ray spectroscopy, scattering and imaging techniques.

Footnotes

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