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Background-Free Intensity Autocorrelation Measurements for Hard X-ray Free-Electron Lasers Using Second Harmonic Generation in Diamond

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Pulse duration of X-ray free-electron lasers (XFELs) is a key parameter for measurements with XFEL pulses. Recent efforts have enabled a direct diagnostics of pulse duration of XFEL pulses thorough an intensity autocorrelation (IAC) technique using two-photon absorption (TPA) [1] where two XFEL pulse replicas are mixed on a metal thin foil as the TPA medium, and then the nonlinear TPA signal intensity (that is here the yield of X-ray fluorescence following TPA) is measured as a function of the time delay between the two replicas. The TPA method has some issues: (1) incoherent nature of TPA where the signal is spread over 4π and insensitive to the phase of the incident wave, (2) inevitable background signals from individual pulse replicas, and (3) a destructive manner where the TPA medium has to be scanned fast enough to illuminate fresh areas shot-by-shot.

To overcome the above issues, we demonstrated another IAC technique with phase-sensitive second harmonic generation (SHG) in a single-crystal diamond at SACLA. The signal of SHG is concentrated in a narrow angular range because of a narrow phase-matching condition of the order of 100 μrad or less [2]. Although the narrow condition typically makes the measurement difficult, it is made possible to eliminate the constant background from individual replicas even on an almost collinear geometry with a tiny angular mismatch of sub-mrad between the two replicas. Furthermore, non-destructive measurements can be realized owing to the radiation hardness of diamond crystals. Through this scheme, we successfully measured autocorrelation traces without constant base at 10 keV. Also, the results clearly showed the difference in autocorrelation traces with and without a Si(311) monochromator, indicating a promising way towards temporal tailoring of XFEL pulses through Bragg diffraction in perfect crystals.

[1] T. Osaka *et al.*, Phys. Rev. Research **4**, L012035 (2022).
[2] S. Shwartz *et al.*, Phys. Rev. Lett. **112**, 163901 (2014).

I plan to submit also conference proceedings

No

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