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Compact diagnostic for spatial and temporal overlap determination of XFEL and optical laser pulses using diffusing material and an imaging device

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The capabilities of XFEL sources enable scientific investigations at the frontiers of spatial and temporal resolutions. One of the key procedures in time resolved experiments combining XFEL and optical lasers is the establishment of temporal overlap, i.e. "time zero", between the ultrafast X-ray and optical laser pulses with sub-picosecond accuracy. In order to determine time zero, several techniques have been developed including ultrafast melting induced by the optical laser and optical transmission change induced by the intense X-ray pulse. However, degradation of the signal contrast (mainly originating from the mismatch of beam profiles between two light pulses) makes it difficult to find time zero using existing techniques. For example, 70~80% of beamtimes using the XPP instrument at LCLS use monochromatic X-rays with micro-J pulse energy and larger intensity fluctuations relative to the full pink beam, as well as a tight focus much smaller than optical laser diameter. These conditions combined make it difficult to locate temporal overlap by using transmission change compared with when using the mJ-pulse-energy and unfocused pink beam. Here we evaluate an alternative diagnostic design, "t0 finder", to increase signal contrast by combining thin, diffusing material and an imaging device for the time zero determination, and we benchmarked it by performing a cross-correlation measurement of transmission change using monochromatic X-rays and an optical laser which covered the wavelength range from UV to near infrared. We obtained time zero to within the resolution of the beamline arrival time diagnostics and pulse durations with 20% of step-like signal change without any normalization. We will report the demonstration of this new diagnostic concept, including delay time, intensity and wavelength dependences.

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