Development of hard x-ray split-delay optics at SACLA

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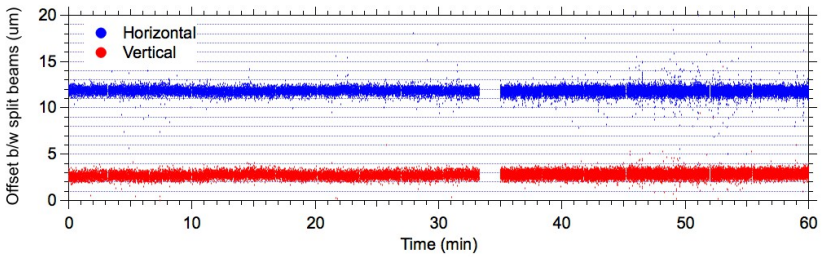
As a new capability of XFEL sources, double XFEL pulses are developing novel experimental opportunities, such as XFEL pump–XFEL probe and two-pulse x-ray photon correlation spectroscopy, which enable investigations of atomic scale dynamics in diverse systems at both equilibrium and non-equilibrium states over wide time ranges from femtoseconds to tens of nanoseconds. Although XFEL pulse pairs have been generated by accelerator-based methods, it is difficult to access a time range from $\sim$ 300 fs to sub nanosecond with these methods. A split-and-delay optical (SDO) system can cover this time gap, which is of particular importance for unveiling spontaneous fluctuations in matter, and therefore, has been extensively developed by several groups [1–3].

We have developed a prototype SDO system with Si(220) single crystals at SPring-8 Angstrom Compact free-electron LAser (SACLA) [2, 4]. In the SDO system, an XFEL pulse is split into two parts by the beam splitter with a wavefront division scheme. The split pulses propagate through different branches, one for the variable delay and the other for the fixed delay with a couple of channel-cut crystals, and finally recombined onto a common path by the beam merger. Utilizing the SDO system as a Michelson interferometer, we have characterized temporal coherence properties of SACLA XFEL pulses by measuring visibilities of single-shot interferograms as a function of the time interval [5]. The measurement not only showed a coherence time of $\sim$ 6 fs but also determines the interval of zero with an accuracy of a few femtoseconds. We also achieved nearly ideal focusing of split beams down to $\sim$ 1.5 μm full-width at half maximum with high pointing stability of fluctuation of $\sim$ 0.3 μm in sigma, as shown in figure, which is of importance for performing the two XFEL pulse measurement techniques. In this presentation, I report on details of these developments and preliminary results of pilot experiments. We also present a future upgrade plan.



Pointing offsets between the focused split beams.

References

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