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Current status of experimental platform for laser-based plasma physics at the XFEL facility SACLA

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X-ray free electron lasers (XFELs)[1, 2] have opened new frontiers in various scientific fields because of high brilliance, short pulse-duration, and pulse coherence of the x-ray pulse. XFELs have delivered new capabilities in the experimental researches related to high energy density (HED) science and plasma physics. The XFEL pulses can be utilized to produce extreme states of matter once the pulse is focused in a submicron diameter spot. Furthermore, the XFEL pulse provides novel approaches to diagnose the matter under extreme states produced by high power optical lasers, which have never been investigated with previous techniques.

At the world's first compact XFEL facility, SACLA[2], an experimental platform for HED science is now open for early users' experiments, where a high intensity laser pulse can be used in combination with an XFEL pulse. The optical laser system consists of two beams with the maximum power of 500 TW. The schematic overview of the experimental platform is shown in Fig. 1. The XFEL pulse with the pulse energy of ~0.5 mJ within the duration of <10 fs is transported to the platform. The typical x-ray photon energies are in the rage from 4 to 15 keV. At the experimental platform, the beam of the XFEL pulse can be focused on a sample down to a few microns by using sets of compound refractive lenses (CRLs) on demand. The sample, which is mounted on motorized stages in a vacuum chamber, is also irradiated with a high power, high intensity optical laser in pump-probe experiments. During the early users' experiments scheduled in 2018, a single beam of the high intensity laser system with the maximum energy of ~7 J is focused on the sample via an off-axis parabolic mirror with the f-number of ~10. The typical pulse duration and spot size are 30-50 fs and 10-30 μm (FWHM) respectively, resulting in the estimated intensity of ~10^{19} W/cm^2 at the focus. As the commissioning of the high intensity laser, the interactions of intense laser and matter have been characterized by measurements of energetic particles (electrons and ions) as well as characteristic x-rays emitted from the laser-irradiated foils. The observed results are consistent with the laser intensity estimated from the laser parameters.

The temporal and spatial overlaps of the two lasers, i.e. optical and x-ray lasers, are crucial for the most of pump-probe experiments. The optical laser is temporally synchronized to the XFEL referring the radio-frequency (5.7 GHz) signals from the SACLA accelerator. The synchronization stability between the two lasers has been measured at the sample position using the spatial encoding technique[3, 4]. To date, the timing jitter in a short period (~5 minutes) has been observed to be ~30 fs (rms), whereas the drift in a long term (~ 24 hours) can be up to a picosecond. The pointing stability of the lasers at the sample position is under evaluation.

The current status and future perspectives of the experimental platform will be presented.

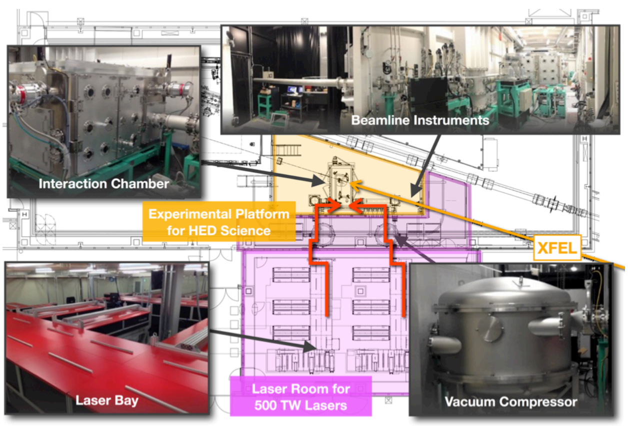

Figure 1. Schematic overview of experimental platform equipped with high-intensity laser at SACLA.

References

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