Experimental capabilities with high-power optical laser systems at the X-ray free-electron laser facility, SACLA

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An x-ray free-electron laser (XFEL) has unique properties as a new light source, which has been opening new scientific frontiers in a variety of research fields. Plasma physics or high-energy-density science using high-power optical lasers is one of the fields. XFEL facilities in the world, for example, SACLA[1] in Japan, the LCLS in the US, and the European-XFEL in Germany have developed experimental platforms equipped with high-power optical laser systems for user experiments. In typical experiments, the XFEL is used as a fast, bright, and coherent x-ray probe to investigate the states of matter or the ultra-fast phenomena under extreme conditions created by high-power optical lasers. At SACLA, two types of high-power laser systems are operational for user experiments at two independent experimental platforms. At either platform, the ultra-high brightness of the XFEL with a pulse duration of <10 fs can be used to capture the ultra-fast phenomena.

The first platform is equipped with a high-power nanosecond laser with energies over 10 J[2]. The experimental platform has been upgraded in late 2018 for experiments specifically to study the behavior and states of matter under a high-pressure[3, 4], or to simulate the hydrodynamics processes related to astrophysics[5]. Typical primary instruments at the experimental platform are a large area flat panel detector for the x-ray diffraction measurements and the high-resolution indirect x-ray imaging camera[6].

At the second platform, users can use a high-power femtosecond laser achieving a typical peak power of over 200 TW[7]. The experimental platform has been opened for user experiments since 2018. Because of the high intensities reaching the relativistic threshold at the focus position, the laser-irradiated sample is rapidly heated, ionized and becomes plasma in a short period[8]. The XFELs are used as a probe with various diagnostics techniques such as x-ray imaging, x-ray scattering, and x-ray spectroscopy.

The details of the basic instruments besides the experimental capabilities at the platforms will be presented in the conference. In addition, a new scheme to carry out experiments remotely during or after the COVID-19 pandemic will be introduced. The scheme is currently under preparation and will be available for pilot experiments at the high-power laser platforms at SACLA in late 2021.

References

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