SACLA Beam Performance

SACLA provided routine operations for users in 2014, despite an accident in the injector system in May 2014 that caused some laser instabilities. This problem was successfully resolved in January 2015. The construction of BL2, a new XFEL beamline, was completed on schedule during our two-month summer shutdown. Although the relatively long summer shutdown decreased the total operation time by 10%, the total public user time increased by 100 hours due to improvements in the efficiency of the tuning and preparation procedures.

Successful beam commissioning of our new beamline, BL2

The construction of BL2, our newest beamline, was completed during the summer shutdown. Figure 1 shows BL2's undulator line, which is composed of 15 undulator segments. Beam tuning began in the last week of September and the facility passed its inspection on October 7. The first laser amplification at BL2 was achieved on October 21 and the laser intensity reached around 20 μJ per pulse at 10 keV. Figure 2 shows the laser profile measured in the optical hutch. During the winter shutdown, two inverse bending magnets were installed in the beam transport line to enable precise beam tuning to achieve a higher laser intensity. The DC beam-switcher was replaced by a combination of a pulse-kicker and DC septum magnets in order to achieve pulse-by-pulse laser switching operations.

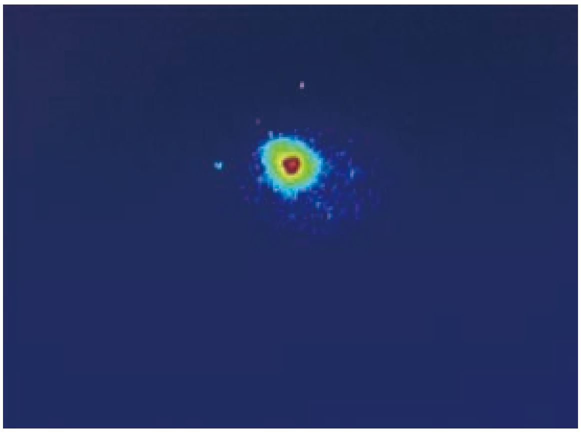

Fig. 2. First lasing achieved at the BL2 undulator line.

Fig. 1. New BL2 undulator line (left) installed in the SACLA undulator hall together with the existing BL3 (right).

Accelerator stabilization and operation reliability improvement

One remaining instability issue is not shot-by-shot fluctuation but a slow parameter drift. We thought that timing drift might be the primary cause of this parameter drift. Therefore, we built an optical-fiber length stabilization system for a reference RF signal transmitter. The system employs an optical interferometer to measure the optical path-length variation and a piezoelectric fiber stretcher to compensate for the variation. By using this system, the timing drift of the reference RF signal transferred through an optical fiber several hundred meters long is suppressed to within 50 fs [1].

One of the critical issues for reliable SACLA operation is to reduce the downtime caused by breakdowns of the thyratrons (the high-voltage plasma switches). SACLA uses more than 70 thyratrons and after three years in operation, most of them are approaching the end of their estimated service life. We have made extensive efforts to shorten the downtime and to ensure a sufficient number of backup thyratrons [2]. For example, we modified a thyratron protection circuit so that the TVS (transient voltage suppressor) diodes are located outside the insulation oil tank, because TVS diodes frequently break down after high-voltage surges as thyratrons age. This modification simplifies repairs and has greatly contributed to making operations more reliable.

Development of a self-seeded XFEL at BL3

We developed an XFEL self-seeding system using a Bragg transmission scheme at BL3 of SACLA to generate a single-mode-like laser with a sharp and constant spectrum. The setup is composed of a small magnetic chicane, which can delay an electron beam of 8 GeV by 50 fs at maximum and a diamond single crystal with a thickness of 180 μm.

Although beam commissioning for the self-seeding system remains underway, we were able to achieve four times higher intensity and a ten times narrower spectral bandwidth at 10 keV compared with those of SASE as shown in Fig. 3 [3]. Further accelerator tuning will continue to improve the reproducibility and long-term stability of the self-seeded XFEL.

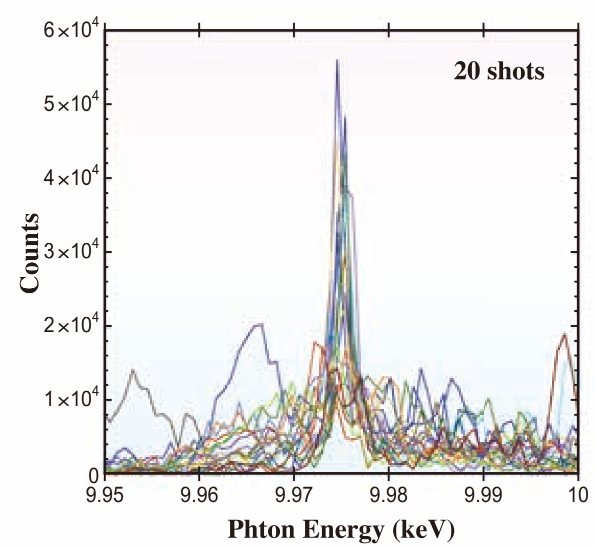

Fig. 3. Single-shot spectra of self-seeded XFELs.

Electron beam instability in the injector

Early on the morning of May 26th the mis-steering of 500 keV electron beams during successive measurements of current setting errors for all the electromagnets broke a bellows at the injector and caused a vacuum leak there. The chamber component with the broken bellows was quickly replaced with a similar one installed in the BL1 linear accelerator under construction and SACLA operations were restarted later that day. However, large fluctuations of the electron beam trajectories continued at the injector after the replacement, causing pointing instability for the XFEL and seriously restricting the XFEL performance.

The preliminary investigation of operations data suggested that a cause of the fluctuations may have been poor vacuum conditions at the gun cathode. To address this problem, during the summer shutdown we added an NEG pump system near the cathode. Unfortunately, the fluctuations were not suppressed at all. Further investigation revealed another potential cause - the build-up of charge at the ceramic chamber adjacent to the bellows by the electron bombardment kicked the beam at random intervals; we found that the replacement chamber component had a wider aperture than the original one, which resulted in increased charge build-up. During the winter shutdown, we exchanged the chamber component with a modified one with a halo scraper and a coated ceramic surface to suppress charge build-up. This modification finally succeeded in stopping the fluctuations.

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References

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