Preface

The Synchrotron Radiation Laboratory (SRL) of the Institute for Solid State Physics (ISSP) continues to promote advanced materials science through the development of cutting-edge soft X-ray spectroscopic techniques at our three research sites in Sendai, Harima, and Kashiwa. Building upon the foundation established over the past years, FY2024 has been a milestone year marked by the long-awaited start of user operations at the new 3 GeV synchrotron facility NanoTerasu and by the rapid progress of next-generation X-ray and laser spectroscopy platforms.

The official launch of NanoTerasu on April 9, 2024 marked a major turning point for our soft X-ray research program. During the first half of the year, more than 30 user proposals were accepted, and the number exceeded 40 in the second half, reflecting strong national expectations for this new facility. The storage ring, operated by the NanoTerasu team, has reached a routine current of 200 mA, delivering exceptionally bright soft X-ray radiation. With the beamlines BL07U and BL08U achieving a spectral resolving power of $E/\Delta E > 15{,}000$, we were able to conduct cutting-edge spectroscopic experiments that were previously unfeasible. At the HORNET-II station, RIXS measurements reached energy resolutions on the order of $E/\Delta E \approx 10{,}000$ in the 400–710 eV range, enabling detailed studies of low-energy elementary excitations. The APXPS station achieved stable operation up to 1 atm, allowing true ambient-pressure in-situ chemical reaction studies, an important step forward in surface science. In 2024, research using BL07U and BL08U resulted in three refereed publications, accompanied by one press release and one news release. Continuous upgrades to beam stability, polarization control, and energy-range extension are underway to further strengthen the capabilities of NanoTerasu.

At the Harima office, the soft X-ray beamline BL07LSU of SPring-8, now reconfigured by RIKEN, has been used as an R&D beamline for next-generation X-ray imaging and optics technologies. A spatial resolution of ~50 nm has been achieved through the development of advanced optical components such as mirrors, gratings, and by further refining ptychographic imaging techniques. Work is underway to extend this system into a four-dimensional spectromicroscopy platform integrating spatial, temporal, and energy domains. At the X-ray free electron laser SACLA, experiments now routinely probe femtosecond-scale dynamics of electrons, spins, and lattice vibrations, and new exploratory studies targeting nonlinear optical responses and X-ray-induced phase transitions have been initiated.

The Kashiwa E-building continues to serve as a hub for high-resolution laser spectroscopy. The high-resolution spin- and angle-resolved photoemission spectroscopy (SARPES) system, which has achieved an energy resolution of 1.7 meV, underwent major stabilization improvements in 2024. Introduction of the fundamental wave into the optical path successfully compensated for long-term degradation of the laser amplifier, resulting in significant improvements in beam focus, intensity stability, and reproducibility of band-dispersion measurements. Planned upgrades include a new high-power optical parametric amplifier (OPA) for tunable pump-probe experiments, enabling studies of nonlinear optical responses and photoinduced phase transitions under strong excitation. Enhancements of real-time laser diagnostics using FROG and related tools are also in progress. The time-resolved soft X-ray spectroscopy (TR-SX) station with the 2D ARTOF analyzer has also continued to evolve,

supporting both 6 eV photoemission and sub-picosecond time-resolved studies. Work is ongoing to introduce an ultra-high-speed readout and visualization system to improve measurement efficiency.

Through the combined use of high-brilliant NanoTerasu, advanced R&D at Harima and SACLA, and state-of-the-art laser spectroscopy in Kashiwa, SRL is steadily advancing toward a fully integrated research platform that covers spatial, temporal, and spin-resolved spectroscopies from the vacuum ultraviolet to the soft X-ray regions.

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