Progress of Facilities

Supercomputer Center

The Supercomputer Center (SCC) is a part of the Materials Design and Characterization Laboratory (MDCL) of ISSP. Its mission is to serve the whole community of computational condensed-matter physics of Japan, providing it with high performance computing environment. In particular, the SCC selectively promotes and supports large-scale computations. For this purpose, the SCC invites proposals for supercomputer-aided research projects and hosts the Steering Committee, as mentioned below, that evaluates the proposals.

The ISSP supercomputer system consists of two subsystems: System B, which was last replaced in Oct. 2020, is intended for larger total computational power and has more nodes with relatively loose connections whereas System C is intended for higher communication speed among nodes. System B (ohtaka) consists of 1680 CPU nodes of AMD EPYC 7702 (64 cores) and 8 FAT nodes of Intel Xeon Platinum 8280 (28 cores) with total theoretical performance of 6.881 PFlops. System C was replaced in June 2022 and the current system (kugui) consists of 128 nodes of AMD EPYC 7763 (128 cores) and 8 nodes of AMD EPYC 7763 (64 cores) with total theoretical performance of 0.973 PFLOPS.

In addition to the hardware administration, the SCC puts increasing effort on the software support. Since 2015, the SCC has been conducting “Project for advancement of software usability in materials science (PASUMS).”In this project, for enhancing the usability of the ISSP supercomputer system, we conduct several software-advancement activities: developing new application software that runs efficiently on the ISSP supercomputer system, adding new functions to existing codes, help releasing private codes for public use, creating/improving manuals for public codes, etc. Two target programs were selected for fiscal year 2023: (1) Enhancement of TeNeS for finite-temperature calculation (proposed by T. Okubo (U. Tokyo)), and (2) First-principles high-throughput computation for database generation (proposed by K. Yoshimi (ISSP)). In addition, since 2021, we have been maintaining the data repository service for secure storage and enhanced usability of results of numerical calculation.

All staff members of university faculties or public research institutes in Japan are invited to propose research projects (called User Program). The proposals are evaluated by the Steering Committee of SCC. Pre-reviewing is done by the Supercomputer Project Advisory Committee. In fiscal year 2023, totally 345 projects were approved including the ones under the framework of Supercomputing Consortium for Computational Materials Science (SCCMS), which specially supports FUGAKU and other major projects in computational materials science. The total points applied and approved are listed on Table. 1 below.

The research projects are roughly classified into the following three (the number of projects approved, not including SCCMS):

First-Principles Calculation of Materials Properties (178)
Strongly Correlated Quantum Systems (36)
Cooperative Phenomena in Complex, Macroscopic Systems (119)

In all the three categories, most proposals involve both methodology and applications. The results of the projects are reported in 'Activity Report 2023' of the SCC. Every year 3-4 projects are selected for “invited papers” and published at the beginning of the Activity Report. In the SCC Activity Report 2023, the following four invited papers are included:

Class	Max Points		Application	Number of Projects	Total Points			
					Applied		Approved	
	System B	System C			System B	System C	System B	System C
A	100	50	any time	24	2.4k	1.2k	2.4k	1.2k
B	1k	100	twice a year	99	58.1k	7.3k	38.5k	6.5k
C	10k	1k	twice a year	185	996.9k	58.4k	513.6k	45.8k
D	10k	1k	any time	8	47.5k	2.3k	40.6k	1.9k
E	30k	3k	twice a year	17	317.0k	25.5k	185.0k	20.7k
S			twice a year	0	0k	0k	0k	0k
SCCMS				12	27.0k	2.6k	27.0k	2.6k
Total				345	1448.9k	97.3k	807.1k	78.7k

Table 1. Research projects approved in Academic Year 2023.
The maximum points allotted to the project of each class are the sum of the points for the two systems; Computation of one node for 24 hours corresponds to one point for the CPU nodes of System B and System C. The FAT nodes require four points for a 1-node 24-hours use.

1. “Density functional theory calculations of H_2O adsorption monolayer on a Pt(111) surface”, Jun HARUYAMA, Osamu SUGINO (ISSP), and Toshiki SUGIMOTO (Institute for Molecular Science, JST)
2. “Theoretical studies on the spin-charge dynamics in Kondo-lattice models”, Masahito MOCHIZUKI, and Rintaro ETO (Waseda Univ.)
3. “Mixing Free Energy and Molecular Dynamics Simulations”, Naoko NAKAGAWA and Akira YOSHIDA (Ibaraki Univ.)
4. “Ab initio optical calculation by RESPACK”, Kazuma NAKAMURA (Kyutech)

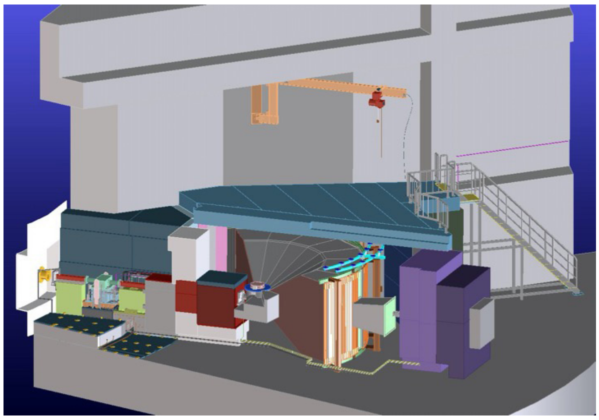

Fig. 2. Schematic view of HRC.

Neutron Science Laboratory

The Neutron Science Laboratory (NSL) has been playing a central role in neutron scattering activities in Japan since 1961 by performing its own research programs as well as providing a strong General User Program (GUP) for the university-owned various neutron scattering spectrometers installed at JRR-3 (20 MW) operated by Japan Atomic Energy Agency (JAEA) in Tokai, Ibaraki (Fig. 1). In 2003, the Neutron Scattering Laboratory was reorganized as the Neutron Science Laboratory to further promote the neutron science with use of the instruments in JRR-3. Under GUP supported by NSL, 12 university-group-owned spectrometers in the JRR-3 reactor are available for a wide scope of research on material science. The submitted proposals were about 300 and the visiting users reached over 6000 person-day in FY2010. In 2009, NSL and Neutron Science Division (KENS), High Energy Accelerator Research Organization (KEK) built a chopper spectrometer, High Resolution Chopper Spectrometer, HRC, at the beam line BL12 of MLF/J-PARC (Materials and Life Science Experimental Facility, J-PARC) (Fig. 2). HRC covers wide energy transfer (100 μeV < $\hbar\omega$ < 0.5 eV) and momentum transfer (0.03 Å^{-1} < Q < 30 Å^{-1}) ranges, and therefore becomes complementary to the existing inelastic spectrometers at JRR-3. HRC has accepted general users through the J-PARC proposal system since FY2011.

Triple axis spectrometers, HRC, a four-circle diffractometer, and a high resolution powder diffractometer are utilized mainly for a conventional solid state physics and a variety of research fields on hard-condensed matter, while in the field of soft-condensed matter science, researches are mostly carried out by using a small angle neutron scattering (SANS-U) and/or neutron spin echo (iNSE) instruments. The upgraded time-of-flight (TOF) inelastic scattering spectrometer, AGNES, is available both for hard- and soft-matter science. Our GUP has produced 2137 publications and 319 dissertations until April 23, 2024. Their lists for the last 10 years are given in Activity Report on Neutron Scattering Research which is available in ISSP and NSL web pages.

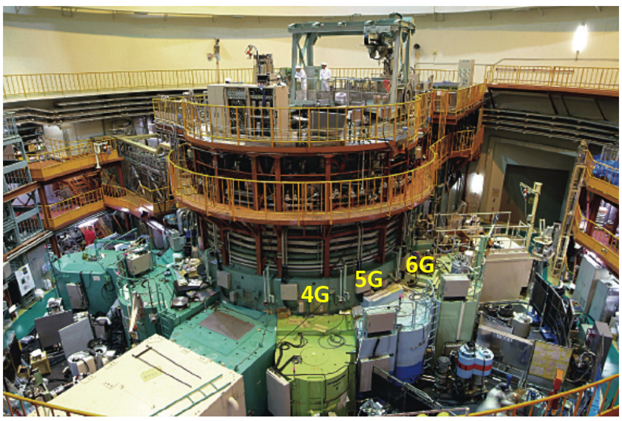

Fig. 1. Reactor hall of JRR-3. Three triple axis spectrometers are shown in the photo.

As for international cooperative programs, NSL operates the U.S.-Japan Cooperative Program on neutron scattering, providing further research opportunities to material scientists who utilize the neutron scattering technique for their research interests. In 2010, relocation of the U.S.-Japan triple-axis spectrometer, CTAX, was completed, and it is now open to Japanese users. In March 2024, we had an international review for the renewal of the cooperative program which is mandated by the MEXT every 10 years. The review and contract renewal were successfully completed and the cooperation program is now entering a new phase. Here, as proposed by the review committee, we plan to further revitalize soft matter science.

After the resumption of JRR-3 operation in 2021, many instrumental advances have been made. First, improvements to the instruments and guide tubes during the beam shutdown period (2011-2021) resulted in a 10-fold increase in the intensity of GPTAS (4G) and an 8-fold increase in AGNES (C3-1-1). Next, a new multiflex-type triple-axis spectrometer HODACA was constructed at C1-1. This spectrometer is 40 times more efficient than the conventional spectrometer (HER). The development and improvement of these instruments and the latest status of the other university spectrometers at JRR-3 are described in detail in a special topics of the Journal of the Physical Society of Japan (JPSJ) (Vol. 93(9)). Some improvements have also been made to the proposal adoption system: multibeam proposals (in cooperation with PF at KEK) were launched in 2022, student proposals (doctor-course students can apply as PIs) in 2023, international proposals (researchers from overseas institutions can apply as PIs) in 2024. Industrial proposals (in which researchers from industry can apply as PIs) are scheduled to begin in 2025.

We had conducted 84 experiments for 155 approved proposals in 2021 (reactor operation: 4 cycles, 92 days), 123 experiments for 166 approved proposals in 2022 (reactor operation: 7 cycles, 152 days), and 122 experiments for 154 approved proposals in 2023 (reactor operation: 6 cycles, 143 days). For these experiments, about 70 papers, including those under review, have been obtained as of May, 2024.

International MegaGauss Science Laboratory

The objective of this laboratory (Fig. 1) is to study the physical properties of solid-state materials (such as metals, semiconductors, insulators, superconductors, and magnetic materials) in a high magnetic field of 100 T or even higher. Such a high magnetic field can control material phases and functions. Our pulsed magnets, at the moment, can generate up to 88.6 Tesla (T) in a non-destructive manner and up to 1200 T in a destructive manner. The world record for an indoor magnetic field of 1200 T was achieved in 2018. The laboratory is open for scientists both domestic and overseas. Lots of fruitful results have come out from the collaborative researches and our in-house activities.

Fig. 1. The building C of the IMGSL.

Our interests cover the studies on quantum phase transitions (QPT) induced by high magnetic fields. Field-induced QPT has been explored in various materials, such as quantum spin systems, strongly correlated electron systems, and other magnetic materials. One of our ultimate goals is to provide joint-research users with a 100 T millisecond-long pulse using a non-destructive magnet and to offer versatile high-precision physical measurements. Measurable physical quantities or properties are magneto-optical spectra, magnetization, magnetostriction, electrical transport, specific heat, nuclear magnetic resonance, and ultrasound propagation. They can be carried out with sufficiently high accuracy. Another ultimate goal is to extend the magnetic field region and discover novel phenomena happening only in extremely strong magnetic fields exceeding 100 T. Recent technical developments allow us to even measure magnetostriction and ultrasound propagation in destructive magnetic fields over 100 T, which can directly reach potential structural changes in the ultrahigh magnetic fields. The recent discovery of magnetic field-induced insulator-metal transitions of strongly correlated materials in 500 T would open a new direction of the megagauss field research, namely the exploration of field-induced novel phases in materials with strong interactions comparable to the thermal energy at room temperature.

A set of supercapacitor power supplies with a total accumulation energy of 150 MJ (Fig. 2) was installed in 2023 and used as an energy source for super-long pulse magnets. The magnet technologies are intensively devoted to the quasi-steady long pulse magnet (an order of 1-10 sec) energized by the giant DC power supply. The supercapacitor

	Alias	Type	B_{max}	Pulse width Bore	Power source	Applications	Others
Building C Room 101-113	ElectroMagnetic Flux Compression	Destructive	1200 T	3μs (100-1200T) 10 mm	5 MJ, 50 kV 2 MJ, 50 kV	Magneto-Optics Magnetization Magneto-Striction Magneto-Transport	5 K – room temperature
	Horizontal Single-turn Coil	Destructive	300 T 200 T	6μs 5 mm 10 mm	0.2 MJ, 50 kV	Magneto-Optics Magnetization Magneto-Striction Magneto-Transport Ultrasound	5 K – room temperature
	Vertical Single-turn Coil	Destructive	300 T 200 T	8μs 5 mm 10 mm	0.2 MJ, 40 kV	Magneto-Optics Magnetization Magneto-Striction Magneto-Transport Ultrasound	2 K – room temperature
Building C Room 114-120	Mid-pulse Magnet	Non-destructive	60 T	40 ms 18 mm	0.9 MJ, 10 kV	Magneto-Optics Magnetization Magneto-Transport Electric-Polarization Magneto-Striction Magneto-Imaging Torque Magneto-Calorimetry Heat Capacity Ultrasound	Independent Experiment in 5 site
			70 T	40 ms 10 mm			Lowest temperature 0.1 K
Building C Room 121	PPMS	Steady	14 T			Resistance Heat Capacity	Down to 0.3 K
	MPMS	Steady	7 T			Magnetization	Down to 2K
Building K	Short-Pulse Magnet	Non-destructive	86 T	2.5 ms 12 mm	0.5 MJ, 20 kV	Magnetization Magneto-Transport	1.4 K – room temperature
	Long-Pulse Magnet	Non-destructive	40 T	1 s 30 mm	150 MJ, 2.4 kV	Resistance Magneto-Calorimetry	0.5 K – room temperature

Table 1. Available Pulse Magnets, Specifications

Fig. 2. Upper: The K-building for the supercapacitor power supply (left-hand side) and a long pulse magnet station (right-hand side). Lower: The supercapacitors have a total accumulation energy of 150 MJ installed in 2023 and are planned to drive the long pulse 60 T magnet and the first stage of the dual-coil 100 T non-destructive magnet.

power source will also be used for the giant outer magnet coil to realize a 100 T nondestructive magnet by inserting a conventional pulse magnet coil in its center bore. Recently, the super-long pulsed magnet has been intensively used to investigate thermal properties such as specific heat and magnetocaloric effects.

Magnetic fields exceeding 100 T can only be obtained with the destruction of a magnet coil. The ultrahigh magnetic fields are obtained in a microsecond time scale. The project, financed by the Ministry of Education, Culture, Sports, Science and Technology aiming to generate 1000 T with the electromagnetic flux compression (EMFC) system (Fig. 3), has been completed. Our experimental techniques using the destructive magnetic fields have intensively been developed. The system, which is unique to ISSP on the world scale, is comprised of a power source of 5 MJ main condenser bank and 2 MJ condenser bank. Two magnet stations are constructed, and both are energized by each power source. Both systems are fed with another 2 MJ condenser bank used for a seed-field coil, the magnetic flux of which is to be compressed. The 2 MJ EMFC system can generate 450 T. The 5 MJ system is used for the generation of a 1000 T-class magnetic field. For the research in the magnetic field range

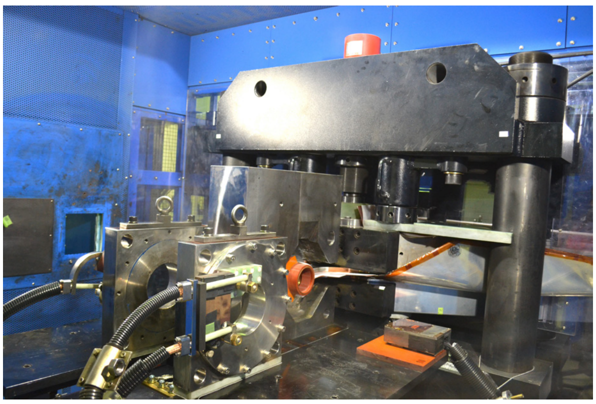

Fig. 3. View of the coil setup of the electromagnetic flux compression inside of an anti-explosive house. The world's strongest indoor magnetic field of 1200 T was achieved in 2018.

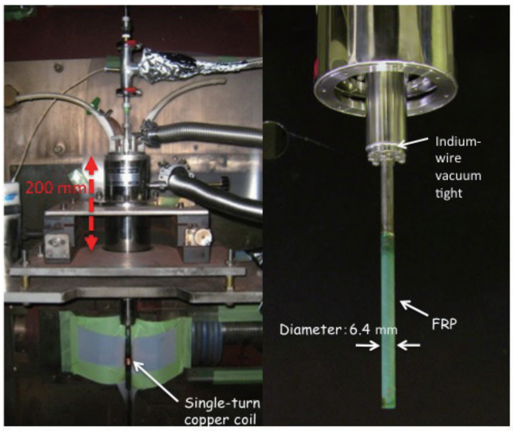

Fig. 4. Schematic picture of the V-type single-turn coil equipped with a 40 kV, 200 kJ fast capacitor bank system. The liquid-helium-bath cryostat with a plastic tail is also shown.

of 100-300 T, we have two single-turn coil (STC) systems that have a fast-capacitor bank system of 200 kJ for each. One is the horizontal type (H-type), and the other is a vertical type (V-type, Fig. 4). Various kinds of laser spectroscopy experiments, such as the cyclotron resonance and the Faraday rotation, are possible using the H-type STC, while a stable low-temperature condition of 2 K is available for the V-type STC.

Center of Computational Materials Science

With the advancement of hardware and software technologies, large-scale numerical calculations have been making important contributions to materials science and will have even greater impact on the field in the near future. CCMS is a specialized research center established in 2011 for promoting computer-aided materials science with massively parallel computers, such as the Fugaku supercomputer, which has been developed in Kobe as the core of a billion-dollar national project. Activities of CCMS are divided into the following three categories: (1) highly efficient and large-scale use of the Fugaku supercomputer and its application to grand-challenge problems in computational materials science, (2) activities as the center for the community of computational condensed matter physics and materials science, and (3) computational physics research aiming to solve intriguing physics emerged from strongly correlated systems.

For the first category, each group in CCMS is carrying out various individual research projects in its own expertise to efficiently utilize large-scale parallel computers. For example, the Ozaki group has been developing efficient and accurate methods and software packages to extend the applicability of DFT to more realistic systems, and investigated the structural and electronic properties of various 2D materials in successful collaboration with experimental groups and industrial companies. There are other activities such as development of Tensor Network (TN) based numerical methods and Markov-chain Monte Carlo methods by the Kawashima group and the Todo group.

As for the activities in the second category, apart from major annual conferences and formal international meetings, the CCMS provided a series of lectures and training sessions at Kashiwa. For example, training sessions "Kashiwa Hands-

On" for getting accustomed to various application programs, such as OpenMX, Hphi, mVMC, AkaiKKR, and MateriApps LIVE!, as shown in Fig. 1, have been held monthly. Each session is designed for more than 10 trainees and takes 4-5 hours. We also coordinate the use of the computational resources available to our community, and support community members through various activities such as administrating the website "MateriApps" for information on application software in computational science as shown in Fig. 2.

For the third category, the Misawa group addressed searching for topological insulators in solids which is one of the main issues of modern condensed-matter physics since robust gapless edge or surface states of the topological insulators can be used as building blocks of next-generation devices, and showed a way to realize a topological state characterized by the quantized Zak phase, termed the Zak insulator with spin-polarized edges in organic antiferromagnetic Mott insulators without relying on the spin-orbit coupling. The finding provides an unprecedented way to realize a topological state in strongly correlated electron systems. Prof. Misawa was also involved in the Data generation and utilisation materials Research and development projects (DxMT).

These activities are supported by funds for various governmental projects including the DxMT project and the Program for Promoting Researches on the Supercomputer Fugaku.

The following is the selected list of meetings organized by CCMS in recent years:

- 2023/3/29 DxMT workshop: recent progresses in machine-learning potentials.
- 2023/4/3-4 ISSP joint workshop for ISSP Supercomputer Co-use and CCMS.
- 2023/6/1 Matching Workshop for industries & graduate students/ postdocs.
- 2023/6/26 Symposium of the Division of Data-Integrated Materials Science, Social Cooperation Research Department at ISSP.
- 2023/12/19-20 MP-CoMS lecture series for OpenMX Workshop: Fundamentals and Practice.
- 2024/2/12-14 MaterialAI2023: utilization of AI technologies in computational materials science
- 2024/2/19-20 ISSP workshop for Integration of Materials Science Simulations and Advanced Experimental Data.

In addition to the events listed above, we organize regular hands-on program for various application, such as RESPACK and SALMON.

Fig. 1. Software in the CCMS community

Fig. 2. MateriApps Website

Laser and Synchrotron Research Center (LASOR Center)

Laser and synchrotron research center (LASOR Center) was established in October 2012 to push the frontiers of the photon and materials science. LASOR has 10 groups in 2023, which is the largest division in ISSP. Most of the research activities on the development of new high-power lasers and their application to materials science are conducted in specially designed buildings D and E with large clean rooms and vibration-isolated floors at the Kashiwa campus. We also have a clean room for a laser processing platform at the Kashiwa II campus. On the other hand, experiments using synchrotron radiation are conducted at SPring-8 and SACLA (Hyogo). Recently, a new beamline has been developed at Nano Terasu in Sendai.

The development of new laser light sources in the vacuum ultraviolet to soft x-ray range has revolutionized materials research, represented by high energy resolution photoelectron spectroscopy, ultrafast time domain spectroscopy, and ultrafast nonlinear spectroscopy. Materials science research with lasers has entered a new era. The ultrashort and high-power lasers are becoming an increasingly attractive light source for both basic research and industry. The state-of-the-art laser source and spectroscopy are being intensively explored.

Synchrotron-based research is another area of activity

Fig. 1. Optical frequency comb

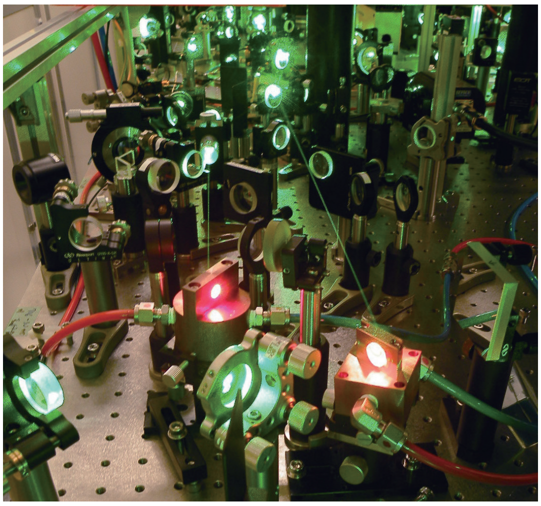

Fig. 2. Close look of a high-peak-power ultrashort-pulse laser

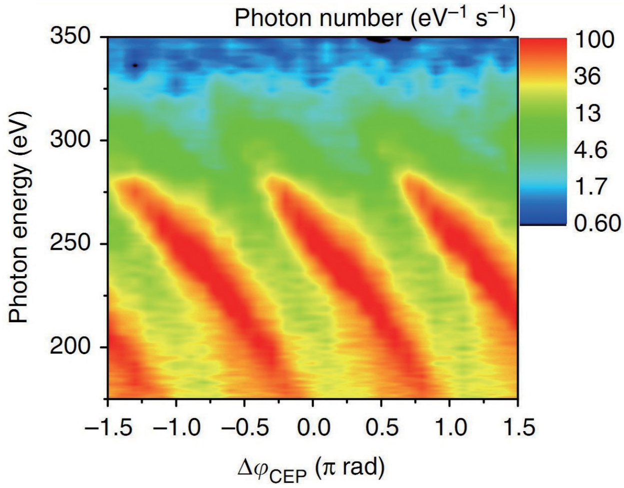

Fig. 4. Phase-dependence of high harmonic spectra in soft X rays.

at the ISSP. The dramatic increase in the brilliance of synchrotron radiation has also opened up a new field of photon science. In 2018, the Japanese government has announced the construction of a new synchrotron facility in Tohoku (Nano Terasu). LASOR has decided to subjectively contribute to this facility from design to operation, and Nano Terasu is now under construction.

Lasers and synchrotrons have developed independently; today, both light sources cover a wide range of photon energies with an overlap in the vacuum-ultraviolet to soft X-ray regions. Recognizing their common interests in research areas and technologies, ISSP integrated the two streams, extreme lasers and synchrotron radiation, into a common platform. Through the mutual interactions between the frontiers of lasers and synchrotrons, LASOR will be the center of innovation in light and materials science through worldwide collaborative research and close cooperation with other divisions of ISSP such as New Materials Science, Nanoscale Science, and Condensed Matter Theory.

The mission of LASOR is to cultivate and advance the following three scientific fields:

1. Laser Science,
2. Synchrotron radiation science,
3. Extreme Spectroscopy,

• Laser science group

We have continued to develop various state-of-the-art laser systems, such as high-power solid-state or gas lasers, high-intensity lasers, ultra-short pulse lasers down to the attosecond time scale (peta-Hz linewidth), ultra-stable 1-Hz linewidth lasers, optical frequency combs, mid-infrared lasers, THz light sources, and semiconductor lasers. The technology of high-power and ultrashort pulse lasers has progressed during these 10 years. It has opened two research directions. One is a coherent extreme ultraviolet light source realized by a high harmonic generation (HHG) scheme. The average power of HHG became high enough to be used for photoemission spectroscopy. Photon energies from 7 eV to 60 eV are now available. They can be either very narrow bandwidth or ultrashort pulse. The other is an industrial science such as laser processing. Variable pulse duration, 100 W average power, femtosecond laser is now available at LASOR for any collaborative research, including companies. We have a laser processing platform for both industrial and scientific applications.

We also aim to develop novel laser spectroscopy and coherent nonlinear optical physics enabled by emerging lasers and optical science/technology, and to comprehensively study fundamental light-matter physics, optical materials science, and applied photonics. Such research includes ultrafast spectroscopy for excited state dynamics, terahertz magnetic field spectroscopy for spin dynamics, quantitative microspectroscopy of semiconductor lasers, and nanostructured photonic devices such as quantum wire lasers, gain-switched semiconductor lasers, multi-junction solar cells, and bioluminescent systems.

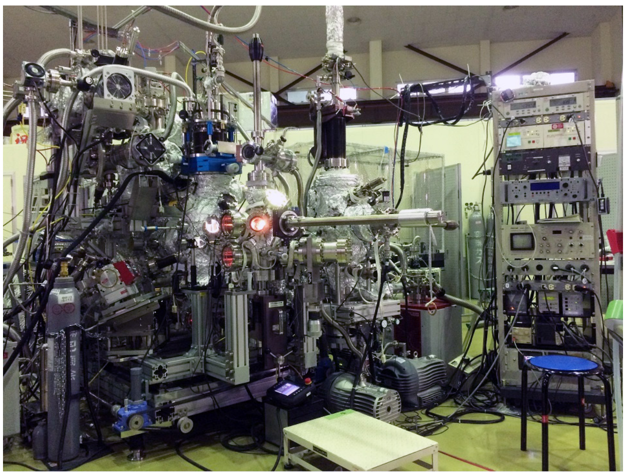

Fig. 3. Spin-resolved photo-emission spectroscopy.

• Synchrotron radiation science group

By inheriting and developing the synchrotron techniques culBy inheriting and developing the synchrotron techniques cultivated for more than 20 years, we are continuously developing world-class spectroscopies such as time-resolved

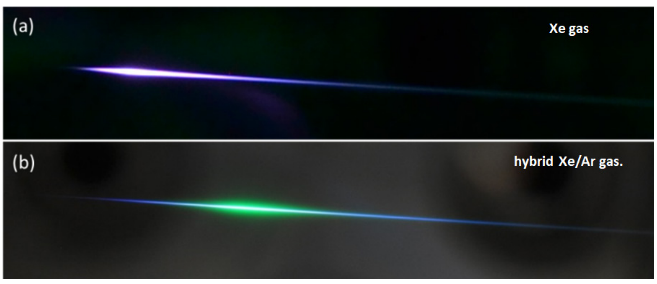

Fig. 5. Generation of 7-eV, femtosecond light with (a) Xe and (b) Xe/Ar gases.

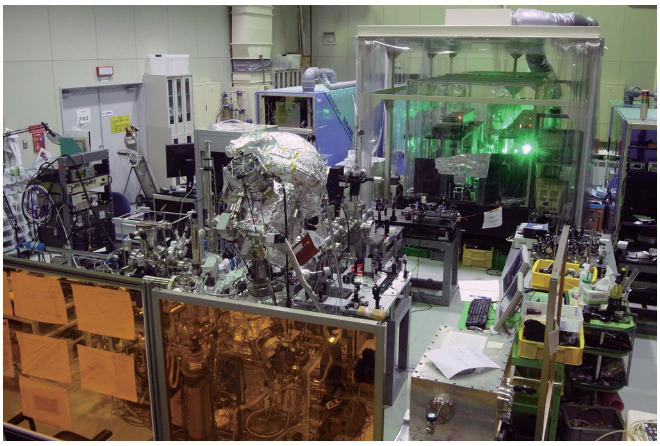

Fig. 6. Pump-probed photoemission system using 60-eV laser

photoemission/diffraction, ultra-high-resolution soft X-ray emission, 3D (depth + 2D microscopy) nano-ESCA, and X-ray magneto-optical effect, and providing these techniques for both basic materials science and applied science that contributes to the instrument applications in collaboration with outside researchers. In order to pioneer new spectroscopies for next-generation light sources, we are improving the fast polarization switching of the undulator light source in collaboration with SPring-8. In addition, we are promoting frontier work on the use of X-ray free-electron lasers, SACLA, with high spatial and temporal coherence comparable to optical lasers in collaboration with scientists of laser light sources and spectroscopy.

• Extreme spectroscopy group

The advent of laser-based light sources in the soft X-ray region opens a new stage in the field cultivated by synchrotron radiation. One of the milestones was the development of a laser-based light source of ~7 eV for sub-meV resolution photoemission spectroscopy. In the last five years, the available photon energy has been increased to 11 eV using Yb fiber laser technology. It has high photon flux(10^{14} photons/sec) with sub-picosecond time resolution. Laser-based spin-resolved ARPES is realized in LASOR with 11 eV laser. This technology would open up a whole new field of spectroscopy. High-harmonic-generation based photoemission spectroscopy in the 20-60 eV region is another direction to be pursued. Femtosecond time domain spectroscopy has been achieved. Combined with picosecond time-domain spectroscopy using the pulsed light delivered by synchrotrons, we are investigating the electronic structures and dynamics of matter in the bulk, on the surface, and down to the nanoscale. The ultimate goal is to extend soft x-ray operando methods to lasers. Diffractions, magneto-optical effects, and inelastic scattering now performed at synchrotrons will be performed by lasers to access the real-time dynamics of chemical reactions and phase transitions down to femtoseconds.

State-of-the-art laser-based organismal spectroscopy is a new direction in LASOR. The ISSP research field is shifting from simple materials and science to a complex one involving living bodies and functional materials with excited state physics.

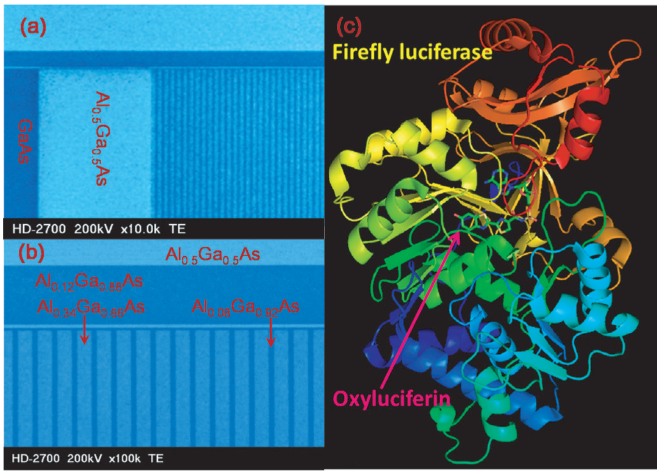

Fig. 7. Photonics devices under study: (left panel) semiconductor quantum wires and (right panel) firefly-bioluminescence system consisting of light emitter (oxyluciferin) and enzyme (luciferase)

Synchrotron Radiation Laboratory

The Synchrotron Radiation Laboratory (SRL) was established in 1975 as a research division dedicated to solid state physics using synchrotron radiation. Currently, SRL is composed of three research sites, the Sendai office, the Harima office and the E-building of the Institute for Solid State Physics.

• Synchrotron soft X-ray experimental stations at Sendai office and Harima office

In 2009 SRL established the Harima branch laboratory in SPring-8 and operated a high brilliant and polarization-controlled 25-m long soft X-ray undulator beamline, BL07LSU until August 2022 in collaboration with Synchrotron Radiation Research Organization (SRRO) of the University of Tokyo. The management of the beamline was transferred to the RIKEN SPring-8 Center in September 2022. In November 2022, the Sendai office was formed on the Aobayama campus of Tohoku University under the auspices of a new SRRO launched in April 2022 and includes six departments of the University of Tokyo. At the end of FY2022, three endstations, ambient pressure X-ray photoemission (APXPS) (Fig. 1a), nanoESCA (Fig. 1c), and high resolution soft X-ray emission spectroscopy (HORNET) (Fig. 1d) stations were relocated to the new 3 GeV synchrotron facility NanoTerasu in Sendai, which started commissioning of the storage ring in early 2023. On March 25, 2022, the Sendai office relocated to the SRIS (International Center for Synchrotron Radiation Innovation Smart) building of Tohoku University which is one of the closest buildings to NanoTerasu. The three endstations, APXPS, nanoESCA and HORNET stations resumed commissioning in the summer of 2023 and were realigned to the beamlines BL07U (nanoESCA and HORNET) and BL08U (APXPS) by the end of FY 2023. During commissioning, the APXPS system achieved 10-100 Torr for XPS measurement; the 3DnanoESCA station obtained a spatial resolution of roughly 100-200 nm; and the HORNET station provided spectra with the energy resolution around 500 meV at 500 eV. All of achievements in NanoTerasu are still considerably below the standards established in SPring-8; however, they will recover and even exceed the criteria once the beamlines are aligned after official operation begins in April, 2024.

The Harima office at SPring-8 continues in 2023 and the soft X-ray imaging (ptychography) (Fig. 1b) station is being developed in collaboration with the RIKEN SPring-8 Center. The novel soft X-ray ptychography system, which uses a total-reflection Wolter mirror, has a resolution of approxi-

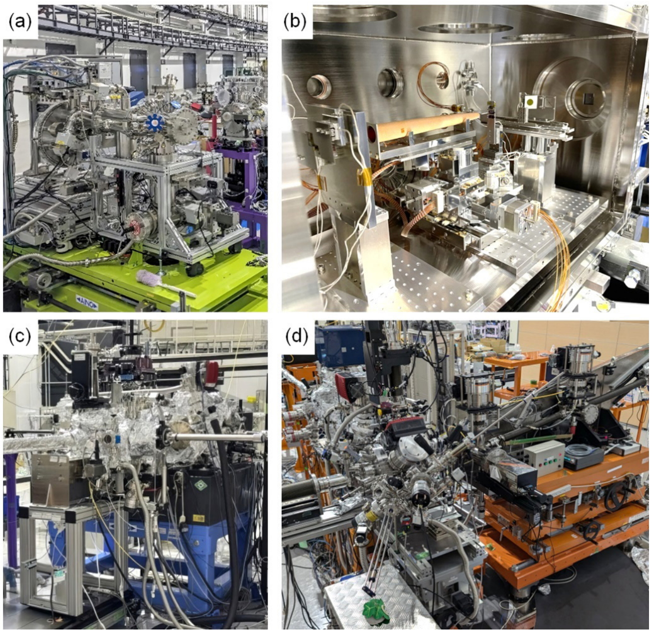

Fig. 1 Soft X-ray advanced experimental stations (a) Ambient pressure photoemission (APXPS) (b) Soft X-ray imaging (c) 3DnanoESCA (d) Soft X-ray emission (HORNET). APXPS, 3DnanoESCA and HORNET stations were transferred to the new 3 GeV synchrotron facility NanoTerasu at the end of FY2022 and installed in BL07U (3DnanoESCA, HORNET) and BL08U (APXPS) at the end of FY2023.

mately 50 nm and its long working distance allows for stereo imaging with a high rotation angle.

• High-resolution Laser SARPES and ARTOF systems at E-building

High-resolution Laser Spin- and Angle-Resolved Photoemission Spectroscopy (SARPES) is a powerful technique to investigate the spin-dependent electronic states in solids. In FY2014, LASOR and SRL staffs constructed a new SARPES apparatus (Fig. 2a), which was designed to provide high-energy and -angular resolutions and high efficiency of spin detection using a laser light at E-building. The achieved energy resolution of 1.7 meV in SARPES spectra is the highest in the world at present. From FY2015, the new SARPES system has been opened the joint-research program. The Laser-SARPES system consists of an analysis chamber, a carousel chamber connected to a load-lock chamber, and a molecular beam epitaxy chamber, which are kept ultra-high vacuum (UHV) environment and are connected to UHV gate valves. The electrons are excited with 6.994 eV photons, yielded by 6th harmonic of a Nd:YVO4 quasi-continuous wave laser with a repetition rate of 120 MHz, and 10.7 eV photons, driven by the third harmonic radiation at 347 nm of an Yb:fiber chirped pulse amplifier laser, which was developed by Kobayashi's lab in LASOR. The hemispherical electron analyzer is a custom-made Scienta Omicron DA30-L, modified for installing the spin detectors. The spectrometer is equipped with two high-efficient spin detectors orthogonally placed each other, associating very low energy electron diffraction, which allows us to analyze the three-dimensional spin polarization of electrons. At the exit of the hemispherical analyzer, a multi-channel plate and a CCD camera are also installed, which enables us to perform the angle-resolved photoelectron spectroscopy with two-dimensional (energy-momentum) detection. The laser-SARPES with 7 eV laser can provide both high-resolution spin-integrated and spin-resolved photoemission spectra in various types of solids, such as spin-orbit coupled materials and ferromagnetic materials. In addition, using the 10.7 eV makes it possible to follow their ultrafast spin dynamics in the time domain by pump-probe scheme. A spectroscopy system using a dichroic mirror (SiO_2/HfO_2 multilayer) was introduced for a stable switching of the 7 eV and 10.7 eV lasers. In 2023, an autocollimator and a laser evaluation system such as FROG have also been assembled to improve the instability of the light source (color dispersion and multi-pulse). In addition, the introduction of a new amplifier (rod fiber) has made it possible to use higher-power light. At present, the pulse laser and the optical system are being adjusted to stably use high-power, high-quality light by using the assembled laser evaluation system. This will enable stable operation of pump-probe time-resolved SARPES as well as wavelength conversion of pump light.

The time-resolved soft X-ray spectroscopy (TR-SX) station was moved from SPring-8 BL07LSU to the E-building in 2020. The measurement chamber is equipped with a unique electron spectrometer, the two-dimensional (2D) angle-resolved time-of-flight (ARTOF) analyzer (Fig. 2b). The system is currently operational for measurements of 2D angle-resolved photoemission spectroscopy with pulsed laser of 6 eV photon energy supplied by Itatani's lab in LASOR. Time-resolved measurements can also be conducted with temporal resolution of 600 fs. An ultra high-speed reading and visualization program is currently in development to enhance usability.

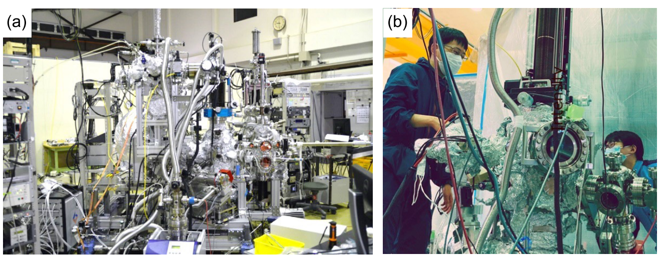

Fig. 2 (a) Laser-SARPES system and (b) ARTOF system at E-building.