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 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 is SGI ICE XA / UV hybrid system that consists of FAT nodes with large memory, CPU nodes based on Intel Xeon, and ACC node enhanced by GPGPU accelerator. Its theoretical performance is 2.6 PFLOPS. System C is HPE SGI 8600 with 0.77 PFLOPS. Replacement of the System B is scheduled in Autumn 2020. The new machine will be much more powerful (more than by the factor of 2) than the current System B in its peak performance.

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 perform some software-advancement activity such as developing new application software that runs efficiently on the ISSP supercomputer system, adding new functions to existing codes, helping in releasing private codes for public use, and writing/improving manuals for public codes. Two target programs were selected in fiscal year 2019 and developed software were released as abICS (proposal made by S. Kasamatsu (Yamagata U.)) and TeNeS (proposal made by N. Kawashima (ISSP)).

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 2019, totally 276 projects were approved. The total points applied and approved are listed on Table. 1 below. Additionally, we supported post-K and other computational-materials-science projects through Supercomputing Consortium for Computational Materials Science (SCCMS).

The research projects are roughly classified into the following three (the number of projects approved):

First-Principles Calculation of Materials Properties (145)
Strongly Correlated Quantum Systems (36)
Cooperative Phenomena in Complex, Macroscopic Systems (128)

In all the three categories, most proposals involve both methodology and applications. The results of the projects are reported in 'Activity Report 2019' of the SCC. Every year 3-4 projects are selected for “invited papers” and published at the beginning of the Activity Report. In the Activity Report 2019, the following three invited papers are included:

1. "Development of Open-Source Parallelized Tensor Network Softwares: mptensor and TeNeS", Satoshi MORITA (ISSP) and Naoki KAWASHIMA (ISSP)
2. "Disorder-Free Glass Transitions of Spins and Orbitals in a Frustrated Pyrochlore Magnet", Kota Mitsumoto (Osaka U.), Chisa Hotta (U. Tokyo), and Hajime Yoshino (Osaka U.)
3. "First-principles calculation of thermophysical properties of solids with strong phonon anharmonicity", Terumasa TADANO (NIMS)

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	100	any time	17	1.7k	0.9k	1.7k	0.9k
B	1k	500	twice a year	88	82.8k	4.7k	58.3k	4.1k
C	10k	2.5k	twice a year	183	1446.2k	91.2k	612.0k	63.7k
D	10k	2.5k	any time	5	26.9k	2.0k	26.9k	2.0k
E	30k	2.5k	twice a year	16	445.0k	41.0k	249k	34.7k
S			twice a year	0	0	0	0	0
SCCMS				32	218.9k	103.5k	218.9k	103.5k
Total				276	2058.3k	312.3k	1180.7k	267.8k

Table 1. Research projects approved in 2019
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 and ACC nodes require four and two points for a 1-node 24-hours use, respectively.

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 for the university-owned various neutron scattering spectrometers installed at the 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 the General User Program supported by NSL, 12 university-group-owned spectrometers in the JRR-3 reactor are available for a wide scope of researches 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 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 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 General User Program has produced 2064 publications and 284 dissertations until Jan. 29, 2020. Their lists for the last 10 years is given in Activity Report on Neutron Scattering Research which is available in ISSP and NSL web pages.

Since the Great East Japan Earthquake on March 11, 2011, JRR-3 has been closed mainly from safety issues. Hence, our domestic activity is only on HRC. To take recent research examples, well-defined spin wave was successfully measured in the pressure-induced magneticphase in $CsFeCl_3$, and novel excitations near quantum criticality was identified [1]. Another progress on HRC was that usage of superconducting magnet up to 5 T became available.

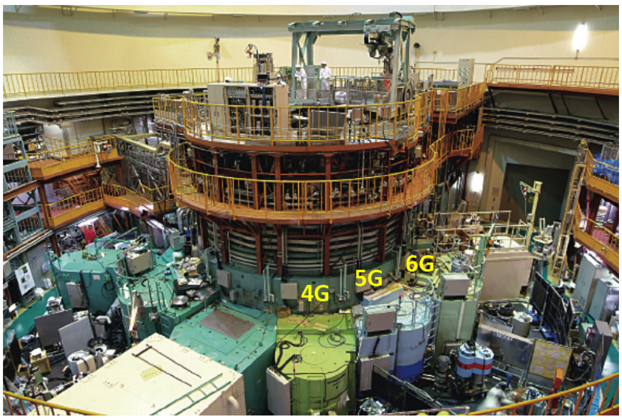

Fig. 1. Reactor hall of JRR-3. Three triple axis spectrometers are shown in the photo.

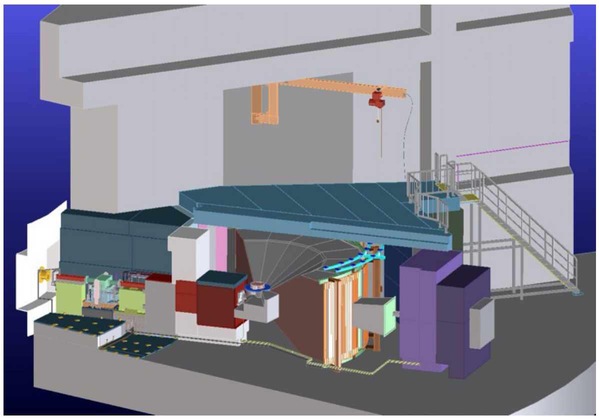

Fig. 2. Schematic view of HRC.

Field dependence of spin-wave spectra in 2D antiferromagnet $Ba_2MnGe_2O_7$ was measured. Since 2012, NSL have managed User-Program Supports for Overseas Experiments. Until March 30, 2020, 398 people (for 297 proposals) have performed their experiments in various foreign facilities and published 106 papers. The lists for User-Program Supports for Overseas Experiments are also available in Activity Report on Neutron Scattering Research mentioned above.

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 users. NSL has another agreement with Australian Centre for Neutron Scattering (ANSTO), which is the main foreign facility for the User-Program Supports for Overseas Experiments.

JRR-3 will restart in February 2021 after long shutdown. During the shutdown period, we have been concentrating our efforts on upgrading the instruments and neutron beam circumstances. Specific actions taken include: the installation of focusing collimation systems, such as focusing monochromator and focusing analyzer, and material lens; and the introduction of polarization optics together with the installation of non-magnetization neutron shield. The neutron guides in the Guide Hall have also been upgraded by replacing the existing ones with super-mirror guides. These upgrades should result in increase in neutron beam flux several times. The sample environments such as cryostat and pressure cells have also been upgraded. Of course, the normal General User Program will also restart from FY2021. We are eagerly waiting for that.

[1] S. Hayashida *et al*., Phys. Rev. B **97**, 140405(R) (2018).

International MegaGauss Science Laboratory

The objective of this laboratory (Fig. 1) is to study the physical properties of solid-state materials (such as semiconductors, magnetic materials, metals, insulators, superconducting materials) under ultra-high magnetic field conditions. Such a high magnetic field is also used for controlling the new material phase and functions. Our pulse magnets, at moment, can generate up to 87 Tesla (T) by non-destructive manner, and from 100 T up to 1200 T (the world strongest as an in-door record) by destructive methods. The laboratory is opened for scientists both from Japan and from overseas, especially from Asian countries, and many fruitful results are expected to come out not only from collaborative research but also from our in-house activities. One of our ultimate goals is to provide the scientific users as our joint research with magnets capable of a 100 T, millisecond long pulses in a non-destructive mode, and to offer versatile physical precision measurements. The available measuring techniques now involve magneto-optical measurements, cyclotron resonance, spin resonance, magnetization, and transport measurements. Recently, specific heat and calorimetric measurements are also possible to carry out with sufficiently high accuracy.

Our interests cover the study 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. Non-destructive strong pulse magnets are expected to provide us with reliable and precise solid state physics measurements. The number of collaborative groups for the research is almost 50 in the FT of 2019.

A 210 MJ flywheel generator (Fig. 2), which is the world largest DC power supply (recorded in the Guinness Book of World Records) has been installed in the DC flywheel gener-

Fig. 1. Signboard at the entrance of the IMGSL.

Fig. 2. The building for the flywheel generator (left hand side) and a long pulse magnet station (right hand side). The flywheel giant DC generator is 350 ton in weight and 5 m high (bottom). The generator, capable of a 51 MW output power with the 210 MJ energy storage, is planned to energize the long pulse magnet generating 100 T without destruction.

	Alias	Type	B_{max}	Pulse width Bore	Power source	Applications	Others
Building C Room 101-113	Electro- Magnetic Flux Compression	destructive	1200 T	μs 10 mm	5 MJ, 50 kV 2 MJ, 50 kV	Magneto-Optical Magnetization	5 K – Room temperature
	Horizontal Single-Turn Coil	destructive	300 T 200 T	μs 5 mm 10 mm	0.2 MJ, 50 kV	Magneto-Optical measurements Magnetization	5 K – 400 K
	Vertical Single-Turn Coil	destructive	300 T 200 T	μs 5 mm 10 mm	0.2 MJ, 40 kV	Magneto-Optical Magnetization	2 K – Room temperature
Building C Room 114-120	Mid-Pulse Magnet	Non-destructive	60 T 70 T	40 ms 18 mm 40 ms 10 mm	0.9 MJ, 10 kV	Magneto-Optical measurements Magnetization Magneto-Transport Hall resistance Polarization Magneto-Striction Magneto-Imaging Torque Magneto- Calorimetry Heat Capacity	Independent Experiment in 5 site Lowest temperature 0.1 K
Building C Room 121	PPMS	Steady State	14 T			Resistance Heat Capacity	Down to 0.3 K
	MPMS	Steady State	7 T			Magnetization	
Building K	Short-Pulse Magnet	Non-destructive	87 T (2-stage pulse) 85 T	5 ms 10 mm 5 ms 18 mm	0.5 MJ, 20 kV	Magnetization Magneto-Transport	2 K – Room temperature
	Long-Pulse Magnet	Non-destructive	43.5 T	1 s 30 mm	210 MJ, 2.7 kV	Resistance Magneto-Calorimetry	2 K – Room temperature

Table 1. Available Pulse Magnets, Specifications

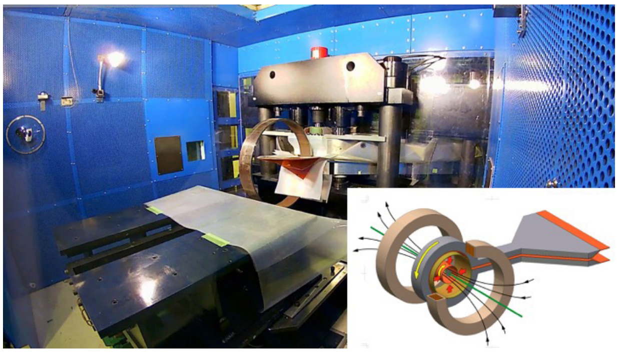

Fig. 3. (Build. C) A view of the electro-magnetic flux compression 1000 T-class megagauss generator set in side of an anti-explosive house. 1000 T project started since 2010, and finally condenser banks of 9 MJ (5 MJ + 2 MJ +2 MJ) as a main system with the 2 MJ sub bank system for the seed field have been installed, and settled in the year of 2014.

ator station at our laboratory, and used as an energy source of 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 giant DC 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.

Magnetic fields exceeding 100 T can only be obtained with destruction of a magnet coil, where ultra-high 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 proceeded. Our experimental techniques using the destructive magnetic fields have intensively been developed. The system which is unique to ISSP in 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 from each power source. Both systems are fed with another 2 MJ condenser bank used for a seed-field coil, of which magnetic flux is to be compressed. The 2 MJ EMFC system is currently under the process for optimizing several mechanical and electrical parameters such as dimensions of coils and liners. And so far, generation of 450 T was successfully done using 1.6 MJ energy. The 5 MJ EMFC system is under conditioning the main gap switches by finely tuning control parameters. And so far, generation of 1200 T was successfully done using 3.2 MJ energy. As an easy

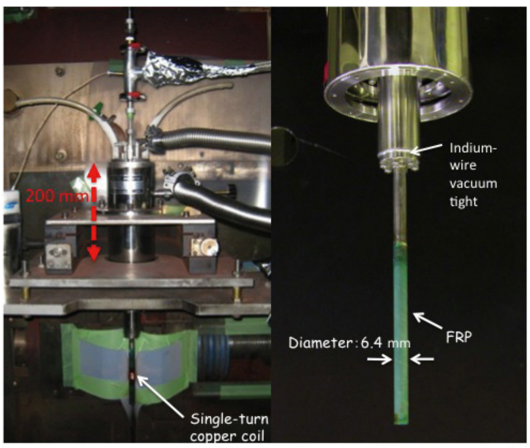

Fig. 4. Schematic picture of the H-type single-turn coil equipped with 50 kV, 200 kJ fast operating pulse power system, capable of generating 300 T within 3 mm bore coil.

access to the megagauss science and technology, we have the single-turn coil (STC) system capable of generating the fields of up to 300 T by a fast-capacitor of 200 kJ. We have two STC systems, one is a horizontal type (H-type, Fig. 4) and the other is a vertical type (V-type). Various kinds of laser spectroscopy experiments such as the cyclotron resonance and the Faraday rotation are possible using the H-type STC.

Center of Computational Materials Science

The goal of the computational materials science is to understand and predict properties of complicated physical systems with a vast number of degrees of freedom and to design new useful materials before actual experiments. Since such problems cannot be solved with bare hands, it is quite natural to use computers in computational materials science. In fact, computer-aided science has been providing answers to many problems ranging from the most fundamental ones to the ones with direct industrial applications. In the recent trends of the hardware developments, however, the growth of computer power is mainly due to the growth in the number of the units. This fact poses a very challenging problem in front of us --- how can we parallelize computing tasks? In order to solve this problem in an organized way, we 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. These activities are supported by funds for various governmental projects in which CCMS is involved. In particular, we acted as the headquarters of Priority Area 7 of MEXT FLAGSHIP2020 Project (so-called "post-K computer project") in the last project year of 2019. In addition to this, CCMS was involved in Priority Area 5 and Pioneering Area (CBSM2) of FLAGSHIP2020 project, Element Strategy Initiative, and Professional Development Consortium for Computational Materials Scientists (PCoMS).

The following is the selected list of meetings organized by CCMS in FY2019:

- 4/2-4/3 Joint Research Meeting of ISSP Supercomputer Joint Use and CCMS Annual Activity Report 2019, ISSP, Kashiwa
- 5/17 PCoMS Matching Workshop for industries & graduate students/postdocs The University of Tokyo, ISSP, Kashiwa
- 7/16-8/8 Computational Approaches to Quantum Many-body Problems 2019 (CAQMP 2019), ISSP, Kashiwa

Fig. 1. Members of CCMS.

- 8/9 Post-K Project Priority Issue 7, The 5th Annual Meeting, Ito-Hall, Hongo, Tokyo
- 10/8-10/10 The 3rd Innovation Camp for Computational Materials Science (3rd ICCMS) The Hohoemi-no-Yado, Yamagata
- 12/6 TIA-Kakehashi Poster Workshop 2019, The University of Tokyo, Kashiwa Campus Station Satellite, Kashiwa
- 2/17-2/18 The 9th Materials Simulation Workshop, Akihabara
- 2/25 PCoMS Skill improvement training for graduate students & postdocs ISSP, Kashiwa

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 2019, which is the biggest division in ISSP. Most of the research activities on the development of new lasers with an extreme performance and the application to materials science are studied in specially designed buildings D and E with large clean rooms and the isolated floor from the vibrations in Kashiwa Campus. On the other hand, the experiments utilizing the synchrotron radiation are performed at beamline BL07LSU in SPring-8 (Hyogo).

The development of novel laser-based light sources in the vacuum-ultraviolet to soft-X-ray regions innovated materials investigations as represented by the highest-energy-resolution photoemission, ultrafast time-domain, and ultra-fast non-linear spectroscopies. Materials science research powered by lasers thus has entered a new era. The ultra-short and high-power lasers are more and more attractive light source for both basic science and industry. The state-of-the-art laser source and spectroscopy are intensively explored.

Another stream pursued at ISSP is the synchrotron-based research. The drastic advance in brilliance of the synchrotron radiation has also opened a new field of its own in photon science. The soft-X-ray beam-line in SPring-8 (BL07LSU) was implemented with the longest undulator in the world: The end stations illuminated by the brilliant soft-X-rays are used to output innovative achievements based on high-resolution spectroscopy data. In 2018, Japanese government has made a statement to construct a new synchrotron facility in Tohoku. LASOR has decided to subjectively contribute to this facility from the design to the operation.

Fig. 1. Optical frequency comb

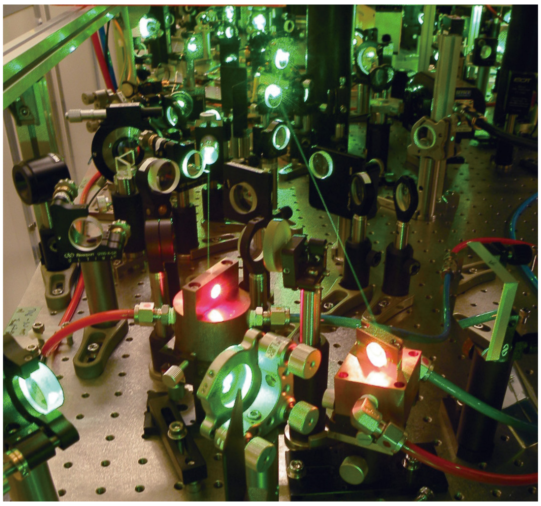

Fig. 2. Close look of a high-peak-power ultrashort-pulse laser

Lasers and synchrotrons have developed independently; now both light sources cover a wide photon-energy range with an overlap in the vacuum-ultraviolet to soft-X-ray regions. Foreseeing their common interests in research fields and technologies, ISSP integrated the two streams, namely the extreme lasers and synchrotron radiations, into the common platform. Through the mutual interactions between the forefronts of lasers and synchrotrons, LASOR will be the center of innovations in light and materials science, with the aid of world-wide joint research and close collaborations with other divisions in ISSP such as New Materials Science, Nanoscale Science, and Condensed Matter Theory.

The mission of LASOR is to cultivate and propel the following three scientific fields:
1. Laser Science,
2. Synchrotron radiation Science,
3. Extreme Spectroscopy,

• Laser science group

We were committed to continuing to developed 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 attosecond time scale (Peta Hz linewidth), ultra-stable lasers with 1-Hz linewidth, optical frequency combs, mid-infrared lasers, THz light source, and semiconductor lasers.

High-power and ultrashort pulse laser technology has progressed for this 10 years. It opened two directions of

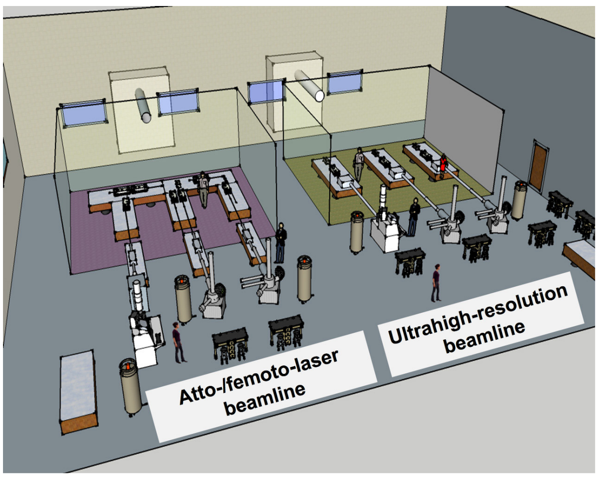

Fig. 3. Design of E building for extreme VUV- and SX-lasers and new spectroscopy.

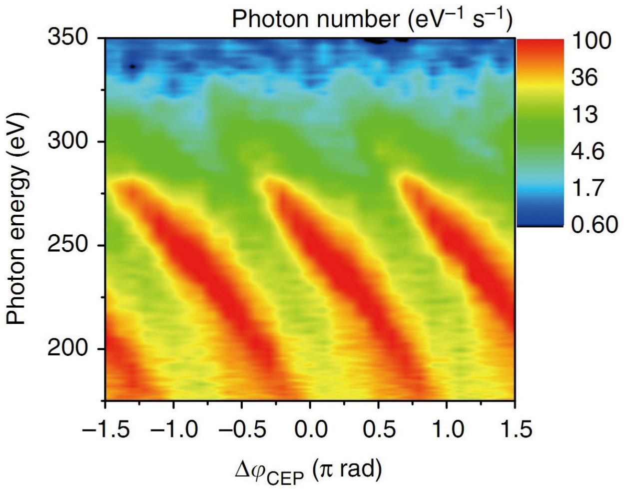

Fig. 4. Phase-dependence of high harmonic spectra in soft X rays.

research. 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 use it for a photoemission spectroscopy. The photon energies of 7 eV to 60 eV are now available. They can be either very narrow band width or ultrashort pulse. The other is an industrial science such as a laser processing. Pulse duration variable, 100-W average power, femtosecond laser is now available in LASOR for any collaborative research including companies.

We also aim to develop novel laser spectroscopy and coherent non-linear optical physics, enabled via emerging lasers and optical science/technology, and extensively study basic light-matter physics, optical materials science, and applied photonics. Such researches include ultrafast spectroscopy for excited state dynamics, terahertz magnetic-field spectroscopy for spin dynamics, quantitative micro-spectroscopy on semiconductor lasers and nano-structure photonics devices, such as quantum wire lasers, gain-switch semiconductor laser, multi-junction solar cells, and bio-luminescent systems.

• Synchrotron radiation science group

By inheriting and developing the synchrotron techniques cultivated for more than 20 years, we continuously develop world cutting-edge spectroscopies such as time-resolved photoemission /diffraction, ultrahigh resolution soft X-ray emission, 3D (depth + 2D microscopy) nano ESCA and X-ray magneto-optical effect and provide these techniques both for basic material science and for applied science, which contributes to the device applications in collaboration


Fig. 5. 10-MHz high harmonic generation in an enhancement cavity.

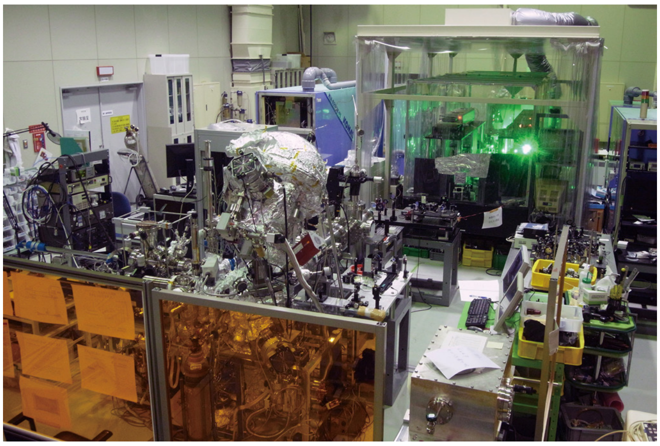
Fig. 6. Pump-probed photoemission system using 60-eV laser

with outside researchers. In order to pioneer new spectroscopies for the next-generation light sources, we upgrade fast polarization switching of the undulator light source in cooperation with SPring-8. In addition, we promote frontier works 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 spectroscopies.

• Extreme spectroscopy group

The advent of laser-based light sources in the soft-X-ray region is opening a new stage in the field that has been cultivated by the synchrotron radiations. One of the milestones is to develop a laser-based light source of ~7 eV for the sub-meV-resolution photoemission spectroscopy. In this five years, available photon energy became 11 eV with help of Yb-fiber laser technology. It has high photon flux (10^{14} photons/sec) with sub picosecond time resolution. Laser-based spin-resolved ARPES is realizing in LASOR. This technology would open brand-new spectroscopy. High-harmonic generation based photoemission spectroscopy in the 20-60 eV region is another direction to be pursued. Time-domain spectroscopy in the femtosecond region was achieved. Combined with the picosecond time-domain spectroscopy utilizing the pulsed light delivered from synchrotrons, we investigate the electronic structures and dynamics of matter in bulk, on surface, and into the nano-scale. The ultimate objective is to expand the soft-X-ray operando methodologies by lasers. Diffractions, magneto-optical effects, and inelastic scatterings now done at synchro-

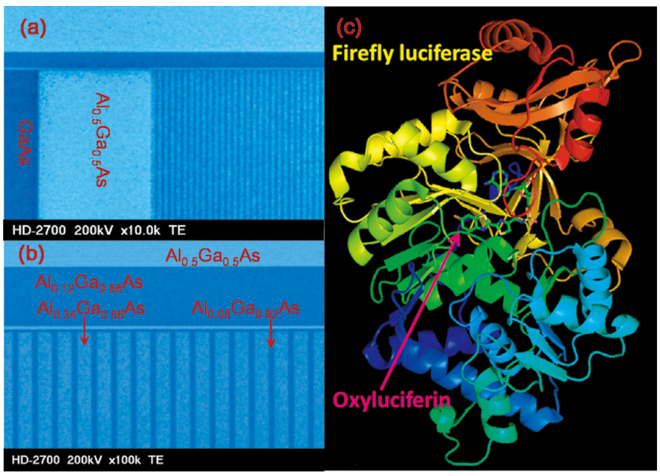

Fig. 7. Photonics devices under study: (left panel) semiconductor quantum wires and (right panel) firefly-bioluminescence system consisting of light emitter (oxyluciferin) and enzyme (luciferase)

trons will be performed by lasers, to access the real-time dynamics of chemical reactions and phase transitions down to the femtoseconds.

State-of-the-art laser based organism spectroscopy is new direction in LASOR. ISSP research area is shifting from simple material and science to complex one including living body and functional material with excited state physics.

Synchrotron Radiation Laboratory

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

•Brilliant soft X-ray beamline at Harima branch

In 2006, the SRL staffs have joined the Materials Research Division of the Synchrotron Radiation Research Organization (SRRO) of the University of Tokyo and they have played an essential role in constructing a new high brilliant soft X-ray beamline, BL07LSU, in SPring-8. The light source is the polarization-controlled 25-m long soft X-ray undulator with electromagnetic phase shifters that allow fast switching of the circularly (left, right) and linearly (vertical, horizontal) polarized photons.

The monochromator is equipped with a varied line-spacing plain grating, which covers the photon energy range from 250 eV to 2 keV. At the downstream of the beamline, a lot of experimental stations have been developed for frontier spectroscopy researches: five endstations, i.e. time-resolved soft X-ray spectroscopy (TR-SX) equipped with a two-dimensional angle-resolved time-of-flight (ARTOF) analyzer (Fig. 1), three-dimensional (3D) nano-ESCA station equipped with the Scienta R-3000 analyzer (Fig. 2), high resolution soft X-ray emission spectroscopy (XES) stations (Fig. 3) are regularly maintained by the SRL staffs and open for public use, and at free-port station many novel spectroscopic tools have been developed and installed such as ambient pressure photoemission (Fig. 4) and soft X-ray diffraction (Fig. 5) which are also open for public use from 2018, and soft X-ray resonant magneto-optical Kerr effect (MOKE) and so on. The beamline construction

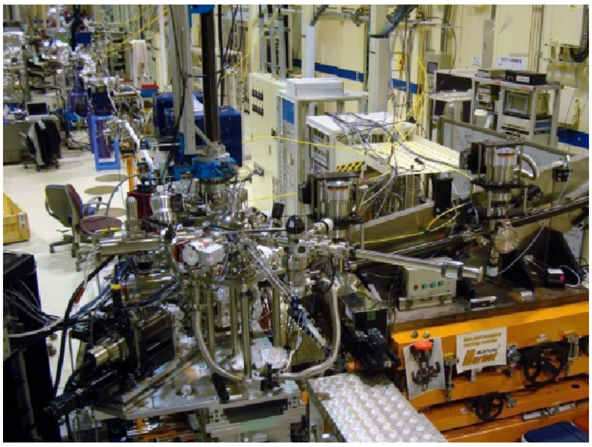

Fig. 3. Soft X-ray emission station

was completed in 2009 and SRL established the Harima branch laboratory in SPring-8. At SPring-8 BL07LSU, each end-station has achieved high performance: the TR-SX station have established the laser-pump and SR-probe method with the time-resolution of 50 ps which corresponds to the SR pulse-width; the 3D nano-ESCA station reaches the spatial resolution of 70 nm; the XES station provides spectra with the energy resolution around 70 meV at 400 eV and enabled real ambient pressure experiments. Soft X-ray resonant MOKE station has been developed to make novel magneto-optical experiment using fast-switching of the polarization-controlled 25-m long soft X-ray undulator. The soft X-ray diffraction station has been fully constructed and the time-resolved measurement is available by using lasers at the TR-SX station. In 2019, 240 researchers made their experiments during the SPring-8 operation time of 4584 hours.

•High-resolution Laser SARPES at E-building

Spin- and angle-resolved photoelectron spectroscopy (SARPES) is a powerful technique to investigate the spin-dependent electronic states in solids. In FY 2014, LASOR and SRL staffs constructed a new SARPES apparatus (Fig. 6), 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 FY 2015, the new SARPES system has been opened to outside users.

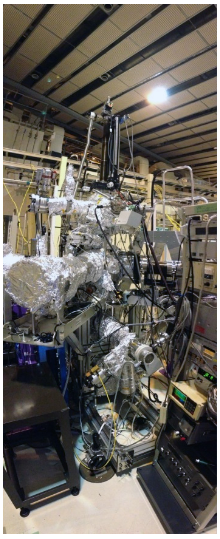

Fig. 1. TR-SX station

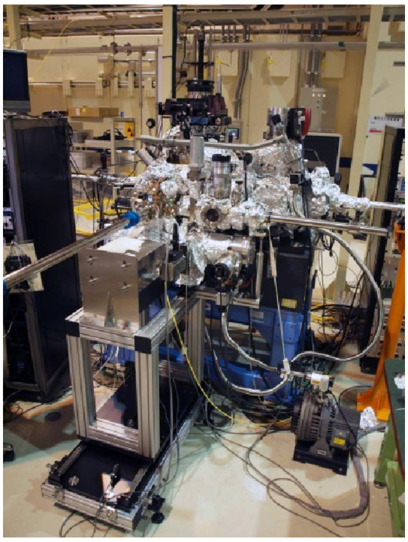

Fig. 2. 3D-nano ESCA station

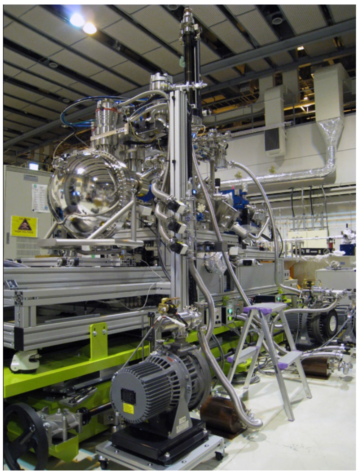

Fig. 4. Ambient pressure photoemission

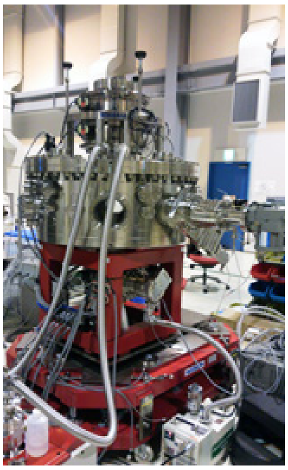

Fig. 5. Soft X-ray diffraction station

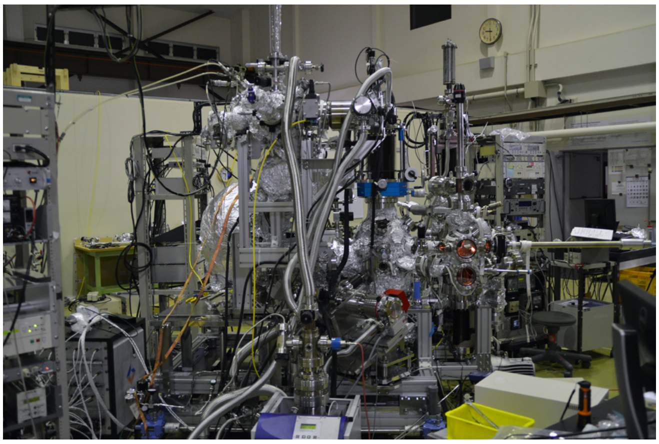

Fig. 6. Laser-SARPES system at E-building

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 each other via UHV gate valves. The electrons are excited with 6.994-eV photons, yielded by 6th harmonic of a Nd:YVO_4 quasi-continuous wave laser with 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 ScientaOmicron DA30-L, modified for installing the spin detectors. The spectrometer is equipped with two high-efficient spin detectors associating very low energy electron diffraction are orthogonally placed each other, 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 machine 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.