# Report of the International Review Committee on the Meeting at the Hiroshima Synchrotron Radiation Center
# March 8-9, 2018

## Review of Scientific Research at HiSOR

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# Executive Summary of the International Review Committee Meeting at Hiroshima Synchrotron Radiation Center, March 8-9, 2018

The International Review Committee (IRC) met at Hiroshima University March 8-9, 2018, to review the scientific programs at HiSOR. The IRC had been provided with extensive background material before the meeting and complementary information during the review. The HiSOR management and scientists were most helpful in answering questions during the review and the IRC commends the Director for a very professionally organized meeting. The IRC also wants to express its gratitude for the hospitality it was shown throughout its stay at HiSOR.

The review was in conjunction with the 22$^{nd}$ Hiroshima International Symposium on Synchrotron Radiation. This gave the IRC the opportunity to listen to a number of excellent presentations by HiSOR scientists and interact with young scientists at a poster session that gave a survey of recent research activities. The posters were very informative and consistently of excellent quality.

In the opening address to the Symposium the Vice President of Hiroshima University, Professor Yamamoto, underlined the important role HiSOR has for research and education at this University. The IRC was very impressed by the commitment the University Administration has to the success of HiSOR. The Director of HiSOR, Professor Shimada, gave a most impressive summary of the research activities during the last five years. The scientific productivity is remarkable with a large number of publications, a significant fraction in the most distinguished peer-reviewed physics, chemistry and biology journals. HiSOR has been highly successful in implementation of the “Joint Usage” concept, in which HiSOR staff scientists are directly involved in the collaborative research triggered by external users. The IRC congratulates HiSOR to this success and strongly recommends that the “Joint Usage” model is continued. Collaborations with world-renowned international researchers account for about 25% of the activities and are an important aspect of the operation of HiSOR. The IRC is of the opinion that HiSOR is in an excellent position to further expand these activities in attracting world-leading researchers. The IRC finds that HiSOR is doing exceptionally well in continued upgrades and maintenance of the accelerator systems, the beamlines and the end-stations; in particular considering the relatively modest staff and operating cost.

Professor Shimada emphasized five focused research areas for HiSOR:

- High-Resolution Photoemission Spectroscopy for Electronic Structure Analysis
- Spin-Resolved Photoemission for Spin Structure Analysis
- Soft X-Ray MCD of Surface Nano Structures
- VUV Circular Dichroism Spectroscopy of Biomolecules
- Light Sources Accelerators and Insertion Devices

**High-Resolution Photoemission Spectroscopy for Electronic Structure Analysis**

Photoemission is a major activity at HiSOR and Dr. Eike Schwier gave an extensive overview of present research and future directions.

*Polarization dependent ARPES.* - The predictive use of dipole selection rules depending on polarization of incident photons is an effective tool to study multiband systems such as pnictide high-$T_c$ superconductors or topological systems. This experimental methodology has presently been introduced in a wide use at HiSOR based on two different polarization control schemes, rotation of the ARPES analysis chamber (BL-1) or the use of variably polarizing APPLE-II undulator (BL-9A and B). A particular attention is paid to "clean" experimental geometry allowing reliable use of the polarization effects. This methodological advance at the HiSOR beamlines is supported by the off-line μ-ARPES facility where polarization control of the laser radiation is achieved by wave plates. The power of the polarization control methodology in application to multiband systems is confirmed by a number of pioneering scientific cases. The IRC commends HiSOR for these developments.

*Improvement of spatial selectivity*. - The IRC highly appreciates the recent effort to reduce spot size of synchrotron radiation of the sample. The present typical spot size of the order of a few hundreds of μm seems actually the main bottleneck to limit instrumental quality of synchrotron light delivered by HiSOR, in particular because crystals of many interesting materials typically appear consisting of small domains with their typical dimensions of the order of a few tens of μm and less. After careful investigation of all options, the HiSOR scientists are advancing an idea of using innovative VUV-range elliptic capillary mirrors (Sigray Inc.) which are expected to reduce the spot size down to 75x30 $\mu m^2$ (BL-1). A large practical advantage of this option is its moderate budget (of the order of 100 KEuro). In addition to the spatial selectivity, the spot size reduction will much increase angular resolution of the ARPES experiment. The IRC highly recommends pursuing this instrumental upgrade route. The research with high spatial selectivity is presently supported by the off-line μ-ARPES facility.

*Sample environment*. - A functional and user-friendly sample environment is a critical part of the spectroscopic experiment. The HiSOR's recent advances in this instrumental direction include (1) high-precision 6-axis goniometric manipulator; (2) cryogenic sample cooling down to 12K at BL-1 and even to 7K at BL-9A; (3) high-temperature (>2000K) sample annealing; (4) surface doping by alkali evaporation during the ARPES experiment. The IRC highly appreciated the HiSOR's constant effort in the sample environment functionality.

*Off-line ARPES facilities*. – The IRC fully supports the intensive development of the off-line laser and UV-lamp ARPES facilities which allow exhaustive preliminary sample characterization and thus most efficient use of the synchrotron beamtime. Furthermore, the μ-ARPES facility allows experiments at extremely high spatial, energy and angular resolution complementary to those with the HiSOR light.

*Molecular and organic systems*. - Molecules adsorbed on crystalline surfaces have recently attracted much attention due to their new emerging functionalities such as realization of single-molecule magnets. Organic systems including perovskites have recently demonstrated their potential, for example, in solar energy conversion. ARPES experiments on such systems are often hindered by radiation damage. The low energy and presently large spot size of the HiSOR's photon beam, minimizing the radiation damage, make ARPES studies of the molecular and organic systems, in the view of the IRC, a promising research field at HiSOR.

**Spin-Resolved Photoemission for Spin Structure Analysis**

Equipped with VLEED that has an efficiency 100 times higher than the conventional Mott spin polarimeter and synchrotron radiation with adjustable photon energy and polarization, HiSOR is one of the most active centers for SARPES research in the world with top level equipment and scientific achievements. In his talk Dr. Taichi Okuda gave a status report of this facility.

The VLEED spin-resolved ARPES system has demonstrated an energy resolution of $\Delta E \leq 10$ meV, an angular resolution of 0.4˚ and the capability of 3D spin vector analysis, which are among the highest resolutions reached in spin-resolved ARPES in the world and enables precise spin-resolved measurements that require high energy and angular resolutions, such as topological insulators and Wyle semimetals. In fact, the IRC takes note and congratulates HiSOR to a system that has produced highly original results and landmark publications in the direct measurements of spin-split electronic states of topological materials and other novel quantum materials.

The versatile sample facilities permit preparation of a variety of samples efficiently and ensure timely responses to new research trends. As pointed out earlier by the IRC the Joint Usage/Research programs are a great asset at HiSOR and enable external users to get efficient support from staff members to acquire high-quality data efficiently.

Due to the synergistic effects of world-class facilities and excellent staff support, the number of users, especially from abroad, is rapidly growing and half of the proposals are now from international participation. The IRC considers the shortage of beamtime as a serious problem for HiSOR to maintain and further enhance its world-leading status in a fast growing and very competitive research field.

The IRC strongly supports the future plan of HiSOR to develop the laser SARPES system and the multichannel VLEED spin polarimeter.

**Soft X-Ray MCD of Surface Nano Structures**

Dr. Masahiro Sawada reported on the XMCD station on BL-14, which is specialized for in-situ synchrotron radiation analysis accompanied by sample synthesis with a focus on studies of magnetic nanostructures. This combination is an important research direction in materials science. HiSOR has been very successful in the implementation to studies of magnetic nanostructures, and in particular to magnetic states of artificially controlled materials. The IRC observes and commends HiSOR that the basic construction of the XMCD station has been completed. Some very impressive research results have been achieved, in several cases in collaboration with outside user groups.

The IRC fully agrees with several of the proposed upgrades listed in the section “perspective” for this experimental station, for instance extension of the operational temperature range and upgrade of the magnet system to allow stronger magnetic fields. The scientific justifications are strong. A limitation to liquid nitrogen temperature excludes studies of ferromagnetic materials with a lower Curie temperature and studies of small magnetic clusters on surfaces. The IRC recommends the addition of a superconducting magnet or a high field electromagnet to open up studies of hard magnetic samples and /or measurements along hard magnetic axis. The IRC further suggests installation of a magnetic field sensor close to the sample, allowing to avoid problems related to the residual magnetization of the electromagnetic core (particularly important for samples with low coercivity). An additional improvement would be to add a sensitive fluorescence detector for measurements on insulating samples.

The system is well equipped with automation that is very important for efficient operation by the users. The IRC recommends that the automation with programmable sequences of the geometry settings should also include adjustments along the z-axis, M(H). The existing STM system with in-situ characterization of the sample is a very important asset and in many cases provides a unique capability. The IRC encourages HiSOR to include in its future plans additional characterization tools as electron diffraction for structural analysis and an ion scattering spectrometer, and/or an SEM column, for surface analysis. The sample preparation is an important aspect and, in addition to existing tools, the IRC recommends monitoring of the substrate temperature during the deposition process. This would enhance the structural quality of the deposited films and precision of their thickness measurements.

So far studies have been focused on samples that require UHV conditions. Since not all studies require UHV, the IRC recommends that HiSOR considers the implementation of a low vacuum/atmospheric pressure sample chamber that can be separated from the UHV beamline with a silicon nitride membrane. The inclusion of the photon-in-photon-out techniques, as is required for this environment, would extend the studies to new classes of magnetic materials, including certain multilayer structures. The IRC is also positive to include reflectivity measurements is a method to probe the dielectric tensor.

**VUV-CD Spectroscopy of Biomaterials**

BL-12 demonstrated by Dr. Koichi Matsuo is proof of a well functioning beamline. The field of interest encompasses the biophysical and structural biology. BL-12 offers a continuous operation during the working hours, allowing circular (CD) and linear (LD) dichroism as well as absorption spectroscopy. The vacuum-ultraviolet (VUV) CD spectrophotometer at BL-12 extends the CD spectra to the VUV region down to 170 nm for aqueous solutions and to 140nm for films. Low noise, low sample consumption (microliter range) and quick data acquisition provide structural information, which is unattainable with conventional CD instruments. Applications include membrane proteins, saccharides, nucleotides and disordered protein structure analysis, as well as protein-protein interactions, protein-nucleotide interactions and protein lipid interactions. Other activities of great value complementing these spectroscopic measurements, are principal component analysis, molecular dynamics and bioinformatics. (Peer reviewed publications and citation numbers, are proof of reliability) The group of Dr. K. Matsuo has recently been joined by a Dr. Y. Izumi, which certainly increases the possibilities for exploring the beamline as well as accommodating and helping users more efficiently. The IRC was impressed by the present output and usage of the VUV-CD. Five posters of BL-12 trained students, have been presented and two of them were rewarded with the poster prize amidst an otherwise very physics driven poster session with 24 eligible students' posters.

External users have collected data during the meeting. Dr. Frank Wien has himself reviewed the beamline and assured the IRC of reproducibility of standards and compliance of results and reproducibility between European Synchrotron Circular Dichroism stations and BL-12.

Developments in place such as the sublimation chamber, for thin film preparations of organic chiral molecules, the installation of a mirco-focusing optic (Schwarzschild) and time resolved devices, including microfluidic continuous flow and stopped flow set-ups are certainly a very good addition to the present possibilities and should in future attract even more users and students. If one recommendation should be given to improve the current setup, then it would be the installation of an automated temperature stepping mode for CD and absorption spectroscopy. For instance, this would allow for thermal stability analysis and thermodynamic studies in combination with calorimetric assays.

Further developments which have been discussed with the beamline staff include the development and implementation of a CCD camera for VUV-CD imaging, and the long-term development and design of a novel Vortex light producing undulator producing circular left and right polarised light. The IRC strongly supports the investigations into these novel developments to pave the way for a new HiSOR light source.

In a conclusion, important improvements over the past 10 years have been made BL-12 has become a very productive tool for structural biology, glyco-biology and in a more general way for chiral macro-molecular studies where other techniques fail due to size of the molecules or their complicated flexible structures.

**Light Sources Accelerators and Insertion Devices**

Dr. Keigo Kawase introduced HiSOR and presented the development by the minute accelerator staff at the HiSOR Light Source. The International Review Committee points out that with the present level of staffs (3 persons in total), a minimum has been reached! Even then, the staff has made several interesting developments as presented at the relevant accelerator conferences.

One area has been the study of new low-emittance lattices to be used in a future HiSOR facility. This has included the so-called “torus-knot” design, but also designs based on the MAX-3 lattice and the ASTRID2 machine. Further developments of these lattices, to result in a detailed design of the future HiSOR machine, can only be strongly encouraged, as this eventually will be needed and will constitute the basis for the future accelerator. Such a study should include a parameter list, and should also develop into the specifications of the various accelerator components in the new source.

Another study performed by the present HiSOR accelerator staff is the study of advanced undulators like quasi-periodic APPLE-II and Knot-APPLE undulators generating Orbital Angular Momentum undulator radiation. Such studies will also be relevant for insertion devices in a future HiSOR light source.

Collaborations with other accelerator facilities like KEK and UVSOR were mentioned, and the International Review Committee strongly suggests such continuations and further collaborations in the future. This will also be important in preparation for the future HiSOR facility.

*General comments and recommendations*:

There is presently limited operation time of the present HiSOR facility, two injections per weekday, which is limited by man-power. Numerous requests for an extended operational beamtime have appeared from the user community over time, and the IRC can only recommend such an extension if at all possible, but clearly not neglecting safety and man-power limitations.

The IRC strongly suggests the development of an almost “diffraction-limited” low-emittance lattice to replace the present HiSOR light source, possibly based on the highly successful upgrade of ASTRID, the HiSOR’s low-energy sister facility. Such a facility should include several insertion-devices (more than 4), top-up injection, 24/7 operation and could deliver beams, which would be orders of magnitude smaller in all dimensions than the present facility. Although, the present research performed at HiSOR is indeed very good, a new facility would expand the quality and quantity of the present HiSOR research facility tremendously way into the 2030’ies.

Stanford, March 30, 2018.

Ingolf Lindau
Chair, on behalf of the IRC

# Introduction

The Hiroshima Synchrotron Radiation Center, HiSOR, is the only one synchrotron radiation facility that is attached to a national university in Japan. It was established in 1996, as part of the academic policies of the Japanese government. The mission of HiSOR is to promote advanced research in the field of condensed matter physics using synchrotron radiation in the ultraviolet and soft x-ray range, as well as to develop human resources. In 2010, HiSOR was authorized as a “Joint Usage / Research Center” by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). As a result of extensive research activities in collaboration with researchers from inside and outside of Japan, HiSOR was graded “A” for the 1st term-end evaluation in 2015 by the MEXT. In 2016, the authorization as the Joint Usage / Research Center was extended for 6 more years. The mid-term evaluation is planned in 2018.

According to this authorization, HiSOR is focusing on the following researches:

1. Researches on quasiparticles by ultrahigh resolution photoemission spectroscopy
2. Researches on spin structures by spin- and angle-resolved photoemission spectroscopy
3. Structural analysis of biomolecules in solution by VUV-CD
4. In situ fabrication and characterization of magnetic nanostructure by SXMCD
5. R&D for a compact low-emittance light source

In this context the International Review Committee (IRC) was charged to evaluate the scientific research activities at HiSOR. Below is a detailed self-assessment of the five research areas listed above by the responsible HiSOR scientists.

# Research Areas

## 1-1. Eectronic structure analysis (BL-1, BL-9A, laser PES)

***Current Status***

Angle-resolved photoemission spectroscopy (ARPES) is a powerful tool to directly reveal the electronic states in solids, such as energy band dispersions and Fermi surfaces. Since the initial stage of HiSOR, we have promoted high-resolution ARPES in the ultraviolet and soft-x-ray region at the undulator beamlines BL-9A (hν=5~35 eV) and BL-1 (hν=22~360 eV). Recently, in order to improve spatial resolution as well as energy and angular resolution, we introduced two VUV laser systems (hν=5.90-6.49 eV) to HiSOR; one providing a Laser beam of around 300 μm size to the BL-9A end-station, and the other, a Laser beam with a spot size as low as 3 μm to a newly commissioned offline μ-LaserARPES machine [H. Iwasawa *et al*., Ultramicroscopy **182**, 85 (2017); refer as #1].

ARPES with low energy photons (hν<~10 eV) is effective to examine the isotope [H. Iwasawa *et al*., Phys. Rev. Lett. **101**, 157005 (2008)] and many-body [2012-(3), 2013-(26) (List of publications)] effects in cuprates, as well as detailed examination of the Rashba splitting in the surface state on Cu(110) [2014-(34)], while higher photon energies are essential to investigate the $k_z$ (i.e. bulk) dispersion of electronic bands and matrix element effects, and distinguish surface-derived states. A combination of the two photon energy ranges allows for detailed spectral analysis in wide momentum and energy spaces.

Recently, it has become indispensable to utilize the polarization dependence of the matrix elements to study multiple Fermi-surface systems such as iron-based superconductor [Y. Zhang *et al*., Phys. Rev. B **83**, 054510 (2011)], topological surface states on W(110) [2012-(35)] and novel layered superconductor [2015-(23)]. In order to utilize the polarization of incident photons, we have constructed a rotatable ARPES system at BL-1 [H. Iwasawa *et al*., J. Synchrotron Rad. **24**, 836 (2017)] and installed a variably polarizing undulator (quasi-periodic APPLE-II) for BL-9A and 9B [S. Sasaki *et al*., Proceedings of IPAC2012, 729 (2012)]. At the μ-LaserARPES machine, a combination of wave plates allows for full control of the light polarization between linear and fully circular polarized photons [#1]. Utilizing the ultimate purity of linear polarization and continuous rotation of the detection plane with respect to the electric field vector, detailed examinations of the photoemission intensity of the Dirac cone in graphene could be performed at BL-1 [2015-(30)].

These days, topological materials have attracted much interests, and many photon-energy-dependent ARPES measurements have been performed at BL-1 to reveal the three-dimensional electronic structures of these materials. In these cases, flat cleaving surfaces were often smaller than the present beam size (900 (H) μm × 200 (V) μm). This in turn reduced the amount of successful measurements on such systems due to the large number of cleaving attempts necessary to obtain a large enough surface, leading to a strong demand to reduce spot size on the sample.

Precise momentum mapping of the band dispersion is crucial when performing high resolution ARPES experiments. To that end all the manipulators are controlled by an in-house LabVIEW software with arbitrary choices of mapping dimensions [#1, H. Iwasawa *et al*., J. Synchrotron Rad. **24**, 836 (2017), refer as #2]. Now, one can automatically perform ARPES mappings using arbitrary combinations of directions (polar, azimuth, tilt, x,y,z). To improve the spatial resolution, we have upgraded the low-temperature 6 axes manipulator of BL-9A and installed a "nano-stage" manipulator at the μ-LaserARPES [#1,#2]. The nano-stage in combination with the micron-sized Laser spot is crucial to the performance of the machine as it enables users to reproduce sample positions with sub-micron precision and perform detailed spatial mappings with high lateral resolution.

To perform various advanced experiments at the beamlines, sample preparation and characterization are also important. On the three machines, standard characterization methods (LEED and Auger electron spectroscopy) are available. For sample preparation Ar Ion sputtering and annealing (direct current as well as electron bombardment) can be performed [#1,#2]. A newly designed preparation chamber manipulator head allows for annealing temperatures higher than 2000 K with room for additional flashing of the sample.

At BL-1 and the μ-LaserARPES, an alkaline metal evaporator has been installed in the main chambers, allowing the evaporation in coincidence with ARPES measurements. The possibility to monitor the evolution of the surface doping has been highly appreciated by users [2014-(2)] as it allows not only fine control over the doping state, but also resolves the coverage dependent electronic structure in greater detail.

Using the ARPES system with variable polarized low energy photons (5-35 eV) provided by the APPLE-II undulator, users can investigate fine details of the electronic structure. Due to continued efforts to improve the beamline optics, and specifically the monochromator stability, photons with linewidths below 1 meV can be provided for energies below 10 eV [M. Arita *et al*., Phys. Rev. B **77**, 205117 (2008)]. To improve the ARPES capabilities further, we have installed a fully motorized 6-axes goniometer (temperature range: 12-370 K, azimuth angle rage: ±65˚, tilt angle range: -25˚ to +50˚). This enables us to measure Fermi surface maps over a wide momentum range via tilt or azimuth rotations. The new goniometer is also effective to measure band dispersions along high-symmetry lines for small Fermi surfaces located close to the Γ point of the surface Brillouin zone. To make use of the high energy resolution provided by the beamline, a cryo-shield has been installed that allows for cooling of the sample to temperatures below 6 K. However, in its current stage it also produces energy and lateral resolution broadening as a tradeoff due to vibrations, and possibly external fields. To increase user experimental time, BL-9A is also equipped with the aforementioned UV laser as well as a high intensity Xe-lamp. Representative results obtained at BL-9A over the last 5 years include the elucidation of the chiral texture of the orbital angular moment in $Bi_2Se_3$ [2012-(34)], the observation of the topological surface states in $Sb_2Te_3$ [2015-(32)] and the first clarification of the electronic structures in the novel superconductor $IrTe_2$ [D. Ootsuk *et al*., J. Phys. Soc. Jpn. **86**, 123704 (2017)].

Starting in 2014 we developed and commissioned the stand-alone μ-LaserARPES machine at HiSOR [#1]. Within the first year we were able to achieve ultimate energy resolution (260 μeV at 7.2 K with 0.75 meV and 1.5 meV resolution as common user choices during experiments) and started establishing a user community. Focusing on achieving ultimate angle as well as spatial resolution we upgraded the manipulator stage ("nano-stage") and replaced pinhole apertures used for reducing the spot size with focusing optics. This let us achieve ultimate angle (undetectable Gaussian broadening at Lorentzian FWHM of 0.0033 $Å^{-1}$ in Bi-2212) and spatial resolution at the same time. We have installed an optical monitoring system (spatial resolution ~14 μm) for sample position adjustments. Based on the results from the μ-LaserARPES system, we have found the linewidths of ARPES spectra can be drastically improved depending on the measurement positions even for layered samples having a good cleavage plane and a seemingly well cleaved surface.

At the moment, users have to choose one of the two manipulators; one reaching 5 K with narrower angular range able to probe superconducting transitions, and the other reaching 11 K with wider angular range. It would be desirable to either have the low-temperature manipulator reach more competitive temperatures (2-3 K) or enhance its angular range.

In 2017 we installed a Xe-lamp to allow for measurements of the valence band at the Brillouin zone boundary. We also connected a preparation chamber for non-cleaving samples. The preparation chamber is independent from the main transfer route allowing for the measurement of cleaving samples while more demanding sample preparation can take place in the preparation chamber.

So far the μ-LaserARPES system has been successfully used to investigate, among other things, c-f hybridization effects in Ce-based single crystals [2015-(31)], temperature dependent band renormalization in FeSe superconductors [M. D. Watson *et al.*, J. Phys. Soc. Jpn. **86**, 053703 (2017)] and quasi 1-dimensional charge-density wave compounds [16BG039 (List of proposals)] as well as novel Dirac materials [16BG039] and a number of graduate student projects focusing on high energy resolution of the BCS gap of superconducting materials.

***Evaluation***

The rotation of the BL-1 main chamber around the light incidence allows for a unique setup where the degree of linear polarization remains at 100% all the time. Such a polarization dependent ARPES measurement enables users to disentangle multi-band system based on the dipole selection rule. Furthermore, this system has been proven useful to extract orbital textures by continuously rotating the incident electric-field vector with respect to the detection plane [2015-(30)].

The high-resolution variably polarized low-energy photons from the APPLE-II undulator at BL-9A, in combination with the available offline sources, provide an excellent environment to investigate fine details in the electronic structure near the Fermi level. The installation of the fully motorized 6-axes goniometer and the control software allows high-quality ARPES measurement in momentum space.

The recently commissioned μ-LaserARPES machine has already proven to be a highly competitive setup. It is now getting attention from different groups inside and outside of japan for its attractive combination of spatial, angular and energy resolution.

***Perspective***

The experience gained from past and future upgrades of the three machines will be transferred to the beamlines of HiSOR-II. It is expected that orders of magnitude more efficient ARPES measurements and/or ARPES with improved spatial resolution of ~1 μm will be possible at the new synchrotron ring. At HiSOR-II more detailed investigations of the electronic structures can be performed which are indispensable to further fundamental understanding of various transport and magnetic properties of solids.

Keeping in mind the current trend of community demands, as well as the future upgrade of the synchrotron towards a low emittance source, it is important to focus on two main points of improvement. On one hand, based on the impressive results from the μ-LaserARPES system, it is of crucial importance to reduce the spot size from its current size (900 (H) μm × 200 (V) μm) to at least below 100 μm to increase the surface selectivity as well as the angular resolution and stay internationally competitive.

It is highly recommended to promote the project to introduce focusing optics to BL-1 and BL-9A which is currently under way. The first upgrade is scheduled to be at BL-1 during the fiscal year 2018. The upgrade of the manipulator to allow for higher lateral precision and control of the measurement position is also recommended. At the same time a deflector type analyzer upgrade should be considered allowing for the effortless mapping of Fermi surfaces without the demand to correct the position of the beam during the otherwise necessary sample rotations. A deflector type analyzer would also allow to probe orbital textures in more detail due to the possibility to counter rotations of the sample surface with a deflector angle allowing for different combinations of mirror-plane and plane-of-incidence geometries while detecting the same electron bands in k-space. A future upgrade of such a deflector type analyzer to integrate a 3D VLEED-type spin detector should also be considered. This would lead to a unique situation at BL-1 where high spatial and angular resolution with surface and kz sensitive excitation energies are combined with resolution of the spin (VLEED) and ultimate resolution of orbital textures. The latter is being possible by the rotatable analyzer system, which allows to keep 100% purity of polarization between p- and s-polarization a feature setting apart BL-1 from other ARPES beamlines around the world.

At BL-9A, similar to the situation at BL-1, one of the user's most frequent requests is the reduction of the photon spot-size. To meet this demand, it is highly recommended to introduce a high magnification ellipsoidal mirror and spatial filter to the main chamber which can reduce the beam size down to ~30 μm. This upgrade will allow the measurements of small domain samples or rough cleaved 3-dimensional sample surfaces. Another demand from many users is the addition of an automated photon energy control system that changes the monochromator and undulator gap automatically. This, together with the 6-axes goniometer would allow users to map the 3-dimensional momentum space in a convenient fashion.

Finally, to advance the capabilities to measure at low temperatures with very high energy, angular and spatial resolutions it is necessary to improve the design of the goniometer to reduce the residual magnetic fields in the chamber and improve the thermal radiation shields to reduce mechanical vibrations. To that end a low-vibration coupling to the cryo-shield should be installed and crucial parts of the manipulator exchanged with non-magnetic materials.

In its current stage the μ-LaserARPES machine is highly competitive and allows for the production of state-of-the-art results. To stay ahead, it is recommended to extend its capability to access ultra-low temperatures (T~2-3K). One of the options is an installation of a low-vibration cryo-shieled in combination with a new goniometer. It has been shown that such a setup can achieve temperatures below 3 K while retaining the rotational degrees of freedom [M. Hoesch *et al*., Rev. Sci. Instrum. **88**, 013106 (2017)].

At the same time, it would be interesting to add the capabilities to resolve the valence band and outer parts of the Brillouin zone (UPS) and/or the chemical state (XPS) of a sample on a comparable length scale as the

Laser does. A focused x-ray source could also be used to obtain structural information via x-ray photoelectron diffraction (XPD). To achieve micro focused He or Xe light a mirror/monochromator setup would be necessary in combination with a capillary type focusing mirror [Capillary focussing morrors by Sigray Inc. (http://www.sigray.com/), refer as #3]. In such a case spot sizes of some 10 μm would be available. For micro focused XPS/XPD the main chamber design would need to be changed to accommodate existing monochromator and x-ray sources and a capillary type optics [#3] would again be employed to achieve micron order spot sizes.

## 1-2. Spin structure analysis (BL-9B, laser spin-ARPES)

***Current Status***

This research division conducts research on quantum spin physical properties of materials by spin- and angle-resolved photoelectron spectroscopy.

So far the staff of HiSOR have developed and being improving spin- and angle-resolved photoemission spectroscopy (spin-resolved ARPES) endstation equipped with a very low energy electron diffraction (VLEED) type spin polarimeter. Since the efficiency of VLEED polarimeter is about 100 times higher than the conventional Mott spin detecotor, higher resolution measurement ($\Delta E \leq 10$ meV, $\Delta k = 1 \times 10^{-2}$ Å$^{-1}$ @ hν = 21 eV) in shorter measurement time has been realized [T. Okuda *et al*., Rev. Sci. Instrum. 87, 103302, (2011)]. In 2013, a second VLEED spin polarimeter, that was set orthogonally to the previous one, was installed at 90 ˚ to enable complete determination of 3-dimensional spin vectors ($S_x$, $S_y$, $S_z$) [2015-(5) (List of publications)]. Also, for accurate Fermi surface measurements, a high precision low temperature 6-axes goniometer is available. At the beamline polarization dependence of incident light (left / right circular polarized / horizontal / vertical polarized) measurement can be done by the APPLE II type variable polarization undulator. The available photon energy of the beamline is hν = 16 to 300 eV.

Because of the high performance of the end-station about 90 collaborative researches (half of which is international collaboration) have been done in the last 6 years and many important results have been obtained as described below. Discovery of ideal topological insulators, $Bi_2Te_2Se$ and $Bi_2Te_2Se$, with high spin polarization (paper No. 2012-(38) in the publication list, Top 10% papers, Press releases (3), Newspaper reporting (5)), elucidation of the polarization and excitation energy dependence of the spin polarization of the prototypical topological insulator $Bi_2Se_3$ [2014-(40), Top 10% papers], the first observation of the Valay Spin Structure of $MoS_2$ [2014-(28), Top 1% papers], discovery of the existence of topological surface state in superconductor β-$PdBi_2$ [2014-(16), Top 10% papers], experimental verification that $YbB_{12}$ is a topological Kondo insulator [2016-(15)], the observation of hidden spin polarized states in the novel superconductor $LaOFBiS_2$ [S. L. Wu *et al*., Nature Commun. **8**, 1919 (2017)] and so on (2 more Top 10% papers).

In addition to the beamline BL-9B, a new spin-ARPES system using vacuum ultraviolet 6 eV laser light is now under commissioning for the purposes of further expansion of collaborative researches and for R&D aiming for usage of the 3rd generation light source in the future. The electron analyzer with special electron deflector (Scienta-Omicron DA-30) that enables to do Fermi surface mapping or angle resolved measurement without using manipulator rotation. By utilizing laser light, not only resulting in improvement of energy and wavenumber resolution, but will also open up research on micron samples or multi-domain samples by using the highly focused laser beam. In addition, research using variable polarization properties will be useful to study detailed polarization dependence in spin-ARPES measurement.

Furthermore, a multi-channel spin detector that can improve the efficiency of spin-detection more than 1000 times higher than the present system is now under construction.

***Evaluation***

The importance of high-performance spin-resolved ARPES experiments and of maintaining its performance and stable operation should be emphasized, given the scarcity of places in the world where high-resolution spin-resolved ARPES experiments using SR light can be conducted. The strategy of having one system running with a well-established and reliably working system is advantageous, while developing in parallel a new spin-resolved ARPES experiment utilizing laser light source which opens new possibilities in the spin-resolved ARPES measurement. Furthermore, the successive efforts of the staff to improve the efficiency and resolution of the spin-ARPES measurement by developing the multichannel spin detector are very important for maintaining a world-leading position in the future.

The VLEED spin-resolved ARPES system has demonstrated an improvement of the spin detection sensitivity by more than 100 times compared to conventional spin detectors and has also achieved an energy resolution of $\Delta E \leq 10$ meV and an angle resolution of 0.4˚ or better, which are among the highest resolutions reached in spin-resolved ARPES in the world. It currently enables precise spin-resolved measurements for materials or surfaces that require high energy and angular resolutions, such as topological insulators or Wyle semimetals.

Actually, the system has produced highly original results in the direct measurement of novel spin splitting electronic states of topological materials. High spin sensitivity of the VLEED spin detector and possible high-resolution measurement, as well as the capability of 3D spin vector analysis, are really helpful to obtain reliable data and the successful measurements of valley electronic system ($MoS_2$), topological Kondo insulator ($YbB_{12}$), hidden spin polarization in novel superconductor ($LaOFBiS_2$) are good examples.

In order to fully exploit the unique features of these spin-resolved ARPES experiments, versatile sample preparation facilities are needed. In the sample preparation chamber of the systems, it is possible to prepare and evaluate clean surfaces of single crystalline metals, nanostructures, and bulk samples including layered materials without changing the experiment setup. These features permit to prepare a variety of samples efficiently and to respond quickly to new research trends in this fast-moving field. For example, the high-temperature annealing system can heat samples up to 2000˚C or more and clean the surfaces of tungsten and other metals, which has proven very useful. Clean tungsten surfaces are often used as substrates for the growth of ultrathin metal films.

The Joint Usage/Research programs using the spin-resolved ARPES instruments always involve HiSOR staff members. This means that users can acquire high-quality data efficiently from the first day even if it is the first visit for them. Due to the uniqueness and the complexity of the equipment, there is no other way to operate.

By the synergistic effects of these facts, the number of users especially from abroad are rapidly growing recently. It is noteworthy that half of the proposals are now from abroad. However, on the other hand, this fact makes the securement of beamtimes for HiSOR staff very difficult. The introduction of a laser source and development of a new and much more efficient multichannel spin detector are meaningful in this respect. But even so, the beamtime is absolutely too scarce compared to other facilities.

The synchrotron radiation is currently unavailable at night and weekend in HiSOR. An intense He lamp has therefore been set up to enable night-time measurements. While this definitely helps to increase the utilization and efficiency of the facility in preparing and characterizing samples and, in some cases also in obtaining high-resolution spin-resolved ARPES measurements, it would be highly desirable to be able to run experiments also during the night and/or weekend with synchrotron radiation.

***Perspective***

The recent boom in spintronics and topological insulators research is raising demands for spin-resolved ARPES measurements. Given the global scarcity of spin-resolved ARPES instruments in operation, HiSOR can help to meet the demand by operating both systems, i.e. systems at SR beamline and with a laser source. With these resources HiSOR can play a prominent role in this research field. The demand is especially high for spin-resolved ARPES measurements using high-brilliance synchrotron radiation sources. Spin-polarized surface states on topological insulators are often located near bulk bands, hence high energy and angular resolutions are required and the possibility to tune the photon energy is crucial. Although the new laser SARPES system will be helpful the use of synchrotron radiation is essential if the characteristics of the high-resolution spin-resolved ARPES systems are to be exploited to the fullest extent. Currently, companies like VG Scienta and SPECS are bringing commercial instruments on the market, but the development of the VLEED type spin detector and also multichannel spin detector at HiSOR will keep this facility ahead of the field.

Staff people at HiSOR have a long-term experience with designing and operating spin-resolved photoemission experiments. The institution is thus in an excellent position to develop a "multichannel spin detector". This would represent one of the world's most ingenious measurement systems for spin-resolved ARPES to dramatically enhance the energy and angle resolution, and potentially to introduce the possibility of ultrafast temporal resolution.

It is strongly desired that HiSOR engages in all these efforts in the future to enhance its capabilities and create the world's finest environment for the most advanced spin-resolved ARPES experiments, making synchrotron radiation available 24/7, and provide a stable supply of user beam time.

## 1-3. Nanomaterial analysis (BL-14)

***Current Status***

The BL-14 beamline has been utilized for some types of absorption spectroscopy experiments in the soft X-ray region between 400 and 1200eV, including the main technique of soft X-ray magnetic circular dichroism (XMCD) measurements. The targets of the XMCD experiments are magnetic nanostructured materials grown on many kinds of substrates, whose samples are fabricated by epitaxial method, controlled monatomically and well characterized in crystallinity and morphology by electron reflection and STM measurement. The XMCD experimental system consists of a SR measurement chamber and a suite of interconnected UHV chambers for the in-situ sample fabrication and analyses, where the samples can be transferred into its neighbor chamber without braking UHV condition.

Sample growth method is well established in the sample fabrication chamber, supported by capabilities of monatomic layer control using real-time RHEED oscillation measurement and deposition method of wedge-shaped over-layers with fine thickness control and sub-monolayer precision. The sample temperature and pressure of reactant gases are also monitored and controlled, which is effective in fabrication process of some kinds of films or interfaces. Fabricated magnetic nanostructures are quickly transferred into the part of XMCD spectrometer, and their native magnetic properties are investigated without an influence of oxidation or surface pollution.

STM system is also incorporated into the XMCD station, which enables in-situ observation of atomic arrangement or microscopic morphology in angstrom scale. The STM component is installed as a part of the interconnected chambers through a UHV pass-way with vibration insulation. Atomic resolution images have been successfully confirmed for a reconstructed surface of Si(111) at the beamline site. Combination experiments between STM observation and XMCD measurement are effectively carried out for magnetic clusters on a single crystal surface, where relation between the size of magnetic cluster and their magnetic properties can be discussed.

In the main part of the XMCD spectrometer, the samples can be exposed to circular polarized synchrotron radiation and magnetic field supplied by a sliding permanent magnet and an electromagnet system. The electromagnet system can control the amplitude of variable field and direction of the field to the sample surfaces, supporting element specific magnetic hysteresis loop measurements and angle dependence analyses of orbital magnetic moment.

***Evaluation***

The HiSOR BL-14 has completed the construction of a combined system for material fabrication, structural information analysis and atomic-specific magnetometory using circularly polarized synchrotron radiation, whose experiment system is based on a philosophy that SR measurements should be carried out in-situ for artificial surface structures fabricated under good quality control at the beamline site. In-situ experiments have been successful to a large degree, especially for ultrathin magnetic films, whose results are supported by the control of deposition and growth by on-line RHEED oscillations, the surface chemical analysis by AES, measurement of the long range symmetry and domain size by LEED, the fine morphological analysis by STM, and the XMCD measurements with quantitatively reliable analysis. Fine interface control in layered structures, monatomic thickness control of ultarathin films, and lateral size control of surface clusters are well regulated in the context of the sample fabrication toward development of functional layered materials in technological applications. Performed quantitative analysis of local magnetic moment and element-specific hysteresis loop measurements are quite significant for the artificial structures that include magnetic elements.

After the recent upgrade of the electromagnet environment, the direction of magnetic field can be freely selected to the sample crystal axis. This improvement is significant, because a data set of XMCD spectra for a sample magnetized along sample normal and in-plane direction provides parallel and perpendicular components of local magnetic moments to the surface. The measurement method of angle-dependent XMCD will contribute to studies of anisotropic orbital magnetic moments existing in two-dimensional magnetic layered structures.

Continuous measurement of STM and XMCD for an identical sample is very attractive for researchers in the fields of surface and interface science. The system integration of STM environment into the beamline station and the successful model study on magnetic surface clusters are worthy of special mention. It is recommended to open the STM system to world-wide users in order to expand the capability of combining experiment of STM and XMCD, if additional man-power for user support becomes available.

The system configuration of the soft X-ray beamline BL14 has provided a sophisticated experimental station for researches and developments of magnetic artificial structures. The strategy to complete materials synthesis, structural analysis and magnetic measurement on-site at a SR beamline, is challenging and important for researches based on a concept of material design. It is appreciated that some efforts along the strategy have been succeeded at BL14 for magnetic nanostructures related to functional materials. Although the performance of the photon beam is limited due to an older generation SR facility, there still remains some points to be improved at the BL14 system, for example, enhancement of magnetic field and temperature control below liquid nitrogen temperature in the XMCD measurement.

***Perspective***

The concept to build SR experimental stations for sample synthesis and fine analysis is one of important ideas for material science, which is followed by the continuous efforts at BL-14 in the research field of magnetic nanostructures. The basic construction of the XMCD station has been finished and some good cases of utilization have been successfully established including collaborative works with outside user groups, leading to deep understanding of magnetic states of artificially controlled materials on an atomic scale.

To enhance the potentiality of the beamline station, improvement of the XMCD spectrometer should be required from some technical viewpoints; an extension of the operation temperature range, an enhancement of the magnet system to apply stronger magnetic field and a device for high throughput operation. The cooling condition for the XMCD measurement is limited down to liquid nitrogen temperature at present, which excludes coverage of ferromagnetic compounds with lower Curie temperature or small magnetic clusters on surfaces. A superconducting magnet or high field electro-magnet is recommended for taking stable spectra of hard magnetic samples or measurements along hard magnetic axis. The system upgrade supporting lower temperature and higher magnetic field, is effective for the BL-14 station to widen a scope of target materials and to attract researchers in various fields. An automatic drive of sample manipulation and rotary stages for angle settings of sample and magnet, enable time-efficient and easy operation for users. Automation with programmable sequence of geometry settings and spectra measurements is a good way to enhance the productivity.

As to the sample preparation segment of the XMCD station, a sophisticated structural analyses is recommended for fabricated samples in-situ. An advanced analysis of electron diffraction provides 3D structural information at the interfaces of layered samples, which is crucial for artificial films related to spintronics devices.

Additional surface analysis tools of ion scattering spectrometer or SEM column in the UHV may benefit surface analysis, which give us complementary information to the existing STM system.

The XMCD station at BL-14 is specialized for in-situ SR analysis accompanied by sample synthesis at the same site, which should be continuously upgraded and utilized by the expertise of internal staff and input from outside users. On the other hand, easy-to-use environment for soft x-ray spectroscopy is also required for beginners and light users, especially, those who do not demand UHV condition. Since UHV condition is not necessarily required as long as electron detection methods are avoided in the spectroscopy experiment, it is a good idea to adopt photon-in-photon-out methods in a low-vacuum/atmospheric pressure chamber that can be separated from the UHV beamline by silicon nitride membrane. Reflectivity measurement in the soft X-ray region is effective to probe the dielectric tensor in materials and to search structural models of multilayers. The XMCD effect is also found in the reflectivity spectra with greater signal than in conventional absorption spectra, which has an advantage to magnetic materials with poor conductivity.

## 1-4. Circular dichroism of biomaterials (BL-12)

***Current Status***

Circular dichroism (CD) a spectroscopy technique, which is very sensitive to the steric structures of optically active materials and widely used for structural analysis of biomaterials such as proteins, sugars, and nucleic acids because it can be applied to a wide range of biomaterial samples under various solvent/experimental conditions. A vacuum-ultraviolet (VUV) CD spectrophotometer can extend the CD spectra to the VUV region below 190 nm by using synchrotron radiation (SR) and thereby provide novel structural information that is unobtainable in conventional CD instruments [2013-(5) (List of publications)]. HiSOR was one of the world's first SR facilities, which successfully developed a VUVCD beamline. Now the SR-VUVCD beamlines are under operation in seven SR facilities (ISA in Denmark, BSRF in China, NSRRC in Taiwan, BESSY2 in Germany, Diamond Light Source in United Kingdom, ANKA in Germany, and SOLEIL in France). Further, Elettra in Italy and LNLS in Brazil are planning to construct new SR-VUVCD beamlines.

The HiSOR-VUVCD spectrophotometer is composed of an optical system that generates left- and right-circularly polarized light at 50 kHz and a detection system that consists of two photomultipliers and a lock-in amplifier. This spectrophotometer has the capacity to obtain the CD signal with high precision down to 120 nm by connecting these two systems using an optical servo control technique. This spectrophotometer was installed into BL-15 first. Afterward, to improve precision and speed for the VUVCD measurements, HiSOR built a new Wadsworth normal incident monochromator (BL-12 since 2013) as a light source for VUVCD, which made SR light available at a photon flux of $5\times10^{10}$ photons/sec/mm$^2$/100 mA at 190 nm (at the sample position).

Recently, a Schwarzschild focus mirror was set up to reduce the size of SR light in the spectrophotometer because the SR beam size of BL-12 was 6 × 6 mm at the sample position. This focusing mirror provided 20 × 20 μm beam size and allowed the reduction of sample volume needed for one measurement (20 μl → 2 μl), allowing to measure rare samples such as membrane proteins. The software for CD measurements was upgraded and allows now the high-tension voltage (HTV) of the photomultiplier or the linear dichroism (LD) to be monitored simultaneously. The HTV is used for obtaining the absorbance spectra of the samples and the LD measurement is particularly valuable for obtaining the information of biomaterial orientations [2016-(30)]. Structural analysis of proteins and sugars are now routinely measured, combining leading-edge computational techniques such as bioinformatics, molecular dynamics (MD) simulation, and time-dependent density functional (TDDFT) methods which substantially increased the structural information content from VUVCD spectra. The combination of these methods reveales the pairwise relationships between structures and CD of monosaccharides in solution [2012-(13)] and also realized the analysis of intermolecular structures of amyloid fibrils [2014-(11)]. Further, these techniques are used for analyzing the solution structures of histone proteins relating to various cell functions such as DNA damage repair [Y. Izumi *et al*., J. Radiat. Res. **58**, 59 (2017)].

***Evaluation***

The VUVCD spectrophotometer can extend the CD spectra down to 140 nm in the VUV region, giving a great advantage in the structural analysis of biomaterials. To enhance this advantage, many important upgrades were conducted last six years. The most important upgrade was the construction of new beamline (BL-12), which successfully increased the photon flux, thereby enhancing the quality and efficiency of measurements. The developments of spectral analysis using TDDFT and MD could disclose new structural information of proteins and sugars in solution. Focusing system using a Schwarzschild focus mirror realized the deduction of sample volume for one CD measurement. These considerable efforts should be highly evaluated.

***Perspective***

BL-12 can provide high photon flux with the VUVCD instrument without any damages to the solution samples. Hence, the optimizations of parameters of M3 mirror and the exchange of coating materials on grating mirror from $MgF_2$ to Ru could be possible to further increase the photon flux and enhance the efficiency of measurements. Most important point is that more than 15 years have passed since the VUVCD equipment was first developed. It is highly desirable that a next-generation VUVCD device that incorporates leading-edge optical and detection systems is constructed. At present, the CD spectra are measured using single detector by scanning the monochromatic SR light from 4 to 10 eV. Then, using new technology such as a multichannel detector or CCD camera, the efficiency of the VUVCD measurement would be extremely enhanced.

At present, the study using VUVCD spectroscopy mainly focus on the static structures of biomaterials, and then these targets should be replaced with the dynamic structures such as the protein folding and the structural change of protein inducing by the interaction with other biomaterials. To conduct these experiments, small size of SR beam is necessary. The focusing system of SR light recently constructed could make micro size SR beam and allow to observe the structural change of biomaterials at the level of millisecond or microsecond. Further, this focusing system could also lead the construction of screening CD system in which the CD spectra of various samples with different solvent conditions on the microplate are automatically measured. This measurement technique would expand the usage of VUVCD tool to various fields such as CD imaging of biomaterials.

## 1-5. Light source accelerators and insertion devices

***Current Status***

The light source accelerator system at the Hiroshima Synchrotron Radiation Center (HSRC) consists of a 150 MeV injector microtron, a beam transport line, and a racetrack type storage ring. This system is called HiSOR (Hiroshima Synchrotron Orbital Radiation). The circumference of this ring is 22 m, and the bending radius is 0.87 m in the normal conducting bending magnet with the magnetic field of 2.7 T. Stored electron beam energy is 700 MeV, and synchrotron radiation having the critical energy of 873 eV from two 180-degree bending magnets can be extracted from 14 photon beam ports. There are two straight sections between these magnets and two undulators are installed at the straight sections. At the present, one of them is a linear undulator (2.4 m long, 57 mm period) that generates 26 – 300 eV linearly polarized radiation. Another one is the quasi-periodic APPLE II type undulator (1.8 m long, 78 mm period).

The HiSOR ring has been successfully operated and has been delivering stable photon beams for HiSOR users since 1996. Operation hours exceed 2,000 hours in each year, and users' operation hours are about 1,600 hours. The machine is running 11 hours a day (with 2 injections) and 4 days a week. Monday is research for maintenance. The machine startup in the morning takes only 30 minutes. Close to turn-key operation is possible for normal use.

Because of the long operation from 1996, some problems have occurred in the last 5 years. One of the most serious problems was the water leakage from an absorber for the synchrotron radiation inside the vacuum chamber of the storage ring in the middle of 2012. Due to this problem, the machine time for users was lost for 400 hours in this year. After this problem, the vacuum was poor of an extended period of time. Thus, the initial beam current was limited to 250 mA because of radiation safety regulations. The complete recovery of this trouble had been finished in 2015. As the result, the machine time for user operation in 2016 has been recovered to the level of before 2011 and the initial stored current is recovered to 300 mA. Although it is not so serious, there are problems of wave leakage in several places, and thus, the replacements and repairments will be systematically continued.

In order to extend the life of the HiSOR operation for the next decade, the power supplies for the magnet system and the accelerating cavity have been replaced during the last 5 years. The power supplies of the bending and quadrupole magnets for the storage ring was replaced in 2013, and those for the microtron were replaced in 2014. The amplifier for the accelerating cavity for the storage ring was replaced from the vacuum-tube type to the solid-state type in 2017. The replacement of the klystron amplifier for the microtron is planned in the next fiscal year. As the results of these upgrades, the reliability for the long-term operation of the HiSOR is significantly improved.

Although the 24-hour operation has been requested from various users for a long time, it is difficult to satisfy due to the lack of technicians.

Before previous international reviewing in 2012, the design study for the upgrade of the light source was based on the design of MAX-III lattice of MAX-lab in Lund, Sweden. It is based on combined function magnets for bending and focusing, has 4 insertions and 4 short straight sections. It has a circumference of 40 m and could be accommodated on the open space of the HSRC. The design value of the equilibrium emittance is 14 nmrad. Because of the short lifetime of the stored beam (below 3 hours), the 3 Hz top up operation is planned.

From 2010, a new design of the storage ring has been vigorously studied. It is based on the Torus-knot concept. It has a lattice structure where the beam orbit closes after multiple turns in the storage ring. By applying this new concept, the orbit length of the beam can be three times longer than the ring perimeter. In addition, the 15-m-diameter ring equipped with 11 bending magnets has 11 long (3.6 m) straight sections capable for installing insertion devices and other necessary accelerator components. During the last 6 years, detailed studies has been done on this design addressing a multi-bend lattice, magnet parameters to optimize the emittance and dynamic aperture.

It is noteworthy that the collaborative work with UVSOR at Okazaki has started for studies of orbital angular momentum of the synchrotron radiation from tandem undulators. These studies are expanded now to the large collaborating research field for the light vortex.

***Evaluation***

Although the accelerator system of HiSOR has been in place for 20 years, it still operates well and can be maintained to accommodate the state-of-the-art synchrotron radiation experiments. It is noteworthy that the turn-key mode of operation is reliable. As a consequence of the recent upgrades of the power supply system, the reliability and long-term maintainability is improved. In order to satisfy the user request to make 24-hour operation, it is necessary to employ additional technical staff.

As part of the upgrading plan for HiSOR, the design study for a new accelerator system was conceptually completed at the time of previous international review in 2012. It is a low emittance storage ring with the energy of 700 MeV, the circumference of 38 m and the emittance of 14 nmrad. The design is based on the MAX-III storage ring at MAX lab, Sweden. In addition, there has been recent progress for a completely new design, namely a storage ring based on the concept of a torus knot. This work has much originality and impact in the research field of accelerator sciences.

The studies of new types of undulator such as the knot-APPLE undulator and quasi-periodic undulator are undertaken in detail. These studies have also contributed to the high-level educational environments for graduate students.

***Perspective***

HiSOR is expected to continue its successful operation for several more years at its present performance, because of the recent and planned upgrades of the accelerator components.

For a long time, 24-hour operation is desired from a lot of users. It is, however, difficult to realize their request because of the lack of operators. The employment of additional technical staff is strongly desired.

Regarding the upgrading plan for the next light source, it is also recommended that comparisons should be made between designs obtained so far as well as including a design from the ASTRID2 facility in Aarhus, Denmark. These design studies should be undertaken in parallel with the tasks of the daily maintenance and long-term upgrade plan for the existing accelerator systems.

# Appendix

Presentation ppt files by HiSOR staffs will be here.

The data are temporarily uploaded in the webpage:

https://share.hiroshima-u.ac.jp/owncloud/index.php/s/mpWGuGs2n4Ouot1

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# List of proposals

**2012**

12-A-1 Hitoshi Yamaoka : RIKEN SPring-8 Center
High resolution photoelectron spectroscopy study on Yb valence fluctuation system and thermoelectric compounds

12-A-2 Peter Dowben : University of Nebraska-Lincoln
Investigations of electron-phonon coupling on Au/Mo(112) in relation to the order-disorder structural phase transitions by means of high-resolution angle resolved photoemission spectroscopy

12-A-3 Yasuyuki Maki : Faculty of Engineering, Gunma University
Aging and hysteresis of polysaccharides gels studied by vacuum ultraviolet circular dichroism

12-A-4 Satoshi Asaoka : Environmental Research and Management Center, Hiroshima University
Oxidation mechanisms of hydrogen sulfide on the surface of manganese or iron oxides

12-A-5 Hiroyoshi Ishi : Graduate School of Science and Engineering, Tokyo Metropolitan University
High-resolution photoemission spectroscopy of metallic carbon nanotubes prepared by CoMoCAT method

12-A-6 Hideki Murakami : Department of Semiconductor Electronics and Integration Sciences, Hiroshima University
Characterization of change in germanium surface chemical bonding feature with surface treatment

12-A-7 Kouji Miyamoto : Hiroshima Synchrotron Radiation Center, Hiroshima University
3 dimensional spin analysis of d electrons in $Sr_2RuO_4$

12-A-8 Kouji Miyamoto : Hiroshima Synchrotron Radiation Center, Hiroshima University
Spin texture for topological insulator of Bi-based alloy

12-A-9 Kouji Miyamoto : Hiroshima Synchrotron Radiation Center, Hiroshima University
Many body effect for topological insulator of Bi-based compounds

12-A-10 Hitoshi Sato : Hiroshima Synchrotron Radiation Center, Hiroshima University
Angle-resolved photoemission spectroscopy of new Kondo-lattice systems $YbNi_3X_9$(X=Al,Ga)

12-A-11 Hitoshi Sato : Hiroshima Synchrotron Radiation Center, Hiroshima University
Inverse-photoemission spectroscopy of FeAs-baesd superconductors IV

12-A-12 Hitoshi Sato : Hiroshima Synchrotron Radiation Center, Hiroshima University
Photoemission spectroscopy of one-dimentional $Ca_{1-x}Na_xCo_2O_4$

12-A-13 Hitoshi Sato : Hiroshima Synchrotron Radiation Center, Hiroshima University
Soft x-ray absorption spectroscopy of one-dimentional $Ca_{1-x}Na_xCo_2O_4$

12-A-14 Yoshihiro Aiura : National Institute of Advanced Industrial Science and Technology
Angle-resolved photoemission study on the kink in the energy dispersion of layered transition-metal oxides VIII

12-A-15 Yoshihiro Aiura : National Institute of Advanced Industrial Science and Technology
Angle-resolved photoemission spectroscopy study on the charge transfer of $Sr_2RuO_4$

12-A-16 Hideaki Iwasawa : Hiroshima Synchrotron Radiation Center, Hiroshima University
High-resolution ARPES study of the superconducting gap of $YBa_2Cu_3O_{7-\delta}$

12-A-17 Hideaki Iwasawa : Hiroshima Synchrotron Radiation Center, Hiroshima University
Many-body interactions in $YBa_2Cu_3O_{7-\delta}$ studied by high-resolution ARPES

12-A-18 Se-Young Jeong : Pusan National University
XMCD study on ferromagnetic spin ordering by hydrogen mediation in ZnCoO

12-A-19 Kyung-Hoi Kim : Graduate School of Biosphere Science, Hiroshima University
Changes of sulfur compound on the surface of granulated coal ash covering organically enriched sediment

12-A-20 Takashi Mizokawa : Graduate School of Frontier Sciences, University of Tokyo
Angle-resolved photoemission study of multi-band effects in layered Fe chalcogenide superconductors

12-A-21 Taichi Okuda : Hiroshima Synchrotron Radiation Center, Hiroshima University
Study of surface electronic state of Au/Si(557) and Au/Si(553) surfaces by means of valence and core-level photoemission spectroscopy

12-A-22 Akihiro Ino : Graduate School of Science, Hiroshima University
Temperature-dependent study of bogoliubov quasiparticles in $Bi_2Sr_2Ca_{1-x}Y_xCu_2O_{8+\delta}$ using low-energy ARPES

12-A-23 Kim Changyoung : Yonsei University
Circular dichroism ARPES studies on bulk inversion symmetry broken materials

12-A-24 Akio Kimura : Graduate School of Science, Hiroshima University
Observation of topological surface states in the Ge(Sn)Te-$Sb_2Te_3$ pseudobinary compounds

12-A-25 Akio Kimura : Graduate School of Science, Hiroshima University
Observation of buried Dirac cone in the Pb based ternary topological insulator

12-A-26 Akio Kimura : Graduate School of Science, Hiroshima University

Direct observation of spin-split surface states at the interface of GeTe/SbTe multilayer using low-energy APRES

12-A-27 Hiroaki Anzai : Hiroshima Synchrotron Radiation Center, Hiroshima University
Momentum and temperature dependence of kink structures in Bi2212 studied by low-energy ARPES

12-A-28 Hiroaki Anzai : Hiroshima Synchrotron Radiation Center, Hiroshima University
Material dependence of superconducting gap in cuprate superconductors studied by low-energy synchrotron radiation

12-A-29 Jian Jiang : Hiroshima Synchrotron Radiation Center, Hiroshima University
High-resolution APRES study of temperature- and polarization-dependence of surface states in Ni(111) and Al(111)

12-A-30 Jian Jiang : Hiroshima Synchrotron Radiation Center, Hiroshima University
High-resolution APRES study of many-body interactions in a strong-coupling superconductor Lead

12-A-31 Kenya Shimada : Hiroshima Synchrotron Radiation Center, Hiroshima University
High-resolution APRES of Ce and La thin films II

12-A-32 Tomohiko Saitoh : Faculty of Science, Tokyo University of Science
Temperature-dependent changes in the valence-band electronic structure of CMR layered Mn oxides

12-A-33 Tomohiko Saitoh : Faculty of Science, Tokyo University of Science
Mg-doping effects on the valence-band electronic structure of a delafossite type oxide $CuCrO_2$

12-A-34 Kojiro Mimura : Graduate School of Engineering, Osaka Prefecture University
Temperature-induced phase transition of layered Tl compounds investigated by photoemission spectroscopy

12-A-35 Kojiro Mimura : Graduate School of Engineering, Osaka Prefecture University
Observation of peculiar dispersive structures in energy bands of quasi one-dimensional Tl compounds

12-A-36 Kojiro Mimura : Graduate School of Engineering, Osaka Prefecture University
High-resolution angle-resolved photoemission study of Pb contained topological insulators

12-A-37 Akihiro Ino : Graduate School of Science, Hiroshima University
Carrier-concentration-dependence of the energy gaps around Z point for 122-type iron-pnictide superconductors

12-A-38 Akihiro Ino : Graduate School of Science, Hiroshima University
Carrier-concentration-dependence of the energy gaps around X point for 122-type iron-pnictide superconductors

12-A-39 Taichi Okuda : Hiroshima Synchrotron Radiation Center, Hiroshima University
Spin-resolved photoemission study of Bi/Ni(111)$\sqrt{3}\times\sqrt{3}$ surface

12-A-40 Galif Kutluk : Hiroshima Synchrotron Radiation Center, Hiroshima University
Photoemission spectroscopy of nano-structured rare earth elements II

12-A-41 Dan Dessau(米国・コロラド大)
Spin-ARPES measurements of the topological to non-topological transition in $TlBi(Se, S)_2$ and related materials

12-A-42 Masashi Arita : Hiroshima Synchrotron Radiation Center, Hiroshima University
Low energy photoemission spectroscopy of $Y_{1-x}Ca_xTiO_3$

12-A-43 Masashi Arita : Hiroshima Synchrotron Radiation Center, Hiroshima University
Topological insulator $GeBi_2Te_4$ studied by angle-resolved photoemission spectroscopy

12-A-44 Shinjiro Hayakawa : Graduate School of Science, Hiroshima University
Simultaneous detection of CEY and XFY for determination of specific surface area with elemental electivity

12-A-45 Shinjiro Hayakawa : Graduate School of Science, Hiroshima University
In situ XAFS analysis of Li secondary battery with a Ti doped cathode material

12-B-1 Koichi Matsuo : Hiroshima Synchrotron Radiation Center, Hiroshima University
Structure analysis of D-Galactose by vacuum-ultraviolet circular dichroism spectroscopy

12-B-2 Kenichi Ozawa : Faculty of Science, Tokyo Institute of Technology
Characterization of satellite structures of metallic bands formed on hydrogen-adsorbed oxide semiconductor surfaces

12-B-3 Han Woong Yeom : Pohang University of Science and Technology
Investigation of spin-resolved band structure of nanowires with a giant Rashba splitting : Pt/Si(110)

12-B-4 Takayoshi Yokoya : Graduate School of Natural Science and Technology, Okayama University
Electronic structure study of functional materials at BL5

12-B-5 Kouji Miyamoto : Hiroshima Synchrotron Radiation Center, Hiroshima University
Observation of electronic structure of W(110) studied by angle resolved photoemission spectroscopy utilizing polarization dependency

12-B-6 Kouji Miyamoto : Hiroshima Synchrotron Radiation Center, Hiroshima University
Accurate determination for many body effect in surface state of Sb(111)

12-B-7 Eike Fabian Schwier : Hiroshima Synchrotron Radiation Center, Hiroshima University
Investigation of the growth of Au on $Bi_2Se_3$ with STM

12-B-8 Mulazzi Mattia : Julius-Maximilians University at Würzburg
Angle-resolved photoemission on the Kondo system $CePd_7$

12-B-9 Tetsuro Ueno : Hiroshima Synchrotron Radiation Center, Hiroshima University
In situ STM and XMCD study of magnetic nano structures

12-B-10 Shinya Yagi : EcoTopia Science Institute, Nagoya University
Reaction study for absorbed amino-acid molecule on metal nanoparticle surface by XAFS measurement

12-B-11 Shinya Yagi : EcoTopia Science Institute, Nagoya University
Reaction study for absorbed amino-acid molecule on metal nanoparticle surface by N-K and O-K adges XAFS measurement

12-B-12 Mao Ye : Hiroshima Synchrotron Radiation Center, Hiroshima University
Core level electronic states of Ag-intercalated $Bi_2Se_3$

12-B-13 Masahiro Sawada : Hiroshima Synchrotron Radiation Center, Hiroshima University
Thickness dependence of magnetic moment in ultrathin magnetic films of Ni/Pd(001)

12-B-14 Camelia Borca : Swiss Light Source
Radiation-induced elemental magnetic change in Fe-Cr alloys using XMCD

12-B-15 Galif Kutluk : Hiroshima Synchrotron Radiation Center, Hiroshima University
Photoemission spectroscopy of Lithium thin films

12-B-16 Kouji Miyamoto : Hiroshima Synchrotron Radiation Center, Hiroshima University
Observation of electronic structures in topological insulator $Bi_2Te_2Se$ and $Bi_2Se_2Te$

12-B-17 Matolin Vladimir : Charles University in Prague
ARPES study of the lattice positions of magnetic ions in Mn-doped topological insulator $Bi_2Te_3$

12-B-18 Shin-ichi Wada : Graduate School of Science, Hiroshima University
NEXAFS spectroscopy of self-assembled monolayers of aromatic thiols with methyl-ester group

12-B-19 Shin-ichi Wada : Graduate School of Science, Hiroshima University
Ultrafast electron transfer measured by Auger spectroscopy of SAMs of ester-terminated aromatic thiols

12-B-20 Tatsuo Nehira : Graduate School of Integrated Arts and Sciences, Hiroshima University
Determination of absolute configurations for chiral non-conjugated dienes by vacuum ultraviolet circular dichroism (VUVCD)

12-B-21 Hiroaki Yoshida : Graduate School of Science, Hiroshima University
Difference in the Coulomb explosion mechanism of difluorobenzene isomers

12-B-22 Shinya Hosokawa : Graduate School of Science and Technology, Kumamoto University
Electronic states and glass-forming ability of Zr-Ni-Cu-Al bulk metallic glasses

12-B-23 Shinya Hosokawa : Graduate School of Science and Technology, Kumamoto University
Conduction-band electronic states and glass-forming ability of Zr-Ni-Cu-Al bulk metallic glasses

12-B-24 Jian Jiang : Hiroshima Synchrotron Radiation Center, Hiroshima University
Spin-resolved ARPES study of the surface-derived state in Lead

12-B-25 Tomohiko Saitoh : Faculty of Science, Tokyo University of Science
Electronic and magnetic structure of perovskite- and double-perovskite-type Co oxides

12-B-26 Kiyohiko Tabayashi : Hiroshima Synchrotron Radiation Center, Hiroshima University
Core-excitation spectra of molecular clusters associated with strong intermolecular interactions : Comparison between the experimental results and those theoretically calculated

12-B-27 Nobuo Nakajima : Graduate School of Science, Hiroshima University
Correlation between surface structures and 2 dimensional electronic gas sates in $SrTiO_3$

12-B-28 Hojun Im : Faculty of Science and Technology, Hirosaki University
Inverse photoemission spectroscopy of A-site ordered perovskite $CaCu_3Ti_4O_{12}$

12-B-29 Atushi Yamasaki : Department of Physics, Konan University
Inverse-photoemission spectroscopy of perovskite-type iridates

12-B-30 Se-Young Jeong : Pusan National University
High resolution ARPES measurement for the contribution of electron-phonon parameter in metal mixed crystal

12-B-31 Se-Young Jeong : Pusan National University
XMCD study on hydrogen mediated ferromagnetic ordering in ZnCoO

12-B-32 Yoko Nitta : School of Human Science and Environment, University of Hyogo
Structural analysis of strawberry allergen Fra a 1

12-B-33 Canhua Liu : Shanghai Jiao Tong University
Spin structures of the single bilayer Bi(111) on topological insulators studied by spin and angle-resolved photoemission spectroscopy

12-B-34 Kim Changyoung : Yonsei University
Temperature dependent dichroism ARPES sturdy on $Sr_2RuO_4$

12-B-35 Mulazzi Mattia : Julius-Maximilians University at Würzburg
Photon-energy-depedent angle-resolved photoemission from the topological insulator surfaces $Bi_2Se_3$, $Bi_2Te_3$ and

$Sb_2Te_3(0001)$

12-B-36 Eike Fabian Schwier : Hiroshima Synchrotron Radiation Center, Hiroshima University
Investigation of the growth of Au on $Bi_2Se_3$ with ARPES

12-B-37 Shigemasa Suga : The Institute of Scientific and Industrial Research, Osaka University
Spin-polarized angle resolved photoelectron spectroscopy of Kondo topological insulator $SmB_6$

12-B-38 Shin-ichiro Ideta : Graduate School of Engineering, University of Tokyo
Orbital characters in the electron-doped iron-based superconductor $Ba(Fe_{1-x}Co_x)_2As_2$ studied by angle-resolved photoemission spectroscopy

12-B-39 Shuyun Zhou : Tsinghua University
Angle-resolved photoemission spectroscopic studies of electron-doped $CaFe_2As_2$ superconductors

12-B-40 Senku Tanaka : Interdisciplinary Faculty of Science and Engineering, Shimane University
Investigation of the electronic structure of organic/metal interface by using inverse photoemission spectroscopy

12-B-41 Kouji Miyamoto : Hiroshima Synchrotron Radiation Center, Hiroshima University
Spin polarized electronic structure of Au nanowires on Ni(110)

12-B-42 Koichi Matsuo : Hiroshima Synchrotron Radiation Center, Hiroshima University
Vacuum-ultraviolet circular dichroism measurements of methyl D-xylopyranoside

12-B-43 Koichi Matsuo : Hiroshima Synchrotron Radiation Center, Hiroshima University
Structure analysis of membrane-binding protein by vacuum-ultraviolet circular dichroism spectroscopy

12-B-44 Yuji Muraoka : Graduate School of Natural Science and Technology, Okayama University
Spin-resolved photoemission spectroscopy of $CrO_2$ thin films

12-B-45 Hiroshi Kihara : SR Center, Ritsumeikan University
Structural analysis of intermediates of SH3 domain protein by vacuum-ultraviolet circular dichroism spectroscopy

12-B-46 Akio Kimura : Graduate School of Science, Hiroshima University
The core-level photoelectron spectroscopy on topological insulators

12-B-47 Shaolong He : Institute of Physics, Chinese Academy of Sciences
ARPES study of Dirac semimetal:$Na_3Bi$

12-B-48 Eiji Ohmae : Graduate School of Science, Hiroshima University
VUVCD measurements of aromatic amino acids

12-B-49 Naoki Ishimatsu : Graduate School of Science, Hiroshima University
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12-B-50 Dan Dessau : University of Colorado
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12-B-51 Kazumasa Okada : Graduate School of Science, Hiroshima University
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12-C-2 Kenya Shimada : Hiroshima Synchrotron Radiation Center, Hiroshima University
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12-C-3 Kouji Miyamoto : Hiroshima Synchrotron Radiation Center, Hiroshima University
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12-C-4 Koichi Matsuo : Hiroshima Synchrotron Radiation Center, Hiroshima University
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13-A-1 Hitoshi Yamaoka: RIKEN SPring-8 Center
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13-A-2 Jun'ichiro Mizuki : School of Science and Technology, Kwansei Gakuin University
High resolution photoelectron spectroscopy study on Ce1-2-10 systems

13-A-3 Satoshi Asaoka : Kobe University Research Center for Inland Seas
Indentifying sulfur species in particulate matter derived from ship fuels using XAFS analyses

13-A-4 Takayoshi Yokoya : Graduate School of Natural Science and Technology, Okayama University
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13-A-5 Kyung-Hoi Kim : Graduate School of Science, Hiroshima University
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13-A-6 Takashi Mizokawa : Graduate School of Frontier Sciences, University of Tokyo

Angle-resolved photoemission study of multi-orbital physics in layered transition-metal chalcogenide superconductors

13-A-7 Yasuyuki Maki : Faculty of Engineering, Gunma University
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13-A-8 Kenichi Ogata : Nanomaterials Microdevices Research Center, Osaka Institute of Technology
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13-A-9 Kenichi Ozawa : Faculty of Science, Tokyo Institute of Technology
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13-A-10 Kojiro Mimura : Graduate School of Engineering, Osaka Prefecture University
Observation of change in the Fermi surface through the two valence trasitions for EuPtP

13-A-11 Kojiro Mimura : Graduate School of Engineering, Osaka Prefecture University
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13-A-12 Hitoshi Sato : Hiroshima Synchrotron Radiation Center, Hiroshima University
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13-A-13 Hitoshi Sato : Hiroshima Synchrotron Radiation Center, Hiroshima University
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13-A-14 Hitoshi Sato : Hiroshima Synchrotron Radiation Center, Hiroshima University
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13-A-22 Kouji Miyamoto : Hiroshima Synchrotron Radiation Center, Hiroshima University
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13-A-24 Kenya Shimada : Hiroshima Synchrotron Radiation Center, Hiroshima University
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13-B-16 Shaolong He : Institute of Physics, Chinese Academy of Sciences
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13-B-33 Eiji Ohmae : Graduate School of Science, Hiroshima University
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13-B-48 Kouichi Takase : College of Science and Technology, Nihon University
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14-B-16 Shin-ichi Wada : Graduate School of Science, Hiroshima University
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Spin- and angle-resolved photoemission spectroscopic studies of spin texture in atomically thin transition metal dichalcogenide films

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Spin- and angle-resolved photoemission spectroscopy of a topological insulator / magnet heterostructure II
16BG002 Oleg E. Tereshchenko : Institute of Semiconductor Physics, Novosibirsk, Russian Federation,Novosibirsk State University
Searching for Rashba-type splitting of 2DEG and edge states at Bi/InAs
16BG003 Phil King : University of Saint Andrews
Observation and control of topological states in transition-metal dichalcogenides
16BG004 Satoshi Asaoka : Kobe University Research Center for Inland Seas
Oxidation mechanism of hydrogen sulfide on the surface of mixture of granulated coal ash and metal oxides
16BG005 Shin-ichi Wada : Graduate School of Science, Hiroshima University
Evaluation of ultrafast electron transfer of conductive aromatic thiol SAMs by X-ray absorption and resonant auger spectroscopy
16BG006 Shin-ichi Wada : Graduate School of Science, Hiroshima University
X-ray spectroscopy of functional self-assembled monolayers modified by thiol molecules
16BG007 Masahiro Hara : Graduate School of Science and Technology, Kumamoto University
Magnetic property of chemically exfoliated manganese oxide nanosheets
16BG008 Sokolov Nikolai Semenovich : Ioffe Physical-Technical Institute of the Russian Academy of Sciences
XMCD and XAS study of hybrid Co(Fe) / iron oxide / GaN heterostructures for spintronic applications
16BG009 Koichi Matsuo : Hiroshima Synchrotron Radiation Center, Hiroshima University
Conformation analysis of β2 microglobulin amyloid fibrils using vacuum-ultraviolet circular dichroism spectroscopy
16BG010 Mattia Mulazzi : Physics Department, Humboldt University
Investigation of the electronic structure of Te(0001), determination of the band structure, surface states and topological order
16BG014 Andrés F. Santander-Syro : Université Paris-Sud(FR)
Probing 3D and 2D Dirac fermions in a single material: novel topological insulators $Zr_2Te_2P$ and $Hf_2Te_2P$
16BG015 Keisuke Fukutani : Institute for Basic Science
Investigation of quasi-one-dimensional electronic states at the surface of low-dimensional semiconductor
16BG016 Kyunghoi Kim : Pukyong National University
Mechanism of phosphate and hydrogen sulfide removal with coal ash
16BG017 Kensei Kobayashi : Graduate School of Engineering, Yokohama National University
Vacuum ultraviolet circular dichroism measurements of bioorganic materials irradiated by circularly-polarized undulator light
16BG018 Yudai Izumi : Hiroshima Synchrotron Radiation Center, Hiroshima University
Structural analyses of methylated histone proteins using VUV-CD spectroscopy
16BG019 Takayoshi Yokoya : Graduate School of Natural Science and Technology, Okayama University
Photon-energy and polarization dependent angle-resolved photoemission spectroscopy study on $Li_x(NH_3)_yFe_2Se_2$
16BG020 Takeshi Kondo : The Institute for Solid State Physics, University of Tokyo
Observation of energy gap in the triple-layered $Bi_2Sr_2Ca_2Cu_3O_{10+\delta}$
16BG021 Masato Sakano : The Institute for Solid State Physics, University of Tokyo
Spin-polarized electronic structure in chiral crystal structure
16BG022 Kentaro Fujii : National Institutes for Quantum and Radiological Science and Technology
VUV-CD measurements of proteins regarding DNA damage repair
16BG023 Shinya Hosokawa : Graduate School of Science and Technology, Kumamoto University
Conduction-band electronic states of amorphous Mg LPSO alloys

16BG024 Shinya Hosokawa : Graduate School of Science and Technology, Kumamoto University
Valence-band electronic states of amorphous Mg LPSO alloys
16BG025 Teppei Yoshida : Graduate School of Human and Environmental Studies, Kyoto University
Momentum-dependence of self-energy in Bi-based high-$T_c$ superconductors
16BG026 Teppei Yoshida : Graduate School of Human and Environmental Studies, Kyoto University
Inverse-photoemission study of Ruthenium nano-sheet
16BG027 Koji Miyamoto : Hiroshima Synchrotron Radiation Center, Hiroshima University
Influence of surface reconstruction on Rashba-type spin-split surface states
16BG028 Hideaki Iwasawa : Diamond Light Source
Evaluation of matrix element effects and extraction of intrinsic spectral function in $Sr_2RuO_4$ by 3D high-resolution ARPES
16BG030 Hideaki Iwasawa : Diamond Light Source
Uncovering intrinsic many-body interactions in Bi2212 using high-spatial resolution ARPES
16BG031 Shinji Kuroda : Graduate School of Pure and Applied Sciences, University of Tsukuba
ARPES measurements on mixed crystal films of topological crystalline insulator SnTe
16BG033 Shinya Senba : National Institute of Technology, Ube College
Study on a spin-orbital interaction in GeTe through a space-inversion symmetry breaking by ARPES
16BG034 Hitoshi Sato : Hiroshima Synchrotron Radiation Center, Hiroshima University
Study on metal-semiconductor transition of mineral tetrahedrites $Cu_{12}As_4As_{13}$ investigated by photoemission and absorption spectroscopies
16BG035 Hitoshi Sato : Hiroshima Synchrotron Radiation Center, Hiroshima University
Unoccupied electronic state of mineral tetrahedrites $Cu_{12}Sb_4As_{13}$
16BG036 Hitoshi Sato : Hiroshima Synchrotron Radiation Center, Hiroshima University
Zr-substitution effect on electronic state of Kondo insulator $YbB_{12}$
16BG037 Hitoshi Sato : Hiroshima Synchrotron Radiation Center, Hiroshima University
Angle-resolved photoemission spectroscopy of Kondo-lattice systems $Yb_2Pt_6X_{15}$(X=Al,Ga) III
16BG038 Shinichiro Tanaka : The Institute of Scientific and Industrial Research, Osaka University
Study of the peculiar spiral structure in the ARPES spectrum of the graphene 2
16BG039 Mao Ye : Chinese Academy of Science
Electronic states of two-dimensional Dirac materials and hourglass fermion materials studied by high-resolution ARPES
16BG040 Kyoko Ishizaka : Graduate School of Engineering, University of Tokyo
Investigation of topological bands in transition-metal dichalcogenides (II)
16BG041 Daniel Dessau : University of Colorado, Boulder
New ARPES methods for determining critical self-energy effects in cuprate superconductors
16BG043 Masashi Arita : Hiroshima Synchrotron Radiation Center, Hiroshima University
Angle-resolved photoemission study of $Sm_{1-x}Yb_xB_6$
16BG044 Akihiro Ino : Hiroshima Synchrotron Radiation Center, Hiroshima University
Excitation-energy-dependent photoemission study of electronic structure of layered superconductor $Zr_{2-x}Se_x$
16BG045 Akihiro Ino : Hiroshima Synchrotron Radiation Center, Hiroshima University
Orbital character of $Ba(Fe_{1-x}Co_x)_2As_2$ studied by polarization-dependent ARPES intensity mapping
16BG047 Akio Kimura : Graduate School of Science, Hiroshima University
ARPES study of chalcopyrite-type Weyl semimetals
16BG050 Toshio Miyamachi : Institute for Solid State Physics, University of Tokyo
Nano-scale exchange coupling of antiferromagnetic Cr and ferromagnetic Ni thin Film heterostructures
16BG051 Sumera Shimizu : DENSO Corporation
Electronic structure of a ZnO film on a Cu electrode surface in a vehicle motor
16BG052 Tetsuya Sato : Science and Technology, Keio University
Magnetic anisotropy of Fe/Pd(001) bilayer dependent on Pd film thickness
16BG053 Kojiro Mimura : Graduate School of Engineering, Osaka Prefecture University
c-f hybridzation effect of $EuPt_2Si_2$ revealed by angle-resolved photoemission spectroscopy
16BG054 Kojiro Mimura : Graduate School of Engineering, Osaka Prefecture University
c-f hybridzation strength in various Eu compounds estimated by Eu 4d-4f resonant photoemission spectroscopy
16BG055 Hiroaki Anzai  Graduate School of Engineering, Osaka Prefecture University
High-resolution ARPES study of rare-earth compound $YbInCu_4$(X=In, Cd)
16BG056 Koji Miyamoto : Hiroshima Synchrotron Radiation Center, Hiroshima University
Observation of $k_z$-dependent bulk electronic structure in $ReS_2$ and $ReSe_2$
16BU001 Shuyun Zhou : Tsinghua University

Spin- and Angle-resolved photoemission spectroscopic (Spin-ARPES) study of surface Dirac cones in type-II Dirac semimetal $PtTe_2$

16BU002 Shik Shin : The Institute for Solid State Physics, University of Tokyo
Search for topological superconductivity on iron-pnictide surface

16BU003 Koji Miyamoto : Hiroshima Synchrotron Radiation Center, Hiroshima University
Observation of surface state in W(100)

16BU004 Tatsuo Nehira : Graduate School of Integrated Arts and Sciences, Hiroshima University
Determination of absolute configurations for chiral arenes by vacuum ultraviolet circular dichroism (VUVCD)

16BU005 Shaolong He : Ningbo Institute of Industrial Technology, Chinese Academy of Science
Systematic ARPES studies on the electronic structures of doped $BaZn_2As_2$ single crystals: a new 122 family of dilute ferromagnetic semiconductor

16BU006 Kouichi Takase : College of Science and Technology, Nihon University
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16BU007 Takashi Tokushima : RIKEN SPring-8 Center
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16BU008 Hoesch Moritz : Diamond Light Source
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16BU009 M. Zahid Hasan : Princeton University
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16BU010 Sokolov Nikolai Semenovich : Ioffe Physical-Technical Institute of the Russian Academy of Sciences
XMCD study of magnetic proximity effect in $Co(Ni)/Y_3Fe_5O_{12}$ heterostructures

16BU011 Monney Claude : University of Zurich
Resolving the complex low-energy electronic structure of the quasi-one-dimensional material $NbSe_3$

16BU012 Yitao Cui : Institute for Solid State Physics, University of Tokyo
The structure of Pt single atom/nano paricles loaded on single graphene supported on Si substrate studied by STM