茨城大学
Ibaraki University

International Review of the Institute of Quantum Beam Science, Ibaraki University

February 2025

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Preface

The Graduate School of Science and Engineering at Ibaraki University, a National University Corporation located in Ibaraki Prefecture, Japan, offers both master's and doctoral programs. Its history dates back to 1995 when the Graduate School of Engineering and the Graduate School of Science were merged and upgraded. In 2004, a new major in Applied Beam Science was introduced to train engineers and researchers in quantum beam science.

In 2016, the master's courses in Applied Beam Science, Materials & Molecular Science, and part of the master's course in science were reorganized. The school now comprises eight master's and six doctoral majors, covering a wide range of science and engineering fields. The full-time academic staff of the Graduate School of Science and Engineering, from two faculties—Faculty of Basic Natural Science, headquartered at the Mito campus, and Faculty of Applied Science and Engineering, headquartered at the Hitachi campus—are dedicated to providing outstanding activities to accomplish the following missions:

(1) Educating talented individuals who can systematically apply scientific knowledge to evaluate and solve problems, and who can acquire practical expertise and deep insights into nature and human society.
(2) Contributing to sustainable societal development in harmony with the natural environment through the promotion of academic studies on an international level. Based on these missions, the school admits students who are highly motivated, inquisitive, creative, and capable of executing plans. These students will conduct advanced research from international and interdisciplinary perspectives and contribute to the development of industrial, cultural, and scholarly activities by applying their academic achievements to real-world problems.

The Institute of Quantum Beam Science (IQBS) at the Graduate School of Science and Engineering, Ibaraki University, was established in April 2016. Quantum Beams are defined as electromagnetic waves (including X-rays, gamma rays, and lasers) and particle beams (including neutrons, electrons, and protons). The IQBS is recognized as a unique institute for conducting research and engineering in Quantum Beam Science in Japan.

Master's students at the IQBS can choose their major from six programs, while doctoral

students can choose from four courses. Each program and course is operated in strong collaboration with the Japan Proton Accelerator Complex (J-PARC), Japan Atomic Energy Agency, National Institute of Advanced Industrial Science and Technology, National Institutes for Quantum Science and Technology (QST), the High Energy Accelerator Research Organization (KEK), the Japan Synchrotron Radiation Research Institute, the Institute for Environmental Science and Technology, CROSS, and several companies around Ibaraki University.

Students at the IQBS are expected to acquire the skills to become advanced engineers and researchers in the fields of life science, chemistry, physics, and materials science, contributing to the development and establishment of a sustainable society.

In March 2021, Ibaraki University formulated its vision for 2030, titled "Ibadai Vision 2030," which outlines the university's aspirations through four visions and twelve actions. This vision explicitly highlights Quantum Beam Science, alongside Environmental Science, as a distinctive research field. IQBS will lead education and research not only at Ibaraki University but also in collaboration with local stakeholders, neighboring institutions, and global research organizations.

At the beginning of FY2024, the Research and Education Center for Atomic Sciences (RECAS) of Ibaraki University was established as a reorganization of the Frontier Research Center for Applied Atomic Sciences (iFRC) of Ibaraki University. In addition, the Carbon Recycling Energy Research Center (CRERC) at Ibaraki University was established in 2023. Ibaraki University aims to become a global center for comprehensive climate change science, promoting climate-resilient development. IQBS collaborates with RECAS and CRERC to conduct research on climate change mitigation measures.

Steering Committee of IQBS

- Prof. Seiji Mori (Director of IQBS, Faculty of Basic Natural Science)
- Prof. Ichiro Tanaka (Deputy Director of IQBS, Faculty of Applied Science and Engineering)
- Prof. Tsuyoshi Nishi (Head of Curriculum Committee, Faculty of Applied Science and Engineering)
- Prof. Yuji Torikai (Environmental Radiation Science Course, Faculty of Basic Natural Science)

- Prof. Keitaro Kuwahara (Quantum Science and Engineering of Materials Course, Faculty of Basic Natural Science)
- Prof. Teruyuki Ikeda (Quantum Science and Engineering of Materials Course, Faculty of Applied Science and Engineering)
- Prof. Hiroyuki Nishikawa (Chemistry and Life Science Course, Faculty of Basic Natural Science)
- Prof. Masaki Unno (Chemistry and Life Science Course, Faculty of Applied Science and Engineering)
- Prof. Kazuaki Iwasa (Beam Line Science Course, Faculty of Applied Science and Engineering, and Director, Research and Education Center for Atomic Sciences)

1 Education in the Institute of Quantum Beam Science, Graduate School of Science and Engineering

1.1 Diploma and curriculum policies of the master courses at the GSSE-IU

The diploma and curriculum policies of the master courses at the Graduate School of Science and Engineering, Ibaraki University are as follows:

Diploma Policy

In the Master's Program at the Graduate School of Science and Engineering, Ibaraki University, in addition to the knowledge, abilities, and attitudes acquired as a graduate of the Master's Program, the following abilities and attitudes are required to be awarded a Master of Science or Master of Engineering degree:

1. **Research Ability in Specialized Fields**: The ability to conduct research based on the knowledge and skills required in the specialized field of science and technology.
2. **Problem-Solving Ability in Specialized Fields**: The ability to identify and solve problems in the specialized field of science and technology.
3. **Comprehensive Understanding of Human Society**: The ability to understand the position of science and technology within human society.
4. **Explanation and Information Dissemination Ability**: The ability to understand the position of the research and technological development within human society, explain it to non-specialists, and provide information to the general public.
5. **Attitude to Contribute to Regional Revitalization**: The attitude to engage in regional revitalization by utilizing the problem-solving abilities acquired through involvement in specialized research and technological development.

Curriculum Policy

To meet the educational goals stated in the Diploma Policy, we ensure the substantiality of credits and conduct rigorous academic evaluations based on the achievement goals and clear grading criteria of each course. We also conduct rigorous dissertation reviews and final examination evaluations based on clear dissertation review criteria and the final examination implementation guidelines. We strive to visualize learning outcomes and promote continuous educational improvement through mutual cooperation and inspection by faculty and students. The policy for organizing the educational curriculum is as follows:

1. **Research Execution Ability in Specialized Fields**: To cultivate the ability to conduct research based on the knowledge and skills required in the specialized academic field, we offer specialized courses centered on seminars and practical training, and provide systematic research guidance under a multiple-supervisor system.
2. **Problem-Solving Ability in Specialized Fields**: To cultivate the ability to understand the position of the specialized field within the overall context of science and technology and to identify and solve problems, we offer relevant courses.
3. **Comprehensive Understanding of Human Society**: By making the completion of common graduate courses that include elements of the humanities and social sciences a graduation requirement, we cultivate the ability to view their specialized science and technology from multiple perspectives.
4. **Explanation and Information Dissemination Ability**: By making the completion of common graduate courses that include elements of the humanities and social sciences a graduation requirement, we cultivate the ability to understand the position of their research results within human society and explain them to non-specialists.
5. **Attitude to Contribute to Regional Revitalization:** By collaborating with nearby advanced scientific and technological research institutions, companies, and local governments such as Ibaraki Prefecture, we cultivate the attitude to engage in regional revitalization.

1.2 Master Programs of IQBS (master courses from 2022-)

IQBS offers six master programs as follows.

Environmental Radiation Science Program (ERSP)
Through advanced education and research on the environmental dynamics of radioactive nuclides and the biological effects of radiation, we aim to cultivate researchers, engineers, and educators who can contribute to radiation safety management and the sustainable maintenance of the Earth's environment.

Materials Science Program (MSP)
In the field of materials science and cutting-edge quantum beam science, students will acquire advanced expertise to conduct material evaluation and development tailored to societal needs.

Forefront Physics Program (FPP)
We strive to train researchers, engineers, and educators who excel in various fields of natural science, technology, industry, and education, possessing advanced knowledge and research skills in physics.

Frontier Materials Chemistry Program (FMCP)
Our comprehensive education and research in chemistry, with quantum beam science as a horizontal axis, aims to foster individuals who can create new substances and contribute to society.

Biomolecular Science Program (BSP)
Students will study various fields of biomolecular science and related quantum radiation measurements, developing advanced expertise to evaluate the structure and function of biomolecules and their applications, thereby creating a societal impact.

Beam Line Science Program (BLSP)
Students gain professional expertise in quantum beam science, including neutrons, synchrotron radiation, and muons. They will acquire advanced specialized knowledge and skills in the control, measurement, and application of quantum beams, contributing to technological development and the functional evaluation of materials to meet societal demands.

1.3 Courses (master courses in 2016-2021 and PhD courses in 2016-)

Environmental Radiation Science Course (ERSC)
The main subjects of the ERSC include molecular and cell biological studies on radiation biology, analysis of the environmental impact of radioactive species, and computer simulation analysis of biological radiation. ERSC students primarily study radiation biology, the molecular mechanisms of radio-adaptive responses and radiation mutagenesis, and environmental radiation sciences.

Quantum Science and Engineering of Materials Course (QSEMC)
The QSEMC encompasses theoretical physics, experimental solid-state physics, and materials science and engineering. Each subcategory provides its own unique focus based on physical and physicochemical approaches to subjects involving elementary particles, strongly correlated electron systems, metal alloys, functional materials, and composite materials.

Chemistry and Life Science Course (CLSC)
The CLSC covers analytical chemistry, polymer chemistry, organic/inorganic chemistry, catalysis, material chemistry, functional molecular sciences, theoretical and computational chemistry, biochemistry, structural biology, and bioinformatics.

Beam Line Science Course (BLSC)
The BLSC is a newly founded course characterized by the development and utilization of quantum beams involving neutrons, muons, and synchrotron radiation. Several unique experimental laboratory materials in this course are operated at J-PARC (Japan Proton Accelerator Research Complex in Tokai, Ibaraki), in collaboration with KEK and JAEA.

1.4 Graduate students of IQBS

Number of Graduate students involving both of Master and Doctoral programs are listed in below:

	Master Course							PhD Course				
	ERSP	MSP	FPP	FMCP	BSP	BLSP	TOTAL(Female)[international}	ERSC	QSMEC	CLSC	BLSC	TOTAL (Female) [international]
2022	8	35	13	24	17	12	109(31)[3]	1	2	3	2	8(0)
2023	11	28	13	28	17	9	106 (21)[1]	2	6	2	1	11(0)[1]
2024	13	41	14	21	25	15	129 (28)[2]	3	4	5	1	13(2)[1]

1.5 Status for the Education in Master Course Program (2023 FY-)

Graduate students of Master Course must be received the credit after the score evaluation of each lecture. One credit corresponds to 45 hours of study, including both classes and self-study. The proportion of class time within these 45 hours varies depending on the nature of the subject. The 1 credit corresponds to 6.5 sessions per quarter (15 hours) for class hours and 13 sessions per quarter (30 hours) for laboratory and practical training courses. Note that regular exams are not included in the number of class sessions. Graduate students have to be received 30 credits for their full-requirement of graduation of master program, and the students have to prepare the thesis or instead until 5th February for their 2nd year. From 2022 FY, four courses for the master program are reorganized to six programs to be more flexible for students to choose subjects. The curriculum is structured with a focus on quantum beam sciences. We have designated "Introduction to J-PARC Accelerators" and "Radiation Handling Regulations" as compulsory courses. Additionally, there is 1 credit for compulsory electives, which include "Laboratory of Radiation Dosimetry," "Laboratory of J-PARC Neutron Beam," and others.

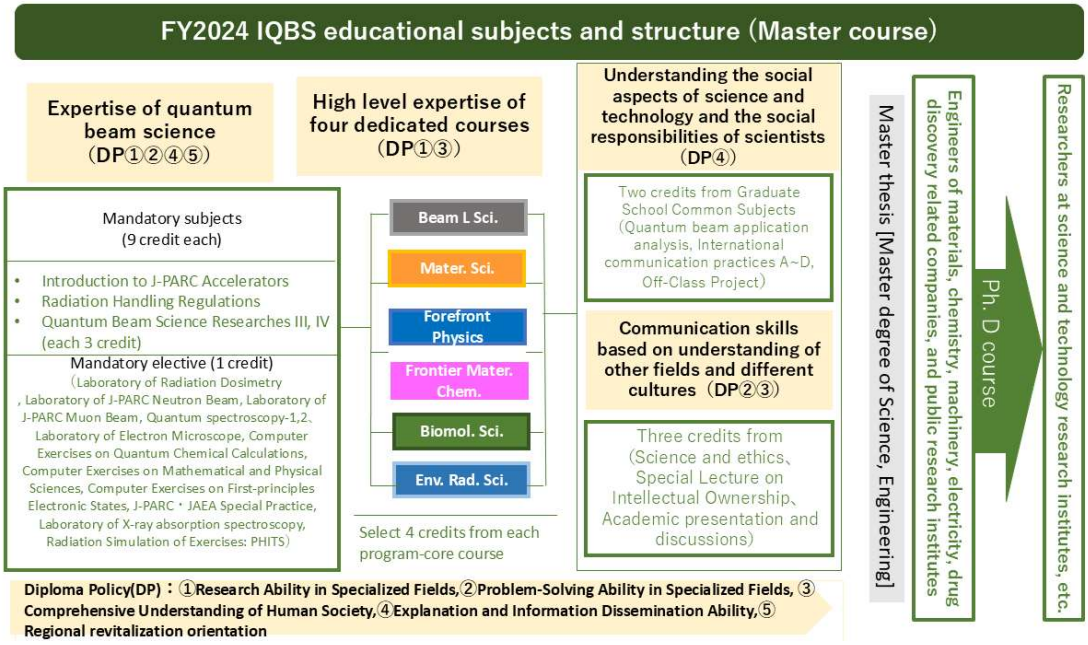
Course	Number of Classes	Class Hours	Preparation and Review Hours	Credits
Lecture Courses	6.5 sessions per semester or quarter	15 hours	30 hours	1 credit
Laboratory and Practical Training		30 hours	15 hours	1 credit

REQUIRED CREDITS FOR GRADUATION IN 2023 FY- (Master Course)

	Mandatory	Semi-Mandatory Subject (Elective)					
		Shared Descriptions through GS of IU	Shared Descriptions through GSSE-IU	Program Core	Course	Elective	Total
Required Credit	9	2	3	4	10	2	30

Shared descriptions through the Graduate School (GS) of IU refer to common subjects, including "Academic Presentation," "Introduction to International Communication A (or B)," "Global Environmental Systems I, II," "Sustainable Society Systems I, II," "Academic Information Literacy," "Fundamentals of Human Systems I," "Advanced Intellectual Property," and others. These subjects encompass ”English” and "Social Understanding," with some courses taught by the Faculty of Humanities and Social Sciences.

The master program structure of IQBS is shown in the bottom Figure.



1.6 Evaluation of Classes for the Master Course Program

In FY2024, out of a total of 137 IQBS classes, 31 were evaluated by examination, while the remaining classes were assessed through reports or oral presentations.

1.7 Challenges in Education

Education in Quantum Beam Science presents some complexities due to the diverse backgrounds of students. Therefore, several tutorials and introductory lectures should be set up. Many students find the biology, physics, and chemistry backgrounds related to Quantum Beam Science challenging to understand. Practical laboratory work at J-PARC, PF, and other facilities is very helpful for empirically understanding the physical and chemical background rather than just studying through texts and lecture classes. IQBS, located near J-PARC and PF, facilitates strong cooperative education in Quantum Beam Science with KEK and JAEA, enabling students to gain valuable hands-on experience in real Quantum Beam Science. For this purpose, cross-cutting lecture classes and laboratory work are strongly recommended for graduate students.

Experiences in an atmosphere of international collaboration are highly effective and exciting for students and early-career researchers. A program is provided to encourage student participation in international collaborations. To further support graduate students in studying in an international environment, they will be sent to various institutes and universities.

Additionally, graduate students are strongly encouraged to present in English at international conferences abroad. Support for participation in international conferences is provided as part of the Ibaraki University Graduate Student International Conference Challenge Project (International Conference Presentation Support). This support comes from Ibaraki University and alumni organizations such as the Ibaraki University Faculty of Science Alumni Association (Mito area) and the Taga Engineering Association (Hitachi area), which are composed of graduates from the Faculty of Science and the Graduate School of Science and Engineering.

Recently, special consideration has been placed on providing equal opportunities for professional development for both women and men, in line with the Diversity and Equality Act of Ibaraki University. The "Ibaraki University Respecting Diverse Sexual Orientations and Gender Identities Basic Principles, Basic Policies and Guidelines " were established in December 2022. Ibaraki University has established the "Women Empowerment Support System" to recognize female researchers who have demonstrated excellence in education, research, and social contribution. This system aims to support their further development by providing research grants to enhance their research capabilities and leadership skills, promoting their future activities both within and outside the university.
To strongly encourage female and young researchers to find employment and continue working in science and engineering at Quantum Beam relevant institutes and industries, efforts will be made to invite female researchers to the International Symposium of Quantum Beam Science at Ibaraki University.

The Faculty of Engineering at Ibaraki University (Hitachi campus) has been selected for the FY2023 'Support Program for Career Choices in Science for Female Junior and Senior High School Students' by the Japan Science and Technology Agency (JST). Under the project titled 'Pride and Joy of Working as an Engineer in Northern Ibaraki - Nurturing Women Who Utilize Engineering for Themselves, Others, and the Community,' we plan to conduct activities such as manufacturing experience classes, laboratory internships, and interactions with female engineers from local companies for female junior and senior high school students in Hitachi and Mito cities.

1.8 Talent Management and Skill Development

Talent management and skill development in IQBS means identifying and developing scientific and engineering talent by providing education based on practical works at nearby institutes like J-PARC, JAEA, QST, and PF with a stimulating research environment and by offering personally benefit research program.

1.9 Mandatory Course Works for the requirement of the master program of IQBS (Total 9 credit)

Mandatory Subjects

Introduction to J-PARC Accelerators (1 credit)
Radiation Handling Regulations (1 credit)
Quantum Beam Science Research III~IV (3 credit each) *Research related works*

Mandatory elective (1 credit)

The mark (*) highlights the Practical Works in Laboratory. Practical work in the laboratory is expected to induce and promote students clearer and deeper understanding of each subject.

*Laboratory of Radiation Dosimetry
*Laboratory of J-PARC Neutron Beam
*Laboratory of J-PARC Muon Beam spectroscopy
*Laboratory of Electron Microscope
*Computer Exercises on Quantum Chemical Calculations
*Computer Exercises on Mathematical and Physical Sciences
*Computer Exercises on First-principles Electronic States
*J-PARC・JAEA Special Practice
*Laboratory of X-ray Absorption Spectroscopy
*Radiation Simulation Exercises: PHITS

Optional Course Works/Research Activity outside of university is also encouraged.
Off-campus Long Term Internship

1.10 Program Core Lectures of the Master Program
The program core lectures of each program are as follows:

Molecular Radiation Biology	ERSP
Radiation Management	ERSP
Genome Life Sciences	ERSP
Applied Cell Biology	ERSP
Simulation Study of Environmental Dynamics	ERSP
*Quantum Biological Chemistry	ERSP
Radiation Biomolecular Science	ERSP
*Quantum Biological Chemistry	BSP
*Advanced Biopolymer Chemistry	BSP
Advanced Bioinformatics	BSP
Advanced Metalloprotein Science	BSP
Biofunctional Chemistry	BSP
Quantum Computational Chemistry	BSP
*Diffraction Crystallography: Structural Biology	BSP
Advanced Chemical Engineering	FMCP
Advanced Polymer Chemistry	FMCP
Functional Molecular Science	FMCP
*Advanced Biopolymer Chemistry	FMCP
Advanced Inorganic Chemistry	FMCP
Quantum Beam Spectroscopic Analysis	FMCP
Diffraction Crystallography:Chemistry	FMCP
Elementary Particle Theory I	FPP
Quantum Field Theory I	FPP
Condensed Matter Physics I	FPP
Physics of Magnetism	FPP
Statistical Physics I	FPP
Quantum Beam Spectroscopy I	FPP
*Introduction to Muon Technology	FPP
Material Science I	MSP
Material Science II	MSP
Advanced Surface Engineering I	MSP
Advanced Surface Engineering II	MSP

Materials Physical Chemistry I	MSP
Materials Physical Chemistry II	MSP
*Diffraction Crystallography: Exercises of Crystal Structure Analysis	MSP
*Diffraction Crystallography: Structural Biology	BLSP
Neutron and X-ray Spectroscopy: Material Dynamics	BLSP
*Diffraction Crystallography: Exercises of Crystal Structure Analysis	BLSP
Overview of Quantum Beam Transport Technology	BLSP
Quantum Mechanics for Quantum Beam Science	BLSP
Diffraction Crystallography:Chemistry	BLSP
*Introduction to Muon Technology	BLSP

Representative Elective Courses as follows:
Introduction to Environmental Radioactivity Measurement
Laboratory of Bioimaging
Quantum Beam Science I
X-ray Absorption Spectroscopy
*Laboratory of X-ray Absorption Spectroscopy
*J-PARC Neutron & Muon School Special exercises

Quantum Beam Science Research I~II (3 credit each)
Off-Campus Long-Term Internship

1.11 Lectures and Laboratory Works in Collaboration with the Other Institutes for the Master Program

A 'Cross-appointment Professor' refers to a professor who holds dual positions at Ibaraki University and an external institute or industry. As of 2020, five professors have been invited as Cross-appointment Professors from KEK, JAEA, and QST. In addition to cross-appointment faculty, Ibaraki University has also invited part-time lecturers from partner institutes and companies. The following lecturers were given by cross-appointment faculty and part-time lecturers from the partner institutes.

Radiation Engineering (Radiation Protection)	JAEA
Radiation Engineering (Radiation Dosimetry)	JAEA
Radiation and Biomolecular Sciences	QST
Molecular Carcinogenesis	QST
Environmental Radioactivity and Radiation	QST
Nuclear Physics	JAEA
Advanced Radiation Chemistry	JAEA
Advanced Positron Science	JAEA
Fundamental Semiconductor Materials I&II	HITACHI High Technologies
Fundamentals of Functional Materials I&II	HITACHI Laboratories
Fundamentals of Inorganic Materials I&II	HITACHI Laboratories
Chemistry of Nuclear Energy	JAEA
Quantum Beam Chemistry	JAEA
Advanced Radioactive Isotopes	JAEA
Fundamental Low Temperature Science and Technology	JAEA
Structural Analysis of Hydrogenous and Non-Crystalline Materials	KEK
Neutron Generation and Its Application: Accelerator-driven Compact Neutron Sources	RIKEN

Seminar/Workshop on J-PARC and JAEA	JAEA
Introduction Course on Muon Engineering	KEK/J-PARC
Nuclear and Radiochemistry	JAEA
Advanced Nuclear Science and Engineering	JAEA
Design and Management of Radiation Facility	KEK/J-PARC
X-ray Absorption Spectroscopy	KEK/PF
Neutron Material Science	KEK/J-PARC
Electron Microscopy	HITACHI High-tech
Cutting-Edge Synchrotron Radiation Science	JASRI
Quantum Computational Chemistry	Qunasys Inc.
Special Lecture on Quantum Beam Science	AIST

Practical Course Works	
Laboratory of J-PARC Neutron Beam	
J-PARC Neutron Beam Exercises	
Laboratory of X-ray Absorption Spectroscopy at KEK-PF	
Practical Training of Synchrotron Beam Experiment at SPring-8	JASRI
Radiation Simulation Exercises : PHITS	JAEA
J-PARC Neutron and Muon School Special Exercises at J-PARC MLF and JRR-3	

The special exercises of the J-PARC Neutron and Muon School are part of the annual "Neutron and Muon School," which aims to teach participants about the characteristics of neutrons and muons and their experimental methods through lectures by leading researchers from around the world. The Institute of Quantum Beam Science (IQBS) at Ibaraki University co-sponsors the event, with several faculty members serving on the organizing committee.

1.12 PhD (Doctoral) Program

The following is a feature of PhD program of IQBS. Under a consistent educational curriculum connected from the Master's Program in Quantum Beam Science, we cultivate individuals with advanced specialized knowledge and skills in quantum beam science in collaboration with leading scientific and technological research institutions located nearby, such as JAEA, KEK, and QST, including the Tokai area in Ibaraki Prefecture. These individuals will possess the expertise required for each course's desired human resource profile.

Ph.D. students of the Graduate School of Science and Engineering must satisfy the following conditions:

- Successfully complete 14 credits for specialization and dissertation coursework.
- One original research paper, primarily based on research conducted during the enrollment period, must be published or accepted for publication in a peer-reviewed academic journal, either as a sole author, first author, or corresponding author.
- Students demonstrating superior progress (such as publishing multiple papers or a journal paper with an impact factor) may be allowed to shorten their academic term.

The diploma and curriculum policies of the Doctoral courses at the Graduate School of Science and Engineering are as follows:

Educational Objectives of the Doctoral Program at the Graduate School of Science and Engineering, Ibaraki University

The educational objectives of the Doctoral Program at the Graduate School of Science and Engineering, Ibaraki University, are to cultivate individuals who possess specialized knowledge and skills, have universal problem-solving abilities, understand the position of their specialized science and technology within human society, and can explain this to non-specialists. These individuals are expected to be active in a wide range of societal fields. Therefore, the University of Ibaraki awards the doctoral degree to those who possess the following abilities:

1. **Research Execution Ability in Specialized Fields:** The ability to independently conduct advanced research based on the advanced knowledge and skills required in each specialized field.
2. **Universal Problem-Solving Ability** The ability to independently identify and solve problems not only in their specialized field but also in related fields**.**
3. **Comprehensive Understanding of Human Society:** The ability to understand the position of their specialized science and technology within human society, particularly in management, environmental management, and organizational operations.
4. **Explanation and Information Dissemination Ability:** The ability to explain research results to non-specialists in relation to their position within human society and to disseminate these results widely both domestically and internationally.
5. **Qualities to Contribute to Regional Revitalization:** The qualities to utilize their expertise and engage in regional revitalization efforts considering social conditions.

Policy for Curriculum Organization to Meet the Educational Goals Stated in the Degree Awarding Policy (Diploma Policy)

1. **Research Execution Ability in Specialized Fields:** To cultivate the ability to independently conduct advanced research based on the advanced knowledge and skills required in each specialized field, we offer advanced specialized courses centered on seminars and practical training. Additionally, we provide systematic doctoral dissertation research guidance under a multiple-supervisor system.
2. **Universal Problem-Solving Ability:** Through discussions with faculty members outside their specialized academic fields, students will understand the position of their specialized field within the overall context of science and technology. To develop the ability to independently identify and solve problems not only in their specialized field but also in related fields, we offer seminar courses as a graduation requirement.
3. **Comprehensive Understanding of Human Society:** By making the completion of courses in humanities and social sciences, such as management, environment, and organizational theory, a graduation requirement, we cultivate the ability to view their specialized science and technology from multiple perspectives.
4. **Explanation and Information Dissemination Ability:** By making the completion of courses in humanities and social sciences, such as management, environment, and organizational theory, a graduation requirement, we cultivate the ability to understand the position of their research results within human society and explain them to non-specialists. Additionally, by making special seminars a required course, we develop the ability to present research results in international academic journals and disseminate them widely both domestically and internationally.
5. **Qualities to Contribute to Regional Revitalization:** By enhancing the curriculum through collaboration with nearby advanced scientific and technological research institutions and local governments such as Ibaraki Prefecture, we cultivate the qualities to utilize their expertise and engage in regional revitalization efforts considering social conditions.
6. **Ensuring the Quality of Education:** We ensure the substantiality of credits and conduct rigorous academic evaluations based on the achievement goals and clear grading criteria of each course. We also conduct rigorous dissertation reviews and final examination evaluations based on clear dissertation review criteria and the handling guidelines for doctoral degree applications at the Graduate School of Science and Engineering, University

of Ibaraki. We strive to visualize learning outcomes and promote continuous educational improvement through mutual cooperation and inspection by faculty and students.

Challenges for PhD Programs

According to the 'Science and Technology Indicators 2021' by the National Institute of Science and Technology Policy of the Ministry of Education, Culture, Sports, Science and Technology, Japan significantly lags behind the United States, the United Kingdom, Germany, and South Korea in the number of PhD holders per million people. In 2018, Japan had 120 PhD holders, while the United States had 281, Germany had 336, the United Kingdom had 375, and South Korea had 284. The low number of students advancing to doctoral programs nationwide is a challenge that needs to be addressed.

1.13 Nuclear Human Resource Development Project Subsidy (Nuclear Regulatory Human Resource Development Project)

Ibaraki University was selected for the Nuclear Regulatory Human Resource Development Project by the Nuclear Regulation Authority in 2023-2027. The title of the project is “Nuclear Regulatory Human Resource Development Based on Proficiency in Radiation and Tritium Knowledge”.

Currently, the number of radiation experts, especially those specializing in tritium, is very limited in Japan. There are approximately 10 experts in the field of nuclear fusion, a few in radiation environmental science, and a few in radiation biology. The complexity of the tritium-treated water issue from the Fukushima Daiichi Nuclear Power Plant accident is believed to be due to the scarcity of tritium experts. Furthermore, as the decision to construct a prototype nuclear fusion reactor is expected in the next decade, the number of tritium experts is decreasing.

In light of this, it is necessary to secure a certain number of personnel capable of handling tritium.

In addition to acquiring sufficient knowledge of radiation and radioactive substances, which forms the basis for human resource development, we also learn about nuclear energy and tritium.

Through this project and the “Radiation and Nuclear Program,” which will be implemented at GSSE-IU in April 2025, we aim to increase the number of successful candidates for the national qualification of Radiation Protection Supervisor from faculty/staff and students (7 people qualified in 2024). Note that Ibaraki University is also participating in the Strategic Nuclear Education Model Project (University Network ATOM), initiated in 2012 under the leadership of the Tokyo Institute of Technology as part of the Global Nuclear Human Resource Development Network.

Education Related to Radiation (Ibaraki University, JAEA, Institute for Environmental Science and Technology)

- Radiation Education (Fundamentals of Radiation, Biological Effects of Radiation, Environmental Radiation, etc.)
- Lectures for obtaining the qualification of First-Class Radiation Protection Supervisor (currently being implemented for this fiscal year)
- Participation in various courses offered by JAEA (Human Resource Development Center)
    - Basic Radiation Course
    - Radiation Safety Management Course
    - Radiation Protection Course
    - First-Class Radiation Protection Supervisor Training, PHITS Training Course, Radiation Measurement Practicals, etc.

Education Related to Nuclear Energy (Ibaraki University, JAEA)

- Education on the basics of nuclear energy.
- Practical training with high-temperature gas reactors.
- Participation in various courses offered by JAEA (Human Resource Development Center)
    - Introduction to Nuclear and Radiation Course
    - General Nuclear Reactor Training Course, etc.

Education Related to Tritium (Ibaraki University, Institute for Environmental Science and Technology)

- Basics of Tritium, Tritium Analysis Methods, Fusion and Tritium, the Fukushima Daiichi Nuclear Power Plant Accident and Tritium Treated Water, etc.

1.14 Goals and Planning

Education in Quantum Beam Science presents complexities for students from diverse backgrounds. Practical laboratory work at J-PARC, PF, and other facilities (excluding the professor's own laboratory) is included in the curriculum to empirically enhance understanding of physical and chemical principles. This strong empirical education in Quantum Beam Science is achieved through robust collaboration with KEK and JAEA.

Student evaluations through examinations in master course will be conducted in 40% of the 137 classes at IQBS. Despite the encouragement of online lecture courses, especially for core program lectures (excluding laboratory courses), computer-based exams may present challenges due to students being spread across three campuses.

Early-career researchers and students will be supported to train at OPAL/ANSTO to gain international research experience. These experiences in an international collaborative environment are highly effective and exciting for students. An encouragement program for international collaboration will be provided. To facilitate this program, professors are asked to apply for research proposals at international Quantum Beam Facilities, allowing graduate students to join these collaborations through their mentors' activities. Professors are also strongly encouraged to collaborate internationally in Quantum Beam Science. In addition to visits to OPAL/ANSTO by eight students and four faculty members, three students visited TRIUMF in Canada, the Paul Scherrer Institute (PSI) in Switzerland, and the Rutherford Appleton Laboratory in the UK to conduct quantum beam experiments from 2022 to 2024.

Students and early-career researchers are strongly encouraged to attend international conferences abroad. The international symposium on Quantum Beam Science at Ibaraki University will allow students to present their work and engage in academic exchanges with scientists. We also coordinate the joint international symposium with the J-PARC Center and KEK.

Advanced education and research in science and engineering at IQBS will be promoted through the introduction of sophisticated instruments and the combinatorial use of Quantum Beams at J-PARC, Photon Factory, Spring-8 (JASRI), JAEA, QST, and the Institute for Environmental Science and Technology.

In Japan, since the Fukushima Daiichi Nuclear Power Plant accident in 2011, there has been a shortage of young talent working in the nuclear industry. Under the common challenges of carbon neutrality and energy security, there is a social demand for a return to nuclear power, making developing nuclear and nuclear regulatory personnel an urgent task. In line with the university's policy of building comprehensive climate change science, RECAS was established to create new nuclear science education that contributes to constructing a carbon-neutral, sustainable society. As a result of the efforts of the Graduate School of Science and Engineering at Ibaraki University and RECAS, there is a need to expand the supply of personnel to nuclear-related companies, government agencies, local governments, and research institutions.

1.15 Expected achievements

All students will have knowledge of the Law and Act of Radiation Protection and Nuclear Safety

and J-PARC accelerator. We aim to produce successful candidates from Ibaraki University for the national qualification of Radiation Protection Supervisor, one of the state qualifications based on Japanese laws regulating radioactive isotopes and other related substances.

A remarkable number of students are expected to join the International Collaboration after their short visits to MLZ/FRM-II, OPAL/ANSTO, and TRIUMF.

Female and early career researchers will be encouraged to be scientists and engineers in Quantum Beam Science through the international symposium of Quantum Beam Science at Ibaraki University based on the diversity and equality program.

2. Collaborative Education of IQBS with Domestic Partner Institutes

2.1 Education and Research Partners of Nearby National Institutes

The Institute of Quantum Beam Science (IQBS) is characterized as a quite unique institute to study Quantum Beam Science research and engineering through the strong collaboration with the nearby National Institutes regarding Quantum Beam Science. The IQBS students study many of quantum beam sciences through the collaboration with Japan Proton Accelerator Complex (J-PARC), Japan Atomic Energy Agency (JAEA), National Institute of Advanced Industrial Science and Technology (AIST), National Institute of Radiological Science, National Institutes for Quantum Science and Technology (NIRS/QST), High Energy Accelerator Research Organization (KEK), and Japan Synchrotron Radiation Research Institute (JASRI). Many temporal lecturers have been invited from those national institutes to give up-to-date science and technology of quantum beams. Several students study at those national institutes as graduate students under the supervision of invited Professors thorough the co-supervision with the Professors of Ibaraki University.

The institutes except for JASRI are all in the Ibaraki Prefecture. KEK is located in Tsukuba and within 40 km from Ibaraki University. JAEA and J-PARC are closest national institutes in Tokai and are of Ibaraki Prefecture by the distance of 12 km from Ibaraki University main campus. In 2017, Ibaraki University Tokai satellite campus has been set in Tokai.

Ibaraki University has started to invite a “Cross-Appointment” Professor to the Institute of Quantum Beam Science from KEK in 2016 and now two professors from KEK. Now, one “Cross-Appointment” Professor has been invited from JAEA since 2017 and one from QST in 2019. The IQBS has five Cross-Appointment Professors from nearby National Institutes now. The IQBS also has adjunct Professors from JAEA, QST, JASRI, and HITACHI Laboratories.

2.1.1 JAEA

Ibaraki University, a national university corporation (hereinafter referred to as "Ibaraki University"), and the Japan Atomic Energy Agency, an independent administrative institution (hereinafter referred to as "JAEA"), signed a collaboration agreement on March 18, 2008.
In 2022, through the reorganization of the master's program, "Laboratory of Radiation Dosimetry" and "Exercises in Simulation of Space Radiation: PHITS" became mandatory elective courses in IQBS. We continue to collaborate with the Nuclear Human Resource Development Center at JAEA, in connection with the Nuclear Human Resource Development Project Subsidy from 2023 to 2027 fiscal year. JAEA provides one cross-appointment professor and seven collaborative graduate school faculty members at IQBS. One IQBS faculty is working as a cross-appointment staff in JAEA.

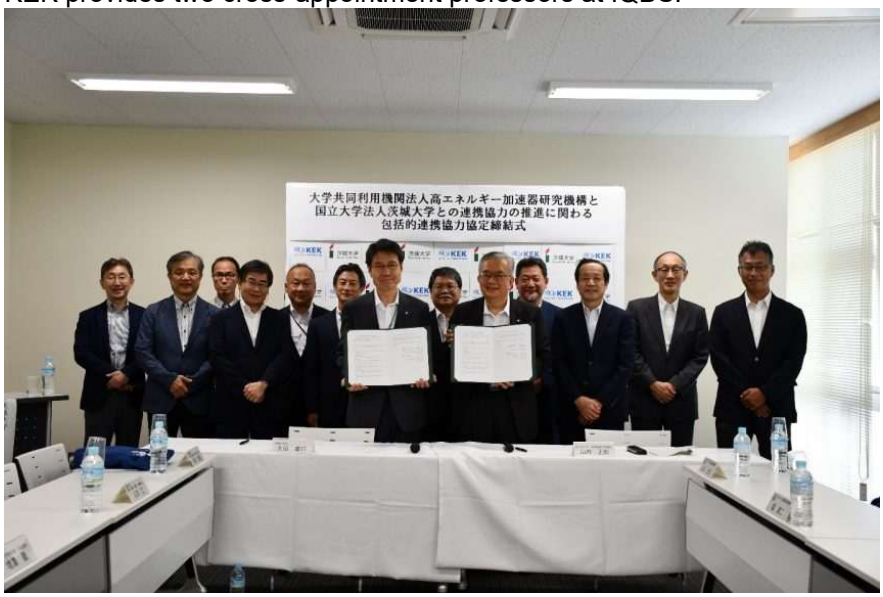
2.1.2 QST

A collaboration agreement with the National Institutes for Quantum Science and Technology’s National Institute of Radiological Sciences was signed in July 2012. QST (Chiba, Takasaki, and Tokai) provides one cross-appointment professor and two collaborative graduate school faculty member at IQBS.
The Quantum Research Workshop, organized by the College of Science, is held every February or March. In the last two years, the subtitles for the 14th workshop (February 11, 2023) and the 15th workshop (March 9, 2024) were “The Intersection of Basic and Clinical Aspects of Cancer Radiation Therapy” and “The Frontline of Research on the Biological Effects of Radiation: Exploring the Intersection with Cancer Radiation Therapy,” respectively. Each year, scientists from QST and other institutions, such as the Central Research Institute of Electric Power Industry, are invited to the workshop.
Based on the agreement for the joint education and research of graduate students, seven master’s course students and three Ph.D. course students stayed at QST (Chiba, Tokai, or Takasaki) for their reseach theses during FY2021--FY2024. Ibaraki University has 53 joint papers with QST between 2020-2024.

2.1.3 KEK

Since signing the collaboration agreement between the Institute of Materials Structure Science of the High Energy Accelerator Research Organization (KEK) and the Frontier Applied Atomic Sciences Research Center in 2015, significant educational initiatives have been undertaken in the IQBS (established in 2016). These include practical training and workshops through the university partnership support projects conducted by KEK, the hosting of "Ibaraki University-KEK Day," the acceptance of Ibaraki University graduate students as KEK special researchers and undergraduates for internships, and the acceptance of KEK students as special research students at our university. This mutual acceptance of students has advanced education and research, and the collaboration with KEK is essential for maintaining cutting-edge education and research in the Quantum Beam Science Department, a distinctive feature of our university.
On July 4, 2022, a signing ceremony for a comprehensive partnership agreement to promote collaboration between Ibaraki University and the High Energy Accelerator Research Organization (KEK), as well as a commemorative symposium, was held at Ibaraki University's Mito campus. Following the signing ceremony, a commemorative symposium was held, featuring lectures by Dr. Naoto Saito, Director of the Institute of Particle and Nuclear Studies at KEK, and Dr. Nobuhiro Kosugi, Director of the Institute of Materials Structure Science at KEK. From Ibaraki University, Associate Professor Hiromi Iinuma of the Quantum Beam Science Department at the Graduate School of Science and Engineering and Executive Director Ashina Kikuchi (Diversity, International, and SDGs) gave lectures.

Ibaraki University and KEK have already been engaged in student and researcher exchanges and joint graduate student education and research. With the signing of this agreement, we will further strengthen our cooperation in research exchanges, joint research, human resource development, and the mutual use of research facilities and equipment.
KEK provides two cross-appointment professors at IQBS.



On January 9th, 2024, we conducted “Ibaraki University-KEK Day” at Mito campus, supported by the International and Inter-institution Network for Accelerator Science to Next Generation (IINAS-NX) of KEK. Between 2020 and 2024, Ibaraki University had 127 joint papers with KEK.

2.1.4 JASRI

A new partnership has been started with the Japan Synchrotron Radiation Research Institute (JASRI), which is public interest incorporated foundation in charge of the operation, maintenance, management, and provision of support for users of the SPring-8 synchrotron radiation facility, in

2019 in Sayo-cho, Hyogo prefecture. Based on the partnership we opened a practical course work, "Practical Training of Synchrotron Beam Experiment at SPring-8," in 2020. More than five graduate students took the class and were trained at SPring-8 in July 2020. We also sent three undergraduate students to SPring-8 to have them participate in the event composed of a facility tour, lectures, and practical works held in SPring-8 in December 2020. Since 2020, graduate students of IQBS visited SPring-8 Summer Schools. JASRI provides four collaborative graduate school faculty members at IQBS. Ibaraki University has 77 joint papers with JASRI between 2020-2024.

2.1.5 CROSS

The Neutron Science Center of the Comprehensive Research Organization for Science and Society (CROSS) at the Tokai office and the Frontier Applied Atomic Science Center (currently RECAS) of Ibaraki University concluded a cooperation agreement on March 31, 2021, aiming to contribute to the development of material science and life science using reactor neutron sources and high-intensity pulsed neutron sources. The agreement stipulates that both institutions will collaborate to promote personnel exchange, education, and training, and the interoperability of research facilities and equipment, as well as to advance joint research aimed at creating new science and technology.

Since 2011, CROSS has been appointed as the “Registered Institution for Facility Use Promotion” for the public-access neutron beam facilities at J-PARC by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). Four IQBS faculty members hold cross-appointments at CROSS to maintain the Ibaraki neutron beamline (iMATERIA) at the J-PARC MLF. Through the cooperation between JAEA, KEK, and CROSS, we collaborate closely with the J-PARC Center. For example, a J-PARC workshop titled "Deuterium Science Entering an Advanced Phase" was held on October 18, 2024, at the Mito campus of Ibaraki University, inviting speakers from Institut Laue–Langevin (ILL), France, ANSTO, Australia, Institute for Science and International Security (ISIS), US, Wuhan University, Asahi Pretec, Gifu Pharmaceutical University, JAEA, KEK, and CROSS.


J-PARC workshop in October 2024

2.1.6 The Institute for Environmental Science and Technology

The Public Foundation Institute for Environmental Science and Technology was established in 1990 at the request of Aomori Prefecture, in conjunction with the siting of the nuclear fuel cycle facility in Rokkasho Village, Aomori Prefecture. Its purpose is to conduct research on the environmental behavior of radioactive substances, dose assessment for humans, and the

biological effects of long-term low-dose exposure, as well as to widely disseminate accurate information about radiation.
In FY 2023, IU jointly implemented the Nuclear Regulatory Agency's "Nuclear Human Resource Development Project Subsidy (Nuclear Regulatory Human Resource Development Project)" with this institute. This collaboration facilitated the exchange of personnel between the institutions, focusing on human resource development. In addition to these efforts, we aim to enhance university-wide research and development and human resource development by concluding a comprehensive agreement signed on July 8, 2024 on the following cooperative matters.

2.1.7 Representative Outreach Activity Through Educational Collaboration

(i) In collaboration with Tokai Village government (Ibaraki Prefecture), J-PARC Center, and Tokyo Metropolitan University, we are undertaking a project to non-destructively inspect the internal structure of the No. 2 Tumulus of the Funazuka Kofun Group in Tokai Village. Utilizing cosmic ray muons, which penetrate matter, we began manufacturing detectors in fiscal year 2023 to measure the cosmic ray muons passing through the tumulus. In fiscal year 2024, we installed the first detector near the tumulus. If there is a cavity (such as a tomb), differences in the transmission rate of the cosmic ray muons will create variations in the image density (similar to an X-ray image). This project is also expected to be a significant achievement for the 70th anniversary of Tokai Village, with high expectations from the village mayor. The research is being led by first-year master's student Masaya Kuzuha. Professor Yutaka Tanaka from the College of Humanities and Social Sciences is also participating, making this one of Ibaraki University's interdisciplinary projects.

Project to See Through Tumuli with Cosmic Ray Muons!!

The results of the above interdisciplinary project were presented under the title "Development of a Detector for Internal Imaging of the No. 2 Tumulus of the Funazuka Kofun Group Using Cosmic Ray Muons" at the Spring Meeting of the Physical Society of Japan in March 2024 by Masaya Kuzuha.

(ii) On Tuesday, October 25, 2022, the Ministry of Economy, Trade and Industry hosted the "1st ALPS Treated Water Monitoring Symposium: Communicating the Safety and Security of Marine

Products" at the Iwaki Washington Hotel in Iwaki City, Fukushima Prefecture. At this symposium, government officials, Tokyo Electric Power Company (TEPCO), and experts provided explanations on the basic knowledge and safety of tritium contained in ALPS treated water, which has been decided to be discharged into the ocean, as well as the monitoring efforts for seawater and marine products before and after the discharge. Professor Yuji Torikai from the Graduate School of Science and Engineering at Ibaraki University, one of the few tritium experts in the world, gave a lecture titled "Basic Knowledge and Safety of Tritium.“

2.2 Educational Collaboration with Private Companies

Hitachi is one of the major cities in Ibaraki Prefecture, Japan. The famous company, HITACHI was founded at Hitachi city, Ibaraki in 1910. HITACHI had an engineering school in Hitachi city to educate and train young engineers. In 1939, Japanese Government decided to make seven Government directed engineering school. In the same time, Ibaraki Prefecture and HITACHI Ltd. were also planning to make a new engineering school. Finally, the Japanese Government decided to make an engineering school in Hitachi in 1939. The engineering school was changed to College of Engineering of Ibaraki University in 1949 after the World War II. HITACHI Ltd. and Ibaraki University have continued great collaboration with HITACHI Ltd. in their research and education for long time. HITACHI Ltd. and related companies give forty-seven internship programs to the Graduate School of Science and Engineering of Ibaraki University, recently, and many of students of Ibaraki University have been employed to HITACHI group companies.

3. Collaboration with Foreign Partners

3.1 MOU with Korea Atomic Energy Research Institute (KAERI), Korea

In 2017, GSSE-IU and the Korea Atomic Energy Research Institute (KAERI) reached an agreement on an MOU to exchange researchers and students through collaboration. Two professors from KAERI visited IQBS and gave lectures at the 2nd International Symposium of Quantum Beam Science at Ibaraki University in December 2017. KAERI has resumed the utilization of the High-Flux Advanced Neutron Application Reactor, HANARO. On October 21, 2024, KAERI and RECAS/GSSE-IU renewed the MOU.

3.2 MOU with Jülich Centre for Neutron Science, Forschungszentrum Jülich GmbH, Germany

The Jülich Centre for Neutron Science (JCNS), embedded in the Forschungszentrum Jülich GmbH, Germany and GSSE-IU agreed to all concerned to establish a cooperative exchange program between the two facilities through encouragement and facilitating the exchange of academic information, students, researchers, and staffs in 2017. The MOU was signed on 9th February, 2018.

In 2017, three professors involving an early carrier professor and two MSc students of IQBS visited JCNS in Munich to do protein neutron crystallographic experiments with Dr. Andreas Osterman and small-angle neutron scattering measurements of a protein molecule with Prof. Dr. Henrich Frielinghaus. JCNS and GSSE-IU signed the MOU on 9th March, 2023, and continuing research collaborations and inviting researchers as lecturers of ISQBS (2023 and 2024). The small angle neutron scattering study on unfolding of cytochrome c' by Yamaguchi, and Kohzuma with Prof. Dr. Henrich Frielinghaus was published on Biomolecules 2022, 12(1), 95 (DOI: 10.3390/biom12010095). One paper of Professors Masaki Unno, Joutsuka, and Mori with Dr. Andreas Ostermann on neutron crystallography and QM/MM calculations of bilin reductase mutants was published in *J. Biol. Chem.* **2023**, *299*, 102763 (DOI: 10.1016/j.jbc.2022.102763). The small angle neutron scattering study on unfolding of cytochrome c' by Yamaguchi, and Kohzuma with Prof. Dr. Henrich Frielinghaus was published on Biomolecules **2022**, *12*(1), 95 (DOI: 10.3390/biom12010095). Ibaraki University and JCNS have 7 joint publications between 2020 and 2024.

3.3 MOU with TRIUMF, Canada

The GSSE-IU and TRIUMF reached the agreement of all concerned to establish a cooperative exchange program between the two facilities through encouragement and facilitating the exchange of academic information, students, researchers and staffs, and temporarily assigned graduate students in 2017. TRIUMF and GSSE-IU renewed MOU on 18 December, 2022. Prof. Nakano group of IQBS including one master course student conducted measurements in TRIUMF (Oct, 2022 and Sept. 2023), and a joint paper with Prof. Kenji M. Kojima was published (M. Hiraishi et al., Interactions **245**, 104 (2024).). Researchers were invited to ISQBS in 2023 and 2024.

3.4 MOU with Ubon Ratchathani University, Thailand

The Faculty of Science, Ubon Ratchathani University, and GSSE-IU reached an agreement as MOU on 23rd September 2019. IQBS invited two students and Assoc. Prof. Dr. Siriporn Jungsuttiwong, who now served as a dean of the faculty of science, in 2018 using the Sakura Science Plan (*vide infra*). Professor Dr. Siriporn Jungsuttiwong, now Dean of the Faculty of Science, was invited to ISQBS in 2022.

3.5 MOU with Australian Nuclear Science and Technology Organisation (ANSTO), Australia

In 2018, GSSE-IU and ANSTO of Australia reached an agreement on an MOU to exchange

researchers and students and promote collaborative research. ANSTO is a core research organization with nuclear reactors dedicated to research. This MOU is expected to enhance research and education using the institute's neutron beams. In 2023, GSSE-IU and ANSTO extended the MOU for another five years.

3.6 Collaboration with ANSTO in Australia and Japan

A small-angle neutron scattering experiment on blue copper proteins, pseudoazurin, and nitrite reductase was conducted in November 2017 at QUAKKA (ANSTO) by a young early-career faculty member. The deuteration of pseudoazurin was performed at the deuteration facility of ANSTO. The MOU between ANSTO and GSSE-IU was signed on February 14, 2019. An introductory course on the operation of neutron beams was provided to ten graduate students visiting ANSTO for three days, and a graduate student joined the AONSA School held at ANSTO in 2019.

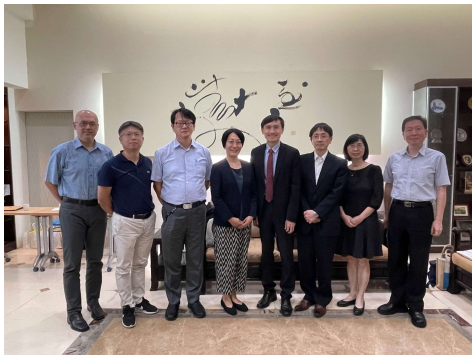
In February and March 2020, five graduate students stayed at ANSTO for long-term (one-month) introductory courses: two weeks at the neutron beamline and two weeks in environmental radiation science. Unfortunately, three students had to return to Japan after three weeks due to COVID-19 and could not complete the planned course, while two students completed it. Student visits to ANSTO restarted in 2022 (two PhD students) and have continued in 2023 (one PhD and two MSc students) and 2024 (one MSc and one PhD student).

Since 2023, the Japan Student Services Organization (JASSO) has approved the Study Abroad Support Program (Agreement Dispatch) from IQBS, providing partial financial support for students' expenses in Australia. Based on a student visit, a joint paper with ANSTO was published (A. Yamaguchi, et al., *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, **2024**, *698*, 134559: https://doi.org/10.1016/j.colsurfa.2024.134559). Several scientists, including Dr. Jamie Schulz (2023, 2024), Dr. Tamim Darwish (2023, 2024), Dr. Nicolas De Souza (2024), and Dr. Eliot Paul Gilbert (2022), visited Ibaraki University. Additionally, a joint paper between Dr. Tamim Darwish's group and Prof. Seiji Mori was published (*Bull. Chem. Soc. Jpn*. **2021**, *94*, 1954). Notably, a PhD female alumni of IQBS, Dr. Yui Obata, who visited ANSTO, has become an assistant professor in the Department of Chemistry at Ibaraki University. Ibaraki University and ANSTO have 4 joint publications between 2020 and 2024.

3.7 Collaboration with Universities in Taiwan

Since 2019, Professor Seiji Mori has been engaged in research collaborations with a professor at National Tsing Hua University (NTHU) in Hsinchu, Taiwan. In addition to Prof. Mori's research, Assistant Professor Kimiko Yamashita visited NTHU to attend a conference on flavor physics in June 2024. The collaboration spans multiple departments, and GSSE-IU intends to establish an MOU with the Faculty of Science at NTHU. In November 2024, Dean of GSSE-IU, Professor Masatomo Inui, visited NTHU to sign the MOU. The physics departments of NTHU and GSSE-IU (including IQBS) have held two joint seminars in a hybrid format.

In addition to the MOU with NTHU, Ibaraki University has a strategic plan to expand MOUs with Taiwanese universities. Based on a college-level MOU with the College of Humanities and Social Sciences of IU, Professor Kazuaki Iwasa (Director of RECAS and IQBS) and Professor Seiji Mori were invited to give lectures at the International Symposium on Science and Education at National Taiwan Normal University (NTNU) in June 2024. Following discussions with high-level university staff, NTNU and IU signed a university-level MOU in November 2024, by the presidents of both universities.

During their visit to Taiwan, Professor Kazuaki Iwasa and Professor Seiji Mori also visited Fu Jen Catholic University in June 2024 to discuss further academic exchanges. Additionally, Professor Seiji Mori and Assistant Professor Kimiko Yamashita visited National Synchrotron Radiation Research Center (NSRRC) with Professor Hsiao-Ching Yang of Fu Jen Catholic University.

3.8 The NTHU, Taiwan, and Ibaraki Univ. co-seminar (Physics)

We held the first NTHU and Ibaraki University co-seminar on October 30, 2024, and the second on November 21, 2024. Since National Tsing Hua University (NTHU) is located in Hsinchu, Taiwan, we conducted the co-seminars in a hybrid format, with onsite participants at NTHU and online participants at Ibaraki University.

The topic of the first co-seminar was high-energy physics. Professor Kingman-Chung (NTHU) and Professor Yoshifumi Hyakutake (IQBS, Ibaraki University) gave talks titled "Primordial Black Hole from Modified Higgs Inflation & NanoGrav Signal" and "Toward the Determination of Higher Derivative (DF)^4 Terms in M-theory," respectively. The co-hosts were Professor Ite Albert Yu (NTHU) and Assistant Professor Kimiko Yamashita (IQBS, Ibaraki University). The first co-seminar followed the NTHU colloquium format. Approximately 100 participants attended in person at the lecture hall at NTHU, with about 16 online participants. During the discussion time for each talk, participants asked numerous questions until the question-and-answer session ended.

The topic of the second co-seminar was astrophysics. Professor Tomo Goto (NTHU) and Professor Yoshinori Yonekura (Ibaraki University) gave talks titled "BURSTT: Bustling Universe Radio Survey Telescope in Taiwan and Its Ogasawara Outrigger Station" and "High-Cadence Monitoring Observations of Methanol Masers in Massive-Star Forming Regions Using Ibaraki 32-m Radio Telescopes," respectively. The co-hosts were Associate Professor Hsiang-Yi Karen Yang (NTHU) and Assistant Professor Kimiko Yamashita (Ibaraki University). The second co-seminar was held in a seminar format. Approximately 19 onsite participants from NTHU astrophysics and about 12 online participants attended. During the discussion time for each talk, participants asked numerous questions until the session ended. Each speaker and a professor attending online from Ibaraki University discussed potential collaborations based on their talks.

We hope these co-seminars enhanced the chances of collaboration between Ibaraki University and NTHU.

3.9 Visit to Laboratory Abroad

By Master Course student A
Institute of Quantum Beam Science, Graduate School of Science and Engineering, Ibaraki University, Japan
Laboratory:
Paul Scherrer Institute (PSI), Switzerland
Dates: October 9th to October 15th, 2024

By Master Course student B
Institute of Quantum Beam Science, Ibaraki University, Japan
Laboratory: Rutherford Appleton Laboratory, United Kingdom
Dates: December 14th of 2024 to December 19th of 2024.

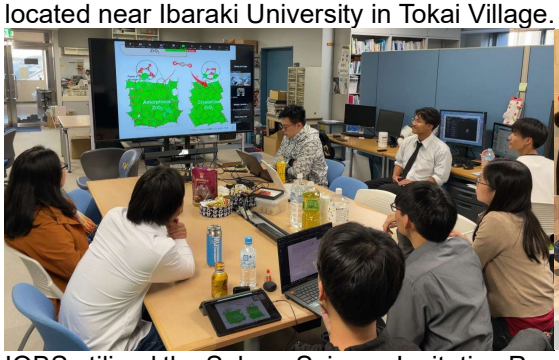
3.10 Sakura Science Program

In 2018-2019, IQBS-IU invited graduate students, postdoctoral fellows, and faculty members from Ubon Ratchathani University, VNU (Vietnam National University) University of Science, Hanoi, Fu Jen University, Taiwan, Kasetsart University, Thailand, Udayana University, Indonesia, and CSIR-Indian Institute of Chemical Technology, This collaborative research program is supported by JST through Sakura Science Plan, which started in 2014 to introduce and offer experiences in Japanese cutting-edge science and technology. The total number of 2018-2019 participants was five (India), three (Indonesia), seven (Vietnam), five (Thailand), and one (Taiwan). They stayed for three weeks, mostly at Ibaraki University. Each year, we organized the Asian Workshop in Experiment and Theory in Quantum Beam Molecular Sciences, and all students/postdocs were invited speakers of the workshops to enhance exchanges with people from Ibaraki University. In 2018, Japan Broadcasting Corporation (NHK) covered their visit to the J-PARC facility. In 2020, one of the collaborations with Ubon Ratchathani University resulted in a publication on Advanced Synthesis & Catalysis (IF: 5.851, **2020**, 362, 4665-4661), This paper was selected as a Very Important Publication (VIP) with Front Cover Picture.

This program was highlighted on the Sakura Science official website in 2019.


In 2020, our application for the Sakura Science Plan to invite eight students, two postdocs, and two faculty members from Mahidol and Chulalongkorn Universities in Thailand was approved by JST. However, due to the COVID-19 pandemic, we had to cancel the invitation. Instead, we held one session of the International Conference of Quantum Beam Science at Ibaraki University on November 21, 2020. In addition to three professors from Mahidol and Chulalongkorn Universities, one student from Ubon Ratchathani University and two students from Ibaraki University were invited speakers. Prof. Dr. G. Narahari Sastry, Director of the CSIR-North East Institute of Science and Technology (NEIST) in Assam, India (currently, Professor at IIT Hyderabad), was the plenary speaker of the session. The session was successfully completed.
In 2023, IQBS invited two graduate students and one faculty member from Mahidol University in Thailand, one graduate student, one undergraduate student, and one faculty member from the University of Science at Vietnam National University, Hanoi, and one graduate student from National Taiwan Normal University with the support of the Sakura Science Program from October

9 to 28, 2023. The program's theme was "International Collaborative Research with Asian Countries on Quantum Beam Molecular Science Simulations," and at Ibaraki University, they conducted cutting-edge theoretical calculation simulations using quantum beams. Subsequently, each research group conducted studies on elucidating catalytic reaction mechanisms through quantum chemical calculations, protein docking simulations using molecular dynamics, and the photophysical properties and evaluation of luminescent polymers. On the morning of October 26, we conducted a facility tour of J-PARC, a world-renowned high-intensity proton accelerator facility located near Ibaraki University in Tokai Village.



IQBS utilized the Sakura Science Invitation Program in 2018, 2019, and 2023 to invite researchers from India, Thailand, Taiwan, Indonesia, and Vietnam. Notably, collaborative research with Thailand and Taiwan under the Sakura Science Invitation Program resulted in two academic journal publications (one of which was featured on the cover of the Advanced Synthesis & Catalysis journal, Vol. 362, Issue 21, in 2020). Moving forward, we aim to continue our collaborative research with these countries, publish academic journal papers, and deepen academic exchanges with these inviting institutions. Additionally, we plan to strengthen academic networks with Southeast and South Asian countries in the research fields of our host laboratory's faculty members. As international collaborative research in quantum beam science progresses, both sides will gain an understanding of Japan's academic culture through advanced science and technology, while we will better understand the developed academic cultures of Asian countries.
In October 2024, the College of Engineering, including several professors from IQBS, utilized the JST Sakura Science Fund to invite five students and one accompanying professor from VNU University of Science, Hanoi for a program titled "Hands-on Learning on the Research and Development of Sustainable Advanced Materials and Related Technologies".

4 International Symposia

ISQBS is an international event held annually since establishing the Institute of Quantum Beam Science at Ibaraki University (IQBS-IU) in 2016. Each ISQBS opens with a specific scientific theme. This event aims to showcase recent advances in quantum beam sciences from around the globe at Ibaraki University. IQBS has already reported on the 1st-5th international symposia in March 2020. This report will cover the symposia from the 6th event onward, starting in 2022.

4.1 The 6th International Symposium of Quantum Beam Science at Ibaraki University

The 6th International Symposium of Quantum Beam Science at Ibaraki University was held online due to the COVID-19 pandemic from February 21st to 22nd, 2022. The international symposium was held with a total of 9 hours of event time, considering time differences, on the evening of February 21, 2022, and the morning and evening of February 22, 2022. The theme was "Structural Biology and Chemistry and their Recent Development in Quantum Beam Applications," featuring researchers focused on neutron structural biology.
The organizing committee members are Yasuto Shomura, Takaaki Hosoya, and Ichiro Tanaka.

Invited speakers with titles of their lectures listed as follows:
Dieter Richter (Forschungszentrum Jülich, Germany): Self-similar Structure and Dynamics of Large Ring Polymers
Esko Oksanen (European Spallation Source, Sweden): Neutron Macromolecular Crystallography at the European Spallation Source
Katsuhiro Kusaka (Ibaraki Univ., Japan): Single crystal neutron diffractometer iBIX at pulsed neutron source MLF, J-PARC
Gloria Borgstahl (Univ. of Nebraska Medical Center, USA): Direct detection of coupled proton and electron transfers in human manganese superoxide dismutase
Rei Narikawa (Tokyo Metropolitan Univ., Japan): Discovery and engineering of diverse cyanobacteriochrome photoreceptors
Hiroshi Sugimoto (RIKEN, Japan): High-resolution structural analysis of the heme proteins using neutron and XFEL crystallography
Shinya Fushinobu (Univ. of Tokyo, Japan): Joint neutron/X-ray crystallography of glucose-tolerant β-glucosidase Td2F2
Toshio Moriya (KEK, Japan): Recent advancements of protein dynamic analysis in cryogenic electron microscopy

Participants: 47 (28 general, 19 students including those from other universities) Affiliation of Participants: 17 institutions (3 overseas, 14 domestic) Presentations and Lectures Breakdown: 8 invited lectures, 6 general lectures, 5 poster presentations

4.2 The 7th International Symposium of Quantum Beam Science at Ibaraki University

The main topics for invited speakers were recent advances in theoretical and computational chemistry and materials informatics related to quantum (beam) sciences and functional organic materials. This symposium was held on December 1-3, 2022, at the Mito campus and Zoom. From this year, the student session was also held as “the International Student Conference at Ibaraki University.”
Organizing Committee: Seiji Mori (Chair), Hiroyuki Nishikawa, and Tatsuya Jotsuka
Student and Young Researchers Session: Daiki Tauchi (Session Coordinator: Nishikawa Lab), Rie Yoshimoto (Mori Lab), Ryuta Yurishima (Ikeda Lab), Azumi Yashiro (Yokoyama Lab), Kaede Ino (Yokoyama Lab)

Invited Lectures: 26 (Japan, France, Thailand, Taiwan, Canada, USA, UK)
Invited Speakers: 14 from abroad, including seven female scientists. In-person Speakers: 13 (including five from abroad: 2 from Thailand, two from France, one from Taiwan)

Invited speakers from Ibaraki University: Assistant Professor Tatsuya Jotsuka and Researcher Masatoshi Hiraishi
Online Speakers: 13 Student Presentations: 22 (from Japan (Ibaraki University and University of Tokyo), USA, Taiwan, Thailand, Singapore); 1 presentation (from Japan) was canceled at the last minute

Pre-registered Participants (excluding speakers): 46 (from Japan, Taiwan, Thailand, Vietnam, Indonesia, and India) Same-day Registered Participants: 13 (only from within Ibaraki University) Total Attendees: 108 (26 speakers + 13 in-person speakers + 22 student presenters + 46 pre-registered + 1 university president)

The symposium began with opening remarks from President Hiroyuki Ohta and an introduction to Ibaraki University and the IQBS at the Graduate School of Science and Engineering by Professor Seiji Mori, the symposium organizing committee chair and Chair of IQBS. While the main focus was on theoretical and computational chemistry and functional organic chemistry, the topics covered a wide range, from the functions of enzymes such as DNA transcription enzymes, nanoparticles, molecular crystals, solids, interfaces, catalysts, positrons, the theoretical chemistry and physics of non-covalent interactions, the synthesis of helical molecules, to the application of machine learning and robotics in chemical reaction research. Many lectures were given by researchers active on the global stage. The symposium was funded by the strategic budget of Ibaraki University. The necessary procedures for export control were completed in advance with the Research Promotion Division. The symposium was held in a hybrid format, using up to three Zoom licenses. Additionally, the Japan Society of Molecular Science co-sponsored the event.
Based on this event, a PhD student (currently, an assistant professor, Kitasato University) is able to visit Prof. Narcis Avarvari, University of Angers, France (an invited speaker). In addition, Prof. Seiji Mori is able to publish a journal paper with Dr. Dmitri Fedorov (AIST, Japan) and Dr. Julia Contreras-Garcia (invited speakers, Sorbonne University, France).

4.3 The 8th International Symposium of Quantum Beam Science at Ibaraki University
Organizing Committee Members: Kenji Ohoyama (Chair), Kazuaki Iwasa, and Kazuhiro Mori (cross-appointment professor of KEK)

The main topics for invited speakers include the collaborative efforts of the IQBS and the Frontier Research Center for Applied Atomic Sciences (iFRC) with various research facilities and institutes in quantum beam sciences, such as J-PARC, JAEA, KEK, and the Institute for Solid State Physics (ISSP) at the University of Tokyo. We have initiated new collaborations in research and education activities with ISSP, based on the steady neutron source JRR-3 (nuclear reactor) of JAEA, which was restarted in 2021 after a long shutdown due to the 2011 seismic event. Considering these recent developments, we will hold a symposium on quantum beam science in the Pacific Rim region to exchange knowledge and information related to material physics, material engineering, chemistry, biology, and quantum beam instrumentations for neutron, synchrotron X-ray, and muon.
This symposium was held at the Mito campus of IU from November 28 to 30, 2023, with 90 registered participants, 22 oral presentations, and 37 posters.

Speakers and titles
Takatsugu Masuda (ISSP, the Univ. of Tokyo): Recent Activity of Neutron Scattering Research in JRR-3
Jae-Ho Chung (Korea University): Unconventional spin dynamics of van der Waals honeycomb ferromagnets
Max Hirschberger (The Univ. of Tokyo) : Probing chiral magnetic textures by quantum beam scattering
Takenao Shinohara (J-PARC) : Development and application of neutron imaging techniques using the pulsed neutron beam
Takahito Osawa (JAEA) : Introduction of prompt γ-ray analysis system (PGA) at JRR-3

Yuta Ishii (Tohoku Univ.): Soft X-ray microscopy for space- and time-resolved measurements of magnetic materials
Masaki Unno (Ibaraki U.): Relationship between protonation states and functions of redox proteins revealed by neutron crystallography
Rintaro Inoue (Kyoto Univ.): Dynamics of multi-domain protein
Dr. Michael Moir (ANSTO, Australia): "Deuteration for Studying Biological Systems"
Iain McKenzie (Centre for Molecular and Materials Science, TRIUMF, Canada): β-NMR Studies of Dynamics in Thin Polymer Films and Energy Storage Materials
Kazuhiko Ninomiya (Osaka Univ.): Bulk elemental analysis for C-type asteroid Ryugu using a muon beam
Yuga Nakazawa (RIKEN): Re-acceleration of ultra slow muon in J−PARC
Shingo Takahashi (PhD student, Ibaraki Univ.): The development of the neutron polarization device for the time-of-flight single crystal neutron diffractometer SENJU at J-PARC
Ryou Toshima (PhD student, Ibaraki Univ.): Introduction of hydrogen-bonding substituent to cobaloxime complexes with photosensitizer "BODIPY" "
Hodaka Kikuchi (ISSP, The Univ. of Tokyo): Development of next-generation triple-axis spectrometer HODACA in JRR-3
Kazuhiro Mori (IMSS, KEK): Direct observation of fast Li-ion diffusion in Li2S–P2S5 superionic conductors using neutron scattering
Akinori Hoshikawa (iFRC, Ibaraki Univ.): Hydrogen bonding in clathrate hydrates
Seungyub Song (IMSS, KEK): Anharmonicity of thermoelectric materials Cu2-xS studied by neutron powder diffraction
Lester Geonzon (ISSP, The Univ. of Tokyo): Elaborating rheological properties from linear to nonlinear regime and spatiotemporal structure of carrageenan gels
Akira Yamaguchi (Faculty of Science, Ibaraki Univ.): Neutron scattering for the study of confined proteins
Hiroki Fukumoto (Ibaraki U.): Synthesis and Chemical Properties of Fluorine-containing Polymers
Kenta Yamanaka (IMR, Tohoku Univ.): Towards understanding phase transformation and microstructural evolution in metal additive manufacturing
Pingguang Xu (JAEA) : Engineering Materials Characterization Techniques using Neutron Diffraction


4.4 The 9th International Symposium of Quantum Beam Science at Ibaraki University
Organizing Committee Members: Ichiro Tanaka (Chair), Yohei Noda, Masahiro Kuramochi, and Masatoshi Hiraishi (currently, KEK)

The 9th ISQBS, held on October 19-22, 2024, addressed the theme "For world-leading quantum beam applications and next-generation facilities." It saw 111 registered participants from Nepal, Germany, USA, Australia, Sweden, UK, and Canada, and featured 21 invited lectures, one general lecture, three student lectures, and 45 posters. This was a satellite meeting of the 4th J-PARC Symposium 2024 (October 14-18, 2024, at Mito City Civic Center) and the related meeting of J-PARC Workshop 2024 (October 18, 2024, at the Mito campus of Ibaraki

University). The student talk session was co-organized as “The 20th International Student Conference in Ibaraki.”

The topics covered included the development of muon spectroscopy and its application for molecules, dynamic studies of molecules using X-ray spectroscopy, scientific instruments of synchrotron facilities, structural studies of molecular crystals and proteins from experimental and computational perspectives, and a lecture from industry on the applications of the synchrotron facility toward the development of rubber for tires.

This year, ISQBS 2024 was supported by the "Promotion of Hosting International Conferences at Universities" initiative (Japan Tourism Agency).
We received cooperation from the following five organizations: the J-PARC Center, the original host of the satellite event; CROSS (Neutron Science Center), also the host of the satellite meeting at J-PARC; the Japan Society of Neutron Science; the Japan Society of Meson Science; and TRiiSTAR (Strategic Program for Fostering Researchers Capable of Excelling Worldwide - Top Runner Development Program through Collaboration between Universities, National Research Institutes, and Companies).

Invited lectures
Yuji C. Sasaki (Univ. of Tokyo): Observation Techniques for High-speed Molecular Dynamics using X-ray Tracking/Blinking: DXT/DXB/SAXB/TXB
Tokushi Sato (European XFEL, Germany): Time-resolved experiments using unique pulse structure at the SPB/SFX scientific instrument of the European XFEL
Takuya Taniguchi (Waseda Univ.): Structural dynamics and materials informatics of organic molecular crystals
Mingoo Jin (Hokkaido Univ.): Two Dimensional Crystalline Molecular Gearbox
Pavel Afonine (LBNL, USA): AQuaRef: Quantum-Based Atomic Model Refinement for Crystallographic and Cryo-EM Data in Phenix
Amba Datt Pant (KEK): Muon in biology: an update
Katsuhiro Kusaka (CROSS): Single Crystal Neutron Diffractometer iBIX at JPARC MLF - Current status and improvement plans –
Toshiyuki Chatake (Kyoto Univ.): Protein hydration observed in D/H contrast neutron crystallography
Takeshi Yokoyama (Toyama Univ.): Resveratrol Derivatives Inhibit Transthyretin Fibrillization: Structural Insights into the Interactions between Resveratrol and Transthyretin
Dmitrii Zabelskii (European XFEL, Germany): Serial femtosecond crystallography experiments at SPB/SFX instrument of European XFEL
Tatsuya Arai (Hokkaido Univ.): Structural diversity of ice-binding proteins observed with X-ray crystallography
Justin Bergmann (ESS, Sweden): NMX Macromolecular Diffractometer at ESS
Yoichi Shinkai (AIST): The Impact of FG Repeat Proteins on Liquid-Liquid Phase Separation and Neurodegenerative Disorders
Hiroshi Sekiguchi (JASRI): Dynamics measurement of bio-soft materials using synchrotron radiation X-rays
Saurabh Kabra (ORNL, USA): Progress on the Second Target Station at Oak Ridge National Laboratory
Josh Pierce (ORNL, USA): Spin Dependent Neutron Protein Crystallography using Dynamic Nuclear Polarization
Tomomi Masui (Sumitomo Rubber Industries, Ltd.): Quantum Beam Studies on the Hierarchical Structure and Dynamics of Rubber for Tire
Yue Zhao (QST): Development of advanced polymer electrolyte membranes using quantum beam technology
Henrich Frielinghaus (JCNS): Complex fluids in a review to different applications
Fransis Pratt (RAL): μSR studies of quantum magnetism in molecular solids
Kenji Kojima (TRIUNF, Canada): Development of Muon Spin Imaging Spectroscopy at the DC beam of TRIUMF

General lecture

Tamim Darwish (ANSTO, Australia): The Deuteration Network (DeuNet): An International Consortium of Deuteration Facilities for Global impact in Deuteration Science

5. Principal Investigators selected from each of the Educational Courses

5.1 Faculty

Environmental Radiation Science

Position	Name	Research field
Professor	TAUCHI Hiroshi	Radiation biology: Mechanism of DNA damage repair
Professor	TORIKAI Yuji	Nuclear Fusion, Tritium, Environmental Radiation
Professor	NAKAMURA Asako	The Chromatin Response to DNA Damage and its role in Genome and Cellular Integrity Maintenance
Professor	YOKOYA Akinari (QST, Cross-appointment)	Radiation Biophysics: Physicochemical processes of molecular and cellular effects of radiation
Visiting Professor	KINASE Sakae (QST)	Radiation Protection, Radiation Dosimetry
Visiting Professor	MORIOKA Takamitsu (QST)	Tumor biology/radiation biology
Visiting Professor	YAMAGUCHI Kenji (QST)	Quantum Beam Science, Nuclear Engineering

Quantum Science and Engineering of Materials

Position	Name	Research field
Professor	IGA Fumitoshi	Functional material design, crystal growth, and those physical-properties research which is mainly concerned with magnetism
Professor	IKEDA Teruyuki	Thermoelectric materials, porous metals, nonequilibrium processing, combinatorial methods, atomic diffusion, phase diagram, phase transformation, solidification
Professor	IWASE Kenji	Structural/Functional Materials
Professor	IWAMOTO Chihiro	Transmission Electron Microscopy, Nanoanalysis, Welding, Interface Engineering
Professor	KUWAHARA Keitaro	Condensed matter physics, neutron scattering experiments, magnetism in strongly correlated electron systems

Professor	SAKAGUCHI Makoto	Quantum Field Theory, Quantum Gravity and Superstring Theory
Professor	SASAJIMA Yasushi	Computer experiments on materials, Science and technology of thin solid films
Professor	SATO Shigeo	Quantum-beam material science, metallography
Professor	SUZUKI Tetsuya	Plastic Deformation of Crystals, Texture
Professor	NAKAGAWA Naoko	Statistical physics and thermodynamics in nonlinear nonequilibrium, theoretical biophysics
Professor	NISHI TSUYOSHI	Metallic Physical Properties, Inorganic Material/Physical Properties
Professor	HYAKUTAKE Yoshifumi	Elementary Particle Physics, Superstring Theory
Professor	FUKUI Takahiro	Condensed matter physics
Professor	MINATO Atsushi	Applied Optics, Image Processing, Kansei Engineering
Professor	YOKOYAMA Makoto	Low temperature physics on strongly correlated electron
Associate Professor	SATO Naoyuki	Plasma Science and Engineering
Associate Professor	TASHIRO Suguru	Friction Stir Welding, Dissimilar Metal Joining, Cu Wiring for LSI (Large Scale Integration), Aluminum Wire Bonding, Tatara Steelmaking
Associate Professor	NAKANO Takehito	nanostructure physics, magnetism, optical properties, cluster, zeolite
Associate Professor	NISHINO Souichiro	Mechanics of materials and materials, Manufacturing and production engineering, Material processing and microstructure control, Composite materials and interfaces, Quantum beam science
Lecturer	NAGANO Takatoshi	Plastic working Simulation using Particle Method, Ab initio Calculation
Lecturer	NODA Yohei	Small Angle Neutron Scattering, Electron Spin Resonance, Dynamic Nuclear Polarization, Polymer composite material
Assistant Professor	YAMASHITA Kimiko	Theoretical particle physics

Visiting Professor	KAGAWA Hiroyuki (HITACHI)	Organic materials, resin materials
Visiting Professor	HIRADE Tetsuya (JAEA)	Radiation Chemistry, Positron Science, Positron and Positronium Chemistry
Visiting Associate Professor	ISHIBASHI Ryo (HITACHI)	Corrosion and Protection Science, metals and alloys

Chemistry and Life Science

Position	Name	Research field
Professor	UNNO Masaki	Chemistry Related to Living Body, Structural Biochemistry
Professor	EGUCHI Mika	Battery and Energy Chemistry
Professor	OTOMO Seiu	Biophysical chemistry on the structure-function relationship of photosynthetic pigment-protein supramolecular complexes
Professor	KITANO Takashi	Phylogenetic and polymorphic analyses of nucleotide sequence data
Professor	KOBAYASHI Yoshio	Development of methods for preparing functional materials by liquid phase reaction
Professor	SATO Itaru	Natural product chemistry and synthetic organic chemistry
Professor	NISHIKAWA Hiroyuki	Functional Material Chemistry, Physical Chemistry
Professor	FUKUMOTO Hiroki	pai-conjugated polymer, polyaromatic hydrocarbon, Fluoropolymer
Professor	FUJISAWA Kiyoshi	Study on structures and spectroscopic properties of transition metal model complexes in biochemistry
Professor **Director of IQBS**	MORI Seiji	Computational chemistry on reaction mechanisms of stereoselective reactions/metal-mediated reactions and biosyntheses of biological active compounds
Professor	MORIKAWA Atsushi	Synthesis of functional polymers using polycondensation
Professor	YAMAUCHI Satoshi	Semiconductor Devices and Multifunctional Integration
Professor	YAMAGUCHI Akira	Development and analytical applications of nanoporous materials

Associate Professor	SHOMURA Yasuhito	Structural biochemistry, Functional biological chemistry, Biophysics
Associate Professor	NAKASHIMA Kouichi	Low Temperature Synthesis and Structural Analysis of Functional Ceramics
Associate Professor	YAMAUCHI Noriko	Composite materials/Surface and interface engineering, Nanomaterials engineering, Reaction engineering/Process system, Organic and hybrid materials, Polymer/Textile materials
Assistant Professor	NAGAKAWA Haruki	Photochemistry, Inorganic chemistry
Assistant Professor	MORITA Masato	Organofluorine Chemistry
Assistant Professor	YAMAGUCHI Takahide	Bioinorganic chemistry

Visiting Professor	WATANABE Masayuki (JAEA)	Spectrochemistry, radiation chemistry, radiochemistry, Actinide coordination chemistry

Beamline Science

Position	Name	Research field
Professor (Director, RECAS)	IWASA Kazuaki	neutron scattering, X-ray scattering, strongly correlated electron system, structural transition
Professor	OHOYAMA Kenji	Materials Science using Neutron scattering technique, Developments of Novel techniques of Neutron scattering
Professor	OKU Takayuki (Cross-appointment, JAEA)	Quantum beam science, Quantum beam science
Professor	KOIZUMI Satoshi	Functional Materials/Device
Professor **(Depury Director of IQBS)**	TANAKA Ichiro	Neutron structural biology and development of neutron diffractometer and methods of crystal growth
Professor	MORI Kazuhiro (Cross-appointment, KEK)	Material Science using neutron scattering, Novel techniques of neutron scattering
Associate Professor	ABE Hitoshi (Cross-appointment, KEK)	X-ray Absorption Spectroscopy (XAS) experiments to characterize various materials (in particular, low dimensional systems and materials) and development of new methods

Associate Professor	IINUMA Hiromi	Experimental physics by use pf polarized muon beam
Associate Professor (RECAS)	HOSHIKAWA Akinori	Quantum beam, Materials Science, Instrument development
Lecturer	HOSOYA Takaaki	Crystal chemistry, Solid-state organic chemistry, Neutron diffraction
Assistant Professor (RECAS)	MAEDA Tomoki	Materials/Mechanics of materials, Polymer/Textile materials

Visiting Professor	KINOSHITA Toyohiko (JASRI)	Study of surface and interface by synchrotron radiation spectroscopy, Development of new spectroscopic equipments and methods
Visiting Professor	KUNIEDA Satoshi (JAEA)	Nuclear Data Engineering
Visiting Professor	KONDO Yasuhiro (JAEA)	Accelerator science
Visiting Professor	SATO Tetsuya K. (JAEA)	Radiochemistry、 Nuclear chemistry
Visiting Professor	TSUTSUI Satoshi (JASRI)	Condensed matter physics
Visiting Professor	HIGO Yuji (JASRI)	High-pressure and high-temperature experiments using synchrotron radiation X-rays
Visiting Professor	METOKI Naoto (JAEA)	Materials science using neutron scattering techniques
Visiting Associate Professor	HOSHINO Masato (JASRI)	X-ray real time imaging

5.2 CVs of the principal investigators

Prof. Kenji Iwase

Scientific Career

University	Material Science; Ibaraki University	1999
MSc Work	Material Science; the University of Tsukuba	1999-2002
PhD Work	Material Science; the Graduate University for Advanced Studies	2003-2006
Post-doc	Material Science; Hokkaido University	2006-2007
Post-doc	Material Science; National Institute of Advanced Industrial Science and Technology (AIST)	2007-2008
Assistant Professor	Material Science; Ibaraki University	2008-2013
Senior Lecturer	Material Science; Ibaraki University	2013-2015
Associate Professor	Material Science; Ibaraki University	2015-2024
Professor	Material Science; Ibaraki University	2024-

Scientific Interests: Crystal structure of hydrogen storage material.

Prof. Tsuyoshi Nishi

Scientific Career

University	Material Science; Tokyo University of Science	1995-1999
MSc Work	Material Science; Tohoku University	1999-2001
PhD Work	Material Science; Tohoku University	2001-2004
Post-Doc	Material Science; Japan Atomic Energy Research Institute (JAERI)	2004-2005
Post-Doc	Material Science; Japan Atomic Energy Agency (JAEA)	2005-2006
Research Engineer	Material Science; Japan Atomic Energy Agency (JAEA)	2006-2013
Assistant Principal Researcher	Material Science; Japan Atomic Energy Agency (JAEA)	2013-2015
Assistant Professor	Material Science; Ibaraki University	2015-2021
Professor	Material Science; Ibaraki University	2021-

Scientific Interests: Thermophysical properties and local structures of nuclear materials cooperated with JAEA.

Prof. Asako J. Nakamura

Scientific Career

University	Pharmaceutical Science, Hiroshima University	1997
MSc Work	Pharmaceutical Science, Hiroshima University	1997-1999
PhD Work	Pharmaceutical Science, Hiroshima University	1999-2002
Post-Doctoral Research Fellow	Radiation Biology, Kyoto University	2002-2004
Special volunteer	National Institutes of Health, National Cancer Institute (the Japan Society for Promotion of Science for Japanese Biomedical and Behavioral Researchers at NIH)	2004-2007
Visiting Fellow	National Institutes of Health, National Cancer Institute	2007-2009
Research Fellow	National Institutes of Health, National Cancer Institute	2009-2011
Junior Associate Professor	Osaka Medical College, Department of Anatomy and Cell Biology	2011-2013
Associate Professor	Biology, Ibaraki University	2013-2017
Professor	Biology, Ibaraki University	2017-
CTO	Dinow Inc,	2020-

Scientific Interests: Radiation cellular biologist specializing in the mechanisms of genome integrity, DNA double-strand break repair and mammalian aging.

Prof. Masaki Unno

Scientific Career

University	Macromolecular Science, Osaka University	1992-1996
MSc Work	Protein Research, Osaka University	1996-1998
PhD Work	Protein Research, Osaka University	1998-2002
Assistant Professor	Institute of Multidisciplinary Research for Advanced Materials, Tohoku University	2002-2009
Associate Professor	Applied Beam Science, Ibaraki University	2009-2013
Professor	Applied Beam Science, Ibaraki University	2013-2016
Professor	Quantum Beam Science, Ibaraki University	2016-

Scientific Interests: Structure and function of biologically interesting proteins, and structure-based rationally drug design. X-ray and neutron crystallography of biomacromolecules.

Professor Hiroki Fukumoto

Scientific Career

University	Department of Macromolecular Science, Faculty of Science, Osaka University	1990-1994
MSc Work	Department of Macromolecular Science, Graduate School of Science, Osaka University	1994-1996
PhD Work	Department of Chemistry, Graduate School of Engineering Science, Osaka University	1996-1999
Assistant Professor	Chemical Resources Laboratory, Tokyo Institute of Technology	1999-2012
Associate Professor	Department of Biomolecular Functional Engineering, College of Engineering, Ibaraki University	2012-2019
Professor	Department of Materials Science and Engineering, College of Engineering, Ibaraki University	2019-
Visiting Researcher	Ecole Nationale Superieure de Chimie de Montpellier, France (Dr. B. Ameduri)	2019

Scientific Interests: Synthesis and application of ν-conjugated functional polymers and organofluorine compounds.

Prof. Teruyuki Ikeda

Scientific Career

University	Metallurgy; Kyoto University	1990-1994
MSc Work	Material Science and Engineering; Kyoto University	1994-1996
PhD Work	Material Science and Engineering; Kyoto University	1996-1999
Research Associate	The Institute of Scientific and Industrial Research; Osaka University	1999-2004
Postdoctoral Scholar	Material Science; California Institute of Technology	2005-2008
Senior Postdoctoral Scholar	Material Science; California Institute of Technology	2008-2009
PRESTO Researcher	Japan Science and Technology Agency	2008-2012
Visiting Associate	Material Science; California Institute of Technology	2009-2012
Laboratory Scientist/Manager	Material Science; California Institute of Technology	2012-2013
Professor	Material Science and Engineering; Ibaraki University	2013-

Scientific Interests: High-throughput materials research techniques, Thermoelectric materials, Microstructure control, Porous materials, Diffusion

Prof. Seiji Mori

Scientific Career

University	Chemistry, Tokyo Institute of Technology	1993
MSc Work	Chemistry, Tokyo Institute of Technology	1993-1995
PhD Work	Chemistry, The University of Tokyo	1995-1998
Post-Doc	Chemistry, Emory University, Atlanta, USA (Keiji Morokuma)	1998-2000
Post-Doc	Chemistry, Kyoto University (Shigeki Kato)	2000 4-9
Assistant Professor	Chemistry, College of Science, Ibaraki University	2000-2001
Associate Professor	Chemistry, College of Science, Ibaraki University	2001-2012
Visiting Professor	Chemistry, Mindanao State University, Iligan Institute of Technology, Philippines	2005 7
Visiting fellow	Emory University, Atlanta, USA	2006 6-8
Professor	Chemistry, College of Science, Ibaraki University	2012-

Scientific Interests: Theoretical and computational chemistry on mechanistic insights into organic/organometallic/biochemical reactions.

Prof. Kazuaki Iwasa

Scientific Career

University	Physics, Keio University	1990
MSc Work	Physics, Keio University	1990-1992
PhD Work	Physics, Keio University	1992-1995
Assistant Professor	Physics, Tokyo Metropolitan University	1995-2003
Associate Professor	Physics, Tohoku University	2003-2016
Professor	Frontier Center for Applied Atomic Sciences, Ibaraki University	2016-2024
Professor	Research and Education Center for Atomic Sciences, Ibaraki University	2024-

Scientific Interests: Condensed-matter physics, Strongly correlated-electron system, Neutron and X-ray scattering.

Prof. Naoko Nakagawa

Scientific Career

University	Physics, Kyoto University	1987-1991
MSc Work	Physics, Kyoto University	1991-1993
PhD Work	Physics, Kyoto University	1993-1996
Post-doc	Tokyo University	1996-1997
Post-doc	RIKEN	1997-1998
Assistant Professor	Physics, Ibaraki University	1998-2003
Associate Professor	Physics, Ibaraki University	2003-2015
JSPS/CNRS Visiting Scientist	Physics, Ecole Normale Superieure de Lyon	2003.5-2004.6
Professor	Physics, Ibaraki University	2015-

Scientific Interests: Thermodynamics and Statistical Physics, Non-equilibrium phenomena, Theoretical biophysics.

Prof. Yuji Torikai

Scientific Career

University	Engineering, University of Miyazaki	1985-1989
MSc Work	Engineering, University of Miyazaki	1989-1991
PhD Work	Nuclear Engineering, Hokkaido University	1993-1996
Researcher	Institute for Environmental Science	1996-1999
Associate Professor	Hydrogen Isotope Research Center, University of Toyama	1999-2016
Professor	Quantum Beam Science, Ibaraki University	2016-

Scientific Interests: Fusion Science and Engineering, Tritium Science and Technology for Fusion, Environmental Dynamics.

Prof. Tetsuya Suzuki

Scientific Career

University	Mechanical engineering; Yokohama National University	1984-1989
MSc Work	Yokohama National University	1989-1991
PhD Work	Yokohama National University	1991-1994
Assistant Professor	Material Science; Ibaraki University	1994-2000
Senior Lecturer	Material Science; Ibaraki University	2000-2005
Associate Professor	Material Science; Ibaraki University	2005-2012
Professor	Material Science; Ibaraki University	2012-

Scientific Interests: Strength and Microstructure of Steel and Light Metals.

Prof. Chihiro Iwamoto

Scientific Career

University	Materials Science, The University of Tokyo	1985-1990
MSc Work	Materials Science, The University of Tokyo	1990-1992
PhD Work	Materials Science, The University of Tokyo	1992-1995
Post-Doc	ERATO, Japan Science and Technology	1995-1998
Assistant Professor	Materials Science, The University of Tokyo	1998-2004
Associate Professor	Mechanical Engineering, Kumamoto University	2004-2014
Visiting Scholar	Materials Science and Metallurgy, University of Cambridge	2008-2009
Professor	Materials Science, Ibaraki University	2014-2016
Professor	Quantum Beam Science, Ibaraki University	2016-

Scientific Interests: Development of observation techniques for the atomic structure and movement at the interface in engineering processes. Interface microstructure produced by ultrasonic welding, or various kinds of welding methods

Prof. Kenji Ohoyama

Scientific Career

University	Physics, Tohoku University	1986
MSc Work	Physics, Tohoku University	1986-1988
PhD Work	Physics, Tohoku University	1988-1992
Assistant Professor	Physics, Institute for Materials Research, Tohoku University	1992-2003
Associate Professor	Physics, Institute for Materials Research, Tohoku University	2003-2014
Associate Professor	Physics, Advanced Institute for Materials Research, Tohoku University	2014-1015
Professor	Applied Beam Science, Ibaraki University	2015-2016
Professor	Quantum Beam Science, Ibaraki University	2016-

Scientific Interests: Condensed matter physics in particular strongly correlated electron system. Neutron science.

Prof. Seiu Otomo

Scientific Career

University	Department of Fuel Chemistry, Akita University	1980-1984
MSc Work	Graduate School of Engineering, Tohoku University	1985-1986
PhD Work	Graduate School of Engineering, Tohoku University	1987-1990
Post-doc	Research School of Chemistry, Australian National University	1991-1993
Lecturer	Graduate School of Engineering, Tohoku University	1993-1995
Associate Professor	Graduate School of Engineering, Tohoku University	1995-2005
Professor	Faculty of Science, Ibaraki University	2005-

Scientific Interests: Bacterial photosynthesis, Spectroscopy, Structural biology, Bioenergetics.

Prof. Fumitoshi Iga

Scientific Career

University	Physics, Tohoku University	1982
MSc Work	Physics, Tohoku University	1982-1984
PhD Work	Physics, Tohoku University	1984-1989
Head Researcher	ElectroTechnical Laboratory, Agency of Industrial Science Technology, The Ministry of International Trade and Industry	1989-1996
Associate Professor	Physics, Hiroshima University	1996-1997
Associate Professor	Quantum Matter, Graduate School of Advanced Sciences of Matter, Hiroshima University	1997-2011
Professor	Physics, Ibaraki University	2011-

Scientific Interests: Condensed matter physics in particular strongly correlated electron system. Material design by high-pressure synthesis and floating zone-melted method using the image furnace.

Assoc. Prof. Noriko Yamauchi

Scientific Career

University	Department of Chemical Engineering, Faculty of Engineering, Tohoku University	2001-2004
MSc Work	Department of Chemical Engineering, Graduate School of Engineering, Tohoku University	2005-2006
PhD Work	Department of Chemical Engineering, Graduate School of Engineering, Tohoku University	2007-2009
Post-Doc	Chemical Engineering, Tohoku University	2010
Assistant Professor	Department of Applied Chemistry and Biochemistry, National Institute of Technology, Fukushima College	2010-2018
Assistant Professor	Faculty of Applied Science and Engineering, Ibaraki University	2018-2022
Lecturer	Faculty of Applied Science and Engineering, Ibaraki University	2022-2023
Associate Professor	Faculty of Applied Science and Engineering, Ibaraki University	2024-

Scientific Interests: Development of Synthesis Processes for Functional Nanoparticles Combining Various Materials, Including Polymers, Inorganic Substances, and Biomaterials.

Assoc. Prof. Koichi Nakashima

Scientific Career

University	Department of Industrial Chemistry, Faculty of Science and Engineering, Nihon University	1996-2000
MSc Work	Department of Industrial Chemistry, Graduate School of Science and Engineering, Nihon University	2000-2002
PhD Work	Department of Human and Environmental Studies, Graduate School of Human and Environmental Studies, Kyoto University	2002-2005
Post-Doc	Venture Business Laboratory, Kyoto University	2005-2006
Post-Doc	Institute of Multidisciplinary Research for Advanced Materials, Tohoku University	2006-2007
Employee	Organic Synthesis Research Laboratory, Sumitomo Chemical Co., Ltd.	2007-2010
Assistant Professor	Department of Applied Chemistry, Faculty of Engineering, University of Yamanashi	2010-2016
Visiting Assistant Professor	Institute of Inorganic Chemistry, University of Zurich, Switzerland	2011-2012
Associate Professor	Department of Biomolecular Functional Engineering, College of Engineering, Ibaraki University	2016-2018

Associate Professor	Department of Materials Science and Engineering, College of Engineering, Ibaraki University	2018-

Scientific Interests: Inorganic chemistry, Ceramics.

Assoc. Prof. Hiromi Iinuma

Scientific Career

University	Physics, Yokohama National University	1991-1995
MSc Work	Physics, Nagoya University	1995-1997
PhD Work	Physics, Kyoto University	2003(*)-2006
Research Associate	Physics, Brookhaven National Laboratory	2006-2008
Post-Doc	Physics, High Energy Accelerator Research Organization (KEK)	2008-2011
Assistant Professor	Accelerator dept., High Energy Accelerator Research Organization (KEK)	2011-2016.9
Associate Professor	Applied Beam Science, Ibaraki University	2016.10-
Visiting Associate Professor	Physics, High Energy Accelerator Research Organization (KEK)	2018. 4-

(*) 1997-2003 Engineer at a private company.

Scientific Interests: High energy accelerator physics experiment, fundamental physics by use of spin 1/2 particle (muon, proton, electron), beam physics, beam line engineering for ultra-cold muon beam. Application of Mu beam for material life science.

Assoc. Prof. Takehito Nakano

Scientific Career

University	Physics, Tohoku University	1991-1996
MSc Work	Physics, Tohoku University	1996-1998
PhD Work	Physics, Tohoku University	1998-2001
Post-Doc	Physics, Research Fellow of Japan Society for the Promotion of Science (JSPS)	2001.4-2001.11
Post-Doc	Physics, JASRI SPring-8	2001.11-2003
Assistant Professor	Physics, Osaka University	2003-2018
Associate Professor	Physics, Ibaraki University	2018-
Visiting Associate Professor	Physics, High Energy Accelerator Research Organization (KEK)	2019-2022

Scientific Interests: Condensed matter physics in nano-structured materials, Muon science.

Assoc. Prof. Akinori Hoshikawa

Scientific Career

University	Physics, Faculty of Science, Hokkaido University	1990-1994
MSc Work	Physics, Graduate school of Sciences, Hokkaido University	1994-1996
PhD Work	Physics, Graduate school of Sciences, Hokkaido University	1996-1999
Post-Doc	Research Fellowship for Young Scientists (PD), Japan Society for the Promotion of Science	1999-2001
Post-Doc	Neutron Science Division, Institute of Materials Structure Science, High Energy Accelerator Research Organization	2001-2004
Post-Doc	Quantum Beam Science Division, Japan Atomic Energy Agency	2004-2007
Assistant Professor	Established preparation room for Frontier Research Center for Applied Atomic Sciences, Ibaraki University	2007-2008
Assistant Professor	Frontier Research Center for Applied Atomic Sciences, Ibaraki University	2008-2010
Associate Professor	Frontier Research Center for Applied Atomic Sciences, Ibaraki University	2010-2024
Associate Professor	Research and Education Center for Atomic Sciences, Ibaraki University	2024-

Scientific Interests: Crystal structure related to hydrogen bonding, especially clathrate hydrate. Besides, development of powder neutron diffraction instrument.

Assist. Prof. Haruki Nagakawa

University	Industrial Chemistry, Tokyo University of Science	2014-2018
MSc Work	Industrial Chemistry, Tokyo University of Science	2018-2020
PhD Work	Industrial Chemistry, Tokyo University of Science	2020-2022
Post-Doc	JSPS Research Fellowship for Young Scientists, The University of Tokyo	2022-2023
Assistant Professor	Faculty of Applied Science and Engineering, Ibaraki University	2023-

Scientific Interests: Photocatalysis, Solar energy conversion, Hydrogen production, Photo-electrochemistry.

Assist. Prof. Masahiro Kuramochi

Scientific Career

University	Engineering, Ibaraki University	2009
MSc Work	Engineering, Ibaraki University	2009-2011
PhD Work	Biology, University of Tsukuba	2014-2017
Assistant Professor	Advanced Materials Science, the Graduate School of Frontier Sciences, the University of Tokyo	2017-2021
Assistant Professor	Department of Materials Science and Engineering, College of Engineering, Ibaraki University	2021-

Scientific Interests: Biophysics, Nano-dynamics observation

Assistant Prof. Tomoki Maeda

Scientific Career

University	Mechanical Engineering, Keio University	2007-2011
MSc Work	School of Science for Open and Environmental Systems, Graduate School of Science and Engineering, Keio University	2011-2013
PhD Work	School of Science for Open and Environmental Systems, Graduate School of Science and Engineering, Keio University	2013-2016
Research Assistant	Global Environmental System Leaders Program (Keio University), Program for Leading Graduate Schools, Ministry of Education, Culture, Sports, Science and Technology	2013-2015
Visiting Researcher	Professor Craig J. Hawker's Group, Materials Research Laboratory, University of California, Santa Barbara	2013 2016
Assistant Professor	Mechanical Engineering, Keio University	2015-2017
Visiting Assistant Professor	Mechanical Engineering, Keio University	2018-2023
Assistant Professor	Frontier Research Center for Applied Atomic Science, Ibaraki University	2018-2023
Assistant Professor	Research and Education Center for Atomic Sciences, Ibaraki University	2024-
Visiting Researcher	Professor Craig J. Hawker's Group, Materials Research Laboratory, University of California, Santa Barbara	2024

Scientific Interests: Harmonizing the synthesis, the structural analysis, and the physical properties is the key to the invention of novel polymeric materials with high functionalities. We utilize electron microscopy and synchrotron-radiation scattering for the nano- and micron-scale structural analyses to link the structure with the physical properties. Atomic-scale molecular structures will be controlled by the synthesis in order to deepen the basic understanding of structure-function relationships of polymers.

Assist. Prof. Kimiko Yamashita

Scientific Career

University	Department of Physics, Yamagata University	2002-2006
MSc Work	Department of Physics, Ochanomizu University	2013-2015
PhD Work	Department of Physics, Ochanomizu University	2015-2018
Course Student with a scholarship	Minor Course of Science and Technology for Global Leaders, Program for Leading Graduate Schools, Ochanomizu University	2014-2018
Visitor	Virginia Tech in the USA	8-12. 2015
Visitor	LPSC Grenoble in France	11.2016-5.2017
Post-Doc	The thematic group 2: "Dark Physics of the Universe" in National Center for Theoretical Sciences in Taiwan	2018
Post-Doc	National Tsing Hua University in Taiwan	2018-2019
Post-Doc	Institute of High Energy Physics, Chinese Academy of Sciences in China	2019-2021
Post-Doc	Chung-Ang University in Republic of Korea	2021-2023
Assistant Professor	Physics, Ibaraki University	2023-

Scientific Interests: High Energy Physics, Cosmology, Dark Matter

5.3 Further Key Scientists through the Strongly Collaborative Institutes

Prof. Takayuki Oku (Cross-appointment, JAEA)	Neutron Science
Prof. Kazuhiro Mori (Cross-appointment, KEK)	Neutron Science
Prof. Akinori Yokoya (Cross-appointment, QST)	Radiation Biology
Assoc. Prof. Hitoshi Abe (Cross-appointment, KEK)	Synchrotron Radiation Chemistry
Prof. Tetsuya Hirade (JAEA)	Positron Science
Prof. Sakae Kinase (JAEA)	Radiation Protection
Prof. Tetsuya K. Sato (JAEA)	Nuclear Chemistry
Prof. Takamitsu Morioka (QST)	Radiation Biology
Prof. Satoshi Kunieda (JAEA)	Nuclear Reactor Engineering
Prof. Masa Watanabe (JAEA)	Radiation Chemistry
Prof. Naoto Metoki (JAEA)	Neutron Science
Prof. Toyohiko Kinoshita (JASRI)	Synchrotron Radiation Physics
Prof. Satoshi Tsutsui (JASRI)	Synchrotron Radiation Physics

JAEA: Japan Atomic Energy Agency, QST: Quantum and Radiological Science and Technology, KEK: High Energy Accelerator Research Organization, JASRI: Japan Synchrotron Radiation Research Institute.

5.4 Activities in the scientific community, honors, awards (selected)

Selected Paper in the *Bulletin of the Chemical Society of Japan*	2016
Editors' Suggestion in *Physics Review*	2016
Best Paper Award, the 18th Int. Conf. Chem. Eng. Appl.	2016
Nishiyama Commemorative Prize, The Iron and Steel Institute of Japan	2016
President Choice, Hamon, The Japanese Society for Neutron Science	2016
Councilor of Crystallographic Society of Japan	2016-2017
The Japanese Radiation Research Society Iwasaki Tamiko Award	2017
Editors' Suggestion in *Physics Review*	2017
VIP paper in *Angewandte Chemie, International Edition*	2017
Selected Paper in the *Bulletin of the Chemical Society of Japan*	2017
AESJ Best Paper Award	2018
Inspector of the Japanese Radiation Society	2017-2018
Member of Photon Factory Synchrotron Radiation Cooperation Experiment Committee	2017-2018
Delegate of the Biophysical Society of Japan	2017-2018
Organizing Committee Member of the 15th International Symposium on Inorganic Ring Systems	2018
The Technological Contribution Award, Society of Automotive Engineers of Japan	2018
Sawamura Award, The Iron and Steel Institute of Japan	2019
Manager of Protein Crystallography Group in Photon Factory User's Association	2015-
Councilor of the Japanese Society for Neutron Science	2017-
Delegate of the Physics Society of Japan	2017-
Head editor of the Journal of Physical Society of Japan	2018-
Achievement Award, 13th Reproc. Recy. Tech. Div. Awd, Atom. Ene. Soc. Japan	2018
Hot Topics Award, Ann. Meet. Jpn Soc. Biosci., Biotech., Agrochem.	2018
NIPPON Mektron Ltd. award, 3rd Ibaraki tech Planter Grand Prix, Leave a Nest Co., Ltd.	2018
Audience award, 3rd Ibaraki tech Planter Grand Prix, Leave a Nest Co., Ltd.6th	2018
Director General Award of KEK Student Day, High Ene. Accel. Res. Org.	2018
Bio-tech Grand Prix, YOSHINOYA CO., LTD. award, Leave a Nest Co., Ltd.	2019
ROHTO Pharmaceutical Co., Ltd. award, Leave a Nest Co., Ltd.	2019
Distinguished Scientist Award, Jpn Rad. Res. Soc.	2019
Presentation Award for Young Researcher, The Japanese Beam Physics Club	2019
The 2019 Fellow Award, Atomic Energy Society of Japan	2020
Silver Prize, Tanaka Kikinzoku Memorial Foundation	2022
Paper Encouragement Award, Japan Radioisotope Association	2022
Encouragement Award, The Japan Petroleum Institute	2022
GSC Award, Japan Association for Chemical Innovation	2022
Academic Award, The Society of Inorganic Materials	2022
Technical Award, The Japanese Society for Experimental Mechanics (JSEM)	2022
Toshiko Yuasa Award from Toshiko Yuasa Laboratory, Ochanomizu University	2023
Society Award (Paper Award), Japan Health Physics Society	2023
Academic Achievement Award, Atomic Energy Society of Japan	2024
Outstanding Research Award, Japanese Society for DNA Polymorphism Research	2024

5.5 Collaborations with Industrial Companies

The IQBS has collaborations with Industry. The representative collaborations between IQBS and industrial companies are listed below.

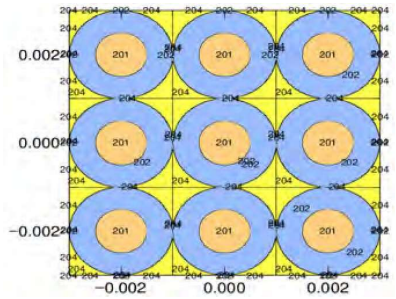
2016FY (Total 30 Industrial companies)
2017FY (Total 34 Industrial companies)
2018FY (Total 30 Industrial companies)
2019FY (Total 30 Industrial companies)
2020FY (Total 44 Industrial companies)

2021FY (Total 31 Industrial companies)
2022FY (Total 45 Industrial companies)
2023FY (Total 46 Industrial companies)
2024FY (Total 54 Industrial companies)

6 Recent Research Topics

Tritium Science and Technology in Ibaraki University
Yuji Torikai

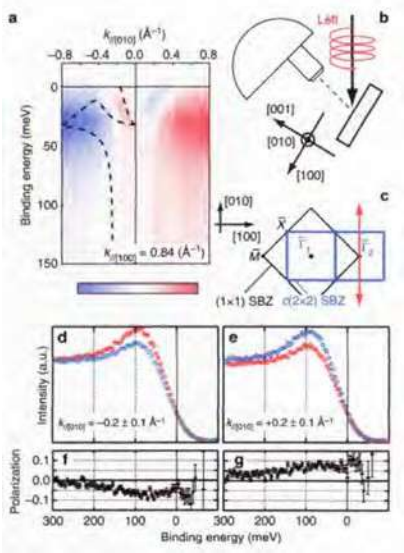
The Fukushima Daiichi Nuclear Power Plant was destroyed by the earthquake that occurred on March 11, 2011. Large amounts of radionuclides leaked into the environment. Tritium also leaked in the form of tritiated water. One million tons of tritiated water (HTO) are filled in many tanks on the nuclear power plant. The tritium concentration was 4,000 Bq/cc at the time of the accident, but it is now about 300 Bq/cc. The most effective and safe method of disposing HTO is releasing out to sea. We are studying how to safely release tritiated water into the ocean. We are investigating the migration pathway to the living area when tritiated water is released into the ocean. We are developing a simple and rapid method of measuring tritium concentration in seawater and food. We are investigating the effects of tritium on human cells. The cells are cultured in tritiated water or tritiated thymidine. We are investigating the relationship between cell viability and dose to cells calculated by the Monte Carlo method using PHITS.



Schematic diagram of the Monte Carlo calculation of cell doses

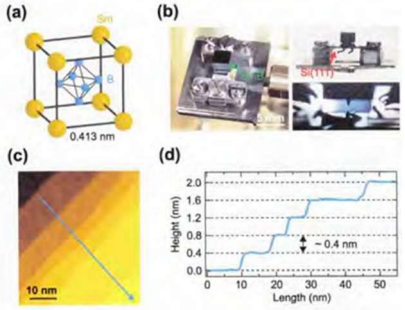
Surface Kondo effect and novel metallic state found in the Kondo insulator YbB_{12}
Fumitoshi Iga

New topological surface states of quantum matter on Kondo insulators (KIs), so-called topological Kondo insulators (TKIs), have been attracted attention. One TKI candidate is the valence fluctuating KI SmB_6, and the origin of the surface states (SS) along the (001) surface and the topological order of SmB_6 have been actively discussed to date. We show the evidence of a metallic SS on a clean surface along (001) of another TKI candidate YbB_{12} using spin and angle-resolved photoelectron spectroscopy. Despite the insulating character of the bulk at low temperatures, the metallic spin-polarized SS with a closed Fermi contour surrounding the Γ point of the surface Brillouin zone has been observed and is consistent with a theoretically expected behaviour for topologically protected SS of TKIs. The electrons in the metallic SS are considered to be new-type Dirac fermions with the strongly correlation to the Kondo insulating state.The right figure was quoted from Nature Communications 7 (2016) 12690 (Hagiwara et al.).



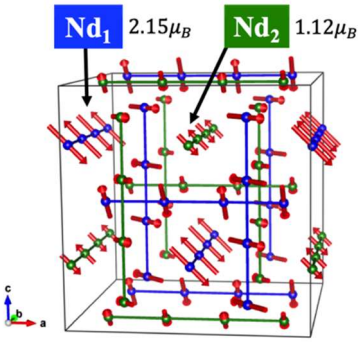
Evidence for in-gap surface states on the single phase SmB_6 (001) surface by STM
Fumitoshi Iga

Structural and electronic properties of the SmB_6 (001) single-crystal surface prepared by Ar+ ion sputtering and controlled annealing are investigated by scanning tunneling microscopy (STM). In contrast to the cases of cleaved surfaces, we observe a single phase surface with a non-reconstructed (1 x 1) lattice on the entire surface at an optimized annealing temperature. The surface is identified as Sm-terminated on the basis of spectroscopic measurements. On a structurally uniform surface, the emergence of the in-gap state, a robust surface state against structural variation, is further confirmed inside a Kondo hybridization gap at 4.4 K by temperature and atomically-resolved spatial dependences of the differential conductance spectrum near the Fermi energy.



(a) Left figure was quoted from Scientific Reports, 7 (2017) 12837 (Miyamachi et al.). (a) Schematic crystal structure of SmB_6. (**b**) Photographs of the SmB_6 (001) single crystal and its mounting. (**c**) STM image of the SmB_6 (001) surface annealed at 1030 C. (**d**) STM height profile of atomic steps along the blue line in (**c**). The interval between the grid lines in height is nearly equal to the lattice constant of SmB_6.

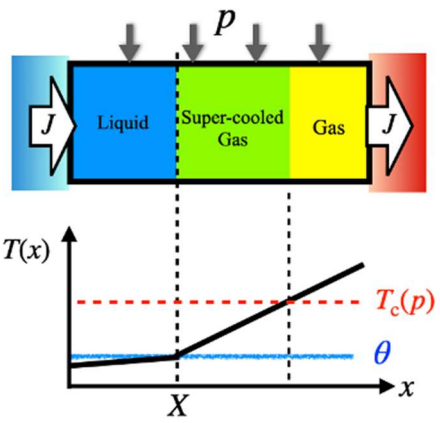
New electronic states along with simultaneous violation of parity and time-reversal symmetry
Kazuaki Iwasa



Symmetry of matters causes unconventional electronic and magnetic states like topological (Dirac/Weyl) fermions in noncentrosymmetric structures. To find such nontrivial electronic states, our laboratory has studied spontaneous formation of noncentrosymmetric crystal structure (parity violation) and magnetic ordering (time-reversal symmetry violation) in $Ln_3Tr_4Sn_{13}$ (Ln = rare earth elements, Tr = Co, Rh and Ir). The series of $Ce_3Tr_4Sn_{13}$ undergoes phase transformations to chiral-symmetry structure and considerably suppressed magnetic degrees of freedom [1]. This phenomenon is successfully explained by the Weyl–Kondo semimetal, which is associated with the hybridized Ce 4*f* and conduction electrons with linear-momentum-dependent energy like a photon particle. We extend the study to reveal magnetic ordering in $Nd_3Tr_4Sn_{13}$, which shows the same chiral structural transformation [2]. As shown in the figure, the determined characteristic magnetic ordered structure indicates a new type of ground state formation by the simultaneous violation of parity and time-reversal symmetry. The studies were conducted under collaboration with the neutron-scattering divisions of J-PARC MLF and The Institute for Solid State Physics (The University of Tokyo), and synchrotron x-ray scattering facility The Photon Factory of KEK.

[1] K. Iwasa, K. Suyama, S. Ohira-Kawamura, K. Nakajima, S. Raymond, P. Steffens, A. Yamada, T. D. Matsuda, Y. Aoki, I. Kawasaki, S.-i. Fujimori, H. Yamagami, and M. Yokoyama, Phys. Rev. Mater. 7, 014201 (2023).
[2] A. Shimoda, K. Iwasa, K. Kuwahara, H. Sagayama, H. Nakao, M. Ishikado, A. Nakao, S. Ohira-Kawamura, N. Murai, T. Ohhara, and Y. Nambu, JPS Conf. Proc. 38, 011091 (2023) and Phys. Rev. B 109, 134425 (2024) Editors' Suggestion.

Global Thermodynamics for heat conduction systems
Naoko Nakagawa

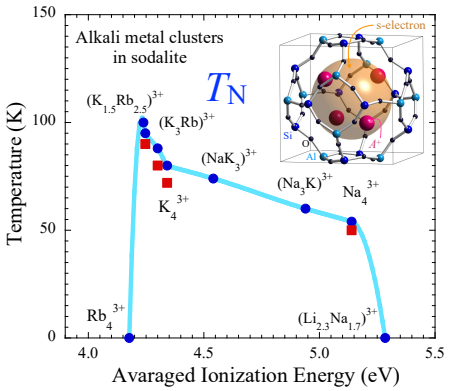


We propose global thermodynamics as a new framework for describing macroscopic properties in the presence of heat flows [1]. Global thermodynamics predicts that steady heat flow can stabilize meta-stable states, such as super-cooled gas and super-heat liquid, although they are not thermodynamically stable in equilibrium. For instance, in H_2O at atmospheric pressure in contact with two thermostats of 95°C and 105°C, the temperature at the liquid-vapor interface is estimated to be 95.2°C by global thermodynamics, which is lower than the equilibrium transition temperature. A macrosopic region is occupied by meta stable states as shown in the figure. Numerical simulations with a microscopic model reproduced the theoretical preditions of global thermodynamics [2].

[1] N. Nakagawa, S.-i. Sasa, *Phys. Rev. Lett.* **119**, 260602 (2017), *J. Stat. Phys.* **177**, 825-888 (2019), *Phys. Rev. Res.*, **4**, 033155 (2022)
[2] M. Kobayashi, N. Nakagawa, S.-i. Sasa, *Phys. Rev. Lett.*, **130**, 247102 (2023)

Magnetic Orders of *s*- and *p*-Electron Systems
Takehito Nakano

Magnetic order typically requires *d*-electrons in transition metals and *f*-electrons in rare earths. An example that defies such conventional wisdom is alkali metal nanoclusters arranged in porous zeolite crystals in which *s*-electrons exhibit various magnetic orders. In our recent study, a systematic change in antiferromagnetic order and Mott and polaron transitions were found by changing the composition of alkali metal clusters in sodalite [1]. We established the phase diagram (the figure). Another example is molecular systems. In alkali superoxide AO_2, *p*-electrons of the O_2^- molecule show interesting magnetism accompanied with molecular orbital order. Recently, we revealed for the first time the antiferromagnetic structure of CsO_2 at low temperatures by neutron diffraction using JRR-3 [2].



[1] T. Nakano, K. Watanabe, A. Hanazawa, Y. Ishida, K. Tanibe, and R. Sakon, Dalton Transactions **53**, 7358 (2024).
[2] T. Nakano, S. Kontani, M. Hiraishi, K Mita, M. Miyajima, and T. Kambe, Journal of Physics: Condensed Matter **35**, 435801 (2023).

Physics Beyond the Standard Model
Kimiko Yamashita

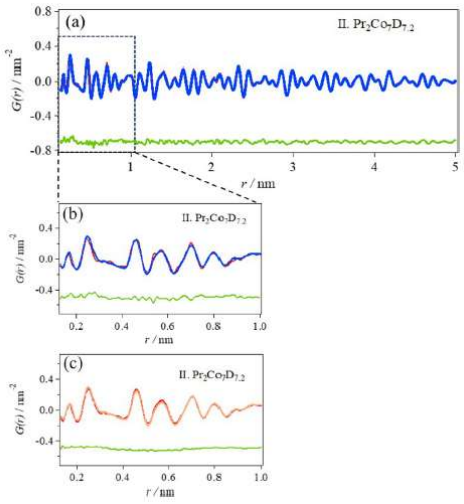
Effective Field Theory Approach in Physics Beyond the Standard Model: I am interested in Physics Beyond the Standard Model. Effective Field Theory (EFT) is useful to include the physics with the massive new particles in a model-independent way. For example, based on the EFT, we see the possibility of some BSM to explain dark matter phenomenology [1,2,3].
Construction and Testing Feasibility of Theory Based on the Experiments: When there is a discrepancy between the predictions of the Standard Model and experimental data, I attempt to explain it in terms of a model that includes new interactions. For the possible muon g-2 discrepancy, which will be theoretically/experimentally confirmed, we construct the model to make the possible muon g-2 discrepancy from the Standard Model and discuss the feasibility of testing the model in future experiments [4,5,6,7].

[1] S. S. Kim, H. M. Lee and K. Yamashita, JHEP **06**, 124 (2023).
[2] S. S. Kim, H. M. Lee and K. Yamashita, JHEP **11**, 119 (2023).
[3] K. Yamashita, JHEP **10**, 205 (2024).
[4] H. M. Lee, J. Song, K. Yamashita, J. Korean Phys. Soc. 79 no. 12, 1121-1134 (2021).
[5] H. M. Lee and K. Yamashita, Eur. Phys. J. C 82, no.8, 661 (2022).
[6] S. S. Kim, H. M. Lee, A. G. Menkara and K. Yamashita, Phys. Rev. D 106, no.1, 015008 (2022).
[7] C. Branchina, H. M. Lee, and K. Yamashita, arXiv:2407.14826 [hep-ph].

Crystal and local structures of $Pr_2Co_7D_x$ during absorption process

Kenji Iwase

The crystal and local structures of Pr_2Co_7, $Pr_2Co_7D_{2.7}$ and $Pr_2Co_7D_{7.2}$ by neutron diffraction. The crystal structure transformed in the order Ce_2Ni_7-type Pr_2Co_7 → Ce_2Ni_7-type $Pr_2Co_7D_{2.7}$ → orthorhombic $Pr_2Co_7D_{7.2}$. The determined structural model of $Pr_2Co_7D_{2.7}$ was the Ce_2Ni_7-type structure by Rietveld refinement, where the deuterium atoms occupied both the $CaCu_5$-type (I) and the $MgZn_2$-type cells. The deuterium contents in these cells were 0.10 and 0.80 D/M, respectively. The expansions of the lattice parameters of $Pr_2Co_7D_{7.2}$ from the original intermetallics were $\Delta a = 5.9\%$, $\Delta b = 6.2\%$, and $\Delta c = 6.4\%$; nearly isotropic expansion was observed. The deuterium contents in the $MgZn_2$-type, $CaCu_5$-type (I), and $CaCu_5$-type (II) cells were 1.11, 0.44, and 0.83 D/M, respectively. The refined structural parameters by a pair distribution function (PDF) analysis on Pr_2Co_7 ($0.18 < r < 5.0$ nm) and $Pr_2Co_7D_{2.7}$ ($0.13 < r < 5.0$ nm) obtained were consistent with those obtained by Rietveld refinement. The refined structural parameters of the short-range structure ($0.13 < r < 1.0$ nm) in $Pr_2Co_7D_{7.2}$ did not correspond to those of the long-range structure ($0.13 < r < 5.0$ nm). The local distortion within the domain of approximately 1.0 nm in size exists in $Pr_2Co_7D_{7.2}$.

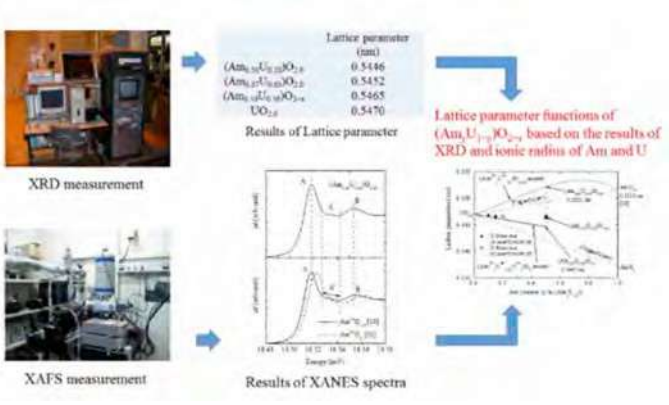


1) K. Iwase, et.al., *Inorg. Chem*. 63, (2024), pp.21252-21259.

Lattice parameter functions of $(Am_yU_{1-y})O_{2-x}$ based on XRD and XANES measurements

Tsuyoshi Nishi

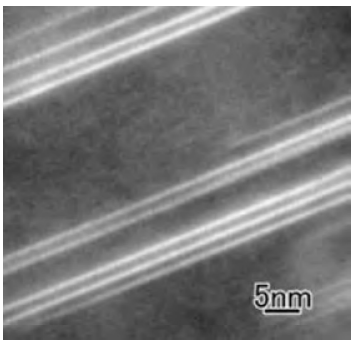
The lattice parameters of $(Am_{0.50}U_{0.50})O_{2.0}$, $(Am_{0.37}U_{0.63})O_{2.0}$, and $(Am_{0.50}U_{0.50})O_{2-x}$ were determined by powder X-ray diffraction with Cu K_α radiation. In addition, the lattice parameter functions of $(Am_yU_{1-y})O_{2-x}$ ($0.00<x<0.25$, $0.00<y<0.50$) were evaluated using models of $(Am^{3+}{}_yU^{4+}{}_{1-2y}U^{5+}{}_y)O_2$ and $(Am^{3+}{}_yU^{4+}{}_{1-y})O_{2-y/2}$ based on the results of X-ray diffraction and the ionic radii of Am^{3+}, U^{4+}, and U^{5+}. To confirm the valence state of Am and U in $(Am_yU_{1-y})O_{2-x}$, the X-ray absorption near-edge structure measurements were performed in the transmission mode at the Am-L_{III} and U-L_{III} absorption edges of $(Am_{0.50}U_{0.50})O_{2.0}$, $(Am_{0.50}U_{0.50})O_{2-x}$, and $UO_{2.0}$.



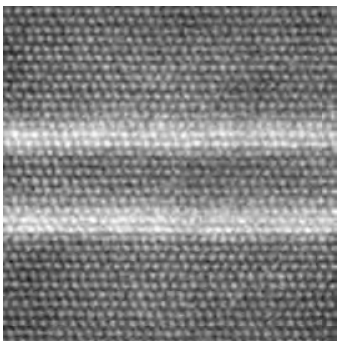
[1] T. Nishi, M. Nakada, M. Hirata, Journal of Solid State Chemistry 256 (2017) 252.

Interface Atomic Structure of Mg-Zn-Y Joints Bonded by Ultrasonic Welding
Chihiro Iwamoto

Mg-Zn-Y alloy with long-period-stacking-order ed (LPSO) structures is actively studied due to its excellent mechanical properties. Toward practical use, ultrasonic welding was applied, and the interface microstructure was investigated using scanning transmission electron microscopy. In the fine grains around the interface, Zn and Y segregated at mainly two atomic layers in the basal plane of the Mg hcp structure. It was suggested that $L1_2$ type Zn/Y units produced from the LPSO phase during the ultrasonic welding.



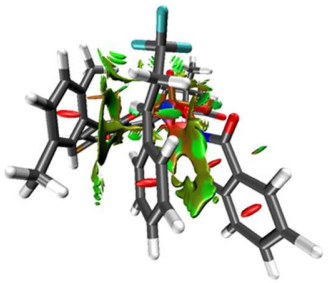
Zn and Y segregation in the Mg matrix


Zn/Y $L1_2$ units formed parallel to the basal plane of Mg hcp structure

(Annual Assembly of International Institute of Welding 2017, Shanghai, China)

Computational Studies on Molecular Bond Activation Reactions
Seiji Mori

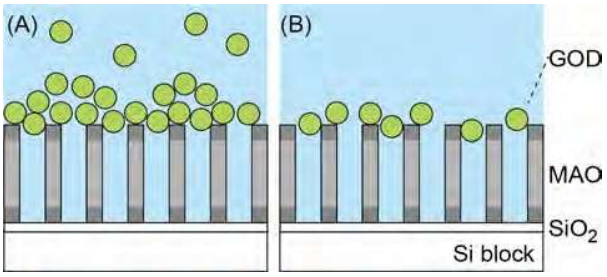
Our interests encompass enzymatic reaction mechanisms and metal-catalyzed, highly selective transformation reactions, such as C-C, C-O, or C-H bond activation. We aim to design catalysts using quantum mechanical computations. For example, the right figure illustrates the noncovalent interactions in a vanadium-catalyzed, stereoselective three-component coupling reaction of styrene with a CF_3 radical.



[1] M. C. Schwarzer, S. Mori, et al. *J. Am. Chem. Soc.* **2017**, *139*, 10347.
[2] T. Yoshimura, S. Maeda, T. Taketsugu, M. Sawamura, K. Morokuma, and S. Mori, *Chem. Sci.* **2017**, *8*, 4475.
[3] H. Mitsuizumi, S. Mori,* Combined MD and QM/MM Investigations of Hydride Reduction of 5α-Dihydrotestosterone Catalyzed by Human 3α-Hydroxysteroid Dehydrogenase Type 3: Importance of Noncovalent Interactions, *J. Phys. Chem. B.* **2021**, *125*, 4998-5008.
[4] C.-T. Chen, Y.-P. Chen, B.-Y. Tsai, Y.-Y. Liao, Y.-C. Su, T.-C. Chen, C.-H. Lu, R. Fujii, K. Kawashima, S. Mori, *ACS Catalysis*, **2020**, *10*, 367.
[5] R. Yoshimoto, A. Taborosi, Q. He, Y. Ano, N. Chatani, S. Mori,* Theoretical Investigations of Palladium-Catalyzed [3+2] Annulation via Benzylic and meta C−H Bond Activation, *Chem Asian J.*, **2023**, e202300531.
[6] C.-T. Chen,* S.-F. Hung, B.-Y. Tsai, T.-C. Chen, C.-I Lein, P.-X. Tseng, Y.-C. Chang, C.-W. Chuang, R. Agarwal, C.-W. Hsu, Y. Shimizu, R. Fujii, S. Mori,* Asymmetric Cross Couplings of Trifluoromethyl Radical to Vinylarenes with N-Hydroxy-oxazinediones and Subsequent Aerobic Oxidative Homocoupling of 2-Naphthols Catalysed by Chiral Vanadyl Complexes, *Adv. Syn. Cat.* **2024**, 366, 248-261.
[7] D. G. Fedorov, D. Inostoza, B. Courbiere, F. Guegan, J. Contreras-Garcia, S. Mori, Decomposition Analysis for Visualization of Non-Covalent Interactions Based on the Fragment Molecular Orbital Method, *J. Chem. Theory Comput.* In press. DOI: 10.1021/acs.jctc.4c01654

Structural Characterization of Biomacromolecules Confined inside Nanopores

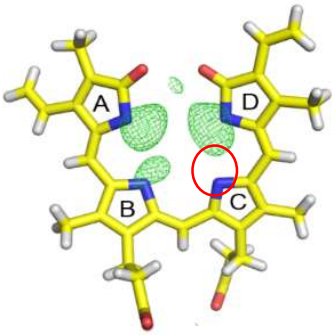
Akira Yamaguchi



Inorganic nanoporous materials have been used as host of functional proteins, and a method for structural characterization of the confined protein has been demanded.[1] We demonstrated that contrast-variation small-angle neutron scattering (CV-SANS) was powerful method to determine tertiary structures of myoglobin confined inside silica nanopores.[2] Neutron reflectometry and differential scanning calorimetry methods are available to determine distribution of protein molecules on/in the nanoporous materirals.[3-5] The fluorescence energy transfer (FRET) is powerful tool for quantitative analysis of DNA duplex formation inside the nanopores.[6]

[1] A. Yamaguchi, et al. *Anal. Sci.* in press (**Invited Review**).
[2] J. Kijima, et al. *J. Phys. Chem. C* **2018**, *122*, 15567.
[3] A. Yamaguchi, et al. *Anal. Sci.* **2018**, *34*, 1393 (**Hot Articles**).
[4] A. Yamaguchi, et al. *Bull. Chem. Soc. Jpn* **2020**, *93*, 630.
[5] A. Yamaguchi, et al. *ACS Omega* **2020**, *5*, 22993.
[6] H. Arafune, et al. *Nat. Commun.* **2014**, *5*, 5151.

Structure-function relationships of important proteins relevant to the global environment and human health
Masaki Unno



We have researched to elucidate various important proteins' steric structures, functions, and reactions. The target proteins are, for instance, photosynthetic pigment synthases [1,2], photosynthesis-related proteins, enzymes that catalyze post-translational modifications known as citrullination [3,4] and their substrate protein [5] in human cells, and a group of proteins that repair some types of human DNA damages. Recently, we have elucidated the mechanism that controls the redox potential of ferredoxin, an electron-transfer protein [6]. We also revealed that differences in the optical absorption wavelengths of photosynthetic pigments correlate with differences in the protonation state of the pigments [2]. Our group is particularly strong in analyzing three-dimensional structures at hydrogen atom-level resolution. By clarifying the role of hydrogen atoms in living organisms, we would like to propose environmental protection solutions and design drugs for disease treatment.

[1] M. Unno, et al., *J. Am. Chem. Soc.*, **2015**, 137, 5452-5460
[2] T. Joutsuka, et al., M. Unno, *J. Biol. Chem.*, **2023**, 299, 102763
[3] S. Saijo, et al., M. Unno, *J. Mol. Biol.*, **2016**, 428, 3058-3073
[4] K. Funabashi, et al., M. Unno, *Arch. Biochem. Biophys.*, **2021**, 708, 108911
[5] M. Unno, et al., *J. Mol. Biol.*, **2011**, 408l, 477-490
[6] K. Wada, et al., M. Unno, *eLife*, **2024**, in press

Probing Structure–Function Relationships in Bacterial Photosynthesis

Seiu Otomo

Photosynthetic bacteria have provided fundamental insight into the biological mechanism of solar energy conversion. Early events in photosynthesis are carried out by the antenna apparatus for light-harvesting (LH) and the reaction center (RC) for charge separation. The native core light-harvesting complex LH1 from the thermophilic purple phototrophic bacterium *Thermochromatium* (*Tch.*) *tepidum* requires Ca^{2+} for its thermal stability and characteristic absorption maximum at 915 nm.[1-3] Recently, this core complex has been crystallized and its structure has been determined.[4,5] Here, we present a cryo-EM structure of the *Thiorhodovibrio* strain 970 LH1-RC complex at 2.82 Å resolution.[6] The LH1 forms a closed ring structure composed of sixteen pairs of the αβ-polypeptides. Sixteen Ca ions are present in the LH1 C-terminal domain and are coordinated by residues from the αβ-polypeptides that are hydrogen-bonded to BChl *a*. The Ca^{2+}-facilitated hydrogen-bonding network forms the structural basis of the unusual LH1 redshift. The structure also revealed the arrangement of multiple forms of α- and γ-polypeptides in an individual LH1 ring. Such organization indicates a mechanism of interplay between the expression and assembly of the LH1 complex that is regulated through interactions with the RC subunits inside.

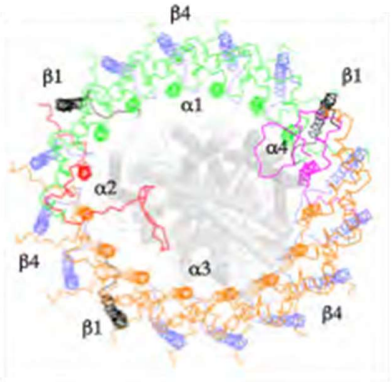
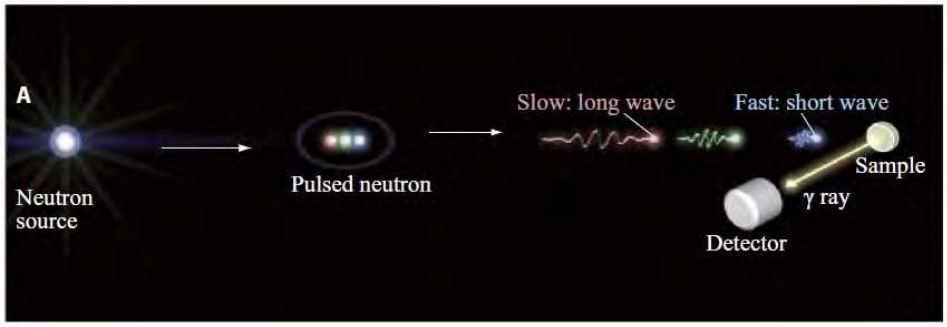


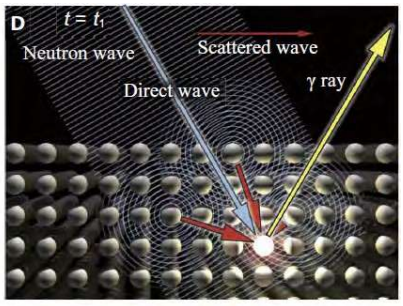
Fig. 1 An LH1 complex containing multiple polypeptides.

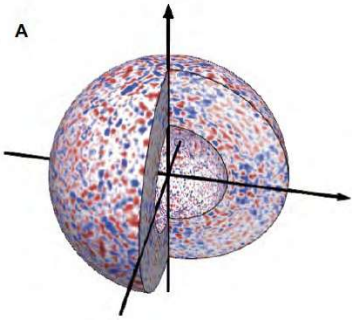
[1] Y. Kimura, et al., *J. Biol. Chem*., **283**, 13867 (2008).
[2] Y. Kimura, et al., *J. Biol. Chem*., **284**, 93 (2009).
[3] L.-J. Yu, et al., *Photosynth. Res*., **106**, 215 (2010).
[4] S. Niwa et al., *Nature*, **508**, 228 (2014).
[5] L.-J. Yu, et al., *Nature*, **556**, 209 (2018).
[6] K. Tani, et al., *Nat. Commun*. **11**, 4955 (2020).

Direct observations of local structure around dopants in functional materials: World-first white neutron holography
Kenji Ohoyama

Prof. Ohoyama's Group has developed novel neutron scattering technique, *white neutron holography*, which is an effective probe for local structures of light elements which exist only around dopants in functional materials[Sci. Adv., **3** (2017) e1700294-1-7]. Neutron holography was developed in 2001 in Europe, but Prof. Ohoyama's Group succeeded in enhancing the accuracy of atomic images drastically. For light elements, only Prof. Ohoyama's Group can investigate local atomic structures in the world, which have important roles in functionality. Recently, they published a paper about qualitative investigation of doping effects to the lattice in typical strongly correlated electron system RB_6 (R: rare earth). Note that the first author was a student of master course. The results have been published in Phys, Rev. B **102**, 054104 (2020).

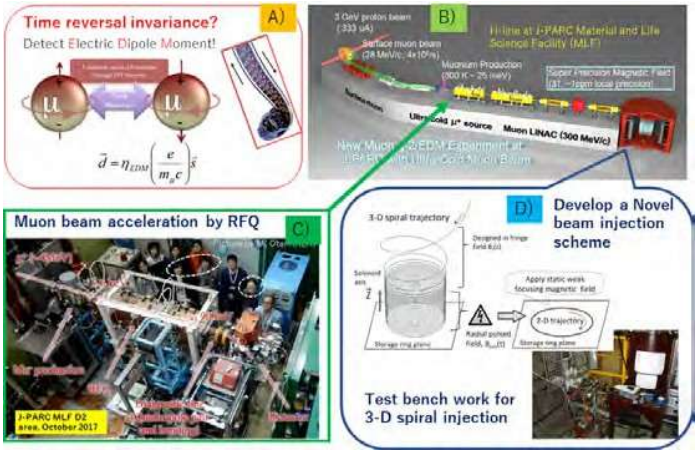






New muon beam line development at J-PARC
Hiromi Iinuma

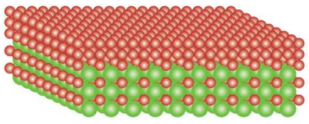
Iinuma group has been working for "J-PARC Muon g-2/EDM experiment" to measure g-2 to a factor 5 better statistical precision and a factor of 100 better sensitivity for the electric dipole moment measurement. (figure-A). An image of experimental setup is shown in (fig.-B)[1]. We are in charge of developing "Accelerate of the muon beam by Radio Frequency Quadrupole Linac [2]" as in (fig.-C) and "muon beam injection and storage [2,3]" as in (fig.-D), into the superconductive storage magnet[4].



[1] M. Abe et al., Progress of Theoretical and Experimental Physics, 2019/ 5, 053C02, 10.1093/ptep/ptz030
[2] S. Bae et al., Nuclear Instriments and Methods in Physics Research Section A, 10.1016/j.nima.2019.05.043
[3] H. Iinuma, H. Nakayama, K. Oide, K. Sasaki,N. Saito, T. Mibe, M. Abe, Nuclear Instruments and Methods in Physics Research A, 832, 51-62 (2016).
[4] M. Abe et al.,Nuclear Inst. and Methods in Physics Research, A, 10.1016/j.nima.2018.01.026

Synthesis of Various Crystals for Functional Materials
Kouichi Nakashima

Our research field is synthesis of functional nanocrystal using wet chemical reaction. We have reported that synthesis of various nanocrystals using solvothermal method and hydrothermal method on bioceramics[1] and dielectric material.[2-5] Additionally, perovskite oxyhydride cubes using the topochemical hydride reactions.[6] In regard to the future, we focus the synthesis of various nanocrystals with multiple facets, keeping in mind the necessity to control morphology of nanocrystals in order to further evolve as a functional material.

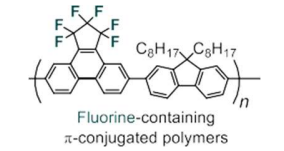


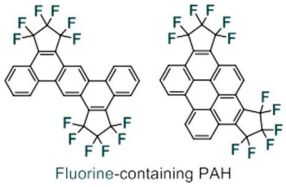
Surface reconstruction $BaTiO_3$ nanocube. Green: Ba, Red: Ti

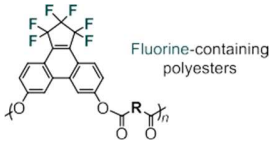
[1] K. Nakashima, S. Misawa, Y. Kobayashi, T. Ishigaki, Y. Ishikawa, S. Yin, M. Kakihana, T. Goto, T. Sekino, *J. Am. Ceram. Soc.*, **107**, 2809-2822 (2024).
[2] K. Nakashima, K. Onagi, Y. Kobayashi, T. Ishigaki, Y. Ishikawa, Y. Yoneda, S. Yin, M. Kakihana, T. Sekino, *ACS Omega*, **6**, 9410-9425 (2021).
[3] K. Nakashima, K. Hironaka, K. Oouchi, M. Ajioka, Y. Kobayashi, Y. Yoneda, S. Yin, M. Kakihana, T. Sekino, *ACS Omega*, **6**, 32517-32527 (2021).
[4] K. Nakashima, H. Takahama, M. Yoshida, K. Yamaguchi, K. Hata, *Inorg. Chem.*, **63**, 44-49 (2024).
[5] K. Nakashima, A. Toi, R. Kuribara, M. Yoshida, N. Hasegawa, T. Kobayashi, K. Yamaguchi, K. Hata, *Chem. Mater.*, **36**, 8323-8329 (2024).
[6] K. Arai, K. Onagi, Y. Tand, T. Ishigaki, H. Sai, Y. Sasahara, G. Caruntu, H. Okabe, M. Harada, K. Nakashima, H. Kageyama, *Inorg. Chem.*, **63**, 23260-23266 (2024).

Synthesis of Fluorine-containing T-Conjugated Molecules and Polymers for Functional Materials
Hiroki Fukumoto

Our research interests is synthesis of fluorine-containing T-conjugated molecules and polymers to show electrical and optical properties. Previously, we investigated fluorine-containing T-conjugated polymers showing photoluminescence by use of intramolecular photocyclization (Mallory reaction) of the corresponding 1,2-diarylhexafluorocyclopentene.[1] Recently, we reported effective synthesis of fluorine-containing polycyclic hydrocarbons (PAHs) [2] and polyesters[3] with high thermal stability. In addition, we are studying highly-ordered structure of fluorine-containing T-conjugated molecules and polymers in solid by their direct observation with AFM and STM.

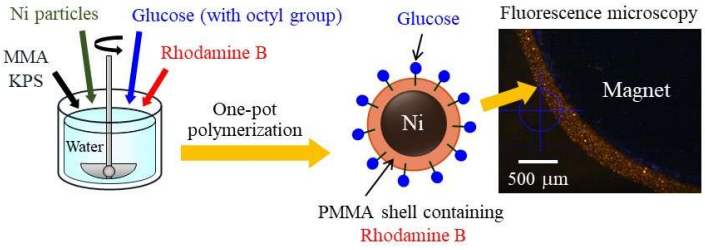






[1] H. Fukumoto, et al. *Macromolecules* **2017***, 50,* 865-871.
[2] O. Gotsu, H. Fukumoto, et al. *Molecules* **2018***, 23,* 3337.
[3] S. Kataoka, H. Fukumoto, et al. *J. Fluorine Chem.* **2019***, 218,* 84-89.

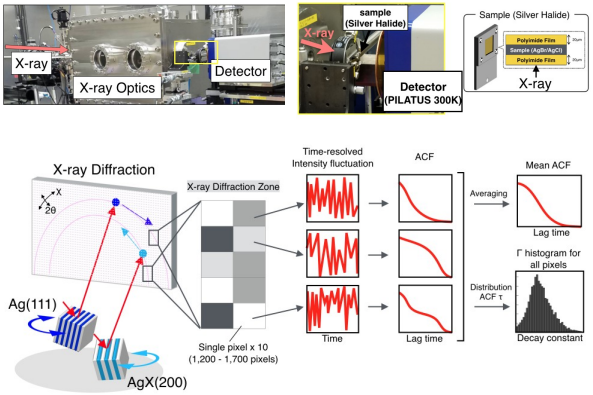
Development of Functional Polymer Particle Synthesis Processes for Medical Applications
Noriko Yamauchi



Our laboratory focuses on developing nanoparticle synthesis processes based on materials chemistry and chemical engineering, aiming for applications in the medical and industrial fields. For instance, we have created polymer particles with sugar chains immobilized on their surfaces [1] [2], aimed at detecting viruses such as influenza, SARS-CoV-2, and noroviruses. By embedding magnetic particles within the polymer particles, these viruses can be rapidly detected using an external magnetic field [3] [4]. Additionally, we synthesized monodisperse hydrogel particles with quaternary ammonium cations on their surfaces, exhibiting excellent dispersion stability in solvents and demonstrating antibacterial properties [5]. These particles are also characterized by being synthesized in aqueous solvents using an environmentally friendly method.

[1] N. Yamauchi et al., *Colloids and Surfaces A*, **580** (2019) 123754.
[2] N. Yamauchi et al., *Colloids and Surfaces A*, **604** (2020) 125299.
[3] N. Yamauchi et al., *Colloid and Polymer Science*, **300** (2022) 213-221.
[4] N. Yamauchi et al., *Particulate Science and Technology*, **42** (2024) 507-514.
[5] N. Yamauchi et al., *Colloids and Surfaces A*, **750** (2025) 135737.

Dynamic Structural Analysis of Polycrystalline Materials Using Diffracted X-ray Blinking
Masahiro Kuramochi

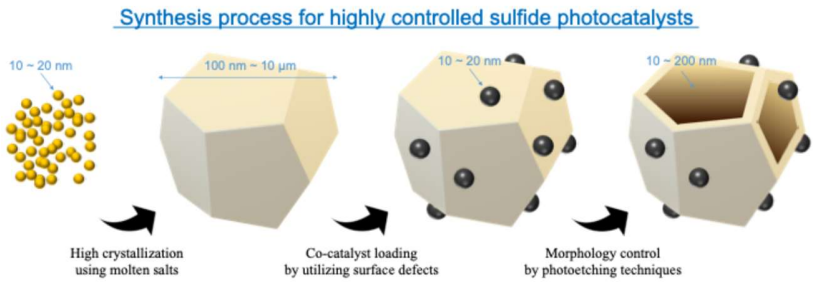


Structural changes in polycrystalline materials are traditionally studied using X-ray diffraction to analyze average properties. However, this approach cannot capture dynamic information such as single-particle dynamics or lattice structure changes related to functional expressions influenced by local environments and interfaces. To address this, we developed the Diffracted X-ray Blinking (DXB) method in 2018[1], applying it to inorganic molecular polycrystals. DXB enables label-free observation of dynamic structural changes. For instance, time-resolved DXB reveals particle motion and lattice deformation in silver halide during photochemical reactions[2]. Using single-pixel autocorrelation analysis, we quantify these dynamics, now extending the method to study soft materials functionality[3].

[1] H. Sekiguchi, M. Kuramochi et al., *Scientific Reports* **2019**, 8, 17090.
[2] M. Kuramochi et al., *Scientific Reports* **2021**, 11, 4097.
[3] M. Kuramochi et al., *Applied Physics Letters* **2023**, 123, 101601.

Innovative Photocatalytic Processes for Solar-Driven Reactions

Haruki Nagakawa

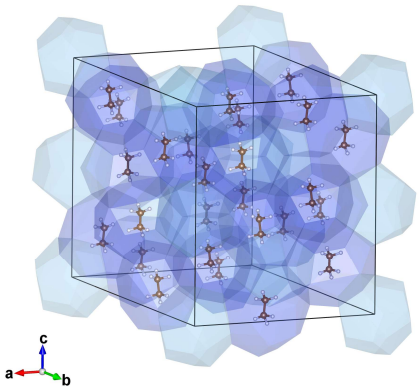


Our laboratory conducts research on novel synthesis and processing methods for photocatalysts. In particular, for sulfide-based photocatalysts, we have developed unique photocatalytic processes such as high crystallization using molten salts[1] and metal organic frameworks[2], co-catalyst loading by utilizing surface defects[3], and photoetching techniques.[4] The photocatalysts we fabricate are applied to hydrogen production,[1-5] nanomaterial synthesis,[6] and chemical conversion. These reactions, driven by solar energy, enable clean chemical processes, contributing to the realization of a sustainable society.

[1] H. Nagakawa, T. Tatsuma, *ACS Appl. Energy Mater.*, **2022**, 5, 14652–14657.
[2] H. Nagakawa *et al.*, *ChemPhotoChem*, **2024**, 8, e202400018.
[3] H. Nagakawa, T. Tatsuma, *J. Phys. Chem. C*, **2023**, 127, 20337–20343.
[4] H. Nagakawa, T. Tatsuma, *PRiME2024*, **2024**, L04-4008.
[5] H. Nagakawa *et al.*, *Adv. Energy Sustain. Res.*, **2024**, 5, 2300295. (**Front Cover**)
[6] H. Nagakawa, T. Tatsuma, *Cryst. Growth Des.*, **2024**, 24, 7858–7864.

Ordered guest molecules in deuterated ethane hydrate
Akinori Hoshikawa

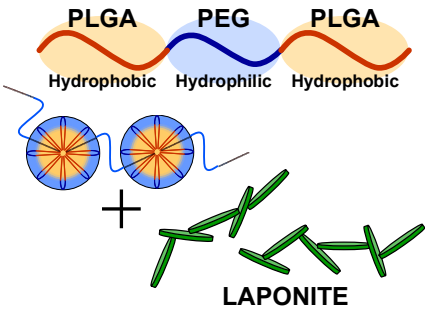
Clathrate hydrates comprise water molecules and various guest molecules. The hydrogen bonds between water molecules are linked as polyhedral cage structures (host lattice). The guest molecules are contained in the cages. The temperature dependence of the crystal structure for deuterated ethane hydrate was investigated by neutron diffraction from 10 K to 150 K. The hexagonal phase, named "Structure Ih", was observed below 30 K [1]. The ethane molecules were ordered as the staggered conformation, and the C-C bond was almost parallel to the c-axis of the hexagonal unit cell. Above 35 K, the ordinary cubic phase as Structure I [2] was mainly observed. This structural phase transition was associated with the thermal motion of the ethane molecule. It is speculated that the quantum tunnel effect of the methyl group is involved as one of the thermal effects.



[1] A. Hoshikawa, Chem. Phys. Lett. **800**, 139679 (2022).
[2] E.D. Sloan Jr., "Clathrate Hydrates of Natural Gases", 3rd ed., CRC Press, Boca Raton, 2007, pp. 45–111.

Polymer nanocomposites: synthesis, structure, and properties
Tomoki Maeda

Polymer nanocomposites are multicomponent materials basically composed of a polymer matrix and nanosized fillers. Due to the multi-component system with hierarchal structures, polymer nanocomposites can exhibit superior properties compared to the single-component system. To understand the origins of those superior properties, it is essential to synthesize the nanocomposites by varying the components systematically and to finely analyze the structure of nanocomposites. Our group has developed a thermoresponsive degradable nanocomposites composed of poly(ethylene glycol) (PEG)-based copolymers and nanosized clay particles[1, 2]. In the works, we systematically varied the composition of copolymers and the composition of nanocomposites, evaluated the properties, and the analyzed the structures at the same time. We have also developed a method of structural analysis for multi-component nanocomposites[3, 4].



[1] T. Maeda *et al.*, Macromolecular Chemistry and Physics, 223(1), 2100316 (2021).
[2] T. Maeda *et al.*, Polymer Degradation and Stability, 187, 109535 (2021).
[3] T. Maeda, Grant-in-Aid for Scientific Research (B), 20H02023 (2020-2023).
[4] T. Maeda, Fund for the Promotion of Joint International Research (Fostering Joint International Research (A)), 22KK0247 (2023-2025).

7 Evidence of education and scientific quality

7.1 Quantitative Indicators

7.1.1 The following quantitative indicators are monitored on a yearly basis in IQBS

		2021	2022	2023	2024
Publications(scientific journals) from Researchmap		171	172	153	95****
Publications (International collaborations) from Researchmap		37	13	22	8****
Books from Researchmap		11	11	6	1***
Third party funding*		JPY 132M	JPY 76 M	JPY 111 M	JPY 121 M***
MSc students	Enrollment**	105 (13)	110 (31)	116 (21)	128 (27)
	Completion**	87 (16)	112 (11)	106 (30)	107 (21)
	In school**	0 (0)	0 (0)	129 (28)	110 (21)
PhD students	Enrollment**	8 (2)	9 (1)	9 (0)	12 (2)
	Completion**	7 (0)	5 (1)	11 (3)	3 (2)
	In school**	-	-	-	34 (3)
Domestic Conference (From Researchmap)		212	219	122	-
International Conference (From Researchmap)		49	32	50	-
International Conference - Invited talks -(From Researchmap)		15	4	7	-
Scientific cooperation agreed upon*		22	28	28	30***
Industry cooperation agreed upon*		31	45	46	54***

*The total amount of commissioned research and joint research, excluding subsidies.
**The number in parentheses is the number of female students.
***As of December, 2024
**** As of January 2025

7.1.2 Employment and Course

Master Course

Graduate year	2018	2019	2020	2021	2022	2023	2024
Materials	14	13	11	9	13	15	14
Chemistry/Drugs/Medical/Food	23	22	15	19	17	17	12
Machine maker	9	10	18	16	12	20	14
Infrastructure/Energy	6	1	2	5	0	3	7
Electronics/ Semiconductor	19	11	18	16	12	22	20

Information	6	6	5	4	11	6	14
Atomic energy	7	5	7	16	10	11	2
Dr. Course（Ibaraki Univ.）	9	3	6	8	3	7	6
Dr. Course（Other Univ.）	1	0	0	0	1	0	1
Civil Servant	1	7	4	0	4	6	4
Other	4	7	4	4	2	5	12
Total	99	85	90	97	85	112	106

PhD Course
2024 Mitsubishi Heavy Industries, Resonac, Ventury Consulting, Co. Ltd., KAKEN Co. Ltd, Elecs, Industry Co. Ltd, ULTRASONIC ENGINEERING CO.,LTD, Hokkaido Univ. Postdoc, Kyoto Univ. Postdoc., etc.
2023 Tokyo Ohka Kogyo Co., Ltd., IMS Corporation, Shindengen Electric Manufacturing Co., Ltd., Resonac, Inc. -> Assistant Professor at Kitasato University, Postdoctoral Researcher at the University of Tokyo -> Assistant Professor at Ibaraki University (Nuclear Regulation Human Resource Development), Special Researcher at RIKEN
2022 Kioxia Corporation, Public Foundation Institute for Environmental Sciences and Technology, Special Postdoctoral Researcher at Ibaraki University
2021 Digital Process Ltd., Human Life Code Co., Ltd., Academic Researcher at the Institute for Materials Chemistry and Engineering, Kyushu University -> Assistant Professor at Kyushu University, Special Postdoctoral Researcher at Ibaraki University

7.2 Top 10% Papers published in 2021-2024 from IQBS : 32 papers

The Top 6 Most Cited Papers Among Top 10% Papers (Accessed on January 22, 2025)

・Nagata, Masakazu, Agou, et al. Angew. Chem. Int. Ed. 2021, 60, 20280-20285. (Time Cited 145)
DOI :10.1002/anie.202108283
Fused-Nonacyclic Multi-Resonance Delayed Fluorescence Emitter Based on Ladder-Thiaborin Exhibiting Narrowband Sky-Blue Emission with Accelerated Reverse Intersystem Crossing

・Hua, Peng, Onuki, Yusuke, et al. NATURE NANOTECHNOLOGY, 2021, 16, 409-413 (Time Cited 128)
DOI :10.1038/s41565-020-00837-5
Nanocomposite NiTi shape memory alloy with high strength and fatigue resistance

・Bonfiglio, D. et al. (Yuji Torikai),…NUCLEAR FUSION, 2022, 62, 042026 (Time Cited 83)
Overview of JET results for optimising ITER operation
1. DOI :10.1088/1741-4326/ac47b4

・Furukawa, Satoshi, Nakamura, Asako J., et al. BIOMED RESEARCH INTERNATIONAL, 2020 **(Review)** (Time Cited 80) (collaboration with QST)
Space Radiation Biology for "Living in Space"
DOI: 10.1155/2020/4703286

・Ooya, Kayato, Abe, Hitoshi, et al. ADVANCED ENERGY MATERIALS, 2020, 11, (Time Cited 69)
Ruthenium Catalysts Promoted by Lanthanide Oxyhydrides with High Hydride-Ion Mobility for Low-Temperature Ammonia Synthesis
10.1002/aenm.202003723

・Thirathipviwat, P. et al. PROGRESS IN NATURAL SCIENCE-MATERIALS INTERNATIONAL, 2020, 30, 545-551. (Time Cited 60)
Compositional complexity dependence of dislocation density and mechanical properties in high entropy alloy systems
10.1016/j.pnsc.2020.07.002

7.3 Papers with Editor's Choice, Cover pictures, and so on

Ami Shimoda, Kazuaki Iwasa, Keitaro Kuwahara, Hajime Sagayama, Hironori Nakao, Motoyuki Ishikado, Akiko Nakao, Seiko Ohira-Kawamura, Naoki Murai, Takashi Ohhara, and Yusuke Nambu
"Antiferromagnetic ordering and chiral crystal structure transformation in $Nd_3Rh_4Sn_{13}$"
Physical Review B 109, 134425 (2024) [10 pages], (**Editors' Suggestion)**
https://journals.aps.org/prb/abstract/10.1103/PhysRevB.109.134425
https://journals.aps.org/prb/highlights?page=22
https://www.ibaraki.ac.jp/news/2024/04/26012343.html

"Chern numbers associated with the periodic Toda lattice",
Kyoka Sato and Takahiro Fukui,
J. Phys. Soc. Jpn. 92 (2023) 073001.
(Papers of **Editors' Choice**)
https://doi.org/10.7566/JPSJ.92.073001

"Moiré Landau levels of a C_4-symmetric twisted bilayer system in the absence of a magnetic field",
Yuki Soeda, Koichi Asaga, and Takahiro Fukui,
Phys. Rev. B 105 (2022) 165422.
(**Editors' Suggestion**)
https://doi.org/10.1103/PhysRevB.105.165422

Control of Metastable States by Heat Flux in the Hamiltonian Potts Model
Michikazu Kobayashi, Naoko Nakagawa, Shin-ichi Sasa
Phys. Chem. Lett. 130, 247102 (2023)
DOI: 10.1103/physrevlett.1
(**Editors' Suggestion**)

M.Hiraishi, H.Okabe, A.Koda, R.Kadono, T.Muroi, D.Hirai, and Z.Hiroi
Phys. Rev. Lett. 132, 166702 (2024).
DOI： 10.1103/PhysRevLett.132.166702
(**Editors' Suggestion**)

Solid-State Photophysical Properties of Chiral Perylene Diimide Derivatives: AIEnh-Circularly Polarized Luminescence from Vacuum-Deposited Thin Films
Aoba Kanesaka, Yuki Nishimura, Akira Yamaguchi, Yoshitane Imai, Toshiko Mizokuro, Hiroyuki Nishikawa*
Bull. Chem. Soc. Jpn., 95, 751–758 (2022). (**Selected Paper**, Inside cover)

Aggregation-induced circularly polarized phosphorescence of Pt(II) complexes with an axially chiral BINOL ligand

Daiki Tauchi, Taiki Koida, Yuki Nojima, Masashi Hasegawa, Yasuhiro Mazaki, Akiko Inagaki, Ken-ichi Sugiura, Yuki Nagaya, Kazunori Tsubaki, Takuya Shiga, Yuuya Nagata, Hiroyuki Nishikawa*
Chem. Commun., 59, 4004–4007 (2023). (Back cover)

Tatsuya Joutsuka, Hiroto Yoshinari, Satoshi Yamauchi, *Bull. Chem. Soc. Jpn.*, 94, 106-111 (2021). (**Selected paper**, Inside Cover)
https://doi.org/10.1246/bcsj.20200236

Kouichi Nakashima*, Kaito Onagi, Yoshio Kobayashi, Toru Ishigaki, Yoshihisa Ishikawa, Yasuhiro, Yoneda, Shu Yin, Masato Kakihana, Tohru Sekino
ACS Omega, 6, 9410–9425 (2021).
Stabilization of Size-Controlled $BaTiO_3$ Nanocubes via Precise Solvothermal Crystal Growth and Their Anomalous Surface Compositional Reconstruction (**Front Cover**)

Kouichi Nakashima*, Kouta Hironaka, Kazuma Oouchi, Mao Ajioka, Yoshio Kobayashi, Yasuhiro Yoneda, Shu Yin, Masato Kakihana, Tohru Sekino
ACS Omega, 6, 32517–32527 (2021).
Optimizing TiO_2 through Water-Soluble Ti Complexes as Raw Material for Controlling Particle Size and Distribution of Synthesized $BaTiO_3$ Nanocubes
(**Front Cover**)

Daichi Ozaki, Hajime Suzuki, Kanta Ogawa, Ryota Sakamoto, Yoshiyuki Inaguma, Kouichi Nakashima, Osamu Tomita, Hiroshi Kageyama, and Ryu Abe, *Journal of Materials Chemistry A*, 9, 8332-8340 (2021). (**Front Cover**)

Hajime Suzuki, Daichi Ozaki, Yusuke Ishii, Osamu Tomita, Daichi Kato, Shunsuke Nozawa, Kouichi Nakashima, Akinori Saeki, Hiroshi Kageyama, and Ryu Abe, *Journal of Materials Chemistry A*, 11, 15159-15167 (2023). (**Front Cover**)

Hajime Suzuki, Masanobu Higashi, Osamu Tomita, Yusuke Ishii, Takafumi Yamamoto, Daichi Kato, Tetsu Kotani, Daichi Ozaki, Shunsuke Nozawa, Kouichi Nakashima, Koji Fujita, Akinori Saeki, Hiroshi Kageyama,* Ryu Abe*, *Chem. Mater*. **2021**, *33*, 24, 9580–9587. (**Front Cover**)

Ayako Inaguma, Haruki Nagakawa,* Sora Kamata, Morio Nagata,* *Adv. Ener. Sust. Res.* 2024, 5, 2300295. (**Front Cover**)
https://doi.org/10.1002/aesr.202300295

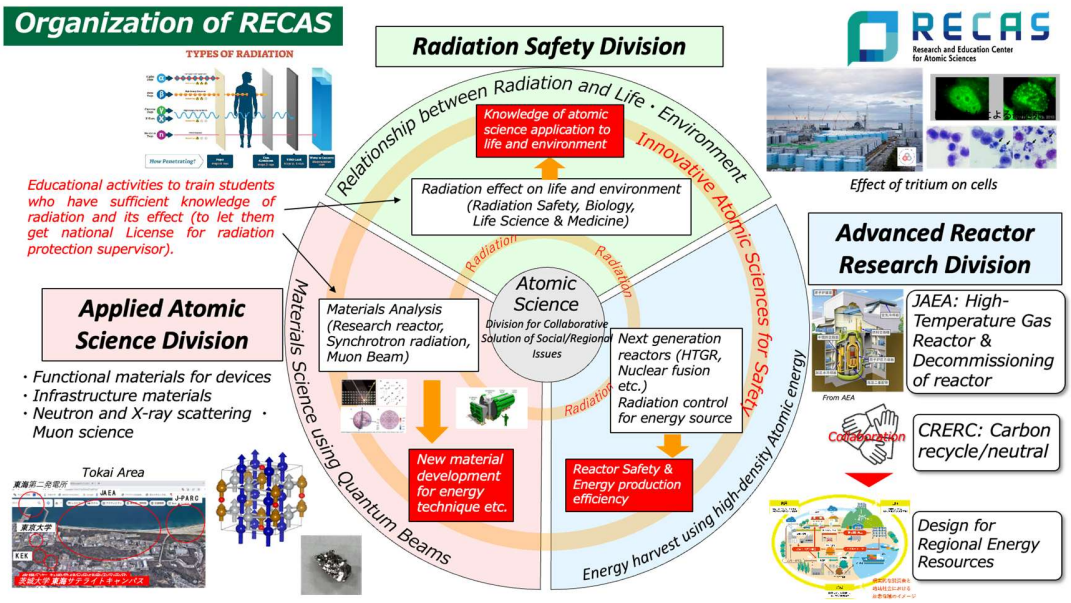
8. Overview of Research and Education Center for Atomic Sciences

8.1 Introduction of Research and Education Center for Atomic Sciences

At the beginning of FY2024, the Research and Education Center for Atomic Sciences (RECAS) of Ibaraki University was established as a reorganization of the Frontier Research Center for Applied Atomic Sciences (iFRC) of Ibaraki University. RECAS is located at Aya's Laboratory Quantum Beam Research Center (AQBRC) in Tokai Village, near the Nuclear Science Research Institute of Japan Atomic Energy Agency (JAEA). The aim of RECAS is to establish a "Collaborative Center for Atomic Sciences" and to maximize the research and educational potential of the Tokai region. The activities are closely correlated with the College of Science, the College of Engineering, and other colleges and departments of Ibaraki University.

The organization of RECAS is shown in the figure. The Applied Atomic Science Division is dedicated to materials science promoted using quantum beam techniques, which is the continuing mission of the former iFRC. The division promotes basic science and industrial application of neutron scattering, synchrotron X-ray scattering, and muon sciences. Originally, the iFRC was established under a contracted research mission to operate the neutron diffractometers iBIX (BL03) and iMATERIA (BL20), owned by the Ibaraki Prefectural Government, of the Material and Life Science Facility (MLF) of the Japan Proton Accelerator Complex (J-PARC). The main mission was the industrial applications of neutron scattering techniques

to produce commercial steel materials, polymers, battery materials, etc. At the beginning of FY2023, the Ibaraki Prefecture mission was succeeded by the Neutron Science and Technology Center of the Comprehensive Research Organization for Science and Society (CROSS). Some faculty members of IQBS are contributing to the industrial use of the neutron diffractometers as the cross-appointed staff members of CROSS and JAEA. The renewed Applied Atomic Science Division of RECAS pursues functional materials (topological electron materials, composite polymers, energy storage materials, biological matters, etc.) using neutron and synchrotron X-ray scattering and developments of new quantum beam techniques (neutron holography, muon for fundamental particle physics, imaging techniques using quantum beams, etc).



The Radiation Safety Division aims at investigating the relationship between radiation and life/environment. The study on DNA damage by irradiation is applied to evaluate human health,

and the new method to measure tritium composition in matters is developed to contribute to the monitoring of environmental tritium quantity. In addition, the division has initiated educational activities for growing human resources who know about the effects of tritium, which is financially supported by the Nuclear Regulation Agency. The staff members of the Radiation Safety Division are originated from IQBS.

The Advanced Reactor Research Division is dedicated to contributing to new technology development for next-generation nuclear power systems, decommissioning of old reactors, and so on. These missions are just initiated by hiring new staff members and are promoted under strong collaborations with JAEA and other institutes nearby RECAS. The staff members of the Advanced Reactor Research Division were filled from outside of Ibaraki University to encourage the research field of nuclear science and engineering, who collaborate with the staffs of the College of Engineering.

The Division for Collaborative Solution of Social and Regional Issues is responsible for forming cross-organizational research projects and offers gathering points for researchers from nearby research facilities, companies, and universities to enhance spontaneous and proactive cross-organizational collaborations.

The four sectors pursue the aforementioned atomic sciences and technologies for innovating energy resources and growing young generations who can be in charge of these fields. Additionally, RECAS concluded MoA with National Institutes for Quantum Science and Technology Agency and The Korean Atomic Energy Agency. RECAS also exchanges information for the research subjects with University of Gadjah Mada (Indonesia).

8.2 Tokai Satellite Campus at AQBRC

The Tokai Satellite Campus was established in 2017 to enhance the IQBS student education activities in the field of quantum beam sciences, located near the quantum beam facilities at JAEA. Each year, approximately 40 IQBS students are part of the research groups at the AQBRC building, shown in the left photo. RECAS reorganized the room assignments as new research groups in the nuclear science fields will emerge in early 2025, necessitating improvements in the students' learning and research environments. Consequently, the size of the Tokai Satellite Campus in the AQBRC building is expected to expand.

In August 2024, the graduate school SwedNess, a union of six Swedish universities, visited J-PARC to gain experience with the facility and exchange information with related institutes, including Ibaraki University. The SwedNess members also visited AQBRC, where the Tokai Satellite Campus and RECAS of Ibaraki University are located. We hosted the Japan–Sweden Collaboration "PhD Student Networking Day" (see group photo below). The attendees included 18 students from Swedish universities, 16 students from Ibaraki University (10 from the IQBS Graduate School and 6 from colleges), 6 students from the University of Tokyo, 1 student from Tokyo Metropolitan University, and a few of their supervisors. Students presented oral talks and posters to share their scientific studies related to quantum beam techniques. They also engaged in Individual Group Discussions and Round Table Discussions to exchange information about student activities in both countries. The students had a valuable time gaining international experience through quantum beam science topics.

9 Future Prospective

9.1 Use of JRR-3 in the education and research

The JAEA research reactor, JRR-3, was restarted in February 2021 after a 10-year shutdown caused by the 2011 seismic event. JRR-3 is one of the high-flux neutron sources, used for materials science, basic science, radioisotope science, and more. Quantum beam science has advanced using JRR-3, in addition to accelerator-based neutron and synchrotron radiation facilities. The proximity of J-PARC and JRR-3 (just 800 meters apart) offers the advantage of complementary use of reactor and accelerator facilities. Similar situations are seen in the US (HFIR with SNS at ORNL) and Europe (ILL (France) with ISIS (UK) and ESS (Sweden)), placing Japan's quantum beam science at a world-class level.
iFRC and iQBS have agreed to cooperate on the operation of the HQR spectrometer, installed at beam hole T1-1 of JRR-3, with the Institute of Solid State Physics (ISSP) of The University of Tokyo, which oversees the co-usage program of JRR-3 neutron beams for Japanese universities. Therefore, reactor-based activities have become part of iQBS's mission. The spectrometer provides opportunities for both student education and research activities. Each year, approximately 25 students from Ibaraki University conduct neutron scattering experiments at the HQR spectrometer, as shown in the bottom left photograph, resulting in several master's theses, some of which are published as scientific articles.
The operation of the spectrometer at JRR-3 fosters collaboration among iQBS staff from different scientific fields, as it increases the number of available channels to quantum beam instruments, in addition to existing collaborations with J-PARC, KEK (Photon Factory), SPring-8, etc. In 2024, RECAS staff also installed a ^{3}He cryostat, as shown in the bottom right photo, enabling 0.7 K neutron measurements to investigate low-temperature quantum electronic phenomena. The combined use of JRR-3 and other facilities enhances research collaborations within iQBS and Ibaraki University.

9.2 Strengthening the PhD program

The Ibaraki University Scholarship for Doctoral Course Students is available for 10 students from the Graduate School of Science and Engineering (GSSE). Additionally, the Japanese government approved the "Scholarship for the Advanced Science and Technology Human Resource Development Project Contributing to the Construction of a Sustainable Society" under the SPRING (Support for Pioneering Research Initiated by the Next Generation) program supported by the Ministry of Education, Culture, Sports, Science and Technology from FY2024. Eight PhD students from GSSE will be awarded scholarship aid and research grants.

The program emphasizes enhanced cooperation with partner organizations. For example, each student will have an external mentor from these organizations in addition to their advisor group within GSSE, and each student is expected to participate in an external internship. Scholarship students must also participate in a study abroad program (preferably at international partner universities) and join job-type internships. Between January 29 and February 8, 2025, eight scholarship students visited Universitas Islam Indonesia in Yogyakarta City, Indonesia, as the first batch of scholars.

We expect that the SPRING program and the support program for graduate students will invigorate the PhD program at IQBS.

9.3 Pursuit of further uniqueness

All the five colleges of the university have just started to commit to quantum beam science including the College of Agriculture, the College of Humanities and Social Sciences, the College of Education. In this context, we are going to incorporate lectures in areas of diaster prevention, biology such as food science and breeding through RECAS. Thus, Ibaraki University is now going to extend quantum beam science or atomic sciences to variety of fields to pursue further uniqueness. Two faculty members of IQBS are researchers at the Carbon Recycling Energy Research Center (CRERC) at Ibaraki University. Established in 2023, CRERC focuses on carbon recycling technology, including the capture of CO_2 through Direct Air Capture, the synthesis of fuels, and their utilization. This advanced research institute is essential for achieving carbon neutrality by 2050.

Ibaraki University aims to become a global center for comprehensive climate change science, promoting climate-resilient development. IQBS will collaborate with RECAS and CRERC to conduct research on climate change mitigation measures.

International Review of the

Institute of Quantum Beam Science of Ibaraki University

March 2025

Executive Summary:

The Institute of Quantum Beam Science (IQBS) of Ibaraki University has made a significant impact through its post-graduate and Ph.D. programs in fields aligned to beam line sciences with a highly interdisciplinary focus spanning chemistry, physics, material science, and life sciences. With over 120 Master's course students and over 30 Ph.D. students in 2024, The IQBS has grown in stature as a major academic hub in post-graduate and Ph.D. programs. Leveraging the expertise available at various collaborating institutes such as J-PARC, JAEA, QST, KEK, JASRI, CROSS and other domestic and international organizations and universities, IQBS has established a strong academic and research foundation. As it continues to promote curriculum internationalization, strengthen research resource integration, and improve talent recruitment and support mechanisms, it firms up its position as a global academic leader and continues to evolve into a world-class research and education institution. At the beginning of FY2024, the Research and Education Center for Atomic Sciences (RECAS) was established as a reorganization of the Frontier Research Centre for Applied Atomic Sciences (iFRC) of Ibaraki University. RECAS aims to establish a "Collaborative Centre for Atomic Sciences" and maximize the research and educational potential of the Tokai region. IQBS is unique in the world covering both education & research in quantum beam science, and together with RECAS it has a great potential to emerge as a unique centre of excellence in the area of beam line sciences and its applications both nationally and internationally.

IQBS has established its distinct global presence, further enhanced Ibaraki University's international reputation while driving progress toward key UN Sustainable Development Goals (SDGs). Notably, its initiatives align with SDG 4 (Quality Education), SDG 7 (Affordable, Reliable, Sustainable, and Modern Energy for All by 2030), SDG 11 (Sustainable Cities and Communities), and SDG 17 (Partnerships for the Goals). These efforts underscore IQBS's pivotal role in advancing sustainable innovation and global academic excellence. Opportunity exists for IQBS to sustain its leadership position, IQBS must establish a comprehensive talent support and development system to attract top-tier students, faculties, staffs and international researchers while continuously enhancing its global competitiveness.

Key Assessment Areas and Observations

This report is based on the evaluation of the Institution of Quantum Beam Science (IQBS) in Japan from March 4 to 6, 2025. Based on the presentation, the report is made on four packages: 1) Education; 2) Collaborative Education, Symposia; 3) Academic Staff; and 4) RECAS and cooperation with research institutes.

During the discussion, several aspects pertinent to education, research, international cooperation, administrative management, infrastructure, financial stability, gender statistics, sustainability and support systems, have been discussed. The members of the committee have good discussions with the presenters on the various aspects and have a detailed discussion of several key assessment areas. The overall discussions have been conducted in a transparent fashion and the committee is very appreciative of various steps taken in the last few years, and deliberated on the plans to be undertaken that will make the IQBS consolidate its position as a unique centre of excellence in the mid-term and long-term.

Package 1: Education:

IQBS's curriculum is well-structured covering both fundamental and applied sciences, aligning with current international educational trends. The six master course programs: 1) Environmental Radiation Science Program (ERSP) 2) Material Science Program (MSP); 3) Forefront Physics Program (FFP); 4) Frontiers Materials Chemistry Program (FMCP); 5) Biomolecular Science Program(BSP); and 6) Beam Line Science Program (BLSP), and the four Ph.D. programs have well defined structure and the enrolment is good. Curricula content primarily focuses on generating employment in quantum beam science, such as industry, academia, and startups. The teaching content very well integrates theory and experiments while meeting advanced academic/industry demands, enhancing students' employability.

Each doctoral program is unique, specialized, and well characterized compared to the master's program. It is desirable to objectively evaluate the skills required for these professions against the current curricula, and the introduction of interdisciplinary subjects connecting the six master courses will be helpful. As an example of the Environmental Radiation Program, research activities related to nuclear fusion and tritium were presented. These topics are very distinctive and important from a social and global perspective. A brief introduction of new issues of this kind to students is considered a good way to broaden their perspectives. Providing clear and appealing development pathways and ensuring students access the best resources during their studies will facilitate a smooth transition into academia or high-tech industries upon graduation. Therefore, syllabi in master's programs may be designed and effectively administered as in the liberal arts (e.g., bottom-up fundamentals). Continuously enhancing interdisciplinary integration, particularly in cutting-edge fields such as quantum science, multi-scale computational modelling, artificial intelligence (AI) data fitting and development, and sustainable energy applications. In particular, the introduction of courses based on artificial intelligence, machine learning, industry 5.0, during the post-graduate level appears to be very helpful.

Package 2: Collaborative Education, symposia:

Developing a well-structured and sustainable domestic and international research collaboration framework, promoting bilateral and multinational joint research projects and exchange mechanisms for doctoral and postdoctoral researchers is one of the most important challenges for any entity. For IQBS, these collaborations are very essential and have great

potential to be the referral point in several of the dimensions. Already IQBS has established a robust collaborative system, with a very fruitful collaboration with ANSTO and with education and research partners of domestic nearby national institutes (JAEA, QST, KEK, JASRI, CROSS, etc.) along with industries that are well established. IQBS collaborated with Foreign Partners through several MOUs (Australia, Korea, Germany, Canada, Thailand, Taiwan, etc.). Furthermore, laboratory visits to quantum beam facilities abroad, supported the development of next-generation and female researcher programs at Ibaraki University, are also reported. IQBS applies the JST-Sakura Science Program and accepts international students and post-doctoral fellows from abroad.

Every effort is made to enhance the ongoing bilateral and multinational joint research projects and exchange mechanisms for doctoral and postdoctoral researchers. Joint publications in frontier areas will come with active collaborations and exchanges of scientists and students. Therefore, efforts have to be made to expand international scholars' visits and develop a well-conceived long-term and sustainable action plan.

Focussed areas for collaboration, especially pertaining to SDGs (sustainable development goals), environment issues and climate change in the area of atomic and subatomic science need to be identified and both academic and industrial partnerships may need to be established. Ensuring international researchers' involvement to enhance academic exchanges and talent mobility will help to boost further IQBS's global academic influence and leadership in this area.

Currently, the active collaborations appear to be quite good, and further developing joint education programs with foreign countries is beneficial for students and enhancing the participation in international workshops and symposia, as well as hosting international academic conferences, are very important measures to boost the collaborations. Obviously, faculty members need to pay attention to the budget application and management of student travel expenses, to the extent that they do not become overloaded with work.

The 8th International Symposium of Quantum Beam Science at Ibaraki University was attended by students and was considered stimulating not only for the faculty but also for the students. So far in all the symposiums conducted by IQBS, the topics were systematically planned, and a good number of outside participants were invited. Expanding international collaborations and seeking multilateral funding programs to increase financial sustainability should be actively pursued by IQBS. Optimization of the allocation of tuition fees and research funding to ensure the institution is not financially burdened in their teaching, administration, and research should also be considered.

Package 3: Academic Staff:

Academic staff are one of the main strengths of the institute; they have excellent expertise, and there is great scope for making a bigger impact, considering the location. IQBS boasts a high-quality faculty and maintains a strong academic culture and collaborative environment. Presentations of the faculty activities reveal the great depth and quality of research in which the faculty and their groups are engaged. Several national and international collaborations have already been established, and these collaborations have resulted in good quality

publications. However, there is much more scope for international collaborations which would assist the IQBS to emerge as the most successful international program in the academic, translational and industrial use of beamline sciences in general and neutron beams in particular. The average age of the faculty was reported to be increasing, and measures must be taken to ensure long-term sustainability and inclusiveness. While the gender ratio appears to be just reasonable from the student's point of view, efforts need to be made to have better representation of females at the faculty level.

The unique area of research, the proximity of the highly specialized centers and industry gives a great opportunity to improve. It is important to further strengthen industry-academic cooperation by seeking corporate sponsorships and technology licensing income to enhance independent financial resources and ensure financial sustainability. It is important that each faculty should be encouraged to have a good plan to engage with academic or industrial partners of global repute and work on challenging problems with a plan to raise adequate budget outside the regular budget of the university.

Package 4: RECAS and cooperation with research institutes:

Cooperation with research institutes is essential to promote personnel exchange, education and training, sharing research facilities and equipment, and collaborative research programs to venture into the new dimensions of science and technology. The Research and Education Center for Atomic Sciences (RECAS) was established, with a MEXT budget, and aims to create a new nuclear science education that sustainable society in 2024-2028. One important objective is to create skilled and quality human resources for nuclear-related companies, government agencies, municipalities, and research institutes.

It is critical for plans to be developed to optimize research resource allocation and infrastructure development, and ensuring access to high-end equipment and technical support is key to healthy growth. Improving the student and alumni support systems by expanding career development programs and strengthening alumni relations to build long-term academic and industry networks, with a focus on financial stability and sustainable resource development is also important.

Way forward:

IQBS has great potential to consolidate its position as a world-class research and education hub for quantum beams science and allied areas by promoting curriculum internationalization, strengthening research resource integration, improving talent recruitment and support mechanisms, and adapting to changes.

The structure of the courses is quite solid. It is good to note that IQBS students are also exposed to the courses given by other faculty, as described in GSSE-IU. Still, it is important to have a very objective look into the restructuring by integrating contemporary advances in artificial intelligence and industry 5.0, as well as courses pertaining to entrepreneurship, innovation and liberal arts. Based on the comprehensive evaluation, IQBS demonstrates excellence in education, research, and international cooperation and has the potential to emerge as a unique centre of uniqueness in terms of research.

IQBS is encouraged to conduct a comprehensive analysis of its key performance indicators (KPIs) over the past five years to identify trends in strengths, weaknesses, and potential challenges. This analysis could inform a strategic plan to reinforce strengths, address challenges, and explore new growth opportunities. A combination of quantitative and qualitative assessments would support the development of concrete strategies, targets, and action plans, ensuring alignment with international standards and best practices for mid-term and long-term development.

Diversifying funding sources and enhancing financial independence to support high-quality research and education are critical to IQBS success. As the budget is a major factor in realizing the grand aspirations of IQBS to forge and sustain the international ties and exchange of students and faculty, a proactive plan has to be formulated. The mutual exchange of students will not only enhance the quality of science and join publications, but most importantly it will have a great impact on appreciating and integrating Japanese culture with that of other nations.

It is recommended that IQBS establishes an alumni network and invites alumni to share industry and academic experiences to assist current students plan their careers. Alumni can play a major role in building long-term academic and industry networks. Strengthen the alumni tracking system, creating a database to analyse career development trends and the impact of curriculum on professional growth will further assist in demonstrating the long-term value and success of IQBS. Expanding support for international students, including language assistance and cultural adaptation programs, to enhance their sense of belonging will also assist.

Report is prepared by the evaluation committee consisting of:

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