Special Research Projects

IMS has special research projects supported by national funds. Five projects in progress are:

(a) Inter-University Network for Common Utilization of Research Equipments
(b) MEXT Program Advanced Research Infrastructure for Materials and Nanotechnology in Japan:
Spoke Organization in Advanced Materials Recycling Technologies and Representative Organization in Cross Sectional Technical Domain of Materials Synthesis Process
(c) "Development of Cold-Atom Based Quantum Simulators and Their Applications to Quantum Computing" within the Framework of Japan's Flagship Program on Quantum Sciences and Technologies "Q-LEAP" by MEXT and "PRISM" by the Cabinet Office of Japan (2018–2028)
(d) "Large-Scale and High-Coherence Fault-Tolerant Quantum Computer with Dynamical Atom Arrays" Supported by the Cabinet Office/JST R&D Program "Moonshot Goal 6": Realization of a Fault-Tolerant Universal Quantum Computer That Will Revolutionize Economy, Industry, and Security by 2050
(e) MEXT Promotion of Development of a Joint Usage/Research System Project: Coalition of Universities for Research Excellence Program (CURE): Frontier of Spin Life Sciences [Spin-L]

These five projects are being carried out with close collaboration between research divisions and facilities. Collaborations from outside also make important contributions. Research fellows join these projects.

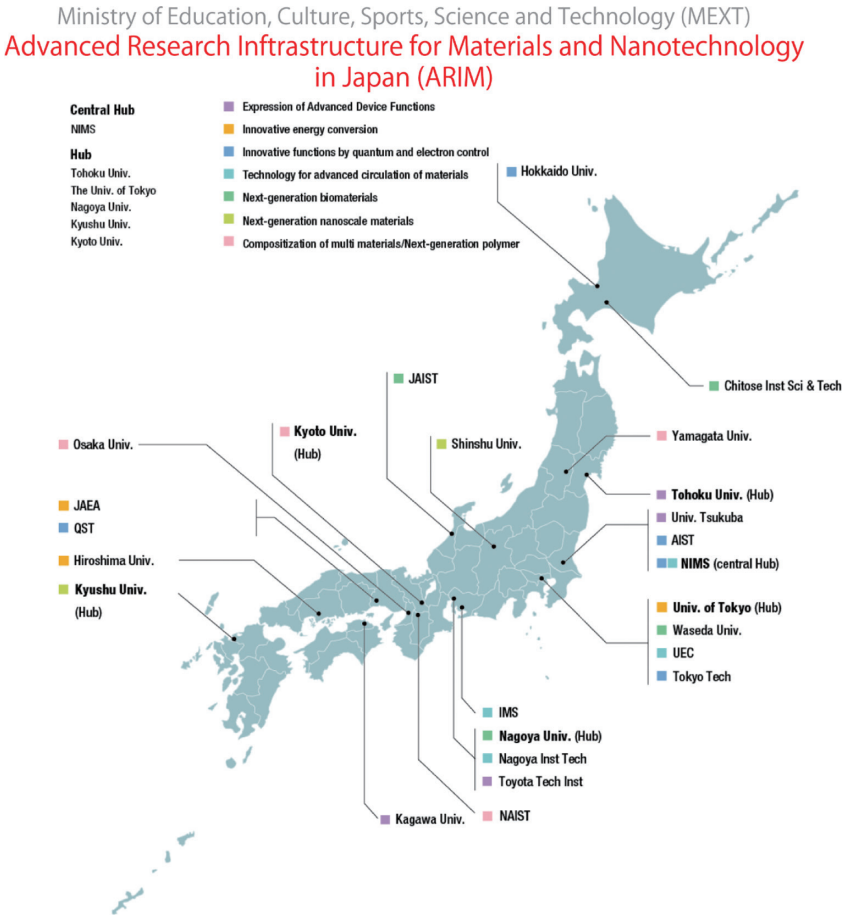
(a) Inter-University Network for Common Utilization of Research Equipments

It is highly important to improve instrumental supporting environments for research and education in the field of science and engineering. Nowadays, advanced research instruments are indispensable for conducting researches and educations with high standard quality. To install such sophisticated instruments, tremendous amount of budgets would be necessary. In 2007, for constructing a national-wide network to provide easy accesses to high-level equipments to researchers and students in universities all over Japan, the five-year project "Functioning of Inter-University Network for Efficient Utilization of Chemical Research Equipments" was launched. The network maintains an internet machine-time reservation and charging system by the help of equipment managers and accounting sections in each university. 72 national universities as well as Institute for Molecular Science (total 73 organizations) all over Japan have been participating in the network. From 2009, the registered equipments are open to the researchers and students of all the public (prefectural *etc.*) and private universities and private companies. Since 2010, the project has been renamed "Inter-University Network for Common Utilization of Research Equipments" still keeping the original strategy and stable functioning. Since 2018, the institutions that provide research facilities are open to public and private universities. Currently, the network is organized by 78 organizations. The number of registered users amounts to 19,500 in 674 universities/institutions/companies (as of July, 2024). Network usage reaches more than 190,000 times a year, in which external usage amounts to 5,400 times, and these numbers continue to grow. Moreover, we have actively provided various opportunities where technical staffs and users can improve their technical skills and frankly communicate with each other.

(b) MEXT Program Advanced Research Infrastructure for Materials and Nanotechnology in Japan: Spoke Organization in Advanced Materials Recycling Technologies and Representative Organization in Cross Sectional Technical Domain of Materials Synthesis Process

Since 2021, ARIM (Advanced Research Infrastructure for Materials and Nanotechnology in Japan) program supported by Ministry of Education, Culture, Sports, Science and Technology (MEXT) has been conducted, succeeding to MEXT Nanotechnology Platform program that was completed in March, 2022. In this new program, seven "key technology domains" are set. Each key technology domain team consist of one hub organization and several spoke organizations, with the center hub of National Institute of Materials Science (NIMS). The hub & spoke networks for collecting, accumulating, and structuring research data that are created from observation, measurement, synthesis and fabrication equipment and facilities, were launched in order to strengthen AI-driven materials & device R&D using informatics techniques. IMS belongs to one of the key technology domains of "Advanced materials recycling technologies" led by the NIMS hub, together with the spoke organizations of Nagoya Institute of Technology and The University of Electro-Communications. Domestic and international equipment sharing is the most important purpose in this program, as in the Nanotechnology Platform program. Moreover, users and staffs are requested to provide experimentally obtained data to the Data Platform Center (DPC) that are being constructed in NIMS. Accumulated structured data will be shared through the NIMS DPC. In addition, we will contribute to strengthening material innovation force by building a "Material D Platform" in collaboration with the Data creation/utilization type material research and development project. In this program, three areas of shared methodology are

set to promote cooperation across the seven key technology domains. IMS also acts as a representative organization for the cross-sectional technological area concerning the material synthesis process to promote technological cooperation among all the participating organizations. Human resource development is also an important aim in this program and IMS regularly conducts training sessions with "EQ-NET" to upskilling of the technical staffs engaged in this program. In IMS, the mission for the ARIM program is mainly organized by Instrument Center, supported by Research Center for Computational Science in data storage and transfer to NIMS DPC. Through this program, a new electron spin resonance (ESR) system and a new superconducting quantum interference device (SQUID) magnetometer, a high-throughput low-temperature single-crystal x-ray diffractometer, and an automatic organic synthesis system were installed in IMS in FY2021–2023. We hope that this program will successfully be performed and equipment sharing and data sharing will be accelerated.



List of Equipment Supports in IMS Spoke (FY2024)

Supporting Element		Responsible Persons	Charging Persons
Organization Management in IMS Spoke		T. Yokoyama	T. Nakamura, M. Ehara, K. Iwahashi, T. Suzuki, K. Nakamoto, Y. Ota, M. Kaku, Y. Funaki, Y. Hyodo
Organization Management in Cross-Sectional Technological Area of Material Synthesis		T. Yokoyama	Y. Ota, K. Nakamoto, M. Kaku, Y. Kurita, A. Ishikawa
UVSOR Synchrotron Radiation	X-Ray Magnetic Circular Dichroism	T. Yokoyama	O. Ishiyama
Microstructure Fabrication	Maskless Lithography with Step Gauge	H. Yamamoto	T. Kondo, S. Kimura, N. Takada, A. Ishikawa
	3D Optical Surface Profiler		
	Electron Beam Lithgraphy		
Electron Microscopy	Field Emission Scanning Electron Microscopy	T. Yokoyama	O. Ishiyama
	Low Vacuum Analytical Scanning Electron Microscopy		
	Field Emission Transmission Electron Microscope		S. Iki, T. Ueda, M. Uruichi

X-rays	Single Crystal X-Ray Diffractometer	T. Yokoyama	Y. Okano
	Low Temperature Single Crystal X-Ray Diffractometer for Microcrystals		
	Powder X-Ray Diffractometer		M. Fujiwara, M. Miyajima
	Operando Multi-Purpose X-Ray Diffraction		M. Fujiwara, M. Miyajima
	Small Angle X-Ray Scattering for Solutions	S. Akiyama	Y. Furuike
	Molecular Structure Analysis using Crystalline Sponge Method	M. Fujita	T. Mitsuhashi, T. Yokoyama
Electron Spectroscopy	X-Ray Photoelectron Spectroscopy	T. Yokoyama	S. Iki, O. Ishiyama
	Angle Resolved Ultraviolet Photoelectron Spectroscopy for Functional Band Structures	S. Kera, K. Tanaka	K. Fukutani
Electron Spin Resonance	Pulsed High Field ESR	T. Yokoyama, T. Nakamura	M. Asada, M. Fujiwara, M. Miyajima, S. Iki, T. Ueda
	X-Band CW ESR		
	X, Q-Band CW ESR		
	Pulsed ESR		
SQUID	Superconducting Quantum Interference Device		M. Asada, M. Fujiwara, M. Miyajima, S. Iki
Thermal Analysis	Differential Scanning Calorimeter (Solutions)	T. Yokoyama	H. Nagao, M. Uruichi
	Isothermal Titration Calorimeter (Solutions)		
	Calorimeter for solids		M. Fujiwara, M. Miyajima
Mass Spectrometer	Matrix Assisted Laser Desorption/Ionization Time of Flight Mass Spectrometer		M. Uruichi, K. Fujikawa
Spectroscopy	Microscopic Raman Spectroscopy		M. Uruichi, K. Fujikawa
	Fourier Transform Far Infrared Spectroscopy		
	Fluorescence Spectroscopy		T. Ueda
	Ultraviolet & Visible Absorption Spectroscopy		
	Absolute Photoluminescence Quantum Yield Spectrometer		
	Circular Dichroism		T. Mizukawa, M. Uruichi, K. Fujikawa
Lasers	Picosecond Laser		T. Ueda
High Field NMR	600 MHz Solids	K. Nishimura	
	600 MHz Solutions	T. Yokoyama	T. Mizukawa, M. Uruichi, H. Nagao
Functional Molecular Synthesis and Molecular Device Fabrication	Organic Field Effect Transistors	H. Yamamoto	T. Sato
	Organic Synthesis DX	T. Suzuki	N. Momiyama, N. Ohtsuka
	Large Scale Quantum Mechanical Calculations	M. Ehara	
	Magnetic Thin Films	T. Yokoyama	
	Supplementary Apparatus in Instrument Center	T. Yokoyama	

(c) "Development of Cold-Atom Based Quantum Simulators and Their Applications to Quantum Computing" within the Framework of Japan's Flagship Program on Quantum Sciences and Technologies "Q-LEAP" by MEXT and "PRISM" by the Cabinet Office of Japan (2018–2028)

Quantum science and technology, such as quantum computers, quantum simulators, and quantum sensors, are qualitatively new technologies that take advantages of the "wave nature" of microscopic particles including electrons and atoms. Since quantum science and technology can revolutionize functional materials, drug design, information security, artificial intelligence, etc., huge investments are being made in the science and technology policies of various countries around the world. In Japan, the "Committee on Quantum Science and Technology" was established in June 2015 by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) to discuss policy issues related to quantum science and technology, and a new national project, the "MEXT-Quantum Leap Flagship Program (MEXT Q-LEAP)" was launched in 2018 based on the discussions by the committee. This research and development program that aims for discontinuous solutions (Quantum leap) to important economic and social issues by making full use of quantum science and technology (https://www.jst.go.jp/stpp/q-leap/en/index.html). The program consists of three technological areas: (1) Quantum information technology (Quantum simulator, Quantum computer), (2) Quantum metrology & sensing, and (3) Next generation laser.

The ongoing research project led by Prof. Kenji Ohmori at IMS and named "Development of cold-atom based quantum simulators by optical control with precisions on the attosecond temporal and nanometer spatial scales and their applications to quantum computing," which has been adopted as a Large-Scale Basic Foundation Research project in the Q-LEAP

"Quantum information technology" area, aims to develop a completely new quantum simulator /quantum computer with core competences, which will cut deeply and sharply into fundamental problems of quantum mechanics, in close collaboration with Kyoto University, Okayama University, and Kindai University.

(d) "Large-Scale and High-Coherence Fault-Tolerant Quantum Computer with Dynamical Atom Arrays" Supported by the Cabinet Office / JST R&D Program "Moonshot Goal 6": Realization of a Fault-Tolerant Universal Quantum Computer That Will Revolutionize Economy, Industry, and Security by 2050

The "Moonshot R&D Program" is a large-scale national program led by the Cabinet Office, aiming to create disruptive innovations originating in Japan to address important social issues such as the super-aging society and global warming, and to promote the realization of ambitious goals "Moon Shots" (Cabinet Office/JST Moonshot R&D Program: https://www.jst.go.jp/moonshot/en/).

Goal 6, "Realization of a fault-tolerant universal quantum computer that will revolutionize economy, industry, and security by 2050," aims to develop a quantum computer that can meet the exploding demand for information processing, while conventional computers are reaching their limits in terms of progress. The key to solving diverse, complex, and large-scale real-world problems with quantum computers is the realization of a fault-tolerant universal quantum computer that can correct quantum errors during computations.

The R&D project "Large-scale and high-coherence fault-tolerant quantum computer with dynamical atom arrays" led by Prof. Kenji Ohmori at IMS under Goal 6 develops dynamical qubit arrays in which each of the cold-atom qubits arranged in a large array of optical tweezers is freely and rapidly moved during computation including gate operations and error detection / correction, or before computation for algorithm dependent optimization of the spatial configuration of atomic qubits. The goal is to realize a practical fault-tolerant quantum computer with high stability and usability through integration and packaging of the key components under the collaboration with industries.

(e) MEXT Promotion of Development of a Joint Usage/Research System Project: Coalition of Universities for Research Excellence Program (CURE): Frontier of Spin Life Sciences [Spin-L]

Frontier of Spin Life Sciences

The MEXT CURE project, "Frontier of Spin Life Sciences (Spin-L)," launched in September 2023, aims to pioneer a new interdisciplinary field by integrating molecular, life, and physiological sciences. This initiative establishes a hub for magnetic resonance (MR) technology and research, leveraging existing joint usage/research systems.

The core of Spin-L is formed by the three Okazaki institutions: NIPS, IMS, and ExCELLS. They focus on developing new MR molecular probes and conducting MR imaging on model animals to explore novel measurement principles and methods for living organisms. To accelerate this cutting-edge research, Spin-L fosters strong collaboration among Japanese researchers, promoting industry–academia partnerships through various mechanisms. These include project research by specially appointed faculty, cross-appointments, human exchange programs, joint usage/research, and human resource development, all operating under a unified framework on the Okazaki Campus.

Beyond the core institutions, the project involves several participating institutions, including Institute for Chemical Research (Kyoto University), Institute for Protein Research (The University of Osaka), Brain Research Institute (Niigata University), and Institute for Quantum Life Science (QST). These collaborations address specialized technologies and compound synthesis. The project not only facilitates joint research and usage across diverse universities, companies, and platforms but also emphasizes training cross-disciplinary researchers and technical staff.

Main achievements in FY2024

The Hub Director General is Dr. Nabekura, Director General of NIPS (to be succeeded by Dr. Isa, Director General of NIPS, in FY2025). An administrative office has been established to manage the Hub, with Dr. Nakamura, Team Leader at IMS, serving as the Head of the Administrative Office. The following committees and meetings are also held:

Steering Committee: Composed of two members from each core institution and one from each node institution. Held approximately once a year.

Core Meeting: Held as needed, approximately four times a year.

Hub Meeting: Held approximately once a year.

Joint Research Committee: Held approximately once a year (Starting from FY2025, email reviews are conducted approximately once a month for project evaluations).

External Evaluation Committee: Composed of four members, including one international member. In FY2024, External Evaluation Committee members participated as observers in

an interdisciplinary research meeting and the Steering Committee, providing an overall assessment of activities.

Project Implementation Details:

Joint Usage Research: A Joint Usage Committee has been established to decide on the adoption of projects and assign project numbers for "Spin-Life Research Projects (each core institution)," "Problem-Setting Type (Open research conducted in collaboration with the Visiting Research Group and other institutions)," and "Collaborative Research by the Visiting PIs and Project Research Staff (within the Hub)." In FY2024, 78 "Spin-Life Research Projects" and 2 "Collaborative Research by Visiting PIs and Specially Appointed Faculty" projects were adopted.

Young Researcher Development Program/Overseas Dispatch Grant: This program supports dispatches to overseas laboratories for several weeks. In FY2024, two applications were received, and overseas dispatches were conducted.

Young Researchers' Retreat: Young researchers from different institutions across the Hub played a central role in planning the overnight retreat. In FY2024, it was held at NIPS from September 11–12, with 32 participants from core and node institutions.

Interdisciplinary Training Course: On the afternoon of September 12, 2024, following the Young Researchers' Retreat, lectures were given at NIPS, IMS, and ExCELLS to 12 researchers and engineers from across Japan.