

Special Research Projects

IMS has special research projects supported by national funds. Four 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 Program “Moonshot Goal 6”: Realization of a Fault-Tolerant Universal Quantum Computer That Will Revolutionize Economy, Industry, and Security by 2050

These four 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 17,000 in ~600 universities/institutions/companies (as of March, 2023). Network usage reaches more than 170,000 times a year, in which external usage amounts to 3,800 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 MEXT (Ministry of Education, Culture, Sports, Science and Technology) 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

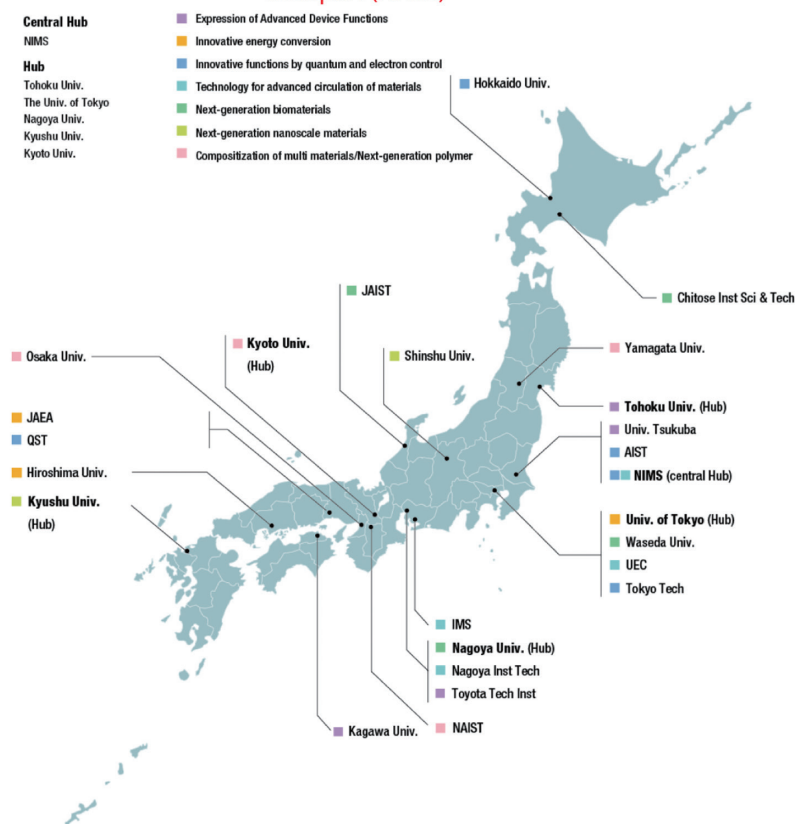
spoke organizations of Nagoya Institute of Technology and The University of Electro-Communications. Domestic and international equipment sharing is the most important purpose in this program, as in the Nanotechnology Platform program. Moreover, users and staffs are requested to provide experimentally 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

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all the participating organizations. Human resource development is also an important aim in this program and IMS regularly conducts training sessions with “EQ-NT” to upskilling of the technical staffs engaged in this program. In IMS, the mission for the ARIM program is mainly rganized by Instrument Center, supported by Research Center for Computational Science in data storage and transfer t NIMS DPC. Because in 2021 equipment sharing was conducted through the Nanotechnology Platform program, FY2022 is the first year for equipment sharing in this program, while the data accumu-

lation mission is in pogrress. Through this program, a new electron spin resonance (ESR) system and a new superconducting quantum inteference device (SQUID) magnetometer were installed in IMS in 2021 and 2022, and a high-throughput low-temperatur single-crystal x-ray diffractometer and an automatic organic synthesis system will be introduced at the end of FY2023 We hope that this program will successfully be performed and equipment sharing and data sharing will be accelerated.

Ministry of Education, Culture, Sports, Science and Technology (MEXT) Advanced Research Infrastructure for Materials and Nanotechnology in Japan (ARIM)



List of Equipment Supports in IMS Spoke (FY2022)

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	T. Koitaya, K. Yamamoto, O. Ishiyama
Microstructure Fabrication	Maskless Lithography with Step Gauge	H. Yamamoto	T. Kondo, T. Kikuchi, 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		

X-rays	Single Crystal X-Ray Diffractometer	T. Yokoyama	Y. Okano
	Low Temperature Single Crystal X-Ray Diffractometer for Microcrystals		M. Fujiwara, M. Miyajima
	Powder X-Ray Diffractometer		G. Kobayashi, F. Takeiri, M. Fujiwara, M. Miyajima
	Operando Multi-Purpose X-Ray Diffraction	S. Akiyama	A. Mukaiyama, Y. Furuike
	Small Angle X-Ray Scattering for Solutions	M. Fujita	T. Mitsushashi, T. Yokoyama
	Molecular Structure Analysis using Crystalline Sponge Method		
Electron Spectroscopy	X-Ray Photoelectron Spectroscopy	T. Yokoyama	T. Koitaya, S. Iki, K. Yamamoto, 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)		M. Fujiwara, M. Miyajima
	Calorimeter for solids		M. Uruichi, K. Fujikawa
Mass Spectrometer	Matrix Assisted Laser Desorption/Ionization Time of Flight Mass Spectrometer		M. Uruichi, K. Fujikawa
Spectroscopy	Microscopic Raman Spectroscopy	T. Yokoyama	M. Uruichi, K. Fujikawa
	Fourier Transform Far Infrared Spectroscopy		
	Fluorescence Spectroscopy		
	Ultraviolet & Visible Absorption Spectroscopy		T. Ueda
	Absolute Photoluminescence Quantum Yield Spectrometer		T. Mizukawa, M. Uruichi, K. Fujikawa
Lasers	Circular Dichroism		T. Ueda
High Field NMR	Picosecond Laser		
	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	Y. Kanazawa
	Magnetic Thin Films	T. Yokoyama	T. Koitaya, K. Yamamoto
	Metal Complexes	T. Kusamoto	R. Matsuoka
	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 advantage of the “wave nature” of 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 to discuss policy issues related to quantum science and technology, and a new national proj-

ect, the “MEXT-Quantum Leap Flagship Program (MEXT Q-LEAP)” was launched in 2018 based on the discussions held in the committee. This program is a 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.

In the ongoing research project “Development of cold-atom based quantum simulators by optical control with preci-

sions 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, the project 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 Hamamatsu Photonics Central Research Laboratory, Kyoto University, Okayama University, Kindai University, University of Oxford, Heidelberg University, University of Strasbourg, University of Innsbruck, and others.

(d) “Large-Scale and High-Coherence Fault-Tolerant Quantum Computer with Dynamical Atom Arrays” Supported by the Cabinet Office / JST 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 research 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.

In the R&D program “Large-scale and high-coherence fault-tolerant quantum computer with dynamical atom arrays” under Goal 6, we are developing the implementation of dynamic qubit arrays in which each of the cooled atomic qubits arranged in a large array of optical tweezers is freely and rapidly moved, and gate operations, error detection and correction are carried out, as well as the implementation of a quantum computer with a quantum error-correction functionality. The goal is to realize a fault-tolerant quantum computer by achieving high stability and usability through integration and packaging of the components under the collaboration of industry and academia.