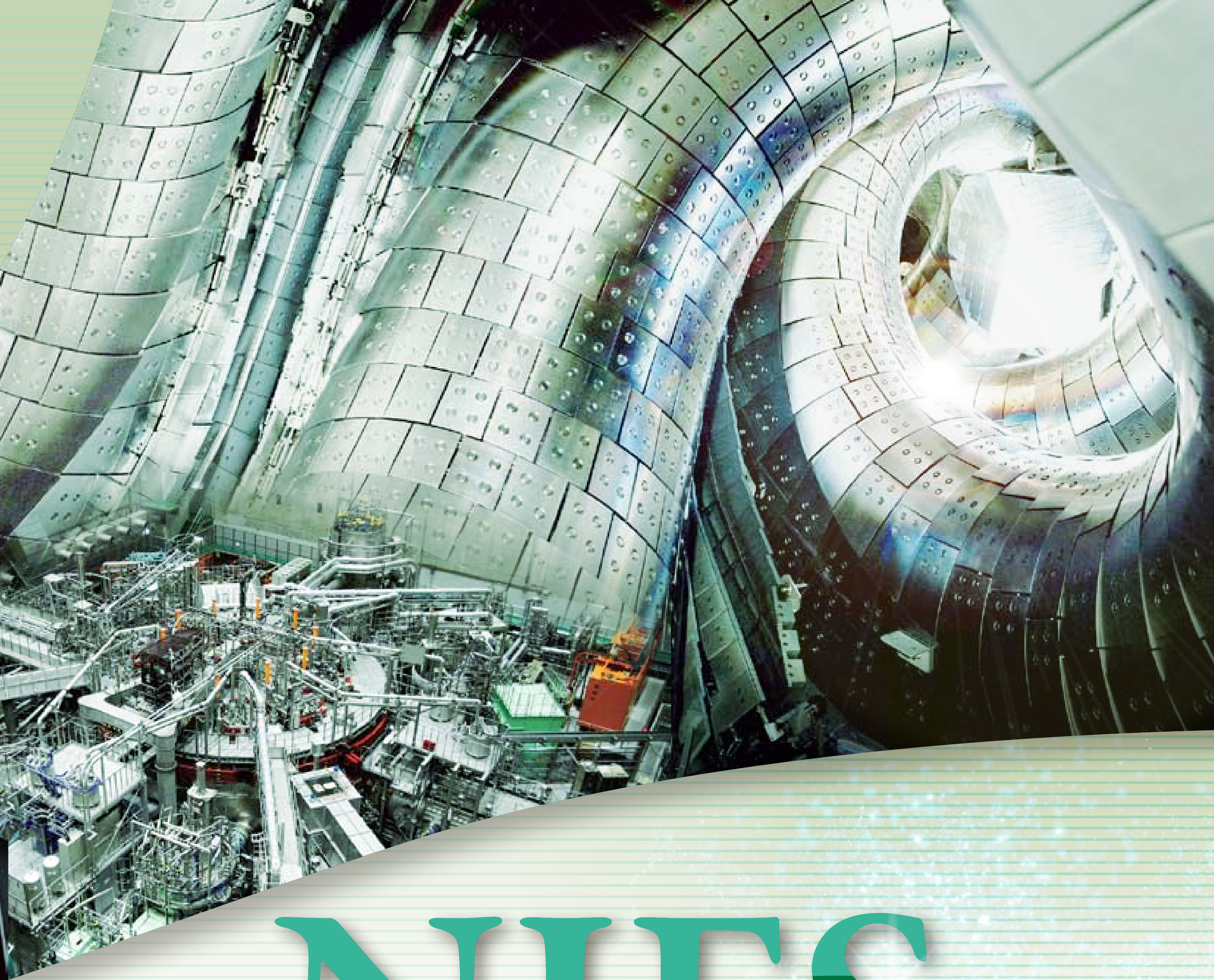

NIFS

NATIONAL INSTITUTE for FUSION SCIENCE

2023 ▸▸▸ 2024

English version
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Inter-University Research Institute Corporation National Institutes of Natural Sciences
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NATIONAL INSTITUTE for FUSION SCIENCE 2023 ▶▶ 2024

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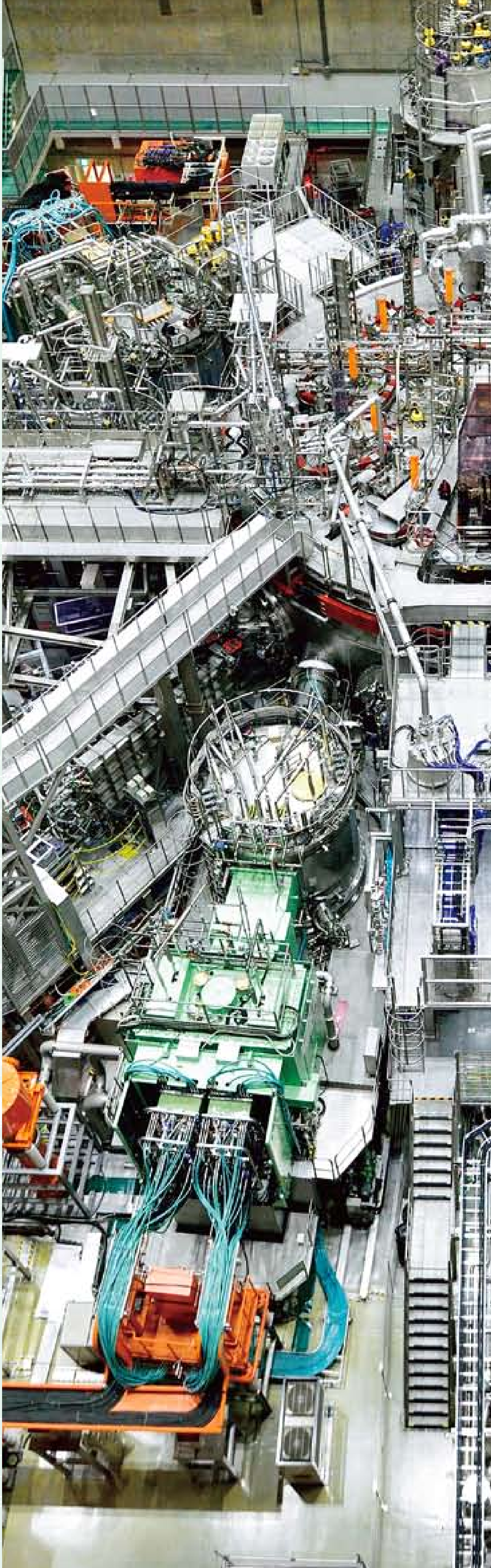
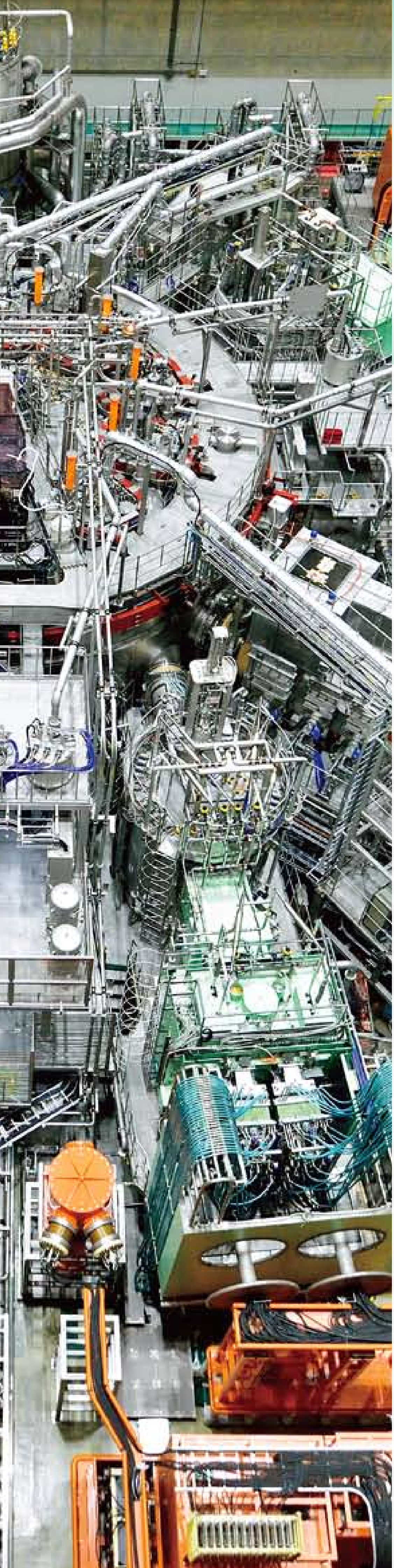




Towards a new era of fusion science

YOSHIDA Zensho
Director General of National Institute for Fusion Science

吉田 善章

Fusion science is a comprehensive area encompassing various disciplines with extremely high potential. Not only the immense merit of fusion energy, but also the possibilities of new discoveries give us the motivation to climb a high mountain - the history of overcoming every challenge has brought academic depth and breadth to fusion science. While the physics of fusion reactions is already well known, we have yet to understand how a “system”, called high-temperature plasma, can maintain a stable condition. It is a macroscopic system producing an internal energy by which autonomous dynamics sustains. The aim of fusion science is to elucidate the mechanism of such a spontaneous process; the fundamental principle must be common to the dynamics of the universe, society, or life. Recognizing the problem in a wide context, we pave the way in a zone of fundamental studies. On the way to fusion, the ultimate energy source, we will encounter many crossroads leading to future science and technology.

As we know, there are three different states of matter, i.e., solid, liquid, and gas. Even if the same molecules constitute matter, its “state” varies as the temperature is changed. At a high temperature, all matter becomes gas, in which molecules are disconnected and distribute sparsely, moving freely. When the temperature is raised further, molecules are broken into ions (positively charged heavy particles) and electrons (negatively charged light particles) by disconnecting the electrical bonding of ions and electrons; we call such a high temperature state “plasma”. While plasma is not common on Earth, it is the most typical state of matter in the universe. Our sun is a huge mass of plasma, consisting mainly of hydrogen. Inside it fusion reactions produce enormous energy. A star is a naturally made sustainable system of high temperature plasma, energized by fusion reactions.

Although the fusion energy is often likened to a “sun on Earth”, we need to think of a system that is completely different from stars. The challenge of fusion science is, indeed, to build a sustainable fusion system, based on a thoroughly new mechanism that we cannot find an example of in nature. A star confines plasma by gravity, but it is a very weak force, only effective against huge masses such as celestial bodies. We have to invoke a much stronger force to create a compact confinement system; magnetic force is the recourse. However, magnetic force acts like a “vortex” and its role in creating macroscopic structures is an interesting subject of contemporary physics and mathematics. We also need a much higher temperature than that at the center of the sun. In a typical star like our sun (the main sequence star), the reaction of synthesizing a helium atom from a hydrogen atom proceeds slowly. This reaction (a so-called p-p chain reaction) is too slow for producing sufficient fusion power in a compact system. We need to apply a faster reaction than that of the sun; the easiest is the deuterium-tritium fusion reaction, which produces helium and neutrons, but occurs at temperatures of around 100 million degrees Celsius. On the other hand, several meters away from the plasma, we have to place super-conducting magnets to generate the magnetic field, which are operated at ultra-low temperature. Therefore, fusion on Earth requires an extreme technology, dealing with ultra-high and ultra-low temperatures, separated only by several meters.

The road to fusion power is purgatorial and much harder than the prediction made at the beginning (the mid-20th century). However, it is not necessarily unfortunate that we encounter unexpected challenges. As many great researchers say that discovery is born from failure, unknown truths exist outside the range that one can predict. Fusion energy is a steep peak for development researchers to climb, but it is also a treasure trove for academic researchers. The task of the academic researcher is to generate new knowledge from the input of difficult problems.

All members of the National Institute for Fusion Science (NIFS) are working on the construction of a lighthouse that illuminates the direction of fusion science in choppy academic waters ahead. NIFS is a broad avenue for many researchers, through which the scope of “fusion science” will extend in the world of science. We hope that many people will pay attention to our endeavor and participate in these activities.

September 2023

Goals of NIFS

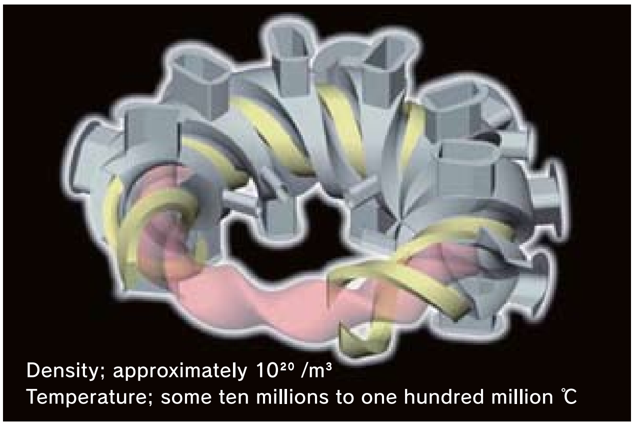
Fusion is a ubiquitous phenomenon in the universe and is the energy source for all activities there. The sun's fusion energy also sustains our earth's environment. The National Institute for Fusion Science addresses a wide range of research topics: plasma physics, microscopic quantum processes and materials science, and engineering technology for the components of fusion devices necessary to realize fusion energy in a form we can use.

Human beings have built the current advanced scientific, technological, and industrial society by using fossil fuels such as coal, petroleum, and natural gas as energy sources. However, the consumption of fossil fuels produces large amounts of carbon dioxide and nitrogen oxides, which seriously impact the global environment, and their reserves are limited. Fusion energy has great potential to be a solution to this problem.

As an Inter-University Research Institute, the National Institute for Fusion Science (NIFS) is committed to contributing to the development of fusion science and forming a broad science and technology base by making large research facilities and various research equipment available, and promoting joint research with domestic and foreign universities and research institutes. In addition, NIFS strongly promotes the education of students who will shape the future by establishing laboratories at the Graduate University for Advanced Studies, Nagoya University, Kyushu University, and the University of Tokyo and by providing research guidance to graduate students from universities throughout Japan. NIFS serves as a focal point where the knowledge of the national and global research community is united.

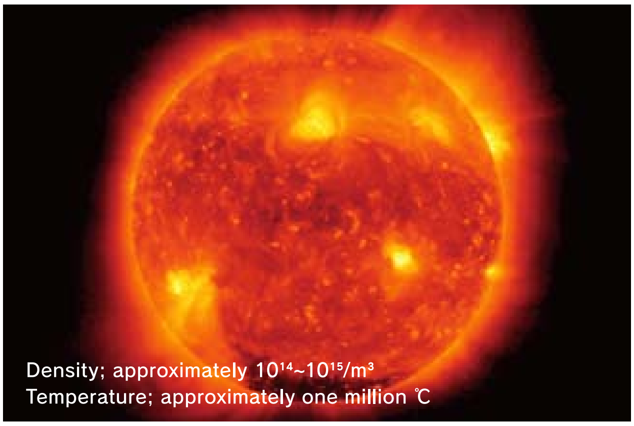
Various Forms of Plasmas

Nuclear fusion plasmas



Density; approximately 10^{20} /m³
Temperature; some ten millions to one hundred million ℃

Solar corona



Density; approximately 10^{14}~10^{15}/m³
Temperature; approximately one million ℃

Photograph: provided by NAOJ/JAXA/MSU

Aurora

Density; approximately 10^{14} /m³
Temperature; One to two thousand ℃

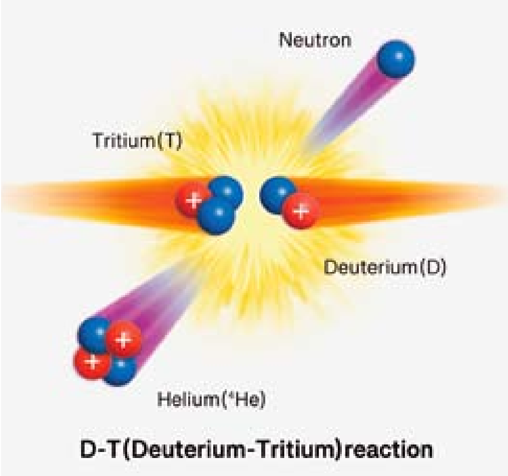
Photograph: provided by National Institute of Polar Research

Flame (inside the field kiln)

Density; approximately 10^{11} /m³
Temperature; Less than two thousand ℃

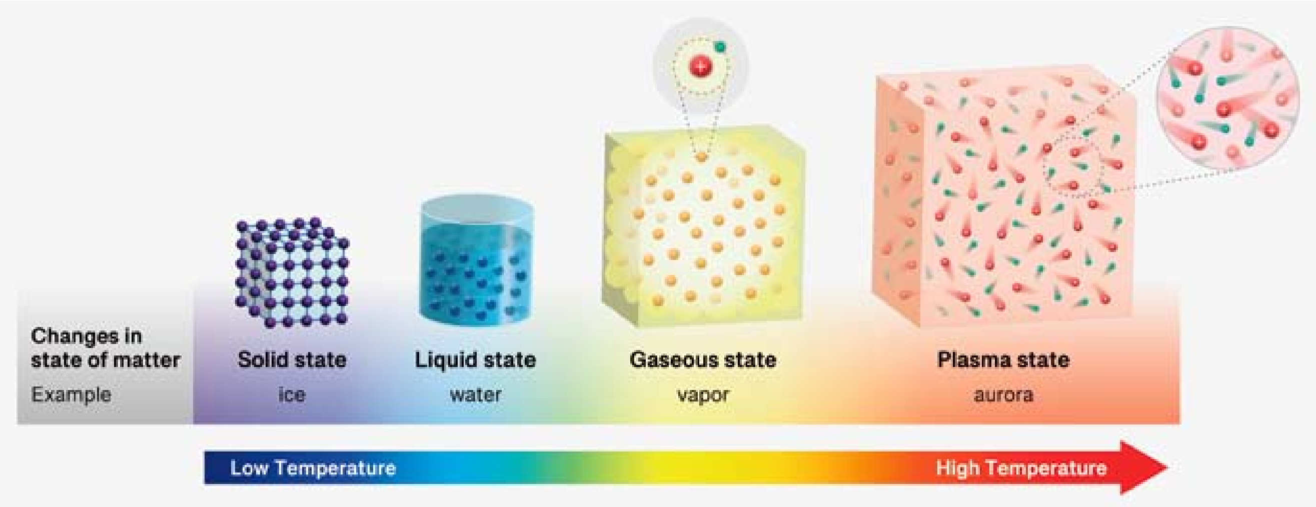
Photograph: provided by the Toki City Junior Chamber

What is FUSION?

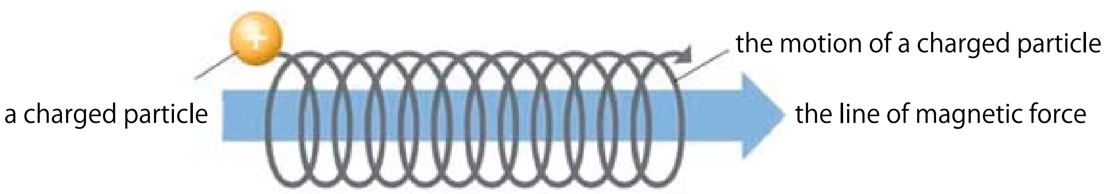


In nuclear fusion, two nuclei with small masses collide to form another heavier nucleus, generating enormous energy. Because the total mass after the reaction is slightly lighter than before the fusion reaction, the mass difference is converted into energy ($E=mc^2$). The fusion reaction is the ubiquitous energy source in the universe. Inside stars like the sun, a fusion reaction that produces helium from four hydrogen atoms has generated energy for over 5 billion years. Fusion research is being conducted to use the universe's energy as our power source. To realize a fusion reaction on Earth, deuterium and tritium, isotopes of hydrogen, are used as fuels. Deuterium and lithium, necessary to produce tritium, are found in seawater and can generate a large amount of energy with a tiny amount of hydrogen isotope.

To initiate a nuclear fusion reaction, deuterium and tritium nuclei (ions) must be brought close together, but Coulomb's repulsive force prevents it. To overcome this repulsive force and bring the nuclei closer together, they must collide at a speed of 1,000 km/s or more. In addition, since the high velocity of the nuclei causes them to escape and energy is lost, it is necessary to confine the fast-moving nuclei within a certain space, and it is also required to increase the density of the nuclei to increase the number of collisions and obtain more fusion energy. Confining many fast-moving nuclei in a certain space is the condition for fusion reactions. Such a state is called a high-temperature plasma.



The sun confines plasma with its enormous gravity, but a magnetic field is used to confine the plasma on the Earth. The motion of charged particles, such as nuclei and electrons, which constitute the plasma, can be limited around the magnetic field lines, confining the high-temperature plasma in a certain space. Plasma research, which aims to understand various complex phenomena occurring in plasmas, is of central importance for the development of fusion reactors and provides many subjects for academic research, and plays an essential role as a basis for understanding cosmic and astronomical phenomena.



Organization

April 2023

- Advisory Committee
- Director General: YOSHIDA, Zensho
- Deputy Director General: TODO, Yasushi

Fusion Science Interdisciplinary Coordination Center	Director	MURAKAMI,Izumi
Safety and Health Promotion Center	Director	OSAKABE, Masaki
Information Systems and Cyber Security Center	Director	YAMAMOTO, Takashi
Rokkasho Research Center	Director	YOKOYAMA, Masayuki
Research Enhancement Strategy Office	Chief	YOSHIDA, Zensho
Platform Management Office	Chief	SAKAMOTO, Ryuichi
Research and Education Innovation Office	Chief	NAGAOKA, Kenichi
Public Relations Office	Chief	TAKAHATA, Kazuya
Fusion Science Archives Office	Chief	MURAKAMI,Izumi
Library	Chief	MURAKAMI,Izumi

Department of Research

Director SAKAMOTO, Ryuichi

Meta-hierarchy Dynamics Unit	Chief	NUNAMI, Masanori
Structure Formation and Sustainability Unit	Chief	YAMAGUCHI, Hiroyuki
Phase Space Turbulence Unit	Chief	KOBAYASHI, Tatsuya
Plasma Quantum Processes Unit	Chief	KATO, Daiji
Transports in Plasma Multi-phase Matter System Unit	Chief	MASUZAKI, Suguru
Sensing and Intellectualizing Technology (S&I) Unit	Chief	UEHARA, Hiyori
Plasma Apparatus Unit	Chief	NAKANO, Haruhisa
Complex Global Simulation Unit	Chief	TOIDA, Mieko
Ultrahigh-flux Concerting Materials Unit	Chief	NAGASAKA, Takuya
Applied Superconductivity and Cryogenics Unit	Chief	HIRANO, Naoki

Department of Engineering and Technical Services

Director HAYASHI, Hiromi

Mechanical Systems Technology Division	Manager	YOKOTA, Mitsuhiro
Design and Development Technology Division	Manager	SUZUKI, Naoyuki
Electrical and Electronic Technology Division	Manager	KONDO, Tomoki
Diagnostics and Analysis Technology Division	Manager	HAYASHI, Hiroshi
Control and Information Technology Division	Manager	MORIUCHI, Sadatomo

Department of Administration

Director IINO, Michiko

General Affairs Division	Manager	ASANO, Masahiro
Financial Affairs Division	Manager	HIROI, Noriaki
Research Support Division	Manager	SHOJI, Madoka
Facilities and Safety Management Division	Manager	YASUE, Akihito

Staff

Director General	1
Researchers	105
Engineers	45
Administrative Staff	41
Employees on Annual Salary System	11
Research Administrator Staff	4

Units and Platforms

Unit

Fusion energy, the most critical outcome of fusion science, is expected to be the next generation power source that can be considered to solve energy and global environmental problems because it is characterized by 1) carbon neutrality, 2) abundant fuel, 3) inherent safety, and 4) environmental conservation. On the other hand, fusion science is a vast research field that encompasses many complex problems, and many research issues remain to be solved. Therefore, in addition to development research that unites various sciences and technologies, academic research to create innovations that open up new possibilities is essential.

The National Institute for Fusion Science (NIFS), an academic research institute, intends to promote interdisciplinary research in fusion science by dividing the challenges of fusion energy into several themes and universalizing each of them. By sharing cutting-edge issues and awareness of the problems of various academic fields through interdisciplinary development, we aim to promote the sharing of brain power, involving an unprecedentedly wide range of areas and to enable the sustainable promotion of fusion development research over the long term.

To promote interdisciplinary research, NIFS has re-defined its identity as an ensemble of research themes as Units, after two years of community-wide discussions. NIFS re-started with ten Units from FY2023.

A Unit is the main body for conducting collaborative research for ten years. It promotes collaborative research that will lead fusion science for the next decade under the banner of a research theme that represents fusion science defined by itself. The Unit will continue to examine its own theme through open discussions and revise it as necessary. The Unit organization will create possibilities for joint usage and collaborative research involving a more comprehensive range of fields than ever.

Below are the names of the ten Units. The research themes of each Unit are listed on page 8-12.

Meta-hierarchy Dynamics Unit	Structure Formation and Sustainability Unit
Phase Space Turbulence Unit	Plasma Quantum Processes Unit
Transports in Plasma Multi-phase Matter System Unit	Sensing and Intellectualizing Technology (S&I) Unit
Plasma Apparatus Unit	Complex Global Simulation Unit
Ultrahigh-flux Concerting Materials Unit	Applied Superconductivity and Cryogenics Unit

Platform

The platform is various research equipment that serves as the basis for joint research conducted by a Unit. As an Inter-University Research Institute, the National Institute for Fusion Science (NIFS) provides large research facilities and various research equipment to promote joint research with universities and research institutes in Japan and abroad. The following three sections of the Platform management office operate in NIFS.

LHD Section	To utilize the legacy of the LHD project, such as high-precision diagnostics and various heating devices, the LHD will be supported as an academic research platform for three years, starting in FY2023. The LHD academic research platform is operated on an open-data basis to promote interdisciplinary studies of the Unit.
Computer Section	The section consists of numerical experiments, a numerical database of atoms and molecules, and a data analysis system. As for numerical experiments, the Plasma Simulator "Raijin," a supercomputer dedicated to the plasma fusion field, has been operating since FY2020 to promote world-class joint research on plasma fusion simulations.
Engineering Facilities Section	The section manages engineering research facilities installed in the experimental buildings (Superconducting Magnet System Laboratory, Fusion Engineering Research Laboratory, Radiation Controlled Area in LHD building, Development Laboratory, and Diagnostics Laboratory) in NIFS.

Meta-hierarchy Dynamics Unit

Fusion science covers a very wide range of spatio-temporal scales and physical parameter regions, from the microscopic scales of atoms or electrons to large scales that can be manipulated by human hands, such as fluids, solids, plasma, and actual devices. Furthermore, the collective behavior of charged particles causes a wide variety of phenomena not only in the plasma itself but also in the materials in contact with it. Understanding of these complex phenomena has been pursued by elemental separation into various hierarchical processes and physical models, or by combining the various hierarchical levels with each other. The separation of electrons and ions into their kinetic scales and the coupling of particle and fluid models are good examples. However, with recent remarkable progress toward higher precision and larger scales in experimental and numerical research, phenomena that cannot be well captured by the separation and coupling of hierarchies have become apparent. In such phenomena, what was once a clearly separable hierarchy becomes continuously obscured according to physical parameters, or the scales of hierarchical separation overlap and appear to be a new hierarchy. In this Unit, we will reconsider the static and dynamic characteristics of such hierarchies from a bird's-eye view (meta-perspective). We focus on the hierarchical nature of complex phenomena such as multiscale turbulences, resonance between wave and particle motion, global propagation of fluctuations, plasma-solid interface phenomena, velocity-space structure, anisotropy of distribution functions, and so on, in fusion plasmas, and we are exploring the universality in the hierarchical dynamics.

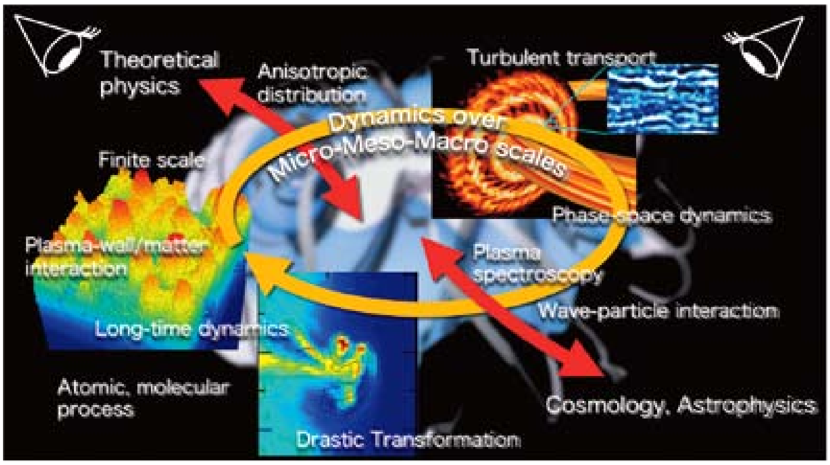
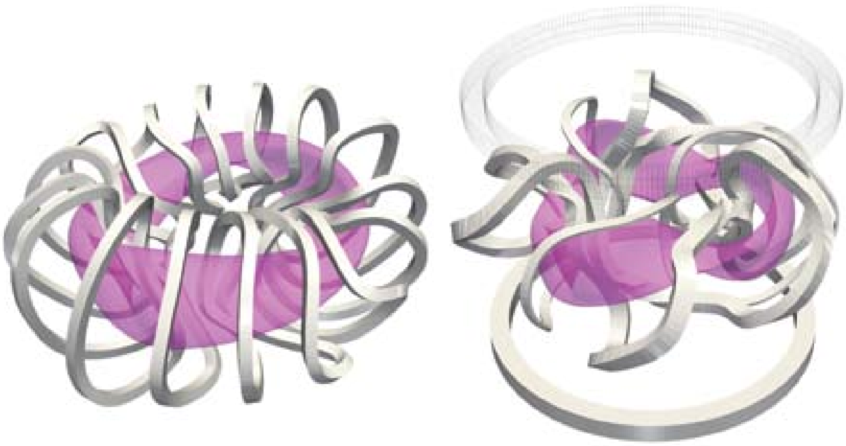


Figure. Meta-hierarchy Dynamics Unit addresses various issues in fusion science. Hierarchical dynamics with clarity and ambiguity will be explored from a meta perspective.

Structure Formation and Sustainability Unit

Many systems in the real world, such as the Earth, where matter circulates under sunlight, and the organisms that live on it, are placed in a flow of energy. Energy tends to eventually turn into uniform thermal energy. On the other hand, when energy flows through the system, there is room for a non-uniform structure to form and persist. In a magnetic confinement fusion reactor, there is an energy flow starting from the nuclear fusion reaction that occurs in the core plasma. This energy flow creates the confined state of the plasma in magnetic field. Various structures have been observed in experiments to be formed in the plasma, such as organized flows, boundaries where the properties of the plasma change over time and space, exhaust of specific kinds of particles, etc. Some of these structure formations have been found to contribute to the efficiency of fusion reactors. The "Structure Formation and Sustainability Unit" explores the universal principle behind structure formations common to various systems, and develops efficient and sustainable plasma confinement methods. An important question is how the flow and distribution of energy is determined in a system composed of multiple elements, and what role magnetic fields play in the case of plasmas. Through advanced measurement systems that quantify high-energy particles driving energy flow, experiments using new confinement magnetic fields, and micro-to-macro theory and simulations, we clarify these from both experimental and theoretical perspectives. The findings are fed back to the design and optimization of the confinement magnetic field and the electromagnetic coil that creates it.



Examples of the coil and plasma configurations derived by the optimization system being developed in the Structure Formation and Sustainability Unit.

Phase Space Turbulence Unit

Magnetically confined fusion plasmas are generally not at all dense so that particle collision rarely occurs. Particles have their electric charges therefore can be trapped or expelled in a phase of electrostatic waves. Those trapped particles travel with the waves while being bounced by the wave potential, like surfing (Fig.1). During this motion, the waves and particles can exchange their energy and momentum, leading to more complicated behaviors. As a result, enhanced plasma transport that makes plasma confinement worse and/or collisionless plasma heating are theoretically predicted to occur. So far, direct observation of those wave-particle interactions has been extremely challenging and therefore experimental knowledge derived from it has been limited. The key quantity is the velocity distribution function, which describes statistical properties of the particle dynamics. In a fluctuation-less situation the velocity distribution function follows Gaussian (normal) distribution.

The Phase-Space Turbulence Unit tries to directly measure the velocity distribution function by cutting-edge diagnostic systems, with unprecedented resolutions in time, real-space, and velocity-space (Fig.2), by which the above-mentioned physics are discussed. This activity contributes not only to nuclear fusion development but also to uncovering far-nonequilibrium plasma dynamics in the universe.

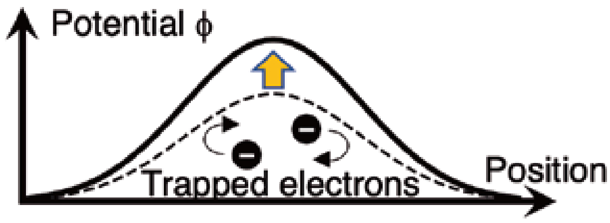


Fig.1. Bounce motion of particles trapped by a potential wave.

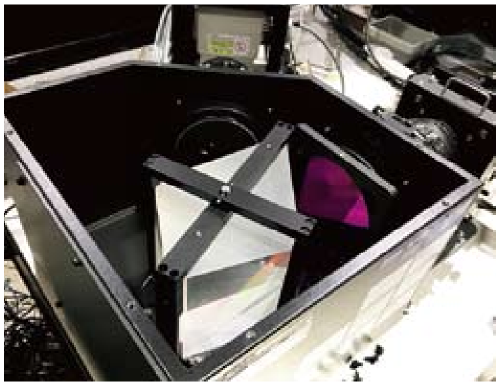


Fig.2. Cutting-edge spectrometer system equipped with grating-prism, CMOS fast-camera, and image-intensifier.

Plasma Quantum Processes Unit

This Unit addresses the question of how collective properties and dynamics are defined and observed as collective phenomena from quantum processes of atoms, molecules, and light in plasmas and materials. Specifically, we measure exotic quantum processes created in the laboratory by highly charged ion sources and intense laser fields, and develop quantitative physical models of non-equilibrium plasmas in fusion reactors, astronomical objects, and the universe, as well as high-density plasmas. From these studies, we aim to elucidate the physics that is universal to collective phenomena on diverse and broad scales.

We are also conducting highly interdisciplinary collaborative research on development of atomic data and spectroscopic models for various astronomical observations (solar corona, solar wind, supernova explosions, kilonovae, etc.), development of short wavelength light sources using laser pumped plasmas, and the dynamics of muon quantum few-body systems. In addition, we are also developing a numerical database of atoms and molecules and making it open (http://dbshino.nifs.ac.jp/) for various plasma research and applications.

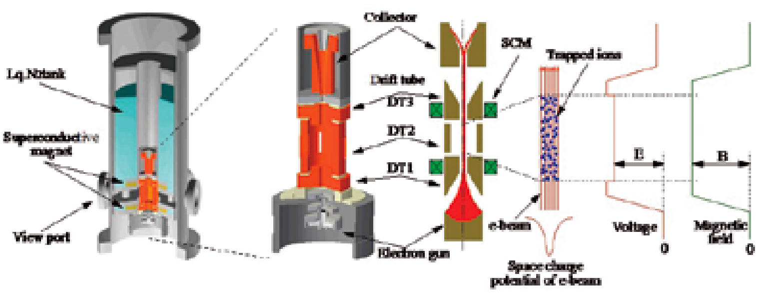


Fig.1 Schematic of a compact electron beam ion trap (CoBIT) developed in collaboration with the University of Electro-Communications to generate, trap, and perform precision spectroscopy of highly charged ions of elements observed in fusion reactors and astronomical plasmas.

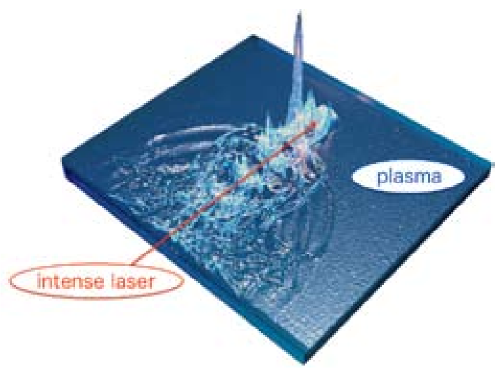


Fig.2 Example of a fully kinetic simulation on laser-plasma interaction. The laser-plasma interaction generates a localized strong electric field through large-amplitude plasma fluctuations and attracts attention as a next-generation compact particle accelerator.

Transports in Plasma Multi-phase Matter System Unit

The term "multi-phase" refers to the three states of matter: solid, liquid, and gas. At the point where the fourth state of matter, plasma, meets the other three, many interesting phenomena occur. In a fusion reactor, relatively cold plasma around the core plasma, where the fusion reaction is taking place, is connected to the solid or liquid reactor wall. In front of the wall, gas is added to lower the plasma temperature to reduce the heat load on the wall. In the “Transports in Plasma Multi-phase Matter System” Unit, the objective of the research is to investigate how heat and particles are transported in the system where the plasma contacts solids, liquids, and gases in a fusion reactor, to predict what a future fusion reactor will look like, and to control the transport of heat and particles. The Unit also aims to apply the knowledge and techniques gained from fusion research to study various plasma and multi-phase fields other than fusion, such as plasma biotechnology, SDGs, and the formation mechanisms of living materials in space, and to contribute to the advancement of these fields. Our research is conducted through experiments using plasma devices, various material analyses using electron microscopes, etc., and computer simulations.

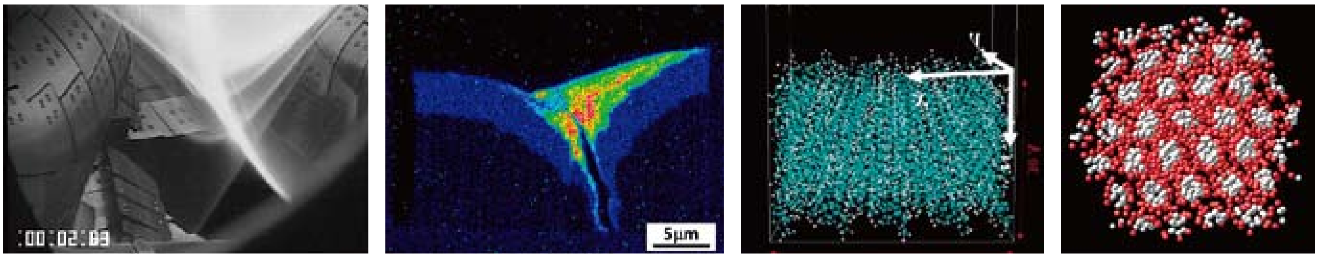


Figure. From left to right: a visible light image of LHD divertor plasma, beryllium distribution on the plasma-facing surface of the tungsten divertor plate in the JET tokamak device, an example of molecular dynamics simulation of hydrogen recycling in an amorphous carbon wall, an example of dissipative particle dynamics simulation of the formation of self-assembled structures in amphiphilic molecular systems.

Sensing and Intellectualizing Technology (S&I) Unit

In this Unit, we aim to conduct “Sensing and Intellectualization (S&I)” of various types of plasma physics. In our definition, S&I is to elucidate the complex structures and relations inside nature and to convert the information into knowledge.

We develop new plasma diagnostics and expand their measurable range. In addition, we maximize the amount of information to extract from the experimental results by utilizing statistical mathematics and data science. Moreover, we reveal hidden correlations inside the obtained data by an interactive method, i.e., converting the data into visual, auditory, and textural information. We collaborate on these research topics with scientists around the world to tackle open issues in fusion science.

The S&I Unit consists of the following three research pillars:

1. Research of plasma dynamics with advanced measurement and analysis

We develop plasma diagnostics such as phase-contrast imaging and laser Thomson scattering measurement, which can pave the way for a deeper understanding of plasma physics. We also work on the development of light sources and detectors that enable new measurements, which can be applied in industry.

2. Sustainable plasma control via predictive/judgment-oriented research using data science

We establish a real-time prediction and judgment method for fusion plasma. In addition, we will investigate the circulation process of stable and radioactive isotopes for the social implementation of fusion reactors.

3. Challenge of understanding data and development of public communication

We study expression methods such as VR display that enables 3D + α analysis, and construction of numerical models for obtaining scientific knowledge. We aim to systematize the intellectual search process that has been conducted empirically so far. In addition, we promote open science and outreach activities for the contribution of our studies to society and the realization of fusion power generation.

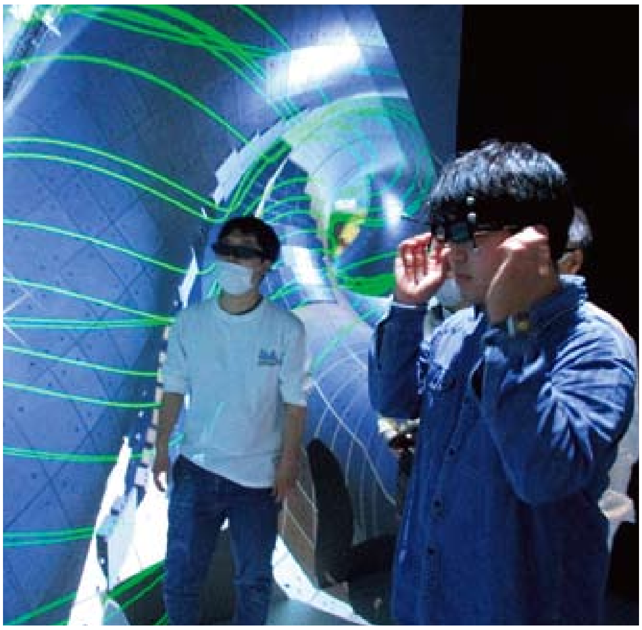


Figure. 360-degree VR display of fusion plasma

Plasma Apparatus Unit

The concept of the Plasma Apparatus Unit is to elucidate the nature of collective phenomena in charged particles with various energy levels and to control and apply the charged particles by utilizing the elucidation. Based on the concept and technologies developed in fusion science, the Plasma Apparatus Unit will find new approaches to elucidating natural phenomena and deepen the elucidation by further sophisticated technologies of plasma apparatus, which involves a charged-particle control apparatus, and by creating new apparatus technologies. Introducing knowledge and technologies in different fields will be done by collaboration and union with them. The Plasma Apparatus Unit will pursue new developments as technology drivers in natural and applied sciences through academic knowledge and extreme apparatus technologies of collective phenomena in charged particles at the leading edge of fusion science.

Interdisciplinary investigations beyond the boundaries of fusion science require diversity. Investigations in The Plasma Apparatus Unit with various plasma apparatus are conducted by a wide range of people, not only inside but also outside NIFS. The main individual investigations at the time of the unit establishment are neutral beam injector (NBI), anti-material plasma, muon and fusion collaboration, and spacecraft electric propulsion. Bases of the four investigations, except NBI, are outside NIFS. Sharing information closely in the Unit, starting from common knowledge and technologies among individual investigations, and addressing issues from multiple perspectives, synergistic effects such as leading to completely new ideas can be expected. This will bring deeper elucidation and new developments in science. In order to maximize the effects, the Plasma Apparatus Unit will make NIFS function as one of the hubs of an academic network that promotes the knowledge and technology of various plasma devices.

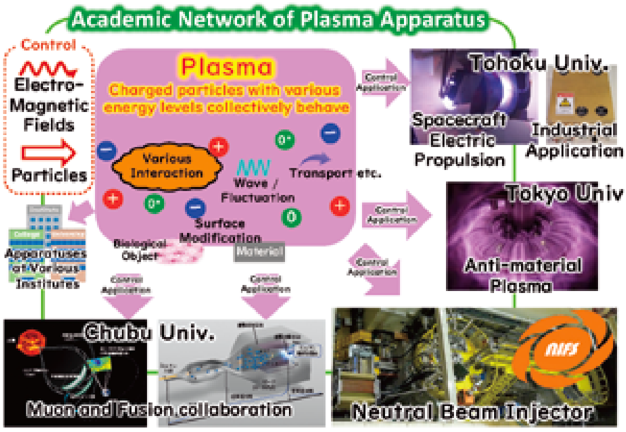
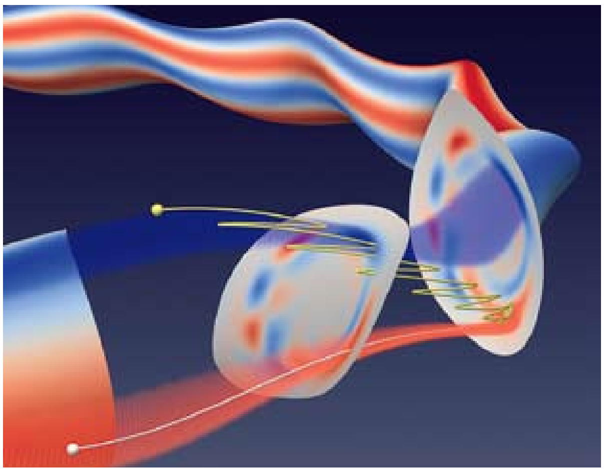


Fig. Academic Network of Plasma Apparatus Unit

Complex Global Simulation Unit

In order to understand the behavior of an entire system composed of multiple hierarchies, individual simulations of each hierarchy are not sufficient. Global simulations that consider the interactions between hierarchies are required. Simulations of magnetic confinement fusion plasma require consideration of the interaction between the microscopic hierarchy of particles in the plasma and the macroscopic hierarchy of magnetohydrodynamic behavior of the entire plasma. Although their realization is not easy, such complex global simulations are important issues that are expected to be actualized not only in the field of nuclear fusion research but also in many other academic fields. The reason for this is that the temporal and spatial scales of the microscopic hierarchy and the entire system are often extremely different, and the capacity and capability of a computer is not sufficient to simulate the entire range of scales based on a single system of fundamental physical equations. The purpose of the Complex Global Simulation Unit is to develop simulation methods to solve this problem and to promote simulation research.

This Unit aims to develop simulation methods that couple different hierarchies and physical models to realize global simulations that predict and elucidate the behavior of entire physical systems that cannot be handled by simulations based on a single system of fundamental physical equations. This Unit will realize global simulations of the whole magnetic confinement fusion plasma including its core and edge, based on kinetic-magnetohydrodynamic hybrid simulation and will elucidate the complex behavior of plasmas. It will also develop a methodology with broad applicability to achieve simulations that more closely reproduce real-world phenomena, beyond the strong limitations imposed by the capacity and capability of the supercomputer. Interdisciplinary research by applying the developed methods to related fields will be promoted.



Pressure perturbation of a magnetohydrodynamic (MHD) instability and orbits of thermal ions in a Large Helical Device plasma simulated with a kinetic-MHD hybrid code. It has been found that trapped ions (shown by the yellow line) suppress the instability and play an important role in maintaining a high pressure plasma. This Unit will extend this simulation model to develop a new method to study interaction between such an MHD instability and micro-instabilities.

Ultrahigh-flux Concerting Materials Unit

Materials for fusion and fission reactors, aerospace craft, chemical plants etc. are used under extreme conditions, which give rise to non-equilibrium states in materials induced by ultrahigh-flux energy and various particles. The non-equilibrium states are expected to bring about the formation of unknown compounds and structural changes in materials such as a self-organization of constituent atoms, including crystal lattice defects. By making good use of these new compounds and structures, The Ultrahigh-flux Concerting Materials (UICoMat) Unit is to create novel materials that adapt themselves to the extreme conditions and engage with the ultrahigh-flux of energy and various particles.

Refractory metals, ceramic nanoparticles dispersion strengthened alloys (shown in the figure), ceramics for electrical insulation, hydrogen control, and various sensors, etc. will be investigated.

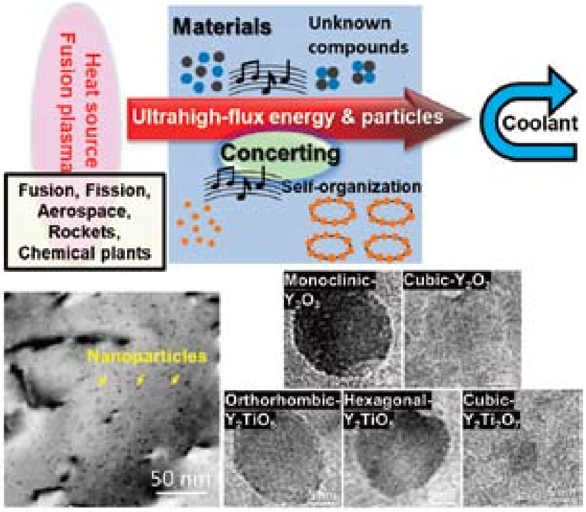


Fig. Schematic illustration of materials concerting with ultrahigh-flux energy and particles environments, and electron micrographs of the oxide dispersion strengthened (ODS) steel developed for fusion reactors. During the fabrication process, various oxide nanoparticles containing yttrium and titanium can be formed under non-equilibrium states.

Applied Superconductivity and Cryogenics Unit

The Applied Superconductivity and Cryogenics (ASC) Unit is a restructured body that consolidates the superconducting and cryogenic engineering research conducted by NIFS, aimed at promoting sustainable societal change through new study in these fields. Our Unit aims to clarify an exit strategy for superconducting systems in sustainable society, conduct research and development towards the societal implementation of superconducting technology, and serve as an academic research hub by offering various low-temperature experimental environments using temperature-variable cryogenic systems available in the Superconducting Magnet Research Building to various users through academia-industry collaborations. Furthermore, we will contribute to the realization of a hydrogen society by accumulating experience in the operation of liquid hydrogen as "clean energy," positioned as an achievable aim of Sustainable Development Goals (SDGs), and enhancing the social acceptability of hydrogen, including its safety. Finally, we will serve as a gateway for attempts ranging from basic research to societal implementation, as well as a hub for a network of liquid hydrogen research and development. Our research topics will be divided into three categories: "Research on Superconductors and Coils," "Research on Cryogenic Engineering," and "Research on Advanced Superconducting Wire," and we will group researchers into these three categories and clearly define milestones for each research topic to promote research activities.

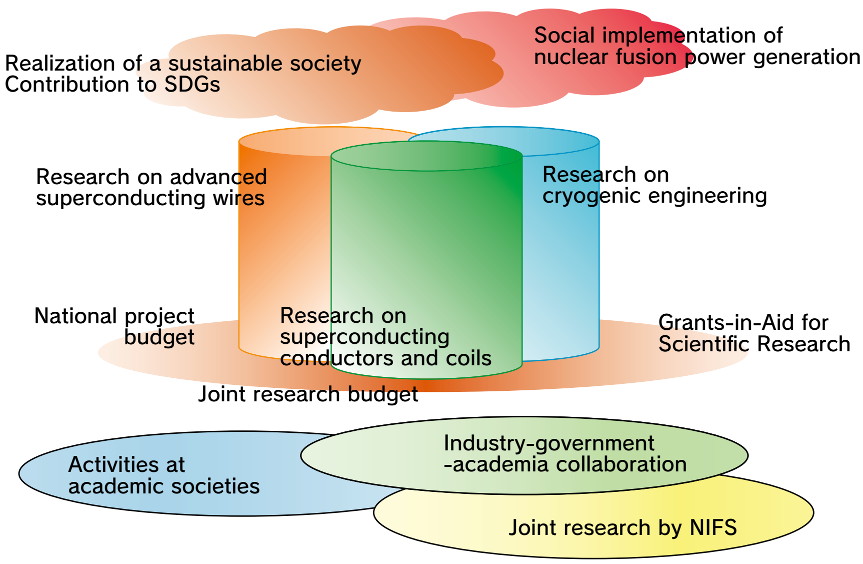


Image of Applied Superconductivity and Cryogenics Unit activities

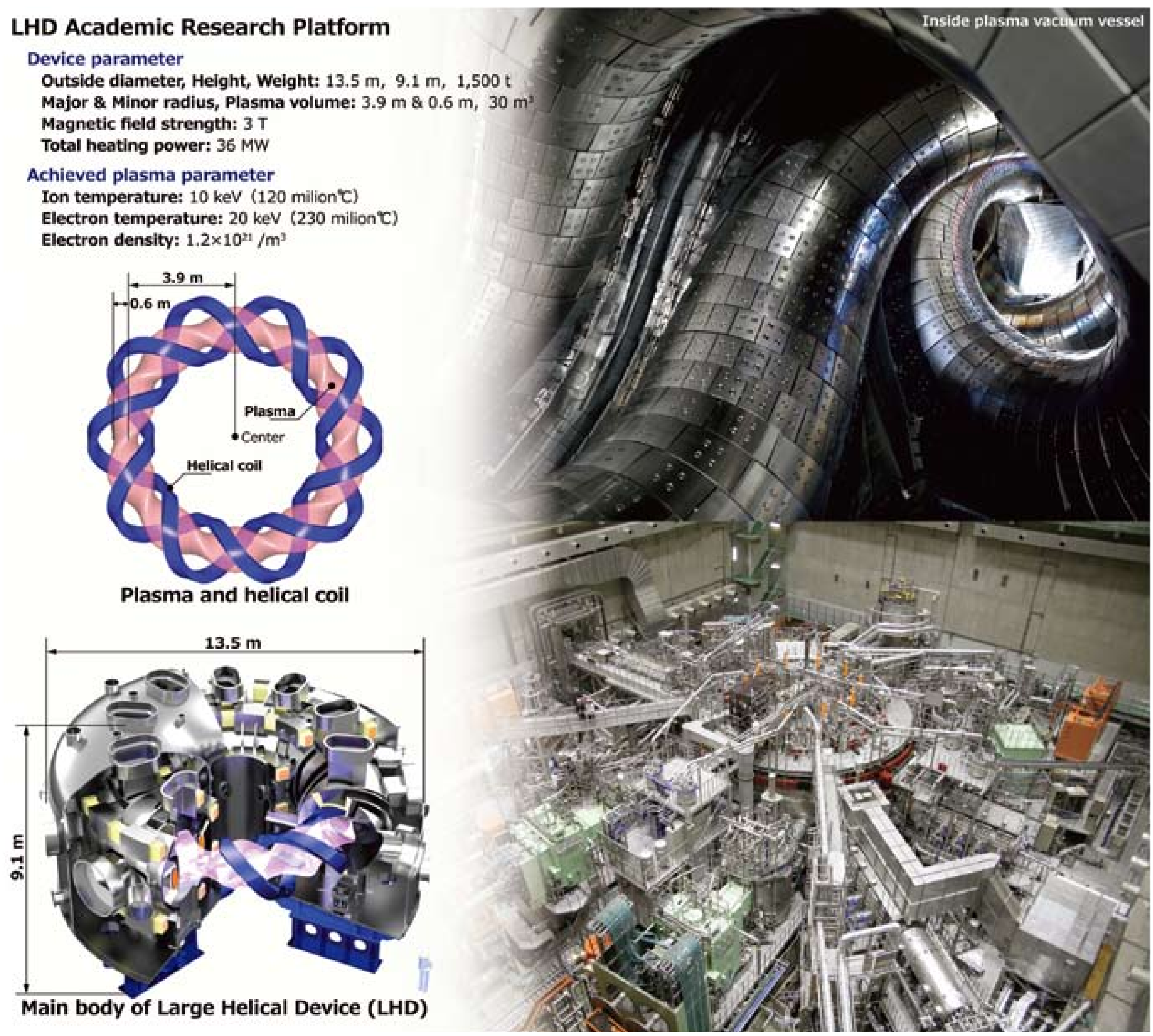
Platform Management Office

Platforms are a group of various research equipment that serve as the basis for cooperative research conducted by the Units. As an Inter-University Research Institute, the National Institute for Fusion Science (NIFS) provides extensive research facilities and a variety of equipment for joint usage to promote collaborative study with domestic and foreign universities and research institutes. The following three divisions operate the Platforms the National Institute for Fusion Science owns.

LHD Section

The LHD is the world's largest superconducting plasma confinement device. It has achieved many results over the quarter of a century since the first plasma was produced in March 1998, with a mission of creating a comprehensive understanding of the torus plasma. The LHD project was completed in FY2022, but the resources of the LHD project, such as precise and high-resolution diagnostics and various high-power heating devices, will be utilized as academic research infrastructure for three years from FY2023, with support from the Ministry of Education, Culture, Sports, Science and Technology.

The LHD aims to elucidate the principles of various complex phenomena common to space and astronomical plasmas as well as fusion plasmas, by measuring the internal structure of plasmas with various precise and high-resolution diagnostics. The Academic Research Platform LHD is based on the principle of open data ※1 and will also provide research infrastructure to promote interdisciplinary collaboration among different research fields.



※1 : LHD data repository: https://doi.org/10.57451/lhd.analyzed-data

Computer Section

Plasma Simulator Task Group

The Plasma Simulator “Raijin” is a massive parallel supercomputer system utilized to promote academic simulation research on nuclear fusion science and to support research and development that can contribute to progress in simulation science. The Plasma Simulator “Raijin” consists of 540 computers, each of which is equipped with one scalar processor for controlling the system and eight “Vector Engine” accelerators for high-speed computing. The 540 computers are connected with each other by a high-speed interconnect network. The computational performance of the system with Vector Engines is 10.5 petaflops. The capacities of the main memory and the external storage system are 202 terabytes and 32.1 petabytes, respectively. The supercomputer system is capable of large-scale simulation of fusion and other complex plasma phenomena. In addition, advanced (heterogeneous) computation combining operations by scalar processors and vector engines is also possible.

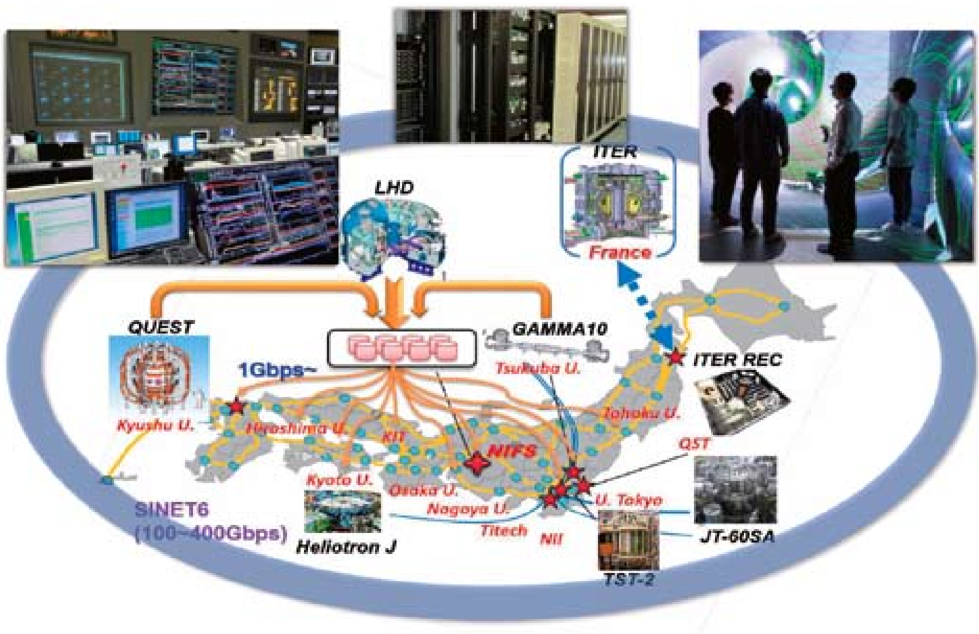
Plasma Simulator “Raijin”

Database Task Group

We provide the NIFS Atomic and Molecular Numerical Database at <https://dbshino.nifs.ac.jp/> for researchers worldwide, which contains numerical data, such as cross-sections, for collision processes between electrons, atoms, and molecules in plasmas. The amount of stored data is the largest in the world, among databases of collision cross-sections and many researchers access our database. We are also making databases, e.g. the Atomic Data and Analysis Structure (ADAS), available for domestic collaborators, which are provided under international collaborations.

Data Analysis Equipment Task Group

Data analysis equipment includes the experimental data acquisition and analysis system, the SNET research collaboration network, and the CompleXcope immersive virtual reality system. The experimental data system has accumulated over 3 petabytes of diagnostic and analyzed data from the NIFS LHD and other universities’ devices via SNET, and makes the entire research resources, including hundreds of analysis programs, available to the public at the same level as local and remote collaborative researchers. This is a research project to develop and build the “Plasma and Fusion Cloud.” The world’s largest nuclear fusion database is expected to be used for fusion energy developments and for “data science” and other fields, to promote “open science” in nuclear fusion research. CompleXcope enables observers to enter 3-D data space and observe plasma from various directions, thereby facilitating the study of plasmas with complex structures.



Data analysis equipment

Engineering Facilities Section

The Engineering Facilities section manages and operates experimental facilities in the Superconducting Magnet System Laboratory, the Fusion Engineering Research Laboratory, the Radiation Controlled Area in the LHD building, the Development Laboratory, and the Diagnostics Laboratory. A task group is assigned to each experimental building to coordinate the dates and systems of experiments. The main experimental facilities are listed in the table below.

<table>
<tr><th>Category</th><th>Platform</th><th>Building</th></tr>
<tr><td>Experimental facilities for cryogenic engineering</td><td>Superconducting magnet system test facility</td><td>Superconducting Magnet System Laboratory</td></tr>
<tr><td rowspan="9">Experimental facilities for in-vessel components</td><td>Heat and material flow loop system (Oroshhi-2)</td><td rowspan="8">Fusion Engineering Research Laboratory</td></tr>
<tr><td>Hot isostatic pressing system (HIP)</td></tr>
<tr><td>Creep testing machine</td></tr>
<tr><td>Planetary ball mill machine</td></tr>
<tr><td>Ultra-thin film nano-scratch tester</td></tr>
<tr><td>High purity arc melting device</td></tr>
<tr><td>Large planetary ball mill under inert atmosphere</td></tr>
<tr><td>High-speed impact test machine</td></tr>
<tr><td>Surface modification test device (SUT)</td><td>R&D Laboratories</td></tr>
<tr><td rowspan="10">Materials analysis equipment</td><td>Ultra-high resolution field emission scanning electron microscope (FE-SEM)</td><td rowspan="6">Fusion Engineering Research Laboratory</td></tr>
<tr><td>Scanning electron microscope (SEM)</td></tr>
<tr><td>X-ray photoelectron spectrometer (XPS(ESCA))</td></tr>
<tr><td>X-ray diffractometer (XRD)</td></tr>
<tr><td>Tandem accelerator</td></tr>
<tr><td>Ultra high heat load test equipment (ACT2)</td></tr>
<tr><td>Transmission electron microscope (TEM/STEM)･Gentle mill</td><td rowspan="4">Radiation Controlled Area in the LHD building</td></tr>
<tr><td>Focused ion beam scanning electron microscopy (FIB-SEM)</td></tr>
<tr><td>Scanning electron microscope (SEM)</td></tr>
<tr><td>Glow discharge emission spectrometer (GE-ODS)</td></tr>
<tr><td rowspan="3">Experimental facilities for ion source and beam</td><td>Neutral beam injection heating test stand (NBI test stand)</td><td>Fusion Engineering Research Laboratory</td></tr>
<tr><td>High intensity ion source</td><td rowspan="2">R&D Laboratories</td></tr>
<tr><td>Multiply charged ion source (CoBIT)</td></tr>
<tr><td rowspan="4">Experimental facilities for basic plasma physics and material irradiation research</td><td>Large bore and high density plasma device (HYPER-I)</td><td rowspan="4">R&D Laboratories</td></tr>
<tr><td>Linear plasma device (TPD-II)</td></tr>
<tr><td>Pen type atmospheric pressure plasma jet device</td></tr>
<tr><td>Wide stripe type, high density, room temperature, and atmospheric pressure plasma device</td></tr>
</table>

Fusion Science Interdisciplinary Coordination Center

The Fusion Science Interdisciplinary Coordination Center promotes interdisciplinary collaboration in fusion science and development research, and social implementation of fusion technology through industry-academia-government cooperation. As a comprehensive center that leads and supports collaborative research with universities, development research institutes, and industry, the center links three new interdisciplinary fields and a group of Units to develop challenging and interdisciplinary joint research that transcends the boundaries of existing fields. In particular, in order to build an interdisciplinary research network with advanced academic research fields, promote open science, collaborate with international research projects, and implement the technologies cultivated through nuclear fusion in society, the (1) Advanced Academic Research Coordination Section, (2) Development Research Coordination Section, and (3) Industry-Academia-Government Coordination Section support various joint research in collaboration with the Units.

As one of the interdisciplinary collaborative projects, researchers from the Phase Space Turbulence Unit and the Meta-hierarchy Dynamics Unit of the National Institute for Fusion Science, the Research Institute for Sustainable Humanosphere of Kyoto University, and Tohoku University have cooperated to launch the Aurora Observation Project. In this project, a two-dimensional spectrometer that can acquire data in two spatial dimensions plus wavelength and a liquid crystal filter camera that can observe images of any emission line were installed in Kiruna, Sweden (67° 51' north latitude) for constant observation. The time-space evolution of the observed spectra will reveal the behavior of down-propagating particles, and phase-space fluctuations (fluctuations in velocity and space) occurring in the magnetosphere will be studied. By measuring physical quantities that have not been measured before, such as images of wavelength spectra and polarization, it will be possible to infer the energy and direction of the downed particles, which is expected to lead to the development of new research methods.

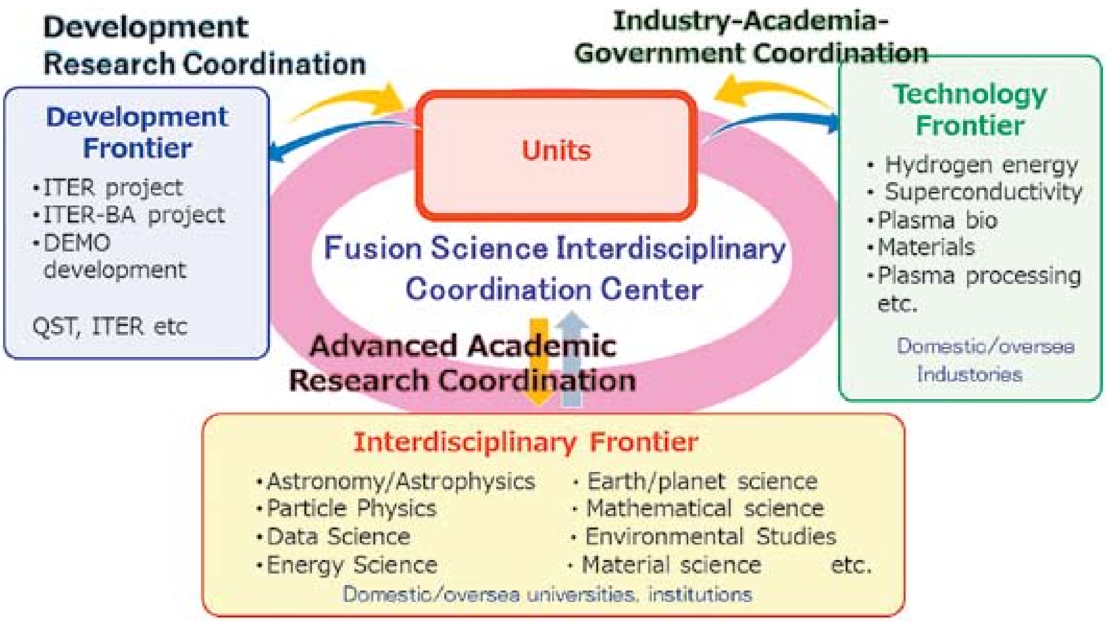


Fig.1 Fusion Science Interdisciplinary Coordination Center

Fig.2 Aurora image spectrometer and aurora from aircraft

Safety and Health Promotion Center

The Safety and Health Promotion Center is devoted to preventing work-related accidents, to ensuring safe and sound operation of machinery and equipment, and to maintaining a safe and healthy environment for all staffs, collaborators, and students. The center is composed of ten offices, as shown in the figure.

safety training

Training lecture held by safety control office leaders and safety management staff.
In 2022, it was held online.

Patrol by members health and safety staff

Safety and health managers regularly patrol the work areas.

Disaster prevention training

All workers attend disaster prevention training held every year.
They practice evacuation and extinguishing fires.

Raditation monitoring post

Nine radiation monitoring posts are placed at the site boundary and five near the laboratory buildings.

Through these activities, the Safety and Health Promotion Center conducts environmental safety, which includes radiation safety, safety education, and radiation training. Furthermore, industrial physicians also patrol the work areas. The Committee of Health and Safety discusses and recommends any safety, health, and environmental issues to improve appropriate safety management. For detailed information, please visit our web-site. https://www.nifs.ac.jp/en/

Rokkasho Research Center (RRC)

General Information on RRC

The Rokkasho Research Center (RRC, established in May 2007) promotes cooperation and joint research with Broader Approach (BA) activities that are being undertaken in parallel with the ITER project and builds the technical foundation for the development of a prototype fusion reactor by supporting the participation of collaborators of NIFS and universities, based on academic standpoints. Furthermore, in order to promote the interdisciplinary expansion of problems being tackled in fusion research, we are focusing on disseminating research issues to a range of academic fields, inviting interdisciplinary meetings, and promoting interdisciplinary joint efforts. As an example, the Fourth Mid-Term Strategic Project of the Research Organization of Information and Systems (ROIS), "Statistical-Mathematical Modeling for Plasma Data, Complementary to Plasma Physics," has been established and we are deepening/widening collaborations with communities such as those doing statistical-mathematics and data science. In addition, we are actively working to contribute to human resource development based on the Graduate University for Advanced Studies, SOKENDAI, through establishing and deepening cooperation with neighboring educational institutions.
RRC's Homepage: https://www.nifs.ac.jp/en/about/rrc.html

Recent Activities of RRC

A number of individual research collaborations had been launched in the fields of nuclear fusion and statistical-mathematics, in order to extract useful information that would contribute to the promotion of fusion research by making the most of large-scale/diverse data produced in nuclear fusion research. By aggregating them, the project; the Research Organization of Information and Systems (ROIS), the Fourth Mid-Term Strategic Project, "Statistical-Mathematical Modelling on Plasma Data: Complementary to Plasma Physics" was approved in FY2022, and NIFS RRC has been a research hub for promoting the project. The meeting for sharing research topics among those undertaking fusion and statistical-mathematical research was held in Dec. 2022 at NIFS RRC/QST Rokkasho Institute and Hachinohe City Public Hall. This project has pursued synergetic development of both research communities by applying/improving a statistical-mathematical approach to fusion and plasma data. A report on the meeting was published in ISM (Institute of Statistical Mathematics) News (No. 159, Feb. 2023) (in Japanese). The activities in FY2022 were highly evaluated by the ROIS Review Board, and a developmental extension was approved.

We are also promoting activities based on SOKENDAI through promoting ties/collaborations with nearby educational institutions. In February 2023, the SOKENDAI Outreach Activities "Training program for next-generation young researchers based in the community at Aomori, the Rokkasho area" was carried out in cooperation with the QST Rokkasho Institute. About 40 students of the National Institute of Technology (KOSEN), Hachinohe College visited the Rokkasho site, and were conducted on a tour of cutting-edge facilities and had stimulating live discussions with researchers/engineers there.

Group photo of the ROIS project meeting in Aomori (at Hachinohe City Public Hall)

Group photo of the SOKENDAI Social Linkage Project (at QST Rokkasho Institute)

Research Enhancement Strategy Office

The Research Enhancement Strategy Office was established in NIFS in 2013, as a result of a selection by the National Institutes of Natural Sciences (NINS) for a “Research University Enhancement Promotion Project” by the Ministry of Education, Culture, Sports, Science and Technology. This project selects domestic universities and inter-university research institutes that conduct superlative research, and supports their research enhancement policies. Special features of this program are the hiring and placement of Research Administrators (URA: University Research Administration staff) and their resulting performance of related activities. Although the project ended in March 2023, the activities of the office continue to develop.

The Office has three URAs, and promotes activities in five task groups: IR (Institutional Research)/ evaluation, enhancement of public relations programs, strengthening of the financial base, enhancement of collaboration activities, and strengthening of human resource development programs. Each task group, headed by the group leader, promotes activities in coordination with other groups and committees in NIFS. These activities are coordinated with the Headquarters for Co-Creation Strategy, established in NINS.

Research Enhancement Strategy Office web page : https://reso.nifs.ac.jp/eng/

Outreach to Society

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The National Institute for Fusion Studies (NIFS) conducts public relations and outreach activities in order for society and the Japanese people to know about fusion research, the research activities, and research results achieved at NIFS.

Every year we open the Institute and its research facilities to the community, so that people may understand our research activities and become interested in our cutting edge research. In 2022, due to the impact of the new coronavirus, the event was conducted in an online format in September, with four live broadcasts including an LHD tour (image ①) and a number of videos introducing our research, available on our website (image ②). A total of about 590 people participated in the live broadcast project.

Moreover, we contribute activities to foster future researchers, such as Super Science High-school (SSH) activities (tours of the facilities, practical training), internship activities, and other projects.

Public Relations Office

The Public Relations Office, as the core organization responsible for public relations and outreach activities, promotes the disclosure and sharing of research achievements with society, including the local community, through a variety of activities. Since the restructuring of this organization in FY2023, there now are four committees: the Scientific and Public Relations Committee, the Social Engagement Committee, the Archives Committee, and the Educational Collaboration Committee. A summary of the committees is depicted in the following illustration.

Many NIFS research staff are active as members of the office. Principal activities include holding press releases (image ③), publishing public relations magazines (image ④), holding scientific events (image ⑤), providing tours of NIFS facilities (image ⑥), scientific classroom activities (image ⑦), organizing and storing historical materials related to fusion science research in Japan, and educational collaboration activities with high schools.

Results of Activities held in 2022

- Q&A for Community Meetings posted on the NIFS web page
- Periodic delivery of e-mail newsletters (Research Updates)
- Campus tours (any time)
- Open lectures for the public (online)
- Science classroom activities

Publications and Videos

- NIFS official pamphlet (in Japanese and in English)
- Public relations magazine: *NIFS News*
- Pamphlet Energy Creating the Future: *Fusion*
- NIFS video: *For Our Children's Future*
- Public relations magazine: *Letters from Helica-chan*

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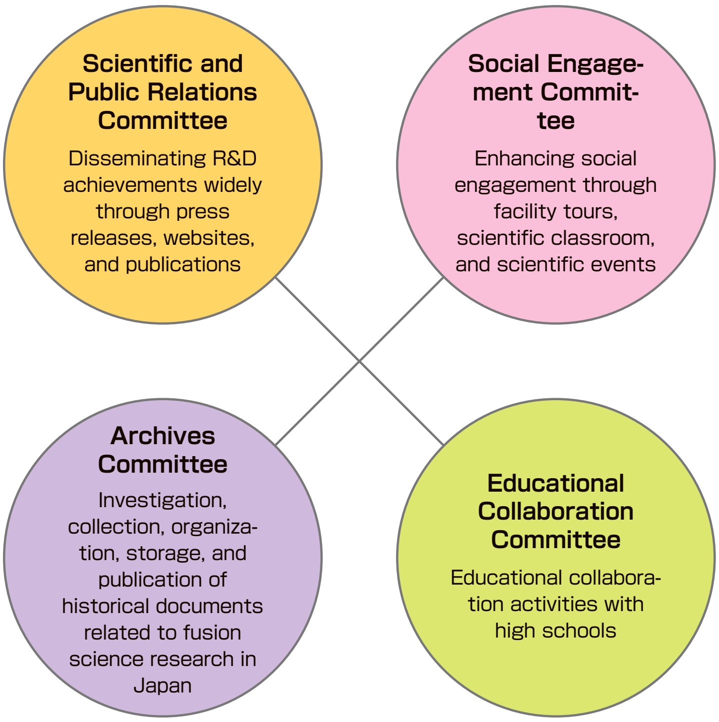

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Library

A library aiming to enrich materials and information provided to fusion researchers around the world

The NIFS Library has 71,000 books and 1,100 titles of journals, mainly on physics, natural sciences and engineering, that aim to enrich materials and information to be provided to fusion and plasma researchers around the world. In addition, as an Inter-University Research Institute, we are also responsible for providing information to inter-university researchers nationwide and training students and young researchers.

The library maintains an online library catalog (OPAC), e-journals, e-books, and other online services in an effort to expand its functions as an e-library. We are also member of Interlibrary Services (ILL) to obtain materials not stocked in NIFS from other libraries.

In January 2021, we jointly procured a new library system with Okazaki Library and Information Center within the same organization. We have started a collection search service on the new OPAC system. With this system, you may research the collections of other institutions such as the National Diet Library and CiNii Research, without having to re-enter keywords. (image①)

In recent years, we have set up an exhibition corner near the library entrance for introducing the collection materials. Exhibitions cover a wide range of themes, not limited to specialized materials. (image②)

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Accumulation and Utilization of Research Activities

The Institute has formulated the "National Institute for Fusion Science Open Access Basic Policy", which is based on the principle of disclosing research results such as academic papers of its staff to the public, and is accumulating and disclosing research results. The library also edits and publishes the NIFS series and English annual reports.

■NIFS Repository

NIFS Repository releases academic results and intellectual products generated by research or educational activities at NIFS. Anyone can access these files free of charge on the Web. (image③) NIFS fulfills social responsibility and makes social contributions by releasing research and educational activities through the NIFS Repository.

■NIFS Series

This preprint publication rapidly disseminates research achievements at NIFS within Japan and abroad. This series consists of five types: NIFS-REPORT, PROC, TECH, DATA, and MEMO. (image ④)

■Annual Report

The Annual Report summarizes all research achievements and activities at NIFS in each fiscal year. The reports are written in English.

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Education and Training of Young Researchers

NIFS has an important role, as the central institute of the field in Japan in developing human resources who will lead fusion science in future. As a part of the human resource development, the Education Council has been promoting education for graduate students comprehensively since AY2023. The education in NIFS is performed in various frameworks, such as the Graduate University for Advanced Studies, SOKENDAI, joint programs of graduate courses and special research collaboration programs for education with Japanese universities, internships, and so on. The achievement has been built steadily as the result of such extensive education.

The graduate University for Advanced Studies, SOKENDAI

The Graduate University for Advanced Studies, SOKENDAI, was established in 1988 as the first Japanese university which offers only graduate courses (no undergraduate courses). As a unique and flexible education system, the five and three-year doctoral programs are provided for students who have finished an undergraduate and a master's course, respectively. The educational framework of SOKENDAI has been upgraded to Graduate Institute for Advanced Studies since April 2023 to foster researchers in the next generation who can deal with complicated and challenging issues. Graduate Institute for Advanced Studies consists of 20 programs. Each one is supported by the corresponding inter-university research institute. NIFS is one of the institutes in charge of the Fusion Science program.

At present, 22 students are learning in the Fusion Science program. The remarkable point of the program is that students learn a wide range of cutting edge scientific and engineering knowledge such as plasma physics, atomic physics, electrical and mechanical engineering, superconductivity engineering, material engineering, vacuum engineering, and information engineering. This is because fusion science requires highly integrated synthetic research.

Joint Program of Graduate Education and Special Research Collaboration Program for Education

In addition to the SOKENDAI education, the graduate course provided at NIFS is based on joint programs with the Graduate School of Frontier Sciences at the University of Tokyo, the Graduate School of Engineering at Nagoya University, the Graduate School of Science at Nagoya University, the Interdisciplinary Graduate School of Engineering Science at Kyushu University, and elsewhere. At present, 26 graduate students are involved in this program. NIFS also accepts 11 graduate students from other graduate universities nationwide and abroad by offering the special research collaboration program and the internship program for education.

Research and Education Innovation Office

The Research and Education Innovation Office is composed of the six committees shown in figure. It plans and implements activities to deal with various problems related to research and education at NIFS and to raise the level of research and education.

The Academic Planning Committee, newly established this year, plans and manages seminars and round-table discussions that benefit research institute members and the community. We also plan international conferences and publications hosted by NIFS. We will transmit information to academia based on suggestions from the installed advisory board.

In the Research and Education Improvement Office, along with the Academic Planning Committee mentioned above, five other committees work together to promote the development and improvement of the research and education environment at NIFS.

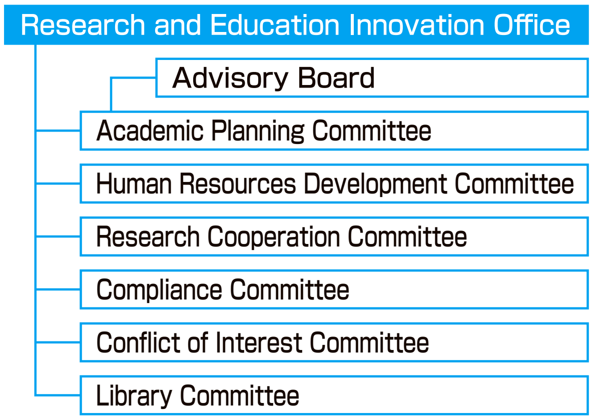


Figure. Composition of the Research and Education Improvement Office and the committees positioned within it.

Information Systems and Cyber Security Center (ISCSC)

Information network, systems and security

At NIFS, research activities generate a large amount of experimental and computational data. A number of results are produced from the data by an information system that is organically connected by an information network.

The Information Network Group provides a stable information network environment. Information networks can be regarded as the foundation of research activities, but they are still in their infancy and cannot be a reliable foundation simply by connecting devices. It is important to examine the functions of network devices and consider security.

The Information Systems Group develops, operates, and maintains the various information systems that form the foundation of NIFS, as well as information systems related to outreach, evaluation, and research support. The processing capability of an information system is improved by data design and programming methods, and the user interface changes the ease of use. At the stage of developing information systems, we conduct appropriate system development by clarifying requirements through hearings with related parties to facilitate and improve the efficiency of research activities.

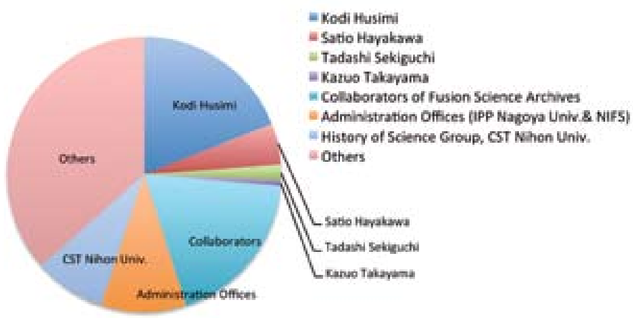
The Cyber Security Group works with the Information Network Group and the Information Systems Group to create a strong security structure. This includes user education. In addition, members of the Information Security Group also serve as the Computer Security Incident Response Team (NIFS-CSIRT), and in the event of a security incident, we will investigate the cause and respond to minimize the damage.

Fusion Science Archives

Taking a Lesson from the Past

Fusion Science Archives preserves and maintains collections of historical documents and materials that are related to fusion research in Japan. These activities are important from the viewpoint of the historical evaluation of fusion research and its social accountability. New items are constantly added through domestic and international collaborations. They are stored in acid-free folders and boxes. The total number of registered items is about 26,200 as of December 2023 (See Figure). Part of those catalogues are available to the public through the internet in a hierarchic structure and can be accessed by the use of an electronic retrieval system.

https://www.nifs.ac.jp/archives/



Provenance of registered items (total number ~26,200)

Coordinated Research Activities

The Coordinated Research aims at a smooth accomplishment of a wide range of coordinated research activities at NIFS. It plans, establishes, supports the framework of coordinated research, and disseminates coordinated research achievements for their effective use. In order to accomplish the above-mentioned purpose, the research cooperation committee with the subcommittees as shown in the figure below were established corresponding to a variety of coordinated research.

Research Cooperation Committee

- Subcommittee for cooperation based on agreements
- Subcommittee for Security Export Control
- Subcommittee for Fusion Field Research Planning on Japan-U.S. Science and Technology Cooperation Project
- Subcommittee for Research Planning on Japan-Korea Fusion Cooperation Project
- Subcommittee for Japan-China Science and Technology Cooperation Project

International Coordination（2023/4/1）

①Multinational Coordination
- ･The IEA Stellarator･Heliotron Technology Cooperation Program(SH-TCP) (Japan, Germany, Spain, U.S.A., Australia, Russia, Ukraine)
- ･PWI TCP (Japan,U.S.A.,EURATOM, Australia)
- ･Spherical Tori (ST)TCP (Japan, U.S.A., EURATOM, Korea).etc

②Binational Coordination
(Japan-United States Collaborative Program, Japan-Korea Fusion Collaboration Programs, Japan-China Collaborative Program, Japan-Russia Cooperation, Japan-EU Cooperation, etc.)

③Coordinaton with Other Institutions (30 International Academic Exchange Agreements)

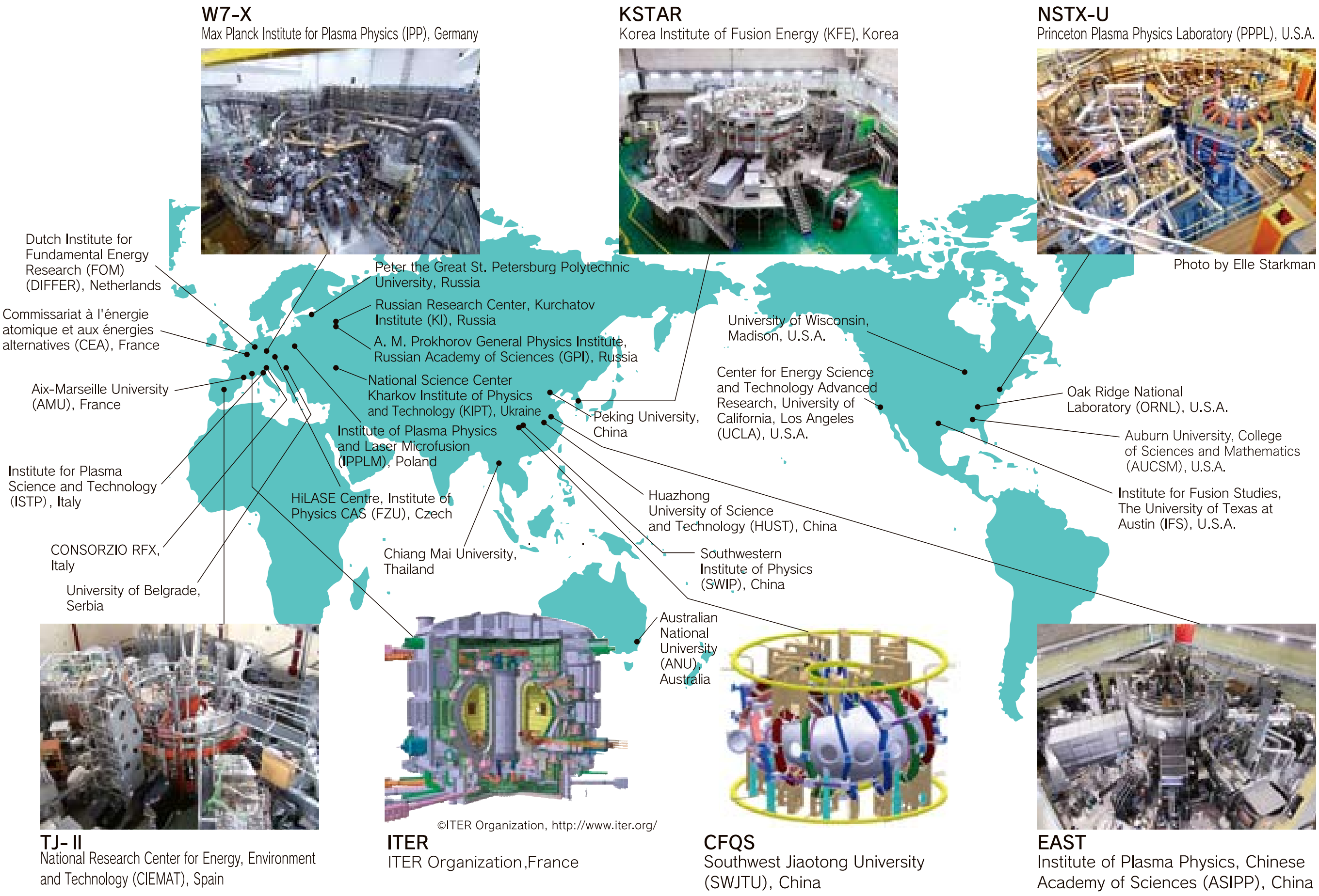
④Hosting of International Conferences (International Toki Conference, etc.)

Academic Exchange Agreements

country	organization	year	organization	year
China	Institute of Plasma Physics, Chinese Academy of Sciences（ASIPP）	1992	Southwestern Institute of Physics（SWIP）	2012
	Peking University	2017	Southwest Jiaotong University（SWJTU）	2017
	Huazhong University of Science and Technology（HUST）	2018		
Germany	Max Planck Institute for Plasma Physics（IPP）	1993		
Russia	Russian Research Center, Kurchatov Institute（KI）	1993	A. M. Prokhorov General Physics Institute, Russian Academy of Sciences（GPI）	2007
	Peter the Great St. Petersburg Polytechnic University（SPbPU）	2017		
Ukraine	National Science Center Kharkov Institute of Physics and Technology（KIPT）	1994		
Australia	Australian National University（ANU）	1995		
South Korea	Korea Institute of Fusion Energy（KFE）	1996		
U.S.A.	Princeton Plasma Physics Laboratory（PPPL）	2006	Institute for Fusion Studies, The University of Texas at Austin（IFS）	2006
	Oak Ridge National Laboratory（ORNL）	2006	Center for Energy Science and Technology Advanced Research, University of California, Los Angeles（UCLA）	2006
	University of Wisconsin, Madison	2019	Auburn University, College of Sciences and Mathematics（AUCSM）	2019
France	Aix-Marseille University（AMU）	2007	Commissariat à l'énergie atomique et aux énergies alternatives（CEA）	2015
	International Associated Laboratory（LIA）	2019		
Spain	National Research Center for Energy, Environment and Technology（CIEMAT）	2009		
Netherlands	Dutch Institute for Fundamental Energy Research（FOM）（DIFFER）	2011		
Italy	Institute for Plasma Science and Technology（ISTP）	2019	CONSORZIO RFX	2015
Czech	HiLASE Centre, Institute of Physics CAS（FZU）	2016		
Thailand	Chiang Mai University（CMU）	2016		
Poland	Institute of Plasma Physics and Laser Microfusion（IPPLM）	2017		
Serbia	University of Belgrade	2019		
ITER Organization		2011		

Coordinated International Research

Since its infancy, fusion research has been advanced through peaceful international coordination, and today broad-ranging research is conducted in many countries around the world. Further research and development toward making fusion reactors a reality requires the promotion of joint research programs based on a long-term outlook which brings together the knowledge of researchers not just in Japan, but from around the world. NIFS plays the role of an organization representing Japan in the international coordination of fusion research. Along with this, we are actively advancing joint research and exchange among researchers through international coordination. Regarding the ITER Project and the Broader Approach (BA), global projects that are currently in progress, we are cooperating in various ways, by contributing to the International Tokamak Physics Activity (ITPA), by sending experts, and by providing several technologically-advanced devices conducive to further development.



Examples of International Coordination

●The IEA Stellarator-Heliotron Cooperation
International Stellarator-Heliotron Confinement and Profile Database Activity

Extensive multi-national and multi-institutional coordinated research among Stellarator-Heliotron (S-H) devices has been promoted under the auspices of the IEA (International Energy Agency) Stellarator-Heliotron Technology Cooperation Program. Contracting parties are Australia, EURATOM, Japan, Russia, Ukraine, and the USA (in alphabetical order). Among them, Japan, through the Director General of the National Institute for Fusion Science, is performing leadership responsibilities as vice-chair.The scaling law for the energy confinement time, the so-called ISS04, was successfully derived based on the extended S-H confinement database. Toward deepening physics understanding and increasing the predictive capability, the profile database activity has been steadily expanded with the participation of multiple institutions.

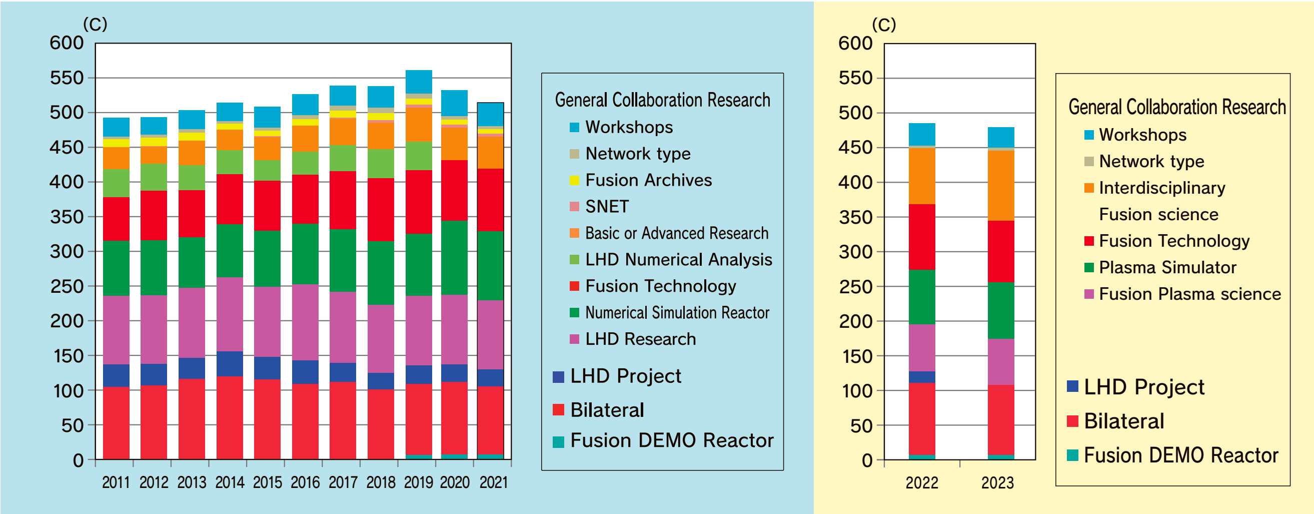
●Japan-USA Cooperation Program
Progress in the Joint Projects

As a Joint Project in the Japan-USA Cooperation Program, FRONTIER (Fusion Research Oriented to Neutron irradiation effects and Tritium behavior at material IntERfaces) Program has been launched for six years from FY2019 to FY2024. In this Program, neutron radiation effects are to be clarified on interactions at the bonding and contact interface for various materials and coolants developed for divertor in fusion power-generation demonstration reactors. Advanced researches are under way utilizing unique devices available only in the United States, such as the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL) and Safety and Tritium Applied Research facility (STAR) at Idaho National Laboratory (INL).

High Flux Isotope Reactor (HFIR)
(courtesy of ORNL)

Domestic Collaboration Research Programs

In order to satisfy the broad needs for advancing cutting-edge research, NIFS conducts four collaboration research programs. These are General Collaboration Research which utilizes facilities of NIFS, and Bilateral Collaboration Research, Fusion Development Collaboration Research, and Fusion DEMO Reactor Collaboration Research which utilize facilities of other institutes. The joint use and joint research activities are powerfully developed by accepting research proposals from researchers each year.



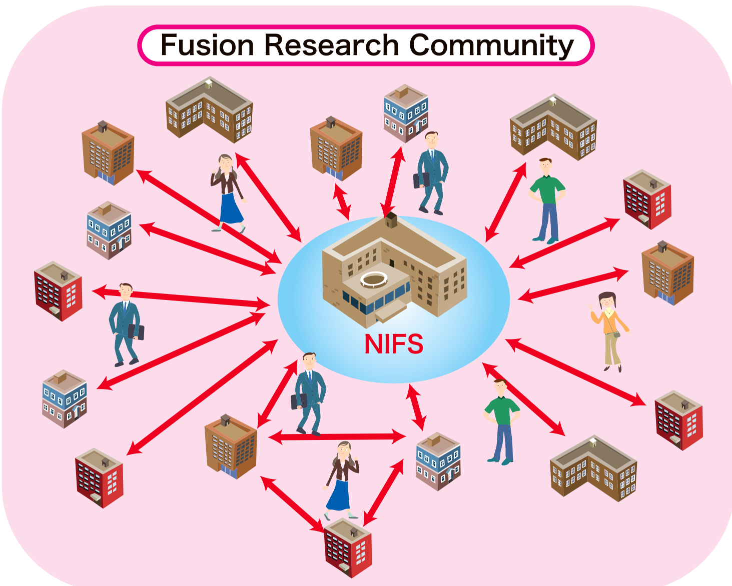
NIFS collaboration research activities are always reviewed and improved so as to be compatible with the latest research trends by changing the categories of collaboration. In FY2022, the categories of General collaboration Research were revised. The figures show the number of accepted collaboration subjects in each category. LHD Project Collaboration Research was closed in FY2022.

General Collaboration Research

General Collaboration Research is a system for the collaborators to carry out their research by using the facilities or the resources of NIFS, including experimental devices, diagnostics, the supercomputer, databases, and others. Because nuclear fusion includes a wide research area in physics and technology, from fundamental research to application, the system has a variety of categories.

In this collaboration, the collaborators come to NIFS and carry out research at NIFS. However, if it is necessary, NIFS staff can go to the university of a collaborator to perform joint research there. Furthermore, in the "network-type collaboration" category, the collaborators may conduct experiments at other universities involved in a particular project.

Many exploratory research proposals are adopted in the General Collaboration Research, and since a graduate student can be a collaborator, it is useful for training young researchers.

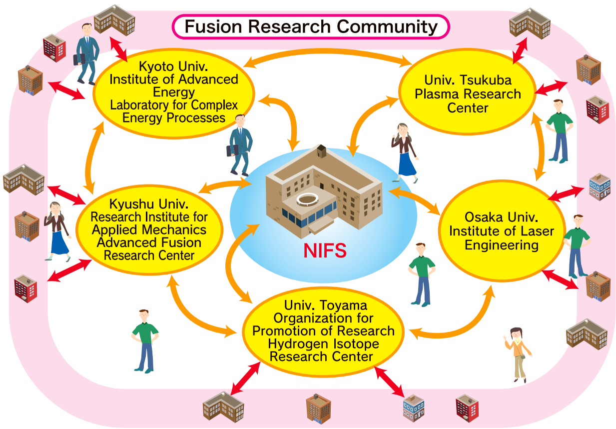


Collaboration Research which utilize facilities of other institutes

Bilateral Collaboration Research

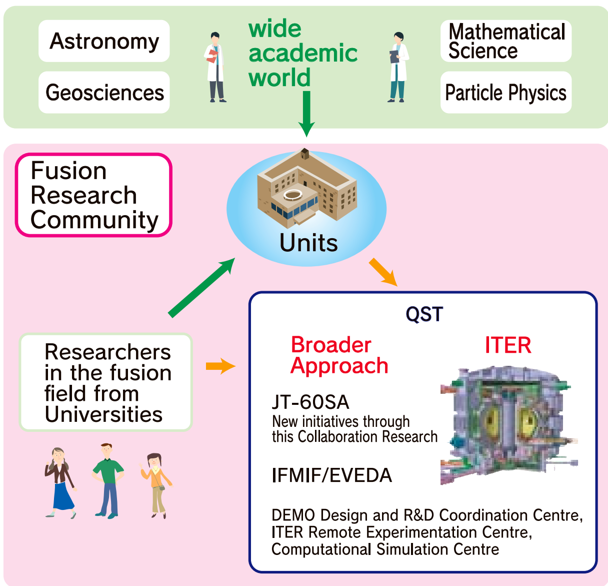
Bilateral collaboration research promotes joint research bilaterally between NIFS and a research institute or a university research center which has a unique facility for nuclear fusion research. Under the collaboration, the facility is open for the researchers all over the country as a joint use program of NIFS, an inter-university research institute.

At present, five research centers are participating in the program. They are: the Plasma Research Center at the University of Tsukuba, the Laboratory for Complex Energy Processes at Kyoto University, the Institute of Laser Engineering at Osaka University, the Advanced Fusion Research Center at Kyushu University, and the Hydrogen Isotope Research Center, Organization for Promotion of Research, at the University of Toyama.



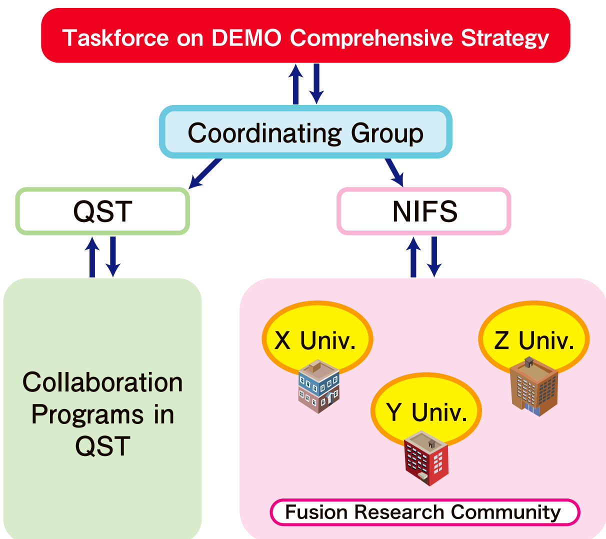
Fusion Development Collaboration Research

Fusion Development Collaboration Research aims to strengthen international competitiveness in the field of fusion science and to strengthen the foundation for human resource development. Fusion Development Collaboration Research promotes academic research using state-of-the-art fusion plasma experiment devices such as JT-60SA led by QST through the joint use program. Fusion Development Collaboration Research strengthens collaboration between academic research and fusion development research through the cooperation of NIFS units and researchers in the field of fusion science and a wide range of academic circles. This joint research is scheduled to start in FY2024.



Fusion DEMO Reactor Collaboration Research

This collaboration program was initiated in fiscal year 2019 as the fourth category of the collaboration programs conducted by NIFS to accelerate the “action plan towards fusion DEMO research and development”, which was composed by the Taskforce on DEMO Comprehensive Strategy in the Ministry of Education, Culture, Sports, Science and Technology (MEXT). This program attempts to solve issues of the “action plan”, together with the collaboration programs conducted by the National Institutes for Quantum Science and Technology (QST).



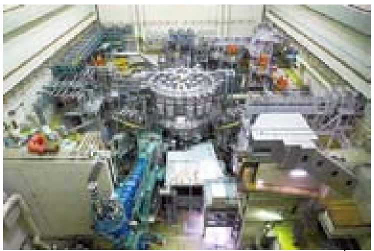
Coordinated Research with Domestic Research Institutions

In many domestic universities and research institutions, the experimental and theoretical research which aims at the realization of nuclear fusion energy is advanced, as shown in the figure below. NIFS is promoting four types of collaboration research programs introduced previously to offer a place for research and interaction among researchers all over the country as a center of excellence of nuclear fusion science aiming at broad development of plasma and nuclear fusion research.

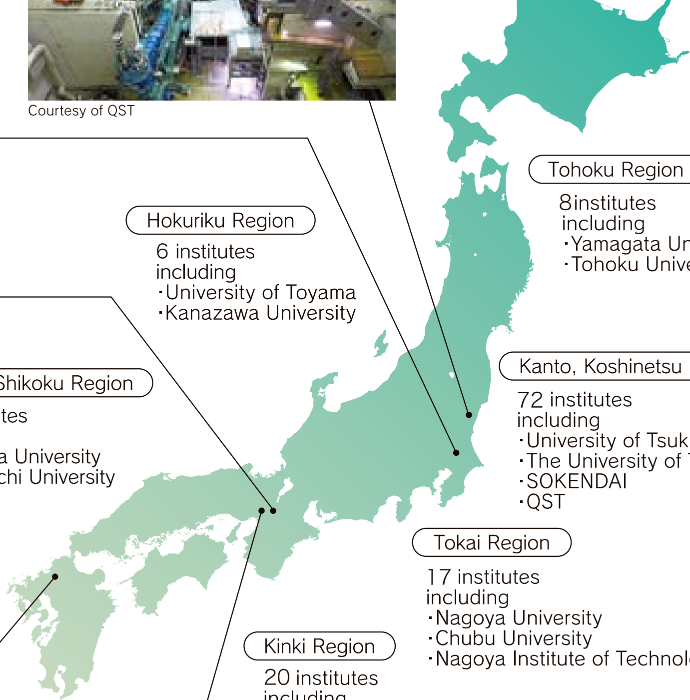
NIFS is also striving for the development of new scientific research fields cooperating with institutions which have excellent specialities through individual academic agreements.

University of Tsukuba
GAMMA 10/PDX

National Institutes for Quantum Science and Technology
JT-60SA



Courtesy of QST



Hokkaido Region
8 institutes including
・Hokkaido University
・Kitami Institute of Technology

Tohoku Region
8institutes including
・Yamagata University
・Tohoku University

Hokuriku Region
6 institutes including
・University of Toyama
・Kanazawa University

Kanto, Koshinetsu Region
72 institutes including
・University of Tsukuba
・The University of Tokyo
・SOKENDAI
・QST

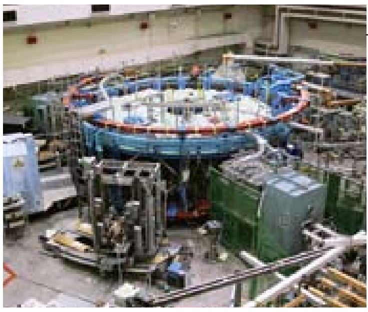
Chugoku, Shikoku Region
16 institutes including
・Okayama University
・Yamaguchi University

Tokai Region
17 institutes including
・Nagoya University
・Chubu University
・Nagoya Institute of Technology

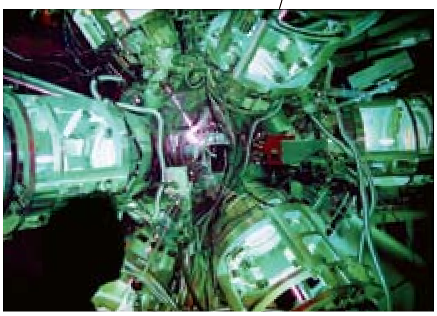
Kinki Region
20 institutes including
・Kyoto University
・Osaka University
・University of Hyogo

Kyushu Region
17 institutes including
・Kyushu University
・University of the Ryukyus

Kyoto University
Heliotron J



Kyushu University
QUEST



Osaka University
GEKKO-XII

Domestic Academic Agreements 12 institutions

・Hokkaido University
・Tohoku University
・University of Tsukuba
・The University of Tokyo
・University of Toyama
・Shizuoka University
・Nagoya University
・Nagoya Institute of Technology
・Osaka University
・Kyushu University
・National Institutes for Quantum Science and Technology
・Tajimi Technical High School

Department of Engineering and Technical Services

The Department of Engineering and Technical Services is involved in the operation and maintenance of research platforms such as the Large Helical Device (LHD) and information facilities such as the research infrastructure network, as well as the design, development, and fabrication of equipment, radiation control, and safety promotion. The Department of Engineering and Technical Services contributes greatly to the creation of results in fusion research through advanced and specialized technical support.

Mechanical Systems Technology

We manufacture precision parts using machine tools. We also provide mechanical design support and design various types of plants.


Machining operation

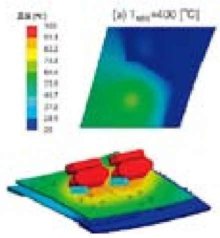

Precision machined products


Welding of vacuum parts

Design and Development Technology

We develop equipment using numerical analysis software for structural, thermal, magnetic, fluid, and electric field analysis. We also design and develop vacuum and cryogenic equipment.


Structural analysis simulation


Thermal analysis


Design of vacuum popping system

Electrical and Electronic Technology

We design and develop electronic circuits. We also design and manage highvoltage power supplies.


Electronic circuit construction


Electronic circuit parts


High-voltage inspection

Diagnostics and Analysis Technology

We support the development of diagnostics, and process, store, and manage the data acquired in experiments. We also perform tasks related to radiation.

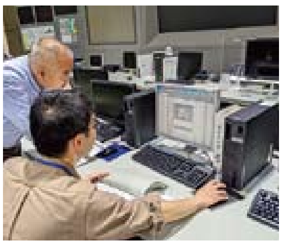

Development for diagnostics

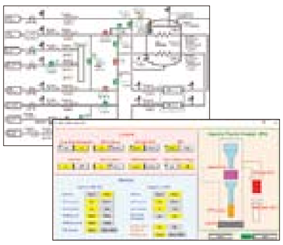

Data Acquisition System


Radiation management support

Control and Information Technology

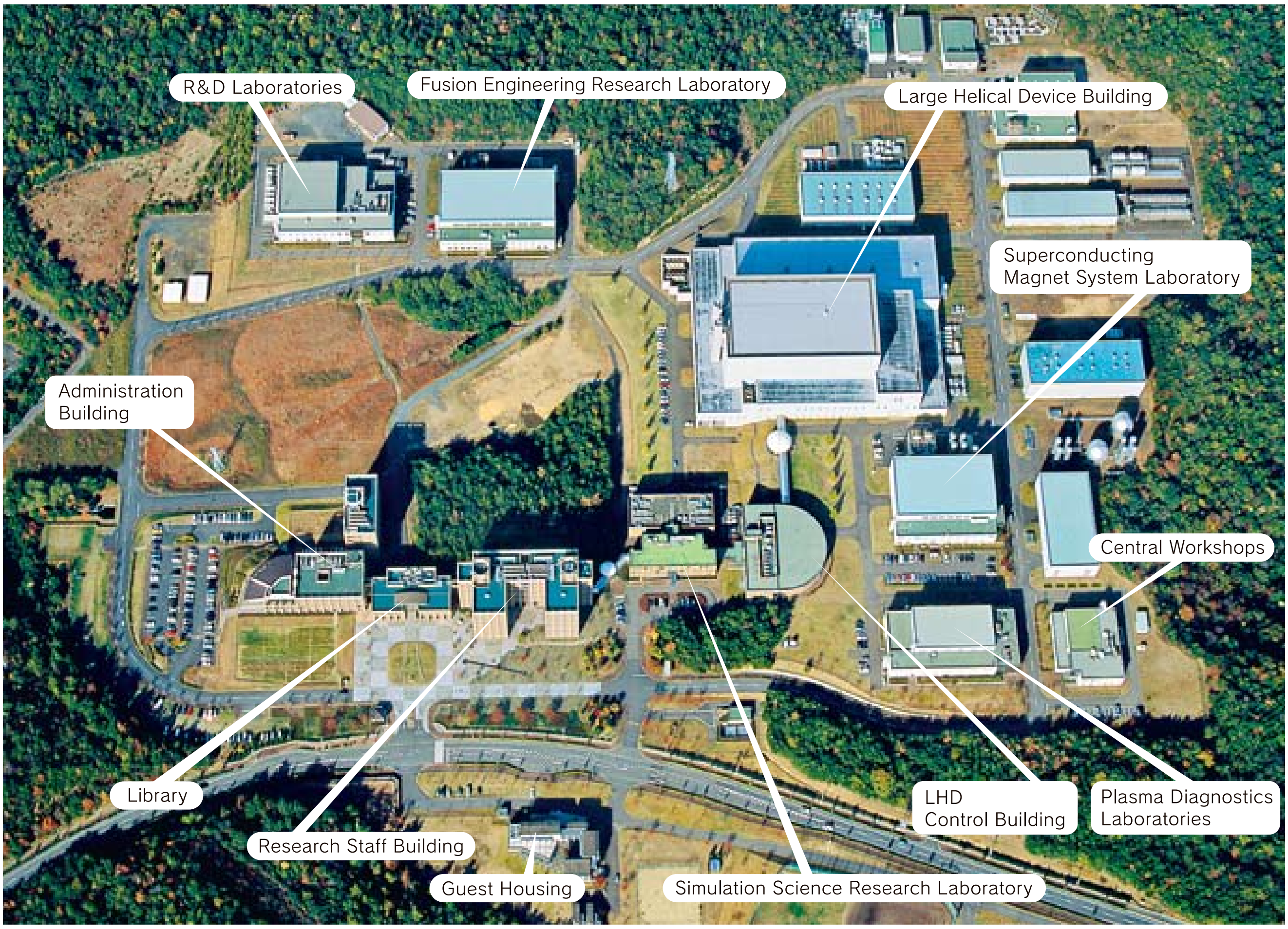
We develop control systems. We also operate and manage information networks and perform web development.


Control system development


Remote control system


Web system development

Site Map



Site 464,445㎡ Total Building Area 39,557㎡ Total Floor Space 71,830㎡

History of NIFS

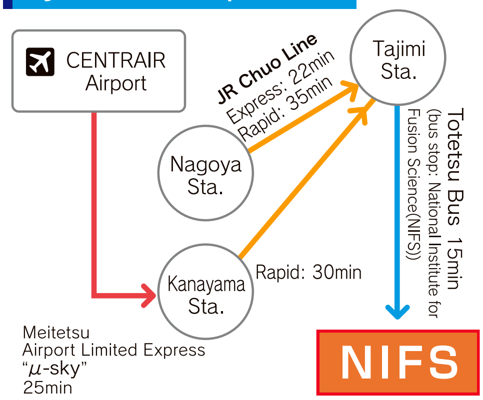
Nov. 1980	Science Council of the Ministry of Education proposes the “Long Range Plan for Fusion Plasma Research in Universities”
Mar. 1988	The structure of the National Institute for Fusion Science (NIFS) and the new project of the Large Helical Device (LHD) outlined
Apr. 1988	The preparation committee and preparation office for NIFS established
May 1989	NIFS established
Apr. 1992	The Department of Fusion Science established at the School of Mathematical and Physical Science, Graduate University for Advanced Studies
Aug. 1995	The LHD building completed
July. 1997	Headquarters of NIFS moved from Nagoya to Toki
Dec. 1997	Completion of LHD
Apr. 1998	The LHD experiments started
Apr. 2004	Inter-University Research Institute Corporation, “National Institutes of Natural Sciences (NINS)” inaugurated NIFS becomes one of the research institutes which constitute NINS National University Corporation,“The Graduate University of Advanced Studies (SOKENDAI)” was established; The Department of Fusion Science established in the School of Physical Sciences, The Graduate University of Advanced Studies (SOKENDAI)
May 2004	The 15th year anniversary held
Apr. 2010	The research section reorganized, and the Department of Helical Plasma Research established
Feb. 2014	Research Enhancement Strategy Office established
Apr. 2016	Division of External Affairs established
Mar. 2017	The LHD deuterium experiments started
May. 2019	The 30th year anniversary held
Dec. 2022	The LHD deuterium experiments completed
Apr. 2023	The research section reorganized and shifted to the UNIT research system The LHD restarted as an Academic Research Platform for interdisciplinary study

NIFS Location and Access

Rokkasho Research Center

Operates inside the building of National Institutes for Quantum Science and Technology's Rokkasho Fusion Institute
2-166 Oaza-Obuchi-Aza-Omotedate, Rokkasho-mura,Kamikita-gun Aomori-ken 039-3212
TEL:0175-73-2151
FAX:0175-73-2199

By Public Transportation



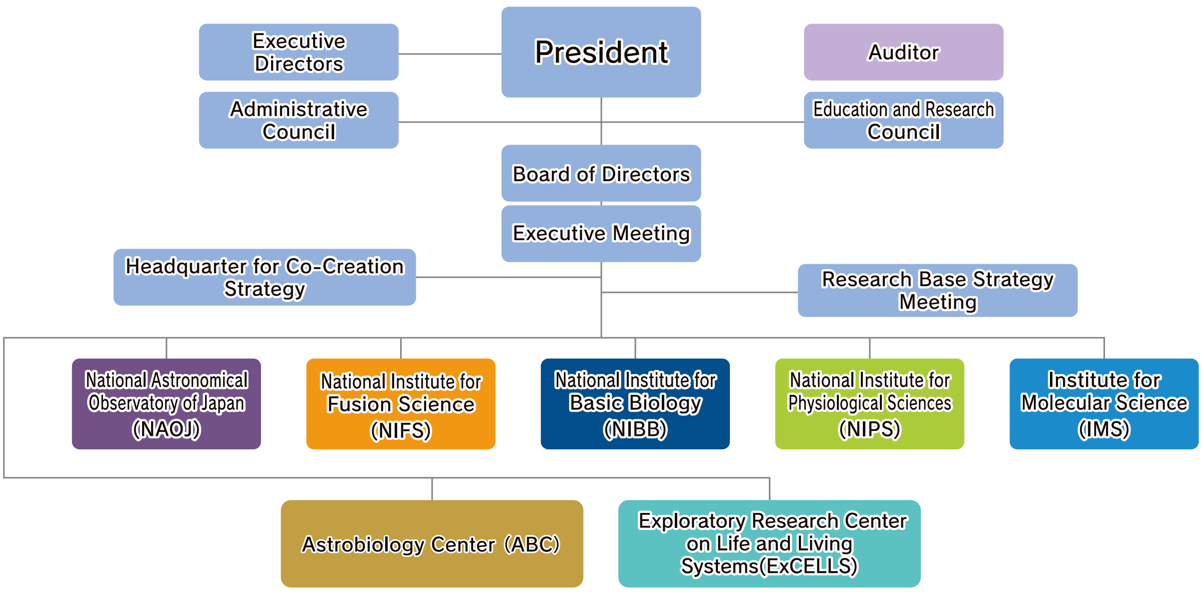
National Institute for Fusion Science

322-6 Oroshi-cho
Toki-shi, Gifu-ken
509-5292
TEL:0572-58-2222
FAX:0572-58-2601

By Automobile

・Toki-Minami Tajimi IC (Tokai-Kanjo Expressway)(5min)
・Tajimi IC/Toki IC (Chuo Expressway)(20min)

NINS National Institutes of Natural Sciences



Inter-University Research Institute Corporation National Institutes of Natural Sciences

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